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Response of Regeneration Diversity of *Carex Lasiocarpa* Community to Different Water Levels in Sanjiang Plain, China

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Abstract: The species diversity at the regeneration stage, inflenced by different water levels, is important for community composition in the later growing season. Regeneration diversity of *Carex lasiocarpa* community under different water levels was studied at two stages, recruitment and adult, in the Sanjiang Plain, Heilongjiang Province, China. The results showed that, at the two growing stages, important value of *C. lasiocarpa* population and species richness of the community decreased with the increasing water level, while the Simpson and Shannon-Wiener diversity indexes and Pielou evenness index increased. Under different water levels, community diversities were higher at the recruitment stage, while population important values of *C. lasiocarpa* were higher at the adult stage. Indexes in vegetation evaluation must be chosen prudentially for successful restoration and effective management of wetlands, and especially for wetland restoration, the optimal time should be selected according to the restoration objectives and costs.
Keywords: water level; population dominance; species diversity; marsh wetland; Sanjiang Plain

1 Introduction

Wetland is a special ecotone between terrestrial ecosystem and aquatic ecosystem. Usually, wetland habitat condition varies significantly within a small area due to the difference of hydrological regimes. Ecological processes are controlled by hydrological dynamics in wetland (Niedermeier and Robinson, 2007). And hydrological modifications have been proved to be the main reasons for wetland degradation (Leira and Cantonati, 2008). The improvement of hydrological conditions is the key process in wetland restoration (Lane and Brown, 2007). Meanwhile, wetland plant is proved to be the most direct and sensitive indicator for hydrological degradation and wetland health (Yamada *et al*., 2007). Responses of wetland plants to hydrological regimes have always been the research focus in wetland studies. Previous studies on the responses were mainly concentrated on flooding effects (Lenssen *et al*., 1999; Leck and Simpson, 1995). Now, more attention has been devoted to responses of plants to water deficit, as wetland degradations are mostly resulted from water loss (Song *et al*., 2007), and importantly, shallow-water or non-flooding environments at recruitment stage are needed for wetland plant (Howard and Rafferty, 2006). Hydrological regime has been proven to affect seedling community composition (Weiher and Keddy, 1995; Seabloom *et al*., 1998). Many plants may disappear with the rising or falling of water level, and may be replaced by plants that can germinate successfully under the new conditions (van der Valk and Davis, 1978). Therefore, to make clear the water requirements of plants at various growth stages is favorable for effective wetlands management.

The Sanjiang Plain, with the largest freshwater marsh of China, is distributed in Heilongjiang Province, Northeast China, containing freshwater marsh, marsh meadow, rivers and lakes. Despite the ecological, hydrological and geographical significances, the area of marsh in the Sanjiang Plain has decreased sharply along with the large-scale agricultural development in recent years. And studies on wetland eco-hydrology are necessary at present. *Carex lasiocarpa* marsh, covering 57%

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of the total area, is the largest marsh type in the Sanjiang Plain (Zhao, 1999). With experiments at two growing stages, recruitment and adult, water requirements of the regeneration of *C. lasiocarpa* community were studied to better understand *C. lasiocarpa* community and provide the basis for wetland management in the Sanjiang Plain.

2 Study Area and Methods

2.1 Study area

The study site is located at the Sanjiang Mire Wetland Experimental Station, Chinese Academy of Sciences (47º35′N, 133º31′E) in the Sanjiang Plain, with a mean annual precipitation of 550–600 mm and a mean annual temperature of approximately 1.9℃. The main soils include meadow mire soil and peatland soil, with a high soil organic matter content. And the distribution of vegetation there shows a typical zonal pattern, varying from *Calamagrostis angustifolia* to *Carex lasiocarpa* as the standing water depth increases. *C. lasiocarpa* community is distributed in the centre of the site. And *C. lasiocarpa* is the single dominant species in the community, and accompanying species are mainly *Carex pseudocuraica*, *Glyceria spiculosa*, *Carex limosa*, *Equisetum limosum*, *Iris laevigate*, *Sium suave*, *Caltha palustris*, *Naumburgia thyrsiflora*, *etc*.

2.2 Experimental method

Nine undisturbed sediments (50-cm diameter and 40-cm height) were dug out, and put into buckets (50-cm diameter and 60-cm height) respectively and then placed at the former sites where the sediments were. Those materials were divided into three sets randomly and treated by inundation of –10 cm, 0 cm and 15 cm respectively. All of the buckets were drilled for water level control. Simultaneously, three pieces of lands (50-cm diameter) were enclosed with iron wire as natural controls. Regeneration experiments were conducted respectively at the general recruitment and adult stages to investigate the diversity characteristics in regeneration. On 15 June 2007, plants on the sediments and control plots were cutoff, and the recruitment stage experiment started. Until 25 July, all plants were cutoff again, and the adult stage experiment started. On 6 September, the experiments stopped.

