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Soil seed banks and their implications for wetland restoration along the Nongjiang River, Northeastern China

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ABSTRACT

Soil seed banks provide seeds for the redevelopment of plant communities in wetlands. They can be important components of the ecological restoration of farmed wetlands, particularly if the seeds can survive periods of cultivation. We assessed if key structural dominant wetland plant species were present as seeds in farmed sedge meadows in northeastern China. We conducted a germination experiment in a greenhouse to compare the seed banks of four natural sedge meadows and four adjacent farmed fields along the Nongjiang River under drained and flooded conditions. We further conducted vegetation surveys in four natural sedge meadows. Sedges (*Carex* species) and the grass *Calamagrostis angustifolia* dominated plant communities in the natural sedge meadows. Many important sedge meadow species (>30 species, e.g., *Calamogrostis angustifolia* and *Potamogeton crispus*) survived cultivation as seeds. Farmed fields converted from sedge meadows are nearly devoid of dominant *Carex* species, including two keystone tussock-forming species, *Carex appendiculata* and *Carex meyeriana*. Species of various life history types require either drawdown (emergent, e.g., *Carex lasiocarpa* and *Calamogrostis angustifolia*) or flooding (submerged, e.g., *Potamogeton crispus* and *Ceratophyllum demersum*) for successful germination. The structure of the seed bank was related to experimental water regime, and the field environments of latitude, number of years farmed, and field water depth based on Nonmetric Multidimensional Scaling (NMDS) analysis. Our study indicated that, although certain critical components of the vegetation are not retained in seed banks, which made it difficult to replicate historic habitat via natural recolonization, the seed banks of farmed sedge meadows could still contribute toward the restoration of novel wetland vegetation assemblages under suitable environmental conditions. *Carex* reestablishment could rely upon artificial introduction if necessary.

1. Introduction

In China, as in other parts of the world, wetlands have declined dramatically in the past century due to land drainage and agricultural intensification (Lu, 1990; State Forestry Administration, 2000). This trend has been particularly marked in the sedge meadows in the Nongjiang River watershed in the Sanjiang Plain, northeast of China, where a huge expanse of wetland habitat once covering more than 80% of the area (1,316,252 hm^2) now totals only 9% (148,460 hm^2) (Wang et al., 2011; Xue et al., 2012). Here habitat loss began from the 1950s with drainage and reclaimation for soybeans. Technological advances since the 1990s have led to suitable conditions for rice production and ultimately to the intensive agricultural land use that is prevalent today. The remaining undrained habitat is now located within a few isolated nature reserves and immediately along the river (Zhao, 1999; Xue et al., 2012).

The dramatic decline in undrained habitat has promoted research in China and elsewhere into the potential for the restoration of sedge meadow and wet grassland vegetation alliances through the utilization of the soil seed bank (Thompson and Grime, 1979; Galatowitsch and van der Valk, 1996; Wagner et al., 2003; Wang et al., 2013a). The composition and resilience of the seed bank play an important role in the process of habitat restoration (Roberts, 1981; Middleton, 2003), particularly if the species remain viable in the soil for long periods of time (van der Valk and Davis, 1978; Nishihiro et al., 2006). If the seeds of key structural dominants are missing from seed banks, farmed fields can be difficult to restore

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back to wetland (Kettenring and Galatowitsch, 2011; Wang et al., 2015). Investigations examining sedge meadow and wet grassland in Europe and North America have generally concluded that important components of vegetation are often missing from farmlands or grazing lands (Matus et al., 2003; Mulhouse and Galatowitsch, 2003; Kettenring and Galatowitsch, 2011; Stroh et al., 2012). In the prairie pothole region of the mid-continental U.S., where wetlands were restored via natural recolonization, many of the native perennials typical of wet meadows have not returned. While some plant guilds have successfully re-established, more than 60 *Carex* species that are common features in natural prairie wetlands rarely return to restorations (Aronson and Galatowitsch, 2008). Similar conditions were also found in Europe (Blomqvist et al., 2003; Stroh et al., 2012). The value of the seed bank to restoration varies greatly according to wetland type, the type and duration of degradation activities, the longevity of the seeds and environmental conditions (Middleton, 2003; Wang et al., 2013a; Wang et al., 2015). Little is known about the composition and resilience of the seed banks in both natural and farmed sedge meadows in northeastern China and their implications for restoration.

Wetland hydrologic regime is a major determinant of plant community development from seed banks (van der Valk, 1981), among other reasons because seed germination of various species is very dependent on water level (Willis and Mitsch, 1995). Flooding may decrease light levels and available oxygen, leading to lower survival of dormant seeds compared to non-flooded conditions (Nicol et al., 2003). As the water level fluctuates, species composition changes quickly; some populations may disappear and other populations may become established. Flooding regime is probably the most important environmental factor affecting the distribution of canopy, community type and biodiversity (Wang et al., 2014).

