Proceedings of the International Symposium on Conservation and Eco-friendly Utilization of Wetland in the Three Gorges Reservoir

Spatial-temporal Dynamics of Vegetation in the Newly Created Water-level-fluctuation Zone of Three Gorges Reservoir: a Case Study in Baijia Stream, Kaixian County, China*

WANG Qiang[1,2], LIU Hong[1], ZHANG Yue-wei[1,2], XIONG Sen[3], YUAN Xing-zhong[1,2]
(1. College of Resource and Environmental Science; 2. Key Laboratory of Southwest Resource Exploitation and Environmental Disaster Controlling Project of Educational Ministry, Chongqing 400030; 3. Pengxi River Wetland Nature Reserve Management Bureau, Kaixian Chongqing 405400, China)

Abstract: After impoundent of the Three Gorges Reservoir, a large permanent sample plot was placed in its water-level-fluctuation zone beside Baijia Stream, Kaixian County, China. Vegetation in the plot was investigated in the summer of 2008, 2009 and 2010. The result indicated that community's component, biodiversity and aboveground biomass showed obvious spatial-temporal dynamics. Total spiecies number of vascular flora inside decreased yearly, from 52 species in 2008 to 41 species in 2009 and to 35 species in 2010. The area below 156 m in elevation was dominated by *Paspalum paspaloides* and *Xanthium sibiricum* in 2008. However, *Paspalum paspaloides* was rapid replaced by *Cynodon dactylo* in 2009 and *X. sibiricum* expanded its distribution in upper area of the plot. In 2010, *X. sibiricum* depressed its population in lower areas of the plot as the Three Gorges Reservoir started to impound half month earlier in the winter of 2009 and decreased seed bank for its germination. Shannon-Wiener Index increased as elevation according to the data of 2009 and 2010, which reflected the influence of submerged gradient. Aboveground biomass of vegetation in each elevation zone of the plot indicated great variation.

Key words: Three Gorges Reservoir; water-level-fluctuation zone; vegetation; spatial-temporal dynamics; biodiversity
Chinese Library Classification: Q145⁺.2 **Document Code**: A **Article ID**: 1672-6693(2012)03-0163-05

The Three Gorges Dam (TGD) in China is the largest such project in the world. In order to decrease sediment deposition and prolong the operation duration of the Three Gorges Reservoir (TGR), water levels will be at their highest in winter (usually 175 m above sea level) and lowest during the summer rainy season (as low as 145 m above sea level), thereby producing a drawdown area about 30 m in vertical height. After declining to the minimum (145 m) in May, 2010, a drawdown area of 348.93 km^2 between the low-water and high-water marks emerged [1].

Water and plant are the most important components of wetland ecosystems. The vegetation of wetlands can be significantly affected by several key hydrodynamic characteristics, including timing, duration and magnitude of flooding [2]. Therefore we can expect that the patterns and dynamics of vegetation in the drawdown area of the TGR would be significantly different from natural riparian zones, and also different from almost all of the littoral zone of large reservoirs in the world. However, it is difficult to predict these patterns and dynamics, because few previous studies have examined to the effects of anomalous winter flooding in regions affected by summer monsoon climate.

In 2008, a permanent field plot was placed in the drawdown area in the Pengxi River Wetland Nature Re-

* **Received**: 02-08-2012
Foundation: National Natural Foundation of China (No. 51179214)
First author biography: WANG Qiang, male, Ph. D. research field is stream ecology; **Corresponding author**: LIU Hong, E-mail: xzyuan63@yahoo.com.cn

serve. The present paper reports the patterns and dynamics of species components, diversity and above-ground biomass of vegetation in this plot from 2008 to 2010. We hope this work will supplement the sparse empirical database of the effects of winter flooding of a sub-tropical reservoir on flora and be useful for reservoir management, long-term biodiversity research and vegetation restoration of the Three Gorges Reservoir Area (TGRA).

1 Materials and Methods

1.1 Study site

The study was conducted at Pengxi River Wetland Reserve in Kaixian County, Chongqing, China. Kaixian includes a drawdown area of 42.78 km^2, which is 12.3% of the total drawdown area of the TGR. This is larger than the drawdown area in any other county in the TGRA. The Pengxi River is one of the secondary branches of the Yangtze River in the TGRA. The region is characterized by north subtropical humid monsoonal climatic conditions with average annual precipitation of 1 200 mm and temperature 18.5 ℃. Usually a summer drought occurs from mid-July to mid-August [3].

