IMPLEMENTING THE STRATEGIC ACTION PROGRAMME FOR THE YELLOW SEA LARGE MARINE ECOSYSTEM:
RESTORING ECOSYSTEM GOODS AND SERVICES AND CONSOLIDATION OF A LONG-TERM REGIONAL
ENVIRONMENTAL GOVERNANCE FRAMEWORK
(UNDP/GEF YSLME Phase II Project)

Impact Assessment of Sea Level Rising for Wading Birds in Dandong

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Contents

1. Background

Sea level rise is a major threat to low - lying coastal areas around the globe. Along with rising sea level, there are changes to all the processes that operate around the coast. The immediate effect is submergence and increased flooding of coastal land, as well as saltwater intrusion into surface waters. Longer term effects also occur as the coast adjusts to the new environmental conditions, including wetland loss and change in response to higher water tables and increasing salinity, erosion of beaches and soft cliffs, and saltwater intrusion into groundwater.

The latest study shows that onset of large-scale transgression in the Yellow Sea during the Quaternary is roughly synchronous and occurred consistently since ~0.8 Ma (Zhang et al, 2019). Sea level rising is an important factor for ecosystem in the yellow sea region.

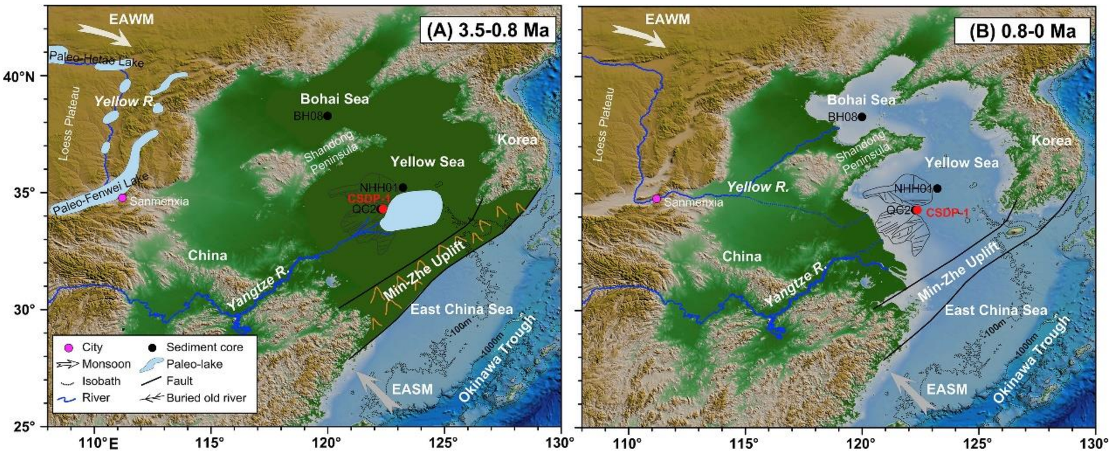

Figure 1-1 Time scales of tectonic schematic diagrams illustrate the evolution of the Yellow River, the Yangtze River as well as the Bohai and Yellow Seas. (Zhang et al, 2019)

Yellow sea is a semi-enclosed shallow sea, it’s about 1000 km north-south span, east-west span about 700 km, includes the wetlands of Yangtze estuary, Liaodong peninsula, the Korean peninsula and Jeju island. The Yellow Sea Large Marine Ecosystem (YSLME) is one of the 64 large Marine ecosystems in the world. The yellow sea region, with its 13,000 km coastline and 20,000 km^2 of tidal wetlands, offers many sites for migratory wading birds, including at least 27 sites that meet international wetlands standards, which means that at least one species of wading bird exceeds 1% of the migratory population or hosts more than 20,000 in total (Barter 2002).

There are 8 major bird migration routes around the world. The East Asian-Australasian Flyway runs from the Russian far East in the north and Alaska in North America, along the western Pacific coast through East and southeast Asia, and extends to Australia and New Zealand in the south. The East Asian-Australasian migration route includes more than 20 countries and regions, with 55 species and 5 million shorebirds migrating through this migration route every year. There are many migration stopping sites on the migration route, among which the most important one is the yellow sea area. There are over three million shorebirds staying in the Yellow Sea during spring and autumn migration(Ning Hua, 2014).

The wetland in the south and north Yellow Sea plays different roles in the migration season. In the south Yellow Sea， the daily mean body mass of all four species(subspecies)did not increase significantly or increased slowly with the date． They deposited little fuel and could not fly to the breeding grounds directly． In the north Yellow Sea， however, the daily mean body mass of shorebirds increased rapidly with the date． The birds deposited large amounts of fuel and were able to fly non—stop to the breeding grounds.(Ning Hua, 2014)

The Yalu river originates from Jilin province, China, and flows into the west Korea bay in the north of the yellow sea. It is 795 kilometers in length, covers a drainage area of 61,990 square kilometers, and has an annual runoff of 32.76 billion cubic meters.

The Yalu river estuary wetland located in Dandong city, with a total area of about 1010 square kilometers, among which the intertidal zone accounts for about 20%. The sediment of the intertidal zone is mud, silt, fine sand and sand successively from shore to sea, which is suitable for the growth of annelids and mollusks and provides enough food for migratory birds. The Yalu river estuary wetland is not only an important resting place for wading birds to migrate, but also has many functions such as storing water and regulating flood, regulating climate and degrading pollution.

The Yalu River estuary wetland nature reserve was established in 1987, promoted to the provincial level in 1995 and approved to the national level in 1997, mainly protecting the coastal wetland ecosystem and rare species. In July 1999, the reserve was listed as the member of the East Asian-Australasian Flyway Partnership (EAAFP).

2. The Migrating wading birds at the Yalu River estuary

Owing to a lack of suitable habitat between the Yalu river estuary and its breeding sites in the high latitudes of Siberia, the mouth of the Yalu river estuary is the last resting place for a large number of long-distance migrating shorebird, before heading for their breeding grounds (Bamford et a1． 2008).

2.1 The shorebird in the West bank of Yalu river estuary (Dandong)

The tidal zone at the Yalu river estuary covers an area of 171 km^2, most of which are mud flat. There are abundant bivalves in the mudflats, which provide important food resources for shorebird during the migrating period. At the same time, the beach at the Yalu river estuary is also a clam farm, many coastal fishermen depend on shellfish farming for their traditional livelihoods. The shellfish seedlings that they releasing can provide another source of food for shorebirds (Ning Hua, 2014).

The spring migration of shorebird starts from the middle of March to early June. Wetlands International organized coordinated wading birds survey in Yellow Sea and Bohai Sea from 2016 to 2018. In April 2018, according to the survey of the Yalu River estuary, the total number of wading birds is 238335, this is the largest number among the 23 wetlands in this program, and it accounts for 26.9% of the total. 9 species of shorebirds, including Bar-tailed Godwit, Great Knot, and other species, exceeds 1% of the total migratory population and reaches the international importance wetlands identification standard.

In 2018, the Bar-tailed Godwit, accounting for 72% of the species' global population, was recorded 107,480 in the Yalu River estuary (Dandong). The number of Great Knot was recorded 61,773, representing 21.3% of the global population of this species. The Yalu River estuary has become the largest resting place and transit area for Bar-tailed Godwit and Great Knot to migrate northward.

During the three-year survey (2016-2018), the highest numbers of wading birds were recorded at the Yalu River estuary wetland recorded in two years: 215,713 in 2016 and 238,335 in 2018. A total of 146,789 wading birds were recorded in 2017.

Figure 2-1 The Shorebird in Yalu river wetland (Dandong)

The record of 2018was showed in table 2-1.

