

The influence of water-sediment regulation on macrobenthic community structures in the Huanghe River (Yellow River) Estuary during 2012–2016

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Abstract

To determine if water-sediment regulation has affected macrobenthic community structure in the Huanghe River Estuary, China, macrobenthic samples were collected following regulation events from 2012 to 2016. We identify seven phyla and 138 macrobenthic species from within samples throughout the survey area, over time. Species richness and abundance in 2012 were significantly higher than in 2016. Biomass did not differ significantly during 2012–2016. Dominant species were mostly small polychaetes, with mollusks, arthropods, and echinoderms all being relatively rare. In 2016, dominant species were small polychaetes. MDS reveals macrobenthic communities at all surveyed distances from the estuary to have become the same community structure over time. Shannon-Wiener diversity and Margalef richness indexes trended down over time. CCA reveals the most dominant sediment-dwelling species to prefer lower dissolved oxygen, sulfides, and pH, and sediments with high D_{50} and low clay content. We speculate that water-sediment regulation has affected seabed communities, particularly Region A in our survey area.

Key words: Huanghe River Estuary, macrobenthos, water-sediment regulation, community structure

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1 Introduction

Estuarine ecosystems are important and fragile habitats, and provide important nutrients for marine organisms (Zhuang, 2006). Both natural and anthropogenic factors have dramatically changed estuarine ecosystems. For example, after decreased runoff and sediment into the sea, Nile Delta salinity increased rapidly and input of biogenic elements decreased, leading to a 95% reduction in phytoplankton biomass and an 80% reduction in catches (Walling, 2006). Due to serious siltation in the Huanghe River, the channel is now flushed by the strategic discharging of large reservoirs containing water and sediment in a process referred to as the Huanghe River water-sediment regulation (Li and Sheng, 2011). From 2002 to 2016, water-sediment regulation has occurred 14 times from the Xiaolangdi Reservoir, increasing the flow in the lower Huanghe River from 1 800 m³/s to 4 000 m³/s. A few studies have reported that, during water-sediment regulation, salinity decreased rapidly in a short term and transport volume of nutrients reached about half of the year's transport volume (Li, 2010). The sediment discharge was more than two thirds of the annual amount (Yang et al., 2008). The concentration and composition of nutrients in the lower Huanghe River have changed obviously (Chen et al., 2013). This large influx of fresh water and sediment into the estuary inevitably affects the environment and its biological resources (Liu et al., 2010; Yu, 2014).

Macrobenthos in the Huanghe River Estuary ecosystem contributes to biogeochemical cycles through feeding, burrow construction, and other activities, and maintains the structure and function of the ecosystem (Liu et al., 2007; Somerfield et al., 2006; Liu et al., 2009). At present, most studies on the macrobenthos of this estuary have focused on community composition and diversity (Li, 2011; Dong et al., 2012; Xia et al., 2009; Leng et al., 2013b), productivity (Wang et al., 2012; Yao, 2010), and benthos size spectra (Hua and Zhang, 2009). Few reports have considered the effects of water-sediment regulation project on local macrobenthic communities.

From 2012 to 2016, we have surveyed the macrobenthos of and adjacent to the Huanghe River Estuary, following water-sediment regulation events. Our objective was to identify any change in macrobenthic community structure, and, if possible, to correlate this with relevant environmental variables. Results both improve our understanding of the impact of large-scale projects on estuarine ecosystems, and provide baseline scientific information for this area.

2 Materials and methods

2.1 Study area

A total of 18 sampling stations were located at 37°40'–38°09'N,

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119°00'–119°40'E. Survey stations were further divided into four regions based on their distance from the estuarine mouth (Fig. 1, Table 1).

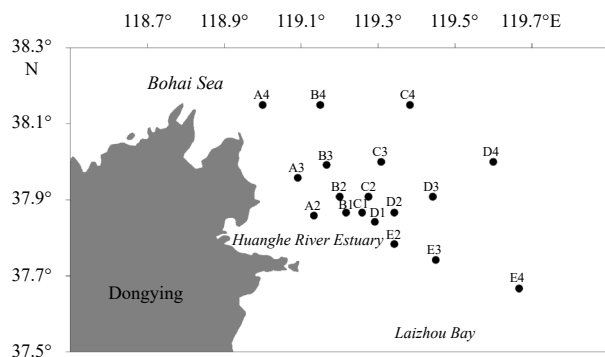


Fig. 1. Sampling station distribution in the Huanghe River Estuary.

Table 1. Allocation of survey stations to regions

Region	1	2	3	4
A	–	A2	A3	A4
B	B1	B2	B3	B4
C	C1	C2	C3	C4
D	D1	D2	D3	D4
E	–	E2	E3	E4
Distance to the estuarine mouth/km	5	10	20	40

Note: Our survey vessel cannot approach Stations A1 and E1, so they were not set in this study.

