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Exploring Innovative Paths for Ecological Scene Exhibitions in Chinese Natural History Museum

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Abstract

Natural ecological scene exhibitions serve as a crucial bridge between natural museums and the public. Their significance extends beyond showcasing species to creating an integrated natural narrative stage that combines science, storytelling, and interactivity. Taking lakes and mountain forest ecosystems in the North China Plain as research samples, this paper analyzes current issues in ecological exhibitions, such as a lack of authenticity, weak local characteristics, and superficial application of technology. Based on this, three innovative directions are proposed: redefining species exhibition logic through ecological relationship visualization to transform isolated species data into dynamic energy flow networks. Enhancing the uniqueness of scenes via local ecological memory to explore regional culture and evolutionary mysteries in North China ecosystems. Expanding narrative dimensions by applying spatiotemporal folding technology to combine virtual and real elements, promoting temporal extension and in-depth interaction in ecological scene presentations. The goal of this research is to provide theoretical foundations and practical guidance for the transformation of ecological scene roles from specimen collections to ecological narrative carriers in natural museums. Through this strategy, it aims to shift science education from mere knowledge transfer to fostering ecological empathy.

Keywords: Natural History Museum; Ecological Scenes; Narrative Exhibitions; Local Ecology; Technology-Enabled.

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1. Introduction: The Dual Identity of Ecological Scenes — Scientific Container and Narrative Medium

When visitors observe grassland creatures displayed in a forest environment at a natural history museum, or see animal specimens as stiff as sculptures, they may wonder, Is this really how nature looks? Such doubts could weaken the effectiveness of science popularization [1]. Ecological exhibitions can be regarded as three-dimensional textbooks for science communication, essentially being selective storytelling about natural environments. Such exhibitions not only require precise species information as a foundation but also need vivid ecological relationships as the essence to allow the public to truly understand that nature is not a pile of isolated species, but an interconnected network of life. The museum experience is a dynamic result of the intersection of three axes: personal context, social interaction, and physical settings. Any ecological scene must simultaneously design the coupling mechanisms of these three axes [2,3].

As a vital link between the public and ecosystems, the natural museum, through its carefully designed ecological scenes, has become an important tool for disseminating ecological science knowledge and plays a significant role in fostering public environmental awareness [5，6]. Currently, ecological exhibitions in natural museums face three challenges: First, a mismatch between scientific accuracy and visual appeal, where some displays prioritize visual effects over the matching of species habitats. Second, a contradiction between local elements and imitation of foreign environments, where blindly copying overseas landscapes leads to incongruous phenomena like "tropical rainforest plants growing in northern forests." Third, a disconnect between static displays and dynamic ecology, making it difficult to reflect the vitality and interconnectedness of ecosystems. Habitat Dioramas in foreign countries offer valuable experiences, These experiences emphasize the completeness of ecosystems. However, due to China unique geographical climate and ecological evolutionary history, we cannot simply replicate these approaches but should establish a scene narrative system that integrates local characteristics.

This study selects lakes and mountain forests in the North China Plain as samples, based on the facts of species combinations, striving to break the limitations of traditional exhibition design and exploring innovative pathways to treat ecological scenes as ecological narrative theaters—making every plant and specimen a storyteller and allowing audiences to experience not only the external forms of species but also understand the meaning of ecology.

2. Current Core Pain Points of Ecological Scene Exhibitions: The Gap from Displaying Species to Telling Ecology

2.1 Logical Confusion in Spatial Narrative

A successful exhibition narrative must have a three-act structure of situation—conflict— resolution so that audiences can experience emotional engagement and meaning construction in the space [McLean,1993]. During the transition from traditional display cabinets to scene layouts in China natural museums, some museums have encountered the problem of spatial stacking: for example, the division of scenes lacks ecological coherence, such as rigidly connecting streams and arid shrub lands. The design of the visitor route does not follow ecological cognitive patterns, making it difficult for audiences to establish a coherent understanding of habitat—species—relationship. The root of this confusion lies in the lack of coordination between physical space and ecological space, like randomly piecing together fragmented forests and wetlands while losing the key to maintaining ecosystem integrity.