Table 2-1 The Wading bird Counts in Yalu river wetland (Dandong) 2018

Wading bird Counts in Yalu river wetland（Dandong）2018.04

Total：238330

Scientific Name	Common Name	Number
	GREBES	
Tachybaptus ruficollis	Little Grebe	101
P. cristatus	Great Crested Grebe	1
	CORMORANTS	
Phalacrocorax carbo	Great Cormorant	11
	HERONS & EGRETS	
E. garzetta	Little Egret	123
E. intermedia	Intermediate Egret	42
E. alba	Great Egret	8
Ardea purpurea	Purple Heron	3
	IBISES & SPOONBILLS	
P. minor	Black-faced Spoonbill	13
	SWANS, GEESE & DUCKS	
A. fabalis	Bean Goose	12

T. tadorna	Common Shelduck	213
Anas penelope	Eurasian Wigeon	5
A. strepera	Gadwall	16
A. formosa	Baikal Teal	2
A. crecca	Common Teal	4
A. platyrhynchos	Mallard	3
A. poecilorhyncha	Spot-billed Duck	84
A. acuta	Northern Pintail	2
A. querquedula	Garganey	11
A. clypeata	Northern Shoveler	260
	Unidentified ducks	41
	RAILS, CRAKES, GALLINULES & COOTS	
Fulica atra	Coot	472
	SHOREBIRDS	
Haematopus ostralegus	Oystercatcher	1028
Himantopus himantopus	Black-winged Stilt	123
P. squatarola	Grey Plover	1943
C. alexandrinus	Kentish Plover	1099
C. mongolus	Lesser Sand Plover	21
C. leuchenaultii	Greater Sand Plover	307
Limosa limosa	Black-tailed Godwit	10323
L. lapponica	Bar-tailed Godwit	107480
Numenius phaeopus	Whimbrel	140
N. arquata	Eurasian Curlew	3747
N. madagascariensis	Far Eastern Curlew	4782
Tringa nebularia	Common Greenshank	13
T. erythropus	Spotted Redshank	1
T. ochropus	Green Sandpiper	12
Xenus cinereus	Terek Sandpiper	27
Arenaria interpres	Ruddy Turnstone	16
Calidris ruficollis	Red-necked Stint	298
C. tenuirostris	Great Knot	61773
C. alpina	Dunlin	42830
	GULLS & TERNS	
Larus crassirostris	Black-tailed Gull	104
L. relictus	Relict Gull	38
L. ridibundus	Black-headed Gull	654
L. saundersi	Saunder's Gull	32
Childonias hybridus	Whiskered Tern	28
Hydroprogne caspia	Caspian Tern	1
Sterna hirundo	Common Tern	32
S. albifrons	Little Tern	39

The Hong Kong Bird Watching Society (HKBWS) has provided technical and financial supports to the China Coastal Wading bird Census since2006. Dandong is a very important member in this project. BAI Qingquan organized and led the investigation in Dandong for ten years.

In the report 2010-2011, an average of 25,063 counts per month in 108 wading bird species were recorded at Yalu river estuarine wetland of Dandong city, Liaoning Province, during monthly wading bird surveys from January 2010 to December 2011. The highest number were 164,949 recorded in April, 2011. Twenty species with their largest number recorded exceeding the 1% criterion including 16 shorebird species were observed, in which the highest counts of Bar-tailed Godwit and Far Eastern Curlew reached 36 times and 16.5 times of the 1% criteria respectively. Fourteen species of globally threatened species including Spoon-billed Sandpiper *Eurynorhynchus pygmeus*, Nordmann's Greenshank *Tringa guttifer*. A total of 138 color-ringed wading bird individuals (from 21 banding sites of 9 countries) were sighted and recorded during this period.

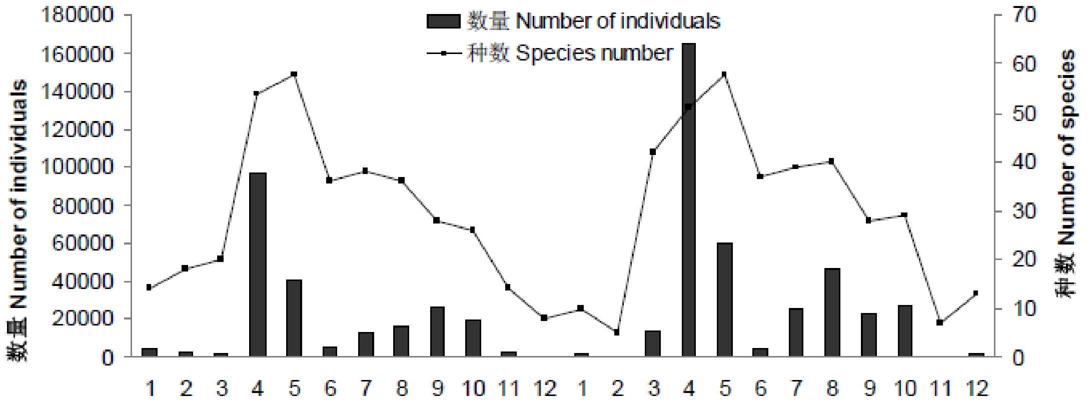

Figure 2-2 Temporal changes of wading bird abundance (bar) and species richness (line) in Dandong in 2010 and 2011

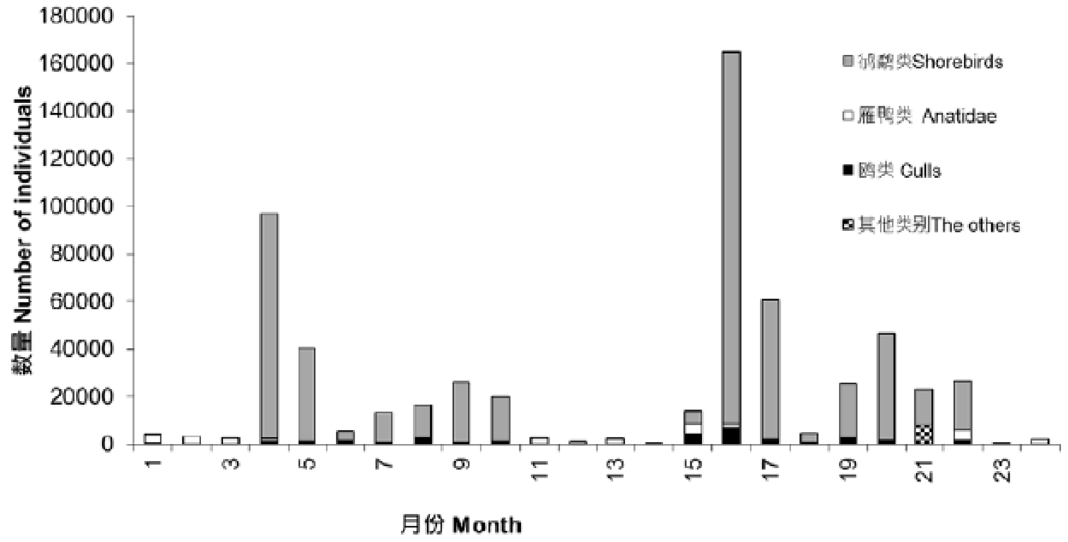

Figure 2-3 The monthly population of different types of wading birds in Dandong in 2010 and 2011

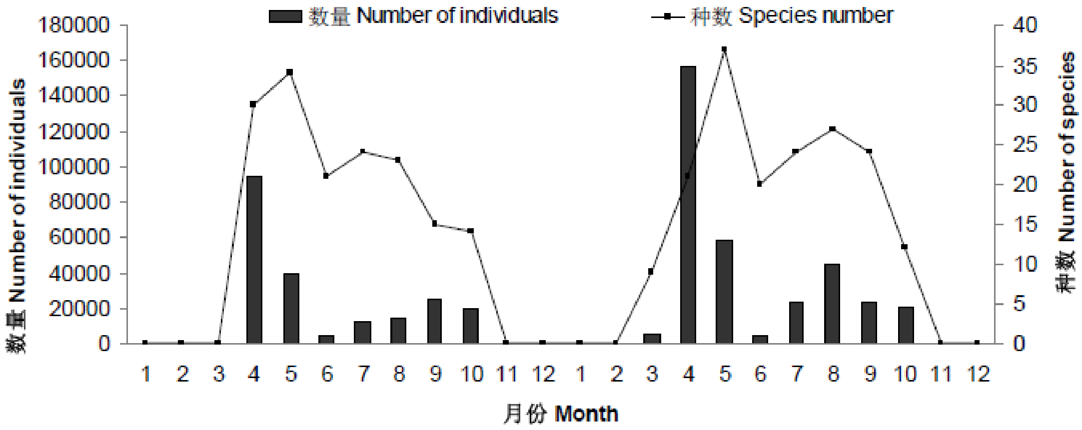

Figure 2-3 Temporal changes of shorebird abundance (bar) and species richness (line) in Dandong in 2010 and 2011.

