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Floristic composition and plant community diversity of water-level fluctuation zone of Nanwan Reservoir

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ABSTRACT

To study the vegetation community structure and diversity characteristics in the water-level fluctuation zone of Nanwan Reservoir, the water-level fluctuation zone of Nanwan Reservoir was divided into two water level elevations, one being 95–100 m and the other being 100–105 m. Subsequently, 3 typical plant communities of the water-level fluctuation zone of Nanwan Reservoir were selected for investigation. In the present study, a total of 34 species of plants were found. In listing the number of plants by family in order, the most abundant was *Compositae*, the second most abundant plant was *Gramineae* and the third most abundant was Legumes. In the present survey, *Compositae* accounted for 40.9% of the total number of species in the present survey, *Gramineae* accounted for 20.7% of the total number of species, and legumes accounted for 19.8% of the total number of species. According to the important values, the dominant species of different water level elevations in the descending zone of Nanwan Reservoir were sequenced. In the low water level elevation region, the first dominant species was *Hemarthria altissima*, the second dominant species was *Erigeron canadensis*, and the third dominant species was *Kummerowia striata*. However, in the high water level elevation region, the first dominant species was *Kummerowia striata*, the second dominant species was *Hemarthria altissima*, and the third dominant species was *Carex neurocarpa*. At the same time, in the low water level elevation region, a total of 19 species of plants were found. Among the 19 species of plants, annual herbs had the highest proportion at 47.37%, and there were 9 kinds of annual herbs. In the high water level elevation region, a total of 28 species of plants were found. In the 28 species of plants, perennial herbs had the highest proportion at 53.57%, and there were 15 kinds of perennial herbs. As the elevation of the water level rose, the diversity index, the evenness index and the richness index all increased, while the dominance index decreased. In conclusion, there was variation in the water level elevation in the water-level fluctuation zone of Nanwan Reservoir. An observation can be made that the different intensity of flood disturbance caused by the elevation change in the water-level fluctuation zone of Nanwan Reservoir is a significant factor in the structure and diversity of plant communities.

Keywords: Nanwan Reservoir; Water-level fluctuation zone; Water level elevation; Plant community; Species diversity

1. Introduction

The floodplain is a zone of interaction between the lowest water level during the dry period (water release period) and the highest water level during the rich period (water storage period), and is formed by natural or artificial waters such as rivers, lakes and reservoirs. In the floodplain, the water level rises and falls periodically owing to regular changes in seasonal water quantity, artificial regulation for flood control, power generation and irrigation, or other

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factors [1,2]. The vast majority of the plant population will have difficulty adapting to the extreme growth environment, which can be attributed to the repeated periodic changes in extinction zone water level caused by drought, leading to ecosystem changes. As a fragile ecosystem, such conditions are unsuitable for plant community growth, resulting in habitat degradation, extinction zone plant diversity, soil erosion and serious ecosystem degradation [3,4].

At present, domestic research on the extinction zone has mainly focused on the Three Gorges Reservoir, and research on the whole Three Gorges Reservoir is relatively comprehensive, including studies on the initial flooded plant communities in the Three Gorges Reservoir area [5–8], and the plant community composition and species diversity in the extinction zone of the Three Gorges Reservoir [9–14]. Compared with the Three Gorges Reservoir, which has a large volume and wide range; there is a scarcity of research on local reservoirs such as Zhejiang Qiandao Lake Reservoir and Sichuan Waterfall Gou Reservoir [15,16]. Nanwan Reservoir was built in the 1950s and is located in Xinyang city, Henan province. After decades of alternating flooding and drought periods, the extinction zone basically formed stable plant communities. In recent years, the soil erosion of the Nanwan Reservoir extinction zone soil has become increasingly serious (Fig. 1), but there has been no research on the plant communities. In the present study, by investigating the Nanwan Reservoir extinction zone plant communities, the impact of different water level elevations on the plant community was determined. So as to provide a reference for the ecological restoration of Nanwan Reservoir.