2.2 The Dual Distortion Presented by Species

The behavioral distortion in animal specimens and the habitat mismatch in plant arrangements jointly weaken the realism of the scene. The poses of some predator specimens appear stiff, failing to convey the sense of urgency during hunting moments; in some extreme cases, Blackfin barbel samples requiring clean streams are placed in murky water environments, which completely contradicts their ecological habits. In plant ecology, when moisture-loving lotuses appear on dry sunny slopes, or when southern species of plants and animals are found in the forests of North China. This habitat mismatch not only easily misleads our perception but also robs the public of a crucial educational opportunity to understand the symbiotic relationship between species and their environment.

3.2 The Superficiality Trap of Technological Application

The empowerment of technology lies not in creating an extremely immersive experience, but in whether it can enable audiences to feel as if they are part of this ecosystem [7]. Currently, some museums are still in the show-off technology phase in terms of application, merely using VR devices to achieve virtual tours while ignoring in-depth integration with species data in the scene. Sound and light technology merely simulates environmental sounds without establishing interaction with the behavior of organisms. Technology was originally supposed to serve as a translator of ecological relationships, but unfortunately, it is no longer the core element and has become background noise, failing to achieve an organic integration of technology — science — experience.

3. The factual foundation of species combinations: The genetic map of the North China ecosystem

3.1 North China lakes: The water quality code of wetland ecosystems

The species composition in lakes and ponds of the North China Plain is a living sample of the correlation between water quality and life. Reed and cattail, these emergent plants, form a water barrier, not only providing habitats for birds but also acting as ecological engineers for water purification. As natural water quality detectors, submerged plants like Ceratophyllum demersum and Najas marina are extremely sensitive to pollution. Their presence or absence can directly indicate the health of the water body.

In the ecological environment, each species acts as a communicator of eaning, and the goal of design is to help the audience interpret these symbols and reconstruct the informational content of the ecosystem [8]. In animal communities, the stable reproduction of the Baer's Pochard indicates the success of ecological restoration in Hengshui Lake, while the concentrated distribution of the black stork demonstrates the ecological status of watrs in Pingshan County. These animals do not exist independently: otters require clean water environments to catch fish, and their reappearance in Baiyangdian is due to the recovery of fish communities. The larvae of EPT insects (mayflies, stoneflies, caddisflies) can only survive in clear water flows, and their population changes are directly linked to the food supply of birds. This species relationship network reminds us that the display of lakes should emphasize the chain-like interactive effects of water quality-vegetation-animals, rather than simply presenting the physical combination of water, plants, and animals. Ecological landscape design integrates science and art and must adhere to the ecological laws of natural environments [19,20].

3.2 Mountain Forest: The Life Stratification of Vegetation Vertical Belts

The forest species community in North China mountains exhibits clear height distribution characteristics. Lithocarpus liaotungensis forests are dominant communities in mid-low elevation areas. Their layered structure of tree, shrub, and herb layers not only supports feeding for roe deer and wild boars but also meets the habitat needs of chickadees and woodpeckers. On arid sunny slopes, Pinus tabulaeformis forests stubbornly grow, forming a coniferous forest exclusive ecological chain with wildcats and red squirrels. In moist gully mixed forests, which are biodiversity hotspots, under the protection of Juglans mandshurica and Toona sinensis, species like the golden-line side-blotched frog and kingfishers jointly form an ecosystem intertwined with streams and forests.

Notably, these species populations contain unique ecological memory. To awaken our ecological memory of this land, it is necessary to restore the geniusloci jointly constructed by terrain, vegetation, and species [9]. The number of herons has increased from 8 to 3,000, demonstrating the significant changes in the ecological environment of Kuancheng Qianheshan. If these ecological stories are incorporated into mountain exhibitions, static species data can be transformed into vivid ecological narratives.

