Effects of Different Inundation Depths on Plant Growth and Vegetative Propagation in Poyang Lake Floodplain Wetlands (Postprint)

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Abstract

Water depth is a critical factor affecting the growth and reproduction of wetland plants, and different wetland species exhibit varying responses to flooding depth. However, against the backdrop of continuously changing hydrological conditions, how plant populations and communities in the beach wetlands of Poyang Lake will change remains unclear. To investigate the effects of flooding depth on wetland plant growth and predict vegetation distribution trends in the beach wetlands of Poyang Lake, a controlled experiment was conducted to simulate the growth and reproduction of three dominant plant species in Poyang Lake wetlands—Carex cinerascens, Miscanthus lutarioriparius, and Phalaris arundinacea—under different flooding depths (0, 0.5, 1 m, and 2 m). Experimental results showed that: 1) Flooding had the most significant effect on the total biomass of Carex cinerascens. When subjected to flooding, Carex cinerascens allocated most of its biomass to underground parts; as flooding depth gradually increased, the biomass of Miscanthus lutarioriparius progressively decreased; different flooding depths did not produce significant effects on the biomass of Phalaris arundinacea ($P>0.05$). In terms of biomass, Phalaris arundinacea demonstrated stronger adaptability to flooding than the other two species. 2) Under different flooding depths, the plant height of Carex cinerascens was significantly reduced; whereas Miscanthus lutarioriparius showed significant height reduction only under the 2 m flooding gradient. During dry years, declining water levels would facilitate the migration of Miscanthus lutarioriparius to lower elevations. 3) Different flooding depths did not produce significant effects on the tillering of Carex cinerascens ($P>0.05$); whereas Phalaris arundinacea exhibited significantly higher tiller numbers after 2 m flooding compared to other flooding depths. During wet years, elevated water levels had less impact on the reproduction of Phalaris arundinacea compared to Carex cinerascens and

Miscanthus lutarioriparius. In a wetland ecosystem with periodically fluctuating water levels, flooding at different depths severely affected plant growth and post-flood reproduction, and the research findings provide an important basis for predicting how hydrological changes will affect the survival and distribution of wetland vegetation.

Full Text

Preamble

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Effects of Different Water Depths on the Growth and Vegetative Reproductive Characteristics of Wetland Vegetation in Lake Poyang

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Abstract

Water depth is a key factor affecting the growth and reproduction of wetland vegetation. Different types of wetland plants respond to flooding in different ways. While the hydrological regime of Poyang Lake is known to be highly dynamic, how wetland vegetation populations and communities change along with varying water depth remains poorly understood. To explore the underlying influence of water depth on wetland plant growth and predict trends in Poyang Lake beach vegetation distribution under changing water conditions, we conducted a controlled experiment simulating different flooding depths (0, 0.5, 1 m, and 2 m) to examine the growth and reproduction of three dominant wetland plants (*Carex cinereascens*, *Miscanthus lutarioriparius*, and *Phalaris arundinacea*) in the Poyang Lake wetland.

The results showed that: (1) Water depth had the most significant influence on the total biomass of *C. cinereascens*. When flooded, *C. cinereascens* concentrated most of its biomass in underground parts. The biomass of *M. lutarioriparius* gradually decreased as water depth increased, while water depth had no significant impact on the biomass of *P. arundinacea* ($p > 0.05$). In terms of biomass, *P. arundinacea* showed greater adaptability to flooding than the other two species. (2) Plant height of *C. cinereascens* was significantly reduced under all flooding depths, whereas *M. lutarioriparius* height was only significantly reduced at depths > 0.05 m. These findings suggest that in low-flow years, decreased water levels may facilitate *M. lutarioriparius* migration to lower elevations. (3) Flooding had no obvious impact on the ramets of *C. cinereascens* (p > 0.05), but the number of ramets of *P. arundinacea* was greatest when grown under a water depth of 2 m. This demonstrates that in high-flow years, elevated water levels have less impact on the reproduction of *P. arundinacea*. Overall, in a wetland ecosystem with periodic flooding, water depth has a significant impact on vegetation growth and reproduction during the flooding period. Our results provide important insights for predicting how hydrological changes affect the survival and distribution of wetland vegetation.

