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)

The feasibility report for designating YSCWM a new MPA

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Content

1. Introduction for Marine Protected Area

In recent years, with the rapid development of economy, marine resources are excessively exploitated and utilized, which cause serious damage to the marine environment and resources in the southern Yellow

Sea. In order to preserve the natural environment and resources, eliminate or reduce the negative impact from human activities, people begin to set up Marine Protected Areas (MPAs) to preserve marine resources and environment, strictly limit the impact interference from human activities both in Korea and China. Ecological environment is the cornerstone of the survival and sustainable development of human society. Despite there are various concepts and classifications of MPAs around the world, it has been proved that MPAs are one of the most effective approach to protect marine biodiversity in practice. MPAs can prevent the deterioration of marine environment, keep sustainable development of marine resources by controlling human activities, which maintain the healthy marine ecosystem and its steady productivity.

1.1 Functions of MPAs

As a preventive management tool for protecting marine habitats and fully reflecting the value of marine ecosystem services, functions of MPAs are mainly reflected in the following aspects:

(1) Conservation for marine biodiversity

MPAs protect natural communities, trophic structures and food chains from excessive interference by human activities. They can restore and maintain the composition and functions of original ecosystems, protect and recover key habitats such as coral reefs, mangroves and seaweed beds, and sustain threatened, rare and endangered marine lives.

(2) Conservation for fishery resources

MPAs can effectively eliminate biotical mortality by accidental capture and indirect deaths from habitat destruction by prohibiting and restricting fishery or any other destructive activities. MPAs conserve the abundance, density and biomass of key species, increase the average size and age of individuals of marine species, provided shelter for spawning and persistent biota. They provide the possibility for sustainable use of vulnerable species and long-term stable development of fishery.

(3) Marine science research

Due to the strong dynamic of the ocean, there are frequent exchange of materials and energy between the marine ecosystem and outside world. Marine ecosystems are more vulnerable to interfered by natural factors, such as typhoons and waves, as well as man-made factors such as land-source pollutant and oil spilling from ships. However, it is difficult to distinguish between natural and man-made factors, when various factors are acting in the same space, simultaneously. MPAs control human activities in particular areas as an experimental approach to obtain environmental background values, which can be compared with those areas that have changed as a result of various human exploitations. With the results of comparison, we can reasonably evaluate the influence from human activities to develop more scientific assessment to support marine management.

(4) Education platform for marine knowledge

The construction and management process of MPAs usually involves multiple stakeholders, such as governments, native residents, managers, experts, consultants, research institutions, local fishermen, private enterprises, media and tourists, etc., which can, to a large extent, enhance the awareness and participation of the whole society. At the same time, the beautiful natural scenery, various marine lives and original marine landscape can attract many tourists to come for leisure and entertainment, as well as marine science education in MPAs, which enhance marine conservation awareness.

1.2 Classifications of MPAs

Despite the usage of inconsistent terminology in different nations or regions, such as concepts and classifications, IUCN category (Table 1.1) has been regard as one of the most effective universal notion for identifying MPAs. IUCN category includes seven kinds of MPAs, such as Strict Nature Reserve, Wilderness Area, National Park, Natural Monument, Habitat/Species Management Area, Protected Landscape/Seascape, Managed Resource Protected Area.

Table 1.1 Definitions of the IUCN MPAs Categories. Information is excerpted from Dudley 2008.

Category	Designation	Definition
Ia:	Strict Nature Reserve: protected area managed mainly for science	Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.
Ib	Wilderness Area: protected area managed mainly for wilderness protection	Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
II	National Park: protected area managed mainly for ecosystem protection and recreation	Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
III	Natural Monument: protected area managed mainly for conservation of specific natural features	Area containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.
IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention	Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.
V	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation	Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.

VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems	Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

1.3 The significance of Marine Protected Area

Over the last 15 years, most coastal fish resources have been overexploited (Castilla, 2000), raising doubts about the long-term sustainability of certain fisheries (Pauly et al., 2002). In addition, fish habitat has also been strongly altered by widely used fishing gears such as trawls and dredges, resulting in reduced seabed complexity and removal of macrobenthic organisms that provide shelter for others (Sumaila et al., 2000).

Marine protected areas (MPAs) are increasingly considered in coastal areas as an instrument to preserve vagile fauna and habitat from detrimental effects of fishing (Halpern, 2003; Claudet et al., 2006). The use of anti-trawling artificial reefs along the boundaries of several French, Italian and Spanish MPAs has proved to be an effective way of excluding non-selective towed fishing gears which bear detrimental effects on habitats (Harmelin, 2000). It is anticipated that MPAs and no-take reserves would be more effective as a fishery and conservation tool for organisms that have relatively sedentary adult life stages and exhibit larval dispersion, enabling biomass exportation to the surrounding areas (Chiappone and Sealey, 2000). There are many documented examples where fished species have benefited from reserve establishment, through increases in mean size and abundance (for reviews, see Halpern, 2003).

2.Technical conditions for designating YSCWM a new MPA

2.1 Ecologically or Biologically Significant Areas

Building upon existing sets of criteria used nationally, regionally and globally, IUCN has been refined and developed a consolidated set of scientific criteria for identifying Ecologically or Biologically Significant Areas (EBSAs) in need of protection in marine habitats. The criteria of EBSAs can be used to identify MPAs in need of protection in the Yellow Sea Cold Water Mass (YSCWM) region. EBSAs are special areas in the ocean that serve important purposes, in one way or another, to support the healthy functioning of oceans and the many services that it provides. EBSAs are geographically or oceanographically discrete areas that provide important services to one or more species/populations of an ecosystem, compared to other surrounding areas or areas of similar ecological characteristics.

EBSAs are important content of large marine ecosystem management on the guarantee for sustainable supply of ecological services. The identification of EBSAs is an important tool for highlighting areas that have particularly high ecological or biological importance for the overall ecosystem. The ocean is under increasing threat from various human activities. The most pressing threats come from overfishing, destructive fishing practices, and illegal, unreported and unregulated fishing activities. Other emerging problems include marine debris, ship-based marine pollution, transfer of alien invasive species, illegal dumping and the legacy of historical dumping, seabed mineral extraction, and noise pollution.

As one of the most important services of ecosystems, maintaining biodiversity can provide ecological and biological products for human society (MA, 2002), and the natural ecological system plays an irreplaceable role to meet the needs of economic and social sustainable development. Identifying and classifying habitats are the foundation and precondition for formulating management policies for biodiversity conservation. Marine habitat landscapes are not as rich as that on land, which have low visibility of species distribution. Therefore, habitat identification and classification are more complex and difficult in marine ecosystems, and which makes the EBSAs as the core of Marine management (Gregr et al., 2012).