Vegetation surveys of those sediments and control plots were conducted every ten days, totally 4 times each stage, in which species appeared in the community were recorded, individual numbers were counted, and height and coverage were measured and evaluated. But some data in the first survey at the recruitment stage were lost.

2.3 Calculation method

The important value of *C. lasiocarpa* population and diversity index of the community were calculated by following equations:

Important value (*IV*):

$$IV=\text{(relative density +relative height + relative coverage)/3} \quad (1)$$

Species richness (*S*):

$$S=\text{number of species appeared in the community} \quad (2)$$

Pielou evenness index (*E*):

$$E=-\sum_{i=1}^{n} P_i \ln P_i / \ln S \quad (3)$$

Simpson diversity index (*D*):

$$D=1-\sum_{i=1}^{n} P_i^2 \quad (4)$$

Shannon-Wiener diversity index (*H*′):

$$H'=-\sum_{i=1}^{n} P_i \ln P_i \quad (5)$$

where P_i represents the relative density of species *i*.

2.4 Statistical analysis method

Data on the 20th day after water treatments at both stages were tested by the analysis of variance (ANOVA). And multiple comparisons of means were performed by Duncan′s test at the 0.05 significance level. And the figures were done with Origin 7.5 and CorelDRAW12.

3 Results

3.1 Response of population dominance of *C. lasiocarpa* to different water levels

IV is an aggregative indicator reflecting the status and functions of plants in a community. Population *IV*s of *C. lasiocarpa* under 15 cm and –10 cm water levels were respectively the lowest and highest among all treatments ($P<0.05$). At recruitment stage, *IV* under 15 cm water level was the only one lower than that of control plots.

*IV*s at adult stage were higher than those at recruitment stage under almost all water conditions. At adult stage, *IV*s of control plots were higher than those of all water treatments except for the –10 cm water level treatment (*P*<0.05) (Fig. 1).

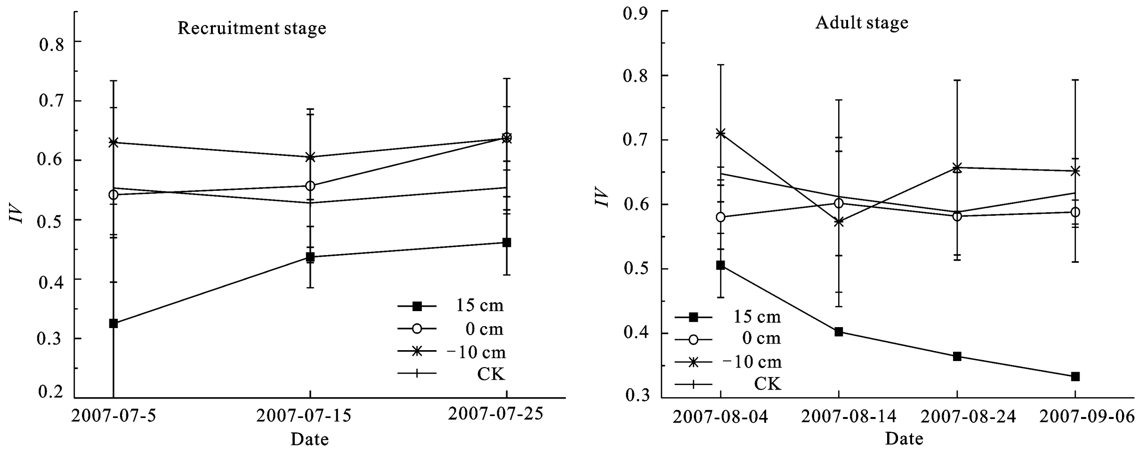

Fig. 1 Important value (*IV*) of *C. lasiocarpa* population under different water levels

3.2 Response of community diversity to different water levels

3.2.1 Species richness

As shown in Fig. 2, at recruitment stage, species richness changed gently under control and 15 cm water level treatments and greatly under other treatments, increasing with the time change and reached the maximum on July 15th. In both the first and last surveys, species richness under 0 cm water level was higher than that under –10 cm water level, but oppositely during the medium surveys. Species richness under 15 cm water level was the lowest all the time. And in the control plots, species richness was the highest at the beginning, but higher only than that under 15 cm water level at the end (*P*=0.334).

