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Niche modelling of marsh plants based on occurrence and abundance data

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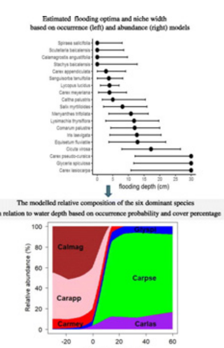
HIGHLIGHTS

- Niche optimum and width for a flooding gradient were modelled for dominant wetland plant species.
- Models based on abundance outperformed those based on presence-abscence.
- We predict a shift from helophytes to wet meadow species as the water level drops below the surface.
- The models are useful as basis for conservation and wetland management.

GRAPHICAL ABSTRACT



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ABSTRACT

The information of species' response (optimum or critical limits along environmental gradients) is a key to understanding ecological questions and to design management plans. A large number of plots (762) from 70 transects of 13 wetland sites in Northeast China were sampled along flooding gradient from marsh to wet meadow. Species response (abundance and occurrence) to flooding were modelled with Generalized Additive Models for 21 dominant plant species. We found that 20 of 21 species showed a significant response to flooding for the occurrence and abundance models, and four types of response were found: monotonically increasing, monotonically decreasing, skewed unimodal and symmetric unimodal. The species with monotonically increasing response have the deepest flooding optimum and widest niche width, followed by those with unimodal curve, and the monotonically decreasing ones have the smallest values. The optima and niche width (whether based on occurrence or abundance models) both significantly correlated with the frequency, but not with mean abundance. Abundance models outperformed occurrence models based on goodness of fit. The abundance models predicted a rather sharp shift from dominance of helophytes (*Carex pseudo-curaica* and *C. lasiocarpa*) to wet meadow species (*Calamagrostis angustifolia* and *Carex appendiculata*) if water levels drop from about 10 cm above soil surface to below the surface. The defined

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optima and niche width based on the abundance models can be applied to better instruct restoration management. Given the time required to collect abundance data, an efficient strategy could be to monitor occurrence in many plots and abundance in a subset of these.

1. Introduction

The ecological response of a plant species to an environmental gradient is essentially one dimension of the realized niche (sensu Hutchinson, 1957), which has received attention in theoretical and applied (management and conservation) studies. So far, efforts to describe species niches have focused on climatic variables because of accessibility of data (Hijmans et al., 2005). Increasingly, ecologists are recognizing the importance of hydrological and edaphic factors in structuring the geographic distribution in plants (e.g. Gilbert and Lechowicz, 2004, Coudun and Gegout, 2006, Romain et al., 2012). However, our knowledge of the geographic variability of species response to hydrological and edaphic factors is still limited, in part due to the difficulty in acquiring data.

Species response curve (SRC) has been developed to model the response of a species to environment gradients, yielding species optima and amplitudes with respect to measured ecological factors (Austin et al., 1990; Vetaas, 2000; Coudun and Gegout, 2006). Many statistical techniques have been developed (Hastie and Tibshirani, 1990; Austin, 2002; Guisan et al., 2002; Oksanen and Minchin, 2002). Generalized Additive Models (GAMs) (Guisan et al., 2002) have been suggested as an approach that allows an explicit and rigorous analysis.

The shape and location of species response curves have always been the core and focus of ecological niche research. Several conceptual models have been proposed for the response shapes, the most familiar being the bell-shaped or Gaussian curve (Austin, 1990). Other models predict a variety of possible shapes (Walter, 1979). However, practical evidence to support or oppose the existence of certain shapes is deficient (Epstein et al., 1996). Meanwhile, the discussion on if species distribution is affected by niche width or optimum has been the focus of biogeography and ecology, but there is a lack of evidence for the impact of these niche parameters on the local abundance of species (e.g. Brandle and Brandl, 2001; Marsden and Whiffin, 2003).

