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)

Assessment of YSLME and policy recommendations

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Contents

1.Introduction of YSLME

The Yellow Sea are facing many environmental problems. Pollution, overfishing, coastal, marine engineering, red tides, macro-algae blooms, introduced species, etc. have been increasingly affecting the Yellow Sea large marine ecosystem. Against the background of global change, these factors pose a significant threat to the sustainable development of the region by providing the normal provision of marine ecosystem services in the Yellow Sea. It is of great scientific and practical significance for China and RO-Korea to jointly implement the protection and management of the YSLME by systematically assessing the changes and influencing factors of the Yellow Sea ecosystem, and then to find out the root causes of environmental problems in the Yellow Sea and to propose strategies to deal with them.

1.1 Basic information of YSLME

Yellow Sea is one of the Large Marine Ecosystems around the world, it covers an area of 400,000 km^2, and is surrounded by 3 countries, Republic of China (PRC), Republic of Korea (ROK), and Democratic People's Republic of Korea (DPRK). The geographic area of the Yellow Sea Large Marine Ecosystem (YSLME) was defined as the body of water bounded: to the west by the Chinese coastline south of Penglai; to the north by a line from Penglai to Dalian; to the east by the Korean Peninsula and Jeju Island and a line drawn from Jindo Island off the south coast of the Korean mainland to the Chaguido, west coast of Jeju Island; and to the south by a line running from the north bank of the mouth of the Yangtze River (Chang Jiang) to the south-western coast of Jeju Island.

The seafloor is a post-glacially inundated portion of the continental shelf with an average depth of 44m and a maximum depth of 140m: the seafloor slopes gently seawards from the Chinese coast and more steeply from the Korean peninsula to a trough in the eastern portion of the basin that runs south to the Okinawa Trench. This trough was carved by the ancient Yellow River (Huang He) when the Yellow Sea was dry during the last glacial period. Meteorologically, the region is located between the Siberian High and the subtropical Pacific Low, which results in cold-dry winters and warm-wet summers.

Figure 1-1. The bordering of Yellow Sea

The bio-geochemistry of the sea is strongly influenced by fresh water and airborne (aeolian) material. Rivers discharge approximately 1.6 billion tonnes of sediment and 1,500 billion tonnes of freshwater into the Yellow Sea annually and 460 billion tonnes of water from rainfall. The huge freshwater inputs result in temperature and salinity differences that limit the water exchange between the Yellow Sea and the East China Sea resulting to a low flushing rate of once every seven years. The low flushing rate combined with weak water circulation makes this sea vulnerable to pollution and its coastal areas highly susceptible to localized pollution discharges. The Yellow Sea is under the influence of the Asian monsoon system, and circulation is predominantly influenced by winter cooling and summer heating, freshwater discharge and the inflow of warm saline waters in a branch of the Kuroshio current.

1.2 Main features of physical oceanography

The major water masses of the Yellow Sea are: 1) the Yellow Sea Cold Water Mass at the bottom of the basin; 2) the Yellow Sea Warm Current Water, which is relatively saline and flows north-west into the Jeju Strait and eastern Yellow Sea; and 3) the Yangtze River mixed water, which predominantly flows to the South but in the summer extends north-eastwards towards Jeju Island and lowers the salinity of the water. Summer circulation consists of the southward flowing Chinese coastal current, northward flowing Yellow Sea Warm Current, and north-eastward moving water from the East China Sea resulting in a central cyclonic gyre. In the winter the cyclonic gyre is not as pronounced and a southward coastal flow is seen adjacent to the Korean Peninsula.

Yellow Sea Cold Water Mass (YSCWM) well developed in summer;

Yellow Sea Warm Current (YSWC)

Changjiang Diluted Water (CDW) influence in the south

1.3 Higher level of nutrient and productivity

The Yellow Sea is part of the temperate shelf seas of the North temperate Indo Pacific Ocean and supports five major, highly productive, marine habitats. YS supports a large population of fish, birds, mammals and invertebrates. These form a substantial living marine resource base for the large human coastal population.

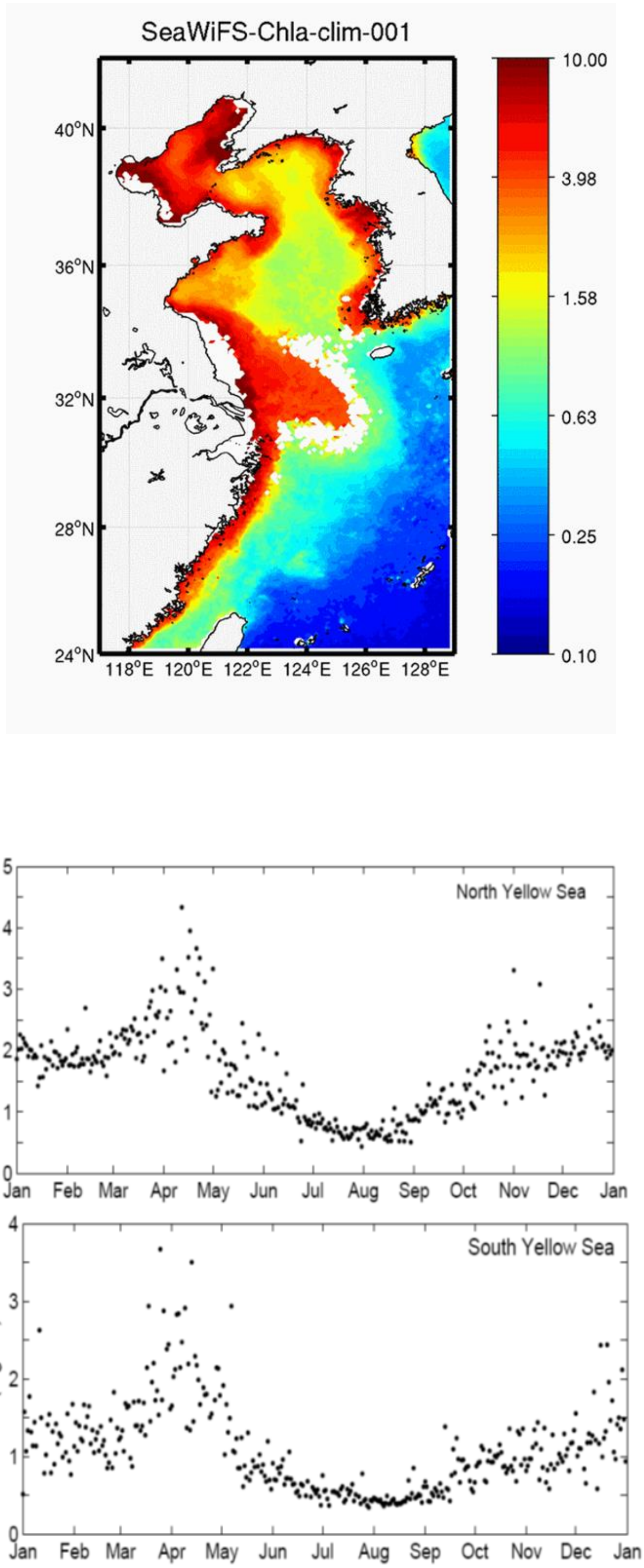


Figure 1-2. SeaWiFS Climatology data

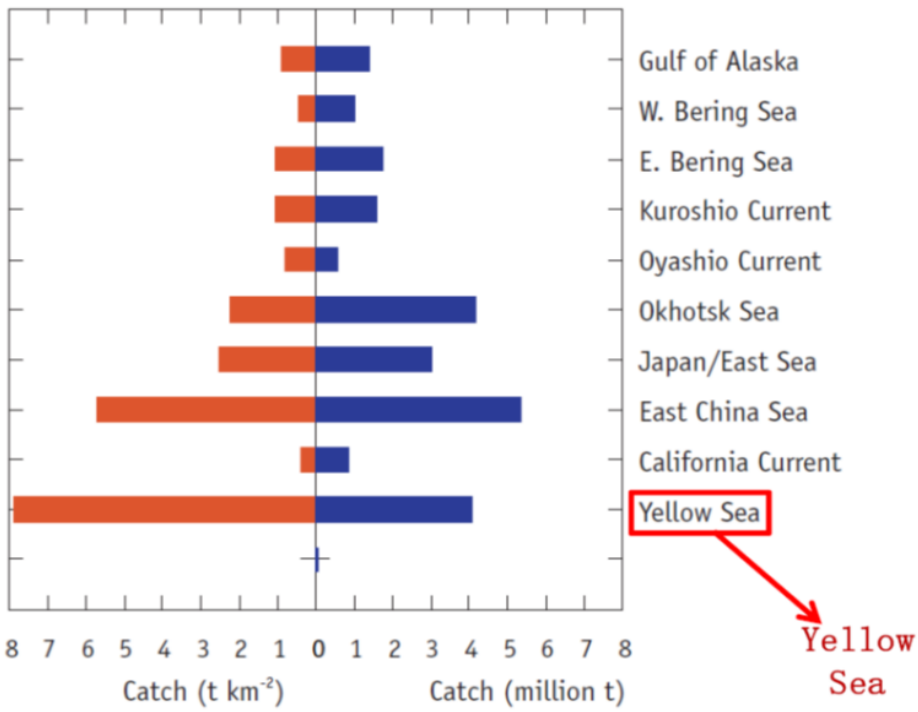


Figure 1-3. The fishery catchment in the north Pacific regions (PICES NPESR, 2004)

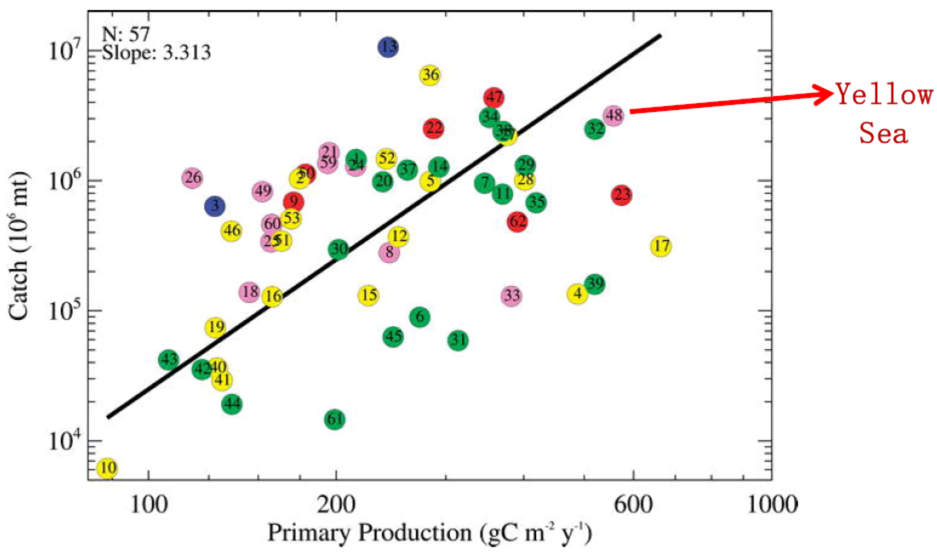


Figure 1-4. The Primary Production of LMEs (Sherman et al, 2009, AMBIO)

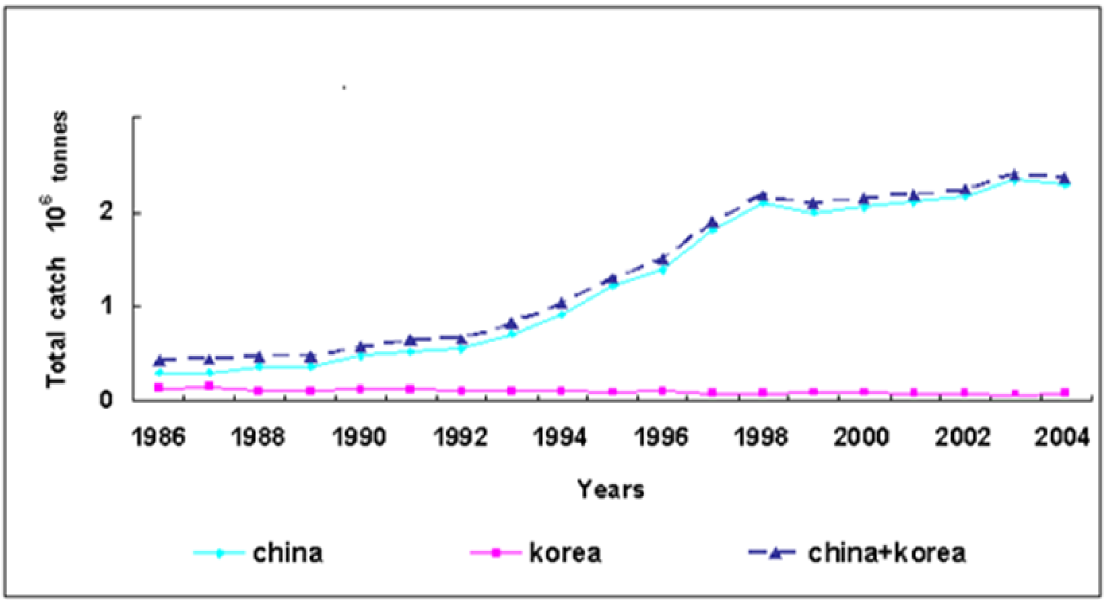


Figure 1-5. Temporal Trend for the Catch from the Yellow Sea of 10 Commercially-Important Species, 1986-2004

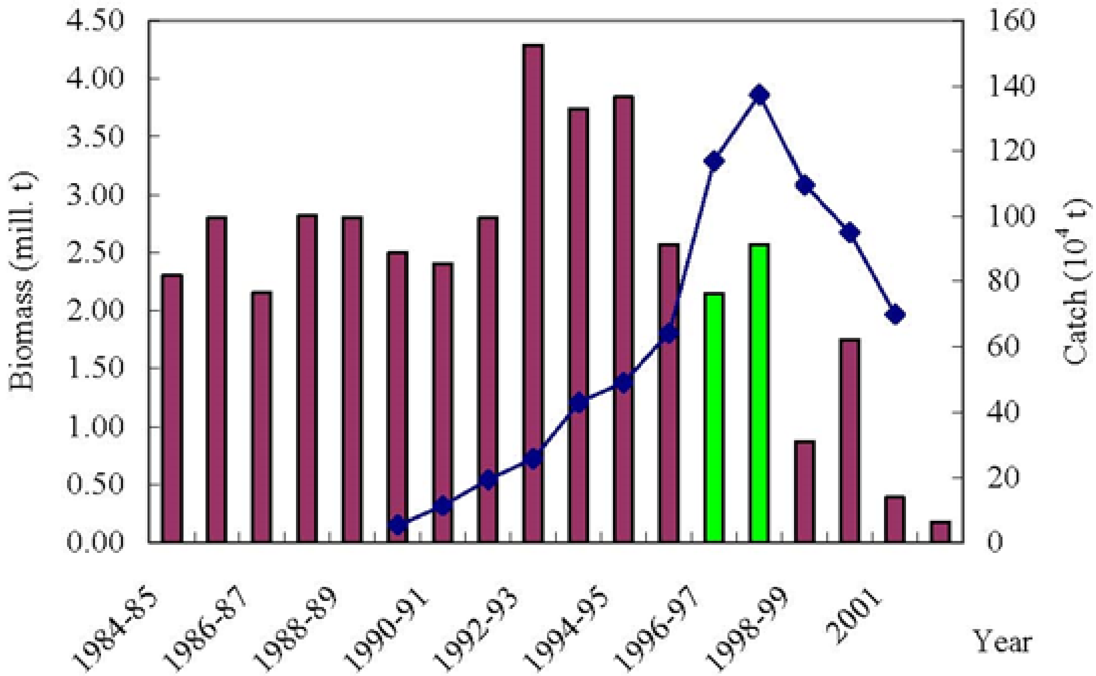


Figure 1-6. Annual Japanese anchovy biomass (bars) and Chinese landings (line)

1.4 High disturbance of human activity

The concentration and composition of nutrients have an important impact on the growth and community composition of phytoplankton. In recent decades, human perturbations have significantly changed the nutrients structure in coastal waters, resulting in disproportionate nutrients ratios and ecological structure of coastal waters.

