

## Postprint: Variation Characteristics of Biodiversity in Bohai Coastal Wetlands

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### Abstract

The intensification of global climate change and human activity disturbances has caused unprecedented disturbance and destruction to global biodiversity. In recent years, with rapid population and economic growth along China's eastern coast and further increases in resource demand, biodiversity conservation faces enormous challenges, thereby affecting the sustainable development of regional economies and ecological environments. Assessing the spatial patterns and change characteristics of biodiversity in China's coastal wetland ecosystems at the regional scale is of great significance for scientifically understanding and rationally protecting coastal wetland ecosystem biodiversity and for formulating ecological environmental protection decisions. This study takes the biodiversity of Bohai Sea coastal wetland ecosystems as the research object and evaluates the current status and changes of biodiversity in the region through the InVEST model and species richness index. The results indicate that: (1) The coastal wetland ecosystems of the Bohai Sea are primarily dominated by reservoirs and ponds, followed by herbaceous marshes. During 2000-2010, the total area of coastal wetland ecosystems in the Bohai Sea remained almost unchanged, with conversion mainly occurring between herbaceous marshes and reservoirs/ponds. (2) Areas with higher wetland biodiversity are mainly distributed in central Liaodong Bay, southeastern Bohai Bay, and northwestern Laizhou Bay. Due to accelerated urbanization and intensified human activity disturbances, the habitat quality of Bohai Sea coastal wetlands has gradually declined over the past decade, with biodiversity showing a degradation trend. Frequent human activities have exerted tremendous negative impacts on wetland biodiversity in this region, and more nature reserves should be established for protection. (3) Hotspot areas of biodiversity change are mainly distributed in southeastern Bohai Bay and northwestern Laizhou Bay. Coldspot areas are mainly concentrated in the north-central part of Bohai Bay. Within these change hotspot areas in southeastern Bohai Bay and northwestern Laizhou Bay, biodiversity

shows an improving trend, indicating that effective ecosystem conversion and the establishment of wetland reserves can achieve coexistence of development and protection, attaining a win-win effect.

## Full Text

### Preamble

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### Spatial Variation Analysis of Biodiversity in the Bohai Region Coastal Wetland

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## Abstract

Unreasonable use of biological resources by humans and climate change have negatively impacted biodiversity at a global scale. Along China's eastern coast, rapid population growth and associated resource demands in recent years have created enormous challenges for biodiversity protection, with significant consequences for regional economic and ecological sustainability. Coastal wetlands represent among the most important ecosystems due to their exceptionally high biodiversity. Human activities are major contributors to biodiversity loss and degradation of biological community structure, while wetland development and reclamation critically affect species habitat, population distribution, and overall biodiversity. Although many researchers have attributed coastal wetland biodiversity loss to long-term human interference and widespread land-use change, recent studies demonstrate that human activities can also improve biodiversity levels in certain regions.

This study investigates the current status of biodiversity in Bohai coastal wetlands and its response to human activities to better understand these complex dynamics. Using habitat quality index and species richness index as evaluation factors, we calculated a biodiversity index and analyzed hotspots and coldspots of biodiversity change through spatial correlation methods. Our results reveal three key findings: (1) Reservoirs and water pits constitute the dominant ecosystem type in Bohai coastal wetlands, followed by grass swamps. While the total wetland area remained almost unchanged from 2000 to 2010, significant internal conversion occurred between grass swamps and reservoirs. (2) High-biodiversity areas are primarily distributed in central Liaodong Bay, southeast Bohai Bay,

and northwest Laizhou Bay. However, accelerating urbanization and intensifying human interference have caused gradual biodiversity deterioration, threatening regional sustainable development. (3) Biodiversity change hotspots are concentrated in southeast Bohai Bay and northwest Laizhou Bay, while coldspots are found mainly in the north-central Bohai Bay region. Notably, biodiversity in the hotspot areas of southeast Bohai Bay and northwest Laizhou Bay showed improvement trends, indicating that effective ecosystem transformation combined with wetland reserve establishment can achieve a win-win outcome for development and conservation.