Table 2-2 Information about the threatened species

濒危等级 **Status**	种类 **Species**	单次最大数量 **Largest number recorded**	记录时间 **date**
CR	勺嘴鹬 *Eurynorhynchus pygmeus*	2	26-31 May, 2010 15-30 May, 2011
EN	小青脚鹬 *Tringa guttifer*	24	5 May, 2011
EN	中华秋沙鸭 *Mergus squamatus*	8	8 Nov, 2011
EN	黑脸琵鹭 *Platalea minor*	6	15Jun, 2010
EN	东方白鹳 *Ciconia boyciana*	1	Apr, 2011
VU	鸿雁 *Anser cygnoides*	27	12 Mar, 2011
VU	小白额雁 *Anser erythropus*	7	Apr, 2011
VU	花脸鸭 *Anas formosa*	365	12 Mar, 2011
VU	白头鹤 *Grus monacha*	99	21,25 Mar, 2010
VU	黑嘴鸥 *Larus saundersi*	383	15 Jun, 2010
VU	遗鸥 *Larus relictus*	269	12 Mar, 2011
VU	黄嘴白鹭 *Egretta eulophotes*	22	02 Sep, 2011
VU	大杓鹬 *Numenius madagascariensis*	5,289	16-17 Jul, 2011
VU	大滨鹬 *Calidris tenuirostris*	40,038	21 Apr, 2011

The results of the 2010-2011 survey in the Dandong Yalu River estuary area recorded 108 species of wading birds, of which Shorebird was the most abundant of 42 species, followed by 28 species of ducks. The average monthly survey was 25,063, the largest number is 164,949 in April 2011. A total of 14 endangered species of threatened bird species were recorded, including Spoon-Billed Sandpiper and Nordmann's Greenshank. A total of 20 species of wading birds in a single survey numbered 1% or more of the standard record, of which 15 species of ferns. These results prove once again that the Yalu River estuary wetlands in the East Asia-Australia migration route of migratory wading birds, especially shorebird, have a very important value of stop. Protecting the wetlands of the Yalu River estuary is of irreplaceable significance for the protection of these endangered threatened bird species.

2.2 The shorebird in the East bank of Yalu River estuary (DPRK)

At the same time of Yellow Sea-Bohai Region, international wading bird survey 2018 was completed in the east bank of Yalu River (DPRK) with the help of Miranda Shorebird Center （New Zealand） and ROK team.

Miranda Team: Adrian Riegen, David Melville, Keith Woodley

ROK Team: Ri Song, Il, Ju Song I, Im Song Hyok, Kim Ji Hyang, Ri Chung Song, Ri Chol Ju

The survey area includes Sindo island and Ryongampo. A total of 19 species of shorebird and other wading birds were counted, with a total of more than 20,000. As expected, it is an important habitat for north Korea as well as east Asia and Australia migratory routes of wading birds. In Sindo island, 3 species of wading bird meet identification standard for international importance standards: the Far Eastern Curlew, Eurasian Curlew and the Bar-tailed Godwit.

Figure 2-4 The Team for the wading bird survey in the east bank of Yalu river (DPRK),2018

Table 2-3 Wading bird Counts in Yalu river wetland（DPRK）2018

Wading bird Counts in Yalu river wetland（DPRK）2018.04 **Total：24924**		
Scientific Name	**Common Name**	Number

	GREBES	
Tachybaptus ruficollis	Little Grebe	20
	SWANS, GEESE & DUCKS	0
T. tadorna	Common Shelduck	105
A. poecilorhyncha	Spot-billed Duck	102
A. clypeata	Northern Shoveler	25
	SHOREBIRDS	
P. squatarola	Grey Plover	739
C. alexandrinus	Kentish Plover	1
L. lapponica	Bar-tailed Godwit	13053
Numenius phaeopus	Whimbrel	72
N. arquata	Eurasian Curlew	2690
N. madagascariensis	Far Eastern Curlew	3895
C. tenuirostris	Great Knot	502
C. alpina	Dunlin	1910
	GULLS & TERNS	
L. argentatus	Herring Gull	1200
L. ridibundus	Black-headed Gull	600
L. saundersi	Saunder's Gull	7
S. albifrons	Little Tern	3

图 8 薪岛的斑尾塍鹬

Figure 2-5 Bar-tailed Godwit in Sindo, DPRK

3. The transition of wetland types in Yalu estuary

3.1 The history of the exploitation in Yalu river estuary

China has a long history of exploitation the Yalu estuary wetland, in the Han dynasty, some criminals were sent to reclaim land and develop agriculture in 132 AD. After 1860, the Government allowed private exploitation of the region, speeding up the economic and social development of the region, and later accelerated the process of agricultural modernization in the region due to the infiltration of foreign capital. In 1945, with the end of the war, Dandong quickly grew into an important coastal city, and the relationship between human and wetland became huge and complex changes. With the developing of productivity, the relationship between people and wetlands was imbalanced.

In recent years, with the change of economic development mode and the improvement of environmental awareness at all levels, wetland development and protection has gradually entered a healthy and sustainable stage. In 2018, the State Council issued an order suspending all reclamation activities， and investing heavily in coastal habitat restoration, which has worked well.

3.2 The transition in recent years of the wetland in Yalu river estuary

Zhang Chunpeng et al. (2014) carried out dynamic monitoring and analysis of the evolution of the wetland structure of the Yalu River estuary by comparing remote sensing data from the three phases of 1983, 1995 and 2007. Between 1983 and 2007, the area of the various types of the Yalu River estuary wetland increased or decreased, and the total area of wetlands increased. The main sources of increase are rice paddies and farms, with significant human impact. The main types of declining wetlands were mudflat and reeds, which decreased at a rate of 1.97 km^2 and 2.28 km^2 per year respectively.

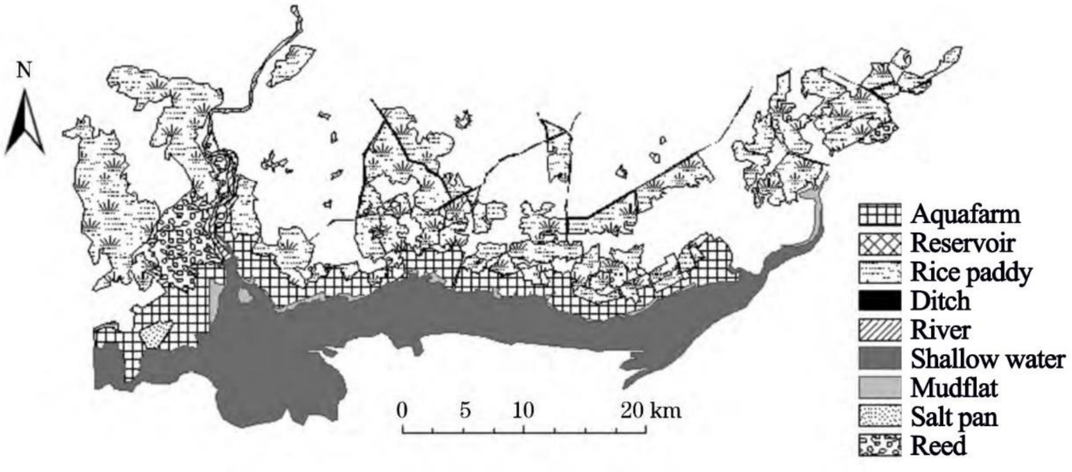

Figure 3-1 Configuration of wetland in Yalu river estuary in 1995.

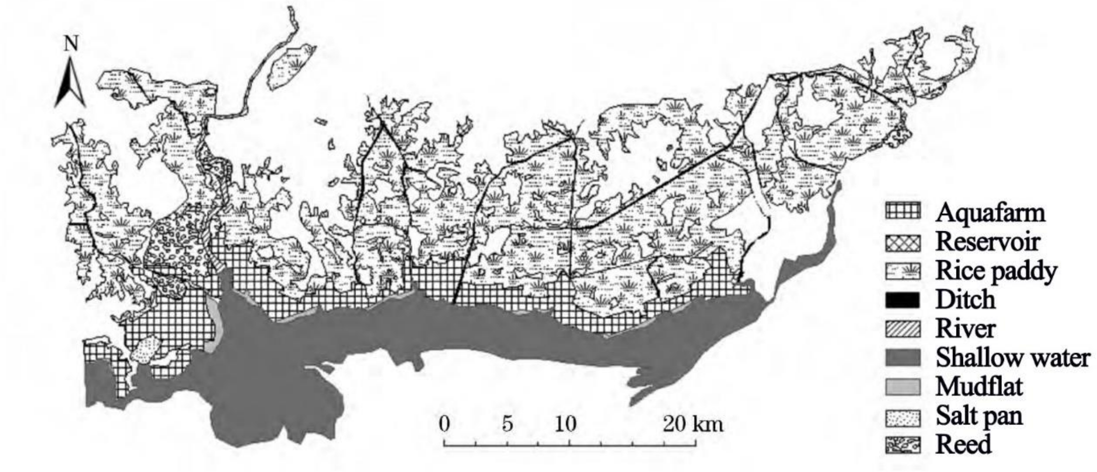

Figure 3-2 Configuration of wetland in yalu river estuary in 2007.