2. Materials and methods

2.1. Overview of the study area

Xinyang, located in southern Henan Province, belongs to the border area of the subtropical and warm temperature transition zone, with a typical monsoon climate. Xinyang City has abundant sunshine throughout the whole year, and the annual average temperature at 1,900–2,100 h can reach 15.3°C–15.8°C. There is also abundant rainfall, with the average annual rainfall being between 993–1,294 mm. Owing to the influence of the special geographical location and climate, the spatial and temporal distribution of precipitation in Xinyang is uneven, and the precipitation also changes significantly from year to year. The precipitation is mainly concentrated in June and August in the main flood season, accounting for 54% of the whole year.

Nanwan Reservoir is located 8.5km southwest of the central city of Xinyang City, Henan Province, between 31.43′–32.11′ northern latitude and 113.41′–114.02′ eastern longitude. As the largest tributary of the Huai River, with a control river basin area of 1,100 km^2, Nanwan Reservoir was built in the 1960s in the early days of the founding of China, being one of the first large-scale Huai River control projects. The main functions of the Nanwan Reservoir are flood control, irrigation, and the comprehensive utilisation of power generation, breeding, urban water supply and tourism development.

2.2. Sample setting and investigation

The method adopted in the present survey was a typical sampling method, in which the place that was less affected by the external environment and best reflected and represented the plant environment in the extinction zone was chosen as the survey sample point. The survey areas selected were the upstream, middle and downstream areas of the east side of Nanwan Reservoir, with a slope of about 5.–15., and a total of three sampling points were set (Fig. 2).

Each sampling point was divided into low water level elevation (95–100 m) and high water level elevation (100–105 m) according to altitude. Five 1 m × 1 m survey samples were set in parallel at the two water level elevations. The square spacing was 1m, and a total of 30 samples were set. The latitude and longitude information and elevation of the drop band were measured using Meghdo T11-8 portable GPS in each sample. The slope was measured using the Changzhou Dadi MPE 02L theodolometer. The slope direction was determined using the Harbin DQY-1 compass instrument. The species name and life type of plants in the sample site were determined and distinguished by combining Flora

Fig. 1. Current situation of soil erosion in the water-level fluctuation zone of Nanwan Reservoir.

Fig. 2. Distribution of sampling sites in the water-level fluctuation zone of Nanwan Reservoir.

Table 1
Fundamental information of the water-level fluctuation zone sampling point

Sampling point number of the water-level fluctuation zone	Name of the water-level fluctuation zone	Latitude and longitude	Aspect	Slope	Soil type
1	Qiangwan village Liujia Wan water-level fluctuation zone	Northern latitude 32°09′, Eastern longitude 114°02′	NW298°	14	Yellow loam
2	Qiangwan village Lu Wan water-level fluctuation zone	Northern latitude 32°08′, Eastern longitude 113°98′	NW231°	17	Yellow loam
3	Xuetanggang village Shujia Wan water-level fluctuation zone	Northern latitude 32°05′, Eastern longitude 113°97′	NW242°	12	Yellow loam

Reipublicae Popularis Sinicae [18] and Flora of Henan [19]. The cover degree and density of each plant in the sample square were investigated and recorded. Estimation of plant cover using the grid visual inspection method. Table 1 for the basic information of the selected sample points.

2.3. Data processing and analysis

2.3.1. Species importance

Species importance values are a practical comprehensive metric for measuring the status and role of a species in a plant community [20].

$$\text{Species Importance}\left(I_v\right) = \frac{\left(\begin{array}{c}\text{Relative frequency} + \text{Relative coverage} \\ +\text{Relative density}\end{array}\right)}{3} \quad (1)$$

In the formula: Relative frequency = Frequency of a given species/Total frequency of all species × 100%.

Relative coverage = Cover for a given species/Total cover for all species × 100%.

Relative density = Number of species in sample square/Number of all species in sample square × 100%.

2.3.2. α diversity indices

α diversity is primarily used to determine intra-community diversity, and is the reference vegetation ecological characteristic index. In the present study, the spatial distribution features of biodiversity were analysed. The specific selection of indicators included the Shannon-Wiener diversity indices (*H*), the Pielou evenness index (*E*), the Simpson dominance index (*D*), and the Margalef enrichment index (*D*′) [21–23].