4. Innovative Design of Ecological Scenes: Constructing Natural Narrative Theaters

4.1 Visual Narrative of Ecological Relationships

Break the traditional species checklist model and reconstruct the scene logic with energy flow as the core. In the North China lake landscape, we can construct an water quality—plants—animals interactive model. Use transparent acrylic panels to display the roots of submerged plants and combine light projection technology to demonstrate the process of root absorption of pollutants. Install a dynamic display next to the specimen of the Baers pochard to show in real time the correlation data between its breeding success and the distribution density of cattails and hornwort, enabling the audience to intuitively understand the causal relationship between plant health and bird habitats. When vision, hearing, and touch all correspond to the same ecological concept, the efficiency of knowledge transfer reaches its peak. At this point, the scene must avoid sensory overload and maintain conceptual unity [10].

In mountain forest scenes, you can incorporate the Food Chain Light and Shadow Theater. For example, using front-projection technology to cast dynamic images of chickadees pecking insects onto the trunks of Quercus liaotung, while pressure-sensitive areas are set on the ground. Once visitors step on these areas, they trigger a chain reaction projection effect of Wild Boar Tilling the Leaf Litter—Startling Insects—Attracting Woodpeckers, making the abstract ecological interaction more vivid and tangible, allowing visitors to better understand and experience it directly.

4.2 Immersive Enhancement of Local Characteristics

Deeply explore the ecological features of North China to create scenes rich in local memory. Local ecological memory is regarded as a form of encoding of local knowledge, and if the museums exhibition lacks this perspective, it may merely become a technical spectacle disconnected from the environment [11]. When selecting plants, priority should be given to dominant native species of North China, such as Quercus liaotung and Pinus tabuliformis, and the introduction of exotic species should be minimized. In the design of animal postures, it should accurately depict typical behaviors of native species, such as roe deer grazing on young oak branches in forest clearings and leopard cats patrolling their territory among rocks, rather than simply using generic models. The narrative of ecological restoration can be integrated into the exhibition: set up a past and present contrast area under the context of Baiyangdian. One side displays the sparse species during the period of ecological degradation, while the other shows the dense reeds and the return of wading birds today. At the same time, infrared camera footage of otter activities is included, making this display a vivid testament to the achievements of ecological protection.

4.3 Deep Interaction Empowered by Technology

To effectively transform ecological knowledge into ecological action, a successful ecological scene requires the audience to experience a complete process: starting from concrete experience, moving to reflective observation, then through conceptual abstraction, and finally engaging in active experimentation in a cycle [12]. Beyond the basic application of virtual tours, it forms a complete closed loop of technology—science—experience. Create an AR Ecological Detective platform where users can see animal information related to the plant after scanning a QR code or identifying a plant. For example, when scanning reeds, the system will display information about the breeding habits of wading birds that nest in reeds. Using lightweight VR devices, people can enter the first-person perspective of the scene species, such as experiencing the daily life of foraging on the water surface to nesting in reed beds from the perspective of a little grebe, or observing the species changes in the same area throughout the four seasons using the temporal-spatial folding function.

Multimedia technology should assist in ecological storytelling: In the scene of a juniper forest, recreate "jays pecking pine nuts — wing vibrations"Sound — seed dropping" sound effect chain; set up a "morning and evening light mode" in the mixed broad leaf forest of gullies. When activated at dawn, add fog effects and bird calls; during dusk, switch to owl calls and falling leaf sounds. Through these changes in natural elements, achieve precise interaction with the behaviors of animals and plants.

