

# Effects of Ecological Restoration on Degraded Riparian Plant Communities

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## Abstract

Riparian areas are the transitional zones between terrestrial and aquatic ecosystems. Riparian have been experienced serious river channelization, riparian hardening and other anthropogenic activities. These disturbances result in degradation of ecological function and reduction of biodiversity of riparian ecosystems. There are many ecological engineering to restore riparian ecosystems in China. The research results of this article indicate that species richness and the Shannon-Wiener diversity index were: restored sites > natural sites > channelized sites, and biomass of natural sites was significantly lower than that of restored and channelized sites. The reason is that river channelization severely changed the composition and structure of plant communities and decreased plant diversity in riparian zone. Practicable ecological restoration measures could effectively reconstruct the plant communities and improved plant diversity in the channelized riparian zones.

## Keywords

Riparian Zone; Plant Community; River Channelization; Ecological Restoration.

## 1. Introduction

Ecological function rivers are one of the most important ecosystems in nature. The riparian zone is an area periodically submerged between the highest and lowest water levels of a river, serving as a transitional zone between aquatic and terrestrial ecosystems. It plays a crucial role in maintaining biodiversity, intercepting pollutants, buffering floods, and regulating water temperature. Rivers are seriously threatened by human factors such as water conservancy engineering construction, pollution emissions, and land use changes. The hydrological conditions, topography, and geomorphological characteristics of rivers have undergone significant changes, leading to the degradation of their ecological functions. Urbanization has changed the distribution pattern of biological species diversity and the structure of functional groups (Jiachen et al., 2021).

The phenomenon of "cutting corners and straightening", "channelization", and "hardening of slopes" in the Yangtze River is not uncommon, resulting in the exposed surface of the riparian zone in the area, low vegetation coverage, and severe degradation of the ecosystem. Vegetation is an important component of riparian ecosystems, with high productivity and playing an important ecological role. The relationship between riparian plant communities and river hydrology, topography, and soil properties is very close (Pielech et al., 2015; Ahmad et al., 2014). The channelization of riverbanks has led to changes in landforms and hydrological rhythms, weakened lateral connectivity of rivers, and thus altered the structure and diversity of plant communities in the riparian zone. The Three Gorges Dam Ecological Restoration Project adopts feasible engineering and technical measures, selects suitable plant species, and through greening construction, builds an ecological restoration demonstration area with plant

diversity (Dingjun Zhang et al., 2023). The author investigated the vegetation of the riverbank in the Chongqing section of the Yangtze River and compared the characteristics of plant communities in different regions. It was found that hydraulic engineering facilities such as river channelization have an important impact on plant diversity in the riverbank, providing scientific basis for river ecosystem management and riverbank biodiversity protection.

## 2. Research Area and Methods

### 2.1. Overview of the Research Area

Chongqing city is an important ecological protection node city in the upper reaches of the Yangtze River, with a well-developed river network and a typical centripetal water system. The characteristics of mountainous rivers are obvious. The Yangtze River runs through the entire urban area from west to east. Under the influence of severe water level fluctuations, the substrate of the riparian zone is mainly gravel and sand. Some plants disappear due to their inability to adapt to deep water flooding in winter and strong flooding in summer. The plant community structure is simple, the landscape type is single, and the integrity of the ecosystem structure is poor.

### 2.2. Method

This article selects typical and representative riparian zone plots. They are respectively (1) The channelized areas, which are areas where artificial cement hard slope protection or other hard retaining walls are constructed in steep and strongly eroded riverbank zones to prevent disasters such as soil erosion and flooding. (2) The natural areas refer to riparian areas that are less affected by human interference. (3) The restored areas refer to the area where a series of ecological restoration attempts are carried out on the surface hardening and other channelized river sections, such as covering soil, reshaping the terrain and landforms of the riverbank, planting water resistant plants, etc., to achieve the restoration and reconstruction of the riverbank ecosystem. Each plot is equipped with three vertical river lines spaced 50 meters apart, with six "1×1 m<sup>2</sup>" along the elevation of each line. Record the plant species, abundance, average height, and coverage within each sample plot.

### 2.3. Data Analysis

The analysis of plant community composition is based on plant important value data, and cluster analysis is performed on various aspects using the bidirectional indicator species analysis method. Compare the differences in plant community composition using principal coordinate analysis (PCoA) and multiple comparisons in the R software Vegan package (R Development Core Team, 2017). Select species richness, biodiversity index, coverage, and biomass to describe the structural characteristics of plant communities. Using the Sparse Standardization method in the EstimateS 9.0 package, calculate the cumulative abundance of plant communities in different regions, and then draw a thinning curve to compare plant species diversity in different regions (Colwell, 2013). Use one-way ANOVA and Tukey method in SPSS 20.0 software to compare the differences in plant richness index, diversity index, biomass, and coverage among different regions.

