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RESEARCH ARTICLE

Relationship between community type of wetland plants and site elevation on sandbars of the East Dongting Lake, China

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Abstract Plant communities on sandbars were important, and restoration of degraded wetland were significant to biological conservation in the East Dongting Lake region. In this study, typical wetland community types on sandbars and their site elevation were surveyed to explore relationship between community distribution and site elevation. Results show that eight major communities in this region were wetland communities dominated by *Juncus effusus*, *Carex brevicuspis*, *Polygonum hydropiper*, *Salix triandra*, *Oenanthe Javanica*, *Phalaris arundinacea*, *Miscanthus sacchariflorus* and *Phragmites communis* respectively. These communities had obvious constructive species and companion species, while site elevation could affect community composition and their species diversity. On sandbars in the East Dongting Lake, vegetation was largely composed of hygrophytes companied with a few mesophytes. The higher the site elevation was, the nearer the site was to the water, and the lower community diversity became. Except soil humidity and site elevation, growth period of plants after inundation could also affect species richness in the communities.

Key words wetland, restoration, sandbar, elevation, the East Dongting Lake

1 Introduction

Wetlands have many ecological functions such as a refuge for plant species and wildlife, flood mitigation, etc. However, making polders of sandbars, industrial drainage, grazing and other economic activities have caused damage to these functions, which is the more recent condition of Dongting Lake, China (Wu et al., 2000; Jiang and Huang, 2004; Zhao and Fang, 2004). After the 1998 flood in the Yangtze River, the Chinese government launched a lake restoration project in Dongting Lake and large areas of impoldered farmland were abandoned for wetland vegetation restoration. Simultaneously, management of three nature reserves in the region had been strengthened to protect natural wetland vegetation (Dou and Jiang, 2000). Exploration of the relationship between vegetation and the factors which affect it, has become a priority issue in the restoration and protection of the wetlands of Dongting Lake. We have studied the relationship between sandbar vegetation and its elevation for the sake of restoring the vegetation in the East Dongting Lake region.

2 Study area and methods

2.1 Study area

Dongting Lake lies to the south of the Jingjiang River in northern Hunan Province, between the coordinates 28°30′–29°31′N, 111°40′–113°10′E. Dongting Lake consists actually of three major lakes, an eastern, southern and western lake and many small scattered lakes. As the second largest freshwater lake and the only lake basin exchanging water with the Yangtze Rivers in China, the lake is regarded as one of the best-preserved historic huge freshwater lake in the world.

The East Dongting Lake covers an area of 1328 km^2 and is the No. 1 water basin in this region. Around the East Dongting Lake, sediments from rivers and lakes contribute to a large floodplain and bogs, with elevations below 35 m in the Huanghai Vertical Datum 1965 and with slopes less than 3°. The landscape of the East Dongting wetlands includes many waterways, sandbars and sandbanks. Vegetation in the wetlands has developed well on the sandbars and provides a rich food supply and shelter for wildlife, especially for many migratory birds. In 1992, the East Dongting Lake Nature Reserve established by the Chinese government, was included in the list of the International Wetland Convention (Dou and Jiang, 2000).

2.2 Study methods

Our research was confined to the sandbars in Xiaoxihu, Tuanzhou and Junshanhouhu in the East Dongting

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Lake. Field research was conducted from November 2006 to April 2007. Eight typical plots were selected, representing major community types in the East Dongting Lake. Since wetland vegetation on sandbars always exhibit ringed or belted patterns along the water line, plots were established from the water line to higher elevations, with 20 subplots of 1 m×1 m. The subplots distributed systematically on plots and were composed of similar plants. In each plot, its geographic coordinates, soil type, community type and disturbance were surveyed, and plant species, density, coverage, height, phenological stage were recorded in each subplot.

Since the water in the lake is dynamic, plots with different elevations suffer variously, both from depth and length of inundation. Plot elevations were represented by the elevation of plot center which is absolute elevations obtained from the benchmark elevation (a point in the Huanghai elevation system). The basic information of the plots is summarized in Table 1.