Most ecological niche models are built on presence-only or presence-absence data (Guisan et al., 2002) and predict the presence, and only occasionally the abundance of the species (Yañez-Arenas et al., 2012; Martinez-Meyer et al., 2013). Ehrlén and Morris (2015) have summarized the effects that are thereby neglected: the future abundance of a species is crucial for its effect on ecosystem function, its future extinction risk (as in theories of island biogeography and metapopulations, Hanski, 1999) and its effect on interacting species. However, probably as a result of the larger field effort required, there are only few studies using abundance data (e.g., Potts and Elith, 2006; Renwick et al., 2012; Johnston et al., 2013). Comparisons between presence-absence and abundance models are also rare. Howard et al. (2014) indicated that abundance data improved species distribution models, and more studies are needed to test this.

Wetlands are suitable habitats for studying changes in the ecological behaviour of species, for several reasons: (1) their species composition is relatively stable compared with other ecosystems (Archibold, 1995); (2) their floristic variation is mostly governed by a dominant environmental gradient, which is well defined and easily measured, e.g. flooding or pH (Nordbakken, 1996; Gignac et al., 2004; Duval et al., 2012). Flooding represents a complex gradient that correlates to many edaphic factors (Lou et al., 2013), not least via its effect on redox potential (Reddy and DeLaune, 2008). However, studies on species distribution along water depth gradient in wetlands are still rare, especially outside North America and Europe.

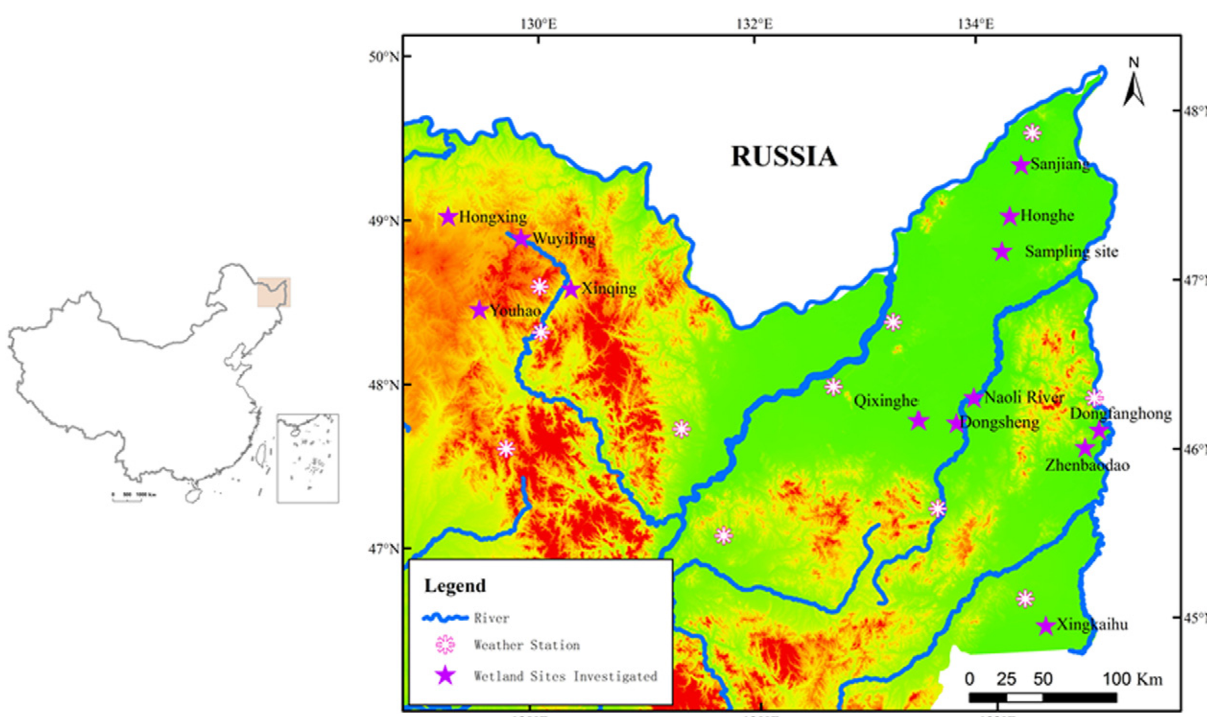

Fig. 1. Distribution of plots investigated in wetlands in the Sanjiang Plain, Northeast China.