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Development of a Spatial-temporal Distribution Dataset of the Tidal Creek Morphological Characteristics in the Yellow River Delta (1998–2018)

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Abstract: A tidal creek is the main channel of interaction between the land and sea ecosystems, and it is highly spatiotemporally dynamic. The spatial-temporal distributions of tidal creeks have obvious spatial-temporal heterogeneity. The results of this study have important theoretical significance and scientific value for rationally constructing coastal engineering facilities and protecting tidal flat resources. Based on Landsat thematic mapper/operational land imager (TM/ OLI) satellite data for 20 scenes from 1998 to 2018 (cloud cover <10%), we extracted tidal creeks using an accurate algorithm for tidal creek network extraction under a heterogeneous background and classified the tidal creeks using the fast automatic classification algorithm. After classifying the tidal creeks, the geographic information system (GIS) spatial analysis function was used. A temporal and spatial distribution dataset of the tidal creek morphological characteristics from 1998 to 2018 was generated by extracting the morphological parameters of the tidal creeks in the study area during the last 5 years. The dataset includes the following data for the Yellow River Delta for 1998, 2004, 2008, 2013, and 2018: (1) the distribution of the tidal creeks; (2) the maximum distribution range of the tidal flat; (3) the kernel density distribution of the tidal creek density; (4) the kernel density distribution of the bifurcation ratio of the tidal creeks; and (5) the non-channel path length distribution. The spatial resolution of the raster data is 30 m. The dataset is archived in .shp and .tif formats, and the projection coordinate system is WGS_1984_UTM_Zone_50N. It contains 120 data files, and the data size is 81.4 MB (14.8 MB is compressed into one file).

Keywords: tidal creek network; morphological characteristic parameter; Yellow River Delta; long time series

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[2] Mou, K. N., Gong, Z. N., Qiu, H. C. Spatial-temporal dataset of tidal creek morphological characteristics in Yellow River Delta (1998–2018) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2022.01.09.V1. https://cstr.escience.org.cn/CSTR:20146.11.2022.01.09.V1.

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2022.01.09.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2022.01.09.V1.

1 Introduction

As a typical geomorphic unit of a tidal flat, a tidal creek is a tidal channel developed in the intertidal zone and formed by marine dynamics. Since the tidal flat is an important channel for material, energy, and information exchange with the outside world, the tidal creek, which depends on the distribution of the tide and sediment supply, plays an important role, is the main driving force in shaping the terrain of the tidal flat, and is an important driving force of the spatial distribution characteristics of the salt marsh vegetation, which directly affects the changes in the coastal wetland ecological environment.

Under the comprehensive influence of natural and human activities, the morphological characteristics of tidal creeks are complex and variable, with high spatial-temporal heterogeneity. Since the diversion of the Yellow River in 1996, the large number of coastal projects and the invasion of *Spartina alterniflora* in the study area have broken the original balance and have seriously affected the habitat function of the tidal creeks, which may eventually lead to the loss of salt marsh habitats and increase the risk of flooding in this region. Therefore, studying the spatial-temporal distributions of the tidal creek morphological characteristics in the Yellow River Delta using a long-time series of data to further understand the evolution of the morphological characteristics of the tidal creek system under the influences of natural and human activities provides key information for actively managing the development of tidal flat resources, invasive species control, and coastal engineering protection. Owing to the limitations of the complex underlying surface of the Yellow River Delta wetland and the frequent morphological changes of the tidal creeks, the traditional field measurement methods cannot be effectively applied. Therefore, compared with point-scale field measurements, remote sensing technology has the advantages of a large coverage, short revisit period, and low cost, and it can solve the problem of the difficult characterization of the morphological characteristics of the tidal creek network caused by the complex geographical environment and the complex structure of the network in the coastal zone.

In this study, the Yellow River Delta was taken as the research area. Through in-depth mining of 20 Landsat thematic mapper/operational land imager (TM/OLI) remote sensing datasets, a spatial distribution dataset of the tidal creek morphological characteristics from 1998 to 2018 was obtained.

