A Study on Changes in the Landscape Pattern of the Yantai Coastal Wetlands in Laizhou Bay

Fengjie Xu[1], Jianbo Zhang[1], Kun Chen[1], Hongwei Wu[1], Penghui Li[2], Ke Ke[1], Hua Huang[1], Tao Yang[1], Tingjin Lv[1], Yunxing Zhao[1*]
[1]Yantai Institute of Marine Economy, Yantai, China
[2]Laizhou Forest Resource Monitoring and Protection Service Centre, Yantai, China

Abstract: Based on the characteristics of the coastal wetlands in Yantai, Laizhou Bay, and field observations, ENVI software was utilised to conduct landscape classification and area transfer analysis on Landsat remote sensing imagery from 1984, 2005 and 2023. The results indicate that the coastal area of Yantai in Laizhou Bay generally exhibits a trend of mutual conversion between wetlands and non-wetlands, with an increase in constructed wetlands and a decrease in natural wetlands. Notably, the conversion of tidal flats into salt fields, construction land and aquaculture ponds, as well as the conversion of construction land and farmland into wetland vegetation, is particularly evident. Landscape pattern indices were analysed using ArcGIS and Fragstates software on the classified remote sensing imagery. The results indicate that, with the exception of tidal flats and bare land where landscape pattern indices declined, landscape pattern indices for all other landscapes showed an upward trend.

1. Introduction

Coastal wetlands are situated at the interface between the sea and the land which possess distinctive regional characteristics and are considered sensitive areas in terms of global environmental change and ecologically fragile zones. With the rapid growth of the acceleration of industrialisation and urbanisation in coastal regions, the risk of ecosystem decline in coastal wetlands worldwide has intensified. In recent decades, scholars have stepped up their efforts in the conservation and research of coastal wetlands.

Internationally, [1-3] have conducted studies on the landscape evolution and driving mechanisms of coastal wetlands along the south-east coast of England, the north-west coast of Galicia in Spain, and the Atlantic coast of the United States. In China, [4] conducted a quantitative study on the erosion and sedimentation evolution of a typical coastal section on the eastern shore of Laizhou Bay using the sedimentation area method. Ref. [5] analysed the characteristics of landscape pattern changes and their driving forces in the eastern wetlands of the Shandong Peninsula, using remote sensing imagery from 1990, 2000 and 2010 as their baseline data. Laizhou Bay is one of the main wetland distribution areas in China [6]. We utilises ENVI software to classify remote sensing imagery using the Random Forest algorithm. Employing ArcGIS and Fragstates software, and applying the traditional landscape pattern index calculation method to nvestigate the overall and spatial characteristics of the landscape pattern in the coastal wetlands of Laizhou Bay. The study aims to explore the natural and anthropogenic drivers of changes in these coastal wetlands, thereby promoting the high-level conservation of the Yantai coastal wetlands in Laizhou Bay.

2. The construction of the study

2.1 Overview of the Study Area

The study area is situated on the north-western flank of the Jiaodong Anticline within the Shandong Anticline and at the northern end of the Jiaolai Plain; it is predominantly a region of low mountains and hills [7], with only the south-western part comprising low-lying plains. The bay extends from the Jiaolai River estuary (37°8’52”N, 119°35’41”E) at the junction of Yantai and Weifang in the west, to Gao’ao on Qiji Island in Longkou (37°41’10”N, 120°13’10”E) in the east, with a coastline of approximately 170 km. Under the combined influence of rivers and the sea, low-lying, broad alluvial plains, fluvial-maritime plains and marine plains have formed. Coastal wetlands are widely distributed, giving rise to coastal features such as mudflats, sandy beaches, submerged shoals (sandbanks) and estuaries, as well as typical wetlands such as tamarisk thickets and seagrass beds. Referring to the Ramsar Convention on Wetlands and China’s Technical Specifications for Coastal Wetland Ecological Monitoring (HY/T080-2005), considering that the influence range of seawater intrusion in this area is about 6-10 km away from the coastline, and the upstream distance in the estuary and coastal low-lying areas can reach 20 km, it has been determined that the study area for this paper shall extend 20 km inland from the Mean Low Water Spring (MLWS) in Yantai Laizhou Bay (shown in Fig. 1.).