2.2 EBSAs Criteria for designating MPAs

Since the 1980s a variety of national agencies, NGOs, and academic researchers have published or promulgated suites of criteria for the identification of areas of biological or ecological importance in the open ocean. The Convention on Biological Diversity took up the call to identify such areas in 2006 at the eighth meeting of the Conference of Parties, and called for the convening of an expert workshop to “Refine and develop a consolidated set of scientific criteria for identifying ecologically or biologically significant marine areas in need of protection, in open ocean waters and deep-sea habitats, building upon existing sets of criteria used nationally, regionally and globally”.

Applicable site-specific considerations refer to uniqueness or rarity Special importance for life history, stages of species, importance for threatened, endangered or declining species and/or habitats, vulnerability, fragility, sensitivity or slow recovery, biological productivity, biological diversity and naturalness. The seven scientific criteria for identifying EBSAs in need of protection are showed in Table 2.1 and 2.2, including core and additional indicators.

Core indicators belong to five criterion, such as biological productivity; biodiversity (species and genetic diversity); reproductive areas; non-reproductive bottleneck areas; habitat for endangered/ threatened species. Biological productivity includes high Chlorophyll concentration, high phytoplankton cell abundance, high zooplankton abundance/ biomass, high benthos abundance/biomass, high productivity, high fishery resource, etc. Biodiversity considers both on the species and genetic diversity, including high biodiversity, high community diversity, high habitat diversity. Reproductive areas are the high larva/egg abundance areas or spawn ground. Non-reproductive bottleneck areas are the overwintering ground or migration paths. Habitats for endangered/threatened species consider both on the endangered species and threatened species.

Additional Indicators belong to two criteria, including naturalness, fragility/ sensitivity and significance. Naturalness means less disturbed by human activity, difficult for humans to reach or low concentrations of pollutants. Fragility/ sensitivity include especially sensitive to human activities, habitats or species recover slowly after disturbance, easy to accumulate pollutants, areas prone to marine disasters.

Table 2.1 Core indicators for ecological or biological significant criterion

Ecological or Biological Significant Criterion	Core Indicators
Biological productivity	● High Chlorophyll concentration ● High phytoplankton cell abundance ● High zooplankton abundance/biomass ● High benthos abundance/biomass ● High productivity ● High fishery resource
Biodiversity **(species and genetic diversity)**	● High biodiversity ● High community diversity ● High habitat diversity
Reproductive areas	● High larva/egg abundance

Non-reproductive bottleneck areas	● Spawn ground ● Overwintering ground ● Migration paths
Habitat for endangered/ threatened species	● Habitat for endangered species ● Habitat for threatened species

Table 2.2 Additional indicators for ecological or biological significant criterion

Ecological or Biological Significant Criterion	Additional Indicators
Naturalness	● Less disturbed by human activity ● Difficult for humans to reach ● Low concentrations of pollutants
Fragility/ sensitivity	● Especially sensitive to human activities ● Habitats or species recover slowly after disturbance ● Easy to accumulate pollutants ● Areas prone to marine disasters

2.3 Available indicators on criteria for designating an MPA in YSCWM

There are few sporadic records for directly designating an MPA in YSCWM, therefore indicators on EBSAs criteria were used for identity the areas in need for protecting. Available indicators can be list as chlorophyll concentration, phytoplankton abundance, zooplankton abundance/ biomass, benthos abundance/ biomass, productivity, fishery resource, larva/ egg abundance or spawn ground, overwintering ground, migration paths, habitat for endangered/ threatened species, etc.

2.3.1 Chlorophyll concentration

Chlorophyll concentration data reference research (Wei et al.,2014) on the seasonal evolution of chlorophyll maximum in the YSCWM. Since the maximum values of Chl-a mostly exist around sub-surface layer with the depth of 30 meter in the YSCWM area, the horizontal distribution of Chl-a at 30-meter-layer was used in Wei's study to indicate the maximum of chlorophyll concentration.

As shown in Fig. 2.1, the concentration of Chl-a in the central YSCWM was relatively high in spring, and gradually decreases to the surrounding waters. The distribution pattern of Chl-a in summer was opposite to that in spring (Fig. 2.2). The high value area was mainly concentrated in the boundary of cold-water mass, and the concentration of Chl-a in this area was significantly higher than that in spring. In autumn (see Fig. 2.3), the concentration of Chl-a in the boundary area of YSCWM decreased, while the concentration of Chl-a increased in the deep-water area of the cold-water mass.

Based on above analysis, it is not difficult to obtain the seasonal evolution rule of Chl-a maximum in the sub-surface layer of the YSCWM in the south yellow sea. The depth of Chl-a maximum layer gradually deepened from spring to summer. The highest concentration of Chl-a emerged at the boundary of cold-water mass in summer, which was significantly higher than other seasons in deep water.

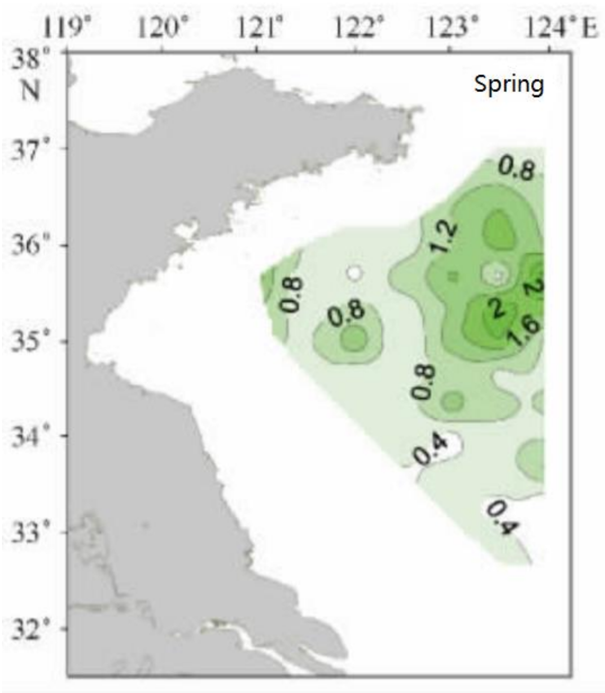

Fig. 2.1 The horizontal distribution of Chl-a at 30-meter-layer in spring (Wei et al., 2013)