XU Yingxue et al. (2006) analyzed the type of wetland in Yalu River estuary protected area. Rice paddy is the main type of cultivated land, but also the main wetland type in this area. Arable land, including water fields and dry fields, accounts for 54.32% of the total area of the protected area, of which water fields account for 41.55% of the protected area. Mudflat is the second largest wetland type, distributed in the coastal intertidal zone, periodically flooded by sea water. Although 3.8043 km^2 of the mudflat was developed into shrimp pond, rivers and tides were washed away 2.1645 km^2, but the silt at the estuary was newly silted into 13.7349 km^2. Compared with 1989, the area of mudflat increased by 7.7319 km^2 in 2000. Shrimp pond was mainly developed from the mudflat, rice paddy or reed marshes. According to statistics, of all the 17.637 3 km^2 shrimp ponds, 8.005 5 km^2 came from reed marshes, 5.764 5 km^2 from the rice paddy,

$3.8043\ km^2$ from the mudflat. And at the same time $3.3858\ km^2$ shrimp ponds converted to other land use types.

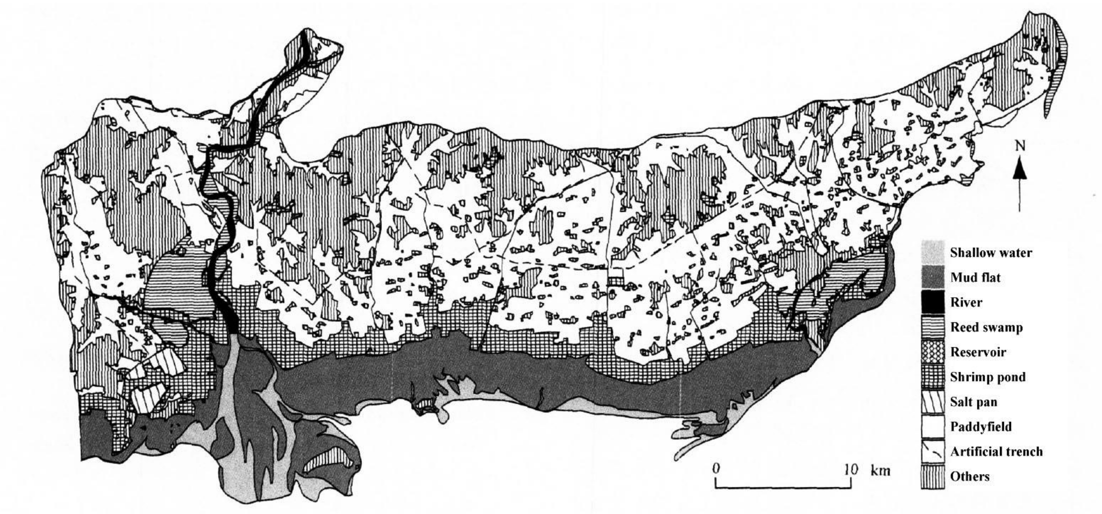

Figure 3-3 The land utilization of coastal wetland around Yalu River estuary in 2000

4. Food supply for migratory birds in Yalu river estuary wetland

As an important wetland on the East Asian-Australasian Flyway migration path, the Yalu River estuary can add enough energy to shorebird and eventually fly to the breeding grounds. According to the research of the experts from Fudan University, when Bar-tailed Godwit, Great Knot, and Dunlin arrived at the Yalu River, they weighed about 240g, 130g, and 50 g, respectively. However, when they leave, they weighed about 480, 240, and 80 g, respectively, and almost gained their weight nearly doubled.

In the spring of 2007-2012, HUA Ning studied two stopping sites in the north and south of the Yellow Sea (Chongming Dongtan in the south and Yalu River estuary in the north of the South) using radio telemetry, directional cage experiments, field surveys and body composition analysis. The shorebird appeared different effects on the long-distance migration . The average stay of The Great Knot individuals at Chongming East Beach was only 2.3 days, while the average stay at the mouth of the Yalu River was 31 days. The average weight of the population during the Great Knot stop at Chongming East Beach did not change significantly, leaving Chongming East Beach was not enough to fly directly to the breeding ground, while the average weight gain in the population during the stop at the mouth of the Yalu River was nearly double, and the energy carried by the left-green estuary was enough to fly directly to the breeding ground. Great Knot of Chongming East Beach had a higher level of migration excitement in windy weather conditions, which was consistent with the results found in field observations that shorebird tended to set off in windy conditions and stop in headwinds; however, it is not affected by weight or wind conditions, which suggests that their migration may be strongly influenced by internal rhythms. In addition, studies of changes in the average weight of the population of shorebird in the southern and northern parts of the Yellow Sea, which migrate long distances such as Red Knot and Bar-tailed Godwit, also showed that birds accumulated significantly less energy in the southern Yellow Sea than in the northern region. This study shows that the southern and northern parts of the Yellow Sea play different roles in long-distance migration: the southern region serves primarily as a temporary resting place for birds, plays an important role in the infirm individuals and in weather conditions that are not conducive to migration;

SONG Lun studied shorebird's feeding pressure on benthic organisms in 2011 by studying the changes in benthic communities before and after the migration season at the estuary of the Yalu River. The peak migration of three dominant shorebirds in 2011 were: Bar-tailed Godwit, March 28 - April 28; Great Knot, April 7-May 15; Dunlin March 28-May 10. In order to study shorebird's feeding pressure, the most abundant sections of the selection of bait organisms were followed on March 21 to 22, April 15 to 16, and May 31 to June in 2011 (shorebird arriving, peak, and departure, respectively). The results showed that the abundance of food species in the mid- and low-tide zone was not changed significantly from March to April, while the decline in the lower region of the low tide zone was changed more significantly, especially the decline of the *Moerella jedoensis*; the variation of the tide zone food species was not changing significantly from March to April. Shorebird's feeding pressure on food species peaked at the peak of migration (mid-April), but after leaving, the abundance and biomass of the food species returned to normal levels, indicating that the population replenishment capacity of the food species in the study area was strong.