**Keywords:** Bohai region coastal wetland; biodiversity; spatial patterns; variation characteristics; InVEST model

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## 1. Study Area

The Bohai coastal wetland extends from Penglai City in Shandong Province in the south to Dalian City in Liaoning Province in the north, passing through the coastal areas of Hebei Province and Tianjin Municipality. Major rivers including the Daling River flow into this region. The area encompasses three primary bays: Liaodong Bay in the north, Bohai Bay in the center, and Laizhou Bay in the south, with Bohai Bay covering the largest proportion. The seafloor topography generally slopes from south to north and from shore to sea. Sediments consist mainly of fine-grained silt and mud.

The region experiences a pronounced continental monsoon climate with significant interannual and intra-annual precipitation variation, increasing from west to east. Annual precipitation ranges from 530-660 mm, and average temperatures range from 12-14°C. Numerous rivers, extensive shallow beaches, and tidal flats create diverse wetland landscapes. The area serves as an important distribution zone for waterfowl in eastern China, characterized by high species richness and frequent occurrence of rare and endangered species. However, groundwater resources are relatively scarce, requiring dependence on surface water for industrial, agricultural, and domestic use, resulting in numerous reservoirs and water pits. Additionally, Bohai Bay and Laizhou Bay are relatively enclosed with weak water exchange capacity and low purification ability, leading to coastal water pollution and frequent red tide disasters.

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## 2. Data Sources and Processing

Ecosystem type maps were derived from Landsat TM and environmental satellite imagery using object-oriented classification techniques [8-10]. Administrative boundary maps, road vector data, nature reserve boundaries, and species richness information served as primary vector datasets. A geographic information system database was constructed through input and aggregation in ArcGIS.

Digital Elevation Model (DEM) data with spatial resolution were obtained from the International Scientific Data Platform. All data were unified to the same projection coordinate system (Albers Conical Equal Area) and spatial resolution (90 m). Detailed data information is presented in .

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### 3. Research Methods

Following the methodology of Xu et al. [11], we selected habitat quality index and species richness index as key evaluation parameters for regional biodiversity characteristics. Using raster cells as statistical units, biodiversity was calculated according to the formula:

$$\mathbf{BI} = \mathbf{SR} + \mathbf{HQ}$$

where BI (Biodiversity Index) is the biodiversity index, SR (Species Richness) is species richness, and HQ (Habitat Quality) is raster habitat quality. Both indices were standardized to a 0-1 range. Indicator species were selected and assigned values based on Li et al. [12] to calculate the indicator species richness index. Habitat quality, representing the capacity of ecosystems to provide conditions suitable for persistent existence of individuals and populations, was calculated using the InVEST biodiversity model. Habitat quality depends on accessibility to human land uses and their intensity, with degradation resulting from increased intensity of nearby land uses [14].

The habitat quality model incorporates: relative impact of each threat, relative sensitivity of each habitat type to each threat, distance between habitat and threat, and protection status mitigating habitat threats. The calculation formula is:

$$\mathbf{HQ} = \mathbf{H} \times (\mathbf{x} + \mathbf{kz})$$

where HQ is the habitat quality of raster x, H is a Boolean map, z is a model coefficient (here valued at 2.5), and k is a half-saturation constant set by users. Threat factors primarily include industry, major roads, and minor roads. Threat intensity values come from the threat source attribute table, threat distances reference relevant literature [16], relative threat weights derive from expert scoring, and habitat sensitivity values reference model recommendations adjusted for study area conditions. Further model parameter details are available in the InVEST model user manual [15].

For hotspot and coldspot analysis of biodiversity change, we employed spatial correlation analysis. Hotspots represent areas with high species aggregation, while coldspots indicate low aggregation. The Getis-Ord  $G^*$  statistic, a local spatial autocorrelation indicator based on distance-weighted matrices, can identify areas of significant species clustering (hotspots) [17]. ArcGIS spatial autocorrelation tools were used to calculate biodiversity change clustering.

#### 4. Wetland Ecosystem Types

Bohai coastal wetlands are primarily distributed around Liaodong Bay, Bohai Bay, and Laizhou Bay, with Bohai Bay comprising the largest proportion. By wetland type, Liaodong Bay features mainly shrub and grass swamps, while Bohai Bay and Laizhou Bay are dominated by reservoirs and water pits. The total wetland ecosystem area remained nearly unchanged between 2000 and 2010, increasing only slightly by 38.93 km<sup>2</sup>. However, internal type conversions were significant, particularly between grass swamps and reservoirs/water pits. During this period, grass swamp area decreased by 540.45 km<sup>2</sup> while reservoir area increased by 485.49 km<sup>2</sup>, representing a 4.69% increase. Grass swamp proportion decreased by 3.93%, while artificial wetland area continued to expand. Rapid coastal urbanization drove intensive aquaculture development, converting natural wetlands (primarily grass swamps) into aquaculture ponds and other high-intensity human-use ecosystems. [Figure 2: see original paper] illustrates the spatial distribution, and details area changes.

