Distribution of *Triarrhena lutarioriparia* and its reserve characteristics of nitrogen and phosphorus in Dongting Lake

Youze Xu¹, Guangyi Fu¹, Nan Tang¹, Zhonghao He², Lincheng Jian¹, and Yuanyuan Zhao^{1*}

¹. Hunan Research Academy of Environmental Science, Hunan Provincial Key Laboratory of Water Pollution Control Technology, 410000 Changsha Hunan, China

². Beijing Normal University-Hong Kong Baptist University United International College, 519000 Zhuhai Guangdong, China

Abstract. *Triarrhena lutarioriparia*, a typical and most abundant macrophyte in Dongting lake wetland, was in the state of abandonment following the papermaking industry revocation in the lake basin. In order to provide scientific basis for precise management of *T. lutarioriparia*, the *T. lutarioriparia* distribution characteristics in Dongting Lake and its storage characteristics of nutrients were investigated in this study. Remote sensing interpretation results showed that the total area of *T. lutarioriparia* in Dongting Lake wetland was 58,450 ha, 48.31% of which distributed in South Doting Lake wetlands. The nutrients contents were significantly different in *T. lutarioriparia* tissues, ranking in the descending order of spikes (TN 27.90 mg/g, TP 3.46 mg/g)>leaves (TN 16.38 mg/g, TP 2.11 mg/g)>stems (TN 5.38 mg/g, TP 0.85 mg/g). The total P quantities in each *T. lutarioriparia* tissue were ranked in the order: stems (560.26 t)>leaves (396.52 t)>spikes (284.67 t), while the total N quantities were within the range of 2170.02~2801.3 t. It was estimated that about 7712.99 t of TN and 1241.45 t of TP were annually removed from Dongting Lake by reaping *T. lutarioriparia*. The nutrients stored in the dead tissues of *T. lutarioriparia* might possess non-negligible impact on the water quality of Doting Lake.

1 Introduction

Dongting Lake is known as the “Kidney of the Yangtze River”, and its runoff is about 1/3 of the total runoff of the Yangtze River [1]. Dongting Lake is a very important natural flood storage reservoir and internationally important wetlands, bearing major responsibilities for water ecology safety in the middle and lower reaches of the Yangtze River Basin [1]. Aquatic plants are indispensable parts both for both the structure and function of lake ecosystems [2]. *Triarrhena lutarioriparia*, a unique fibrous perennial herbaceous macrophyte in China, widely distributed in Dongting lake wetland [3-5]. The ecological functions of *Triarrhena lutarioriparia* such as purification of water bodies are extremely important to the ecosystem of Dongting Lake wetland. Meanwhile, compared with *Phragmites australis*, *T. lutarioriparia* has higher biomass per unit area and excellent cellulose quality [3, 6]. Thus, *T. lutarioriparia* has been applied as the main raw material for pulp production in Dongting Lake area since the early 1960s [7-10]. In order to protect Dongting Lake from pulping and papermaking wastewater pollution, an implementation plan was issued by Hunan Provincial People’s Government for guiding exit of papermaking enterprises in Dongting Lake Area (Government Office Letter No. 36, 2018), requesting paper-making enterprises around Dongting Lake to fully withdraw from pulp production capacity and to withdraw from paper-making production capacity in 2019. The

overall withdrawal of papermaking makes it difficult to develop alternative resource utilization methods for *T. lutarioriparia* in the lake area within a short time. Therefore, a large amount of *T. lutarioriparia* will stay uncut in the lake wetland, causing problems in how to manage and protect them from exerting non-negligible impact on the water quality of Doting Lake [11-13].

Mastering the distribution status and nutrient characteristics of *T. lutarioriparia* is highly essential to formulate an effective management for it [14]. However, as the artificial planting development of *T. lutarioriparia* in recent years, the current distribution of *T. lutarioriparia* in Dongting Lake is still unclear. Moreover, the nutrient characteristics in *T. lutarioriparia* have been given less concern. The lack of research on *T. lutarioriparia* greatly increases the difficulty in the precise management of *T. lutarioriparia*. Therefore, remote sensing interpretation methods were used in this study to explore the distribution characteristics of *T. lutarioriparia* in Dongting Lake wetland. The dry-weight biomass and nutrient contents of each *T. lutarioriparia* tissue in different areas of Dongting Lake were investigated, and the total quantities of nutrients stored in *T. lutarioriparia* were further calculated. Results obtained in this study can provide scientific basis and strong supports for management of *T. lutarioriparia* after the withdrawal of the paper industry in Dongting Lake district.

