

PLANT DIVERSITY AND QUANTITATIVE CHARACTERISTICS OF WETLAND COMMUNITY ON THE NORTH BANK OF HANJIANG RIVER IN CHENG GU, SHAANXI PROVINCE, CHINA

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Abstract

Four water ecological surveys were carried out on the north bank of Hanjiang river in two seasons from 2020 to 2021. Based on the field wetland quadrat survey and literature data, the species diversity index was determined. The research showed that there are 360 species of wetland plants belonging to 108 families and 264 genera on the north bank of Hanjiang river, and the geographical composition of seed plants is at the genus level, mainly temperate distribution types, with 160 species. In the community species diversity index, the mean value of Patrick index was 18.80 ± 5.19 . The mean Shannon Wiener diversity index was 2.15 ± 0.39 . The mean value of Simpson dominance index was 0.81 ± 0.10 . The average Pielou evenness index was 0.75 ± 0.10 . The mean value of Margalef index was 3.44 ± 0.87 . The Patrick index and Margalef index of the *Bidens pilosa* form were the lowest. The Shannon-Wiener diversity index, the Simpson index, and the Pielou index of the *Potamogeton malaianus* form were the lowest. The Patrick index of the *Colocasia esculenta* form was the highest, and the Pielou of the *Sapium sebiferum* form was the highest. The Shannon-Wiener diversity index and Simpson index of the *Populus canadensis* form group were the highest, and the Margalef index of the *Flueggea virosa* form was the highest. The research results provide basic data and scientific basis for the protection and restoration of wetland ecosystems and management of wetland resources in Yuan'an and similar areas.

Introduction

According to the definition of the "Wetland Convention", wetland refers to natural or artificial, perennial or seasonal, static or flowing fresh water, semi-aqueous or aquatic swamp, peatland or water area, including water depth of not more than 6 m at low tide Sea area (Liu *et al.* 2020). They are the most biologically diverse ecosystems in nature and one of the most important living environments for human beings (Parreño *et al.* 2021, Su *et al.* 2021). They are used in flood storage and drought prevention, climate regulation, soil erosion control, land siltation, and environmental degradation. Pollution and other aspects reflect important ecological functions. With the rapid development of society and economy, about 80% of the world's wetland resources have been lost or degraded, which has seriously affected the sustainable development of the ecology, economy and society of the wetland area. Therefore, understanding the structure and function of the wetland ecosystem is of great significance to the management of the wetland ecosystem.

Within a certain time and space, biodiversity is an important link that maintains the energy flow, material circulation, and information transmission of the ecosystem, and it is also the material basis for human survival. Among them, species diversity is the most important structural and functional unit of biological diversity (Fu *et al.* 2021). In addition to energy supply, plants also have ecological functions such as environmental instructions, biological habitat, soil improvement, etc., and play an important supporting role in the maintenance of the wetland ecosystem structure

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and the performance of ecological service functions. There is a complex interaction between wetland plant species diversity and wetland ecosystem services, which is also the key basis for studying ecosystem services. Understanding the species diversity of wetland vegetation helps to reveal the response of wetland ecosystems to climate change and human activities and is a key prerequisite for the development of wetland ecosystem management.

The north bank of the Hanjiang River is an important part of the wetland in the middle reaches of the Yangtze River. Its topography and geomorphic conditions are complex with sufficient rain and heat conditions, diverse local microclimates, rivers, reservoirs and other types of wetlands are widely distributed, and the wetlands are rich in biodiversity (Han *et al.* 2021, Yabe *et al.* 2021). However, there are few related studies at present, and the diversity of wetland vegetation is still not clear. The results of Zhang's research on plant diversity on the north bank of the Han River focused on the analysis of species composition and floral types, but did not provide in-depth analysis of community species diversity (Zhang *et al.* 2021). The present study intends to combine literature data and wetland sample surveys to investigate the plant species, flora, typical communities and diversity characteristics of the wetland on the north bank of the Hanjiang River, in order to provide basic data for the protection and restoration of wetland ecosystems on the north bank of the Hanjiang River and similar areas and wetland resource management and scientific basis.