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#### 5. Biodiversity Patterns

Spatial variation in geographic location, habitat quality, and species richness produces distinct biodiversity patterns. High biodiversity values are concentrated in central Liaodong Bay and northwest Laizhou Bay, where abundant vegetation provides excellent habitat for flora and fauna. These high-value areas typically correspond to nature reserves or vegetated marsh zones with limited human disturbance due to topographic constraints. Conversely, low biodiversity values occur near Bohai Bay, where Tianjin and Hebei administrative zones feature developed economies, high population density, and intense human interference.

The mean biodiversity index for Bohai coastal wetlands was 0.55 in 2000, decreasing to 0.50 in 2010—an 8.3% decline. All wetland types (shrub swamp, grass swamp, reservoir, river, canal) experienced degradation. The primary driver was rapid urban development around wetlands, with urbanized area increasing by 2,372.93 km<sup>2</sup> (30.96% growth) during 2000–2010. This intensifying human activity destroyed many suitable habitats, creating biodiversity degradation risks. summarizes biodiversity index values.

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#### 6. Drivers of Biodiversity Change

Correlation analysis between biodiversity change and potential influencing factors revealed significant negative correlations with road density ( $r = -0.486$ ,  $p < 0.01$ ), GDP ( $r = -0.856$ ,  $p < 0.01$ ), and population density ( $r = -0.812$ ,  $p < 0.01$ ). As population and economy grew, rising fishery food prices drove frequent conversion of grass swamps to aquaculture ponds or farmland. Real estate

and transportation development, including dense road construction, exerted substantial negative impacts on wetland biodiversity. [Figure 3: see original paper] shows spatial biodiversity patterns, and [Figure 4: see original paper] illustrates correlations with driving factors.

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## 7. Biodiversity Change Hotspots and Coldspots

Hotspot analysis identified areas with Z-values  $> 1.96$  as statistically significant hotspots ( $p < 0.05$ ), while Z-values  $< -1.96$  indicated coldspots. Biodiversity change hotspots concentrated in southeast Bohai Bay and northwest Laizhou Bay, with additional hotspots in central Liaodong Bay coastal wetlands. Coldspots were primarily located in north-central Bohai Bay. The high absolute Z-values reflect intense, concentrated changes with strong spatial clustering. Notably, the presence of national wetland reserves in hotspot areas contributed to biodiversity improvement in southeast Bohai Bay and northwest Laizhou Bay, demonstrating that converting bare soil to reservoirs/water pits and establishing protected areas can effectively enhance habitat quality, achieving coexistence of development and conservation. [Figure 5: see original paper] presents the hotspot/coldspot distribution.

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## 8. Conclusion

Based on Bohai coastal wetland ecosystem types, threat factors, and parameter attributes, this study employed the InVEST biodiversity model combined with species richness to assess biodiversity and identify change hotspots and coldspots. Key findings include:

The total Bohai coastal wetland area remained essentially unchanged, but internal type conversions were dramatic, primarily between grass swamps and reservoirs, representing a continuous decrease in natural wetlands and increase in artificial wetlands. High-biodiversity areas are distributed in central Liaodong Bay, southeast Bohai Bay, and northwest Laizhou Bay, including Linghai City, Kenli County, and Dongying District. Rapid urbanization has reduced suitable habitat area and degraded habitat quality.

Biodiversity change in Bohai coastal wetlands is closely related to human activities, showing significant negative correlations with road density, GDP, and population density. Intensified human activity has caused biodiversity degradation. Hotspot analysis reveals that change hotspots are located in southeast Bohai Bay and northwest Laizhou Bay (including Wudi County, Kenli County, and Dongying District), while coldspots concentrate in north-central Bohai Bay (including Binhai New Area, Fengnan District, and Caofeidian District). Within hotspot areas, biodiversity improvement trends demonstrate that effective ecosystem

transformation and wetland reserve establishment can improve habitat quality and achieve win-win outcomes for development and protection.

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