At adult stage, species richness was lower than that in the former stage under most treatments except the 0 cm water level treatment. Species richness was still the lowest under 15 cm water level, and lower under control treatments than under 0 cm and –10 cm water levels whose species richness were similar (*P*=0.401) (Fig. 2).

3.2.2 Pielou evenness

Species evenness changed similarly with the time change under various water levels, which decreased greatly at the recruitment stage and increased gently at the adult stage (Fig. 2). Species evenness was the highest under 15 cm water level, followed by that under 0 cm water level (*P*<0.05). Species evenness in control treatment was higher than that under –10 cm water level treatment only at the recruitment stage, and lower than those under 15 cm and 0 cm water level treatments at both stages. Species evenness at the two stages were similar under 15 cm water level, while higher at the recruitment stage in other treatments (Fig. 2).

3.2.3 Simpson and Shannon-Wiener diversity indexes

Responses and changing patterns of Simpson and Shannon-Wiener diversity indexes were similar at both stages (Fig. 2). At recruitment stage, the diversity indexes increased as the water level increasing and the indexes under control treatment were lower than that under 0 cm water level (*P*<0.05). In addition, diversity indexes decreased under all treatments and most fiercely under the control treatment with the time change.

At adult stage, under the three artificial water levels, the diversity indexes still increased with increasing water level (Simpson diversity index: *P*=0.147; Shannon-Wiener diversity index: *P*=0.446). And indexes under control, 15 cm and 0 cm water level treatments were lower than those at the recruitment stage, and both were lowest under control treatment. Meanwhile, the diversity indexes increased as time change, and fluctuated significantly under 15 cm water level.

4 Discussion

Many studies showed that hydrological requirements of wetland plants at regeneration stage were different from those at adult stage (Alvarez and Cirujano, 2007). Al-