*Corresponding author: zhaoyunxing901x@yt.shandong.cn

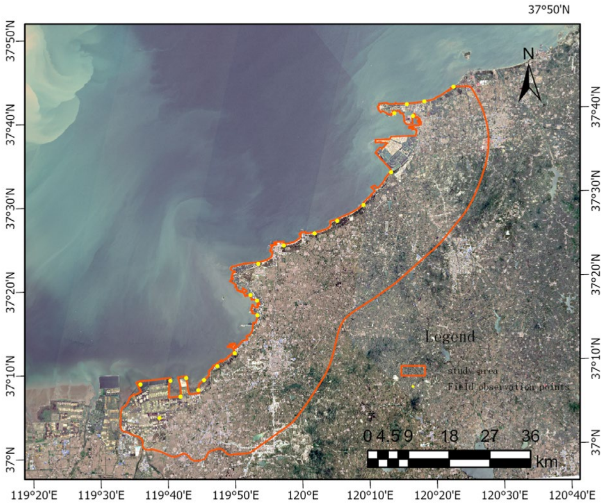


Fig. 1. Research area and observation station in Yantai Laizhou Bay

2.2 Data Sources and Processing

Based on field surveys of the Yantai coastal wetlands in Laizhou Bay conducted between 2017 and 2021, raw multispectral remote sensing imagery from the Geospatial Data Cloud (http://www.gscloud.cn/), specifically Landsat 5 satellite imagery from August 1984 and June 2005, and Landsat 8 satellite imagery from August 2023 was used as the quantitative data source. The selected remote sensing imagery has a row-column designation of 120/34, a spatial resolution of 30 m, and a cloud cover rate of less than 5%, meeting the requirements for visual interpretation. The satellite passes over on days that coincide with or are close to the first or fifteenth day of the lunar month, which theoretically correspond to the spring and neap tides each month. The theoretical lowest tide level was used to minimise coastline boundary errors, and all remote sensing images were selected for the low tide period. The spatial reference system uniformly adopted the WGS 84 coordinate system. *ENVI 5.6* software was utilised to perform masking and enhancement processing on the remote sensing images. Firstly, L2SP-level multispectral remote sensing imagery from the evaluation year was utilised. Spectral enhancement was achieved through linear stretching (2%), and the remote sensing imagery was converted from BSQ format to BIL format to meet classification requirements. Masking techniques were employed to extract the study area from the remote sensing imagery of each time period. The 432 and 543 nm bands of the remote sensing imagery were fused to generate a false-colour composite image. Following preliminary visual interpretation of the spatial attribute data from this composite image, combined with field surveys and high-resolution imagery from Tianditu, classification was performed using the Random Forest algorithm in ENVI. Post-processing of the classified imagery included principal analysis, clustering and manual editing, and the classification results were validated using a confusion matrix. ArcGIS Pro software was utilised to map the distribution of landscape types in the Yantai coastal wetlands of Laizhou Bay from 1984 to 2023. *Fragstate* software was employed to conduct statistical analysis on the classified coastal wetland remote sensing imagery, analysing the characteristics of landscape pattern changes.

2.3 Research Methods

1) Classification System: Based on domestic and international classification systems for coastal wetlands, such as the Ramsar Convention on Wetlands, and the Classification of Wetlands (GB/T 24708-2009), and taking into account the findings from field surveys as well as the visibility and interpretability of visual interpretation, coastal wetlands are classified into two categories (shown in Table 1).

Table 1. Laizhou Bay Yantai coastal landscape marker and its interpretation sign

Primary landscape	Secondary landscape
Natural wetlands	tidal flats (beaches including sandy and muddy shores, riverbanks and lake shores), wetland vegetation (including grasslands, saline-alkali lands, marshes, salt marshes, estuarine wetlands and coastal shelterbelts), water bodies (including rivers, reservoirs, ponds and ancient lagoons), bare ground (including sandy areas, bare land and vacant land)
Constructed wetlands	aquaculture ponds (located on both sides of river basins and near the coast), salt pans (located on both sides of river basins and near the coast)
Non-wetlands	land for development(Including village and town settlements, urban and port developments, and land used for transport), farmland (Located further inland, including paddy fields and dry fields, as well as fallow land and land used for crop rotation), mountain vegetation (Located further inland, including woodland and grassland within mountainous areas)