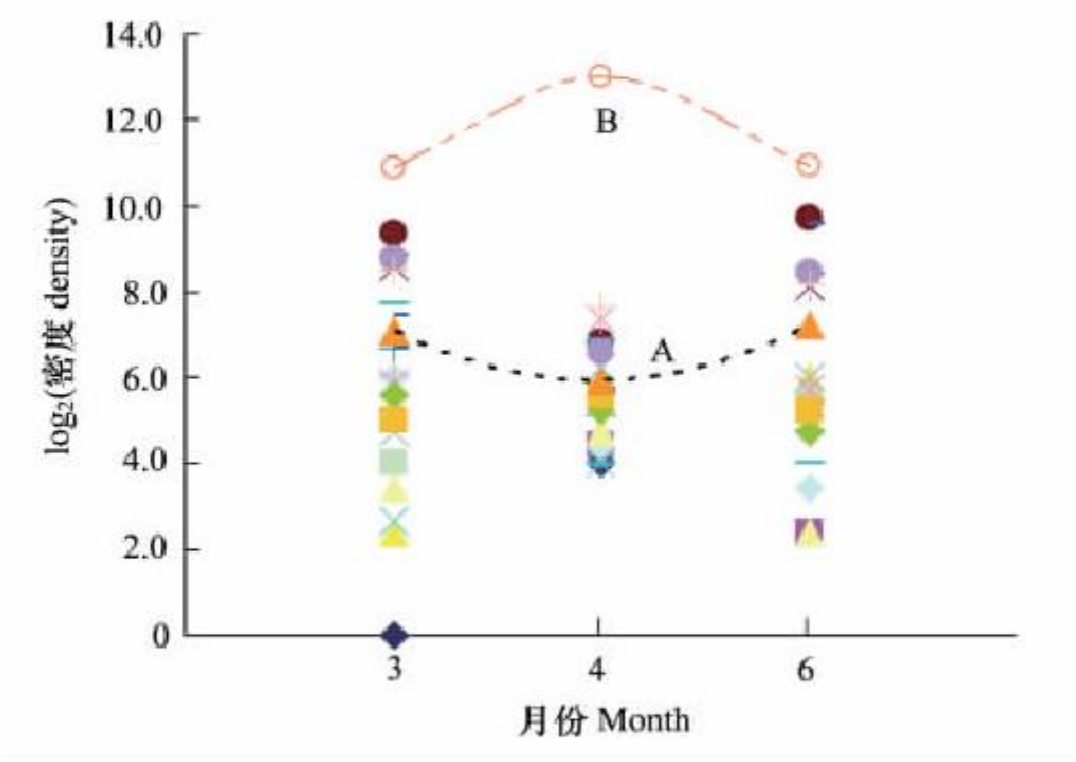

Figure 4-1 The influence law of shorebirds to density of food organisms

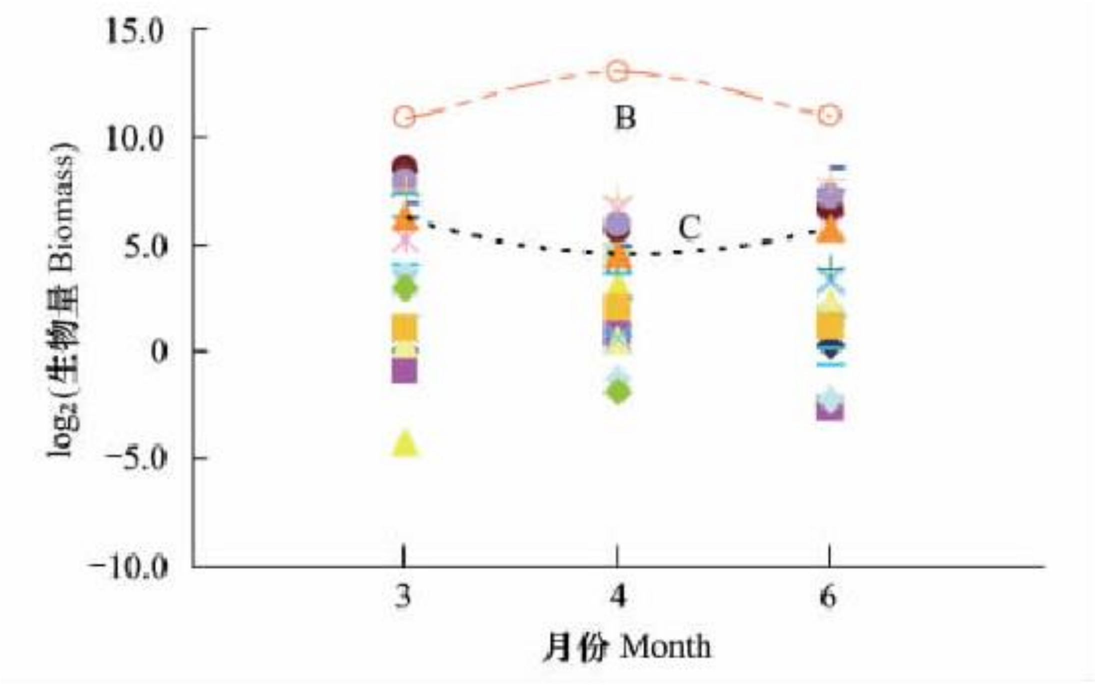

Figure 4-2 The influence law of shorebirds to diet biomass

LI Ai ‘s study (2014) showed that in the three key biological components of the coastal wetlands at the estuary of the Yalu River, the benthic fauna provides sufficient food sources for migratory birds, which do not pose a significant threat to farmed shellfish communities, while artificial shellfish farming affects the natural distribution of shellfish species in benthic communities. In the 2010 survey, a total of 29 species of intertidal benthic animals were recorded, including 5 species of artificial breeding seedling, 18 species of natural lysing non-harvested species, with an average density of 84 ind./m^2. The community structure is relatively simple, with molluscs accounting for 52.0% of the total species and 75.9% of the total number. There are six species of intertidal animals, including *Moerella jedoensis*, *bullacta ex-arata*, *cyclina sinensis*, and *Meretrix meretrix* as well as the *Glycera chirori* and *Platynereis bicanaliculata*. In the early 1980s, the dominant species of the Yalu River estuary were *Dosinorbis japonica*, *Dosin-ia laminata*, *Scapharca subcrenata*, *Solen strictus*, etc., but it's hard to collect at the present time. And the widely distributed bottom-shaped benthic species - *Bullacta exarata* has been replaced as the dominant species. There is a competition between *Bullacta exarata* and other molluscs for living space and food. But its body surface secretes a toxic mucus which makes it not to be eaten by shorebird. This community structure is obviously not conducive to the healthy development of the ecological function of the migration stop at the mouth of the Yalu River.

According to Zhang Shoudong’s study in 2018, monitoring of the macrozoobenthos, considered as food for these shorebirds, from 2011 to 2016 showed declines of over 99% in the densities of the bivalve *Potamocorbula laevis*, the major food here for both Bar-tailed Godwits and Great Knots. The loss of the bivalve might be caused by any combination of, but not limited to: (1) change in hydrological conditions and sediment composition due to nearby port construction, (2) run-off of agrochemicals from the extensive shoreline sea cucumber farms, and (3) parasitic infection. Surprisingly, the numbers of birds using the Yalu Jiang coastal wetland remained stable during the study period, except for the subspecies of Bar-tailed Godwit L. l. menzbieri, which exhibited a 91% decline in peak numbers. The lack of an overall decline in the number of bird days in Great Knots and in the peak numbers of L. l. baueri, also given the published simultaneous decreases in their annual survival, implies a lack of alternative habitats that birds could relocate. This study highlights that food declines at staging sites could be an overlooked but important factor causing population declines of shorebirds along the Flyway. Maintaining the quality of protected staging sites is as important in shorebird conservation as is the safeguarding of staging sites from land claim. Meanwhile, it calls for immediate action to restore the food base for these beleaguered migrant shorebirds at Yalu Jiang coastal wetland.

In total 8,835 macrozoobenthic individuals (from 11 classes, 65 families, and 94 genera or species) were collected at Yalu Jiang in 2011–2016. More than 98% of the individuals came from six classes (Anthozoa, Polychaeta, Malacostraca, Bivalvia, Gastropoda, and Inarticulata). The most common taxa were *Potamocorbula laevis* (45.6% of the total individuals), *Capitellidae* (Polychaeta, 17.7%), *Nephtys ciliate* (Polychaeta, 5.7%), *Bullacta exarata* (Gastropoda, 3.6%), *Glycera chirori* (Polychaeta, 2.6%), *Mactra veneriformis* (Bivalvia, 2.6%), *Stenothyra glabar* (Gastropoda, 2.1%), and *Moerella iridescens* (Bivalvia, 1.5%). The macrozoobenthos taxa found were similar among years, while the inter-annual variation in biomass was significant ($F = 5.23$, $P < 0.01$, $n = 264$). The macrozoobenthos biomass (mean per month from March to May, mean ± SE) declined by 83% from 2011 and 2012 (means of 20.55 ± 6.19 g AFDM m-2 from the entire core and 16.34 ± 4.54 g AFDM m^{-2} from the upper 5 cm) to 2013–2016 (means of 3.35 ± 0.91 g AFDM m^{-2} from the entire core and 2.74 ± 0.66 g AFDM m^{-2} from the upper 5 cm) (Figures 4-3 and 4-4). This was a consequence of a huge decline in the abundance and biomass of *P. laevis*. Numbers declined by 99.7% from 2011 (708.06 ± 175.66 ind m^{-2}) to 2016 (2.21 ± 2.21 ind m^{-2}) (Figure 4-5) and biomass declined by 99.9% from 2011 (14.00 ± 4.76 g AFDM m^{-2}) to 2016 (0.01 ± 0.01 g

AFDM m^{-2}) (Figure 4-3). A dramatic decrease of P. laevis was the main cause to the decline of the macrozoobenthos: *P. laevis* accounted for 94% of the total macrozoobenthos biomass (across months) in 2011, but only 0.3% in 2016 (Figure 4-5). The biomass of other groups did not exhibit a significant decline ($P > 0.1$ for all)