2.2 Sampling design

2.2.1 Macrobenthos

From 2012 to 2016, sampling was undertaken once a year in late July following water-sediment regulation. Surveys were performed according to *The Specification for Oceanographic Survey* (GB/T 12763–2007). Five replicate samples were taken at each site using a Van Veen grab (0.05 m²). Grab contents were sieved in the field through a 0.5-mm mesh screen, placed into appropriately labelled pottles or bags, and immediately fixed in 5%–7% buffered formaldehyde solution. In the laboratory, macrobenthos were sorted and identified to the lowest possible taxonomic level, counted, and weighed; taxa were referable to one of Annelida, Molluska, Arthropoda, Echinodermata, or a group of miscellaneous phyla, hereafter called “others” (e.g., Nemertea, Turbellaria, and Cnidaria).

2.2.2 Environmental variables

Bottom water temperature (TEM), salinity (SAL), depth (DEP), pH, suspended solids (SS), dissolved oxygen (DO), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), dissolved inorganic nitrogen (DIN, including NO₃-N, NO₂-N, and NH₄-N), total organic carbon (TOC), sulfide (S), petroleum (Oil), and heavy metals (Cu, Pb, Zn, Cd, Hg, As), were recorded for each sampling event. Grain-size analysis was also performed, with sediments divided into fractions of sand (63–500 μm), fine silt (4–63 μm), and clay (<4 μm); median particle diameter was expressed as D₅₀. Among these, TEM, SAL, DEP, pH, and DO were recorded using a profiler (YSI EXO Handheld, Yellow Springs Instrument Co., Inc., USA). DIN were filtered through a 40 μm Whatman GF/F glass-fiber filters. The filtrate was ana-

lyzed by segmented flow analysis (SFA). Heavy metals were determined by flame atomic adsorption spectrometer (PE-4100ZL) and AF Spectrophotometer (AF-610A). Oil was measured by Fluorescence Spectrophotometer (FL-4 500). COD was measured by the basic potassium permanganate method. Sediment grain size analysis was performed on a laser particle size analyzer (Malvern Mastersize 2000, UK).

2.3 Data analysis

Biological properties include total biomass (B), abundance (A), number of species (S), and Margalef richness (d), Shannon-Wiener diversity (H'), Pielou evenness (J'), and the dominant (Y) indexes, in accordance with:

$$d = (S - 1) / \log_2 N, \quad (1)$$

$$H' = - \sum_{i=1}^S P_i \log_2 P_i, \quad (2)$$

$$J' = H' / \log_2 S, \quad (3)$$

$$Y = (n_i / N_t) \times f_i, \quad (4)$$

where N is the total abundance of individuals in a sample, N_t is the total abundance of individuals at all stations, S is the total number of species, n_i is the total abundance of the i th species at all stations, P_i is the ratio between n_i and N (n_i/N), and f_i is the frequency of occurrence of the i th species at all stations. S , d , H' , and J' were calculated using PRIMER 6.0 software, as were characteristics of the macrobenthic community (using the CLUSTER and nMDS functions). To analyze relationships between dominant macrobenthic species and environmental parameters, canonical correspondence analysis (CCA) was performed using Canoco for Windows 4.5; the significances of all CCA ordination axes were examined by Monte Carlo test (Ter Braak, 1987). Species i is defined as dominant when $Y > 0.02$. ANOVA and Pearson correlation analysis were performed using SPSS 17.0.

3 Results

3.1 Species, abundance, and biomass

A total of seven phyla and 138 macrobenthic species were collected from the Huanghe River Estuary between 2012 and 2016. Among them, mollusk species were most rich (48), followed by polychaetes (47) and arthropods (33). In addition, six species of echinoderms, two nemerteaans, and one each of a cnidarian and planarian, were found. Throughout the study period, the highest number of species occurred in 2013 and the lowest in 2016. Temporal changes in the number of species are presented in Table 2.

ANOVA revealed the number of species in 2012 and 2013 to be significantly higher than in 2016, and for species abundance in 2012 to be significantly higher than in 2016. Biomass did not differ significantly over time (Table 3).

3.2 Dominant species

Dominant macrobenthic species in the Huanghe River Estuary from 2012 to 2016 were mostly small polychaetes (Table 4); mollusks, arthropods, while echinoderms were relatively rare. In 2016, only polychaetes were dominant. *Heteromastus filiformis* was always dominant over the survey period. SIMPER revealed all dissimilarity indexes among years to exceed 70%. The 2016

Table 2. Macrobenthic species composition summary statistics in the Huanghe River Estuary during 2012–2016

Survey time	Total species	Taxa				
		Annelida	Molluska	Arthropoda	Echinodermata	Others
2012	79	31	26	15	5	2
2013	86	34	24	20	4	4
2014	67	27	21	13	3	3
2015	82	30	25	18	5	4
2016	58	24	19	10	3	2

Table 3. Variation in macrobenthic species number, abundance, and biomass in the Huanghe River Estuary during 2012–2016

Survey time	Species number	Abundance /ind.·m ⁻²	Biomass/g·m ⁻²
2012	17.22±2.79 ^a	364.17±87.29 ^a	5.71±2.85 ^a
2013	16.50±2.37 ^a	196.67±39.95 ^{ab}	4.06±1.39 ^a
2014	14.06±1.80 ^{ab}	196.22±55.57 ^{ab}	3.35±0.91 ^a
2015	14.89±1.85 ^{ab}	268.89±69.94 ^{ab}	4.47±1.50 ^a
2016	9.22±1.02 ^b	115.56±18.72 ^b	7.28±2.71 ^a

Note: Different superscript letters indicate significant differences ($p < 0.05$).