5. Practical Implementation: The Three-Dimensional Implementation Path of the North China Ecological Scene Innovation Exhibition

5.1 The Scene Translation Technology of Scientific Data

According to the research of the Japanese Museum Society, the three exhibition models—Fixed, Dynamic, and Ecological—are progressively advancing relationships. The highest-level Ecological Exhibition should focus on the ecological environment, allowing visitors to experience the connections between systems rather than merely acquiring single pieces of information [13]. To transform the species combination data of North China lakes and mountain forests into scene elements, we need to break through the conventional mindset of data listing and establish translation rules between scientific indicators and scene symbols. This means converting specific scientific data indicators into visual or sensory symbols that reflect the characteristics of the environment. For example, the fish diversity in lakes can be represented by dynamic water ripple changes, while the plant species in mountain forests can be converted into color differences and density variations of different tree species. Through this approach, we can not only present the ecological features behind the data more intuitively but also enhance peoples perception and understanding of natural environments. In the North China lake environment, the water quality indicator values of submerged plants can be used to construct a visual hierarchy. For water-quality-sensitive species like large Chara, high-intensity lighting can be used to highlight them. Meanwhile, miniature electronic screens can be installed to display in real time the correlation curves between water quality cleanliness and large Chara growth status. As foundational producers in ecosystems, diatoms and green algae can use transparent acrylic underwater devices combined with projection technology to vividly demonstrate the microscopic process of photosynthesis releasing oxygen, making abstract ecological foundational functions tangible.

In a mountain forest environment, about the community structure data of the Quercus liaotung forest, a vertical stratification narrative can be created: The tree layer emphasizes the status of Quercus liaotung as the dominant species, showcasing its competition and cooperation relationship with associated tree species (such as oak and aspen) through signs hanging on the trunks. In the shrub layer, a scent interaction device is arranged around Vitex and Lespedeza.

Visitors need only press a button to release volatile chemicals from related plants, such as the essential oil of Vitex. At the same time, a screen displays the ecological functions of these scents, such as how they deter pests or attract pollinating insects. In the Carex lancifolia zone of the herbaceous layer, a pressure-sensitive floor is installed, which activates a projection when stepped on, showing the ecological interaction of wild boar overturning the leaf litter layer—Carex seed dispersal. This transforms the vegetation stratification from a static landscape into dynamic ecological activity.

5.2 The Narrative Implantation Strategy for Local Ecological Memory

The unique features of the northern ecosystem are not only reflected in species records but also hidden in the geographical ecological evolution and the history of interaction with human activities. Scene design must deeply explore these ecological memory symbols to make the display not just a copy of nature but become a carrier of culture. According to Clark & Silvers (2016) scene theory, this study redefines the reed marsh as a symbol of North China culture, so that the audience can emotionally identify with the local ecology. Restoration [14]. In the lake scene of Baiyangdian, an interactive display wall named Ecological Restoration Timeline can be set up: on the left, images of species decline during the late 20th century water quality deterioration period are played (e.g., sparse reeds, disappeared waterfowl); on the right, the real restoration of the reed marsh and the bluewinged teal breeding area is displayed. In the middle, a touchable water quality indicator slider connects them. When the audience slides the slider, the plant models in the scene dynamically show effects from withering to flourishing based on changes in water quality data, thus intuitively revealing the causal relationship between ecological restoration and species return.Against the backdrop of the Yan Mountains acting as an ecological barrier, an animal migration narrative can be introduced in the mountain forest setting. This design will establish an infrared camera image projection area in the transition zone between the Pinus tabulaeformis forests and the mixed woodlands of gullies. Here, monitoring clips of the leopard cat and the Chinese goral migrating from deep mountain areas to urban green spaces (such as the Wenyu River Park) will be cyclically displayed. Ground-mounted glowing light strips will be used to simulate their migration paths, with labels such as Habitat Connectivity Improvement Measures (e.g., ecological corridor construction, vegetation restoration projects) to help audiences recognize that forest health is not only related to deep mountains but also affects urban ecosystems.

5.3 Technology-Enabled Immersive Boundary Breaking Scheme

The scene has five-dimensional characteristics of Conventionality — Drama — Metabolism to prevent the surface-leveling [15] of technology applications. In the North China lake landscapes, an AR Water Quality Detective system has been introduced. Users can activate the Ecological Chain Tracking function by scanning plants or animals with a tablet. For example, scanning reeds will display the energy transfer chain of reed → insects → waterfowl, while scanning the Baers pochard will show real-time relationship data of its reproductive rate and water chestnut coverage density. The system also allows audiences to modify virtual nvironmental parameters, such as increasing pollutants, to observe the dynamic responses of species combinations and help understand the fragility of ecological balance.