Keywords: *Carex cinereascens*; *Miscanthus lutarioriparius*; *Phalaris arundinacea*; water depths; recovery growth

Introduction

Wetlands, known as the "kidneys of the earth," play important roles in water purification and biodiversity maintenance. Water level variation is a key factor constraining wetland vegetation growth and distribution. Periodic water level fluctuations divide wetland systems into flooded states during wet seasons and terrestrial states during dry seasons. Most wetland plants begin to emerge from water, and vegetation distributed at higher elevations experiences seasonal drought effects. Seasonal drought plays an important role in the growth, reproduction, and distribution patterns of wetland vegetation on beaches. Numerous studies have shown that drought affects plant leaves first, and some wetland plants adapt to this external stress by reducing leaf area. As seasonal drought extends, the reproductive mode of wetland plants may shift toward seed reproduction. When wetland vegetation begins experiencing flooding stress at different depths, light and oxygen become the main factors limiting plant growth. Under such conditions, plant morphological characteristics, physiological and biochemical traits, and reproductive strategies all undergo different changes, which ultimately affect interspecific competition and community composition.

Poyang Lake is China's largest freshwater lake and an internationally important wetland, with high amplitude water level variations both within and between years. This periodic water level change is significant for wetland plant community dynamics and biodiversity maintenance. Due to climate change and human factors such as water conservancy projects, Poyang Lake has experienced frequent low water levels, significantly impacting the wetland ecosystem. While numerous studies have analyzed Poyang Lake's water level fluctuations, eutrophication, fish resources, and waterbird population dynamics, research on how hydrological changes affect Poyang Lake beach vegetation remains relatively limited, particularly under low water level conditions. Changes in Poyang Lake' s hydrological regime mainly manifest as extended dry seasons in autumn and winter, and lower water levels in spring and summer flood seasons. For wetland plants, this translates to changes in flooding duration and depth.

The three dominant plant species in Poyang Lake—*Carex cinereascens*, *Miscanthus lutarioriparius*, and *Phalaris arundinacea*—are important components of the Poyang Lake ecosystem. These plants are important carbon sources in Poyang Lake, and their shoots are also the main food source for herbivorous waterbirds. In Poyang Lake' s vast beach areas, these three dominant species are distributed in bands at different water level elevations: *M. lutarioriparius* at 14-16 m, *P. arundinacea* at 12-15 m, and *C. cinereascens* communities at lower elevations. In recent years, Poyang Lake has shown phenomena of low flood season water levels and extended dry periods. Although studies have indicated that the lower distribution limit of *Carex* communities has shifted downward along the elevation toward the lake center, and *M. lutarioriparius* communities have also moved to lower water level areas, it remains unclear how water level changes alter the distribution of Poyang Lake' s dominant species.

We hypothesized that the three dominant beach species—*C. cinereascens*, *M. lutarioriparius*, and *P. arundinacea*—have different response strategies to different depths of flooding. Through simulation experiments, we aimed to clarify the mechanisms of vegetation distribution changes and provide a scientific basis for Poyang Lake vegetation restoration by examining biomass changes, height responses, and reproductive strategies of the three dominant species under different water level gradients.

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1. Experimental Materials

Carex cinereascens is a perennial herb of the Cyperaceae family. *Miscanthus lutarioriparius* is a perennial grass of the Poaceae family. *Phalaris arundinacea* is a perennial grass of the Poaceae family.

1.1 Experimental Treatment

In March 2016, we collected *C. cinereascens*, *M. lutarioriparius*, and *P. arundinacea* from the East Lake of Nanji Mountain Wetland National Nature Reserve in Jiangxi (28°52 5 -29°6 50 N, 116°10 33 -116°25 5 E). We selected healthy clones of similar size, removed existing buds, and transplanted these ramets into circular pots (diameter 19 cm, height 17 cm). Soil was collected from the Nanji Mountain beach of Poyang Lake and thoroughly mixed. All plants were cultivated in a moist environment. On April 20, 2016, plants were moved into experimental pools set up with four water depth gradients: 0, 0.5, 1, and 2 m (where 0 m represents no flooding but moist conditions). Each species was placed in each gradient with 20 replicates. The experimental pools received natural light, and all experimental groups were in the same pool receiving identical light conditions. Water transparency in the experimental pools was 1.5–1.7 m.

1.2 Data Collection

We recorded plant height and ramet number for all plants every two weeks. On August 20, 2016, all plants were harvested and separated into aboveground and belowground parts to calculate dry weights. To simulate growth after water recession, we also recorded plant height and ramet number after plants entered the recovery growth period.

1.3 Data Analysis

All data were analyzed using Excel and SPSS 21.0. Biomass and underground bud number were analyzed using one-way ANOVA. Ramet number data were analyzed using repeated measures ANOVA. Significance tests were used to compare differences among flooding gradients at a 95% confidence level ($p < 0.05$). Since *C. cinereascens* grows in clumps and observing ramet number during late growth stages was difficult, we used plant cluster circumference as an indicator of ramet production capacity.