Shannon-Wiener diversity indices (H) represent the relative abundance of the species in the community, in which the more biological species in the community, the higher the complexity of the community. That is, the larger the H value, the greater the amount of information the community contains.

$$H = \sum P_i \ln P_i \quad (2)$$

The Pielou evenness index (E) mainly represents the uniform distribution of other indicators, such as biomass, and cover different species in the community.

$$D = 1 - \sum_{i=1}^{S} P_i^2 \quad (3)$$

The Simpson dominance index (D) measures the degree of dominance of plant species in a community, it reflects the concentrated nature of the species.

$$E = H \ \ln(S) \quad (4)$$

In the Margalef enrichment index (D'), S represents the number of species in the community and N represents the total number of individuals observed in the sample square.

$$D' = \frac{(S-1)}{\ln N} \quad (5)$$

2.3.3. Data analysis

Statistical analysis was performed using SPSS24 software. Independent sample t-test analysis was performed for each of the α diversity index values of plant species at different elevations. The confidence level was $p < 0.05$. Mapping was conducted with ORIGIN 2021.

3. Results and analyses

3.1. Plant distribution and composition in the water-level fluctuation zone

In the present study, 32 species of vascular plants in 31 genera and 14 families were identified in the water-level fluctuation zone of Nanwan Reservoir, including five genera and eight species of *Compositae*, five genera and five species of *Gramineae*, five genera and five species of *Leguminosae*, four genera and four species of *Labiatae*, two genera and two species of *Polygonaceae*, two genera and two species of *Salicaceae*, one genera and one species of *Oxalidaceae*, one genera and one species of *Amaranthaceae*, one genera and one species of *Cyperaceae*, one genera and one species of *Apiaceae*, one genera and one species of *Rosaceae*, one genera and one species of *Juncaceae*, one genera and one species of *Plantaginaceae*, and one genera and one species of *Primulaceae*. Among said species, the family *Compositae* had the largest number of plants, while *Gramineae* and *Leguminosae* ranked second and third, accounting for 40.9%, 20.7%, and 19.8%, respectively, of the total number of species in the present survey. It is the dominant family in the area, with little difference between the other families.

As shown in Table 2, the number of plant species in the low level elevation region was 19, while that in the high level elevation region was 28. Low water level elevation region was significantly less than high water level elevation region. Many species appearing at high elevation regions in the survey were not found at low elevation regions, and the extinction zone water level changes had a significant impact on the composition of plant communities. Low water level elevations have fewer species that can adapt to the harsh environment due to longer periods of inundation, and as elevation increases, high water level elevations have relatively fewer periods of inundation and an increasing variety of plants that can adapt to grow. As shown in Fig. 3, the dominant species across elevations were clearly distinct. The top three dominant species in the low water elevation regions were *Hemarthria altissima*, *Erigeron canadensis* and *Kummerowia striata*. The top three dominant species in the high water elevation regions were *Kummerowia striata*, *Hemarthria altissima* and *Carex neurocarpa*.

3.2. Plant life-type characteristics in the extinction zone

The Flora Reipublicae Popularis Sinicae and Flora of Henan were used to classify the life types of all the plants surveyed in the sample plots. The water-level fluctuation zone of Nanwan Reservoir contained 5 plant species, as shown in Table 3.

In the sample square survey, a total of 34 species were found. The species included: 11 annual herbs, accounting for 32.35%; 4 species of annual or biennial herbs, accounting for 11.76%; 15 species of perennial plant, accounting for 44.13%; 2 species of shrub, accounting for 5.88%; and 2 species of tree (seedling), accounting for 5.88%. Although there were tree species in the survey sample, said species were actually tree seedlings, and no adult trees were observed. In the low water level elevation region, 9 of the 19 plants surveyed belonged to annual plants, accounting for the highest percentage of 47.37%. Meanwhile, in the high water level region, 15 of the 28 plants surveyed belonged to perennial plants, accounting for the highest percentage of 53.57%. An observation can be made that the flooding time of the low water level elevation regions was longer and more conducive to annual herbs, while the flooding time of the high water level elevation regions was relatively short, being more conducive to perennial herbs and shrubs.