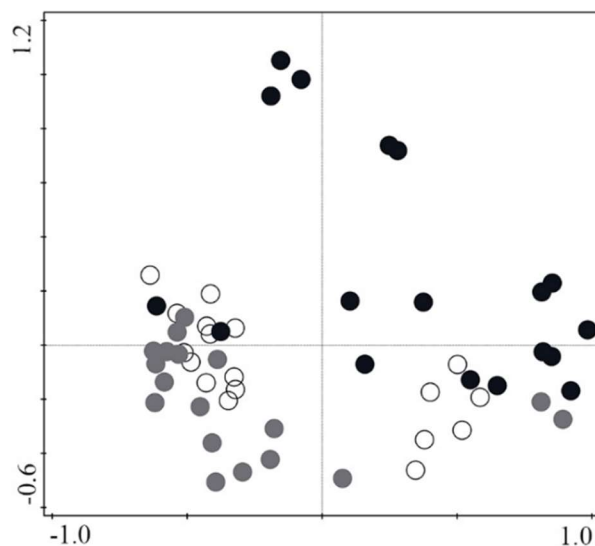
## 3. Results and Analysis

### 3.1. Species Composition of Riparian Zones in Urban Areas

According to the survey results of 9 plots, there are 138 species of herbaceous plants, belonging to 33 families and 110 genera. Among them, Compositae, Gramineae, Cruciferae, Polygonaceae, Labiatae, and Umbelliferae have the most plant species, accounting for 50% of the total number of plants. The number of species in the restoration area is significantly higher than that in the

natural and channelized areas, and the channelized area maintains the lowest number of species. There are a total of 103 species of plants belonging to 85 genera and 30 families in the restoration area. The dominant plants are *Cynodon dactylon*, *Hemarthria altissima* and *Polygonum lapathifolium*. *Polygonum fugax*, *Alternanthera philoxeroides*, and *Cyperus rotundus* *Phalaris arundinacea* community types; There are 75 species of plants belonging to 63 genera and 22 families in the natural area, with the dominant plants being *Cynodon dactylon*, *Chenopodium album* and *Leonurus artemisia* community; There are 62 species of plants belonging to 53 genera in 20 families in the channelized area. The dominant plants are *Cynodon dactylon*, *Humulus scandens*, and *Bidens pilosa* and *Daucus carota* community.

The analysis of variance and principal coordinates of plant communities in three different regions (Fig.1) showed significant differences in plant community composition ( $R^2=0.20$ ,  $F=1.80$ ,  $p<0.05$ ). There were significant differences in plant community composition between channelized areas and restoration and natural areas ( $p<0.05$ ), while there was no significant difference in plant community composition between restoration and natural areas ( $p>0.05$ ). This indicates that riverbank channelization significantly changes plant community composition, Ecological restoration can reconstruct the plant community in the area. The Asteraceae and Poaceae plants have advantages in all three regions, among which Poaceae plants such as *Cynodon dactylon*, *Hemarthria altissima* are the most widely distributed in the three regions and are common species in the riverbank zone of Chongqing urban area. The proportion of single species and few species in the restoration area is relatively high, such as Primulaceae, Caprifoliaceae, Geraniaceae, and Onagraceae. Poaceae plants have increased, such as *Avena fatua*, *Roegneria kamoji*, and *Poa annua*. Compared with natural areas, there are fewer plant species in the Poaceae, Asteraceae, and Cruciferae families in the channelized area.

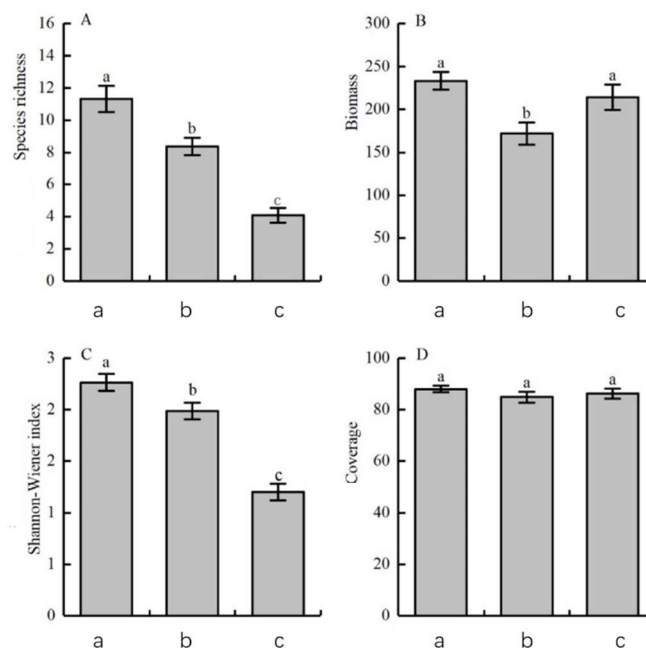


**Fig. 1** PCoA of riparian plant communities in different areas (black:channelized sites; grey:natural sites; white: restored sites)