2) Analysis of Landscape Type Shifts*:* Use a transition matrix to analyse the direction and intensity of transitions between different landscape types. The formula for the landscape type transition matrix is

$$S_{\overline{ij}} = \begin{bmatrix} S_{11} & \cdots & S_{n1} \\ \vdots & \ddots & \vdots \\ S_{1n} & \cdots & S_{nn} \end{bmatrix} \quad (1)$$

where S represents the area; n represents the total number of landscape types; i and j (i, j = 1, 2, …, n) represent the landscape types before and after the transition, respectively; S_{ij} denotes the change in area of the landscape type before and after the transition.

3) Analysis of Landscape Pattern Indices: Using Fragstates software, the study selectes four indicators, which are number of patches (NP), landscape shape index (LSI), largest patch index (LPI) and proportion of landscape area occupied by patches (PLAND), employing traditional landscape index calculation methods to conduct a correlation analysis of the types of coastal wetland landscape patches in the study area to Reflect the landscape characteristics of the coastal area of Yantai in Laizhou Bay[8-9].

 https://doi.org/10.1051/e3sconf/202672801006

3. The Results and Analysis of the Study

3.1 Analysis of Changes in the Landscape Area of the Yantai Coastal Wetlands in Laizhou Bay

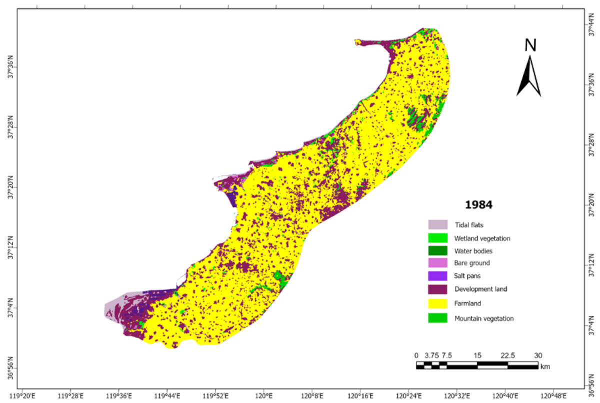
The area of the Laizhou Bay coastal wetlands showed an upward trend between 1984 and 2023, increasing by approximately 60 km² over the 40-year period, (the area of natural wetlands decreased by nearly 25.57 km² and the area of constructed wetlands increased by 85.58 km² overall), with an average annual increase of around 1.50 km². The results are shown in Table 2.

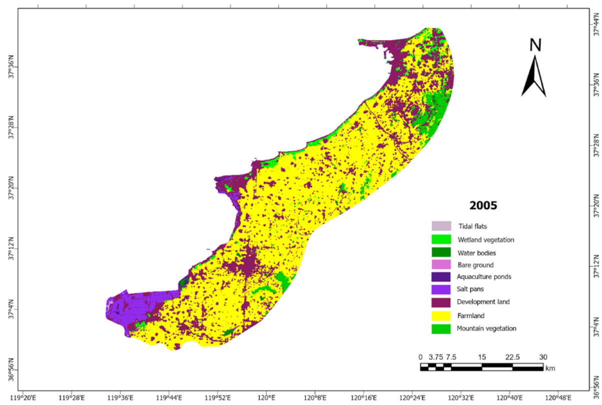
Table 2. Changes in the area of coastal wetlands in Yantai Laizhou Bay from 1984 to 2023

Category	Square (km^2)		
	1984	*2005*	*2023*
Natural wetlands	89.63	65.73	63.44
Constructed wetlands	23.92	83.75	80.25
Non-wetlands	113.55	149.48	143.69

3.2 Classification Results and Accuracy Assessment of Remote Sensing Images

Remote sensing images were classified using the Random Forest algorithm in ENVI software (Fig. 2.), and a transfer matrix for coastal landscape types was established, followed by an analysis of the coastal landscape pattern index. Using ground-truth areas of interest, confusion matrices were constructed for the classified imagery (1984, 2005 and 2023). The overall accuracy of the confusion matrices was 97.5%, 98.6% and 93.4%, with Kappa coefficients of 0.9677, 0.9810 and 0.9243 (for reasons of space, the tables have been omitted but is available on request), meeting the accuracy requirements for medium-resolution remote sensing imagery. However, the sandy coastal beaches, which were already relatively narrow, have become even narrower following decades of development and erosion, resulting in lower interpretation accuracy for coastal tidal flats in 2005 and 2023.