The plot was placed in the riparian zone of a branch of Pengxi River, with the name Baijia Stream. The plot ranged from the waterline (145 m above mean sea level) to 175 m above mean sea level. The width of the plot is 60 m and the former land uses were rice paddy and dry farm land.

1.2 Field sampling

Field work was conducted in late August to early September. We divided the plot into six elevation zones at 5 m height intervals (Zone I: 145 ~ 150 m, Zone II: 150 ~ 155 m, Zone III: 155 ~ 160 m, Zone IV: 160 ~ 165 m, Zone V: 165 ~ 170 m, and Zone VI: 170 ~ 175 m). In every elevation zone, the representative vegetation type was selected and three 1 m × 1 m plots were used to visually estimate the percent total vegetation cover and percent cover of each species. Within each plot, substrate, soil type, soil humidity and phenophase of species were also recorded. Any additional species lying immediately outside the plots were also listed. The above-ground biomass of each 1 m × 1 m plot was measured after harvesting and drying at 75 ℃ for 24 h.

1.3 Data analysis

Importance values were calculated using relative cover and relative height [4]. Duncan's multiple range test was employed to compare Shannon-Wiener Index and above-ground biomass of different elevation zones. The above analyses were performed with the SPSS 15.0 statistical package. Differences were considered statistically significant for $p < 0.05$.

2 Results and Analysis

2.1 Dynamics of species components

The total vascular species richness decreased year after year. From 2008 to 2010, we recorded 52, 41 and 35 species respectively. The dominant species of each elevation zone also varied greatly (Tab. 1). Zone I located on the floodplain of Bajia Stream was affected by winter impoundment of the TGR and summer natural flooding. In 2008, Zone I was dominated by *Xanthium sibiricum*, *Paspalum paspaloides*, and *Cyperus rotundus*. In 2009, there was no vegetation in Zone I as a result of serious sediment deposition by short-term summer flooding of Baijia Stream. In the next year, Zone I was occupied by *Cynodon dactylon* and *C. rotundus*. *X. sibiricum* dominated Zone II in 2008 and 2009 at high densities, while in 2010 *X. sibiricum* was replaced by *Cynodon dactylon*. Zone III was flat and occupied by *P. paspaloides* in 2008. However, after the TGR was impounded to 173 m above mean sea level, *C. dactylon* replaced *P. paspaloides*. Zone IV was not submerged before the winter of 2008 and the dominant species there were *Alternanthera philoxeroides* and *P. paspaloides*. In 2009, this elevation was occupied by *X. sibiricum*, while in 2010 this was replaced by *Setaria viridis*. *Imperata cylindrica* quickly disappeared in Zone V after the first flooding in the winter of 2008 and was replaced by several annual species.

X. sibiricum is a fast-growing annual herb, monoecious and wind-pollinated. It usually invades pastures, road banks, wasteland, floodplain and lakeshore

[5]. A previous study indicated that more than ninety percent of seeds submerged for eight months were still alive [6]. The submerged seed exhibited a rapid germination rate and higher germination percentage than unsubmerged seeds (unpublished date). Therefore, *X. sibiricum* had become widely distributed in the water-level fluctuation zone of the Three Gorges Reservoir after its impoundment to 156 m in elevation. In 2009, *X. sibiricum* further expanded to the area above 156 m in elevation as the water level rose to 173 m in elevation for the first time in the winter of 2008 and its seeds were dispersed by the water. In 2009, the TGR started to be impounded in the middle of September, almost half a month earlier than previously. The consequence of this changing time schedule in 2009 was that the seed bank of *X. sibiricum* was severely damaged as most seeds of *X. sibiricum* were immature and rotted under water. In the summer of 2010, several devastating floods occurred in Baijia Stream and as a consequence *X. sibiricum* almost disappeared in the plot.