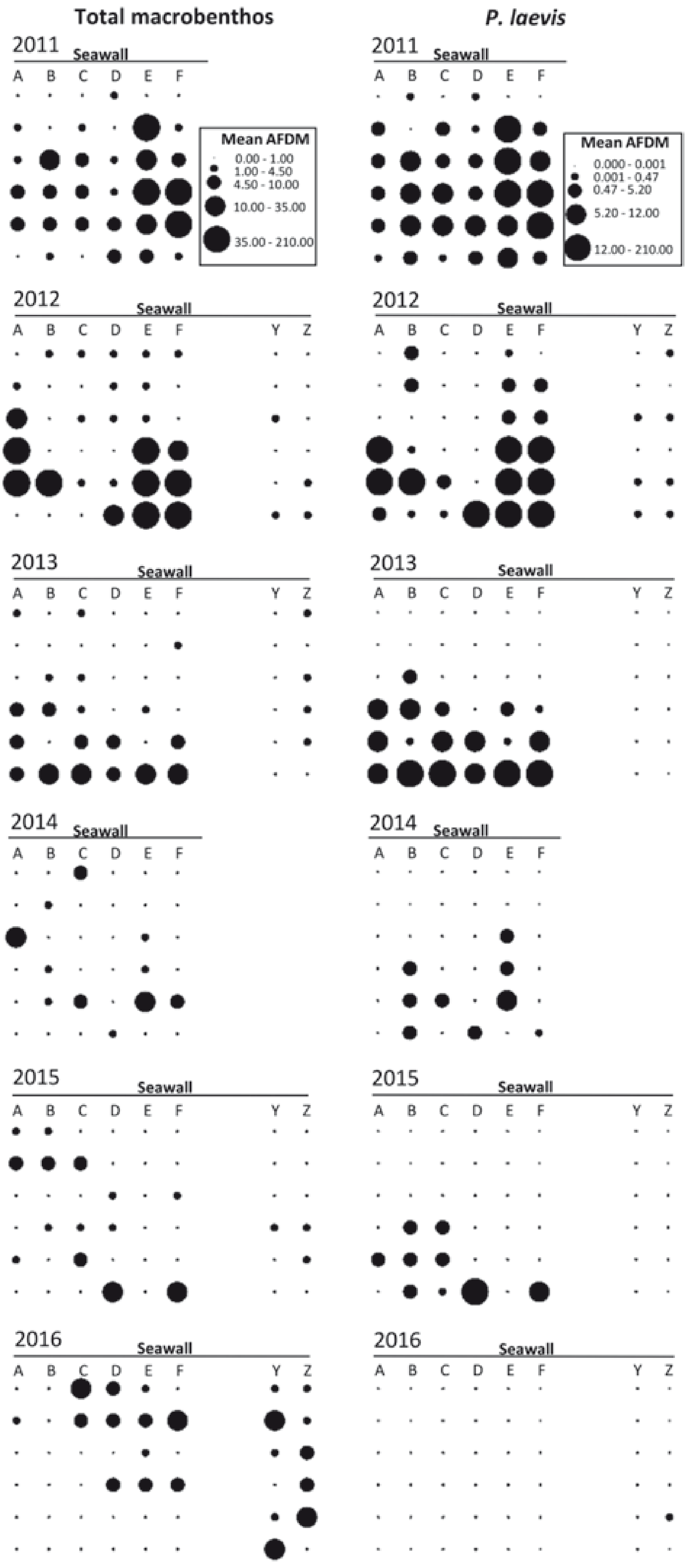
Total macrobenthos
P. laevis
2011
2012
2013
2014
2015
2016
Seawall
A B C D E F
Y Z
Mean AFDM
0.00 - 1.00
1.00 - 4.50
4.50 - 10.00
10.00 - 35.00
35.00 - 210.00
Mean AFDM
0.000 - 0.001
0.001 - 0.47
0.47 - 5.20
5.20 - 12.00
12.00 - 210.00

Figure 4-3 Distribution of benthos biomass across the intertidal flats from 2011–2016. Circles show the mean biomass (g AFDM m-2) for March–May for the total macrozoobenthos (left-hand plots) and P. laevis (right-hand plots). Data represent the benthos contained in the upper 5 cm sampled from 36 sampling stations in 2011 and 2014 and 48 sampling stations in 2012, 2013, 2015, and 2016.

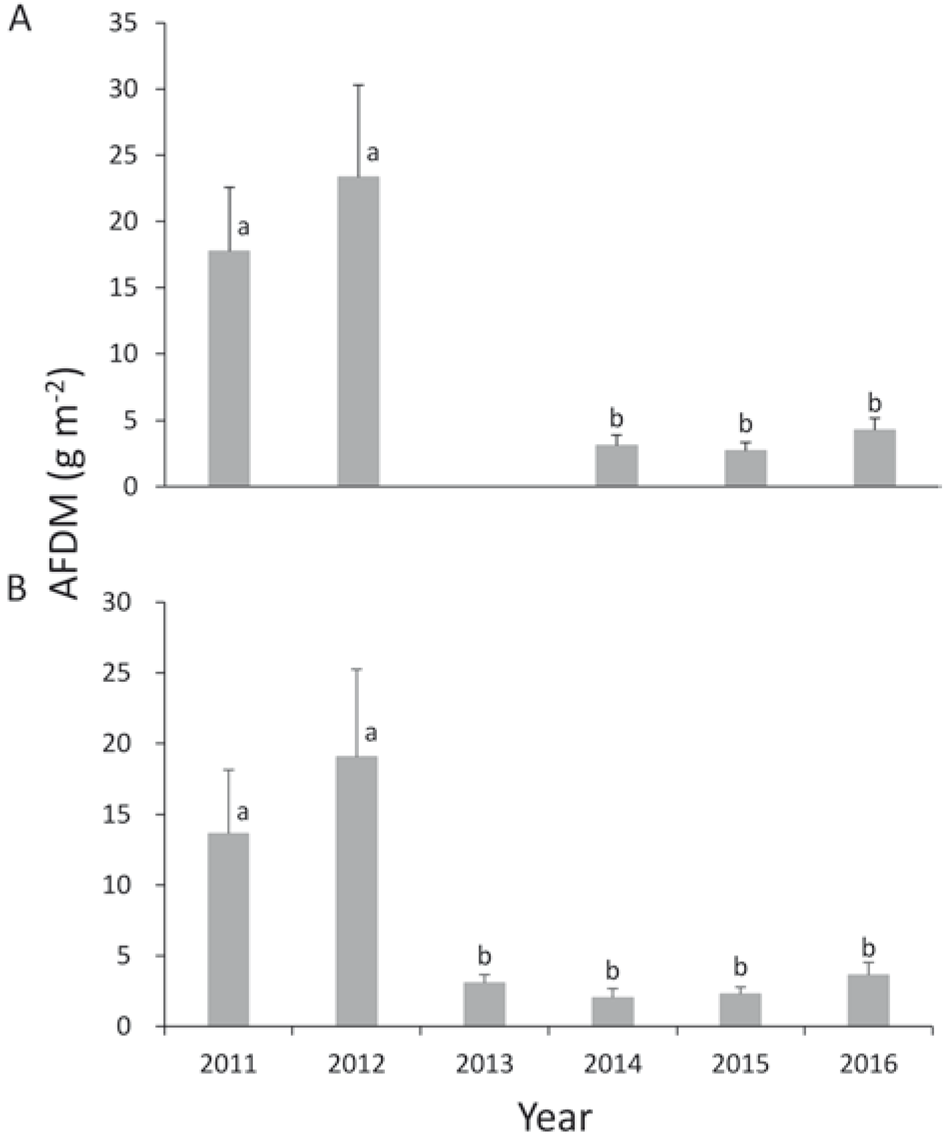

Figure 4-4 Annual variation from 2011–2016 in the mean

macrozoobenthos biomass (total AFDM from all taxa, averaged from March–May). (A) shows total biomass in the whole 30 cm cores (except 2013); (B) shows the biomass in the upper 5 cm. Different lower-case letters represent significant differences between years ($P < 0.05$).