* Corresponding author. E-mail: zyyhjgc0601@163.com

2 Method and Material

2.1 Sample Collection and Pretreatment

After preliminary investigation and research in November 2018, a global positioning system was used to locate *T. lutarioriparia* in the whole lake area of Dongting Lake, and 6 sampling points were selected to collect *T. lutarioriparia* samples. The stems, leaves, and spikes of each plant of *T. lutarioriparia* are separately processed and marked on site. Then the collected *T. lutarioriparia* samples are washed with ultrapure water, dried and weighed. After green removing at 105 °C for 30 min, the plant samples were dried to constant weights at 80 °C. The dried samples were then placed in a desiccator, cooled to room temperature and weighed, and water contents of the plant samples were measured.

2.2 Remote sensing interpretation of *T. lutarioriparia* resources in Dongting Lake

The geological conditions and plant species of the Dongting Lake area were investigated. Furthermore, the variations in remote sensing pictures of *T. lutarioriparia* due to seasonal changes were analyzed. Based on the cloud analysis of difference in water levels due to seasonal changes and the remote sensing pictures, the distribution of *T. lutarioriparia* in Dongting Lake wetland was interpreted by applying the Landsat 8 OLI-TIRS image data [15, 16]. The remote sensing images of the Dongting Lake area in early spring of 2018 were selected for interpretation, and ENVI 5.3 and ArcMap 10.2 software were used to process the images. The maximum likelihood method is used to supervise and classify the images through the visual method. In order to improve the accuracy of the interpretation work, the unclear distribution areas of *T. lutarioriparia* in Dongting Lake wetlands were clarified by on-site survey and sampling.

2.3 Data analysis

The total nitrogen (TN) and phosphorus (TP) contents in the remaining litter (leaves, stems and spikes) were measured using Kjeldahl digestion followed by colorimetric analysis. Data shown in the figures herein are averages. Analysis of the variance was performed by one-way ANOVA and two-tailed paired t test using the PASW statistics software package version 18 (SPSS, Inc., Chicago, IL). Differences were considered significant when the significance level was <0.05 (e.g. $\alpha=0.05$).

3 Result and Discussion

3.1 The distribution characteristic of *T. lutarioriparia* in Dongting Lake

Comprehensively considering the three factors including *T. lutarioriparia* distribution, natural conditions and geographic location, six sampling points (D1-D6 seen in Figure 1) were set up in the field investigation for the

precise interpretation of the distribution of *T. lutarioriparia* in the Dongting Lake area. Figure 1 illustrated the interpretation results of *T. lutarioriparia* distribution in Doting Lake wetland. The specify areas of *T. lutarioriparia* in different districts were shown in Table 1. The total distribution area of *T. lutarioriparia* in early 2018 was nearly 58,467 ha (Table 1). As shown in Table 1, the specify areas of *T. lutarioriparia* in different districts were ranked in the descending order: South Dongting Lake (50.40%) > East Dongting Lake (31.39%) > West Dongting Lake (18.21%). In the basin of South Dongting Lake, *T. lutarioriparia* with the area of 29,457.78 ha was mainly distributed in district of Yuanjiang city, accounting for 95.8% of the total *T. lutarioriparia* in South Dongting Lake. In the basin of East Dongting Lake, the distribution area of *T. lutarioriparia* in Yueyang City and Xiangyin city has an area of 9,707.68 ha and 7,948.50 ha, accounting for 96.40% of the total distribution area in this basin. In the basin of West Dongting Lake, *Triarrhena lutarioriparia* was mainly distributed in Hanshou County followed by Anxiang County. Among all the districts in Dongting Lake basin, Yuanjiang City has the widest distribution area with 28,235.89 ha of *T. lutarioriparia*, followed by Yueyang County (9,707.68 ha) and Xiangyin County (7,948.5 ha).