After data entry, several species indices were calculated, including relative density, relative coverage, relative frequency and importance value. Based on the importance value of a species, the Shannon-Wiener index was calculated to show the species diversity. Equations used for calculating importance value and Shannon-Wiener index are:

$$\mathrm{IV}_i = (\mathrm{RD}_i + \mathrm{RC}_i + \mathrm{RF}_i)/3$$

where IV_i refers to the importance value index of the ith species and RD_i, RC_i and RF_i are, respectively, the relative density, relative coverage and relative frequency of the ith species.

$$H'_j = -\sum_{i=1}^{s} p_i \lg p_i$$

where H'_j is Shannon-Wiener index, representing species diversity of the jth plot; P_i refers to the rate of the importance value of the ith species to the sum of importance values of the entire community of the jth plot; S is the number of plant species in the community. The calculations were conducted on Excel Software.

3 Results

3.1 Major plant community types

The constructive species of the eight surveyed plots are *Juncus effusus*, *Carex brevicuspis*, *Polygonum hydropiper*, *Miscanthus sacchariflorus*, *Phragmites communis*, *Salix triandra*, *Oenanthe javanica* and *Phalaris arundinacea*. Their average heights (H) and importance values are listed in Table 2, as well as the companion species in these eight community types. In our study region, wetland communities are largely composed of hygrophytes companied with a few mesophytes. *Carex brevicuspis* is widely distributed in the different communities.

3.1.1 Juncus effusus community

The elevation of plot 1 is very low and *J. effusus* communities are the nearest plant community to water among the surveyed plots, next to bare, muddy beaches around the water. At the site, the water level is very high and the community area is often small. The dominant species in the community is *J. effusus* and companion species include *C. brevicuspis* and *Polygonum hydropiper*, etc.

3.1.2 Carex brevicuspis community

Carex brevicuspis communities are located on very low sandbars with little sedimentation and flooded for 4 to 6 months each year. As one of the most common wetland vegetation types, its major dominant species is *C. brevicuspis*, companied with *C. lyrata*, *Polygonum hydropiper* and *J. effusus*.

3.1.3 Polygonum hydropiper community

Polygonum hydropiper communities are scattered on sandbars of middle elevation with shorter inundation times than those of *C. brevicuspis* communities. The communities usually show up as wetland vegetation mosaics. Its dominant species is *Polygonum hydro-*

Table 1 Basic information of the surveyed plots in the East Dongting Lake

Plot	Constructive species	Elevation (m)	Soil type	Location
1	*Juncus effusus*	25.1	Swamp meadow soil	Xiaoxihu
2	*Carex brevicuspis*	26.0	Swamp meadow soil	Xiaoxihu
3	*Polygonum hydropiper*	27.0	Swamp meadow soil	Xiaoxihu
4	*Miscanthus sacchariflorus*	29.0	Swamp meadow soil	Tuanzhou
5	*Phragmites communis*	29.0	Swamp meadow soil	Tuanzhou
6	*Salix triandra*	27.2	Swamp meadow soil	Junshanhouhu
7	*Oenanthe javanica*	27.4	Swamp meadow soil	Junshanhouhu
8	*Phalaris arundinacea*	27.4	Swamp meadow soil	Junshanhouhu

Table 2 Species composition of typical wetland communities on sandbars in the East Dongting Lake

Plot	Constructive species			Companion species
	Species	Height (m)	Importance value	
1	*J. effusus*	0.22	78.73	*Carex brevicuspis*, *Polygonum hydropiper*, *Phalaris arundinacea*
2	*Carex brevicuspis*	0.25	89.14	*Cardamine lyrata*, *Polygonum hydropiper*, *J. effusus*
3	*Polygonum hydropiper*	0.76	57.89	*Carex brevicuspis*, *J. effusus*, *M. sacchariflorus*, *Galium aparine* var. *tenerum*, *Strobilanthes cusia*, *Carex lyrata*, *Potentilla chinensis*
4	*M. sacchariflorus*	2.94	21.61	*Carex brevicuspis*, *Carex dispalata*, *Phragmites communis*
5	*Phragmites communis*	3.46	27.48	*Carex brevicuspis*, *M. sacchariflorus*, *Carex dispalata*, *Euphorbia esula*
6	*S. triandra*	3.14	18.19	*Carex brevicuspis*, *Artemisia selengensis*, *Carex lyrata*, *Polygonum hydropiper*, *Phalaris arundinacea*, *Calystegia hederacea*, *Equisetum ramosissimum*
7	*O. javanica*	0.44	52.28	*Phragmites communis*, *Alternanthera philoxeroides*, *Carex dispalata*, *Polygonum lapathifolium*, *Carex brevicuspis*, *Calystegia hederacea*
8	*Phalaris arundinacea*	0.77	47.56	*Carex brevicuspis*, *Rumex acetosa*, *Cephalanoplos segetum*, *Galium aparine* var. *tenerum*, *Cynodon dactylon*, *Alternanthera philoxeroides*, *Artemisia selengensis*, *Phragmites communis*, *Medicago lupulina*, *Carex lyrata*, *Ixeris denticulate*