3.3. Plant diversity in the water-level fluctuation zone

Species diversity is an important manifestation of biodiversity, and reflects the mutual influence between organisms, biology and the environment. Species diversity is usually expressed by the species diversity index, which can be divided into three major categories, namely, α diversity index, β diversity index and γ diversity index [24,25]. Among said indices, the α diversity index is primarily used to reflect the number of species within the community and the relative abundance among species, reflecting the competition and coexistence results between different species within a certain community [26]. In the present study, the species diversity indices in the high and low water level elevation regions were calculated, including the Shannon-Wiener diversity

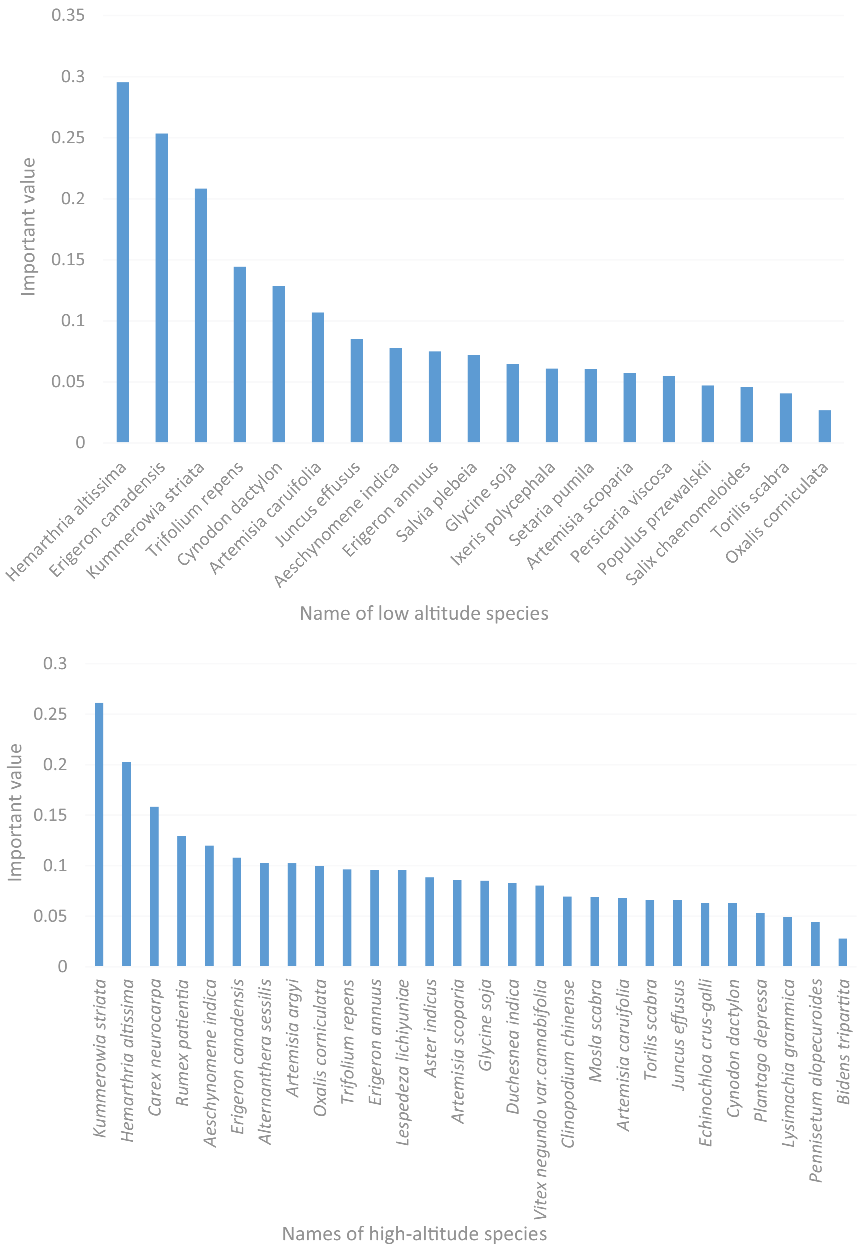

Fig. 3. Important values of species at different water level altitude in water-level fluctuation zone of Nanwan Reservoir.

indices (*H*), the Pielou evenness index (*E*), the Simpson dominance index (*D*), and the Margalef enrichment index (*D*′). The relationships between the indices and different water level elevations were investigated, as shown in Fig. 4.