Fig1. Distribution status of *T. lutarioriparia* in Doting Lake wetland

Table1. Distribution area of *T. lutarioriparia* in different Doting Lake regions

Lake	District name	Distribution area (ha)	Total area (ha)
South Dongting Lake	Ziyang	28.07	29457.78
	Nanxian	1193.82	
	Ruanjiang	28235.89	
	Anxiang	2951.36	
West Dongting Lake	Jinshi	32.15	10646.45
	Hanshou	7252.43	
	Dingcheng	410.51	
East Dongting Lake	Junshan	132.78	18345.86
	Yueyang	9707.68	

Xiangyin	7948.50
Huarong	557.00

3.2 Nitrogen and Phosphorus distribution in *T. lutarioriparia*

Ten copies of each *T. lutarioriparia* tissue were collected from sampling sites (D1-D6). Basic properties including biomass and water content were statistically calculated and showed in Table 2. The proportion for dry-weight biomass of over-ground *T. lutarioriparia* tissues was ranked in the descending order of stems (70.73%) > leaves (20.98%) > spikes (8.28%). The TN and TP contents of *T. lutarioriparia* in D1-D6 sampling sites of Dongting Lake wetlands were demonstrated in Figure 2 and Figure 3, respectively. The TN (5.76 ~11.07 mg/g) and TP contents (1.14 ~2.11 mg/g) varied significantly with different *T. lutarioriparia* tissues ($P < 0.05$), both exhibiting the sequence of spikes > leaves > stems. The average contents of TP in spikes, leaves, stems and roots of *T. lutarioriparia* tissues were 3.76 mg/g, 2.07 mg/g, 0.85 mg/g and 2.08 mg/g, respectively. Meanwhile, the average contents of TN in spikes, leaves, stems and roots of *T. lutarioriparia* tissues were 27.58 mg/g, 15.37 mg/g, 4.42 mg/g and 6.23 mg/g, respectively. No significant differences were observed in the nutrient content of *T. lutarioriparia* from different area of Dongting Lake wetlands ($P > 0.05$). The nutrient contents in rhizosphere soil where *T. lutarioriparia* grew were shown in Table 3. The TN and TP contents in rhizosphere soils were within the range of 11.8~13.4 mg/g and 6.13~11.1 mg/g. There is a positive correlation ($R^2 > 0.99$) between the nutrient contents in *T. lutarioriparia* and its rhizosphere soil.

Table2. Basic properties of *T. lutarioriparia* in Dongting Lake wetlands

Tissues	Moisture content/%	Dry-weight biomass per plant /g
Spikes	12.96	10.10
Leaves	12.79	25.58
Stems	28.69	86.23
Roots	37.06	72.88

Fig2. TN content of *T. lutarioriparia* tissues in Dongting Lake wetland

Fig3. TP content of *T. lutarioriparia* tissues in Dongting Lake wetland

Table3. Nitrogen and phosphorus content of rhizosphere soil in *T. lutarioriparia* growing area

Sampling sites	TN /mg·g ⁻¹	TP / mg·g ⁻¹
D1	12.18	6.7
D3	13.4	6.46
D5	11.8	7.7

3.3 Quantities of Nitrogen and Phosphorus stored in *T. lutarioriparia*

According to statistics, the total output of *T. lutarioriparia* in Dongting Lake is about 900,000 tons/year (dry weight). Based on the biomass proportion and the nutrient (N and P) content of each *T. lutarioriparia* tissue, the annual yield and nutrient reserves of each *T. lutarioriparia* tissue were calculated and shown in Table 4. The annual yields of the

over-ground parts of *T. lutarioriparia* tissues in Dongting Lake wetland were 74,500 tons, 188,800 tons, and 636,700 tons for spikes, leaves and stems, respectively. The quantities of nitrogen and phosphorus that can be annually removed from Doting Lake by cutting the *T. lutarioriparia* were 7712.99 tons and 1241.45 tons, respectively. There was no significant difference in the total amount of nitrogen (2,170-2,801 tons/year) stored in different tissues of *T. lutarioriparia* in Dongting Lake. On the contrary, the phosphorus reserves of different *T. lutarioriparia* tissues were quite different, exhibiting the descending order of stems (560.26 tons/year) > leaves (396.52 tons/year) > spikes (284.67 tons/year). In the absence of harvesting, the dead tissues of the uncut *T. lutarioriparia* with large scale will lie down and decay in the lake water, and the release of *T. lutarioriparia* nutrients during decomposing process possesses non-negligible impact on the water quality of Doting Lake.