Materials and Methods

Chenggu County is located in the central area of the Hanzhong Basin in southern Shaanxi, between 107°03'~107°30' east longitude and 32°45'~33°40' north latitude. The county is 101 km long from north to south and 42 km wide from east to west. The highest elevation is 2602.2, the lowest is 467.0, and the total county area is 2265 sq km. The topography of the city is high in the north and low in the south. It has a subtropical humid monsoon climate, warm and humid, with four distinct seasons, with an average annual temperature of 14.3°C, and an annual rainfall of 800-900 mm. It is known as the "most suitable city in the Northwest".



Fig. 1. Survey sample area.

Based on the results of the second national wetland resource survey on the north bank of the Hanjiang River in Chenggu County, this study was conducted a more comprehensive survey of the plant communities in the wetland patches on the north bank of the Hanjiang River in Chenggu County using the sample survey method. In accordance with the "Main Contents, Methods and Technical Specifications of the Inventory of Plant Communities", typical plant communities were randomly selected in each wetland patch, and standard squares of trees 5×5 m, shrubs, 2×2 m, herbaceous and aquatic $1\text{m} \times 1\text{m}$ were set up respectively (Correa-Araneda *et al.* 2021, Ohore *et al.* 2021). Forty plots were set up and the wetland type, geographic location, altitude, all species, number of plants, and coverage of the plant community were recorded where the plots are located.

Through on-site investigation of plant communities in wetland patches on the north bank of the Han River, site identification and identification, investigation and recording of plant species names, photographs and records of suspected species, and samples taken back to the laboratory for identification. Combining previous research data, the list of wetland plants in Chenggu County was summarized, and statistical analysis was carried out on plant families, genera and flora distribution types (Hong *et al.* 2021). The important value is used to represent the degree of dominance of each species in the wetland plant community (Li *et al.* 2021), and the calculation formula is:

$$\text{Important species value (ISV)} = \frac{\text{Relative coverage} + \text{Relative density}}{2}$$

$$\text{Relative coverage} = \frac{\text{Coverage of a species}}{\text{The sum of all kinds of coverage}}$$

$$\text{Relative density} = \frac{\text{The number of individuals of a species}}{\text{Individuals of all species}}$$

Patrick Index (R) , Margalef index (m), Simpson index (D), Shannon-wiener index (H) and Pielou evenness index (E) were used to measure plant species diversity and evenness, the calculation formula for each indicator is as follows: The Patrick index uses the number of species to represent the degree of species diversity (Hu *et al.* 2021, Zhang *et al.* 2021), focusing on the total number of different species existing in the plot:

$$R=S$$

The Margalef index is a species richness index based on the ratio of the number of species in the sample to the total number of individuals:

$$M = \frac{S-1}{\ln N}$$

The Simpson dominance index is the sum of the ratio of the number of individuals of each species to the total number of individuals (Zhang, *et al.* 2021, Zhan *et al.* 2021), which comprehensively reflects the species richness of the sample community:

$$D = \sum_{i=1}^s \left(\frac{N_i}{N} \right)^2$$

Shannon-Wiener diversity index applies the calculation formula of entropy in information theory (Hong *et al.* 2021), and the result reflects the degree of uncertainty of the individual appearance of the species:

$$H = -\sum_{i=1}^S (P_i \ln P_i)$$

The Pielou evenness index is the ratio of the Shannon-Wiener diversity index to the total number of species (Wang *et al.* 2021a), reflecting the uniformity of the number of species in the plot:

$$E = \frac{H}{\ln S}$$

In the above formula, S is the total number of plant species in the plot; N is the total number of plant individuals in the plot; N_i is the number of individuals of the i-th species in the plot; P_i is the important value of the i-th species and the species in the plot The ratio of the sum of important values.