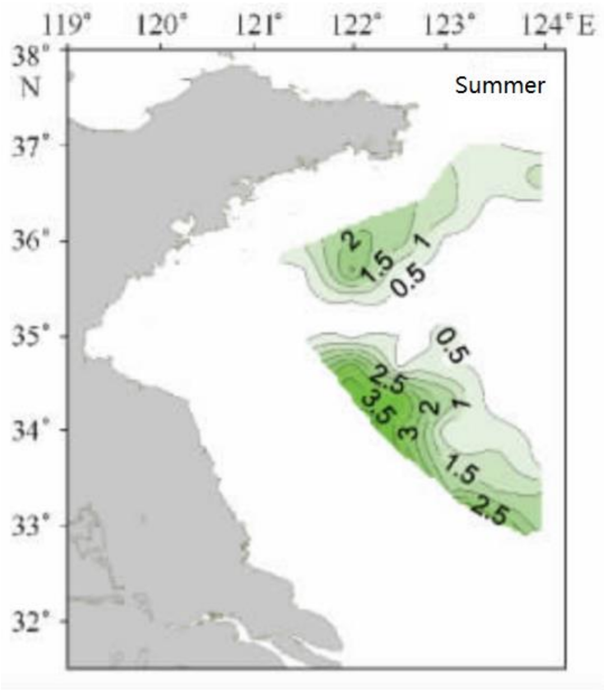

Fig. 2.2 The horizontal distribution of Chl-a at 30-meter-layer in summer (Wei et al., 2013)

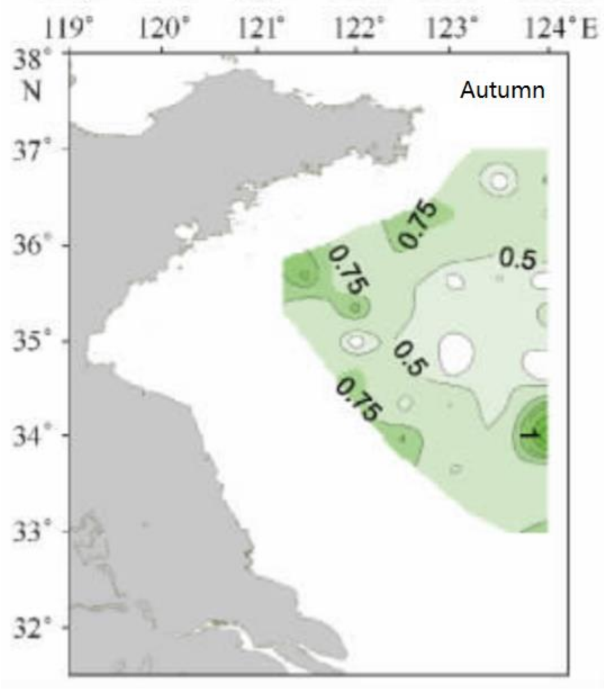

Fig. 2.3 The horizontal distribution of Chl-a at 30-meter-layer in autumn (Wei et al., 2013)

2.3.2 Phytoplankton abundance

In our research in 2008, there were totally 62 species of phytoplankton identified in winter and 139 species in summer, respectively. The quantity of dominant species in winter was much more than that in summer (Table 2.3), while *Chaetoceros lorenzianus* and *Pseudonitzschia pungens* are the dominant species.

Several diatoms dominated with similar dominance indexes in the net samples collected in winter. 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 (Fig. 2.4).

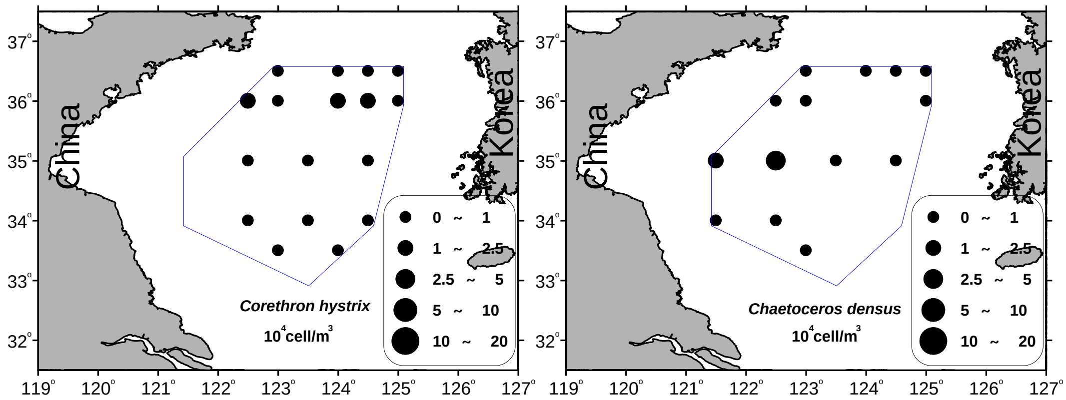

Fig. 2.4 Distribution of *Corethron hystrix* (left) and *Chaetoceros densus*(right) in net samples in winter.

Table 2.3 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 oculusiridis	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		

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 in the summer net samples. 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 (Fig. 2.5). *Chaetoceros lorenzianus* was the most dominant species, accounting for 52% of the total abundance and averaging 374×10^4 cells/m^3. This species shaped the main features of total abundance in the net samples.

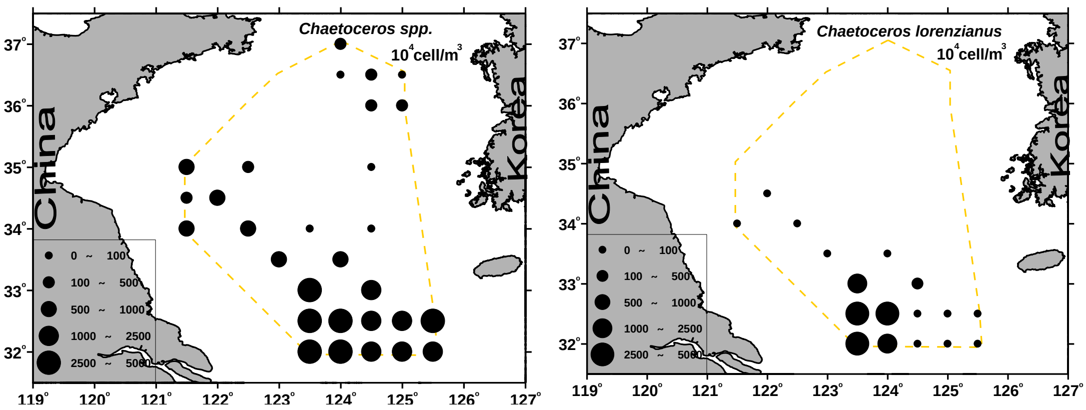

Fig. 2.5 Distribution of *Chaetoceros spp.* (left) and *C. lorenzianus* (right) in the summer net samples.

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 (Fig. 2.6, 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 (Fig. 2.6, right panel).

