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Original Research Article

Prediction of the changes in ecological pattern of wetlands due to a new dam establishment in China

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ABSTRACT

Marsh wetlands play an important role in the conservation of biodiversity. However, marshes suffer from constant water scarcity resulting in intensifying habitat degradation, owing to the coupled impacts of global climate change and decline in available regional water resources. Scientific research is required to provide appropriate management strategies for marsh restoration and conservation. The Honghe National Nature Reserve (HNNR), a Wetland of International Importance in China, was selected as a case study to quantitatively demonstrate the relations between hydro-geomorphological gradients and spatial ecological patterns of plant communities. Digital abstraction and analyses of the hydrologic gradient were carried out in the HNNR based on hydrological data with the support of geographic information system and remote sensing techniques. A correlation between wetland water level and corresponding distribution of plant communities in wetland ecosystems was empirically derived based on field surveys and previous scientific research. In accordance with this correlation, management efforts were focused on restoring and optimizing wetland ecosystems resulting from artificially raised water levels. Results show that with a water-level increase of 30 cm at a new dam located in north-eastern HNNR, both areas of marshes and open water markedly increase, while the area of degraded marsh (wet meadow) and non-marsh communities decline. Results from three scenarios (increased water levels of 30, 50 and 70 cm) indicate recovery of wetland vegetation is non-linearly correlated with water-level change. This research provides a case study to show the scientific capacity in analysis, prediction, control and management of wetland ecological restoration.

1. Introduction

Freshwater marsh wetlands are some of the most important habitats for biodiversity, and, therefore, it is incumbent to preserve vital ecological functions such as biodiversity conservation and gene pool maintenance of rare flora and fauna. Currently, marsh wetlands have suffered from severe degradation due to extensive reclamation and land-use alteration (Wang et al., 2011b). Moreover, remaining wetlands are worsened by unfavourable conditions, *e.g.*, altered hydrological regime and damaged habitats (Zhao, 1999; Zhou et al., 2007; Zhou et al., 2008); hence it is necessary to immediately undertake wetland restoration and conservation. However, marsh wetlands are distributed along the transition zone between terrestrial and aquatic environments, and

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the hydrological regime in these wetlands is extremely complex, resulting in highly fragmented and diverse wetland habitats. These factors are responsible for the present insufficient understanding of both the quantitative relationship between hydrological regime and habitat characteristics of wetlands, and on the evaluation of measures for restoring and conserving wetland ecohydrological pattern (Datta, 1990; Zhou et al., 2009).

Wetland restoration and conservation have been extensively carried out and brought into practical application in western countries (Zalewski, 2002). In recent years, relevant reports have been increasingly released in China as well. For the most part current theoretical research in China is mostly limited to field measurement and fundamental studies. Most field experiments involve the physiological and ecological responses of specific wetland plants under various artificially controlled conditions, generally by the control of water level or the establishment of certain threshold values. Manipulations and observations are subsequently performed for the study objects, typically on diverse physiological and ecological indices for specific pre-selected plant communities, followed by research on the pattern of ecological response. Other ecologists conduct research at specific locations on typical wetland habitats, where, under natural or semi-natural conditions, long-term observations are carried out for specific plants or plant communities. These studies have provided important scientific bases for the field application of wetland restoration and conservation. However, with intensifying degradation of natural wetlands, there is an urgent need to promote studies on real-demand-oriented applications of wetland restoration and conservation (Wang et al., 2011).

At present, wetland restoration projects strongly emphasize localized specific targets, such as restoring the hydrological regime, bank slope design and the implementation of other engineering methods to improve water quality. This type of work tends to lack understanding of the relationships between regional natural ecosystem pattern and physical habitat alterations. Moreover, follow-up scientific assessment is relatively insufficient after the completion of wetland restoration and conservation projects. Improvement in such aspects can greatly benefit the advancement in theories and methodologies in wetland science. Additionally, outcomes from current scientific studies on ecological recovery mechanisms in wetlands should be actively integrated into practical projects on ecological restoration and conservation (Cui and Ai, 2006), so as to expand the general methodological significance and test the practical validity of restoration achievement. Emphasis should be put on the evaluation of recovery objectives and management strategies that are directly linked with actual wetland restoration projects.

As an internationally important protected area on the Ramsar list, the Honghe National Natural Reserve (HNNR) is a key focus for ecological restoration of marsh wetlands by management authorities. To overcome the deficit in environmental water demand in the marsh wetland, a new dam has been constructed on the northeast boundary of the HNNR (Fig. 1) and has resulted in an expansion of flooded area, leading to change in the physical characteristics of marsh habitats, which further result in modifications to the ecological pattern in the wetlands. Study of such issues requires understanding of ecohydrological principles and the integration of multiple techniques to accurately predict ecological restoration processes (Cui et al., 2005), so as to better contribute to wetland management and conservation. The objectives of this study are as follows: (1) to predict spatial and temporal modifications in surface water level due to new dam construction by integration of digital terrain spatial analysis and field data on water level; (2) to predict changes to wetland ecological patterns caused by water-level modifications in the study area, based on former studies on wetland plant communities and corresponding water levels in Northeast China and long-term observations on the coupling pattern between plant ecology and hydrology in the HNNR; (3) to derive the most appropriate ecological restoration strategy under changing water conditions in the study area by establishing three scenarios with different controlled water levels. The present study is an informative practical case for wetland conservation and restoration, and a valuable exploration in the formulation of scientifically sound strategies in wetland management.

2. Data source and methods

2.1. Description of study area and data preparation

The Sanjiang Plain is the region with the most extensive and concentrated aquatic habitats of various types in China, including freshwater marsh, marshy meadow, meadow, river, lake, *etc*. Wetlands in this region are of international and regional concern owing to their role in genetic conservation of numerous plant species and important habitat for rare and endangered waterfowl. The HNNR (Fig. 1) is located in the northeast of the Sanjiang Plain in Heilongjiang Province. Known for its 'unique gene pool of wildlife in the Sanjiang Plain,' the HNNR is a landscape miniature of the pristine freshwater marsh wetland complex. The HNNR was recognized as a Wetland of International Importance by the Ramsar Convention in January 2002. Nongjiang River, a primary tributary of Heilong River, is a natural northern boundary of the HNNR. The Woyalan River flows northwards from the centre of the HNNR into Nongjiang River, forming a relatively complete drainage area. It is particularly favourable for wetland formulation being a low-lying, flat area in the confluence area of three rivers. The basic characteristics of the hydrology–ecology relationship for pristine marsh wetland in the Sanjiang Plain are highly representative of the regional wetland ecosystem complex.

A digital elevation model (DEM) of the study area was derived by vector extraction from topographic maps that were published in 1994 by the Land Survey of Helongjiang Province at the scale of 1:10 000 with 1 m elevation intervals. Multiple topographic maps were digitally scanned to cover the whole study area. Screen track was then carried out to control the precision, which was followed by the extraction of contour lines and elevation points with the vector conversion software, R2V. Different topographic maps were then stitched together, and elevations and contours of the study area were thus built.