Mariculture

The discharge of mariculture wastewater is a threat to the YSLME. The mariculture wastewater can lead to eutrophication, disease transmission and so on. The rapid development of mariculture in Yellow Sea area need to focus on.

Land Reclamation

Preserving and restoring coastal wetlands are essential elements in the protection of Yellow Sea ecosystems. Large areas of wetlands have disappeared around Yellow Sea in the past30 years. In July 2018, the Chinese government announced a moratorium on all reclamation approvals to enhance the protection of coastal wetlands in nationwide including Yellow Sea.

1.5 Threats and problems facing the Yellow Sea

In the nearly decade since the end of the first phase of YSLME, China and RO Korea have made various efforts to alleviate environmental pressure in the Yellow Sea, including reducing nutrient emissions, reducing fishing vessels， extending the closed fishing season and developing sustainable mariculture. However, the Yellow Sea is a shelf edge sea and the environmental impact is even more pronounced in the broader context of global climate change. Some new environmental problems or changes have arisen in recent years in Yellow Sea, such as the Harmful Marine Organism Blooms (red tide, green tide, gold tide and jellyfish bloom), loss of the habitat, Micro plastic.

Harmful Marine Organism Blooms

Compared with Bohai Sea, East China Sea and South China Sea, the red tide problem in the Yellow Sea is not serious. However, red tides are still common in this area and can spread from hundreds of square kilometers up to thousands of square kilometers. In August 2008, a toxic tiny Alexander algae (Alexandrium minutum) bloom in Haizhou Bay in the coastal waters of Lianyungang, resulting in the poisonous Filipino clams (Ruditapes phillippinarum), and causing 6 people poisoned and 1 killed (Yu Rencheng, 2016).

The green tide caused by large green algae is a kind of marine ecological disaster occurring off the coast of many coastal countries in the world. From 2007 to 2018, the green tide formed by large green algae (Ulva prolifera) broke out in the South Yellow Sea every year. It did a lot of damage to tourism, ecological environment and mariculture along the coast of Shandong and Jiangsu Province in China, and inevitably, its severity become a social focus. Every summer, the government in the green tide affected areas need to invest a large amount of manpower and material resources to collect, salvage and dispose of the green algae. And therefore, how to deal with the green tide has become an important task that local government must face every year. Generally, in the early stage, the green tide appeared in the shoal area of north Jiangsu, entered the south yellow sea under the action of wind and sea current, and accumulated in large quantities on the south bank of Shandong peninsula. The green tide not only caused environmental pollution but also damaged the development of tourism, aquaculture as well as causing huge economic losses.

The gold tide is a marine ecological disaster caused by the fulminant proliferation of the floating state of Sargasso. Similar to the green tide, the gold tide also causes a series of ecological environment problems imposing a negative impact on tourism and aquaculture. In recent years, the gold tide phenomenon formed by Sargasso has shown an upward trend in the world and has the potential to develop into a global disaster problem of algal blooms. In the Yellow Sea, the threat of gold tide is gradually emerging. The results of the remote sensing data analysis show that a great quantity of Sargasso have appeared in the outer Sea during the period from 2010 to 2012 (Cai Yongxu, 2014; Qi et al., 2017). And it did not attract enough attention only because it did not land in the main coastal areas.

From April to June in 2017, 35 ° N sections along the south yellow sea appeared rare green tide, gilding, and further to harmful algal blooms phenomenon such as red tides.

In 2016-2017, sargasso blooms (gold tide) in the southern waters of the Yellow Sea. According to satellite remote sensing monitoring results, in October 2016, the floating sargasso was mainly distributed in the northern waters of the south yellow sea. And in December, the floating sargasso was mainly distributed in the coastal waters of Jiangsu, with a maximum distribution area of 7,700 square kilometers, affecting the radiation sandbar waters off the coast of Jiangsu. In January 2017, the distribution area of sargasso in coastal waters of Jiangsu continued to decrease. In early February, sargasso was found sporadically in the coastal waters off Qidong, Jiangsu province. This Sargasso bloom affected laver farming in the southern part of Yancheng city and Nantong city of Jiangsu province, resulting in collapse of farming raft and breakage of cable lines. The 91.8 km2 laver farming area was badly damaged or even no harvest in some area. The disaster causes a direct economic loss of 5 million RMB.

Loss of the habitat

The Yellow Sea intertidal flat is the largest beachfront mud flat in the world, and this vast ecological hotspot, including western Korea and eastern China, provides a wealth of food, habitat and safe shelter for millions of migratory waterbirds. Nowadays, the disappearance of the Yellow Sea intertidal flat is threatening the survival of migratory birds on the East Asia-Australia migration route. As an significant breeding ground and migration stop for migratory birds, the loss of habitats will not provide enough space and food for birds, and will severely threaten the survival of some endangered birds. In recent decades, there has been a significant decline in the number of migratory bird populations， which regard the Yellow Sea as the main resting place for migration.

With the growing demand for the development of the Yellow Sea region, reclamation projects have been carried out intensively, encroaching on many beach wetlands. Reclamation provides a large amount of cheap land resources for emerging cities and industrial zones, providing a strong support for the development of regional economies. Even some international organizations working on the Environment Protection and migratory birds protection have located their offices in Songdo, an international business district formed by reclamation.

In addition, the Spartina alterniflora on the beach in the west coast of the Yellow Sea is spreading gradually, devouring the intertidal habitat for the shorebirds. The Spartina alterniflora has strong adaptability and rapid diffusion speed. It can quickly form a single dominant population, threaten the benthic biodiversity and encroach on the shorebird habitat. At the same time, the Spartina alterniflora will speed up the siltation rate of the beach, and eventually lead to the complete disappearance of the intertidal flat. And accordingly, the loss of habitat caused by the spread of Spartina alterniflora is becoming one critical threaten for the survival of shorebird in the Yellow Sea.

2. Scope of the Assessment for YSLME

2.1 Geographical Scope

The Yellow Sea is located between China and the Korean peninsula and is a semi-closed shallow sea that is approximately north-south. It is bounded by the Laotieshan Angle at the southern end of the Liaodong Peninsula and Penglai Angle on the north shore of the Shandong Peninsula, and the south bound line from south-west corner of Jeju Island, to the north bank of the Yangtze River estuary. The Yellow Sea has an average depth of 44 meters and a flat sea floor, which is part of the East Asian continental shelf. The narrowest part is the line between the corner of the Mountains of the Jiaodong Peninsula to the long mountain strings of North Korea, and it is customary to use this line to divide the Yellow Sea into the North Yellow Sea and the South Yellow Sea.

The climate condition of this area is monsoon climate, the northerly wind prevails in winter, the north Yellow Sea is mostly northwesterly, the south Yellow Sea is mostly north-easterly and the north-easterly wind, and the summer is mainly south-easterly and south-south wind. The temperature change is cold in the north and south warm. The seasonality of precipitation, the prevalence of dry and cold air in winter, very little water, the prevalence of south-east and southwest air flow in summer, a large amount of water to carry over the area, forming a large amount of precipitation.

The region's main water groups include the Yellow Sea Cold Water Mass, the Yellow Sea Warm Current and the Yangtze Diluted Water."

2.2 Disciplinary Scope

Nutrients

Nutrients are elements that are functionally related to biological processes. In this report it main refers to Silicon, Phosphorus, Nitrogen,

Planton

Plankton generally refers to drifting organisms that live in water and lack the ability to move efficiently. There are phytoplankton and zooplankton.

Fishery

Fishery is one of the main Marine development activities, including mariculture, fish cataching and other activities.

Jellyfish bloom

Jellyfish bloom refers to the bloom of jellyfish in a specific season, in a specific sea area.

HABs and drifting macroalgae bloom

HAB and drifting macroalgae bloom are harmful ecological phenomenons caused by the explosive proliferation or high concentration of phytoplankton, protozoa or bacteria in seawater under specific environmental conditions.

Introduced species

Introduced species refers to the geographical expansion of non-native Marine species from the original distribution area to the local area (not distributed in evolutionary history) due to natural or human factors.

3. Status and Problems

3.1 Nutrients

3.1.1 Current status

3.1.1.1 Interannual variation of nutrients in the South Yellow Sea

The locations of survey stations in the southern Yellow Sea during 1950s to 2017 is shown in Figure 1. The annual average concentration changes of DIN, phosphate and silicate are shown in Figure 2.

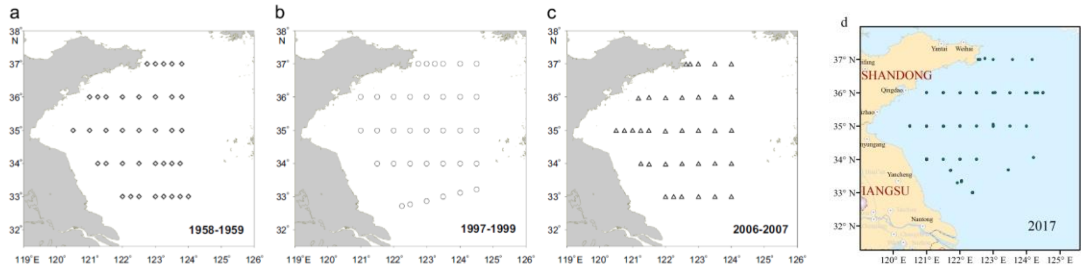


Figure 3.1 Locations of survey stations in the southern Yellow Sea during different time periods

From 1990s to 2017, DIN concentrations in the surface and bottom layer of the South Yellow Sea increased from 1990s to 2000s, and then starting decreased from 2000s to 2017. DIN concentration was highest during 2006-2007, with an average concentration of 0.081 mg/L at the surface and 0.131 mg/L at the bottom.

The surface and bottom concentration of phosphate exhibited a similar variation pattern, with the concentrations decreasing from 1950s to 2017. From 1990s to 2017, the average phosphate content was similar, with an average concentration of 0.007 mg/L at the surface and 0.015 mg/L at the bottom.

During 1950s to 2017, the concentration of silicate fluctuates dramatically. From 1950s to 1990s, the concentration decreased by nearly half, with 0.286 mg/L in 1950s and

0.141 mg/L in 1990s. From 1990s to 2000s, the concentration slightly increased to 0.172mg/L, and the concentration remained basically unchanged in recent years. Compared with the surface layer, the concentration of the bottom silicate showed a similar pattern with surface layer. But the concentration of the bottom silicate in 2017 was significantly higher than that of 1990s and 2000s.

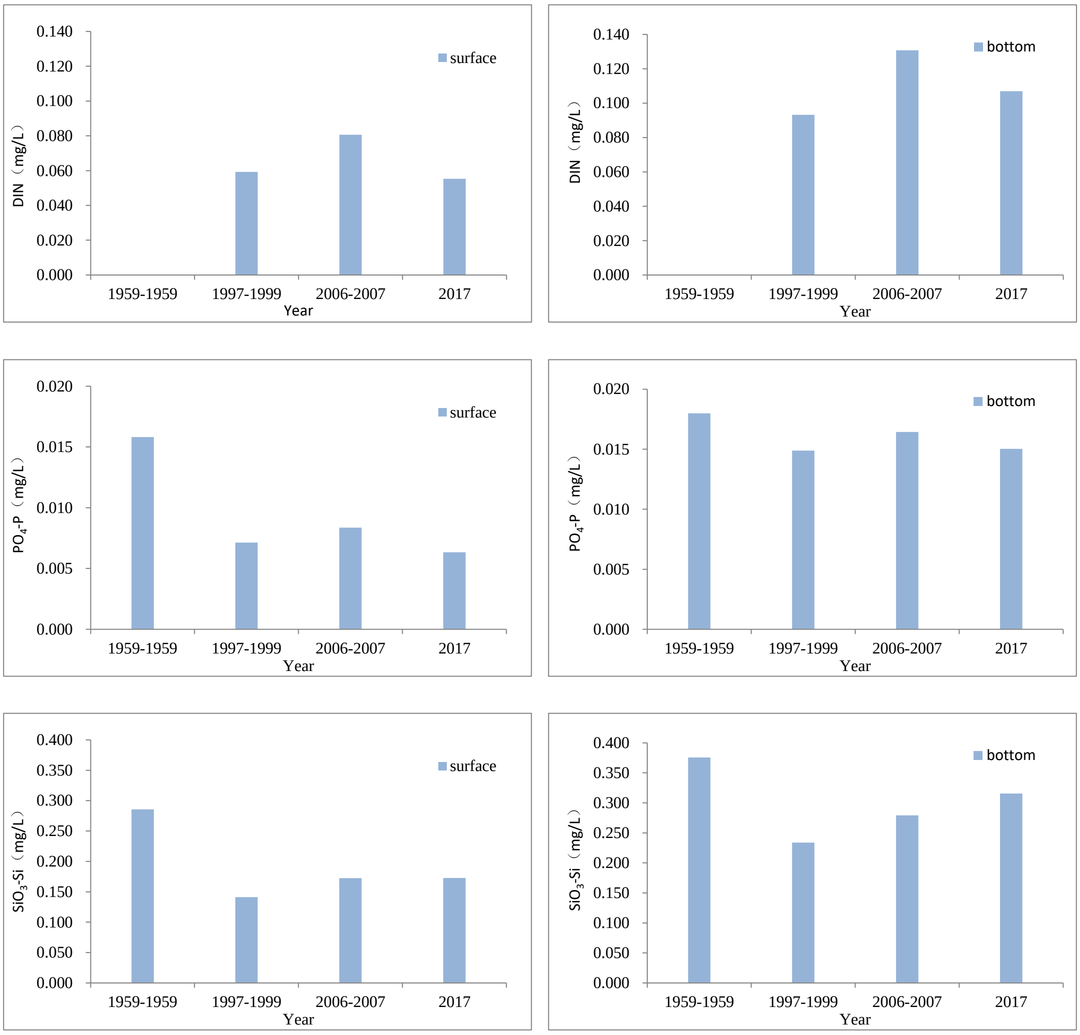


Figure 3-2. Temporal variations in concentration of nutrients in the southern Yellow Sea during different periods.

Variations of nutrients structure

The variation of nutrients structure in the southern Yellow Sea are analyzed during 1990s to 2017. Table 1 shows the surface and bottom N/P ratio and Si/N ratio. Overall, the N/P ratio was increased from 1990s to 2010s, with the surface N/P ratio increased from 20.72 to 22.17 and the bottom N/P ratio increased from 13.95 to 22.17. The maximum surface N/P ratio (23.7) occurred in 2000s and the maximum bottom ratio (22.17) occurred in 2017, In 2017, the ratio of N/P is greater than the Redfield ratio(16:1). Si/N ratio decreased slightly to 1.08(surface) and 1.07(bottom) during 1990s to 2000s and then started to increase to 2.20(surface) and 1.76(bottom) in 2017.

Table 3-1. Temporal variations in nutrient ratios in the southern Yellow Sea during different periods

Period	N:P		Si:N		literature
	surface	bottom	surface	bottom	
1997-1999	20.72	13.95	1.20	1.26	[2]
2006-2007	23.7	17.71	1.08	1.07	[2]
2017	22.17	22.17	2.20	1.76	

3.1.1.2 Interannual variation of nutrients along 36°N transect

Temporal variations of nutrients

Interannual variation of nutrients along 36°N transect west of 124.5°E was analyzed using the winter and summer data(Figure 3-3,Figure34).The figure shows that nitrate and DIN at the surface and bottom both increased continuously, with a more rapid increase occurring after the mid-1990s. During the period from 1970s to 2000s, the phosphate of surface layer and bottom layer showed similar changes. The concentration decreased slightly first, and increased gradually after mid-1990s. The long-term sequence change trend of silicate is similar to that of phosphate, showing that the concentration of silicate decreased from the 1970s to the early 1990s and then stabilized before starting to increase gradually in the mid-late 1990s.