Table 4. Dominant macrobenthic species in the Huanghe River Estuary during 2012–2016

Phyla	Dominant species	Survey time				
		2012	2013	2014	2015	2016
Polychaeta	<i>Heteromastus filiformis</i>	+	+	+	+	+
	<i>Glycinde gurjanovae</i>				+	+
	<i>Prionospio queenslandica</i>	+				
	<i>Arabella iricolor</i>		+	+		
	<i>Sigambra bassi</i>	+	+	+		+
	<i>Nephtys oligobranchia</i>		+			
	<i>Aricidea fragilis</i>				+	+
	<i>Capitella capitata</i>				+	
	<i>Cirratulus cirratus</i>					+
	<i>Sternaspis scutata</i>				+	
Molluska	<i>Moerella jodoensis</i>		+	+	+	
	<i>Vokoyamaia acutangula</i>	+				
Arthropoda	<i>Eriopisella sechellensis</i>	+				
	<i>Ampelisca brevicornis</i>		+			
Echinodermata	<i>Amphioplus japonicus</i>		+	+		

community differed markedly from that between 2012 and 2014 because of differing abundances of *Cirratulus cirratus*, and all dissimilarity indexes exceeded 80% (Table 5).

3.3 Community structure

MDS (Table 6, Fig. 2) revealed that from 2012 to 2015, a single community comprising small polychaetes, gammarids, bivalves,

Table 5. Average macrobenthic community dissimilarity (%) during 2012–2016

	2012	2013	2014	2015
2013	76.16	–	–	–
2014	78.15	75.73	–	–
2015	78.00	74.36	77.71	–
2016	82.26	81.85	82.31	77.45

and ophiuroids occurred in Regions 3 and 4 in the outer study area. Stations nearest the estuary represented a single community type characterized by small polychaetes. However, communities in 2016 were significantly different from those between 2012 and 2015 (pairwise tests $R_{2012, 2016} = 0.198$, $p = 0.001$; $R_{2013, 2016} = 0.293$, $p = 0.001$; $R_{2014, 2016} = 0.236$, $p = 0.001$; $R_{2015, 2016} = 0.098$, $p = 0.008$), with the macrobenthos at most stations similar throughout the survey area, characterized by small polychaetes, while other taxa were rare.

3.4 Diversity

Averages Shannon–Wiener diversity, Margalef richness, and Pielou evenness indexes were 2.73, 2.26, and 0.82, respectively. Shannon–Wiener and Margalef richness indexes trended down over time, with the lowest values for each occurring in 2016. Pielou evenness index fluctuated from 2012 to 2016. While the Margalef richness index in 2016 differed significantly from that in 2012 and 2013, there was no significant difference in any other index over time (Fig. 3).

3.5 Relationship with environmental factors

The Pearson correlation between 25 environmental factors and the community structure of the macrobenthos were analyzed based on the data of five cruises. The result showed that species abundance was positively correlated with bottom water salinity ($p < 0.05$), and negatively correlated with clay ($p < 0.05$) (Table 7).

Detrended correspondence analysis (DCA) with species reveals the first axis gradient length to be 3.106, so CCA can be used. Seven environmental factors with significant impact ($p < 0.01$) were selected: pH, TEM, DEP, DO, S, clay, and D_{50} . Dominant species in Table 4 were also selected.

Table 6. Community composition in the Huanghe River Estuary during 2012–2016

Survey time	Major community
2012	I. <i>Heteromastus filiformis</i> – <i>Glycinde gurjanovae</i> – <i>Notomastus latericeus</i> II. <i>Eriopisella sechellensis</i> – <i>Amphioplus japonicus</i> – <i>Glycinde gurjanovae</i>
2013	I. <i>Heteromastus filiformis</i> – <i>Aricidea fragilis</i> – <i>Lineus</i> sp. II. <i>Arabella iricolor</i> – <i>Ampelisca brevicornis</i> – <i>Sternaspis scutata</i>
2014	I. <i>Prionospio queenslandica</i> – <i>Sigambra bassi</i> – <i>Ophiodromus angutifrons</i> II. <i>Moerella jodoensis</i> – <i>Heteromastus filiformis</i> – <i>Theora lata</i>
2015	I. <i>Sternaspis scutata</i> – <i>Sigambra bassi</i> – <i>Cirratulus cirratus</i> II. <i>Glycinde gurjanovae</i> – <i>Aricidea fragilis</i> – <i>Moerella jodoensis</i>
2016	I. <i>Cirratulus cirratus</i> – <i>Siphonodentalium japonicum</i> – <i>Corophium sinensis</i> II. <i>Cirratulus cirratus</i> – <i>Heteromastus filiformis</i> – <i>Aricidea fragilis</i>