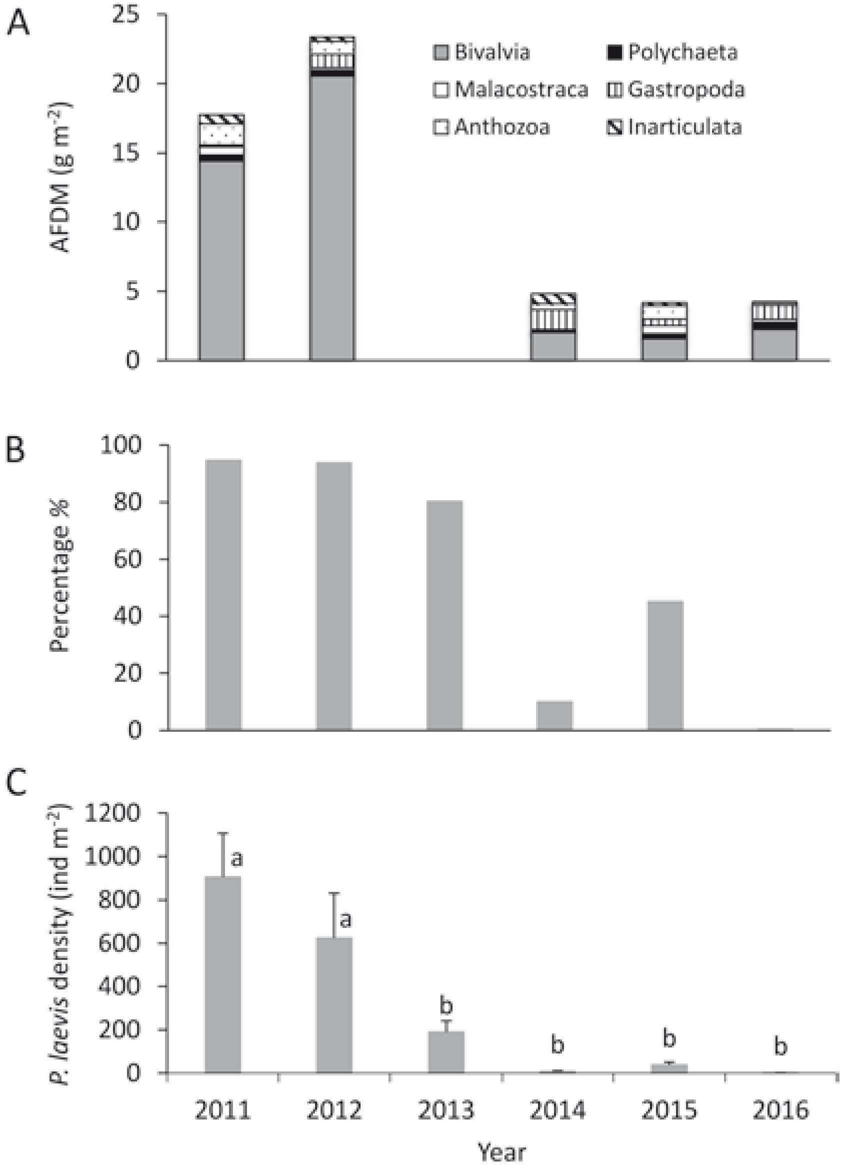

Figure 4-5Macrozoobenthos by taxonomic group by year from 2011–2016. (A) AFDM of Bivalvia, Polychaeta, Malacostraca, Gastropoda, Anthozoa and Lingulata. (B) Percentage of the bivalve P. laevis AFDM in the total

Bivalvia AFDM. (C) Annual variation in the mean density (March–May) of P. laevis. Different lower-case letters represent significant differences between years ($P < 0.05$). N equals 36 sampling stations in 2011 and 2014 and 48 in 2012, 2013, 2015 and 2016.

5. Effects of sea level rise on wetland in Yalu river estuary

From 1980 to 2018, the sea level of China has kept rising at a rate of 3.3 mm / year, higher than the global average level over the same period.

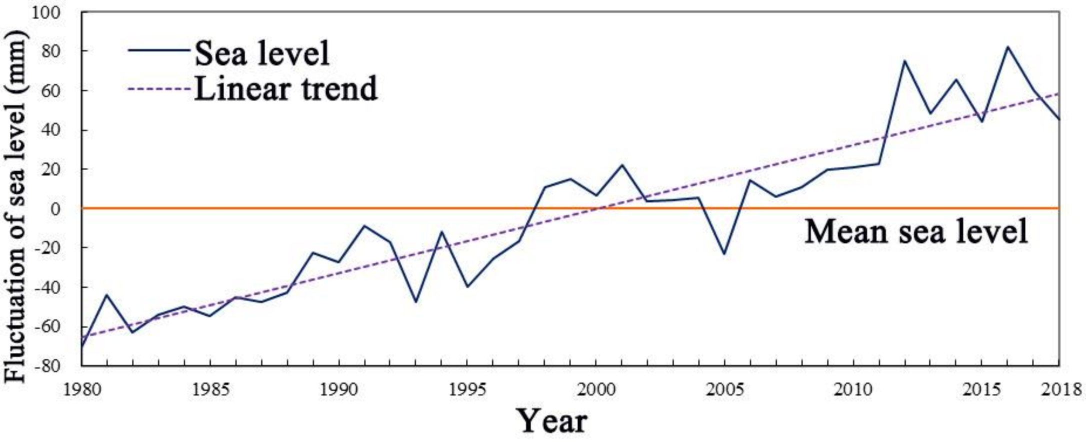

Figure 5-1 The sea level of China from 1980 to 2018

In 2018, the sea level along the yellow sea was 28 mm higher than average. The sea level in August was the second highest in the same period since 1980, 105 mm higher than the average in the same period of the years.

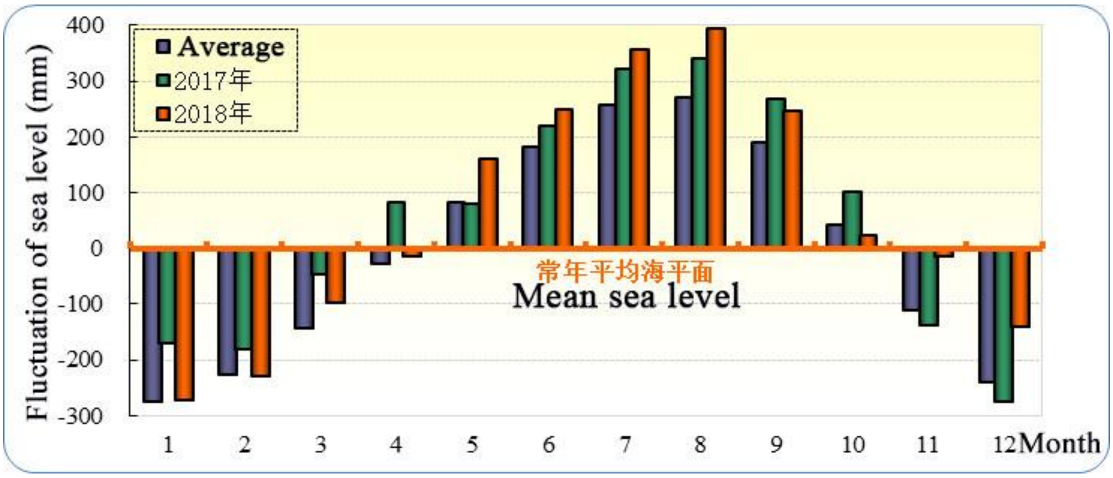

Figure 5-2 Monthly mean sea level changes along the yellow sea in 2018

Sea levels along the yellow sea are estimated to rise by 70 to 165 mm in the next 30 years.

The long-term cumulative effect of sea level is persistent, which directly causes mudflat lost, lowland inundation and habitat damage or change, and leads to the aggravation of storm surges, coastal urban floods, salt tides, coastal erosion and seawater intrusion. At the same time, the ground subsidence of coastal areas leads to relative sea level rise, which increases the risk of disasters in coastal zones.

(a) Storm surge

High sea level raises the basic water level of the storm's water, increasing the damage of storm surge disaster.

(b) Flooding in coastal area

The discharge of floods from the sea-level top-to-sea channels at high sea levels increases the difficulty of flooding and drainage in coastal area and aggravates flooding. The main urban area of Dandong City is only 30 km from the mouth of the Yalu River, and the Dandong section of the Yalu River belongs to the tidal section. With the tide rising and falling, a large number of marine sediment was brought upstream by the tide, covering the entire river bottom and shoal, the river bed was gradually raised, affecting the flood discharge.

(c) Salt tide

Sea level, tides, storm surges and upstream water affect the distance and degree of salt tide invasion.

(d) Coastal erosion

Sea level rise leads to increased wave and tidal energy, increased storm surge, increased coastal erosion and shore erosion, while increasing the difficulty of repairing erosion coasts.