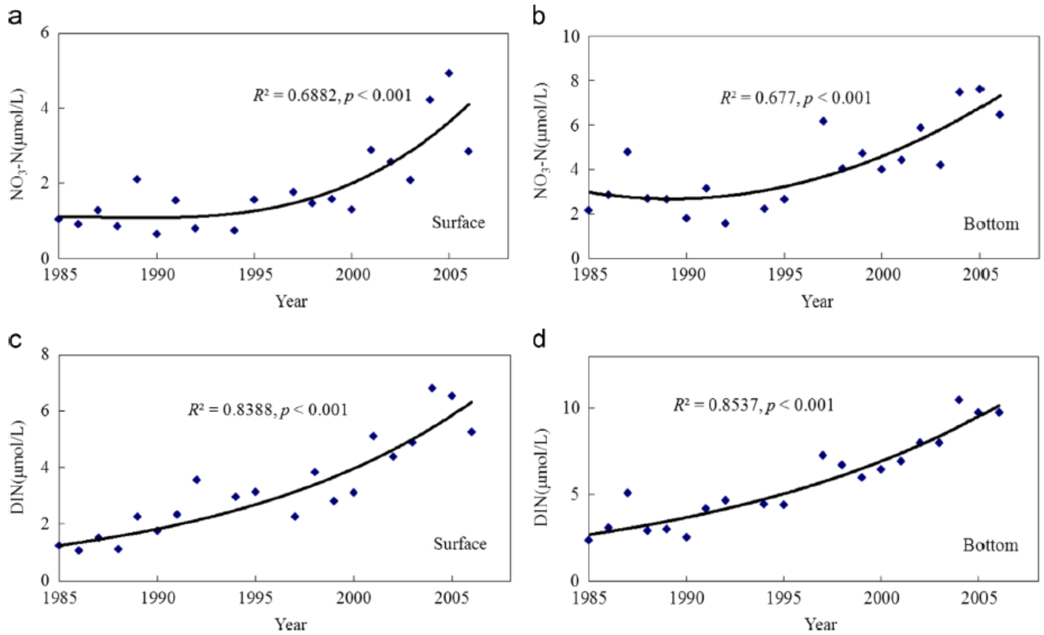


Figure 3-3 Temporal variations in nitrate and DIN concentrations along the 36°N transect west of 124.5°E

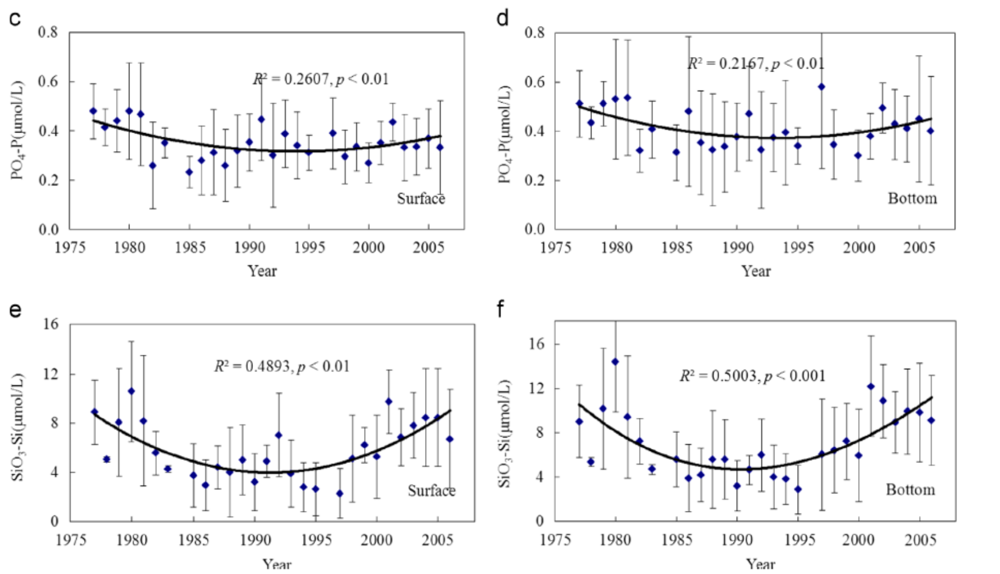


Fig. 12. Temporal variations in nutrient concentrations with the marked standard deviations along the 36°N transect in the sea area west of 124.5°N in the southern Yellow Sea in winter during 1977–2006.

Figure 3-4. Temporal variations in phosphate and silicate concentrations along the 36° N transect west of 124.5°E

Variations of nutrients structure

From 1985 to 2006, the N/P ratio at the surface and bottom of the 36°N transect west of 124.5°E increased dramatically, and the Si/N ratio decreased gradually(Figure 3-5). Before the end of the 1990s, the N/P ratio was relatively low, and then gradually higher than the Redfield ratio (16:1). The highest N/P ratio on the surface (30) and bottom (20.19) layer appeared simultaneously in 2004. The Si/N ratio decreased rapidly from the mid-1980s to the mid-1990s and then remained at around 1. The Si/P ratio decreased from the 1970s to the mid-1990s and then gradually increased.

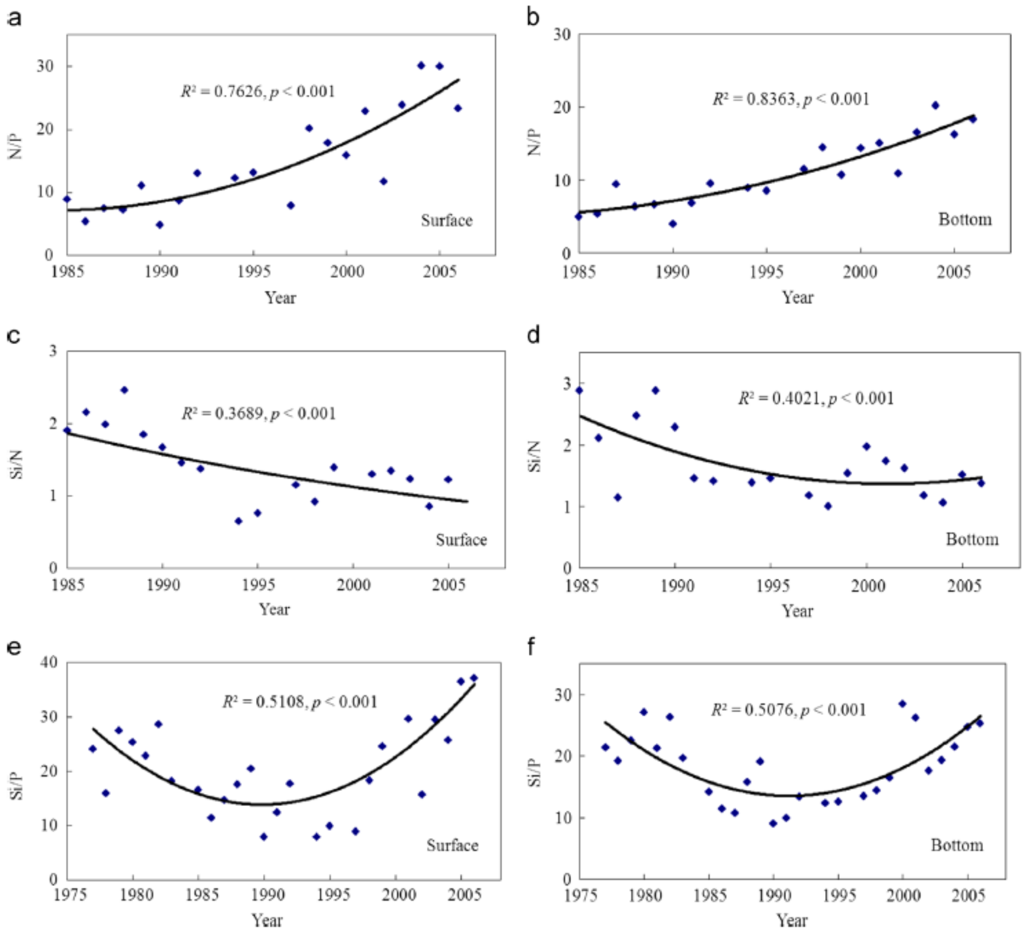


Figure 3-5. Temporal variations in nutrient ratios along the 36°N transect west of 124.5°E

3.2 plankton

3.2.1 Phytoplankton

Table 3-2. Dominant species of net phytoplankton samples in 2008. Dominance (Y) was calculated by the product of proportional abundance of the specific species (n_i/N) and its occurrence frequency (f_i).

Winter		Summer	
Species	Dominance	Species	Dominance
Corethron hystrix	0.051	*Chaetoceros lorenzianus*	0.239
Chaetoceros densus	0.039	*Chaetoceros* spp.	0.039
Ditylum brightwelli	0.032	*Chaetoceros affinis*	0.030
Chaetoceros lorenzianus	0.029	*Chaetoceros pseudocurvisetus*	0.013
Coscinodiscus oculus-iridis	0.028	*Pseudonitzschia pungens*	0.010
Odontella sinensis	0.028		
Bacillaria pacillifera	0.025		
Coscinodiscus wailesii	0.016		
Ceratium intermedium	0.015		
Coscinodiscus sp.	0.015		
Pseudonitzschia pungens	0.013		
Guinardia flaccida	0.013		
Coscinodiscus asteromphalus	0.010		

There was a total of 62 and 139 species of phytoplankton identified in winter and summer, respectively. In winter, the number of dominant species is much more than that in summer (Table 3-2). *Chaetoceros lorenzianus* and *Pseudonitzschia pungens* are the common dominant species in both seasons.

In the net samples collected in winter, several diatoms dominated with similar dominance indexes. For example, the abundance of *Corethron hystrix* was higher in the north than that in the south, while *Chaetoceros densus* showed high density in the central zone and was not found in the southeast part of the study area (Figure 3-6).

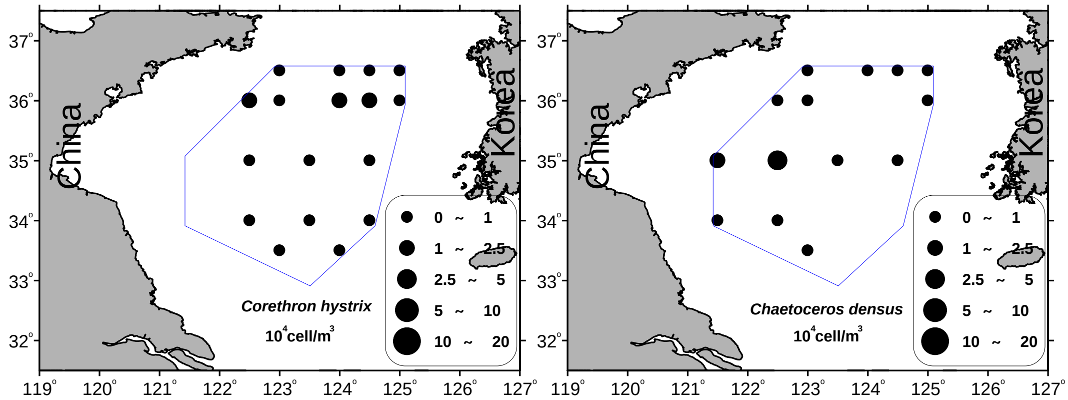


Figure 3-6. Distribution of *Corethron hystrix* (left) and *Chaetoceros densus* (right) in net samples in winter.

In the summer net samples, the genus *Chaetoceros* was the most dominant taxon with an average of 632×10^4 cells/m^3, and accounted for 87.8% of total abundance. It defined the horizontal distribution features of phytoplankton abundance, i.e., the overall distribution pattern showed higher values in the southwest and low values in most other parts (Figure 3-7). *Chaet. lorenzianus* was the most dominant species, averaging 374×10^4 cells/m^3, and accounting for 52% of the total abundance. This species shaped the main features of total abundance in the net samples.

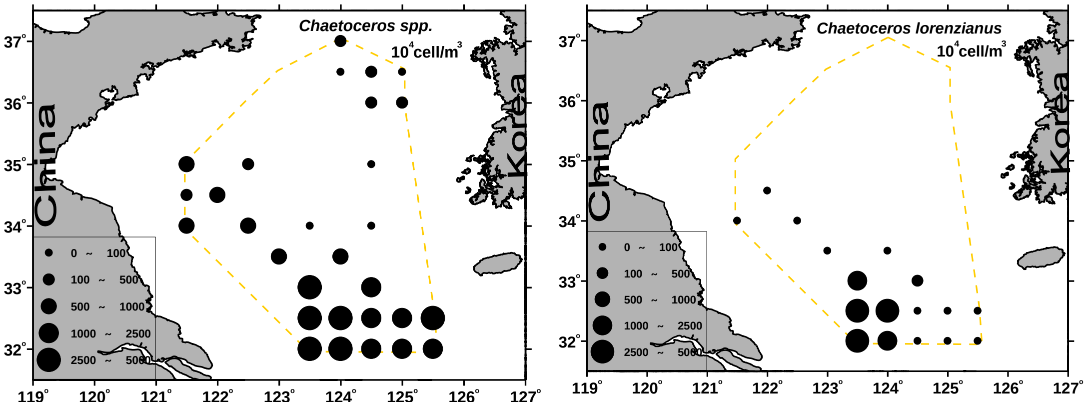


Figure 3-7. Distribution of *Chaetoceros spp.* (left) and *C. lorenzianus* (right) in the summer net samples.

Net sampled phytoplankton species diversity (*H'*) in winter varied between 0.22-4.24. The highest diversity occurred at the stations with high cell abundance (southwest zone). In general, the species diversity indexes of phytoplankton were higher in the south as compared to the north (Figure 3-8, left panel). In the summer, the diversity of net samples scored from 0.19-3.84 with a mean value of 1.87. Low levels of diversity were found in the southeast and northwest (Figure. 3-8, right panel).

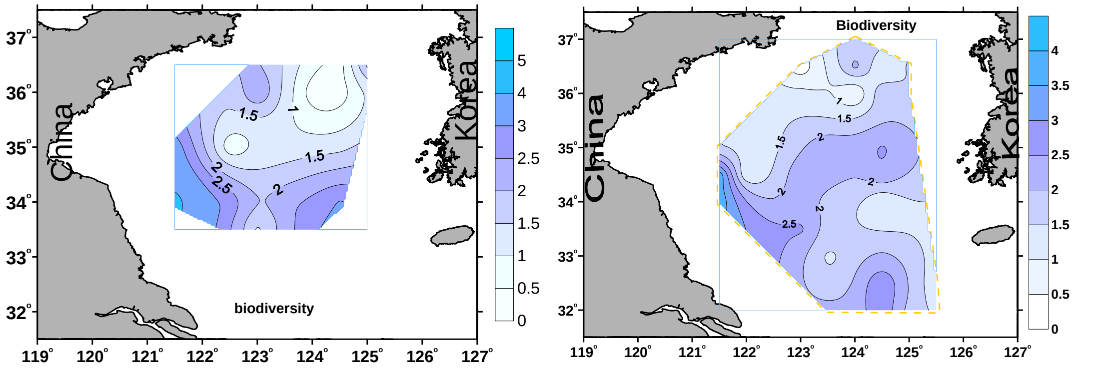


Figure. 3-8. Species diversity (*H'*) of phytoplankton community in winter (left) and summer (right).