Analysis was performed by independent sample *t*-test, the Shannon-Wiener diversity indices, the Pielou evenness index, the Simpson dominance index, and the Margalef enrichment index of the water-level fluctuation zone of Nanwan Reservoir flora all varied significantly in different water level elevation gradients ($P < 0.05$). The average Shannon-Wiener diversity index for high water elevation was 1.67, greater than the average of 1.50 of low water elevation; the average Pielou evenness index of high water elevation was 0.86, greater than the average of 0.82 of low water elevation; and the average Margalef enrichment index for high water elevation was 1.40, greater than the average of 1.23 for low water elevation. However, the average Simpson dominance index of low water elevation was 0.27, greater than the average of 0.22 of high water elevation. Overall, the species diversity of high water levels was significantly higher than low water elevation.

4. Conclusions and discussions

Vascular Plants of 14 families, 31 genera and 34 species were found in the investigation area of the water-level fluctuation zone of Nanwan Reservoir, Xinyang City. Among said plants, *Compositae* had the largest number of plants, followed by *Gramineae* and *Leguminosae*, accounting for 40.9%, 20.7%, and 19.8%, respectively, of the total number of

Table 2
Plant composition and importance index of different water level elevation in water-level fluctuation zone of Nanwan Reservoir

Name of species	Family	Genus	Low water level elevation importance index	High water level elevation importance index
Hemarthria altissima	*Gramineae*	*Hemarthria*	0.295	0.202
Erigeron canadensis	*Compositae*	*Erigeron*	0.254	0.108
Kummerowia striata	*Leguminosae*	*Kummerowia*	0.208	0.261
Trifolium repens	*Leguminosae*	*Trifolium*	0.144	0.096
Cynodon dactylon	*Gramineae*	*Cynodon*	0.129	0.063
Artemisia caruifolia	*Compositae*	*Artemisia*	0.107	0.068
Juncus effusus	*Juncaceae*	*Juncus*	0.085	0.066
Aeschynomene indica	*Leguminosae*	*Aeschynomene*	0.078	0.120
Erigeron annuus	*Compositae*	*Erigeron*	0.075	0.096
Salvia plebeia	*Labiatae*	*Salvia*	0.072	–
Glycine soja	*Leguminosae*	*Glycine*	0.065	0.085
Ixeris polycephala	*Compositae*	*Ixeris*	0.061	–
Setaria pumila	*Gramineae*	*Setaria*	0.061	–
Artemisia scoparia	*Compositae*	*Artemisia*	0.057	0.086
Persicaria viscosa	*Polygonaceae*	*Polygonum*	0.055	–
Populus przewalskii	*Salicaceae*	*Populus*	0.047	–
Salix chaenomeloides	*Salicaceae*	*Salix*	0.046	–
Torilis scabra	*Apiaceae*	*Torilis*	0.041	0.066
Oxalis corniculata	*Oxalidaceae*	*Oxalis*	0.027	0.100
Carex neurocarpa	*Cyperaceae*	*Carex*	–	0.158
Rumex patientia	*Polygonaceae*	*Rumex*	–	0.130
Alternanthera sessilis	*Amaranthaceae*	*Alternanthera*	–	0.103
Artemisia argyi	*Compositae*	*Artemisia*	–	0.102
Lespedeza lichiyuniae	*Leguminosae*	*Lespedeza*	–	0.096
Aster indicus	*Compositae*	*Aster*	–	0.088
Duchesnea indica	*Rosaceae*	*Duchesnea*	–	0.083
Vitex negundo var. cannabifolia	*Labiatae*	*Vitex*	–	0.080
Clinopodium chinense	*Labiatae*	*Clinopodium*	–	0.069
Mosla scabra	*Labiatae*	*Mosla*	–	0.069
Echinochloa crus-galli	*Gramineae*	*Echinochloa*	–	0.063
Plantago depressa	*Plantaginaceae*	*Plantago*	–	0.053
Lysimachia grammica	*Primulaceae*	*Lysimachia*	–	0.049
Pennisetum alopecuroides	*Gramineae*	*Pennisetum*	–	0.044
Bidens tripartita	*Compositae*	*Bidens*	–	0.028

Note: "–" Undiscovered species.

species in the present survey. *Compositae* was the dominant family of the region, and a single genus phenomenon was obvious.