### 3.2. Species Richness, Diversity Index, Biomass and Coverage

There were significant differences ( $p<0.05$ ) in species richness, Shannon Wiener diversity index, and biomass among the three plant communities in the riverbank zones of the two rivers and four banks in the urban areas of Chongqing, while there was no significant difference ( $p>0.05$ ) in coverage. As shown in Fig. 2, among the three regions, the species richness in the restoration area is the highest ( $11.31 \pm 0.81$ ), followed by the species richness in the natural area ( $8.37 \pm 0.54$ ), and the species richness in the channelized area is the lowest ( $4.09 \pm 0.46$ ). The variation trend of Shannon Wiener diversity index and species richness in the three regions

is similar. The Shannon Wiener diversity index in the restoration area is the highest ( $2.26 \pm 0.08$ ), followed by natural areas ( $1.99 \pm 0.08$ ), and the Shannon Wiener diversity index in the channelized area is the lowest ( $1.20 \pm 0.08$ ). These results indicate that riverbank channelization reduces plant diversity, and ecological restoration can improve riverbank plant diversity. The difference in coverage among the three regions is not significant, while the plant biomass in natural areas ( $171.92 \pm 13.12$ ) is significantly lower than that in restoration areas ( $233.30 \pm 10.22$ ) and channelized areas ( $214.32 \pm 7.63$ ) ( $p < 0.05$ ).



**Fig. 2** Comparison of species richness, Shannon-Wiener diversity index, biomass and coverage of plant communities in different areas (a: restored sites; b: natural sites; c: channelized sites)

## 4. Result and Discussion

### 4.1. Characteristics of Plant Communities in Riparian Zones

There are 138 species of herbaceous plants belonging to 110 genera and 33 families in the riverbank zone of the Chongqing section of the Yangtze River, mainly in the Asteraceae and Poaceae families. This study found that dogtooth root and bullwhip grass are widely distributed in the riparian zone of urban areas and are typical species in the riparian zone of Chongqing. In addition, species such as *Polygonum lapathifolium* and *Alternanthera philoxeroides* with certain water resistance are distributed in the area, while the upper part of the riparian zone is mainly composed of annual herbaceous plants (*Conyza canadensis* and *Bidens Pilosa*). Due to the short duration of flooding, the upper area is less susceptible to flooding stress. The above herbaceous plants mainly germinate and settle rapidly in the riparian zone through seed reproduction to adapt to the unstable habitat of the riparian zone, resulting in high species diversity and a more uniform distribution of individual numbers. In contrast, the lower part of the riparian zone has lower plant diversity and a single composition of plant communities, but relatively higher stability. This is mainly due to the fact that only a few species that are extremely tolerant to flooding can survive and form stable communities in long-term deep water inundation environments (Chen et al., 2015).

## 4.2. The Impact of Riverbank Channelization on Plant Diversity

The richness and diversity index of plant species in channelized areas are lower than those in natural areas, indicating that river channelization has a significant negative impact on plant diversity in riparian zones. Standish et al. (2014) argue that the construction of a large number of water conservancy projects has changed the hydrological conditions of rivers, affecting the hydraulic characteristics of rivers, as well as the sedimentation and transport patterns of plant reproductive bodies, and has a significant impact on the richness and diversity of plant species in riparian zones. There are also significant differences in the composition of plant communities between channelized areas and natural areas. There are fewer plant species and relatively single community types, which is consistent with the research results of Schmitt et al. (2018) on the Weser and Rhine rivers. River channelization leads to homogenization and discontinuity of riverbank morphology, reducing habitat heterogeneity and biodiversity. On the other hand, hardened riverbanks sever the connection between rivers and land, posing significant obstacles for plant reproductive bodies to reach the riverbank and making it difficult for plant reproductive bodies to settle and develop, thereby reducing the species richness of riverbank plants (Richardson et al., 2007). In addition, hardened riverbanks are conducive to the settlement and reproduction of alien species, leading to a decrease in the quality of riverbank habitats and affecting the species and structural stability of riverbank plant communities. Compared with nature, plants such as *Polygonum fugax* and *Leonurus artemisia* are rarely distributed in channelized areas, while species such as *Humulus scandens*, *Bidens pilosa*, and *Daucus carota* with strong adaptability and competitiveness are widely distributed, which is consistent with Paul et al.'s (2013) study. As a dominant species in channelized areas, *Humulus scandens* forms a carpet like covering layer on cement hardened slopes, resulting in higher biomass than natural areas. However, *Humulus scandens* inhibits the growth of other plants, with only sporadic distribution of plants such as *Sinosenicio oldhamianus* and *Youngia japonica*.