Huang Bei analyzed the changes of phytoplankton community structure and diversity in the South Yellow Sea During 2007-2017. Diatoms and Dinoflagellates are the two main groups of phytoplankton in the South Yellow Sea. The main dominant species are

Gymnodinium sp., *Nitz . Delicatissima*, *Chroomonas* sp., *Thalassionema nitzschioides*, *Scrippsiella trochoidea*, and *Gyrodinium* spp . Since 2007, the number of phytoplankton species in the south yellow sea has increased significantly. (Huang, 2018)

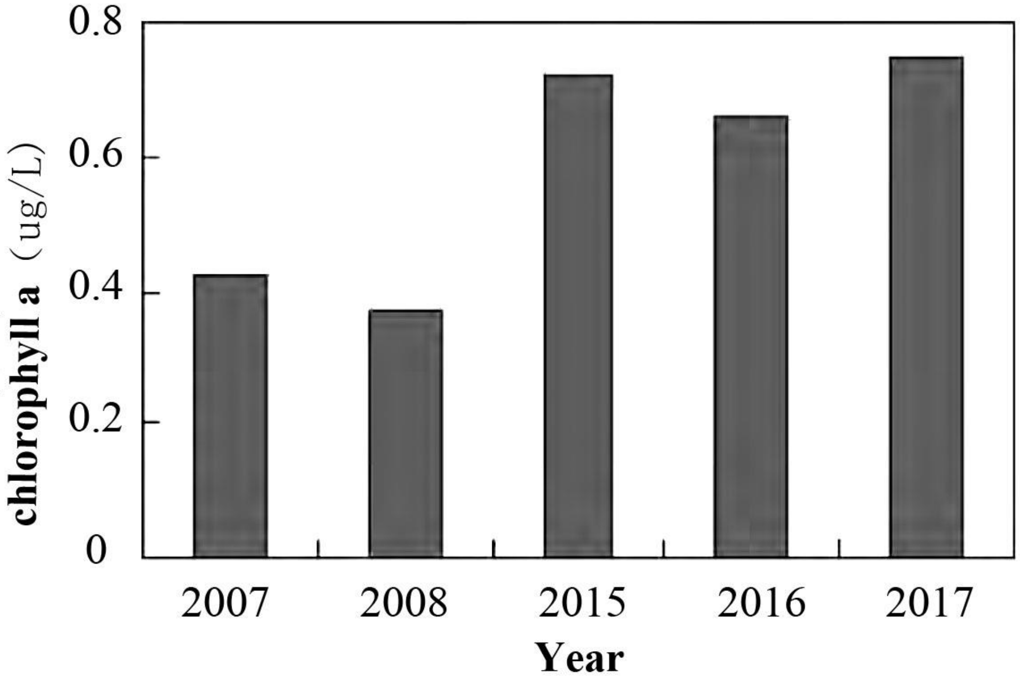


Figure 3-9. Annual changes of chlorophyll a in the South Yellow Sea (2007 to 2017)

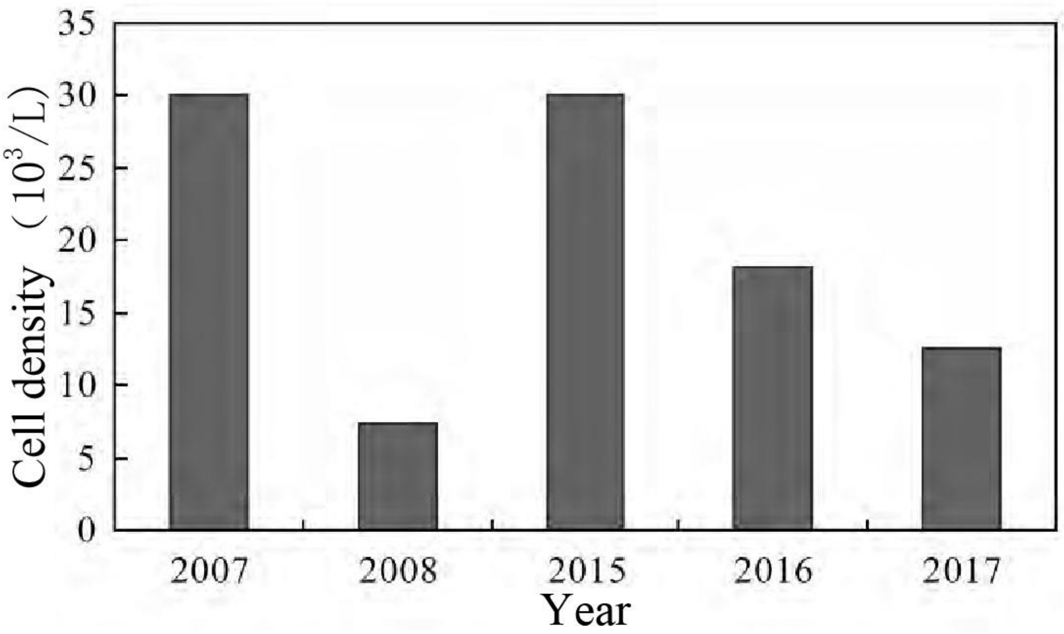


Figure 3-10. Cell density of phytoplankton from 2007 to 2017

Luan Qingbin reported the Long-term (1985-2015) changes in phytoplankton communities in 2020. The abundance of dinoflagellates increased significantly from 2005 to 2015, and the species richness showed an increasing trend, increased by 78.9% from 2005 to 2015, and the proportion of warm water species increased to 10.3% on average. The species diversity in the north Yellow Sea remained stable, while that in the south Yellow Sea increased by 28.9% from 1985 to 2000. (Luan, 2020)

3.2.2 Zooplankton

Data from the samples collected with the 505 μm mesh plankton net were used here to show the zooplankton community structure. In winter, a total of 71 zooplankton species (otherwise lowest taxonomy level) were identified, including copepods (26 species), larvae (18 species), mysidacea (6 species), medusa (5 species), mastigopus (3 species), chaetognaths (2 species), euphausiids (2 species), and other groups. In summer, a total of 77 zooplankton species were identified, including copepods (37 species), medusa (11 species), mysids (9 species), tunicates (4 species), pteropods (3 species), decapods (3 species), and other groups. The survey results showed that *Calanus sinicus* and *Sagitta crassa* were the main dominant species in the YSCWM area, and the composition of dominant species was similar between winter and summer (Table 3-3).

Table 3-3. Dominant species of net zooplankton samples in 2008. Dominance (Y) was calculated by the product of proportional abundance of the specific species (n_i/N) and its occurrence frequency (f_i).

Winter		Summer	
Species	Dominance	Species	Dominance
Sagitta crassa	0.383	*Calanus sinicus***	0.467
Calanus sinicus	0.343	*Sagitta crassa***	0.175
Oithona plumifera	0.092	*Oithona plumifera**	0.054
Parathemisto gaudichardi	0.036	*Parathemisto gaudichardi*	0.048
		Macrura larvae	0.020

In winter, *Sagitta crassa* was the most abundant specie, and its abundance varied between 4 and 202 ind./m^3 (mean: 98 ind./m^3). There was higher abundance of *S. crassa* in the western coastal areas than that in the open sea (Figure 3-11, left panel). The abundance of *Calanus sinicus* varied between 2 and 205 ind./m^3 (mean: 37 ind/m^3). There was higher abundance of *C. sinicus* in the north than that in the middle and south (Figure 3-11, right panel).

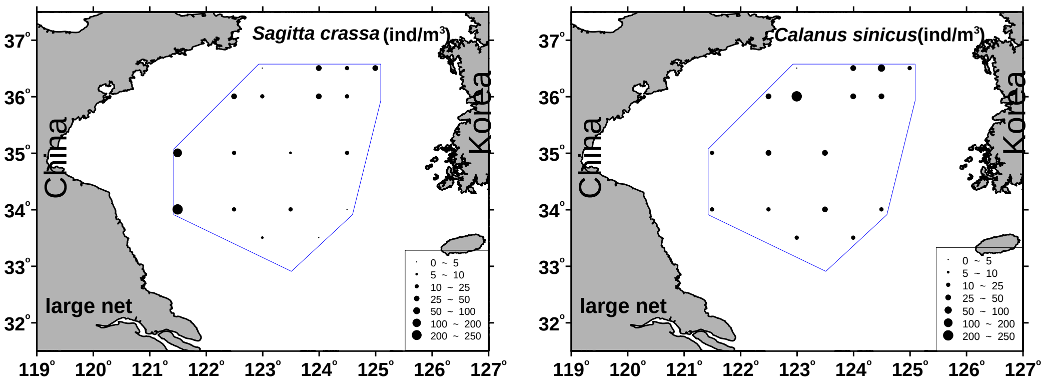


Figure. 3-11. Distribution of *Sagitta crassa* (left) and *Calanus sinicus* (right) abundance in winter.

In summer, *C. sinicus* was the most abundant species and largely contributed to total individual density. The abundance of *C. sinicus* varied from 1 to 536 ind./m^3 and the magnitude was much higher (mean: 113 ind./m^3) than that in winter (mean: 37 ind./m^3). *C. sinicus* was evenly distributed throughout most of the study area (Figure 3-12, left panel). The abundance of *Sagitta crassa* varied from 2 to 202 ind./m^3 (mean: 40 ind./m^3), and the most abundant zone was located at the west and north of the study region (Figure 3-12, right panel).

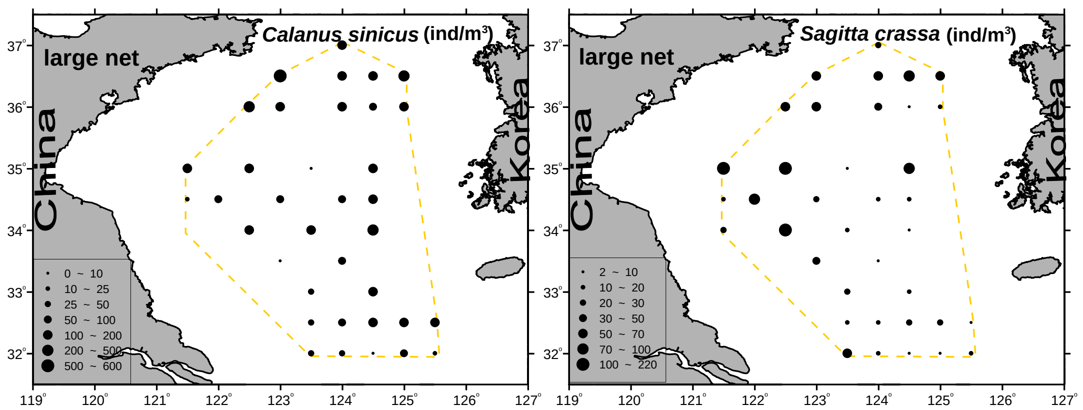


Figure 3-12. Distribution of *Calanus sinicus* (left) and *Sagitta crassa* (right) abunda nce in summer.

The non-gelatinous zooplankton biomass in winter averaged 110.5 mg/m^3 (in the range of 17.5-285.4 mg/m^3) in the south YSCWM area, and lower biomass was found in the central and northern zones (Figure 3-13, left panel). In summer, zooplankton biomass averaged 194.0 mg/m^3 (in the range of 13.2-606.2 mg/m^3), and higher biomass was found in the southeast zone (Figure 3-13, right panel).

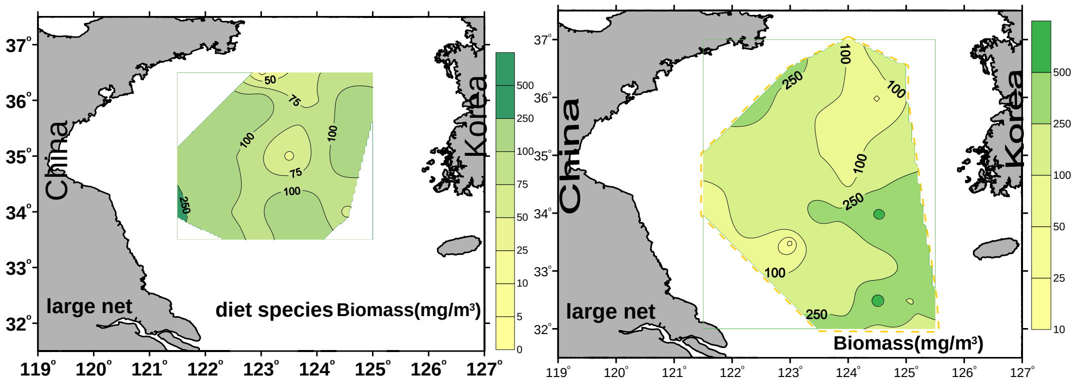


Figure 3-13. Distribution of zooplankton biomass (mg/m^3) in winter (left) and summer (right).

In winter, the diversity index of zooplankton community was in the range of 0.64-2.87, and the lowest biodiversity was found in the west coastal areas and increasing from northwest to the southeast (Figure 3-14, left panel). In summer, the diversity index was in the range of 0.92-3.16, and the higher biodiversity was found in the southern areas and decreasing from southwest to northeast (Figure 3-14, right panel).

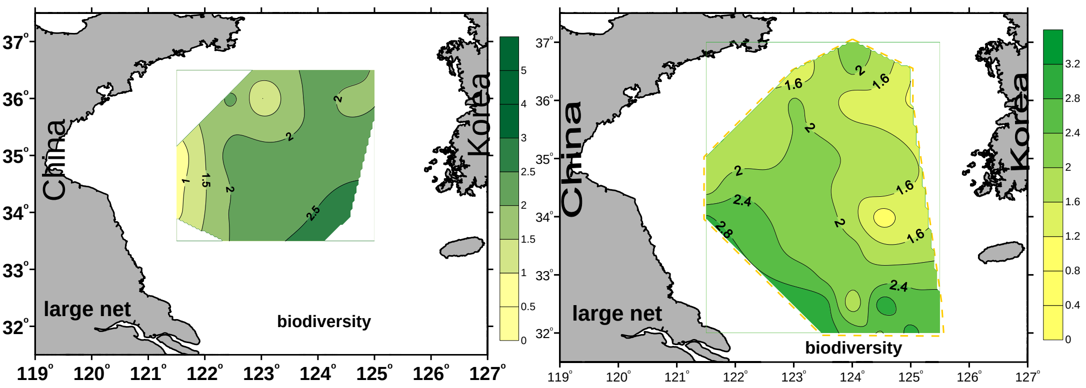


Figure 3-14. Species diversity (*H'*) of zooplankton community in winter (left) and summer (right).

According to the study in Korea, in 2011-13, phytoplankton dominant species showed greater differences in seasonality, water layer, and latitude than annual differences. The predominant species identified in the surface mixed layer (0-20 m) of A line in spring were diatoms *Skeletonema* spp., *Thalassiosira nordenskioeldii*, and *Ditylum brightwellii*, while *Skeletonema* spp., *Thalassiosira* spp., and nano-flagellates predominated in the E line at lower latitude. *Skeletonema* spp., *Chaetoceros* spp., and *Paralia sulcata* were commonly dominant in the bottom layer (20-80 m) in the A and E lines. In spring when water masses were well mixed, diatoms prevailed in all water layers, and the nano-flagellates dominated in the E line. In the A line, the summer dominant species were *Thalassiosira proschkinae, Chaetoceros compressus*, and *Thalassiosira* spp. in the surface mixed layer (0-20 m), while the nano-flagellates, *Skeletonema* spp., and *Heterocapsa triquetra* were dominated in the E line. The dominant species in the bottom layer (20-80 m) of the A line were *Skeletonema* spp., and *Thalassiosira* spp. while nano-flagellates and *Skeletonema* spp. dominated in the E-line. Based on the distribution of *T. proschkinae* showing high concentration in the YSCWM in summer during the 2011-13 survey, it could be effectively used to understand the reactions of the YSCWM characteristics through long-term data acquisition. (Kang, 2020).

Dr. Kang's study shows that, During the summer when the typhoon did not pass, subsurface chlorophyll maximum developed near 20 to 30 m of water, whereas high concentration of chlorophyll was observed in the surface water after the typhoon. Relatively cool seawater mixtures associated with typhoons, large amounts of phytoplankton and high abundance of zooplankton were observed in the southeastern Yellow Sea during the summer. In terms of annual variation, the mean abundance of zooplankton in the surface mixed layers was the lowest at 754 inds./m^3 in 2010, the highest at 25,216 inds./m^3 in 2011, and 2,702 and 2,588 inds./m^3 in 2012 and 2013, respectively. Characteristically, male and female of the copepod Calanus *sinicus, Acartia omorii, Paracalanus parvus s.l.* and *Oikopleura* spp. occurred especially high in the surface waters in 2011, when the typhoon MUIFA passed immediately through the study area. It means that if the surface water temperature gets cooler in the summer after typhoon passage, representative copepods that remained only in the YSCWM may appear on the surface. It also means that the zooplankton, which was previously known to stay in the YSCWM in summer, can expand the amplitude of diel vertical migration of zooplankton if the environment changes, rather than only staying at the bottom. (Kang, 2020).

3.3 Fishery

A significant growth in commercial fisheries in the Yellow Sea over the past several decades has been a positive socioeconomic force, but has resulted in overexploitation of the fishery and changes to the species composition of fisheries.