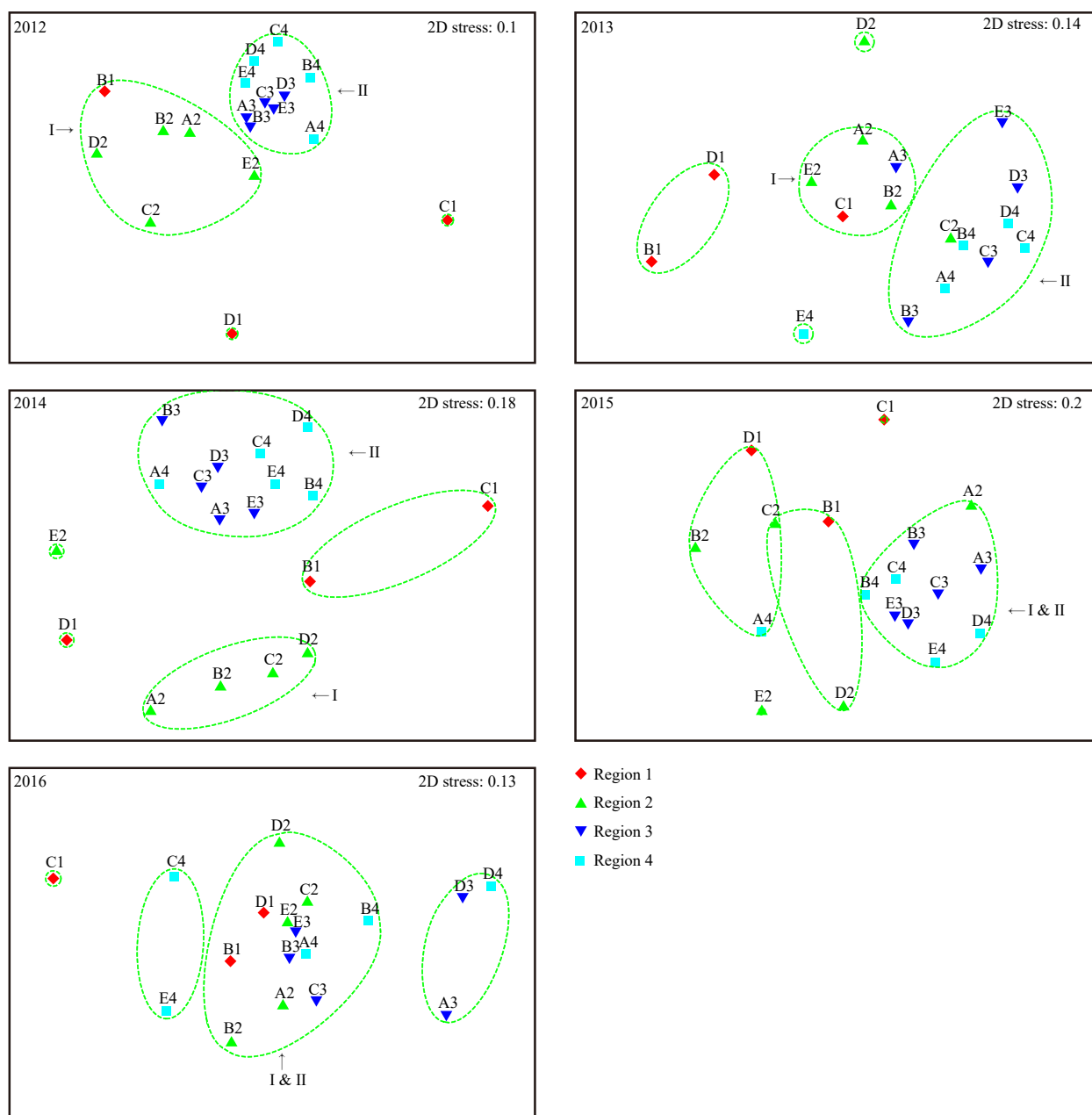


Fig. 2. MDS analysis of macrobenthic community structures in the Huanghe River Estuary during 2012–2016. I and II represent different major community.

CCA identified species-environment correlations with the first and second axes to be 0.823 and 0.718, respectively. All four axes explained 89.9% of variability, with Axis 1 contributing 35.9% and Axis 2, 25.2%. DO ($R=0.466$) was most highly, positively correlated with Axis 1, then pH ($R=0.427$). DEP ($R=-0.487$) was most highly, negatively correlated with Axis 2. In the Huanghe River Estuary, most polychaetes preferred lower DO, S, and pH, while some echinoderm and arthropod taxa preferred the opposite. Most species preferred high D_{50} and low sediment clay content (Fig. 4).