Results and Discussion

Results showed that there are 360 species of wetland plants on the north bank of the Hanjiang River in Chenggu County, belonging to 108 families and 264 genera, including Charaphyta, 1 family, 1 genus, 1 species, 10 families, 11 genera, and 12 species of ferns, 3 families, 3 genera, and 3 species of gymnosperms. Angiosperms have 344 species in 251 genera and 94 families. The number of families, genera and species of vascular plants accounted for 30.31%, 8.29% and 1.20% of the total number of vascular plants in China, respectively. Including 5 species of national key protected plants, 1 species of first-level key protected wild plants, *Ginkgo biloba*, and 4 species of cultivated species of second-level key protected wild plants, namely *Cinnamomum camphora*, *Nelumbo nucifera*, *Glycine soja*, and *Juglans regia*.

Figure 2 showed that among the 107 families of vascular plants in the wetland on the north bank of the Hanjiang River in Chenggu County, there are 6 families containing 8 genera and above, and a total of 88 genera, accounting for 33.46% of all species. The number of families containing less than 8 genera is 101, accounting for 66.54% of the total number of species and genera. The families containing more than 8 genera are *Asteraceae* (24 genera), *Poaceae* (24 genera), *Fabaceae* (13 genera), *Rosaceae* (10 genera), *Lamiaceae* (9 genera), and *Euphorbiaceae* (8 genera).

Results presented in Fig. 3 showed that in Chenggu County, the number of families containing 10 species or more of vascular plants in the wetland on the north bank of the Hanjiang River in Chenggu County is 8, including 147 species, accounting for 40.95% of the total number of species; the number of families containing less than 10 species. There are 99, including 212 species, accounting for 59.05% of the total number of species; the number of families containing only one species is 60, accounting for 16.71% of the total number of species. *Poaceae*, *Rosaceae*, *Fabaceae* and *Polygonaceae* are families containing more than 10 species in order.

The total number of vascular plant genera in the wetland on the north bank of the Hanjiang River in Chenggu County is 263, 207 genera containing only one species, accounting for 78.41% of the total number of genera, and 57.50% of the total number of species; containing more than one species of genera. There are 56 in total, accounting for 21.21% of the total number of genera, and the number of species accounting for 41.67% of the total number of species. Figure 4 showed the top 8 genera with the largest number of species, namely *Polygonum*, *Artemisia*, *Rubus*,

Euphorbia, Potamogeton, Cyperus, Sedum, Lysimachia.

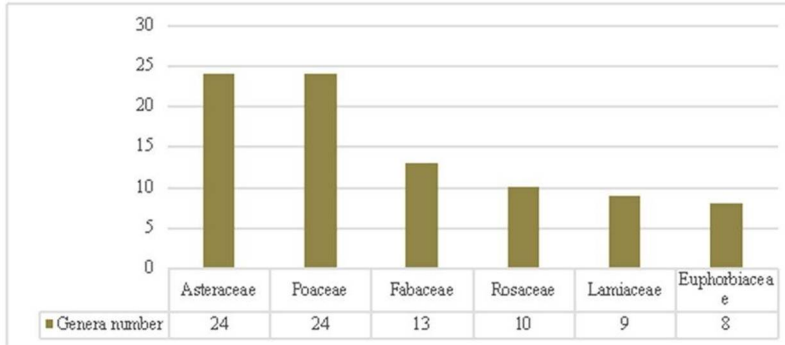


Fig. 2. Number of dominant families and genera of wetland plants on the north bank of Hanjiang River in Chenggu County.