2 Metadata of the Dataset

The metadata of the Spatial-temporal dataset of tidal creek morphological characteristics in Yellow River Delta (1998–2018)[1] are presented in Table 1.

3 Methods

In this study, 20 Landsat satellite datasets with good quality (cloud cover <10%) from 1998 to 2018 were selected. Specifically, 12 landsat-5 TM images, 8 LANDsat-8 OLI images, 1 SPOT-6 image, and 1 GF-1 panchromatic and multispectral (PMS) images were selected. The level-1 products of the Landsat series satellite data were obtained from the United States

Geological Survey Remote Sensing Image database[1], and the Gaofen series satellite datawere obtained from the China Resources Satellite Center[2]. Radiometric calibration, atmospheric correction, and geometric correction were conducted to preprocess the image. Using the Google Earth Engine platform and background homogenization and linear feature enhancement, a tidal creek automatic extraction algorithm was used to extract the tidal creeks and obtain the complete tidal creek data after manual supplementation[3]. A fast automatic classification algorithm was used to classify the tidal creeks[4]. The maximum distribution range of the tidal flat in the study area was obtained by stacking the tidal flat area exposed at high and low tides in the same year.

Table 1 Metadata summary of the Spatial-temporal dataset of tidal creek morphological characteristics in Yellow River Delta (1998–2018)

Items	Description
Dataset full name	Spatial-temporal dataset of tidal creek morphological characteristics in Yellow River Delta (1998–2018)
Dataset short name	TidalCreekYRD_1998–2018
Authors	Mou, K. N., College of Resource Environment and Tourism, Capital Normal University, moukuinan@163.com Gong, Z. N., College of Resource Environment and Tourism, Capital Normal University, gongzhn@cnu.edu.cn Qiu, H. C., College of Resource Environment and Tourism, Capital Normal University, qiu_huachang@163.com
Geographical region	Estuarine wetlands at the mouth of the Yellow River Delta
Year	1998–2018
Temporal resolution	year
Spatial resolution	30 m
Data format	.tif, .shp
Data size	81.4 MB (Compress to a file,14.8 MB)
Data files	Tidal creek distribution data, tidal flat maximum distribution range data, tidal creek density kernel density distribution data, tidal creek branching point kernel density distribution data, and tidal creek non-channel path length distribution data for the Yellow River Delta from 1998 to 2018
Foundations	Ministry of Science and Technology of P. R. China (2017YFC0505903); National Natural Science Foundation of China (41971381)
Data computing environment	ArcGIS, ENVI
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[2]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

The tidal creek density (D) is defined as the total length of tidal creeks per unit area of tidal flat[5]:

$$D = \Sigma L / A \tag{1}$$

1 https://earthexplorer.usgs.gov/.

2 http://www.sasclouds.com/chinese/home.

where ΣL is the total length of tidal creeks in the tidal flat, and A is the area of the tidal flat.

The bifurcation rate (R)[6] is usually defined as the number of intersecting points of tidal gullies per unit area on the tidal flat[5]:

$$R = \Sigma N / A \tag{2}$$

where ΣN is the number of tidal creek intersection points on the tidal flat, and A is area of the tidal flat.

Kernel density analysis of the tidal creek density and tidal creek bifurcation ratio was conducted to explore the distributions of the tidal creek morphological characteristics.

The non-channel path length is defined as the minimum slope distance from all points in the catchment area to the tidal creek system[7]. In this study, the method of demarcating the catchment was combined with Chirol's method of demarcating the catchment boundary, that is, the shoreward side is the boundary of the reclamation area, and the seaward side is the line of the terminal apex of the tidal creek. In the middle and upper sections of the adjacent tidal creek, it is determined by the isometric distance of the adjacent tidal basin. To quantitatively describe the non-channel path length of the tidal creek catchment, the overmarsh path length is often used to evaluate its drainage efficiency[5,8].