Tab. 1 Spatial-temporal dynamics of the importance value of species

Year	Species	Importance values					
		Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI
2008	*Imperata cylindrica*						90.6
	Xanthium sibiricum	24.7	65.9	22.3			
	Alternanthera philoxeroides	11.8		12.0	48.9	49.9	
	Paspalum paspaloides	18.9	23.3	54.8	45.1		
	Cyperus rotundus	15.1					
	Aster subulatus					23.2	
2009	*X. sibiricum*		69.4		41.6		
	Cynodon dactylon		26.8	91.2	11.5		
	Setaria viridis					47.3	34.8
	Bidens tripartita						23.3
	Digitaria sp.					36.1	
	Arthraxon lanceolatus					11.1	
	Conyza canadensis						12.7
2010	*X. sibiricum*					20.1	
	S. viridis				56.9	28.6	34.1
	C. dactylon	59.1	69.3	92.9	24.1	23.3	
	A. philoxeroides	17.6					
	Artemisia carvifolia					10.3	
	C. rotundus	15.8	23.5				
	C. canadensis						35.8

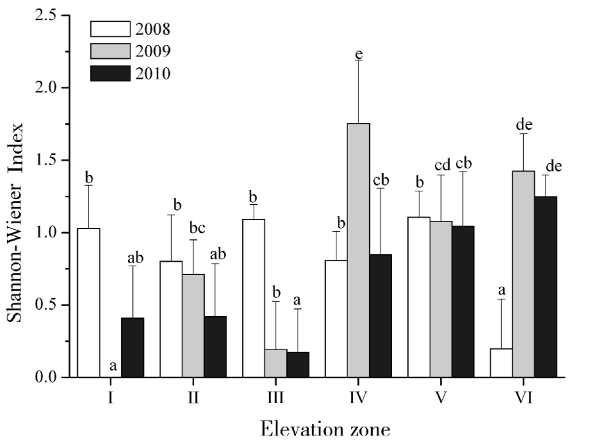
Only the species with importance values more than 10 % are listed.

P. paspaloides occupied the area having shallow water after the TGR was impounded to 156 m in elevation, but it was quickly replaced by *C. dactylon*. This phenomenon is probably explained by the variation of soil physical properties after impoundment and the differences in the physiological responses of these two species to water submergence. Previous study has shown that soil water content, capillary porosity and non non-capillary porosity decreased, while soil bulk density increased and soil aerated capability decreased in the submerged area, illustrating that soil structure and quality have been degraded due to seasonal flooding [7]. Field observations indicated that *C. dactylon* had the higher survival rate following submergence; its survival rate was 100 % even submerged to a depth of 25 m [8]. However, the survival of *P. paspaloides* decreased with increasing depth of submergence, although its survival rates were more than 80 % at the submergence depths of 15 m and 25 m.

2.2 Spatial-temporal dynamics of shannon-wiener

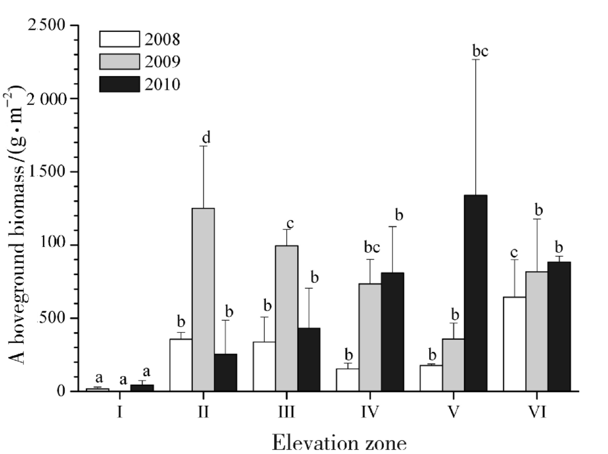
indexes

In 2008, there was no significant difference among Shannon-Wiener Indexes of elevations from I to V (Fig. 1, $p>0.05$). Shannon-Wiener Index of Zone VI was significantly lower than other elevations as it was



Different letters (a, b, c) above the boxes indicate significant differences for $p < 0.05$.

Fig. 1 Spatial-temporal dynamics of Shannon-Wiener Index



Different letters (a, b, c) above the boxes indicate significant differences for $p < 0.05$.

Fig. 2 Spatial-temporal dynamics of above-ground biomass

dominated by dense *I. cylindrica* which depresses growth of other species. Both in 2009 and 2010, Shannon-Wiener Indexes of each elevation zone exhibited an increasing pattern as elevation rose, which reflects the influence of the submergence gradient [9-11]. Shannon-Wiener Indexes of each elevation zone except V zone were significantly different ($p < 0.05$) among our three samplings. The indexes of Zone II and Zone III decreased from 2008 to 2010. However, the Shannon-Wiener Index for Zone VI increased after impoundment, which may be explained by death of *I. cylindrica* and consequent opportunities for growth of other species.