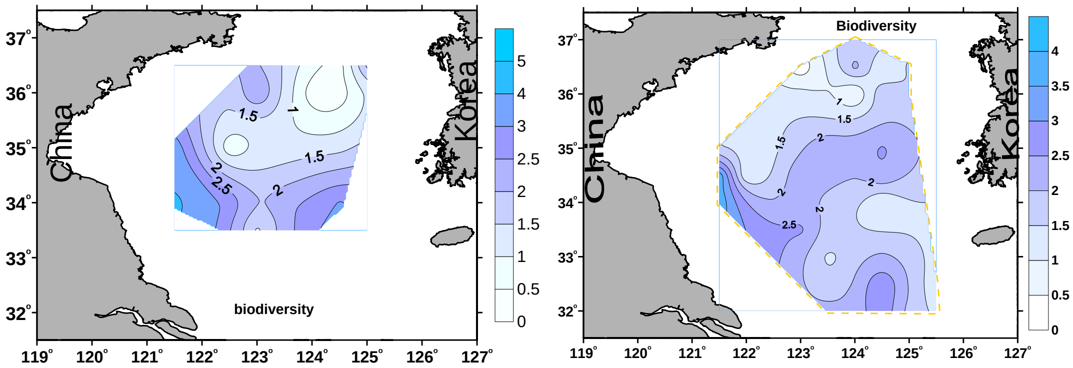

Fig. 2.6. Species diversity (*H′*) of phytoplankton community in winter (left) and summer (right).

2.3.3 Zooplankton abundance/biomass

In our research in 2008, data from the samples collected with the 500 μm mesh plankton net were used here to show the zooplankton community structure and its variety. In winter, a total of 71 zooplankton species were identified, including 26 copepods, 18 larvae, 6 mysidacea, 5 medusa, 3 mastigopus, 2 chaetognaths, 2 euphausiids and other groups. In summer, a total of 77 zooplankton species were identified, including 37 copepods, 11 medusa, 9 mysids, 4 tunicates, 3 pteropods, 3 decapods 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 2.4).

Table 2.4 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

Sagitta crassa was the most abundant specie, and its abundance varied between 4 and 202 ind./m^3, while the average was 98 ind./m^3 in winter. There was higher abundance of *S. crassa* in the western coastal areas than that in the open sea (Fig. 2.7, left panel). The abundance of *Calanus sinicus* varied between 2 and 205 ind./m^3, while the average was 37 ind/m^3. There was higher abundance of *C. sinicus* in the north than that in the middle and south (Fig. 2.7, right panel).

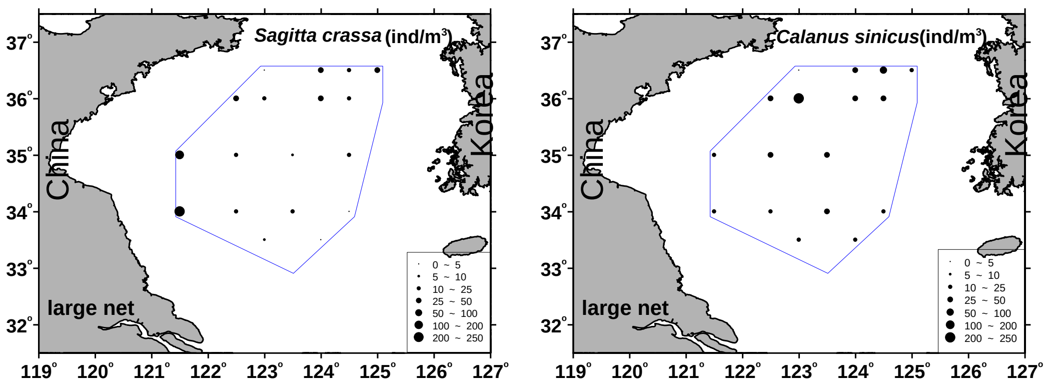

Fig. 2.7 Distribution of *Sagitta crassa* (left) and *Calanus sinicus* (right) abundance in winter.

Calanus sinicus was the most abundant species and largely contributed to total individual density in summer. The abundance of *C. sinicus* varied from 1 to 536 ind./m^3 and the magnitude was much higher (average= 113 ind./m^3) than that in winter (average= 37 ind./m^3). *C. sinicus* was evenly distributed throughout most of the study area (Fig. 2.8, left panel). The abundance of *Sagitta crassa* varied from 2 to 202 ind./m^3 (average= 40 ind./m^3), and the most abundant zone was located at the west and north of the study region (Fig. 2.8, right panel).

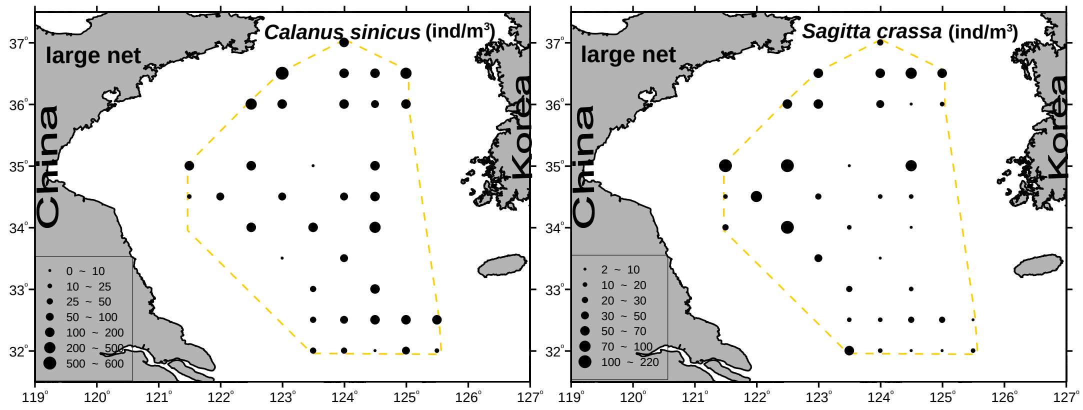

Fig. 2.8 Distribution of *Calanus sinicus* (left) and *Sagitta crassa* (right) abundance in summer.

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 (Fig. 2.9, left panel). 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 in summer (Fig. 2.9, right panel).