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2. Results

2.1 Effects of Different Flooding Gradients on Biomass

In August 2016, we harvested *C. cinereascens*, *M. lutarioriparius*, and *P. arundinacea* and conducted one-way ANOVA on their total, aboveground, and belowground biomass. For *C. cinereascens*, both total and belowground biomass in the three flooded gradients (0.5, 1, and 2 m) were significantly higher than in the control (0 m) ($p < 0.05$), though differences among the three flooded gradients were not significant. The total biomass of *C. cinereascens* in the control was 22.90 g, significantly higher than in flooded conditions, with belowground biomass reaching 19.36 g. However, in flooded gradients, *C. cinereascens* showed differences: the 2 m gradient had the lowest aboveground, total, and belowground biomass, while aboveground biomass showed no significant difference between 0.5 and 1 m gradients ($p > 0.05$).

For *M. lutarioriparius*, total and belowground biomass gradually decreased with increasing water depth, with significant differences among the three water depth gradients ($p < 0.05$). The total biomass of *M. lutarioriparius* at 0 m was 46.84 cm, while at 0.5 m it was lowest at 10.66 cm. At 1 m water depth, plant height first increased then gradually decreased.

For *P. arundinacea*, neither total nor belowground biomass showed significant differences across water depth gradients ($p > 0.05$). The total biomass at 0 m was 11.64 g, with belowground biomass reaching 4.20 g, while at 0.5 m, total biomass was 3.21 g with no significant difference from other flooded gradients ($p > 0.05$).

[Figure 1: see original paper] The biomass distribution of three dominant species under different water depths

2.2 Effects of Flooding Treatment on Plant Height

Repeated measures ANOVA for the three dominant species showed that flooding treatment and time both significantly affected the height of *C. cinereascens* and *P. arundinacea*, while *M. lutarioriparius* height was mainly affected by flooding treatment. Specifically, *C. cinereascens* under different flooding gradients showed rapid growth during flooding, with height gradually increasing. After entering the recovery growth period, height continued to increase over time, though there was no significant difference among 0.5, 1, and 2 m gradients.

Miscanthus lutarioriparius showed different height responses to flooding stress compared to *C. cinereascens*. At 0, 0.5, and 1 m water depths, height showed no significant change over time whether under flooding stress or in recovery growth. At 2 m depth, the main stems turned yellow and leaves withered, with height gradually decreasing to a minimum of 43.00 cm. After a period of adaptation, plants remained viable and new branches emerged from withered main stems, with height gradually increasing to 84.12 cm.

Phalaris arundinacea reached maximum height of 36.76 cm at 0, 0.5, and 1 m gradients, with no significant difference among flooding gradients ($p > 0.05$).

Repeated measures ANOVA analysis of the effect of time on height under different water depths

2.3 Effects of Flooding Treatment on Ramet Number

Repeated measures ANOVA on cluster circumference of *C. cinereascens* and ramet numbers of *M. lutarioriparius* and *P. arundinacea* showed that only *C. cinereascens* cluster circumference was significantly affected by treatment, while all three species were affected by treatment time. *Miscanthus lutarioriparius* and *P. arundinacea* showed no obvious change in ramet number across different treatment gradients.

Under flooding stress, *M. lutarioriparius* showed few ramets, with only some ramets at the 0.5 m gradient. After entering the recovery growth period, ramet number gradually increased, with significant differences among treatment gradients ($p < 0.05$), being highest at the 0.5 m gradient. *Phalaris arundinacea* showed no ramets under flooding, but ramet number gradually increased after water recession, with significant differences among treatment gradients ($p < 0.05$), being highest at the 2 m water depth.

Repeated measures ANOVA analysis of the effect of time on ramet number under different water depths

[Figure 2: see original paper] The effect of time on height of three dominant species under different water depths (dashed line right side indicates recovery growth period)

[Figure 3: see original paper] The effect of time on ramet number of three dominant species under different water depths (dashed line right side indicates recovery growth period)

2.4 Effects of Different Flooding Gradients on Underground Bud Number

We counted underground buds of the three dominant species and conducted one-way ANOVA on bud numbers across treatment gradients. For *C. cinereascens* under flooding, underground bud numbers were not lower than the control group, but only the 2 m flooding depth showed significantly higher bud numbers than the control. For *M. lutarioriparius* and *P. arundinacea*, underground bud numbers showed similar trends across flooding gradients, with bud numbers at 0.5, 1, and 2 m being higher than the control (0 m), though differences were not significant ($p > 0.05$).

[Figure 4: see original paper] The number of underground buds of three dominant species under different water depths (bars represent means; different letters indicate significant differences among water levels)

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3. Discussion

Hydrological processes are the main factors constraining wetland plant growth and distribution. Vegetation at lower elevations is more easily flooded and experiences longer flooding duration. In such gradient flooding environments, plants undergo adaptive changes in functional traits. The aboveground parts of wetland plants respond most directly to water level gradients by altering plant height and leaf area to adapt to stressful environments. Numerous studies have shown that a plant' s ability and strategy to adapt to environmental changes determine its survival and distribution range.