The Heilongjiang Provincial Government suspended wetland development to prevent further conversion to farmland in 1998. This edict was reinforced in 2003 with the provincial adoption of the Regulation on Wetland Conservation (Li, 2008). The province developed plans for wetland restoration of >150,000 ha of farmland in the Sanjiang Plain, and their forestry department began implementation of the restoration program. The first stage of the program was to establish plants in hydrologically restored wetlands relying on both the remaining seed bank of the farmed fields and movement of propagules from nearby remnant wetlands along the river (Wang et al., 2002; Xue et al., 2012).

The main purpose of this study was to compare the composition of the seed banks of natural sedge meadows to farmed fields and evaluate the potential influence of the seed bank on wetland restoration along the Nongjiang River in the Sanjiang Plain, northeastern China. Through the collection of data on seed banks and standing vegetation, we addressed the following questions: (1) How does the composition of seed banks change due to farming activities and what is the value of farmed seed banks for restoration of the vegetation of sedge meadows? (2) How do hydrological conditions influence seed banks in farmed fields and natural wetlands? and (3) which environmental factors influence the composition of seed banks in farmed fields and natural wetlands?

2. Materials and methods

2.1. Study sites

The study sites are in the Nongjiang River watershed, which is 14.8% of the area of the Sanjiang Plain. The Nongjiang River basin is located in the confluence of the Songhua, Heilongjiang and Wusuli Rivers in a vast alluvial floodplain. In 1954, wetlands covered more than 80% of this area (Zhao, 1999). Large areas of wetlands were converted for production of soybeans from the 1950s. A major transformation of the type of agriculture occurred in the Nongjiang River watershed from 1990 to 2010, when large amounts of wetlands and soybean fields were converted to rice paddy fields. The wetlands along the Nongjiang River were also converted and farmed for rice (Xue et al., 2012), and therefore the farmlands adjacent to the remaining wetlands are mainly paddy fields. By 2010, the areas of paddy fields reached 693,777 hm^2, and wetlands covered less than 9% of total area (148,460 hm^2) (Xue et al., 2012). Intact wetlands are now found only in wetland reserves or along the Nongjiang River (Fig. 1).

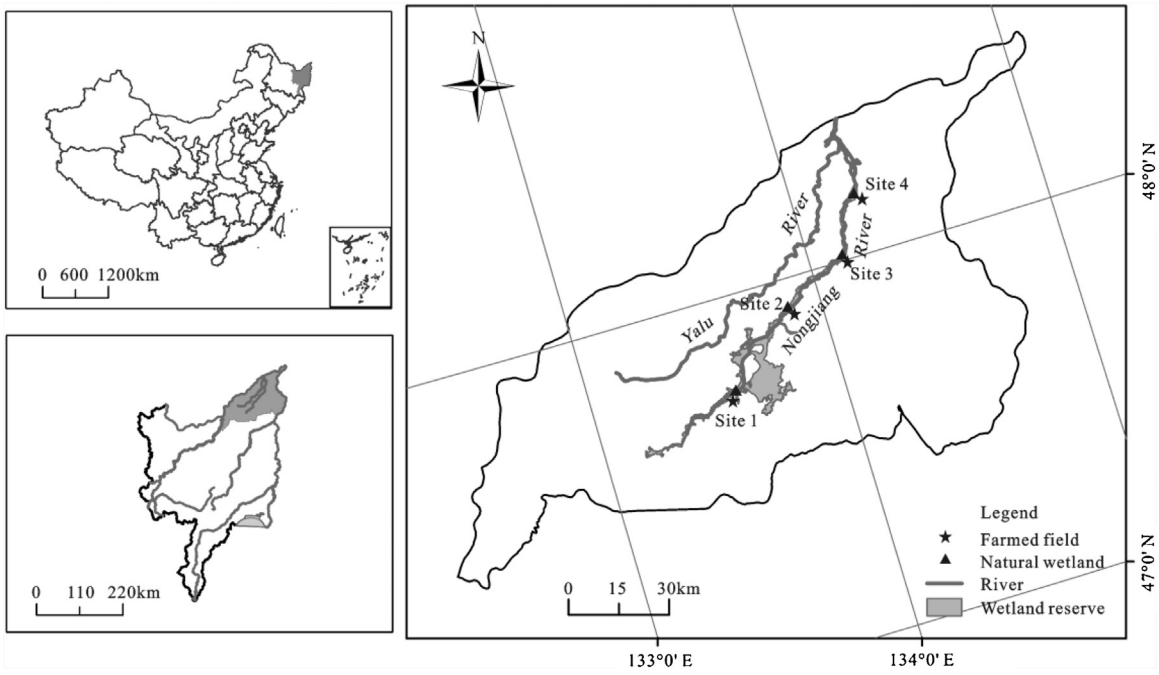

Fig. 1. Site locations for seed bank sample and field vegetation survey along the Nongjiang River, Sanjiang Plain, northeastern China.

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