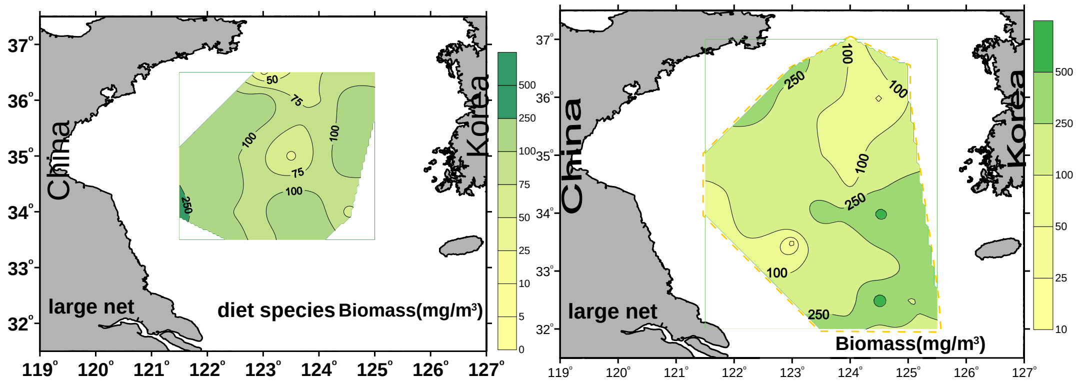

Fig. 2.9. Distribution of zooplankton biomass (mg/m^3) in winter (left) and summer (right).

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 in winter (Fig. 2.10, left panel). 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 in summer (Fig. 2.10, right panel).

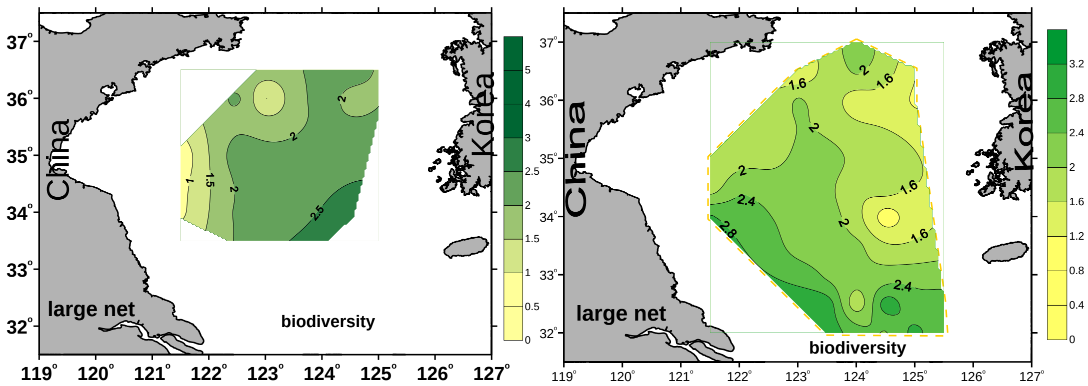

Fig. 2.10 Species diversity (*H'*) of zooplankton community in winter (left) and summer (right).

2.3.4 Benthos abundance/biomass

Zhang et al. (2017) analyzed the data collected in three marine surveys in July 1959, June 2004, and August 2012 in 18 stations to compare the benthic community structure and inter-annual variation in/out the Yellow Sea Cold Water Mass (YSCWM) in summer (Fig. 2.12).

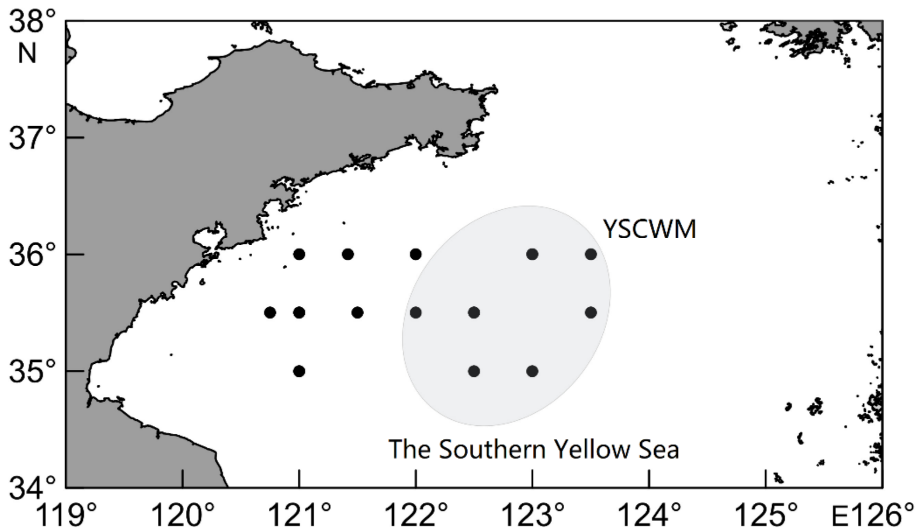

Fig.2.12 The sketch map of sampling stations and YSCWM (Zhang et al., 2017)

In previous study on the Southern Yellow Sea (Zhang et al., 2017), 87 species were identified outside the cold-water center, while 33 species were identified in the cold-water center (Table 2.4). The number of molluscs in the cold-water center is significantly higher than that outside the cold-water center.

Table 2.4 The identified species of research surveys in summer in 1959, 2004 and 2012 (Zhang et al., 2017)

Joannisiella cumingi	*Pectinaria sp.*	*Periploma*
Monascida	*Clinocardium sp.*	*Tharyx multifilis*
Thuiaria triserialis	*Sternaspis scutata*	*Tharyx tesselata*
Terebratella coreanica	*Nuculana yokoyamai*	*Harmothoe imbricata*
Goniada maculata	*Lumbriconereis sp.*	*Nucula tenuis*
Thyasira tokunagai	*Hiatella orientalis*	*Asychis gangeticus*
Notomastus latericeus	*Amphipoda*	*Melitidae*

Tambalagamia fauveli	*Ampelisca brevicornis*	*Glycinde gurjanovae*
Nephtys oligobranchia	*Callianassa divergens*	*Corophium sp.*
Laonice cirrata	*Lima orientalis*	*Harmothoe sp.*
Lima hakodatensis	*Nucula sp.*	*Temnopleurus*
Ehlersileanira incisa hwanghaiensis		

The results of three survey cruises showed that the variation of community abundance in the cold-water center was less than that outside the cold-water center ($P<0.01$).

In July 1959 (Fig. 2.13a), the abundance of benthos outside the cold-water center was lower than that inside the cold-water center. The highest abundance in the cold-water center was 250 ind./m^2, and the lowest was 85 ind./m^2. The highest abundance outside the cold-water center was 80 ind./m^2 and the lowest abundance was 45 ind./m^2. Echinoderms accounted for 36% of the total abundance outside the cold-water center, while polychaetes accounted for 22%, other groups took 20%, molluscs took 14%, and crustaceans took the lowest 8%. In the YSCWM center, Polychaetes accounted for 78% of the total abundance, followed by molluscs at 16%, and crustaceans, echinoderms, and other groups accounted for 2%. There was significant difference on abundance among biotas inside the cold-water center, while it was not obvious outside the cold-water center.