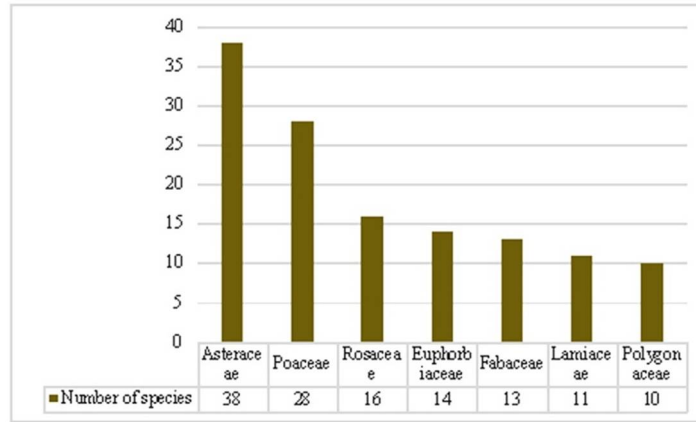


Fig. 3. Number of dominant family species of wetland plants on the north bank of Hanjiang River in Chenggu County.

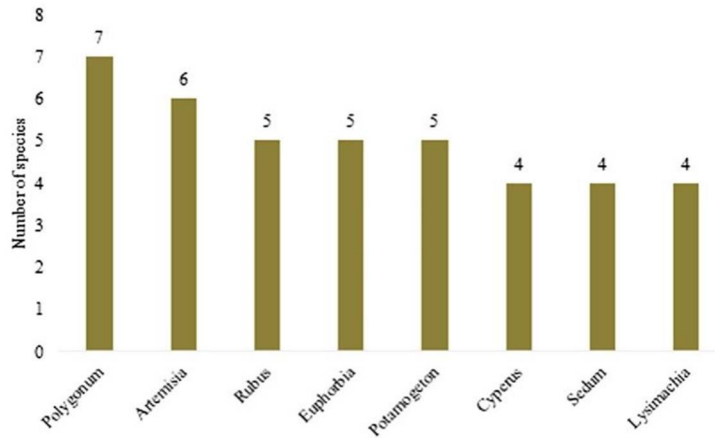


Fig. 4. Species of dominant genus of wetland plants on the north bank of Hanjiang River in Chenggu County.

According to Flora of China, there are 107 families of vascular plants in the wetland on the north bank of the Hanjiang River in Chenggu County, which can be divided into 7 distribution types and 5 variants (Table 1). Among them, the world-wide type has 43 families, accounting for 40.19% of the total number of families; it contains a total of 164 genera, accounting for 62.36% of the total number of genera. The families with a large number of species are Asteraceae, Poaceae, Rosaceae, Fabaceae, Lamiaceae, Asclepiaceae, Amaranthaceae, Cyperaceae, Ranunculaceae, Brassicaceae, Rubiaceae, Apiaceae, Crassulaceae, Primulaceae, Convolvulaceae, Pentoniaceae, Moraceae, Caryophyllaceae, Solanaceae.

Table 1. Typical statistical table of species and genera distribution of wetland seed on the north bank of Hanjiang river in Chenggu county.

Regional character of distribution	Distribution type and its variant	Genera number	%	No. of species	%
World zone	1. World-wide distribution type	43	40.19	164	62.36
Tropical zone	2. Pantropical distribution type	27	25.23	55	20.91
	3. Tropical asia-tropical africa-tropical america distribution	1	0.93	1	0.38
	4. Pan-tropical distribution dominated by the southern hemisphere	3	2.8	4	1.52
	5. Discontinuous distribution in east asia (tropical, subtropical) and tropical south america	5	4.67	5	1.9
	6. Old world tropical distribution	1	0.93	1	0.38
Temperate zone	7. North temperate distribution	8	7.48	9	3.42
	8. Intermittent distribution in the north temperate zone and the south temperate zone	9	8.41	14	5.32
	9. Temperate discontinuous distribution in europe, asia and south america	1	0.93	1	0.38
Paleo-mediterranean zone	10. Mediterranean, east asia, new zealand and mexico-chile intermittently distributed	1	0.93	1	0.38
	11. Discontinuous distribution in east asia and north america	7	6.54	7	2.66
Specific zone	12. China-specific distribution	1	0.93	1	0.38
Sum		108		264	