3.6 The temporal and spatial variation of main environmental factors

ANOVA revealed that, for temporal variation, SAL, pH, DO, and clay content in 2016 were significantly lower than in 2012 ($p<0.05$). TEM was opposite. For spatial variation, SAL, DEP, and

pH increased from Regions 1 to 4. The values between the two regions were significantly different ($p<0.05$). Clay content was the highest in Region 2, while D_{50} was the lowest. In terms of clay and D_{50} , there were significant differences between Region 2 and other three regions ($p<0.05$) (Tables 8 and 9).

Compared with 2012, in 2016, the low-value area of bottom TEM, SAL, pH, DO, and S moved to the west of survey region, near Region A. Moreover, the high-value area of D_{50} that appeared in Region A in 2012 almost disappeared in 2016. The clay content in estuary mouth in 2016 was higher than that in 2012 (Fig. 5).

4 Discussion

In recent decades, changes in natural characteristics and anthropogenic disturbance have reduced or stopped the Huanghe River water-sediment flux to the sea. This has created an increas-

ingly saline, low-temperature estuarine environment, and affected reproduction of surrounding biological resources. Water-sediment regulation in the Huanghe River is an effective strategy

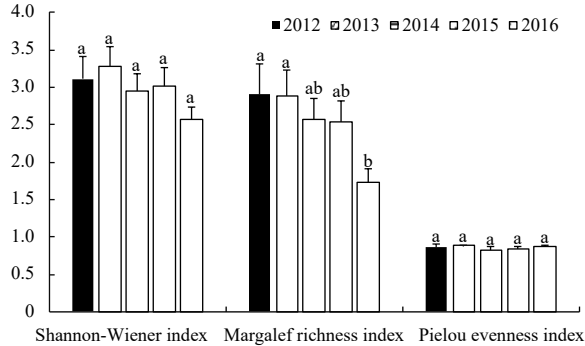


Fig. 3. Macrobenthos diversity indexes in the Huanghe River Estuary during 2012–2016. Different superscript letters indicate significant differences ($p < 0.05$).

Table 7. Correlation between environmental factors and abundance of macrobenthos in the Huanghe River Estuary during 2012–2016

Environmental factor	r (coefficient value)	p (significances value (2-tailed))
SAL	0.241*	0.022
Clay	-0.221*	0.036
TEM	-0.010	0.926
DEP	0.044	0.680
pH	0.166	0.118
SS	-0.090	0.401
DO	0.131	0.219
COD	-0.162	0.128
TN	0.122	0.252
TP	0.077	0.473
NO ₃ -N	0.045	0.675
NO ₂ -N	0.082	0.444
NH ₄ -N	-0.074	0.490
TOC	-0.202	0.057
S	-0.159	0.134
Oil	0.075	0.483
Cu	0.119	0.263
Pb	-0.119	0.266
Zn	0.059	0.582
Cd	0.036	0.737
Hg	-0.114	0.284
As	0.136	0.203
Sand	0.166	0.117
Finesilt	-0.073	0.494
D ₅₀	0.190	0.073

Note: * Correlation is significant at the 0.05 level (2-tailed).

Table 8. The temporal variation of main environmental factors in the Huanghe River Estuary during 2012–2016

Survey time	TEM/°C	SAL	DEP/m	pH	DO/mg·L ⁻¹	S/10 ⁻⁶	Clay/10 ⁻²	D ₅₀ /μm
2012	22.78±1.23 ^b	33.21±1.61 ^a	13.67±3.72 ^a	8.21±0.11 ^a	8.40±1.23 ^a	34.43±37.59 ^b	11.32±11.30 ^a	36.05±16.83 ^a
2013	22.51±2.20 ^b	29.81±2.48 ^c	13.08±4.57 ^a	8.00±0.12 ^c	8.75±1.41 ^a	62.74±13.52 ^a	12.28±7.39 ^a	34.24±14.02 ^c
2014	23.02±1.38 ^{ab}	28.77±0.94 ^d	12.51±3.80 ^a	8.11±0.06 ^b	5.78±0.67 ^b	36.17±46.87 ^b	9.62±6.10 ^{bc}	36.25±18.96 ^a
2015	22.41±1.61 ^b	29.86±0.88 ^c	12.64±5.07 ^a	7.93±0.08 ^d	6.08±0.80 ^b	16.61±16.13 ^b	10.22±7.17 ^b	35.21±13.05 ^b
2016	23.92±0.96 ^a	30.82±0.48 ^b	13.53±3.34 ^a	8.11±0.10 ^b	5.98±0.21 ^b	20.80±17.85 ^b	8.93±7.84 ^c	35.99±15.13 ^a

Note: Different superscript letters indicate significant differences ($p < 0.05$).

to deal with the settling of sediment, and each year large volumes of water and sediment have been transported into the estuarine environment within a short period of time (Fan et al., 2009; Li et al., 2015). However, few studies have reported on the transport and settlement of sediments, and any lethal effects of this activity or effect it might have on species in the receiving environment.