In June 2004 (Fig. 2.13b), the abundance of benthos outside the cold-water center was higher than that inside the cold-water center. The highest abundance was 415 ind./m^2, and the lowest abundance was 60 ind./m^2 outside the cold-water center. The highest abundance was 140 ind./m^2 in cold water center, and the lowest was 55ind./m^2. Polychaetes accounted for 57% of the total abundance, followed by crustaceans and echinoderms (17%), molluscs (7%) and other groups (2%) outside the YSCWM. In the cold-water center, the abundance of mollusks accounted for 58% of the total abundance, followed by polychaetes (24%), echinodermata (15%) and other groups (3%). *Nucula tenuis* distributed in all three stations.

In August 2012 (Fig. 2.13c), research results showed that the abundance of benthos outside the cold-water center was higher than that inside the cold-water center. The highest abundance outside the cold-water center was 1140 ind./m^2, and the lowest abundance was 275 ind./m^2. The highest value in the cold-water center appeared 250 ind./m^2, and the lowest value appeared 80ind./m^2. Echinoderms (55%), polychaetes (39%), crustaceans (3%), and molluscs (3%) were the dominant species outside the cold-water center. The abundance of echinoderms accounted for 47% of the total abundance in the cold-water center, while the proportion of molluscs was 37%, polychaetes took 15%, and echinoderms took 1%.

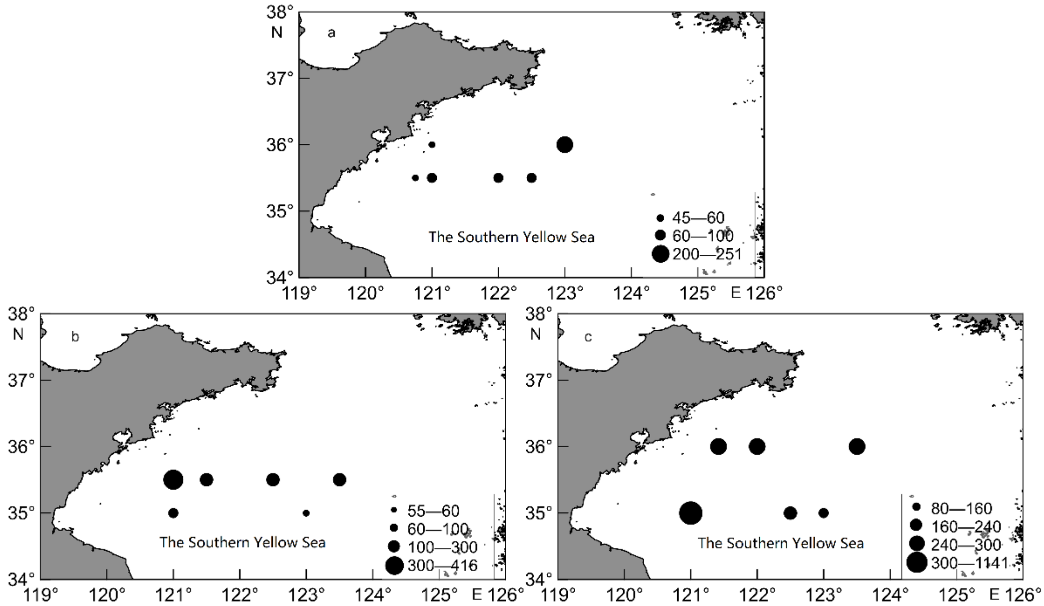

Fig. 2.13 Abundance distribution of benthic communities in and outside the cold-water mass of the southern Yellow Sea in summer of in 1959 (a), 2004 (b) and 2012(c) (Zhang et al., 2017)

In the cold-water center, the biomass of echinoderms showed an increasing tendency, and the proportion of mollusks remained constant in each year, accounting for about 40% of the total biomass. The biomass of polychaetes is significant higher outside the cold-water center.

As we can see from fig. 2.14a, the biomass of benthos in the cold-water center was higher than that outside the cold-water center in July 1959. The total biomass was 70.6 g/m^2 in the cold-water center and 39.5 g/m^2 outside the cold-water center. The station with the highest and lowest biomass both located in the cold-water center, which were 7.15 g/m^2 and 3.05 g/m^2, respectively.

In July 2004, the biomass of benthos in the cold-water center was less than that outside the cold-water center. The highest biomass is 221.7

g/m^2, appear outside of the cold water (Fig. 2.14b), biomass is significant higher than other sites, contributing from the biomass of *Charybdis japonica* (110 g/m^2), sea cucumber (Holothuriidae, 38.95 g/m^2) and sea squirts (Ascidiacea, 45.05 g/m^2). The highest biomass value in the cold-water center was 26.05 g/m^2.

In August 2012, the biomass of benthos in the cold-water center was lower than that outside the cold-water center (fig. 2.14c). The highest biomass value was 234.59 g/m^2, which occurred outside the cold-water center contributing by the biomass of brittle stars (227.5 g/m^2).

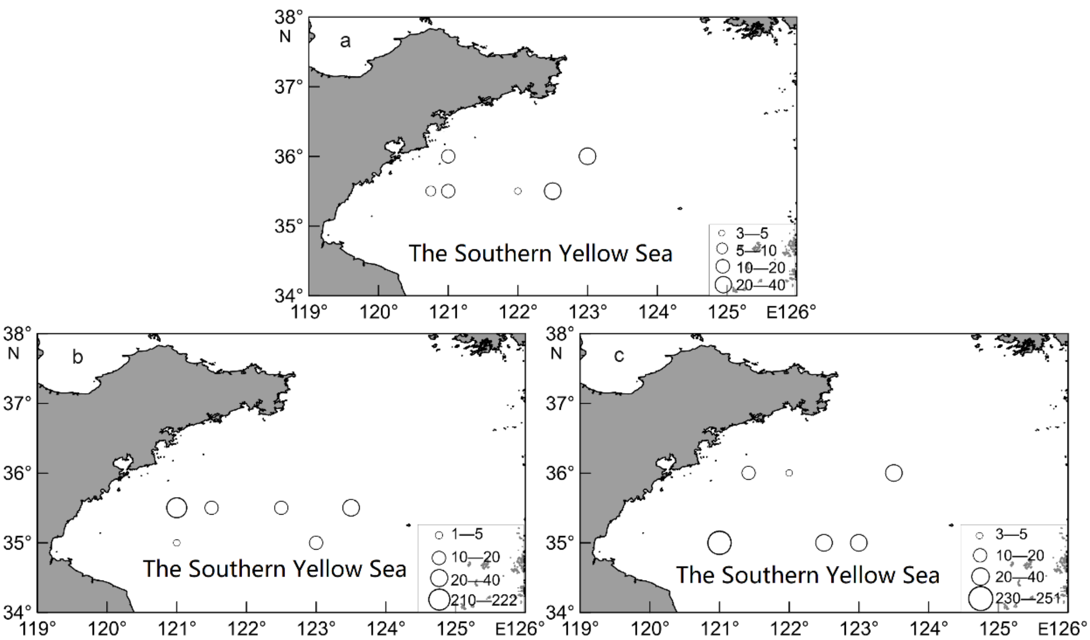

Fig. 2.14 Biomass distribution of benthic communities in and outside the cold-water mass of the southern Yellow Sea in summer of in 1959 (a), 2004 (b) and 2012(c) (Zhang et al., 2017)

2.3.5 Productivity

In 2006, Fu et al. investigated the primary productivity of the euphotic layer in the southern Yellow Sea. The possible pathways of carbon flow in the euphotic layer were studied under two different hydrodynamic conditions (summer and winter).