In the present investigation, the water-level fluctuation zone of Nanwan Reservoir was divided into two water level elevations, one being 95–100 m and the other being 100–105 m. In the high water level elevation region (100–105 m), the number of plants, as well as the genus and species, were consistent with relevant findings [9,11,12,14,27–29]. The distribution of plants in the extinction zone is mainly affected by water level changes [30]. Although the difference in water level elevation in the extinction zone was not different, the length of flooding time caused by different water level elevation was particularly obvious. In the present investigation, the dominant species across elevations were also clearly distinct. The top three dominant species in the low water elevation regions were *Hemarthria altissima*, *Erigeron canadensis* and *Kummerowia striata*. The top three dominant species in the high water elevation regions were *Kummerowia striata*, *Hemarthria altissima* and *Carex neurocarpa*. The two regions had a clear difference.

Through the survey, the perennial herb was the main dominant species in the Nanwan Reservoir extinction zone, with a total of 15 species, accounting for 44.13%. From different water level elevation points, a total of 19 plants were found in low water level elevation regions, including 9 annual herbs, accounting for 47.37%, which was the main dominant species. A total of 28 plant species were found in

Table 3
Plant life type in water-level fluctuation zone of Nanwan Reservoir

Plant species	Survey area of water-level fluctuation zone		Low water level elevation		High water level elevation	
	Species number	Ratio (%)	Species number	Ratio (%)	Species number	Ratio (%)
Annual herb	11	32.35	9	47.37	8	28.57
Herbs annual or biennial	4	11.76	3	15.78	3	10.72
Herbs perennial	15	44.13	5	26.32	15	53.57
Shrubs	2	5.88	0	0	2	7.14
Arbor (seeding)	2	5.88	2	10.53	0	0
Total	34	100	19	100	28	100