Poyang Lake' s low water level phenomenon is pronounced, seriously affecting beach vegetation growth and distribution. Biomass change is a comprehensive response of wetland plants to environmental changes. Plants often adopt optimal biomass allocation ratios to obtain more resources and survive stressful environments like flooding. However, the decreasing trend of biomass along water depth gradients varies among species. This study found that flooding generally reduced biomass in all three plants, but the trends differed. *Carex cinereascens* showed huge differences in biomass between flooded and non-flooded conditions, but no differences among flooding gradients. Combined with height and ramet changes, this indicates *C. cinereascens* adopts a tolerance mechanism—when flooded, it concentrates biomass in underground parts and enters dormancy.

Miscanthus lutarioriparius biomass decreased with increasing water depth, while its height increased at shallow depths, suggesting an escape strategy. However, as depth increased further, photosynthesis declined and could not support rapid height increase, causing it to adopt a tolerance strategy similar to *C. cinereascens* and enter dormancy. *Phalaris arundinacea*, with its slender stems, showed no significant biomass differences across gradients, indicating it can grow rapidly after water recession.

Poyang Lake' s vast beach areas subject vegetation at different elevations to different flooding depths, with each vegetation type developing its optimal biomass allocation strategy. When water levels change, vegetation faces new flooding depths, and its biomass adaptation strategy will determine survival and distribution boundaries at the new depth.

The three dominant species on Poyang Lake beaches show different growth responses to different water level gradients. From biomass changes, *C. cinereascens* only distinguishes between flooded and non-flooded conditions, with height gradually decreasing. To reduce energy consumption from respiration during flooding, *C. cinereascens* leaves begin to wither. At 0.5, 1, and 2 m flooding gradients, *C. cinereascens* height gradually decreases. Without obvious stems, *C. cinereascens* reduces height to adapt.

Miscanthus lutarioriparius only shows significantly reduced height at 2 m flooding gradient. With obvious main stems, at 0.5 and 1 m depths, stem nodes increase rapidly to expose more leaves above water and increase photosynthesis. However, as flooding depth continues increasing, this risky strategy causes greater damage to plants and affects post-flooding recovery growth. During dry years, previously suppressed *M. lutarioriparius* can grow normally, and its community expands to lower elevations. While low water fluctuations may not significantly affect *C. cinereascens* growth, as *M. lutarioriparius* communities shift downward, interspecific competition with *Carex* communities intensifies.

In the context of fluctuating water levels, wetland plant growth and reproductive responses often determine distribution patterns. Poyang Lake's flood season water level changes significantly impact vegetation growth and post-flooding reproduction. Different flooding depths had no significant effect on *C. cinereascens* cluster circumference increase. *Carex cinereascens* has well-developed rhizomes and tolerates different flooding depths by concentrating nutrients underground. In field conditions, since different flooding depths did not significantly affect *C. cinereascens* reproduction, only underground buds can regrow after water recession, giving *C. cinereascens* the widest distribution range on Poyang Lake beaches.

Although *P. arundinacea* mostly appears as standing dead vegetation on beaches after water recession, our experiments showed significant differences in ramet numbers across flooding gradients, with maximum ramet number at 2 m depth. Some wetland plants store more nutrients as buds after experiencing certain flooding depths. *Phalaris arundinacea* is a Poaceae species with strong flooding adaptability. Field surveys show its underground bud bank density is greater than adjacent *Carex* and Polygonaceae species. During high-flow years when Poyang Lake water levels rise, this high water level change has less impact on *P. arundinacea* reproduction, and its underground buds can expand to higher elevations.

Poyang Lake’ s water level changes significantly. Studying growth of Poyang Lake beach dominant species under different flooding depths is particularly important. The growth characteristics and reproductive strategies of *P. arundinacea* under different water levels are important clues for predicting its survival and distribution. *Carex* can tolerate deeper flooding through well-developed rhizomes, enabling broad distribution across different elevations. *Miscanthus lutarioriparius* distribution approaches higher elevations because ramet production is inhibited at 0.5 m depth. *Phalaris arundinacea* shows no ramet number reduction at 0.5 m depth and can grow well, indicating it is suitable for lower elevation habitats.

This study of three dominant Poyang Lake beach species at the individual level has far-reaching significance for understanding vegetation growth changes under fluctuating water levels. Water level fluctuations not only affect individual plant growth but also alter interspecific relationships. Future research should focus on interspecific and intraspecific relationships to comprehensively understand vegetation distribution patterns in this changing environment.

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Note: Figure translations are in progress. See original paper for figures.