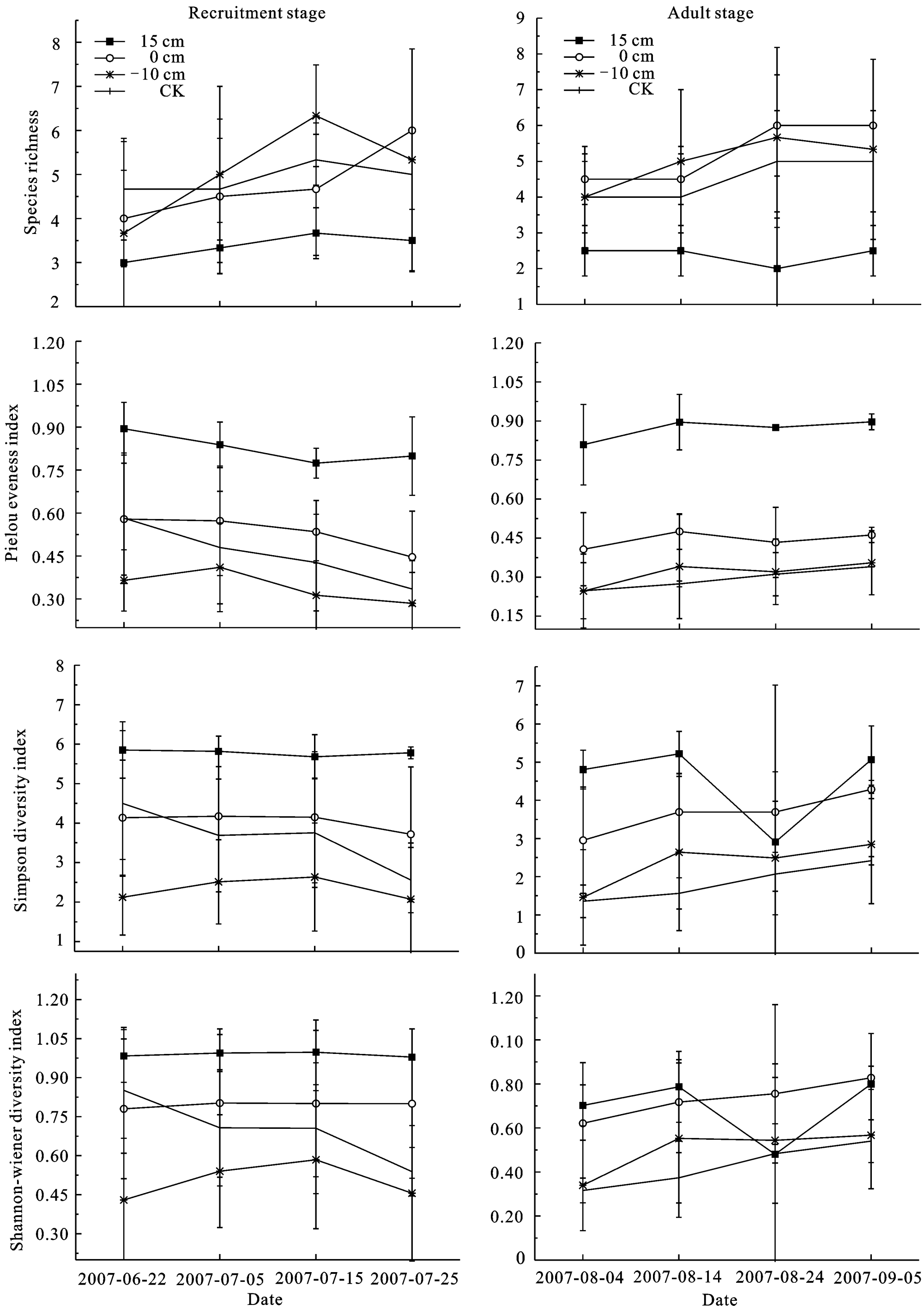

Fig. 2 Species diversity of *C. lasiocarpa* community under different water levels

though some plants can grow in relatively low-water environment, they can not regenerate there. And successful regeneration can only be realized in a narrow range of water conditions. The hydrological requirements of plant regeneration inhibit plant dispersal (Bakker *et al*., 2007). And in a territory, species that appear or start to grow earlier can obtain more resources (Pausas and Sandra, 2003), suggesting that community compositions may be determined at regeneration stage.

4.1 Response of species diversity to different water levels

Different from plants in other ecosystems, plants in wetlands develop special reproductive strategies adapting to the over-wet environment. In this study, plants in the *C. lasiocarpa* community mostly reproduce by tillering of rhizomes or creeping stems, while probabilities of sexual reproduction are rather lower under natural conditions (Editing Committee of Wetland Vegetation in China, 1999). And these are the reasons for the development of the regeneration studies of wetland plants.

Previous studies showed that population growth was inhibited by inundation, and the population density decreased with increasing water level (Howard and Rafferty, 2006; Wang *et al*., 2007). In our study, population dominance of *C. lasiocarpa* decreased with increasing water, which is consistent with previous studies. It can also be concluded that to survive and become dominant species under certain conditions may not due to their adaptation to the stress, but to their competitiveness in the stress environments (Temperton *et al*., 2004). And in this study, species richness decreased with water level increasing, while species evenness increased due to the decrease of population dominance of *C. lasiocarpa*, indicating that the effects of water level increasing on dominant species were greater than those on accompanying species.

In addition, the two diversity indexes here increased as water level increasing. This is also a result from the decrease of population dominance of *C. lasiocarpa* and an evidence for the contribution of species evenness to community diversity. Especially under 15 cm water level, there were only two to four species in the community, and each species had just several individuals. So for wetland management, the evaluating standards must be determined prudentially along with the management objectives and one single diversity or species dominance index is not reasonable for optimal management.

4.2 Selection of restoration time for wetland vegetation

Wetland restoration can be conducted at different stages through the growing season. At present, the main practice for wetland restoration is to irrigate and restore the hydrological regimes (Klimkowska *et al*., 2007). According to the local climate of the Sanjiang Plain, to conduct wet land restoration at the rainy season can realize the restoration objective at a low cost.

In our research, restoration experiments for *C. lasiocarpa* community were done on recruitment and adult stages respectively. Species richness, evenness and community diversity were higher at recruitment stage. This may be caused by premature endings of the life histories for special species that disappear in the later season, as showed in previous studies (Macek *et al*., 2006). However, in the adult stage experiment, population dominance of *C. lasiocarpa* was higher. The results showed that relatively higher diversity could be achieved by irrigation at local recruitment stage, while at local adult stage, restoration of dominant species can be realized better. So, the restoration time could be determined according to different objectives, considering the evaluation of benefits and costs of the restoration practices at different stages.

5 Conclusions

Through the study on the response of regeneration diversity of *C. lasiocarpa* community to different water levels in the Sanjiang Plain, it can be concluded that inundation inhibits plants germination and only plants that can tolerate the stress will germinate successfully. Population *IV* of *C. lasiocarpa* and community species richness decreased with water level increasing, while community Pielou evenness index, Simpson and Shannon-Wiener diversity indexes increased. Influences of inundation on population growth were stronger than those on plants germination. Plant evaluation index must be chosen synthetically for wetland management and restoration, and the optimal time for wetland vegetation must be determined according to the objectives and costs of the practices.