For macrobenthic communities, Zhang et al. (1990a, b) reported 150 macrobenthic species within the Huanghe River Estuary and adjacent waters in May 1985. Both bivalves and echinoderms had significant advantages in abundance and biomass respectively. However, we report an average of about 75 species each year. Leng et al. (2013a) reported 153 species in the Huanghe River Estuary from 2004 to 2009, with dominant species such as *Glycinde gurjanovae*, *Raphidopus ciliatus*, and *Iphinoe tenera*, slightly more than the 138 species we have reported from 2012 to 2016 (this study). Dominant species are now small polychaetes (e.g., *H. filiformis*, *Capitella capitata*, and *C. cirratus*), the likes of which Pearson and Rosenberg (1978) identified as opportunistic, which can rapidly proliferate when sedimentary organic content increases. These taxa can be used to indicate environmental pollution, climate change, and human disturbance (Vandalfsen et al., 2000; Yoana et al., 2018). Li et al. (2015) studied macrobenthos alteration during water-sediment regulation period. It revealed by BOPA index and statistical analysis of environmental variables that the pollution in mouth region tended to be worse, and the proportion of benthic opportunistic polychaetes increased. There was certain negative effect

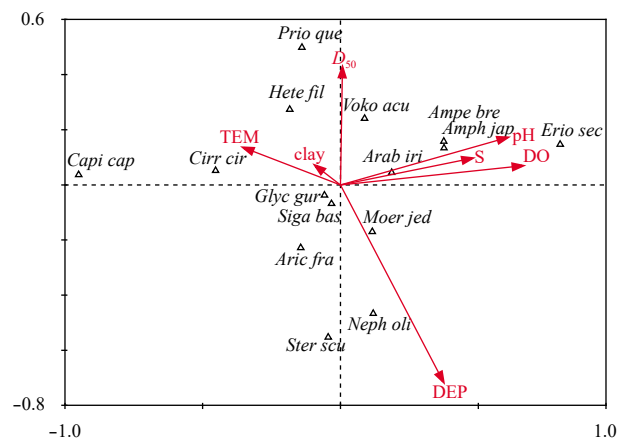


Fig. 4. CCA ordination for macrobenthos and environmental factors in the Huanghe River Estuary. *Hete fil* represents *Heteromastus filiformis*, *Glyc gur* *Glycinde gurjanovae*, *Prio que* *Prionospio queenslandica*, *Arab iri* *Arabella iricolor*, *Siga bas* *Sigambra bassi*, *Neph oli* *Nephtys oligobranchia*, *Aric fra* *Aricidea fragilis*, *Capi cap* *Capitella capitata*, *Cirr cir* *Cirratulus cirratus*, *Ster scu* *Sternaspis scutata*, *Moer jed* *Moerella jedoensis*, *Voko acu* *Vokoyamaia acutangula*, *Erio sec* *Eriopisella sechellensis*, *Ampe bre* *Amphiplos japonicus*, and *Amph jap* *Amphioplus japonicus*.

Table 9. The spatial variation of main environmental factors in the Huanghe River Estuary during 2012–2016

Survey region	TEM/°C	SAL	DEP/m	pH	DO/mg·L ⁻¹	S/10 ⁻⁶	Clay/10 ⁻²	D ₅₀ /μm
1	22.75±1.24 ^a	29.49±1.58 ^c	8.97±3.89 ^d	8.00±0.11 ^b	6.68±1.46 ^a	29.32±26.02 ^a	4.91±1.32 ^b	46.93±12.87 ^a
2	23.17±1.40 ^a	29.75±2.40 ^{bc}	11.16±2.77 ^c	8.05±0.15 ^{ab}	7.25±2.11 ^a	27.25±30.60 ^a	14.73±5.41 ^a	22.48±14.82 ^c
3	22.78±1.59 ^a	30.86±1.72 ^{ab}	13.85±3.01 ^b	8.10±0.14 ^a	6.81±1.48 ^a	38.18±40.16 ^a	5.87±1.89 ^b	43.62±12.72 ^{ab}
4	22.93±1.98 ^a	31.47±1.87 ^a	16.71±2.75 ^a	8.11±0.10 ^a	7.12±1.24 ^a	39.92±31.89 ^a	7.50±6.43 ^b	35.52±14.13 ^b

Note: Different superscript letters indicate significant differences ($p < 0.05$).