In summer, the total primary productivity (carbon) of euphotic layer was 3.54 to 139.65 mg/ (m^2·h) in southern Yellow Sea, and the average value was 30.69 mg/ (m^2·h). The distribution space of primary productivity was significantly variety. Influenced by the diluted water from Changjiang river and the coastal water from Jiangsu province, the primary productivity was significantly higher than that in other areas of the southern Yellow Sea. The primary productivity of 4 stations was higher than 75 mg/ (m^2·h). The primary productivity of other stations is lower than 40 mg/ (m^2·h), and over 55% of stations are lower than 20 mg/(m^2·h). The lowest productivity appeared in the upper layer of the YSCWM (figure 2.15).

Compared with summer, the primary productivity distribution of euphotic layer showed a opposite trend in winter in the southern Yellow Sea. The high value area transferred from the southern sea area to the Haizhou bay (see Fig. 2.15). The Haizhou bay was considered as the traditional spawning ground for anchovies in the yellow sea. The highest primary productivity was higher than 30 mg/ (m^2·h), while the primary productivity decreased to the surrounding area. The southern part of the yellow sea, where primary productivity value was highest in summer, obtained the lowest value in winter.

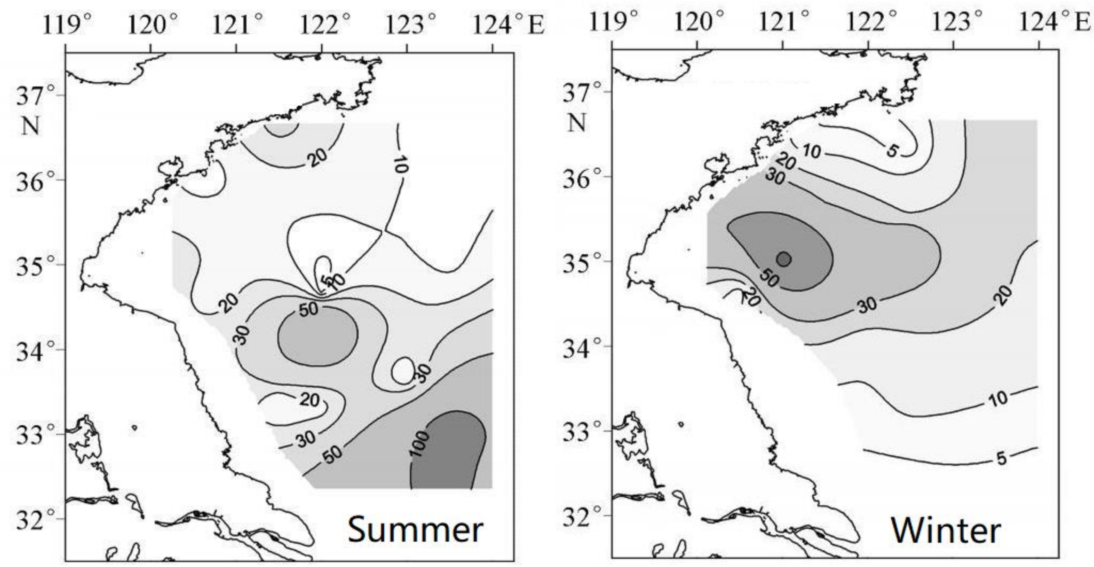

Fig. 2.15 The horizontal distribution of primary production [mg/ ($m^2 \cdot h$)] (Fu et al., 2006)

2.3.6 Fishery resource

In order to investigate the dynamic of fishery resources in the Yellow Sea, Dai et al. (2019) analyzed the species composition, dominate species, spatial distribution of fishery species based on the bottom trawl survey data in the Yellow Sea, which collected in summer and autumn 2013 (Table 2.5).

A total of 185 fishery species were collected, including 92 demersal fish species, 31 pelagic species, 48 crustacean species, 7 cephalopod species and one mollusk species. Among these fish species, the richest species was found in Perciformes (27 families, 47 genera and 56 species). There was no obvious seasonal variation of dominate species.

In summer, the dominate species were sand shrimp *Crangon affinis*, hairtail *Trichiurus lepturus*, while in autumn, the dominate species were the swimming crab *Portunus trituberculatus*, yellow small croaker *Larimichthys polyactis*, anchovy *Engraulis japonicus* and hairtail *Trichiurus lepturus*. The average catch per haul was higher in autumn (46.60 kg/h) than that in summer (39.35 kg/h). The spatial distribution of fishery resource in autumn concentrated in the Changjiang River estuary and Lvsi fishing ground.

Table 2.5 Species composition of different fishery ecotypes in the Yellow Sea and East China Sea during summer and autumn in 2013 (Dai et al., 2019)

	Bottom fish	Pelagic fish	Cephalopods	Crustaceans	Shellfish	Total
Summer	74	21	42	11	1	149
Autumn	71	23	39	10	0	143

In the summer survey, the average biomass of bottom fish was 17.27 kg/h and pelagic fish was 10.68 kg/h, respectively. The percentage of bottom fish was 43.88% and pelagic fish was 27.15%, respectively. In the autumn survey, the average biomass of bottom fish was 23.43 kg/h and pelagic fish was 11.40 kg/h, respectively. The percentage was 50.27% and 24.46%, respectively. In autumn, fishery resources are more concentrated than in summer, mainly distributed around Changjiang estuary and Lvsi fishery ground. The average biomass was 178.51kg /h. (Fig. 2.16)