Table4. Annual output and nutrient reserves of *T. lutarioriparia* tissues

Tissues	Biomass/($\times 10^4$ t)	N Storage/t	P Storage/t
Spikes	7.45	2170.02	284.67
Leaves	18.88	2741.67	396.52
Stems	63.67	2801.3	560.26
Total	90	7712.99	1241.45

4 Conclusion

The total growing area of *T. lutarioriparia* in Dongting Lake wetland was about 58,450 ha, and *T. lutarioriparia* mainly distributed in South Doting Lake wetlands, accounting for 50.40% of the total growing area. The annual yields (calculated in dry weight) of the over-ground parts of *T. lutarioriparia* tissues in Dongting Lake wetland were 74,500 tons, 188,800 tons, and 636,700 tons for spikes, leaves and stems, respectively. The nutrients showed similar distributing characteristics in over-ground tissues of *T. lutarioriparia*. Both the average contents of TN and TP exhibited the high-to-low sequence of spikes (TN 27.58 mg/g, TP 3.76 mg/g) > leaves (TN 15.37 mg/g, TP 2.07 mg/g) > stems (TN 4.42 mg/g, TP 0.85 mg/g). The quantities of nitrogen and phosphorus that can be annually removed from Doting Lake by cutting the *T. lutarioriparia* were 7712.99 tons and 1241.45 tons, respectively. Thus, the dead tissues of the uncut *T. lutarioriparia* with large amount of nutrient reserves may possess non-negligible impact on the water quality of Doting Lake.

References

1. S.M. Wang, H. S. Dou, *China Lake Records. Science Press*, Beijing, China (in Chinese)
2. P.E. O'Sullivan, C.S. Reynolds. *Chapter 11. Aquatic Plants and Lake Ecosystems [M]/The Lakes Handbook, Limnology and Limnetic Ecology*, **1**, Blackwell Science Ltd (2007)

3. S.L. Chen, S.A. Renvoize, *A new species and a new combination from China of Miscanthus (Poaceae)*, *Kew Bulletin*, **60(4)**, 605-607 (2011)
4. G. Han, G. Zhang, *On the feedaimed potentialities and further development exploitation of Phragmites communis and Miscanthus sacchariflorus in the region of DongTing lake, Resources and Environment in the Yangtze Basin*, 232-236 (1998)
5. Liou L, Cao X, *Studies on the Autotetraploid of Triarrhena lutarioriparia*, *Acta Genetica Sinica*, **24**, 544-549 (1997)
6. N. Dang Z. Huang, H. Li, *Advances in Biology and Applications of Fiber Plant Triarrhena lutarioriparia*, [J], *Tropical and Subtropical Botany*, **20(4)**, 418-424 (2012, in Chinese)
7. X. Chen, L. Zhu, Z. Deng, et al., *Effects of Clipping on Bud Bank and Population Regeneration of Triarrhena lutarioriparia in Dongting Lake Wetland, China*[J], *Wetlands*, 1-8 (2020)
8. L. Liu, *Unique parper-making raw materials in China: Triarrhena lutarioriparia*, *Plants*, **17**, 6-7 (1990)
9. Xianjun W. *Study on the Comprehensive Utilization of Reeds in the South Dongting Lake Area, Agricultural Technology and Equipment*, 2019. (in Chinese)
10. L. Liu, *Chinese endemic papermaking materials-Miscanthus lutarioriparius*[J], *Plant magazine*, **5**, 6-7 (1990, in Chinese)
11. Y. He, N. Song, H. L. Jiang, *Effects of dissolved organic matter leaching from macrophyte litter on black water events in shallow lakes*, *Environmental Science and Pollution Research* (2018)
12. E.M. Eid, K. H. Shaltout, Y.M. Al-Sodany, *Decomposition dynamics of Phragmites australis litter in Lake Burullus, Egypt*, *Plant Species Biology*, **29(1)**, 47-56 (2014)
13. H. P. van Dokkum, D. M. E. Slijkerman, L. Rossi, M. L. Costantini, *Variation in the decomposition of Phragmites australis litter in a monomictic lake: the role of gammarids*, *Hydrobiologia*, **482**, 69-77. (2002)
14. Y. Xie, Y. Xie, H. Xiao, et al., *Controls on Litter Decomposition of Emergent Macrophyte in Dongting Lake Wetlands*[J], *Ecosystems* (2017)
15. R. C. Estoque, Y. Murayama, *Classification and change detection of built-up lands from Landsat-7 ETM+ and Landsat-8 OLI/TIRS imageries: A comparative assessment of various spectral indices*[J], *Ecological Indicators*, **56**, 205-217 (2015)
16. H. Huang, L. Zhang, Z. Gao, *The vegetation resource at the intertidal zone in Shanghai using remote sensing*[J], *Acta Ecologica Sinica*, **25(10)**, 2686-2693. (2005, in Chinese)