(e) Seawater intrusion

Sea level rise exacerbates the degree of seawater intrusion and affects coastal ecosystems and industrial and agricultural production.

As sea levels rise, some intertidal zones are submerged by seawater, beach areas will gradually decrease, and the loss of habitat will directly threaten the population of the species. Rising sea levels will also change the current conditions and silting balance of the Yalu River estuary.

The National Geographic made a prediction in 2013. If we keep burning fossil fuels indefinitely, global warming will eventually melt all the ice at the poles and on mountaintops, raising sea level by 66m. At that time, most of the urban area in Dandong will be covered by sea water.

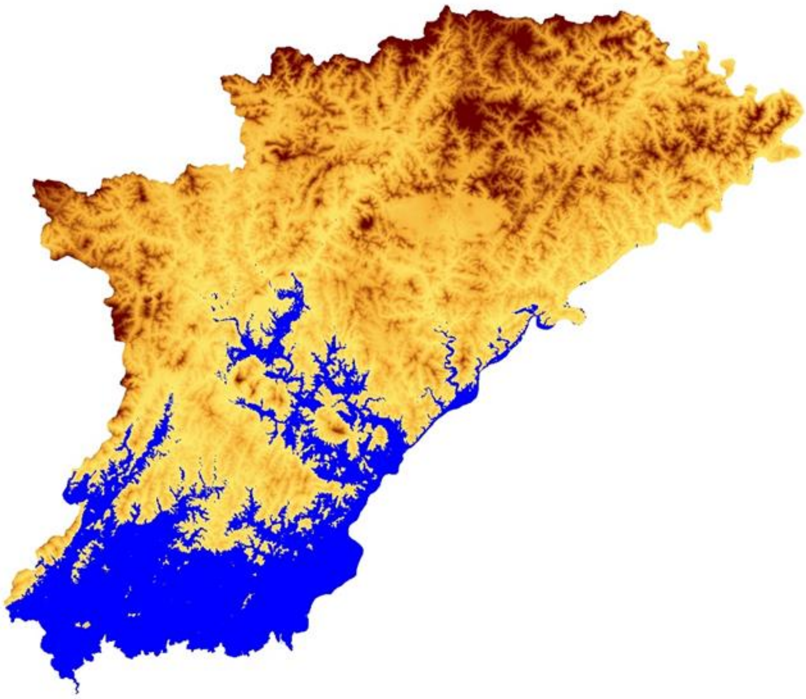

Figure 5-3 The situation of Dandong when all the ice melted at the poles and on mountaintops

6. Adoption and Management Measures

In order to effectively cope with the impact of sea level rise and ensure the sustainable economic and social development and ecological civilization construction of coastal areas, scientific investigation monitoring and evaluation should be strengthened, ecological protection and restoration should be strengthened, and land-sea space planning and strict use control should be optimized.

6.1 Strengthening the monitoring and evaluation of scientific investigations

Scientifically promote the construction of sea level survey and monitoring system, improve the level of sea level rise analysis and prediction and impact assessment technology, and provide support for ecological protection restoration and land-sea space use control.

Optimize the existing ocean observation network, strengthen the benchmark tide level approval, unify the coastal sea level elevation benchmark, grasp the facts of sea level change, carry out in-depth research on the attribution and estimation of sea level change, and scientifically estimate the future trend of sea level change.

Carry out the investigation of the impact of sea level rise on storm surges, coastal urban floods, salt tides, coastal erosion, seawater intrusion, typical coastal ecosystems and coastal engineering; Strengthen the monitoring of ground subsidence and embankment elevation in coastal areas to prevent the increased risk of relative sea level rise due to ground subsidence and improve the defense capability of marine disasters.

Actively promote pilot assessments of typical regions affecting the impact of sea level rise, conduct assessment of the impact of sea level rise on beach-draped areas, study the impact of sea-level rise and coastal zone development activities and coastal engineering construction on coastal erosion in key coastal areas, and provide a scientific basis for the rehabilitation of coastal zones.

6.2 Protection and restoration of existing habitats

Sea level rise threatens the integrity of coastal ecosystems and natural landscapes, and we should combine protection with the management of the whole process of restoration, strengthen the conservation of coastal ecosystems, research and development of restoration technology and promote the application, and enhance the function of ecosystem services.

In the important ecological protection areas along the coast, strengthen the protection of coastal vegetation, mudflat and near-shore sand reefs, avoid destroying vegetation and large-scale excavation and other development activities, maintain the natural characteristics of the ecosystem, and reserve land-based living space for the coastal ecosystem.

Depending on the natural function of the coast, ecological restoration of the coastal zone is carried out by means of vegetation restoration, beach conservation and shore protection, creating buffer zones on coasts affected by sea level rise, and enhancing resilience to and adaptation to sea level rise.

To promote the construction of ecological seawall, to transform the existing coastal engineering protection system based on the concept of ecological protection and care, and to take measures such as slope protection with beach protection, engineering and biological combination, giving priority to moisture safety, taking into account the function of landscape greening, and forming a three-dimensional coastal protection model to cope with sea level rise.

The implementation of ecological seawall construction, through ecological technical to promote the existing coastal engineering protection project, the adoption of slope protection and beach protection, engineering and biological combination of measures, giving priority to moisture safety, taking into account the function of landscape greening, the formation of a three-dimensional coastal protection model to cope with sea level rise.

6.4 Scientific guidance and management of shellfish culture

Change the traditional shellfish culture, through innovative policy and technical, teach the fisherman to change the breeding varieties and method, improve the biodiversity, increase the species and quantity of shorebird. Through environmental education and adjustment of shellfish farmers' planting time, to reduce the feeding pressure of shorebird on seedling. Establish a certain compensation mechanism to compensate for the loss of shellfish farmers shellfish caused by shorebird. Through the above methods, at the same time strengthen law enforcement inspection, reduce the behavior of shellfish farmers to chasing or hurt birds.

All departments need to pay attention to the contradiction between the development of coastal shellfish farming and the protection of migratory birds. The important ecological function of the Yalu River estuary wetland in the migration route of east Asia-Australia flyway should be protected and the interests of coastal shellfish farmers should be taken into account.

We need to carry out environmental education and skill training to shellfish farmers in the Yalu River estuary. The low-efficiency mudflat shellfish cultivation should be gradually reduced. On the premise of ensuring the livelihood of residents, we will gradually guide shellfish farmers to switch to businesses that do not occupy tidal flat resources, such as planting and deep-water aquaculture, through training and policy arrangement.

6.5 Protection of the bird resting zone at high tide area

The high tide area can provide an area to rest for birds after foraging during high tide time, and its important role has not received enough attention before. The presence of high tide area allows birds to avoid the need to go further into the land to seek shelter. The high tide area can help the birds to keep away from human interference and to reduce the distance to the feeding area, and to reduce energy consumption.

In recent years, in order to reduce the loss caused by natural disasters such as storm surge and typhoon, seawalls and artificial shorelines have been built, and the high tide area has been gradually encroachment, and the coastlines have been artificially fixed. In the future, as the sea level rises year by year, the area of the high tide area will be further compressed or even disappear. The birds that rest there will have to go deeper into the land to find their resting place when the tide comes, consuming more energy and facing more risks. This will affect the birds' energy accumulation here, and if they cannot accumulate enough energy here, it will affect the birds' northward migration reproductive success rate, thus affecting the stability of the population.

In the future, we should try to restore the natural coastline and consider setting up some bird resting areas to provide birds with enough space away from disturbance.

6.6 Innovation in the Management Model of Community Co-management

The contradiction between protection and development has always been a prominent problem in the management of protected areas. After many years of practice of the community co-management system, it is feasible to establish the system in some nature reserves, and it can also solve the contradiction between the protection of nature reserves and the economic development of the surrounding communities.

It is necessary to make systematic provisions on the system in the legislation first, so as to determine the legal status of the system and provide a legal basis for the specific establishment of the community co-management system. Secondly, we should make specific provisions on the community co-management system in local laws or policies.

Increase the investment mechanism in community co-management, increase financial support to maintain the continued operation of community co-management activities. The establishment of community compensation and incentive mechanism Nature Reserve is a change of interest pattern for local residents, and this pattern is not conducive to local residents, but also unfair. Therefore, to compensate the local community residents for the loss of benefits, which is also the embodiment of the concept of fairness.

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