Note: Companion species are listed according to their IV from large to small in each plot.

piper and companion species are *C. brevicuspis* and *J. effuses*, etc.

3.1.4 Miscanthus sacchariflorus community

Miscanthus sacchariflorus communities appear on higher sites compared to the first three communities. They are inundated for less than 2 months each year. In this community, the dominant species, *M. sacchariflorus*, grows fast and its biomass accumulates very quickly. In the understory, the importance value of *C. brevicuspis* is as high as 67.37.

3.1.5 Phragmites communis community

Suitable sites for *Phragmites communis* communities are similar in elevation as *M. sacchariflorus* communities. Both communities can keep growing at low inundation levels and the two dominant species sometimes grow together. Dominant species in this community is *P. communis*, with an importance value of 62.08 for *C. brevicuspis*.

3.1.6 Salix triandra community

Salix triandra communities occur on sandbars of middle elevation with heavy sedimentation; the upper layer of this community is dominated by the woody species *S. triandra* and the understory by *C. brevicuspis* with an importance value of 43.79.

3.1.7 Oenanthe javanica community

Oenanthe javanica communities are often located on sandbars at middle elevations and sandbanks with heavy sedimentation. Today, this community is not widely present in the region. The dominant species in this community is *O. javanica* and is companied with *Phragmites communis*, *Alternanthera philoxeroides* and *C. dispalata*, etc.

3.1.8 Phalaris arundinacea community

Phalaris arundinacea communities appear on middle elevation sandbars and sandbanks of flood channels with heavy sedimentation. In the middle of bare, muddy beaches and various meadows, this community often shows belt-shaped patches. In this community, the dominant species *P. arundinacea* is always mixed with companion species *C. brevicuspis* and *Rumex acetosa*, etc.

3.2 Species diversity of the surveyed plots

The eight surveyed plots can be categorized into three groups according to their species diversity. Plots 1 and 2 are as first group with the Shannon-Wiener index below 1.0. Plots 3, 4 and 5 are the second group with a Shannon-Wiener index between 1.0 to 1.6, and plots 6, 7 and 8 form the third group with a Shannon-Wiener index over 2.0 (Fig. 1).

Species diversity of the first group is the lowest among three groups, because only very few plants can endure the high soil humidity and long periods of inundation on the low sites near the water. On newly formed bare, muddy beaches, fluctuation of the water level can inundate sites for 4 to 10 months each year, where only plants that can sprout quickly after flooding will survive. For instance, *Carex brevicuspis* can sprout twice each year in October after the flood re-

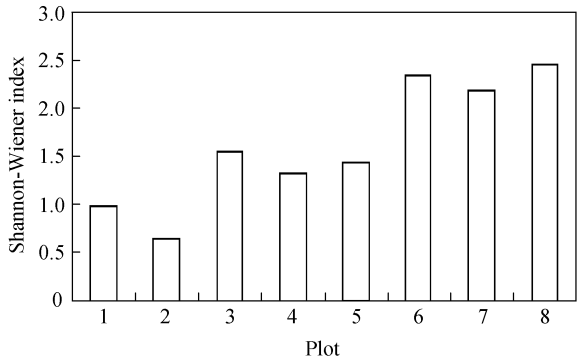

Fig. 1 Species diversity of typical communities on sandbars in the East Dongting Lake