There are 27 families of tropical plants, accounting for 25.23% of the total number of families; 55 genera, accounting for 20.91% of the total number of genera. The families with a large number of species are Euphorbiaceae, Urticaceae, Araceae, Apocynaceae, Pteridaceae, Commelinaceae, Cucurbitaceae, Malvaceae. In addition, it also includes two tropical distribution variants, namely the tropical Asia-Tropical Africa-Tropical America distribution type and the pan-tropical distribution dominated by the southern hemisphere. The former includes *Iridaceae*, and the latter includes *Amaryllidaceae*, *Phytolacaceae*, and *Millinaceae*.

Both the old world tropical distribution type and the Chinese endemic distribution type only contain 1 family and 1 genus. The former includes *Musaceae* and the latter includes *Ginkgo biloba*. The proportions of both the total number of families and the total number of genera are 0.93 and 0.38%, respectively.

There are 8 families in the northern temperate zone, accounting for 7.48% of the total families; including 9 genera, accounting for 3.42% of the total genera. They are Loniceraeae, Pinaceae, Stemonaceae, Liliaceae, Asparagaceae, Cannabisaceae, Hypericaceae and Wufuhuaceae. In addition, there are 3 variations of the distribution types in the northern temperate zone, namely the discontinuous distribution types in the north temperate zone and the south temperate zone, 9 families and 14 genera, accounting for 8.41 and 5.32% of the total number of families and genera; the discontinuous distribution types in the Eurasian and South American temperate zones 1 family and 1 genera, accounting for 0.93 and 0.38% of the total number of families and genera; Mediterranean, East Asia, New Zealand and Mexico-Chile discontinuous distribution type 1 family and 1 genera, accounting for 0.93 and 0.38% of the total number of families and genera %. The number of families with discontinuous distribution types in East Asia and North America is 7, accounting for 6.54% of the total number of families; including 7 genera, accounting for 2.66% of the total number of genera. They are Pteriaceae, Schisandraceae, Saururaceae, Magnoliaceae, Acoraceae, Nelumboraceae, and Rootsaceae.

Results of the species diversity index of 54 typical wetland plant communities on the north bank of the Hanjiang River in Chenggu County showed that they included Patrick index (R), Shannon-Wiener diversity index (H), Simpson index (D), Pielou evenness index (E) and Margalef Index (M). The Patrick index is between 9 and 30, with a mean of 18.80 ± 5.19 ; the Shannon-Wiener diversity index is between 0.62 and 2.82, with a mean of 2.15 ± 0.39 ; the Simpson index is between 0.22 ± 0.92 , with a mean of 0.81 ± 0.10 ; Pielou The uniformity index is between 0.27 and 0.88, and the average is 0.75 ± 0.10 ; the Margalef index is between 1.72 and 5.06, and the average is 3.44 ± 0.87 .

In Patrick's index, *Bidens pilosa* has the lowest diversity at 9, and taro community is the highest at 30; the Shannon-Wiener diversity index, Simpson index, and Pielou evenness index of the Pondweed community are the lowest, respectively At 0.616, 0.218, 0.267, the Shannon index and Simpson index of the *Populus euphratica* community were the highest at 2.817 and 0.925, respectively; the Pielou evenness index was the highest at 0.882; in the Margalef index, *Flueggea virosa* was the highest at 5.059, and *Bidens pilosa* was the lowest at 1.719. After being standardized, different wetland plant community diversity indexes have similarities in the changing trends of different community types.

In the wetland patch on the north bank of the Hanjiang River in Chenggu County, a total of 360 species of plants were investigated belonging to 108 families, 264 genera and charaphyta, including 1 family, 1 genera and 1 species, pteridophytes, 10 families, 11 genera, and 12 species, gymnosperms, 3 families, 3 genera, and 3 species. Angiosperms have 344 species in 251 genera and 94 families. The number of families, genera and species of vascular plants accounted for 30.31%, 8.29% and 1.20% of the total number of vascular plants in China, respectively. There are 8 families containing more than 10 species, including a total of 147 species, accounting for 40.95% of all wetland species on the north bank of the Han River in Chenggu County.