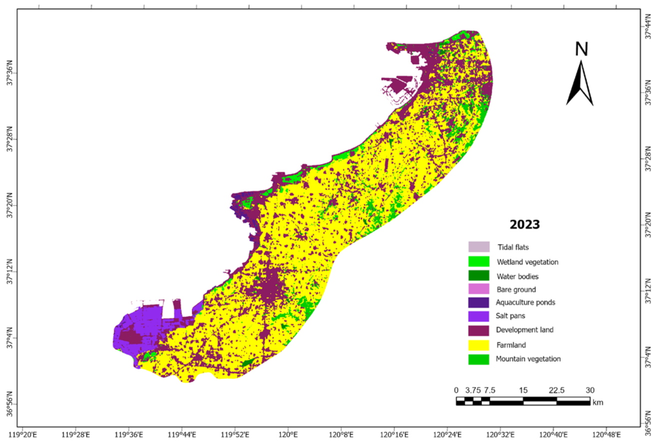


Fig. 2. Research area and observation station in Yantai Laizhou Bay from 1984 to 2023

3.3 Changes in Area Between Landscape Types

As shown in Fig. 2., within the natural coastal wetlands of Laizhou Bay, tidal flats have undergone the most significant conversion into salt pans and construction land; in particular, during the 11-year period from 1984 to 2005, the areas converted amounted to approximately 22.49 km² and 17.18 km² respectively (Tables are omitted). Wetland vegetation is monotypic, consisting mainly of coastal shelterbelts. Due to agricultural development and urban-rural construction, there has been a marked conversion of wetland vegetation into farmland and construction land; however, owing to the emphasis placed in recent decades on afforestation and the establishment and protection of shelterbelts, wetland vegetation has generally shown an upward trend. The conversion of farmland into construction land was the most significant, with a conversion area of 222.14 km², followed by mountain vegetation and wetland vegetation, with conversion areas of 34.91 km² and 22.73 km² respectively. There was an increasing trend in the conversion of farmland into water bodies such as ponds and small reservoirs.

Between 2005 and 2023, compared with the previous period, tidal flats continued to show a trend of conversion into salt pans and construction land, but the rate of conversion slowed significantly, with conversion areas of approximately 1.3 km² and 0.36 km² respectively (Table is omitted). The conversion of wetland vegetation into construction land and farmland showed a marked increase, with conversion areas reaching approximately 12.51 km² and 15.27 km² respectively; simultaneously, there was also a trend towards the conversion of wetland vegetation into salt fields and aquaculture ponds. Farmland saw the greatest conversion to construction land, with a conversion area of approximately 139.84 km². At the same time, the rate of conversion of farmland to mountain vegetation and wetland vegetation accelerated, with conversion areas reaching 37.67 km² and 12.49 km² respectively. Salt fields converted to construction land by approximately 29.11 km². Bare land showed a continuing trend of reduction, primarily converting to farmland.

