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General plant strategies and functions in wetlands: global trait-based analyses

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Summary

Wetland ecosystems provide important ecosystem services including water purification, flood abatement, biodiversity support and carbon sequestration. Wetland ecosystems are distinguished from non-wetland terrestrial ecosystems by their unique hydrological regime and consequent anoxic substrates. The quick depletion of oxygen in the rhizosphere and associated biogeochemical processes can cause the potential accumulation of phytotoxic compounds. Specifically, the utilization of electron acceptors alternative to oxygen results in the production of toxic chemical matter, including ferrous iron, sulphide and low-weight monocarboxylic acids (e.g. acetic, propionic, butyric and hexanoic acids).

To cope with the adverse environmental conditions and survive in wetlands, wetland plants have developed a suite of ecophysiological adaptive traits. Such traits include root porosity, shoot elongation, a decreased root/shoot ratio, a root radial oxygen loss (ROL) barrier, leaf gas films, and enhanced underwater photosynthesis. These adaptive traits do not only ameliorate the oxygen deficit in plant tissues and improve aerobic metabolism. Moreover, ecophysiological researches have shown that these traits also affect the biogeochemical processes in the sediment through enhancing the plants' inner aeration and releasing excess oxygen to the rhizosphere. However, previous studies on wetland ecophysiological adaptive traits mainly discussed these principles for single or few plant species across a local species pool or under experimental conditions only. Therefore, we lack the understanding of the general drivers of these adaptive traits at regional to global scales - a knowledge gap this thesis addresses. Chapter 2 explores the general potential drivers of wetland adaptive traits (root porosity, root/shoot ratio and underwater photosynthetic rate) at a broader scale, and reveals that bioclimatic variables (temperature and precipitation) are strong drivers for all of the three adaptive traits. Additional locally important drivers, e.g. local habitat, hydrology and plant life form, are also involved, but in different ways for each of these traits. This suggests that a variety of mechanisms affect the local expression of different adaptive traits.

Next to wetland adaptive traits that are critical for plants to survive in wetlands, leaf economics traits that express how plants acquire and allocate resources and are crucial in terrestrial systems may also play an important role. However, whether and to which extent this leaf economics spectrum (LES) also exists in global wetland ecosystems has remained unknown. In addition, the cost and consequent trade-offs in resources budget may modify the LES pattern compared to non-wetland terrestrial ecosystems. Chapter 3 tests the LES in global wetlands ecosystems and reveals that wetland plants in general show shifted trait-trait relationships, compared to non-wetland plants, with lower leaf mass per area, higher leaf nitrogen and phosphorus, faster photosynthetic rates, and shorter leaf life span. The different leaf structure and functioning of wetland plants may be the cause for a faster turnover of energy and biomass, and a potentially higher payback on leaf investment.

Chapter 4 reviews the important but distinct ecological roles of wetland adaptive traits and leaf economics traits, and proposes to incorporate the two suites of traits into a trait-based wetland ecology by first understanding the interactions between these two suites of traits. Chapter 4 shows that the two groups of traits may be largely decoupled based on preliminary evidences, indicating that there can be multiple mechanisms behind the strategies of wetland plants in terms of resources acquisition and survival under wetland conditions. Chapter 4 also illustrates from a conceptual view how wetland adaptive traits and leaf economics traits together impact wetland ecosystem functioning. The potentially decoupled relationships between the two groups of traits provides possibilities to quantify the functioning such as methane emission and denitrification processes.

Chapter 5 demonstrates that wetland adaptive traits, leaf economics traits and size-related traits are indeed along three independent trait axes, based on a comprehensive analysis of global trait database. This suggests that wetland plants have rather flexible strategies in adaptation, resources acquisition and competition, respectively.

In conclusion, this thesis reveals that wetland plants have flexible strategies in coping with the complex stressors in wetlands. Wetland plant adaptive strategies can be cheap to develop without necessarily causing trade-offs with other strategies (such as with leaf economics traits). In the meantime, even though ecological roles of different wetland adaptive traits are similar, the correlations between different wetland adaptive traits can be weak, and the driving mechanisms can be different. This provides a flexibility to wetland plants in adapting to different wetland environmental conditions, such as oxygen shortage, submergence, and phytotoxic compounds in the substrate. The largely independent strategies of wetland plants in relation to growth, competition and adaptation imply that flexible wetlands management practices are possible on the different trait dimensions. Through the control of individual environmental driving factors for each trait dimension separately, we can potentially achieve multiple management goals concurrently to optimise the ecosystem services provided by wetlands.