The 107 families of vascular plants in the wetland on the north bank of the Hanjiang River in Chenggu County can be divided into 7 distribution types and 5 variants. Among them, the world's widespread families account for 40.19% of the total number of families, accounting for the highest proportion. Followed by tropical distribution families and their variants, accounting for 34.28% of the total number of families. Among them, the pan-tropical distribution type subjects are the main ones, accounting for 25.23% of the total number of subjects. The temperate distribution type and the Chinese endemic type families are relatively few. The temperate distribution type families and their variants have a total of 26 families, accounting for 24.30% of the total number of families; the Chinese endemic distribution is only 1 family, 1 genus and 1 species in the Ginkgo family,

accounting for the total number of families. Of 0.93%. The results show that the flora in this area has significant tropical characteristics, and at the same time has certain temperate characteristics. The north bank of Hanjiang River in Chenggu County is located in the northern subtropical region, with the subtropical continental monsoon climate as the main climate type. The characteristics of the wetland plants distributed in this area are consistent with the regional climate and environment at the family level.

Among 54 typical wetland plant community types on the north bank of Hanjiang River in Chenggu County, the average Patrick index is 18.80 ± 5.19 ; the average Shannon-Wiener diversity index is 2.15 ± 0.39 ; the average Simpson dominance index is 0.81 ± 0.10 ; the average Pielou uniformity index is 0.75 ± 0.10 ; the average value of Margalef index is 3.44 ± 0.87 . *Ass.B.pilosa* has the lowest Patrick and Margalef indexes, *Ass.P.malaianus* has the lowest Shannon diversity index, Simpson dominance index, and Pielou evenness index; *Ass.C.esculenta* has the highest Patrick index, and *Ass.C.sebiferum* The Pielou uniformity index of *Ass.C.canadensis* is the highest, the Shannon diversity index and Simpson dominance index of *Ass.C.canadensis* are the highest, and the Margalef index of *Ass.F.virosa* is the highest. The results show that the species diversity of aquatic plant communities or wet herb communities is generally low, while the wet shrub communities or arbor communities generally have higher species diversity. The reason may be that in the aquatic environment or wet environment with large changes in water level, flooding conditions have played a greater role in restricting and screening plant colonization, and herbaceous plants with shorter life cycles occupy most of the ecological niches. Among them, a few highly adaptable species have formed obvious advantages in the community. The community hierarchical structure is relatively simple and the species diversity is low. In wet shrub communities or tree communities, plants need sufficient water conditions, but are less affected by flooding (Fang *et al.* 2021). The community environment can support the colonization and survival of more species, and the wetland plant community can succeed to a higher level. In this stage, a richer community hierarchy and species diversity have been formed.

From the research results on the plant species, flora, typical communities and diversity characteristics of the wetland on the north bank of the Hanjiang River in Chenggu County, it can be seen that the wetland on the north bank of the Hanjiang River in Chenggu County is widely distributed and has more wetland plant species. In addition to the world's widespread type of wetland flora, the tropical distribution type occupies the largest part, which is consistent with the main climate types of the region (Chi *et al.* 2021). Wetland plant communities are rich in types, in which aquatic or wet herb communities are the main ones, and tree or shrub communities are few. However, compared with herb communities, arbor or shrub communities have more diverse species composition and usually have a higher species diversity index (Wang *et al.* 2021b). In recent years, the wetland protection and restoration work implemented on the north bank of the Han River in Chenggu County has shown results, but there are still some problems, such as the invasion of alien species such as *Eclipta prostrata* and *Eichhornia crassipes*; water pollution and soil erosion caused by agricultural or industrial and mining production. It needs to be focused on in the future wetland protection and restoration work.

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