4 Data Results and Validation

4.1 Dataset Composition

The dataset created in this study consists of the following data: (1) the distribution of the tidal creeks in the Yellow River Delta from 1998 to 2018; (2) the maximum distribution of the tidal flat in the Yellow River Delta from 1998 to 2018; (3) the kernel density distribution of the tidal creek density in the Yellow River Delta from 1998 to 2018; (4) the kernel density distribution of the bifurcation ratio of the tidal creeks in the Yellow River Delta from 1998 to 2018; and (5) the non-channel path length distribution in the Yellow River Delta from 1998 to 2018.

4.2 Data Results

Using the above described equations, 20 Landsat TM/OLI satellite images were used to obtain a dataset of the distributions of the tidal creek morphological characteristics in the Yellow River Delta from 1998 to 2018. The spatial resolution of the dataset was 30 m, and the total size was 81.4 MB.

Figure 1 shows the tidal creek core density map and the statistical map of the tidal creek density by region in the study area. The tidal creek density in the study area exhibited a gradual increasing trend, but the rate of increase gradually slowed down. In Area Ⅰ, the tidal creek density decreased from 0.92 km/km^2 in 1998 to 0.56 km/km^2 in 2004 after the diversion of the Yellow River, and then, it remained at 0.88–0.93 km/km^2 after 2008. The tidal creek density in Area Ⅱ decreased from 0.69 km/km^2 in 1998 to 0.56 km/km^2 in 2004 and then increased to 0.80 km/km^2 in 2008. The rapid expansion period of *Spartina alterniflora* occurred from 2008 to 2013. The tidal creek density increased rapidly from 0.80 km/km^2 to 1.17 km/km^2 (46.25%). From 2013 to 2018, the distribution of *Spartina alterniflora* slowly expanded, and the tidal creek density increased to 1.18 km/km (only 0.85%). The tidal creek density in Area Ⅲ increased each year, from 0.94 km/km^2 in 1998 to 1.42 km/km^2 in 2008. After the completion of the reclamation project, i.e., after 2008, the tidal creek density was in a relatively stable stage, remaining at 1.50–1.65 km/km^2 from 2008 to 2018.

Figure 2 shows a kernel density diagram of the tidal creek branching points and a statistical diagram of the tidal creek bifurcation ratio in the study area. In Area Ⅰ, owing to the

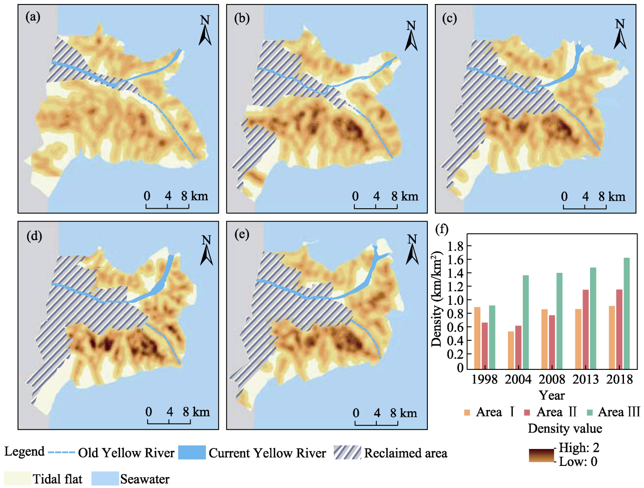

Figure 1 Kernel density of tidal creek in the Yellow River Delta National Nature Reserve: (a) 1998, (b) 2004, (c) 2008, (d) 2013, (e) 2018, and (f) statistics of tidal creek density by area