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For example, scanning reeds will display the energy transfer chain of "reed→ insects→waterfowl", while scanning the Baers pochard will show its real-time relationship data between "reproduction rate and water chestnut coverage density". The system also allows audiences to modify virtual environmental parameters, such as adding pollutants, to observe the dynamic responses of species combinations and help understand the fragility of ecological balance.

6. Discussion: Multidimensional Thinking from Theoretical Innovation to Practical Transformation

The three innovative approaches proposed in this paper—'Ecological Relationship Visualization', 'Local Ecological Memory Implantation' and 'Technology-Enabled Deep Interaction'—not only respond to current issues in natural museum exhibitions but also represent a systematic reconstruction from exhibition philosophy to design methodology. Building on this foundation, this section will further explore the intrinsic logic, practical challenges, and potential future trends of these innovative directions, aiming to provide a deeper dialogue space for research and practice in related fields.

6.1 Ecological Narrative: Paradigm Shift from 'Exhibited Objects' to 'Narrative Fields'

Traditional natural museum exhibitions have often been criticized as 'warehouses of specimens,' with their core logic centered on the classification and display of objects. The 'Natural Narrative Theater' concept advocated in this research essentially treats the exhibition as a dynamic, relationship-driven 'narrative field’. Within this domain,species are no longer isolated exhibits but roles in ecological stories; scenes are not just backdrops but stages for narrative progresses. This transformation reflects a deeper understanding of the museum's educational function—from transmitting knowledge to constructing meaning, from stating facts to evoking empathy. Ecological relationship visualization is not merely a technical tool but a reshaping of cognitive frameworks; it demands curators to adopt systemic ecological thinking and translate complex abstract relationships like energy flow and species interaction into perceivable and participatory exhibition language. However, this also imposes higher requirements on exhibition content planning, spatial design, and technological integration. Balancing the risk of 'narrative overreach' against scientific accuracy remains a key challenge to be continuously addressed in practice.

6.2 Locality as the 'Meaning Anchor' of Ecological Display

In the current era where globalization and ecological crises intertwine, the exploration and representation of local ecological memory hold special cultural and educational value. The 'local characteristics' emphasized in this paper are not merely a pile of regional symbols, but rather an attempt to integrate local ecological knowledge, evolutionary history, and traces of human activity into the exhibition narrative, fostering emotional identification and a sense of place among audiences. This 'localized' strategy helps counter the homogenization tendency of exhibitions and serves as an emotional foundation for cultivating public ecological responsibility. However, the construction of 'locality' also faces numerous challenges: on one hand, the systematic organization and scientific transformation of local ecological knowledge still need strengthening; on the other hand, in the context of rapid urbanization, how to evoke resonance in audiences—especially younger generations—towards the 'disappearing' local ecology requires curators to possess stronger historical awareness and narrative skills. Additionally, local narratives must avoid falling into closed regionalism and should, within the context of global ecological crises, demonstrate the ecological connections between the local and the global.

6.3 Technology Empowerment: Seeking Balance Between 'Immersion' and 'Intervention'

VR, AR, interactive projection, and other digital technologies provide powerful tools for 'spatiotemporal folding' and 'relationship revelation' in ecological scenarios. The 'technology-science-experience' closed loop proposed in this paper aims to emphasize the deeper purpose of technological application—promoting understanding of ecological principles, rather than creating fleeting sensory stimuli. Ideal 'deep interaction' should guide audiences from passive observation to active exploration, even simulating ecological decisions in virtual environments to understand their consequences. However, the 'superficial trap' of technological application remains widespread, often rooted in the disconnect between technology and content design, as well as a one-sided pursuit of 'immersion'. In the future, technological advancements (such as AI, real-time data integration, wearable devices) will enable 'living exhibitions' and personalized narratives, but at the same time, we must be vigilant against the 'mediatization' or even 'substitution' effects of technology on natural experiences. Technology should serve as a bridge to extend perception and enhance understanding, rather than a barrier isolating audiences from real nature.