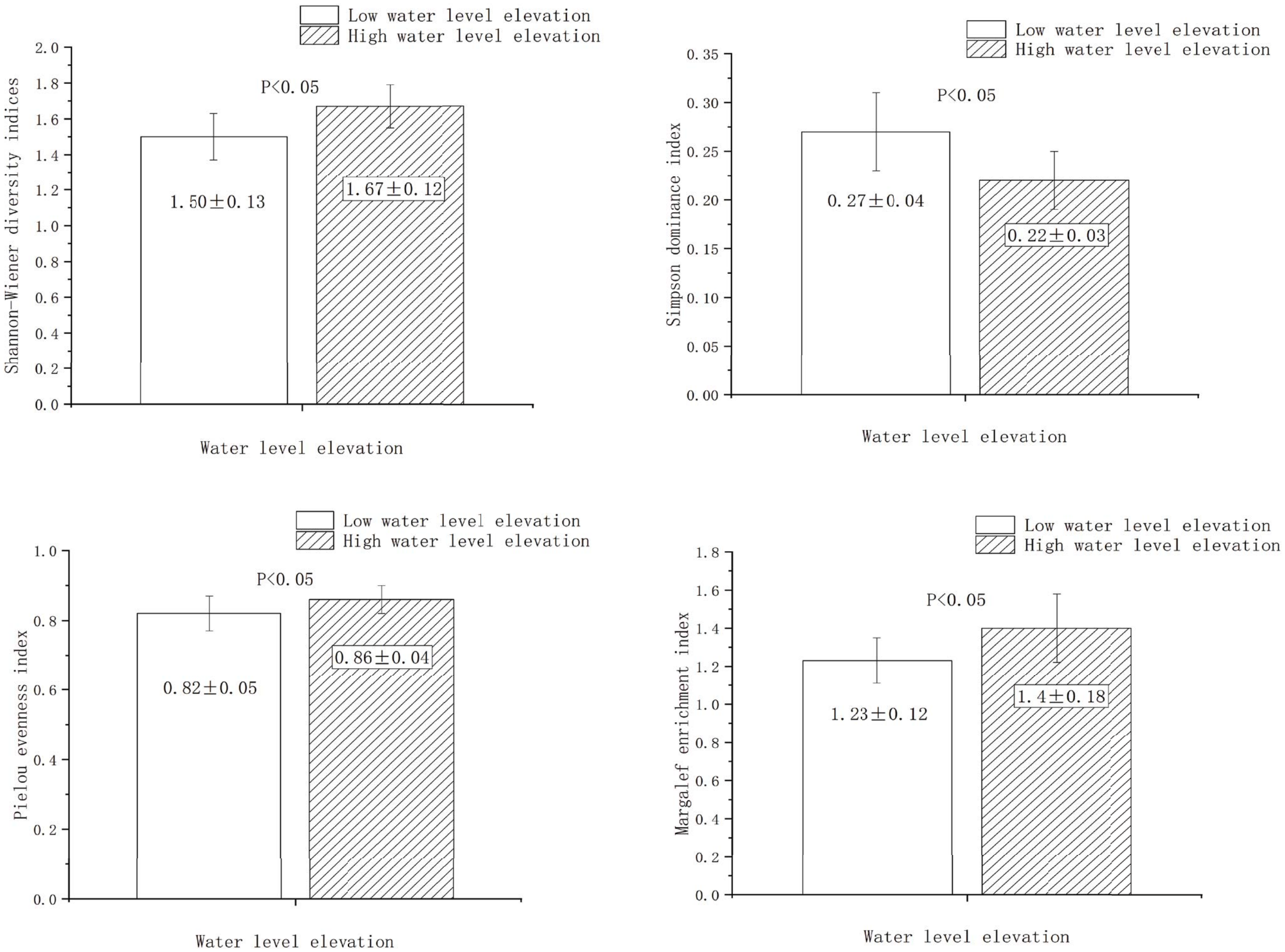

Fig. 4. Plant community diversity index of different water level elevation in water-level fluctuation zone of Nanwan Reservoir.

high water level elevation regions, including 15 perennial herbs, accounting for 53.57%, as the main dominant species. Such results are consistent with those of prior research [31]. The analysis of the water level change of Nanwan Reservoir provided by Xinyang Hydrological Water Resources Survey Bureau found that Nanwan Reservoir did not present a typical "high water level (dry period) – low water level (abundant period)", but presented an irregular water level change, which is different from the study of the extinction zone of the Three Gorges Reservoir [9,14,31]. Field surveys also found that Nanwan Reservoir was sometimes flooded for a long time, up to a year. Due to the irregularity of the changes in water level at Nanwan Reservoir, low water elevation regions experience relatively long periods of flooding. This can result in annuals needing to complete their entire life history quickly once the water level has faded.

When prolonged flooding occurs, annuals are also able to ensure rapid germination and growth under suitable environmental conditions once the water has receded by delaying seed germination. Thus, annual herbs can be dominant in low water elevation regions. In the high water level elevation region, although the plant communities were not as stressed as those in low water level elevation regions, the competition between species in the high water level elevation regions was more intense. The perennial herbs were able to take advantage to occupy the living space and resources first and become the dominant living type. At the same time, the high water level elevation region is closer to land, and the probability of plant seeds blowing into the area through wind, animals and other media, is also one of the reasons for higher water level elevation regions having more species than low water level elevation regions.

In the water-level fluctuation zone of Nanwan Reservoir, all α diversity indices were higher at high water level elevation regions, including the Shannon-Wiener diversity indices, the Pielou evenness index and the Margalef enrichment index. The Simpson dominance index was the highest in the low water level elevation, indicating that the low water level elevation region of the extinction zone suffered from prolonged flooding and changes in water level fluctuations. The erosion of lake water, soil erosion and other factors were considerably harsh, resulting in low species diversity, while the high water level elevation region was relatively less affected and rich species diversity.

The annual herb *Kummerowia striata* was also found to account for a higher proportion in the community in both low and high water level elevation regions. The important value of *Kummerowia striata* ranked third in low water level elevation regions and first in high water level elevation regions. The effect of *Kummerowia striata* has been demonstrated in previous studies [32,33]. As such, *Kummerowia striata* has some influence on the diversity of colony zone plant communities, which needs to be further explored and demonstrated.

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