influence of the diversion of the Yellow River, the bifurcation ratio of the tidal creeks decreased from 0.32 pieces/km^2 in 1998 to 0.17 pieces/km^2 in 2004, and it basically remained stable at about 0.3 pieces/km^2 after 2008. The bifurcation ratio of the tidal creeks in Area Ⅱ decreased from 0.15 pieces/km^2 in 1998 to 0.13 pieces/km^2 in 2004. After 2004, with the continuous development and evolution of the tidal creek system, the bifurcation ratio of the tidal creeks gradually increased. The abundance of *Spartina alterniflora* in Area Ⅱ promoted the development of tidal creek branching to a certain extent[9]. From 2008 to 2013, rapid expansion of *Spartina alterniflora* occurred, and the percentage of braided streams increased the most, from 0.32 pieces/km^2 to 0.61 pieces/km^2 (90.63%). The rapid development of the tidal creeks in Area Ⅲ and the wetland restoration increased the bifurcation ratio of the tidal creek from 0.36 pieces/km^2 in 1998 to 1.09 pieces/km^2 in 2008. After the wetland restoration, the bifurcation ratio of the tidal creeks gradually increased and reached a stable state.

Figure 3 shows the distribution of the average recirculation length of the main tidal creeks in the study area and a statistical diagram of the average recirculation length of the main tidal creeks in the different areas. In Area I, the average length of the tidal creek system increased

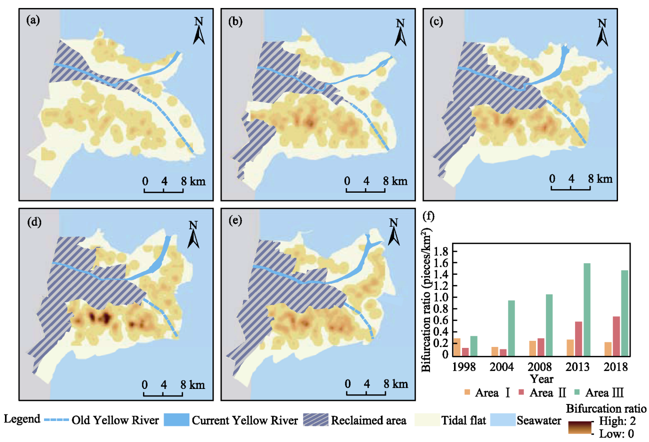

Figure 2 Distribution of tidal creek branch points in the Yellow River Delta National Nature Reserve: (a) 1998, (b) 2004, (c) 2008, (d) 2013, (e) 2018, and (f) statistics of tidal creek bifurcation ratio by area

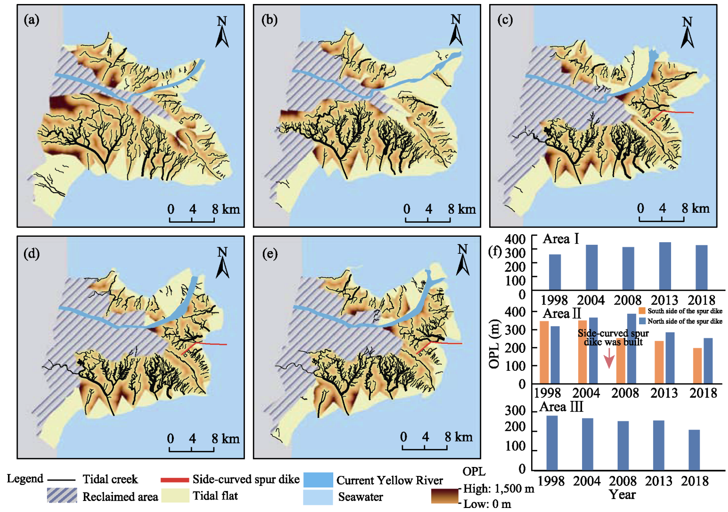

Figure 3 Overmarsh path length of main tidal creek systems in the Yellow River Delta National Nature Reserve: (a) 1998, (b) 2004, (c) 2008, (d) 2013, (e) 2018, and (f) statistical chart showing overmarsh path length (OPL) of the main tidal creek networks annually

from 259.9 m in 1998 to 328.4 m in 2004, and the drainage efficiency decreased. After the water diversion and sediment regulation experiment, the tidal creeks developed rapidly, and the average length of the tidal creeks returning to the channel decreased to 312.1 m in 2008. After 2008, owing to sedimentation in the new estuary, the area of tidal flat increased, and the average length of the tidal channel system increased to 347.1 m. After 2013, with the expansion of *Spartina alterniflora*, the average return length of the tidal creek system decreased slightly to 326.4 m.