Two mechanisms are likely responsible for these shifts in species dominance, with implications for both stock decline and recovery. The first is knows as systematic replacement. This occurs when a dominant species declines in abundance, either naturally or through overfishing. Another competitive species takes advantage of the surplus food and vacant space to increase its abundance. The second mechanism is ecological replacement. This occurs when environmental changes gradually restructure the ecosystem, resulting in changes in stock abundance. In the long term, these two drivers may be intermingled (NSAP-China) .

3.4 Habitat

The wetland around the Yellow Sea are an important an irreplaceable area for the migration birds of East Asian-Australian migratory route. In 2019, Yancheng mudflat is listed as a World Heritage Site at the 43rd World Heritage Congress.

In the 11th five-year plan, China put forward Major Function Oriented Zoning (MFOZ) to optimize the spatial pattern of regional development and conservation. In 2010, the Chinese Central Government formally issued the MFOZ report, which demarcated the Development Prohibited Zones (DPZ, 12.5% of China's landmass) and Development Restricted Zones (DRZ, 40.2% of China's landmass). The DPZ include national nature reserves, national forest parks, national geo-parks, national tourism resorts, and world cultural and natural relics. Therefore, industrial and urban development is generally prohibited in DPZ to sustain good ecological functioning and environmental quality. With the establishment of new national nature reserves and parks, the DPZ will be enlarged accordingly. The DRZ are composed of 25 regions with high potential for ecological functions, including biodiversity conservation, freshwater provisioning, soil and nutrient conservation, and carbon sequestration. The DRZ hosts 8.5% of the human population in China, and the functional roles of the DRZ include ecological conservation and demonstrating the harmonization of human–nature relationships; subsequently, large-scale and intensive resource extraction, urbanization, and industrial development are highly restricted in DRZ.

The Government of China launched on 17 September 2010 the National Biodiversity Strategy and Action Plan (2011-2030) (abbreviated as "NBSAP"). Together with relevant national plans developed with a view to building an ecological civilization, NBSAP has provided a relatively comprehensive set of national targets for biodiversity conservation. According to the Fifth National Report on the Implementation of the Convention on Biological Diversity, in recent years China has been implementing several actions to conserve its biodiversity: Improving legal and regulatory system and institutional mechanisms; Launching and implementing a series of plans for biodiversity conservation; Strengthening conservation systems; Promoting sustainable use of biological resources; Conserving and restoring habitats; Developing and implementing incentives favorable for biodiversity conservation; Enhancing establishment of biosafety management system; Controlling environmental pollution; and Promoting public participation.

In 2015, the State Council issued the Suggestions on speeding up the construction of eco-civilization, in which strict guard on resource and environment redline, scientifically design the forestry, grassland, and wetland and marine redline were suggested. Then, in 2016, SOA issued the Suggestions on national-wide construction of the marine redline mechanism. Until now, the 11 coastal provinces/cities have established their marine redline designation. The marine redline mechanism has been fully established in China. More than 30% sea area under jurisdiction and 35% coastal line have been included in the redline paradigm.

Generally, there are two types of marine ecological redline areas: DPZ and DRZ. DPZ means the area prohibits any kind of development activity. It mainly includes core area and buffer area of nature reserve, and important protected area and reserve zone of marine special protected area. In nature reserve DPZ, no construction of production facilities is allowed. No organization or individual is allowed entry without special reason. In marine special protected area, the important protected area prohibits any construction project not related to protected area. In reserve area, human disturbance is strictly controlled, no constructions allowed. Any production activities that might change the natural ecological condition will be prohibited. Other areas of the MPAs, important estuary system, important coastal wetland, important fishery area, important sandy coastal line, special protected island, natural landscape and historical culture relics, and important coastal recreational areas were ascribed to development-restricted zones (DRZs).

The table below shows the Yellow Sea eco-redline designation in three provinces. In each province more than 10% of the sea area are designated as redline areas. Those area will be strictly protected. According to the redline design for Shandong, Jiangsu and Liaoning provinces, the development prohibited redline area bans all construction activities. The development restricted redline area strictly controls construction activities, reclamation is prohibited. This regulation will help prevent the habitat loss in YSLME area.

Table 3-3. Yellow sea eco-redline designation in three Provinces

Province	Number	Area (km²)	% of YS area in that Province
Shandong	151	3,134.84	10.10
Jiangsu	73	9,676.07	27.83
Liaoning	52	6,796.90	25.40

Marine Protected Area

In 2012, the State Council authorized the National Marine Functional Zoning (2011–2020), setting a goal to improve the marine environment with an expansion of the MPA coverage in the sea areas under national jurisdiction to 5%. Until the end of 2016, there were 31 national level MPAs, and 21 National level Aquatic Germplasm Resources Conservation Zones in the Yellow Sea area. And this number will keep increasing to reach the 5% goal.

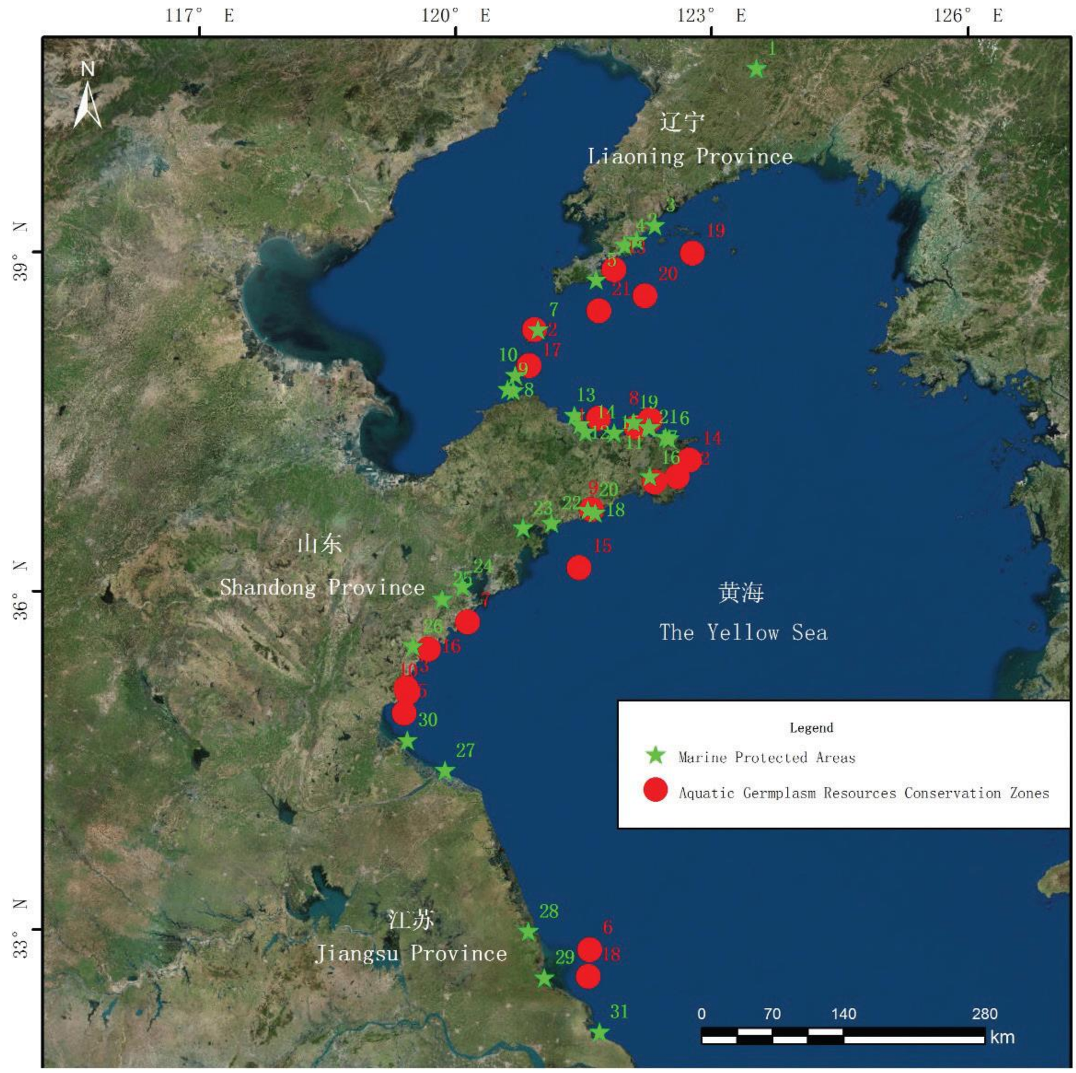


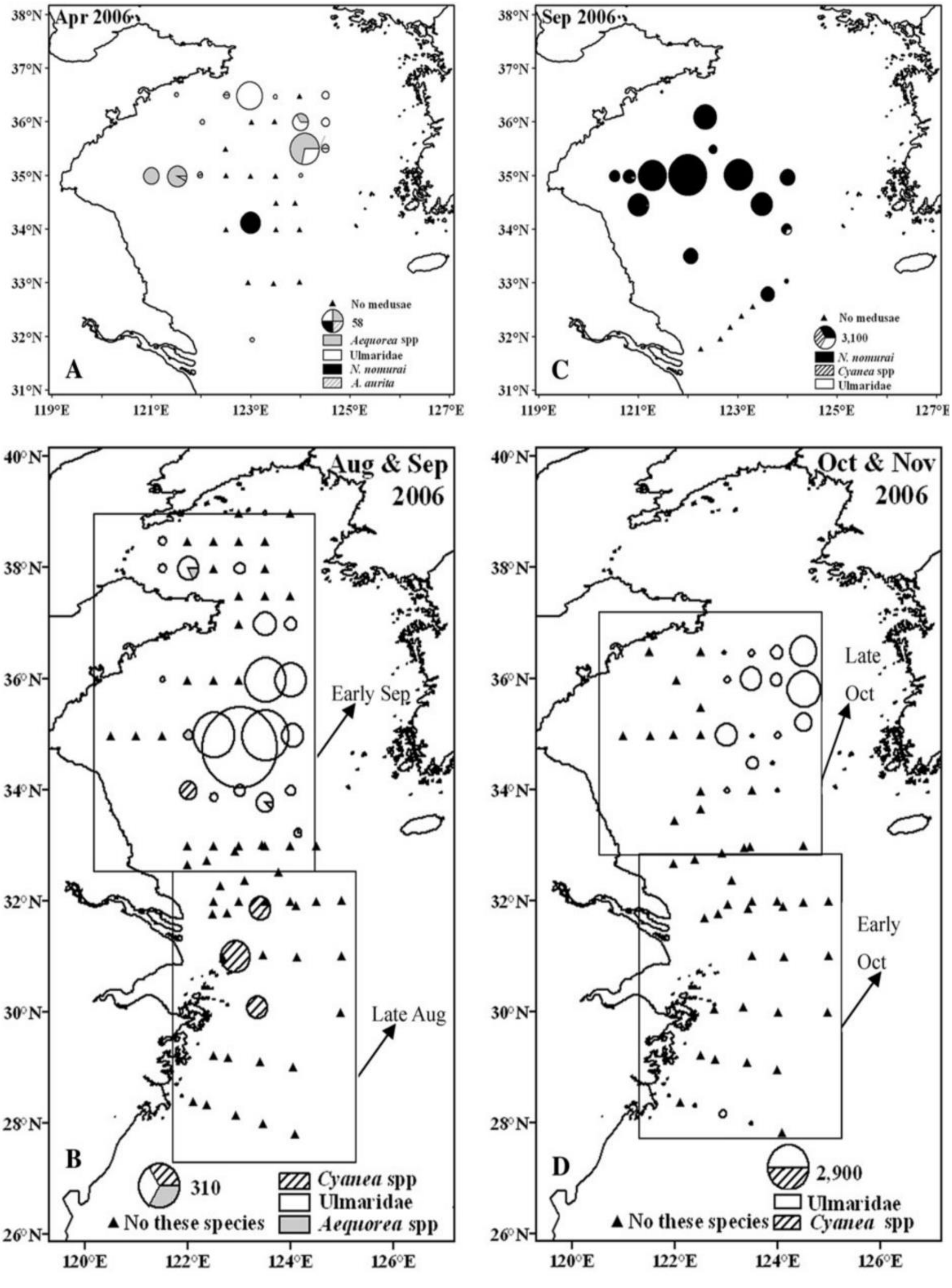
Figure 3-15. National level MPA and Aquatic Germplasm Resources Conservation Zones in Yellow Sea

3.5 Jellyfish bloom

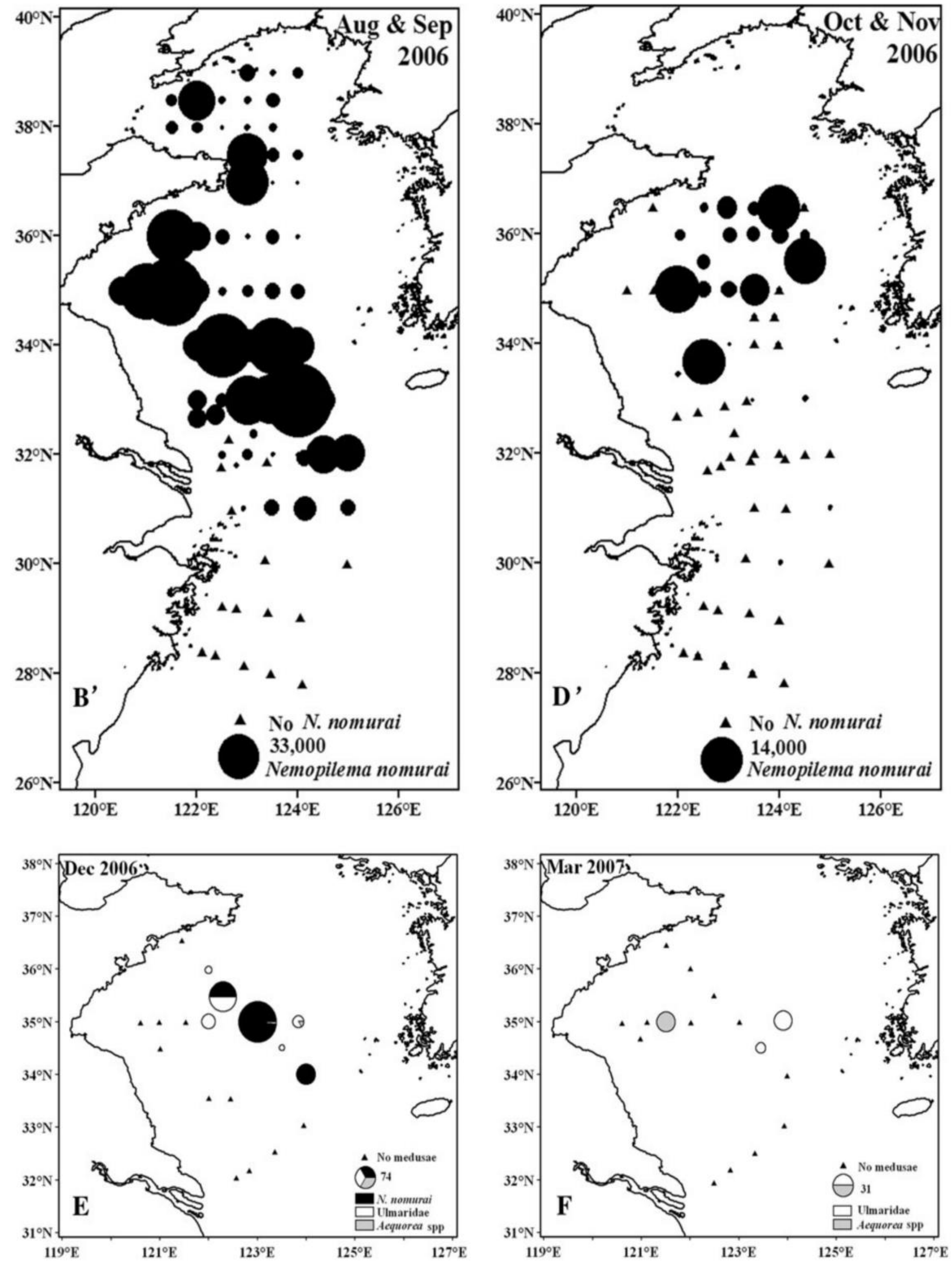
Jellyfish blooms have become a new type of marine ecological disaster after red tide, green tide and other ecological disasters globally. Jellyfish disasters were formed by an abnormal increasing number of jellyfish in local waters, which undermined the safety of outdoor bathing place, and impacted the normal intake of industrial water and fishing seriously. Jellyfish bloom is a natural phenomenon, which blooms about every 40 years in history. However, the outbreak frequency is higher and higher, even to an alarming rate of once every year in recent years.