2.3 Spatial-temporal dynamics of above-ground biomass

Above-ground biomass exhibited obvious variations among the three annual samplings. In 2008, there were significant differences in above-ground biomass at elevations from I to V ($P < 0.05$). Zone I had the lowest above-ground biomass and Zone VI had the highest. There were no significant differences in above-ground biomass between submerged Zone II and unsubmerged zones including III, IV and V. In 2009, the above-ground biomass of elevation zones I to V showed a decreasing pattern as elevation rose, while in 2010 the pattern was the opposite. The changed biomass pattern was probably related to invasion by *X. sibiricum*. The biomass of Zone IV, which suffered the shortest duration of submergence, exhibited no significant differences among the three samplings.

3 Conclusion

After impoundment of the Three Gorges Reservoir, a large permanent sample plot was placed in its water-level-fluctuation zone beside Baijia Stream, Kaixian County, China. Vegetation in the plot was investigated in the summer of 2008, 2009 and 2010. The results indicated that species components, biodiversity and above-ground biomass showed obvious spatial-temporal dynamics. The total number of species of vascular flora within the plot decreased yearly, from 52 species in 2008 to 41 species in 2009 and 35 species in 2010. The area below 156 m in elevation was dominated by *P. paspaloides* and *Xanthium sibiricum* in 2008. However, *P. paspaloides* was rapidly replaced by *C. dactylon* in 2009 and *X. sibiricum* expanded its distribution in the upper area of the plot. In 2010, the population of *X. sibiricum* became depressed in lower areas of the plot as impoundment of the Three Gorges Reservoir began half a month earlier in the winter of 2009 and this decreased the available seed bank for subsequent germination. Shannon-Wiener Index increased with elevation according to the data for 2009 and 2010, which reflected the influence of the submergence gradient. Above-ground biomass of vegetation in each elevation zone of the plot varied greatly from year to year, and zone to zone.

References:

[1] Zhang H. Characteristic analyses of the water-level-fluctuating zone in the Three Gorges Reservoir [J]. Soil and Water Conservation Bulletin, 2008, 28(1):46-49.

[2] Nilsson C, Svedmark M. Basic principles and ecological consequences of changing water regimes: riparian plant communities[J]. Environ Manage, 2002, 30(4): 468-480.

[3] Wang Q, Liu H, Yuan X Z, et al. Pattern and biodiversity of plant community in water-level-fluctuation zone of Pengxi River after impoundment of Three Gorges Reservoir [J]. Journal of Chongqing Normal University: Natural Science, 2009, 26(4):48-54.

[4] Wang Y J, Tao J P, Zhang W Y, et al. Dynamics of species diversity in vegetation restoration on Tudiling of Mao County, Southwest China [J]. Acta Ecologica Sinica, 2006, 26(4):1028-1036.

[5] Sugiyama H, Hirose T. Growth schedule of *Xanthium canadense*: Does it optimize the timing of reproduction? [J]. Oecologia, 1991, 88(1):55-60.

[6] Wang Q, Yuan X Z, Liu H, et al. The effect of flooding on the germination of *Xanthium sibiricum* seed in the water-level fluctuation zone of the Three Gorges Reservoir [J]. Wetland Science, 2011, 9(4):328-333.

[7] Cheng R M, Wang X R, Xiao W F, et al. Study on the soil physical properties and metal content in the early submerged water-level-fluctuating zone of Three Gorges Reservoir [J]. Journal of Soil and Water Conservation, 2009, 23(5):156-161.

[8] Tan S D, Zhang S J, Zhang K R, et al. Effect of long-time and deep submergence on recovery growth and photosynthesis of three grass species in Three Gorges Reservoir Area [J]. Journal of Wuhan Botanical Research, 2009, 27(4):391-396.

[9] Wang Z W, Xing F, Zhu T C, Li X C. The responses of functional group composition and species diversity of *Aneurolepidium Chinense* grassland to flooding disturbance on Songnen plain, Northeastern China [J]. Chinese Journal of Plant Ecology, 2002, 26(6). 708-716.

[10] Blom C W P M, Voesenek L A C J. Flooding: the survival strategies of plants[J]. Trends in Ecology and Evolution, 1996, 11:290-295.

[11] Wang Q, Yuan X Z, Liu H, et al. Effect of initial impoundment on the vegetation and species diversity in water-level fluctuation zone of the Three Gorges Reservoir [J]. Journal of Natural Resources, 2011, 26(9): 1680-1693.

(Editors: Martin WILLISON, FANG Xing)
(English Translator: WANG Qiang)