## 4.3. The Role of Ecological Restoration on Riparian Plants

The species richness, diversity index, and biomass of the restoration area are higher than those of the natural area. There is no significant difference in plant community composition between the restoration area and the natural area, indicating that ecological restoration can restore the channelized plant community to a near natural state. The ecological restoration work in the riparian zone of Chongqing city has taken measures such as surface soil covering, water resistant plant planting, and terrain shaping, which have enriched the plant community structure of the riparian zone and played a positive role in improving the habitat conditions of the riparian zone, thereby increasing biodiversity. Plant flood tolerant trees and shrubs such as *Salix variegata*, *Taxodium ascendens*, *Sapium sebiferum*, etc. These measures have changed the original substrate of the riparian zone, increased habitat heterogeneity, enriched plant community structure, improved ecosystem stability, and made plant diversity more abundant. Ecological restoration can stabilize the riverbank structure and change the riverbank topography. Schmitt et al. (2018) used soil cover, planting plants such as sedge and reeds, installing willow shrub mattresses, and hardwood structures to restore the riverbank, reducing flood erosion on the riverbank, promoting the growth of the endangered species *Inula Britanica* in the area, and significantly increasing the total number of plant species. Ecological restoration can enhance the hydrological connectivity of riparian zones and increase microclimate gradients and improve habitat heterogeneity by forming diverse habitat interlacing zones. Paul et al. (2013) constructed water pits of different sizes using riprap at the bottom of the Rhone River bank, avoiding extreme drought and providing a space for the survival of halophytes. Planting water resistant plants creates a complex spatial structure of plants in the riparian zone from top to bottom, altering the microclimate environment of the riverbank. In addition, ecological restoration can intercept a large amount of sediment, increase the effectiveness of

nutrients such as N and P, change the temperature and humidity conditions of the riparian substrate, and retain seeds in highland habitats and upstream seeds drifting with floods on the riverbank. Janssen et al. (2019) adopted the measure of plant fence walls in riverbank restoration, which helps to intercept sediment during high flow periods, increase soil nutrient content, and increase the number of retained seeds, providing necessary conditions for plant germination and growth. Therefore, implementing reasonable ecological restoration measures can improve the habitat conditions of the riparian zone, increase habitat heterogeneity, and rebuild the plant community of the riparian zone, thereby increasing the diversity of riparian plants.

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## References

- [1] Ahmad SS, Murtaza R, Shabir R, et al. 2014. Environmental diversification and spatial variations in riparian vegetation: A case study of Korang River, Islamabad. *Pakistan Journal of Botany*, 46: 1203-1210.
- [2] Chen F, Zhang J, Zhang M, et al. 2015. Effect of *Cynodon dactylon* community on the conservation and reinforcement of riparian shallow soil in the Three Gorges Reservoir Area. *Ecological Processes*, 4: 3.
- [3] Colwell RK. 2013. Estimates: Statistical estimation of species richness and shared species from samples [EB/OL]. [2019-05-04]. <http://viceroy.eeb.uconn.edu/EstimateS/>.
- [4] Dingjun Zhang, Jun Li, Liwen Qiu et al. 2023. Influence of Flooding on Plant Survival Rate in the Ecological Restoration of Pianyanzi Riparian zone in the Upstream of Three Gorges[J].*China Resources Comprehensive Utilization*,41(03):168-171+184.
- [5] Janssen P, Cavallé P, Bray F, et al. 2019. Soil bioengineering techniques enhance riparian habitat quality and multi-taxonomic diversity in the foothills of the Alps and Jura Mountains. *Ecological Engineering*, 133: 1-9.
- [6] Jiachen Shena, Ge Qina, Rendong Yu et al.2021. Urbanization has changed the distribution pattern of zooplankton species diversity and the structure of functional groups[J]. *Ecological Indicators*. 120. 106944.
- [7] Paul C, Dommanget F, Daumergue N, et al. 2013. Biodiversity assessment following a naturality gradient of riverbank protection structures in French prealps rivers. *Ecological Engineering*, 53: 23-30.
- [8] Pielech R, Anioł-Kwiatkowska J, Szcześniak E. 2015. Landscape-scale factors driving plant species composition in mountain streamside and spring riparian forests. *Forest Ecology and Management*, 347: 217-227.
- [9] R Development Core Team. 2017. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.
- [10] Richardson D, Holmes P, Esler K, et al. 2007. Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions*, 13: 126-139.
- [11] Schmitt K, Michael Schäffer, Koop J H E, et al. 2018. River bank stabilisation by bioengineering: potentials for ecological diversity. *Journal of Applied Water Engineering and Research*, 6: 262-273.
- [12] Standish RJ, Hobbs RJ, Mayfield MM, et al. 2014. Resilience in ecology: abstraction, distraction, or where the action is?. *Biological Conservation*, 177: 43-51.