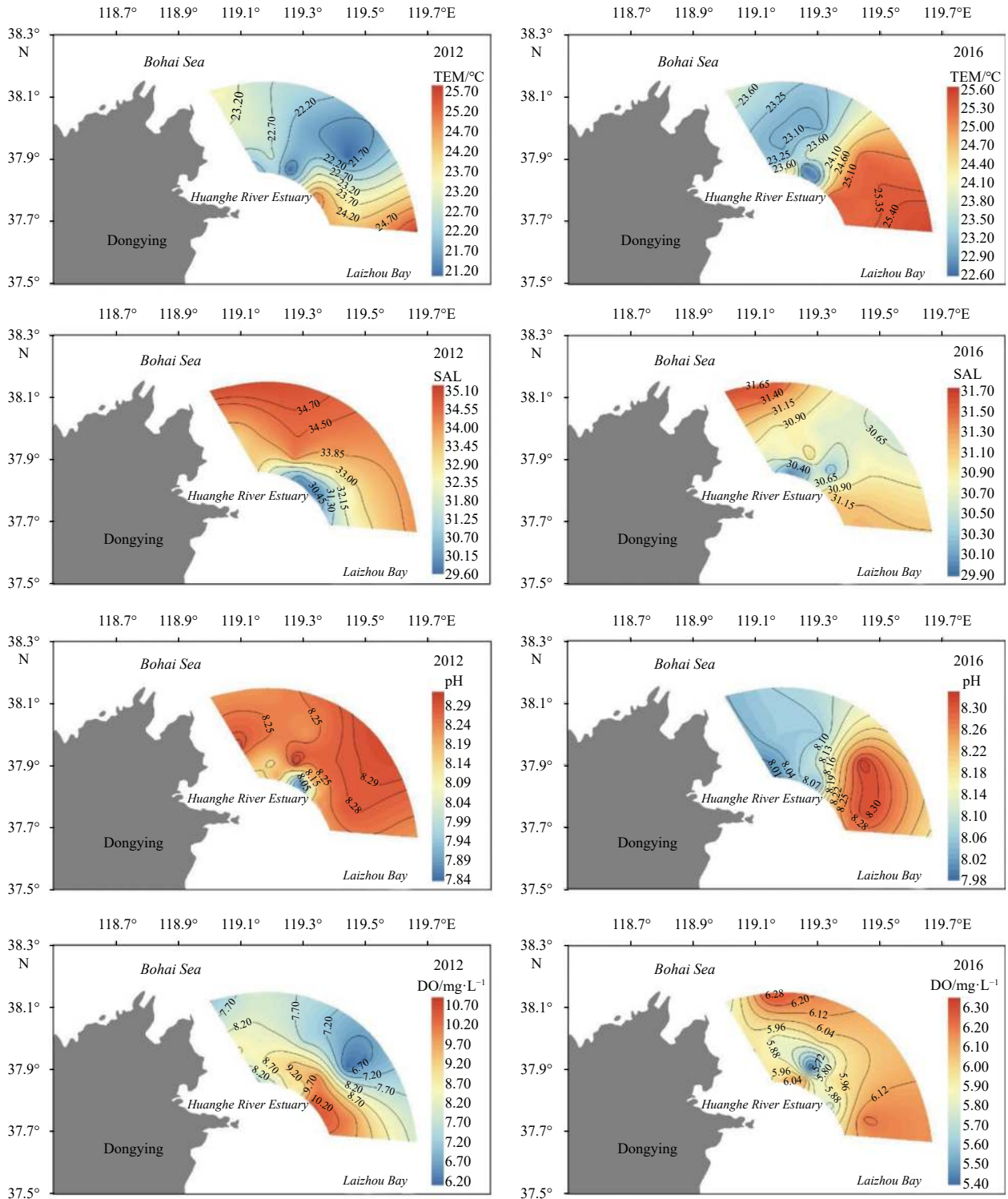


Fig. 5.