3.4 Analysis of Landscape Fragmentation

The number of patches (NP) not only reflects landscape heterogeneity but is also correlated with fragmentation. In the study area, whilst the number of tidal flat and bare ground patches showed a declining trend, the number of patches for other coastal wetland landscape types exhibited an increasing trend, reaching its maximum growth rate between 1984 and 2005. The increase in most landscape-level NP values reflects a growing degree of landscape fragmentation, which has significantly compromised the integrity, stability, and connectivity of coastal wetland ecosystems. However, the increase in water-area NP values primarily reflects a rise in the number of small-scale wetlands—such as farm ponds and reservoirs—which play a crucial role in sustaining populations of key farmland species, flood control and water storage, and water abstraction for irrigation. The number of patches for built-up land was significantly higher than that for other landscape types (Table 3), indicating a higher degree of landscape fragmentation in built-up areas. Although salt pans and farmland cover a large area of the study area, the number of patches is not particularly high, suggesting the presence of a large number of dominant patches. This is consistent with the distribution of the LPI shown in Fig. 2. and the actual conditions of the coastal wetlands. The Landscape Shape Index (LSI) serves as a measure of landscape fragmentation. The LSI varied to differing degrees across landscape types within the study area: water bodies, aquaculture ponds, farmland and mountain vegetation showed an increasing trend, whilst wetland vegetation, salt fields and built-up land exhibited minor changes- particularly wetland vegetation, which remained largely unchanged. Conversely, tidal flats and bare land experienced significant declines, with reductions in their LSI reaching as high as 78% and 74%, respectively. This indicates that the intensity of human activities has increased, which has exacerbated the fragmentation of coastal wetland landscapes, resulting in increased spatial and temporal heterogeneity in the study area. The Largest Patch Index (LPI) provides a simple measure of landscape dominance; the LPI for farmland decreased from approximately 68% in 1985 to 52% in 2023, indicating a reduced influence of farmland on the composition of the Yantai coastal wetlands in Laizhou Bay. The increase in the LPI for construction land was particularly pronounced, rising from 2.63 in 1985 to 8.99 in 2023, indicating a trend towards the centralisation of urban construction land. This aligns with the results of the Landscape Shape Index shown in Figure 2. The proportion of landscape area occupied by construction land patches (PLAND) also increased from 22% in 1985 to approximately 30% in 2023. In fact, The fragmentation of coastal wetland landscapes has complex and profound impacts on coastal ecosystems. Take Jiaozhou Bay, for example, an important wetland distribution area in northern China. Over the past three decades, the area of natural wetland types-excluding river and estuarine wetlands-in Jiaozhou Bay's coastal wetlands has been shrinking. The degree of soil salinization and landscape fragmentation has worsened, leading to a decline in biodiversity in the bay's coastal wetlands, reduced environmental purification capacity, increased pollution, the degradation and succession of wetland vegetation, the decline of fishery resources, and a decrease in the value of ecosystem services. These environmental effects hinder the healthy and sustainable economic and social development of the region.

Table 3. Changes in the area of coastal wetlands in Yantai Laizhou Bay from 1984 to 2023 (2005 is omitted)

Category	1984				2023			
	NP	*LSI*	*LPI*	*PLAND*	*NP*	*LSI*	*LPI*	*PLAND*
Tidal flats	168	15.52	1.22	2.18	12	3.27	0	0.01
Wetland vegetation	439	22.47	0.06	1.63	506	23.56	0.26	2.37
Water bodies	17	4.75	0.01	0.03	82	8.87	0.12	0.65
Bare ground	246	16.70	0.05	0.58	19	4.33	0	0.02
Aquaculture ponds	-	-	-	-	251	15.87	0.11	0.82
Salt pans	87	9.40	0.37	1.18	90	7.88	3.53	4.39
Development land	1718	50.18	2.63	22.37	1681	49.15	8.99	30.31
Farmland	223	25.78	68.62	69.35	459	34.77	52.17	56.63
Mountain vegetation	280	16.77	0.32	1.91	1202	34.61	0.47	4.81

3.5 Analysis of the Causes of Changes in Landscape Pattern

The changes in the landscape pattern of the study area are the result of combined influences from the natural environment and human activities. The following sections analyse some typical areas of change within the Yantai coastal wetlands of Laizhou Bay.