References

Alvarez C M, Cirujano S, 2007. Multilevel responses of emergent vegetation to environmental factors in a semiarid floodplain. *Aquatic Botany*, 87(1): 49–60. DOI: 10.1016/j.aquabot.2007.03.002

Bakker C, van Bodegom P M, Nelissen H J M *et al*., 2007. Preference of wet dune species for waterlogged conditions can be explained by adaptations and specific recruitment requirements. *Aquatic Botany*, 86(1): 37–45. DOI: 10.1016/j.aquabot.2006.08.005

Editing Committee of Wetland Vegetation in China, 1999. *Wetland Vegetation in China*. Beijing: Science Press, 26–29, 123–124. (in Chinese)

Howard R J, Rafferty P S, 2006. Clonal variation in response to salinity and flooding stress in four marsh macrophytes of the northern gulf Mexico, USA. *Environmental and Experimental Botany*, 56(3): 301–313. DOI: 10.1016/j.envexpbot.2005.03.003

Klimkowska A,Van Diggelen R, Bakker J P *et al*., 2007. Wet meadow restoration in western Europe: A quantitative assessment of the effectiveness of several techniques. *Biological Conservation*, 140(3–4): 318–328. DOI: 10.1016/j.biocon.2007.08.0-24

Lane C R, Brown M T, 2007. Diatoms as indicators of isolated herbaceous wetland condition in Florida, USA. *Ecological Indicators*, 7(3): 521–540. DOI: 10.1016/j.ecolind.2006.06.001

Leck M A, Simpson R D, 1995. Ten-year seed bank and vegetation dynamics of a tidal freshwater marsh. *American Journal of Botany*, 82(12): 1547–1557.

Leira M, Cantonati M, 2008. Effects of water level fluctuations on lakes: An annotated bibliography. *Hydrobiologia*, 613(1): 171–184. DOI: 10.1007/s10750-008-9465-2

Lenssen J, Menting F, van der Putten W *et al*., 1999. Control of plant species richness and zonation of functional groups along a freshwater flooding gradient. *Oikos*, 86(3): 523–534.

Macek P, Rejma´nkova´E, Houdkova K, 2006. The effect of long-term submergence on functional properties of Eleocharis cellulosa Torr. *Aquatic Botany*, 84(3): 251–258. DOI: 10.1016/j.aquabot.2005.11.003

Niedermeier A, Robinson J S, 2007. Hydrological controls on soil redox dynamics in a peat-based, restored wetland. *Geoderma*, 137(3–4): 318–326. DOI: 10.1016/j.geoderma.2006.08.027

Pausas J G, Sandra L, 2003. A hierarchical deductive approach for functional types in disturbed ecosystems. *Journal of Vegetation Science*, 14(3): 409–416. DOI: 10.1658/1100-9233(2003)014[0409:AHDAFF]2.0.CO;2

Seabloom E W, Valk A G, Moloney K A, 1998. The role of water depth and soil temperature in determining initial composition of prairie wetland coenoclines. *Plant Ecology*, 138(2): 203–216. DOI: 10.1023/A:1009711919757

Song K Y, Zoh K D, Kang H, 2007. Release of phosphate in a wetland by changes in hydrological regime. *Science of the Total Environment*, 380(1–3): 13–18. DOI: 10.1016/j.scitotenv.2006.11.035

Temperton V M, Hobbs R J, Nuttle T, 2004. *Assembly Rules and Restoration Ecology*. Washington D.C.: Island Press, 189–190.

van der Valk A G, Davis C B, 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. *Ecology*, 59(2): 322–335. DOI: 10.2307/1936377

Wang Li, Hu Jinming, Song Changchun *et al*., 2007. Effects of water level on the rhizomatic germination and growth of typical wetland plants in Sanjiang Plain. *Chinese Journal of Applied Ecology*, 18(11): 2432–2437. (in Chinese)

Weiher E, Keddy P A, 1995. The assembly of experimental wetlands. *Oikos*, 73(3): 323–335.

Yamada S, Okubo S, Kitagawa Y *et al*., 2007. Restoration of weed communities in abandoned rice paddy fields in the Tama Hills, central Japan. *Agriculture, Ecosystems and Environment*, 119(1–2): 88–102. DOI: 10.1016/j.agee.2006.06.011

Zhao Kuiyi, 1999. *Mires of China*. Beijing: Science Press, 55–56. (in Chinese)