From 2003 to 2014, there were several incidents of jellyfish blooms, causing blockages in the water intake of power plants, loss of offshore catches and injuries on beaches. In 2004, the abnormal proliferation of *Cyanea nozakii* in Liaodong Bay of Bohai Sea was particularly significant, which resulted in the reduction of *Rhopilema esculentum* and fishing industry. From June to September 2007, a very rare bloom of *Aurelia aurita* occurred in the coastal areas in Yantai and Weihai, Shandong province. Since 2008, the coastal power plants in the north areas of Qingdao and Longkou have suffered from jellyfish boom for many years. In July 2009, the jellyfish bloom hit power plant in Qingdao and hampered the safe operation. In late July 2013, a high-density jellyfish population formed in the waters around the Hongyanhe nuclear power plant in Liaoning province. On July 21, 2014, the Hongyanhe nuclear power plant suffered an outage because *Aurelia aurita* blocked the cold water intake system. In the south of China, jellyfish invaded the cold water system of nuclear power in Daya Bay from February to March 2017. From 2003 to 2016, the average number of people stung by jellyfish on the beach was up to 1,400 per year, and the total number of deaths was 21. An eight-year-old boy was stung by *Nemopilema nomurai*, which caused acute pulmonary edema, and he died in rescue on August 2, 2013.

Blooms of giant jellyfish have formed increasingly in the southern Yellow Sea (YS) and northern East China Sea (ECS) during summer and fall since the end of the 1990s. The distribution of giant jellyfish varies with seasons, temperature, salinity and other hydrological conditions throughout the coastal waters in the southern YS and northern ECS. The distribution was mainly in the Yangtze Estuary and Subei shoal. Zhang et al. (2012) sampled giant jellyfishes using bottom trawl surveys during 2006–2007 in the YS and ECS. Bottom trawl surveys provided the first opportunity to sample giant jellyfish in the YS and ECS to assess population biomass and abundance over large area and in different season. Distribution, biomass, and biomass composition of the jellyfish assemblage during April 2006 to August 2007 surveys in Chinese waters were shown in Figure 3-16. Wei et al. (2015) described the observation of distribution of *N. nomurai* made on R/V Beidou from July 29 to August 7, 2009 (Figure 3-17). Most medusae were observed gathering between the 30 m and 50 m isobaths near the tidal front to the south of the Shandong Peninsular. All stations with *N. nomurai* abundance exceeding 1.0 × 10^4 ind./km^2 were located in the tidal front area.



Apr 2006
A
No medusae
58
Aequorea spp
Ulmaridae
N. nomurai
A. aurita
Sep 2006
C
No medusae
3,100
N. nomurai
Cyanea spp
Ulmaridae
Aug & Sep 2006
Early Sep
Late Aug
B
310
No these species
Cyanea spp
Ulmaridae
Aequorea spp
Oct & Nov 2006
Late Oct
Early Oct
D
2,900
No these species
Ulmaridae
Cyanea spp



Aug & Sep 2006
B'
No N. nomurai
33,000
Nemopilema nomurai
Oct & Nov 2006
D'
No N. nomurai
14,000
Nemopilema nomurai
Dec 2006
E
No medusae
74
N. nomurai
Ulmaridae
Aequorea spp
Mar 2007
F
No medusae
31
Ulmaridae
Aequorea spp

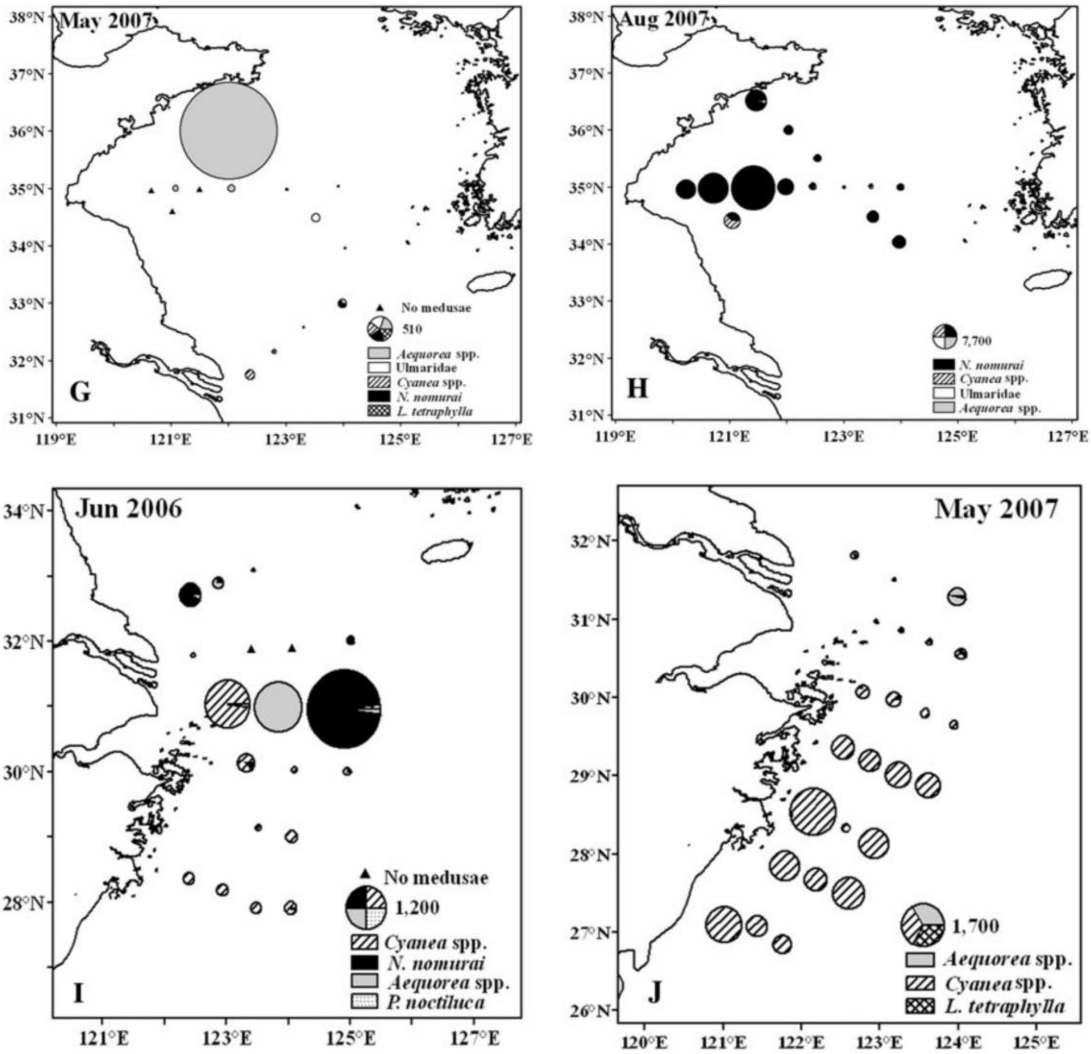


Figure3-16. Distribution, biomass, and biomass composition of the jellyfish assemblage during April 2006 to August 2007 surveys in Chinese waters.

A–J Pies indicated total jellyfish biomass (pie size: biomass, kg km–2. Biomass increased linearly with the pie area at each station), different shadings indicated different jellyfish species, with proportions as percentages of the pie area. Note that in (B) and (D), biomass of *Nemopilema nomurai* was excluded to show biomasses of other species, which otherwise would be masked by *N. nomurai* due to their huge biomass. The biomass of *N. nomurai* was shown instead in (B') and (D'). Different scale bars used for different surveys. *A. aurita* = *Aurelia aurita*; *L. tetraphylla* = *Liriope tetraphylla*; *P. noctiluca* = *Pelagia noctiluca*.

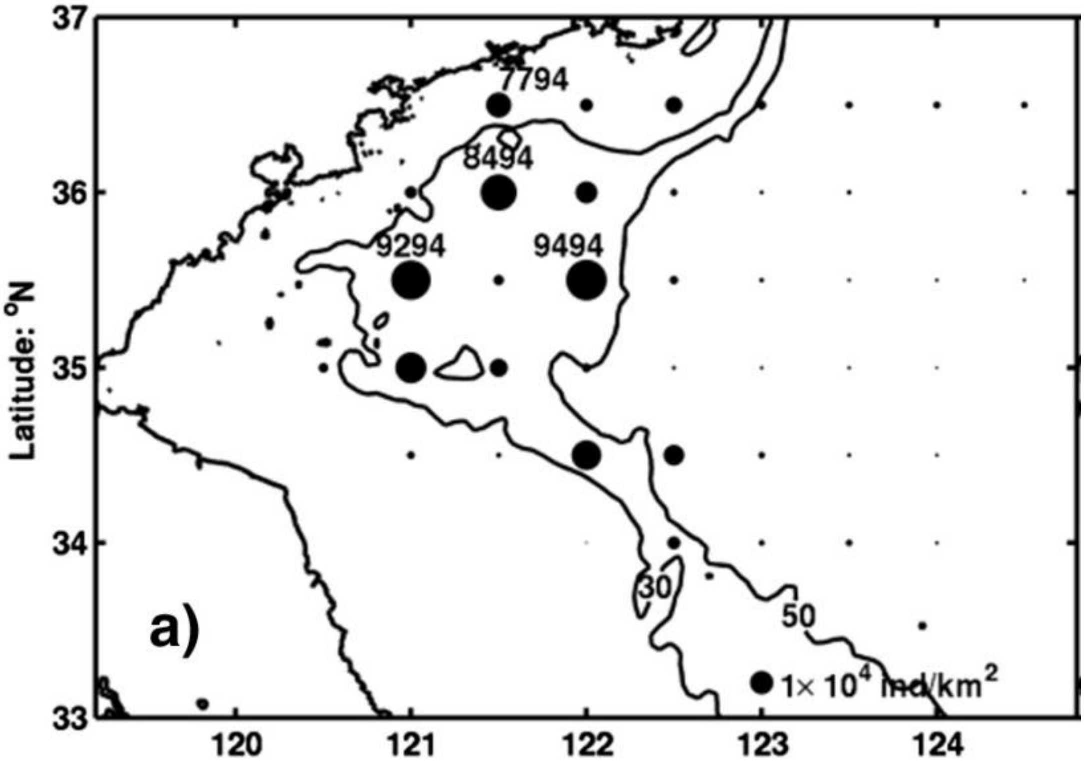


Figure 3-17. Observed distributions of *N. nomurai* in early August, 2009.

Observations were made from July 29 to August 7. The station numbers of observations are denoted. Contour lines are water depth. Solid dots represent the abundance.

3.6 HABs and drifting macroalgae bloom

China started the research on HAB in the 1970s. A monitoring network on HAB was also established by SOA. HAB is routinely included in marine environment monitoring. In the bulletins, the content related to HAB has been included. In 2007, the first large-scale green tide caused by Ulva broke out in Qingdao coast. From then on, green tide affected Qingdao coast each year. Figure 3-18 shows the maximum distribution area and maximum covering area of green tide from 2013 to 2017 in Shandong Province.

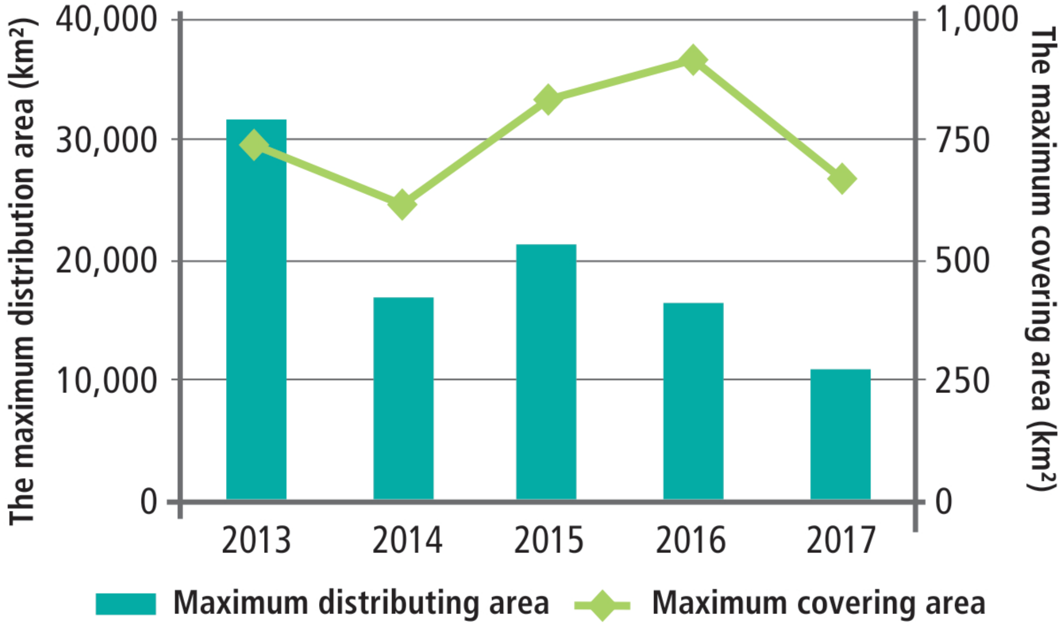


Figure 3-18. The maximum distribution area and maximum covering area of green tide from 2013 to 2017 in Shandong Province.

Figure 3-19 shows the red tide number and distribution area in Shandong Province from 2008-2017. Red bars indicate the number of red tide occurrences, while blue bars indicate the area (km^2) of red tide.

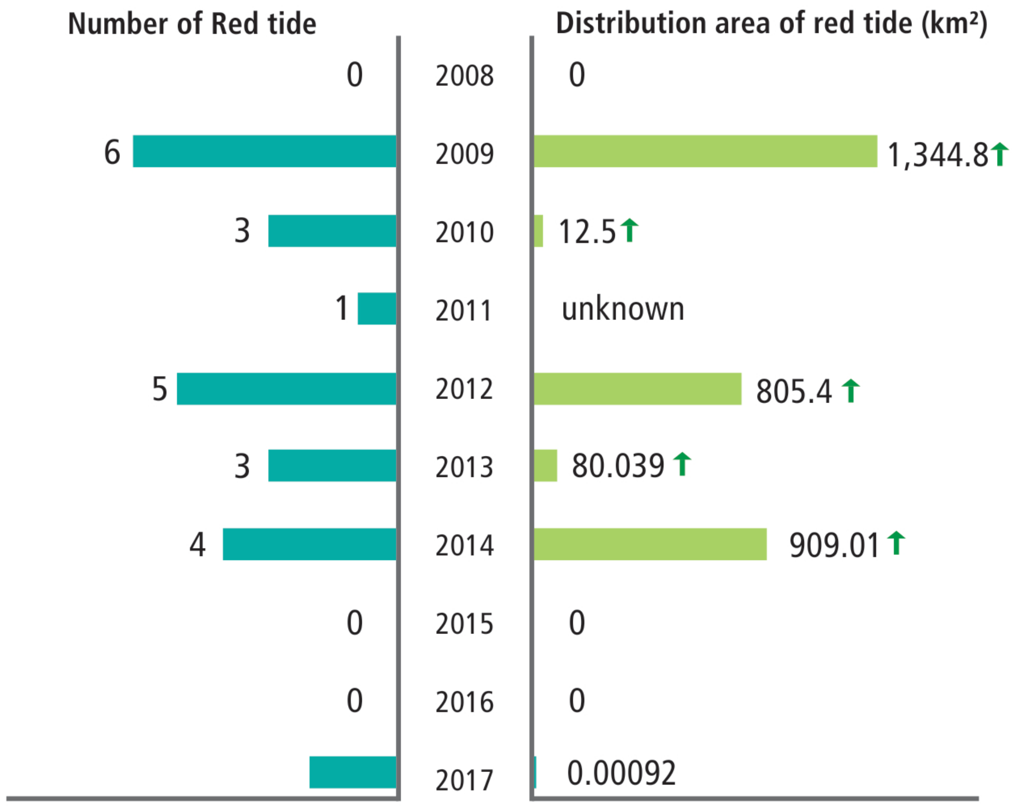


Figure 3-19. Shandong Province red tide number and distribution area (2008-2017).