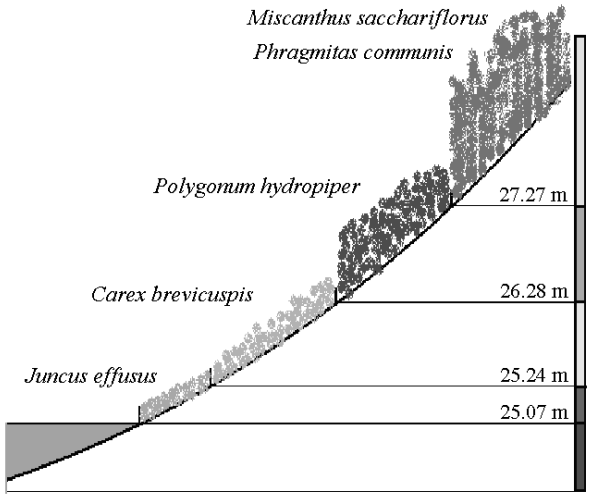

Fig. 2 Community types and site elevations on sandbar in Xiaoxihu, the East Dongting Lake

cedes and before it returns in April of the following year.

In the second group, sites for plant growth are higher due to landform and sandbar development. Plants such as *M. sacchariflorus* and *Phragmites communis* can accumulate organic matters very fast and grow quickly in height, which can help them avoid submerging in floods for a long period. Meanwhile, communities in this group are often stratified vertically, allowing other lower species to live underneath the dominant species (Table 2), which also contributes to a higher species diversity of the plots in the second group.

Comparison of the first two groups suggests that soil humidity and the length of inundation are critical to species diversity of wetland vegetation on sandbars. However, diversity indices of the third group are much higher than those of the other two groups. Except for reasons mentioned above, a longer growth period for plants is also important. Plots in the first and the second groups were surveyed in the autumn immediately after the water level of the lake receded, which means that the communities were in their early stages of development. In contrast, plots in the third group had been surveyed in the spring before the water level increased, implying that the communities developed through the winter and more species had invaded the community. The water level and growth period together contribute to the highest biodiversity in the third group.

3.3 Relationship between community type and site elevation

Among the factors affecting community types on sandbars, the most important and direct one is site elevation, i.e., the elevation of the sites relative to the water surface. To explore the relationship between community types and site elevations on sandbars, we measured a series of communities and the sites where they are present, on one large isolated sandbar in Xiaoxihu, the East Dongting Lake (Fig. 2). As shown in Fig. 2, the presence of *J. effusus*, *Carex brevicuspis*, *Polygonum hydropiper*, *M. sacchariflorus* and *Phragmites communis* communities is correlated with their elevations on this sandbar.

We observed that undisturbed vegetation appears in belts parallel to the water line on large sandbars, while on small sandbars, the pattern is similar to a ring centered on the highest locations. This phenomenon, determined by landform, water dynamics and flooding resistance of plant, is common in the East Dongting Lake, indicating that soil humidity and length of inundation are the most important factors to affect the distribution of wetland communities.

4 Discussion

Sandbars lying between water and land and their vegetations are often affected by many factors such as soil type, salinity, water inundation, etc. However, the distribution pattern of wetland vegetation often indicates a close relationship between community type and distance to a water body, whether a marsh or swamp (Fu et al., 2006; Yan et al., 2007; Wu et al., 2008). Species diversity of sandbar communities is affected by a combination of natural and human influences (Shen et al., 2008). During our field survey, we also found that grazing in *Carex brevicuspis* communities caused a change of community composition in Xiaoxihu, and a latter calculation showed that the Shannon-Wiener index increased from 0.65 in an undisturbed community to 1.60 in a grazed community nearby.

In the Dongting Lake region, natural wetland vegetation shows a mosaic pattern on most sites. A few investigations, described in the literature, have indicated this belted or ring-shaped vegetation distributions on large isolated sandbars (Peng et al., 1986; Du

and Hu, 1993; Yao et al., 2005; Yuan and Xie, 2005). Our results agree with those in the literature, which is important in proceeding of the Dongting Lake Restoration Project, especially in wetland restoration of abandoned farmland and banks. However, the relationship between the rate of community development and other factors such as silt sedimentation and the history of land use, needs further research in the future.

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