On the southern shore of Laizhou Bay, at the Jiaolai River estuary, tidal flats and bare land are generally in decline due to river-borne sediment transport and the action of coastal currents carrying sediment. The southern shore of Laizhou Bay is predominantly characterised by muddy coastlines, and storm surges also cause a degree of erosion to tidal flats and embankments. Since the early 1980s, influenced by construction activities such as salt fields, aquaculture farms, ports, power stations and fishing piers, as well as river sedimentation and climate change, the tidal flat wetlands in the study area have shown a trend of shrinkage and degradation. Since 1985, marine aquaculture ponds have gradually emerged, distributed in a strip-like pattern between the backshore of the supratidal zone and the shelterbelt, becoming the primary form of artificial wetland occupying the foreshore. In 1991, the Shandong Provincial Government proposed the development of 'Maritime Shandong', and the 'cultivating the sea and raising fish' strategy was successively implemented along the southern shore of Laizhou Bay, leading to rapid development of tidal flat aquaculture. Between 1984 and 2005, the primary area of vegetation conversion in tidal flats and wetlands was the Tushan waters of Laizhou Bay, with land being converted mainly into salt fields and construction sites, covering areas of 22.49 km² and 17.18 km² respectively. In the early 1980s, China implemented the rural 'Household Contract Responsibility System', which significantly boosted farmers' enthusiasm for production. However, due to a lack of effective supervision, some wetland vegetation was cleared for conversion into farmland, with the converted area reaching 12.34 km². At the same time, as greater emphasis has been placed on the development of agricultural water conservancy infrastructure, there has been a clear trend toward the conversion of some farmland and construction land into water bodies such as reservoirs and ponds; however, the pace of this conversion has slowed since 2005. Between 1984 and 2005, approximately 23 km², 38 km² and 2.5 km² of tidal flats, construction land and farmland, respectively, were converted into constructed wetlands. As shown in Fig. 2., prior to 1984, the region was characterised primarily by tidal flats, with the exception of a small area of salt pans. By 2005, this area had been rezoned as salt pans, and by 2023, with the exception of a small area of bare land, almost all land had been put to use.

The area of aquaculture ponds has increased most significantly in the constructed wetlands on the eastern shore of Laizhou Bay, and the primary reason for the rapid growth in the overall area of these ponds is the extensive conversion of intertidal mudflats and Salt fields into aquaculture ponds. In addition, the combined effects of precipitation and human activities, as well as the implementation of wetland conservation policies in recent years, have all contributed to changes in the area of coastal waters and wetland vegetation along the Yantai coastline of Laizhou Bay[10]. Yantai City boasts extensive coastal tidal flats and extremely abundant salt resources. In particular, Tushan Town in Laizhou contains 485 million cubic meters of high-concentration brine underground, making it ideal for the production of raw salt. Consequently, since the 1970s, salt production has expanded rapidly, and salt fields have developed at a rapid pace.

The primary natural driver of changes in the coastal wetland landscape pattern along the Yantai section of the southern shore of Laizhou Bay is seawater intrusion [11]. Under its influence, the landscape types along the southern shore, moving from sea to land, generally follow a sequence of *tidal flats-aquaculture ponds-salt fields-wetland vegetation-developed land-farmland*. Furthermore, seawater intrusion has a significant impact on industrial and agricultural production, the ecological environment, and vegetation succession. Land reclamation and enclosed-sea aquaculture are the primary anthropogenic drivers of changes in the coastal landscape pattern along the eastern shore of Laizhou Bay. Enclosed-sea aquaculture is mainly concentrated along the northern coast of Laizhou City, evolving from the bay scallop aquaculture of 1993 to the 'greenhouse & deep-well seawater' industrialised aquaculture and pond aquaculture models adopted after 2006. The aquaculture industry utilises large areas of supratidal land; whilst there are also industrialised aquaculture farms in the supratidal zones of Zhaoyuan and Longkou, these are small in scale and most are currently inactive. Land reclamation has primarily mainly occurs near Longkou Bay, particularly since 2005, with the scale of land reclamation activities-represented by salt fields and marine pastures-continuing to expand. Furthermore, in 2010, the state approved the regional sea use plan for the construction of the Longkou artificial island group project, which has a great role in promoting the overall planning of land and sea and intensive sea use.

In 2023, the maximum patch index for land designated for construction reached 8.99%, indicating a concentration effect of human activities. The increase in landscape indices between 1984 and 2005 indicates that landscape fragmentation in the Laizhou Bay coastal wetlands of Yantai has intensified, primarily due to urban development, the expansion of salt pans and aquaculture ponds, which have disrupted the integrity of landscape patches. Since 2005, the increase rate of various landscape indices showed a slight downward trend, which may be related to the stability of industrial development, the construction of industrial intensive sea areas, and the balance of ports and urban settlements.