From May to July 2017, green tide happened in the south coast of Shandong Peninsula, jointly caused by Ulva and Sargassum. Golden tides caused by brown macroalgae (Sargassum) were reported to have increased in recent years. At the end of December 2016, a seaweed farming area of *Poryphyra yezoensis* in the Jiangsu Shoal of the Yellow Sea was severely affected by floating brown macroalgae, which was identified as *Sargassum horneri*. At the sites severely affected by drifting Sargassum, the *Poryphyra yezoensis* aquaculture facilities were taken over by Sargassum and collapsed. By a rough estimate, the area of *Poryphyra yezoensis* aquaculture zone that was affected by the floating *Sargassum horneri* in Jiangsu Province was about 22,700 ha. An economic loss of 0.5 billion CNY (about U.S. $73 million) was estimated due to the damaged seaweed aquaculture, which is the largest direct economic loss in seaweed aquaculture caused by floating Sargassum in China (Xing et al., 2017).

In 2016-2017, *sargassium* blooms, sometimes called ‘golden tide’, occurred in the southern waters of the Yellow Sea. According to satellite remote sensing monitoring results, in October 2016, the floating *sargassium* was mainly distributed in the northern waters of the south yellow sea, and in December, the floating *sargassium* was mainly distributed in the coastal waters of Jiangsu, with a maximum distribution area of 7,700 square kilometers, affecting the radiation sandbar waters off the coast of Jiangsu. In January 2017, the distribution area of *sargassium* in coastal waters of Jiangsu continued to decrease. In early February, *sargassium* was found sporadically in the coastal waters off Qidong, Jiangsu province. This *sargassium* bloom affected laver farming in the southern part of Yancheng city and Nantong city of Jiangsu province, resulting in collapse of farming raft and breakage of cable lines. The 9.18-thousand-hectare laver farming area was affected by the disaster and a large number of production cuts or even no harvest of laver, resulting in a direct economic loss of 448 million yuan.

Figure 3-20. Golden tides in Jiangsu, 2017

3.7 Introduced species

According to Bai and Ma, 2015, the number of marine invasive species in YSLME was 120, in which, 6 species were microbes, 45 species were animals and 69 species were plants.

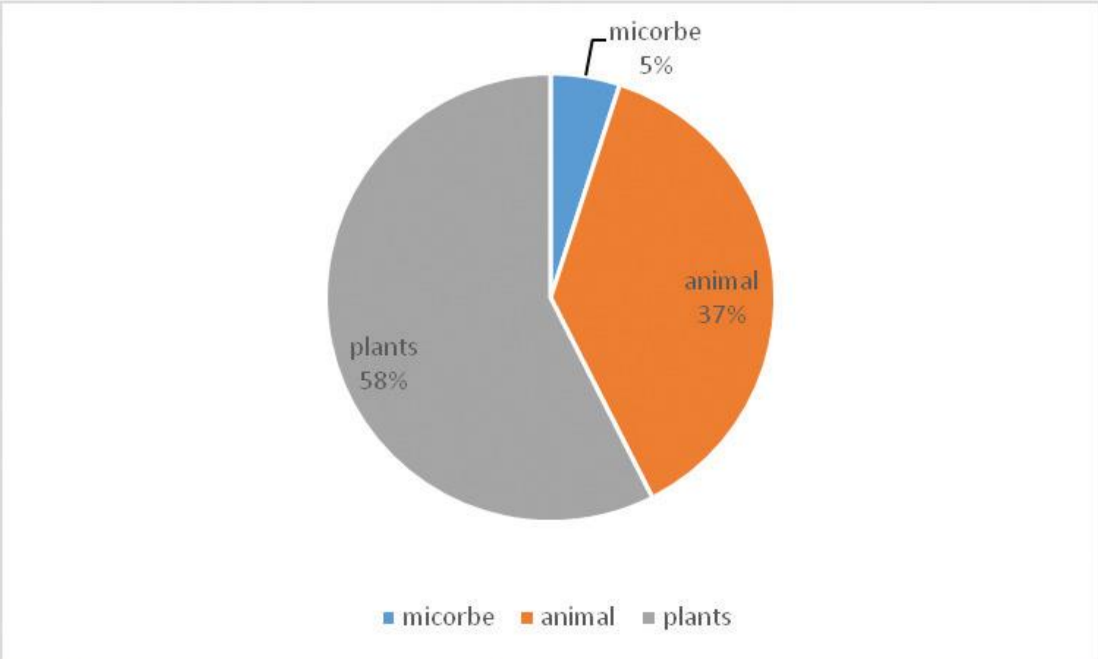


Figure 3-21. The marine invasive species composition in YSLME.

S.alterniflora is listed in the first batch of China invasive species list. It was originally distributed in the coast of the American Atlantic. It was introduced into China from U.S. in 1979 for its ability in ecological restoration. But, due to its strong adaptability and high reproduction, it spread extensively in the coast of China, especially in Jiangsu coastal wetland, resulting in significant impact on wetland ecosystem health and safety. According to Wang et al., 2018, the area of S. alterniflora was only 0.49 km^2 in 1985, then in 2007, it was as high as 123.17 km^2, in 2012, the expansion was still increasing, with an area of 153.8 km^2.

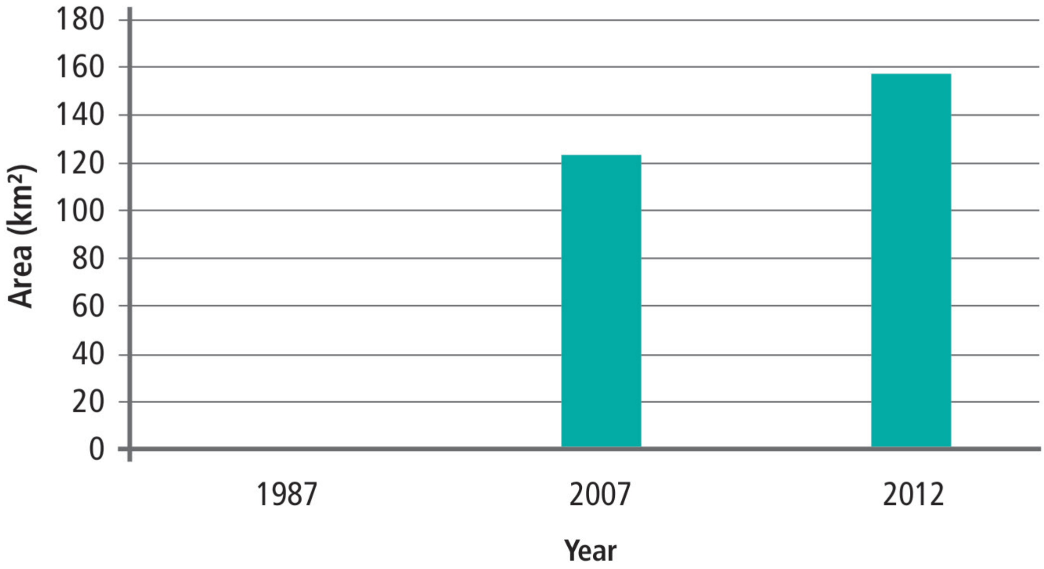


Figure 3-22. The area of S. alterniflora in Yancheng, Jiangsu.

According to a study conducted in the core area of Yancheng National Nature Reserve (Wang et al., 2018), over the period of 2006 to 2015, patch density of S. alterniflora was increasing. In the study area, the expansive rate of S. alterniflora was 1.35 km^2/year. Also, the forecast of its expansion trends was also conducted. Figure 2.46 shows the forecasted landward expansion trend. In 2020, more than 11.45 % area of Suaeda salsa will be occupied compared with 2.28% in 2016.

Risk of ballast water

Considering safe navigation, cargo loading and other needs, ocean transport vessels will inevitably have to inject or discharge ballast water in coastal waters. The amount of ballast water in a ship with 100 000 tons of cargo carriers can be up to 50 to 60 thousand tons. According to the estimate of several researchers, there is about 3.5 to 12 billion tons of ballast water transferred and emitted across the world each year (Oemcke DJ, et al., 2003; Endresen O, et al., 2004; Pimentel D, et al., 2005; Chen C, 2013).

Large quantities of ballast water discharge from ocean going ships in sea ports of

Yellow Sea is one of the important factors which cause the spread of aquatic nonindigenous harmful species isolated geographically by waters, the deteriorating environment of the near-shore water area and the frequent outbreaks of red tides.

4. Monitoring program

4.1 HAB and drifting macroalgae bloom

HAB monitoring network of China

There are two forms of HAB monitoring program, one is the regular HAB monitoring program, the other is the emergency HAB monitoring program. There are 19 HABs Monitoring Area in Chinese coastal waters for regular HABs monitoring, among which, there are four HABs Monitoring Area located in the Yellow Sea, which are Donggang HABs Monitoring Area, Zhangzidao HABs Monitoring Area, Yantai HABs Monitoring Area, and Haizhouwan HABs Monitoring Area. In the regular HAB monitoring program, water samples were sampled bi-weekly, and the most abundant phytoplankton species and the major nutrition were analyzed.

Locations of the regular HABs monitoring network in china coastal waters

Emergency HABs monitoring is conducted only after water discoloration or fishery damage is reported. Table below shows the objectives and monitoring parameters of the above monitoring types.

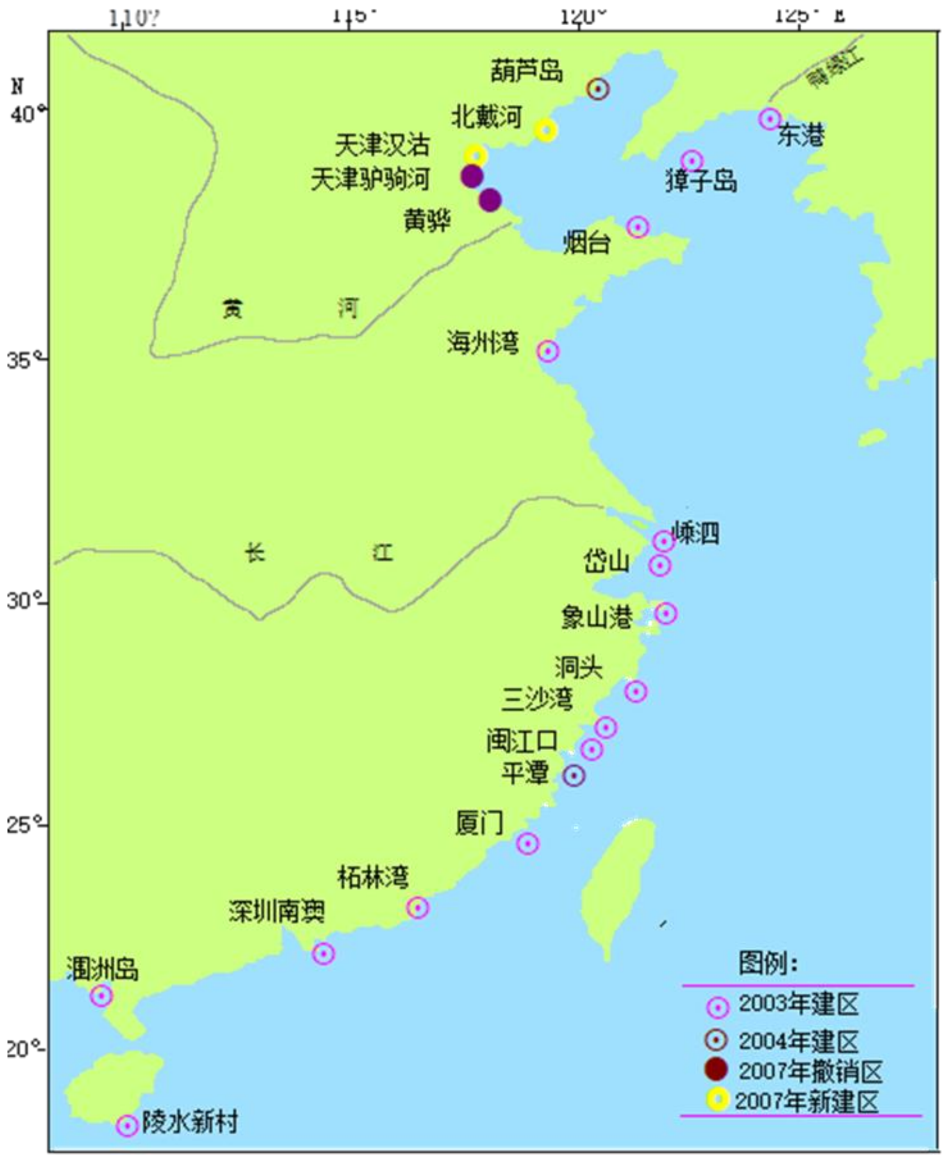


Figure 4-1 HABs monitoring network in china

Macroalgae

Intertidal zone: Surveys of intertidal zones are conducted on rocky shores, embankments or soft-sediment tidal flats with green algae, where at least three survey transections is generally set. At each transection, two stations are usually set up in the high tide area, three stations in the middle tide area, and one or two stations in the low tide area. In the short intertidal zone on the beach, one station is set up in the high tide area, three stations in the middle tide area, and one station in the low tide area.

Cultivation rafts：In each cultivation area, three breeding rafts are selected as three transections, three stations for each transection, and no less than two samples for each station.

Survey time: Surveys are conducted third times between March and May. The sampling in the intertidal zone are carried out during the spring tide as much as possible. The investigation in the cultivation zone can be conducted in a sunny day.

4.2 Jellyfish

Plankton nets are recommended to sample jellyfish ephyra and larvae. And the anchor drift net is a better choice for medusa monitoring in the coastal waters. Such net has been practically used for four years at regions adjacent to Hongyanhe by NMEMC.

Sight survey (Modified from sighting survey method using ship of opportunity of Yoon *et al*, 2018) is easy to operate, economical and labor-saving. And it is more applicable for offshore areas, especially a vast area; And the cruise line depends on ferry route. The current cruise line covers "Incheon → Yantai → Dalian → Bayuquan → Incheon " by Wonduk Yoon from Korea which has already been in operation. However, without the permission of the Chinese government it is forbidden to enter the Chinese inland sea (Bohai Sea) for investigation and research, so we suggest the research line end to Dalian station (the Yellow Sea waters). And one or two more trips (excluding Bohai Sea) are advised from China to be introduced from Dalian to Nagasaki (an alternative, Fukuoka) in August and September (Figure 4-2).