6.4 Systemic and Sustainable Challenges of Practical Transformation

The '3D implementation pathway' proposed in this article involves scientific data translation, narrative integration, and technical integration, its implementation requiring close collaboration from an interdisciplinary team (ecologists, curators, designers, engineers, etc.), and puts new demands on the museum's funding investment, operational capabilities, and evaluation systems. For example, dynamic updates to exhibitions based on real-time data require a stable field monitoring data stream and corresponding IT infrastructure support. Additionally, the sustainability of innovative scenarios is reflected not only in technical operations but also in the update mechanisms for exhibition content and the long-term effects on audience learning. How to establish an effective audience feedback loop to enable exhibitions to continuously evolve and maintain appeal is a challenge museum must face when transitioning from 'project-based' innovation to a 'systemic' transformation Research topic。

6.5 The Future Role of the Natural Museum as an 'Ecological Dialogue Platform'

Building on the prospects outlined in this article, future natural museums might go beyond the 'educational engine' role and further develop into 'dialogue platforms' and 'practice communities' for public engagement with ecological issues. By connecting exhibitions to field conservation areas, research projects, and public science activities, the museum's walls can become permeable. The empathy and understanding sparked in the museum for audiences can be transformed into sustainable lifestyle actions or attention to ecological protection policies outside the museum.

This means the museum's ecological narratives must not only tell 'nature's stories' but also include 'stories of human-nature interaction,' including conflicts, restoration, and collaboration. Only in this way can museums truly become the 'collective experimental fields' advocated by Latour, where science, culture, and public action intertwine to shape a more ecologically conscious future.

7.Conclusion: From Displaying Nature to Cultivating Empathy

In the ecological exhibition at the Natural History Museum, infrared cameras, visitors, specimens, and curators form a diverse interactive network, with the ultimate goal of conveying the spirit of ecology rather than merely replicating the form of nature [17]. Here, the public can understand in the reed marshes of North China lakes that every plant is a guardian of water quality, and under the oaks of the Yan Mountains, comprehend that every organism is an important node in the ecosystem. From precise scientific data to regional memories, narrative contexts, and in-depth interactions facilitated by technology, the key to innovation always revolves around making ecological relationships visible, perceiving local values, and implementing conservation measures. When audiences shift from mere spectators to active participants who discover through scene interaction that the existence of teal ducks is closely related to wetland health, and are moved by emotional resonance about protecting local ecosystems inspired by stories of native species, the ecological scenes in natural museums successfully evolve from static displays to ecological education engines. This is precisely the scientific communication capability and social influence that top-tier natural museums should possess.

In natural museums, ecological scenes should not merely replicate specimens of nature but should instead become lively mediums for spreading ecological knowledge. When people can understand how a single reed protects a wetland, or how a leopard cat reflects the health of a forest, and when technological power makes ecological relationships no longer abstract concepts but tangible realities, and when native species become narrators of ecological stories around us, at that moment, ecological scenes have transformed from containers of scientific knowledge to arenas for cultivating ecological empathy.

In the future, as in-depth factual research on species combinations deepens and technological advancements continue to progress, ecological exhibitions may evolve into dynamically updated living exhibitions. By connecting field monitoring databases, changes in species distribution can be updated in real time. Adjustments based on audience feedback will enhance the effectiveness of interactive designs, ensuring scientific communication remains aligned with public needs. Therefore, authenticity is not a fixed objectivity but an authorized narrative formed through ongoing discussions between curators and communities, thus making natural museums a lasting bridge for public engagement with nature [18].

In the future, the core competition among natural museums will lie in ecological narrative capabilities. This is also one of the difficult points. Based on precise species information, combined with innovative narrative design and leveraging the power of technology, every visitor can plant the seed of respect for nature and ecological protection in their hearts—this is the ultimate meaning of ecological exhibitions in natural museums.

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