4. Conclusions

As of 2023, the total area of the Yantai Coastal Wetlands in Laizhou Bay, was approximately 143.7 km², of which natural coastal wetlands covered about 63.4 km² and artificial coastal wetlands about 80.3 km². In recent years, the overall trend in the coastal wetland landscape has been a decline in natural coastal wetlands and an increase in artificial coastal wetlands. Wetland vegetation has shown a trend of increasing year by year due to the establishment of shelterbelts. The natural drivers of landscape pattern changes are primarily estuarine sedimentation, seawater intrusion and climate change; the anthropogenic drivers are mainly land reclamation for aquaculture, salt field development, urbanisation and the planned development of intensive marine use zones. Between 1984 and 2005, landscape fragmentation in the Yantai coastal wetlands of Laizhou Bay intensified. This increase in fragmentation was primarily due to urban development, port and wharf construction, and the expansion of aquaculture and salt production, which disrupted the integrity of landscape patches. After 2005, the trend of fragmentation slowed somewhat due to the agglomeration effects of population and construction land.

Acknowledgment

This work was supported by the “Conservation of Tamarix wetlands and ecological restoration techniques for saline-alkali land along the Yantai coastline of Laizhou Bay” (2024YD090).

References

1. A. J. Long, and M. P. Waller, P. Stupples, “Driving mechanisms of coastal change: Peat compaction and the destruction of late Holocene coastal wetlands,” Marine Geology, vol.225, pp.63-84, 2006, doi:10.1016/j.margeo.2005.09.004
2. R. Bao, A. Alonso, C. Delgado, and J. L. Pagés, “Identification of the main driving mechanisms in the evolution of a small coastal wetland (Traba, Galicia. NW Spain) since its origin 5700 cal yr BP”, Palaeogeography, Palaeoclimatology, Palaeoecology, vol.247, pp.296-312, 2007, doi:10.1016/j.palaeo.2006.10.019
3. M. D. Koneff, and J. A. Royle, “Modeling wetland change along the United States Atlantic Coast”, Ecological Modelling, vol.177, pp.41-59, 2004, doi:10.1016/j.ecolmodel.2003.12.051
4. F. Yi., X.. Li, C. Zhan, et al.,“Quantitative Study on the Erosion and Deposition Evolution of a Typical Coastal Section on the Eastern Shore of Laizhou Bay Based on the Erosion-Deposition Area Method”, Bulletin of Oceanography and Limnology, vol.3, pp.43-51, 2019, doi:10.13984/j.cnki.cn37-1141.2019.03.006.
5. Y. Zeng, G. Li, Q. Chen, et al., “Analysis of Landscape Pattern Changes and Driving Forces in Wetlands of the Eastern Shandong Peninsula”, People’s Yellow River, vol.37, pp.78-82, 2015, doi:10.3969/j.issn.1000-1379.2015.08.020.
6. Z. Ren, J. Yu, Q. Wang, et al., “Evolution of the southern coastline and subsea topography of Laizhou Bay since 1958”, Frontiers of Marine Geology, vol.39, pp.1-12, 2023, doi:10.16028/j.1009-2722.2022.207.
7. J. Huang, W. Zheng, N. Wan, et al., “A Study on the Characteristics of Landscape Pattern Changes in the Coastal Wetlands of Laizhou Bay over the Past 30 Years”, Marine Science, vol.45, pp.76-90, 2021, doi: 10.11759/hykx20191003001.
8. B. Fu, *Principles and Applications of Landscape Ecology (Second Edition)*, Beijing: Science Press, 2011.
9. W. Chen, D. Xiao, X. Li, “Classification, application, and creation of landscape indices”, Chinese Journal of Applied Ecology, vol.13, pp.121-125, 2002, doi:10.19807/j.cnki.DXS.2025-04-018.
10. H. Deng, A. Li, H. Liu, et al., “Impacts of Climate Fluctuations on Water Resources and Extremes in the Laizhou Bay Area”, Scientia Geographica Sinica, vol.20, pp.56-60, 2000, doi: 10.3969/j.issn.1000-0690.2000.01.010.
11. Z. Zhang, L. Wang, “Study on the driving mechanism of land use/cover change in the saltwater intrusion area on the southern shore of Laizhou Bay”, Scientia Geographica Sinica, vol.27, pp.40-44, 2007, dio: 10.3969/j.issn.1000-0690.2007.01.006.