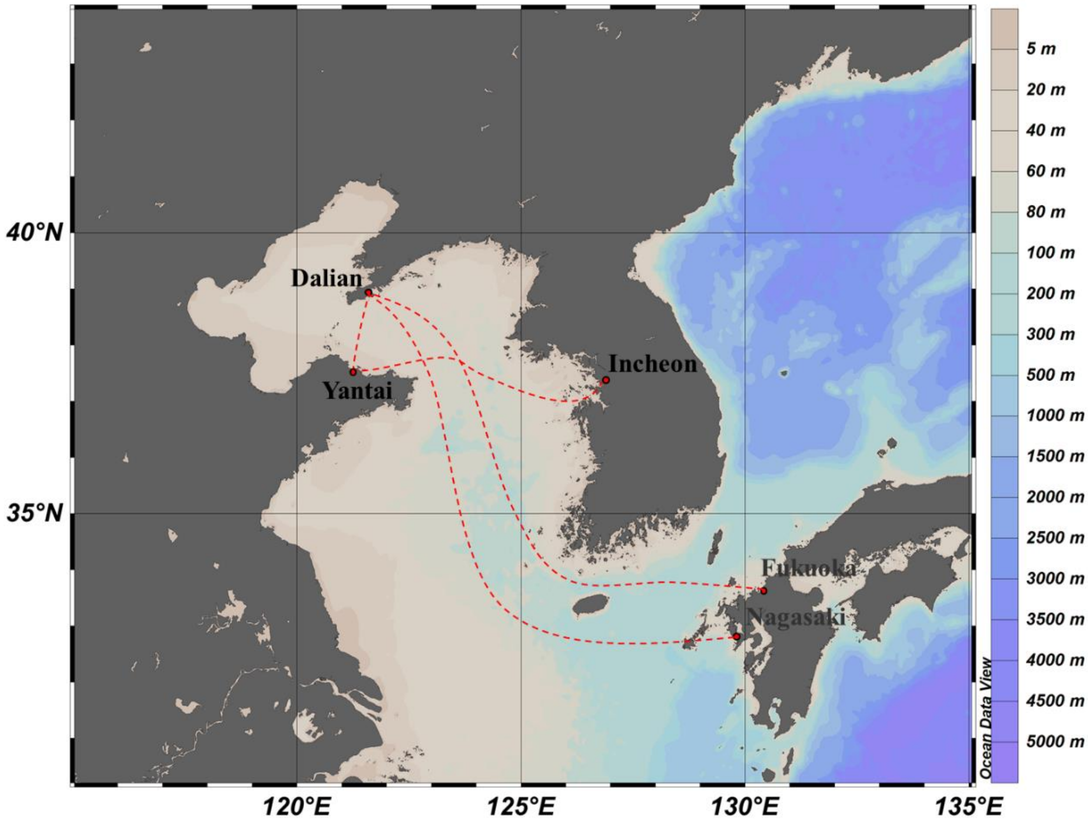


Figure 4-2 The sight survey route map in YS

1) Net gear

The anchor drift net is a better choice for medusa monitoring in coastal waters. Such net has been practically used for four years at regions adjacent to Hongyanhe by Guan Chunjiang *et al*, and the sampling proves to be effective. The net is single-chip jellyfish anchor drift net, which is a kind of long band net composed of rectangle net chip. The height and length of the net is 8 m and 60 m, respectively, the mesh is 10 cm. The direction of net chip and ocean current should be vertical, and the net coupled with ocean currents should be drawn. Monitoring time is often at one-hour interval.

2) Sight survey

First, the place for jellyfish monitoring should be chosen to measure the height (H) from the sea surface to the place of monitoring using laser rangefinder or tapeline, or string with marked meters. After setting sail, the GPS should be turned on to record geographical position and time. During cruise at steady speed of ship, the goniometer is used to measure the angle (a, between the ship and the foam). The width of foam can be estimated(P):

$$\tan (a) = \text{width of foam } (P) / \text{height } (H)$$

Calculate angle b:

$$\tan(b) = (P+10 \text{ m})/H.$$

If the situation is not favorable, or there are too many jellyfish in the 10 m width, we suggest decreasing the width to 5 m to make it easy to count. X (monitoring width) will be estimated. The amount of jellyfish will be counted every 5 minutes from dawn to sunset or from departure to arrival at port.

After cruise, such data as 5 min's distance (from GPS data), monitored surface with monitoring width, and jellyfish density in individuals in 100 m^2 will be estimated. Histogram figure will be worked out and put in a map.

3) Expressive methods of jellyfish biomass

For net gear, species name, abundance and diameter for every species should be recorded. Monitoring results should be expressed using ind/(net/h), jellyfish number/ (net/hour); or kg/(net/h), jellyfish weight/ (net/hour).

For sight survey, GPS data and the number of jellyfish should be recorded every 5 min. Monitoring results should be expressed using ind/100m^2, jellyfish number/every 100m^2.

Sampling time

Jellyfish ephyra occurred in May, larvae occurred from May to June, medusa blooms usually from July to August every year in usual. Therefore, we recommend setting sampling time from May to August, and the sampling frequency is once a month.

4.3 Introduced species

A comprehensive Yellow Sea invasive species information database will be established, including invasive species geographic distribution information, field survey data, species safety assessment, DNA barcoding information, remote monitoring system, etc. We need to promote the establishment of early warning system for invasive species in the Yellow Sea, including invasive biology database, alien biology inspection and quarantine system, monitoring system, risk assessment system, network communication platform, early warning decision system, biological prevention and control training system, and emergency plan. We need to establish an alien invasive species prevention and quarantine points, management sites, ecological positioning monitoring station maintenance, watchtower, mission and education points.

We should promote the control mechanism of foreign invasive species in the Yellow Sea region coordinated by multiple departments and the public. We will encourage the departments of agriculture, industry and commerce, public security, transportation, publicity and finance to establish coordination mechanisms and improve the efficiency of their control. Strictly implement the international convention on control and management of ballast water and sediment, prepare performance reports and exchange management experience. Carry out various forms of publicity activities to raise public awareness and mobilize the public to control alien invasive species.

5. Policy recommendations

5.1 Enhance the joint research of YSLME

Regional policy - making needs to deepen the scientific understanding of the YSLME. A scientific, systematic and accurate assessment of YSLME is the basis of all work. There are three countries along the coast of the Yellow Sea, and there are technical difficulties in carrying out trans-bordering diagnostic analysis, which requires all relevant international organizations and the coastal countries to make joint efforts under an effective mechanism. The members can enhance joint research on YSLME in a variety of ways.

China-Korea Joint Survey on the Yellow Sea is necessary for the comprehensive study. Ecosystem assessments require detailed cruising data. Due to the jurisdictional restrictions in the central Yellow Sea, the investigation of one single party cannot cover the entire area, thus resulting in data missing and discontinuity. In 2008, YSLME Project organized voyages in winter and summer seasons and achieved good results. However, because of the funding shortage of both sides and lack of government approval, the joint voyages were not implemented in the following years. Now it has been more than 10 years since the voyage in 2008. To seize the new changes in the Yellow Sea ecosystem, it is necessary to carry out joint investigation voyages again.

5.2 Cooperation in Protecting the Yellow Sea Ecological Important Zone

Ecological Important Zone is important to maintain the stability and sustainability of YSLME. The protection of Yellow Sea Ecological Important Zone is crucial to the ecosystem of northeast Asia, the northwest Pacific and even the global ecosystem. The surrounding waters of the Yellow Sea provide the areas of pawning, feeding and migrating for many species. The Yellow Sea coastal mudflats provide an important stopover for migratory birds of East Asia-Australia route.

The protection of the ecological important area is a trans-bordering issue, which requires the joint efforts of all countries and organizations in the region. It is necessary to promote the construction of the network of Marine Protected Areas, formulate the standards, objectives, procedures and joint action plans for the network of protected areas, and implement coordinated monitoring and common protection measures among protected areas with similar types, similar protection objects and close ecological links.

Priority protected areas should be identified through scientific analysis of key habitats needed in biodiversity conservation. The key to find a balance point in protection and development is based on the two countries deep cooperation, scientific research, and strong guide to the government decision-making.

5.3 Establish an Ecosystem-based Yellow Sea Management System

The purpose of ecosystem management is to maintain a balance between natural resources and socio-economic systems, to ensure that ecosystem services and biological resources are not irreversibly consumed by human activities, and to achieve long-term sustainability of the regions in which ecosystems are located. The YSLME is one of the LMEs, and has the relative independence and the integrity. The ecosystem-based management is the approach to obtain the regional sustainable development.

Establish a regional cooperation management mechanism, actively implement integrated marine management based on marine ecosystems, and continuously explore new ways and modes in marine strategic research, integrated coastal management, delineation of ecological red lines, and scientific reclamation. Based on scientific natural boundaries rather than administrative boundaries as the scope of management, with integrated management, adaptive management and prevention as the basic principles, importance is attached to human factors in the management process, and then safeguard the health, biodiversity and sustainable utilization of natural resources of marine ecosystems.

5.4 Cooperation in Legislation of Marine Environment and Biodiversity Conservation

The Yellow Sea is surrounded by 3 countries. The 3 countries have different mechanisms in legislation and policymaking. It is necessary to enhance the legislation cooperation in Yellow Sea region. The YSLME phase I organized a workshop on the issue of YSLME attended by the NPC delegates of China and the ROK parliamentarians. The workshop delegates fully recognized the environmental problems in the Yellow Sea and believed that effective actions should be taken to protect the yellow sea and the issue of the yellow sea should be taken into consideration in decision-making.

Make Joint Efforts to Improve the Comprehensiveness and Consistency of China and Korea in Marine Environment and Biodiversity Conservation Legislation.

This is crucial in solving the cross-border problems of the Yellow Sea ecosystem and also helps to deal with similar environmental issues in two countries. Scientific evidence can be provided for government legislation by holding academic seminars or setting up research topics.

5.5 Develop the Master Strategy for Conservation and Sustainable Use of the Yellow Sea

In line with the actual development requirements of the two countries, formulate master plans with the actual condition and specific problems of the Yellow Sea, coordinate the relationship between various marine industries, promote the overall benefits of marine economic development, and make medium and long-term deployment. Management strategies for related industries, energy production, land development, aquaculture, and marine fisheries are proposed to deal with specific issues, for example, the control and supervision of illegal fishing and breeding and main fishing production means of fishing boats and fishing gear. Keep improving the supporting technologies and policy measures for the protection and restoration of fishery resources and the development of marine aquaculture, thus creating methods to control the pollutants entering the sea. Meet the technical standards for marine environmental protection and establish a sound marine environmental monitoring system.

Reference

1. Zheng Q, Fang G, Song Y T. Introduction to special section: dynamics and circulation of the Yellow, East, and South China Seas[J]. Journal of Geophysical Research: Oceans, 2006, 111(C11).
2. Ichikawa H, Beardsley R C. The current system in the Yellow and East China Seas[J]. Journal of Oceanography, 2002, 58(1): 77-92.
3. Wei Q S, Yu Z G, Wang B D, et al. Coupling of the spatial–temporal distributions of nutrients and physical conditions in the southern Yellow Sea[J]. Journal of Marine Systems, 2016, 156: 30-45.
4. Wei Q, Yao Q, Wang B, et al. Long-term variation of nutrients in the southern Yellow Sea[J]. Continental Shelf Research, 2015, 111: 184-196.
5. Bai Jia-yu, Ma xue-guang. Spatial distribution of Marine ecosystems of Marine invasive species from China [J]. Marine environmental science. 2015,34(03):347-353.
6. Guo Ya. Dynamics of international standards in the field of ship ballast water [J]. Ship standardization and quality. 2017(03):50.
7. HUANG Bei , WEI Na , TANG Jingliang , JIN Yimin, Changes of Phytoplankton Community Structure and Diversity in the South Yellow Sea During 2007-2017[J]. Environmental Monitoring in China, 2018(6):137-148.
8. LUAN Qingshan, KANG Yuande, WANG Jun, Long-term changes within the phytoplankton community in the Yellow Sea (1985–2015) [J]. Journal of Fishery Sciences of China, 2020 (1): 1-11.
9. DU Huan, ZHANG Xiao-fang, ZHANG Zhi-tao. Input characteristics and risk analysis of ballast water from offshore entry ships in China [J].Marine Science

Bulletin,2017,19(02):20-37.

10. Agawin N R S, Duarte C M, Agustı S, 2000. Nutrient and temperature control of the contribution of picoplankton to phytoplankton biomass and production. Limnology and Oceanography 45, 591–600.

11. Fu M Z, Wang Z L, Pu X M et al, 2012. Changes of nutrient concentrations and N:P:Si ratios and their possible impacts on the Huanghai Sea ecosystem. Acta Oceanologica Sinica, 31 (4): 101–112

12. Fu M, Wang Z, Li Y, et al., 2009. Phytoplankton biomass size structure and its regulation in the Southern Yellow Sea (China): Seasonal variability. Continental Shelf Research, 29: 2178-2194.

13. Li H M, Zhang C S, Han X R, et al., 2015. Changes in concentrations of oxygen, dissolved nitrogen, phosphate, and silicate in the southern Yellow Sea, 1980-2012: Sources and seaward gradients. Estuarine, Coastal and Shelf Science, 163: 44-55.

14. Lie H J, Cho C H, Lee J H, et al, 2001. Does the Yellow Sea Warm Current really exist as a persistent mean flow? J. Geophys. Res. 106 (C10), 22199–22210.

15. Lin C L, Ning X R, Su J L et a1, 2005. Enviromental changes and respondes of ecosystem of the Yellow Sea during 1976—2000. Journal of Marine Systems, 55: 223–234

16. Liu P, Song H, Wang X, et a1, 2012. Seasonal variability of the zooplankton community in the southwest of Huanghai Sea (Yellow Sea) Cold Water Mass. Acta Oceanologica Sinica, 31(4):127-139.

17. Montagnes D J, Franklin D J, 2001. Effect of temperature on diatom volume, growth rate, and carbon and nitrogen conten: reconsidering some paradigms. Limnology and Oceanography 46, 2008–2018.

18. Park S, Chu P C, Lee J. 2011. Interannual-to-interdecadal variability of the Yellow Sea Cold Water Mass in 1967-2008: Characteristics and seasonal forcings. Journal

of Marine Systems, 87(3-4):177-193.

19. Park S, Chu P C. 2006. Thermal and haline fronts in the Yellow/East China Seas: surface and subsurface seasonality comparison. Journal of Oceanography, 62 (5), 617–638.

20. Song H, Ji R, Xin M, et al. 2019. Spatial heterogeneity of seasonal phytoplankton blooms in a marginal sea: physical drivers and biological responses. ICES Journal of Marine Science (accepted)

21. UNDP/GEF. 2011. Seasonal variation of the major environmental parameters in the Yellow Sea Basin. UNDP/GEF Yellow Sea Project, Ansan, Republic of Korea (102 pages).

22. Wang R, Zuo T, Wang KE. 2003. The Yellow Sea Cold Bottom Water—an oversummering site for Calanus sinicus (Copepoda, Crustacea). Journal of Plankton Research, 25(2): 169-183.

23. Yang Q, Liu H, Liu G, Gu Y. 2018. Spatio-temporal distribution pattern of Calanus sinicus and its relationship with climate variability in the northern Yellow Sea. ICES Journal of Marine Science, 75(2): 764-772.

24. Oemcke D J, Vanleeuwen J, 2003. Chemical and physical characterization of ballast water. Part 2: Determining the efficiency of ballast exchange. Journal of Marine Environment and Engineering, 7 (1): 65-76.

25. Endresen O, Behrens H L, Brynestad S, et al, 2004. Challenges in global ballast water management. Marine Pollution Bulletin, 48: 615 - 623.

26. Farrah T C, Sarah A B, Chris J W, et al. Relative risk assessment forballast-mediated invasions at Canadian Arctic ports. Biological Invasions, 2013, 15: 295-308.

27. Pimentel D, Zuniga R., Morrison D, 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States.

Ecological Economics, 52, 273-288.

28. Chen Chong, Control and management of ballast water in ships. Water transport management, 2013.(10):30-31

29. Fu M Z, Wang Z L, Pu X M et al, 2012. Changes of nutrient concentrations and N:P:Si ratios and their possible impacts on the Huanghai Sea ecosystem. Acta Oceanologica Sinica, 31 (4): 101–112

30. Zhang F, Sun S, Jin X, Li C (2012) Associations of giant jellyfish distributions with temperature and salinity in the Yellow Sea and East China Sea. Hydrobiologia, 690:81-96

31. Wei H, Deng L, Wang Y, et al. Giant jellyfish Nemopilema nomurai gathering in the Yellow Sea—a numerical study[J]. Journal of Marine Systems, 2015, 144: 107-116.

32. GUO H, DING D W, LIN F A, GUAN C J. Characteristics and patterns of red tide in china coastal water during the last 20a. Advances in Marine Science, 2015, 33(4):547-558.

33. Jung Hoon KANG, A Study on the relationships between the changes of Yellow Sea Cold Water Mass and structure of plankton communities, UNDP/GEF YSLME II. 2020.