In Area Ⅱ, a side bend groin was built in 2006, which resulted in a large difference in the average lengths of the tidal creeks to the north and south of the groin[9]. After the construction of the side bend groin in 2006, the average length of the tidal creek system to the north of the groin increased from 366.3 m in 2004 to 388.1 m in 2008. However, owing to the rapid expansion of *Spartina alterniflora*, the average length of the tidal creek system returned to 283.9 m in 2013. With the continuous development of the tidal creek system and the continuous expansion of *Spartina alterniflora*, the average length of the tidal creek system returned to 251.7 m in 2018. The average length of the tidal creek system to the south of the groin decreased from 349.8 m in 2004 to 252.1 m in 2008. Since the tidal flat to the south of the groin was eroded by seawater, the area of the tidal flat gradually decreased, and the average length of the tidal creek system in this area also gradually decreased, from 252.1 m in 2008 to 236.7 m in 2013. It was eventually reduced to 197.5 m in 2018.

In Area Ⅲ, after the diversion of the Yellow River, the original estuary of the Yellow River transitioned from siltation to erosion, and the wetland restoration project reclaimed the beach surface, which was located far away from the tidal creeks. Therefore, the average length of the tidal creek system decreased from 281.3 m in 1998 to 208.9 m in 2018.

4.3 Data Validation

In the study area, 500 random points were randomly generated, and the land surface types of the random points were visually interpreted using Google Earth and SPOT-6 and GF-1 PMS high spatial resolution satellite images acquired in 1998, 2004, 2008, 2013, and 2018. The overall extraction accuracy of the tidal creeks was 85%. Due to the low resolution of the Landsat images, the accurate algorithm for the extraction of the tidal creek network under a heterogeneous background can extract a limited number of tidal creeks, so the complete tidal creek data can be obtained after manual supplementation. In the study area, the accuracy rate of the automatic tidal creek classification nodes was 92%, and the misclassified nodes had no influence on the results of the tidal creek classification. No errors were identified in the results of the tidal creek classification through visual inspection, and the accuracy rate was 100%.

5 Discussion and Conclusion

In this study, 20 Landsat TM/OLI satellite images were used to obtain a 30 m resolution dataset of the distribution of the tidal creek morphological characteristics in the Yellow River Delta from 1998 to 2018. The results show that the morphological characteristics of tidal creeks, including the density, bifurcation ratio, and non-channel path length, exhibited significant spatial-temporal heterogeneity during the different periods and in the different heterogeneous environments. The morphological characteristics of the tidal creeks in the study area were mostly in a moderately stable to stable state, and the growth rate began to slow down. The diversion of the Yellow River resulted in an increase in the average return channel length, and the construction of the side bend groin caused a great difference in the average return channel lengths to the north and south of the groin. In addition, the rapid expansion of *Spartina alterniflora* caused a decrease in the average return channel length. By analyzing the spatial-temporal distribution characteristics of the tidal creeks in the Yellow River Delta during 1998–2018, we provided a scientific basis for understanding the evolution mechanism of the tidal creeks in the Yellow River Delta and for the management of the Yellow River Delta. The results of this study also provide data support for the national major needs of ecological protection and high-quality development of the Yellow River Basin.

Author Contributions

Gong, Z. N. created the general design for the development of the dataset, conducted the final review of the dataset, and provided suggestions for revising the paper; Qiu, H. C. participated in data collection; and Mou, K. N. conducted the data processing and wrote the data papers.

Conflicts of Interest

The authors declare no conflicts of interest.

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