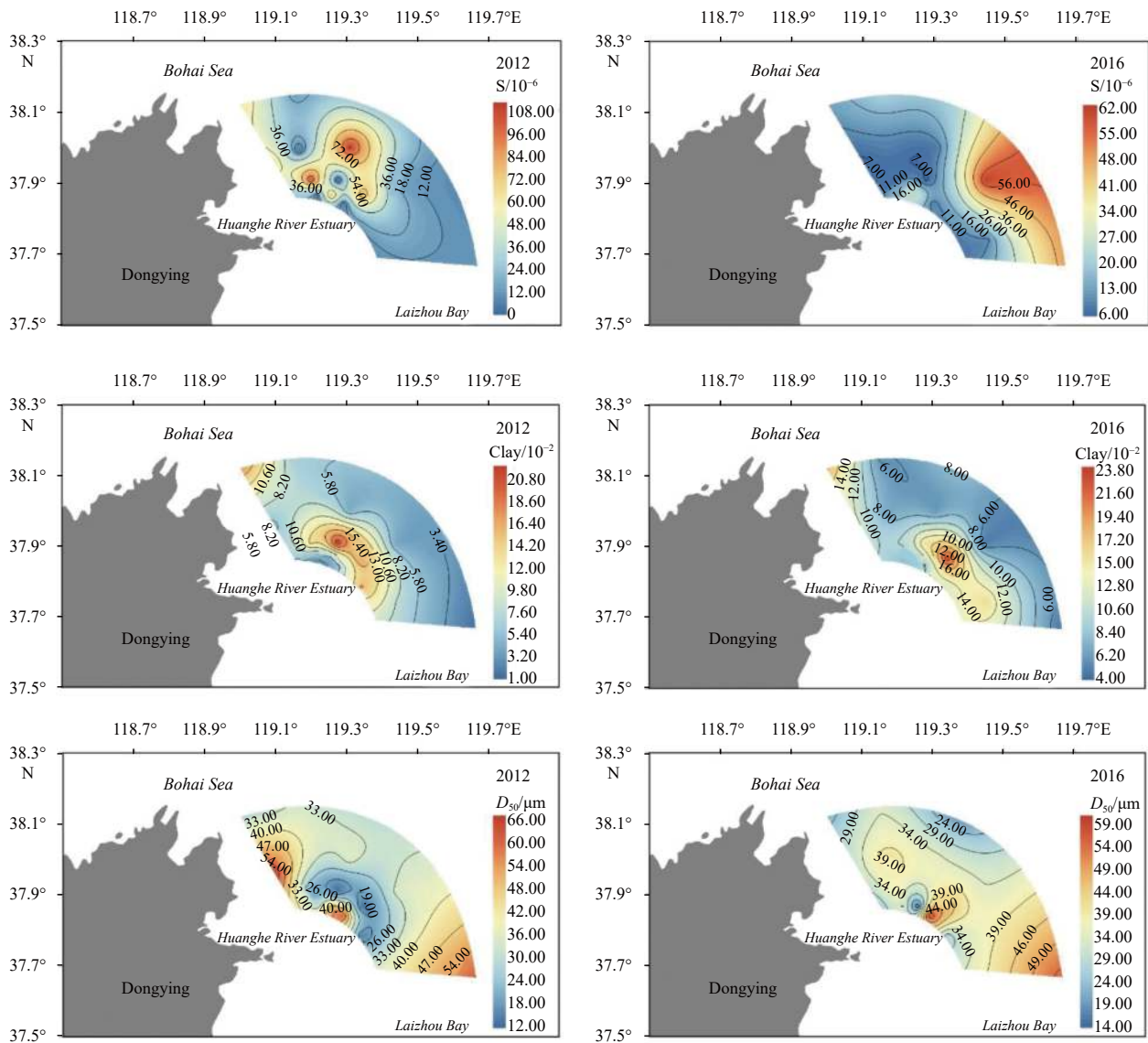


Fig. 5. The temporal and spatial variation of main environmental factors in the Huanghe River Estuary. Red represents the high-value area and blue represents the low-value area.

on macrobenthos during the regulation. The present dominance of small polychaetes in our study indicates changed estuarine water quality, so we infer that water-sediment regulation has resulted in changed benthic community structure and estuarine ecology.

Hu et al. (2014) reported during water-sediment regulation that runoff mixed with seawater, and diluted water then diffused into the open sea. The diffusion extended dramatically to the northwest, with diffusion to the southeast representing only a third of the total. In this study, eight bottom water and sedimentary environmental factors were selected, which were closely related to macrobenthic communities. The analysis of temporal and spatial variation revealed that, to a certain extent, the low-value region of important bottom water environmental factors moved to Region A. The sediment particle in Region A became smaller and the value of D_{50} decreased. Meanwhile in our study Region A, located in the northwestern survey area, the number of species, biomass, and macrobenthic diversity index were the lowest of the five survey regions we identified, but density was

the highest, with large numbers of small individuals occurring there. For example, in 2015, *C. capitata* reached 1 180 ind./m² at Station A2. These high abundances may be related to the diffusion of diluted water from water-sediment regulation, or to near-shore impacts.

Many studies have investigated relationships between benthos distribution and sediment types. Long and Lewis (1987) found that the number, abundance, and diversity of benthos increased with the proportion of coarse gravel in sediments. Coleman et al. (2007) reported the abundance of macrobenthos to be 25% higher in coarse sand than other sediment types. Shou et al. (2018) considered macrobenthos could not easily utilize nutrients in fine particles with small pore size, and that spatial heterogeneity in coarse sediments provided suitable habitat for various types of benthos. These results are consistent with our conclusions. According to CCA, most macrobenthos preferred high D_{50} and low sediment clay content. Many studies have demonstrated that during water-sediment regulation a southward passage with high-concentrations of suspended sediment occurred in the

Huanghe River Estuary, and that sediment grain size near the estuary was more coarse (Hu et al., 2014; Wang et al., 2015). Therefore, it is necessary to establish survey stations south of the Laizhou Bay to further study the ecological impact of water-sediment regulation.

5 Conclusions

The Huanghe River Estuary is a transitional zone where the land, freshwater, and ocean meet. It is affected by natural and anthropogenic disturbances, and has a fragile ecosystem. Since implementation of water-sediment regulation in 2002, the local estuarine ecology has changed. We conducted a 5-year post-regulation survey, sampling macrobenthos within and adjacent to this estuary from 2012 to 2016. We report: (1) a total of seven phyla and 138 macrobenthic species in this region. The number of species and their abundance in 2012 were significantly higher than those in 2016. Dominant species in 2016 are small polychaetes. (2) MDS depicts macrobenthic communities near and away from the estuary to have become the same community structure over time. Diversity indexes trended down. (3) CCA reveals the most-dominant species prefer lower DO, S, and pH, low sedimentary clay content, but high sedimentary D_{50} . We speculate that water-sediment regulation has affected Region A of our survey area.

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