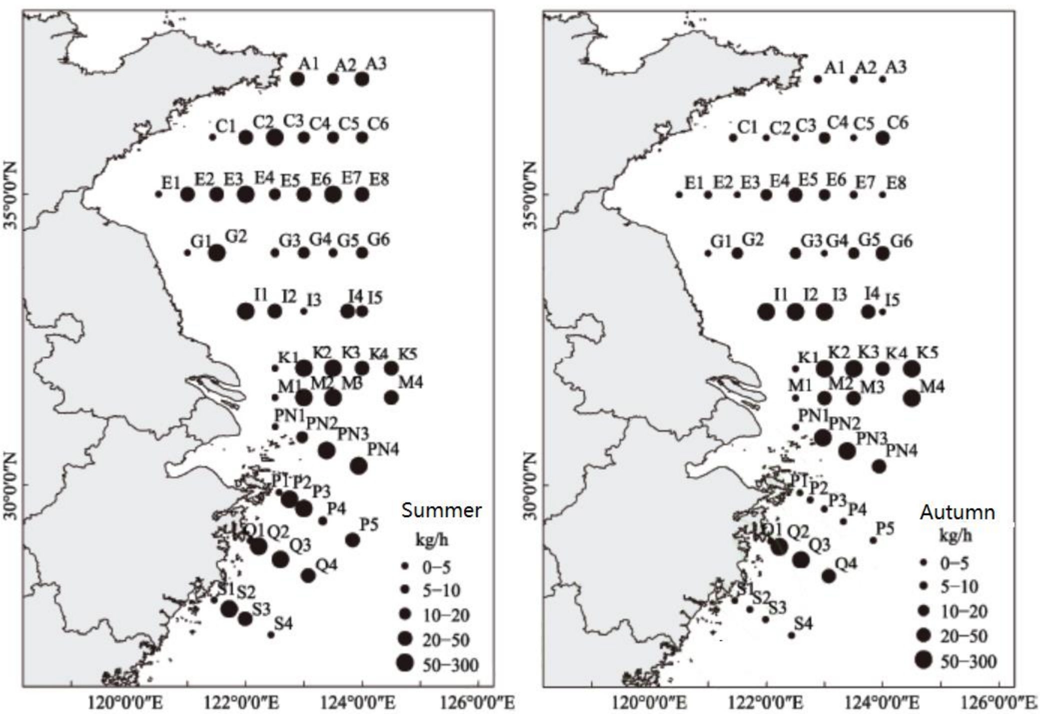

Fig. 2.16 Distribution of average catch per haul in the Summer and Autumn of 2013 (Dai et al., 2019)

2.3.7 Spawning, feeding and overwintering grounds

Migration routes and spawning, feeding and overwintering grounds were indispensable important links in marine lives' life cycle, which were significance to maintaining the structure and quantity of population. The previous investigation (Li et al., 2018) showed spawning grounds in the yellow sea were Rushan offshore spawning grounds, Haizhou bay spawning grounds, Haiyang island spawning grounds, Lvsi spawning grounds, Changjiang estuary spawning grounds and Sheshan spawning grounds (Fig. 2.17).

The overwintering ground for short-distance migratory species located from the center of southern Yellow Sea to the northeast China Sea with 40-100m depths. Bottom water temperature was 10-13 ℃ and salinity was 32.5-34.5‰. The overwintering period is generally from December to March of the following year. The overwintering ground for cold-water species located in the YSCWM.

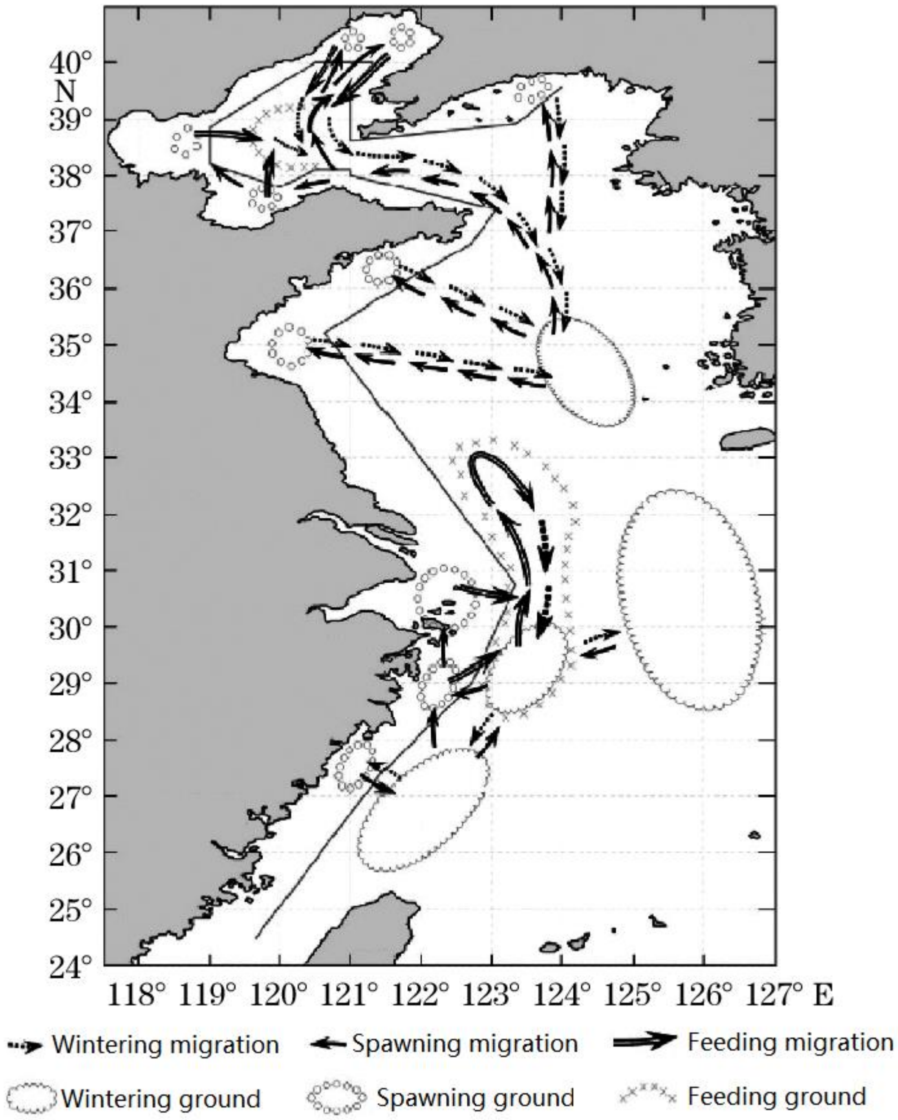

Fig. 2.17 Migratory routine of fishery resource (*Argyrosomus argentatus*) in the Bohai Sea, Yellow Sea and East China Sea. (Li et al., 2018)

2.3.8 Migration paths and habitat for endangered/threatened species

The spotted seal (*Phoca largha*) was critically endangered in the Yellow Sea of China and Korea because of habitat destruction and human harassment in the region (Won et al., 2004). Their migratory routes, including breeding and summer routes, located in the Yellow Sea and Bohai Sea (Fig. 2.18).

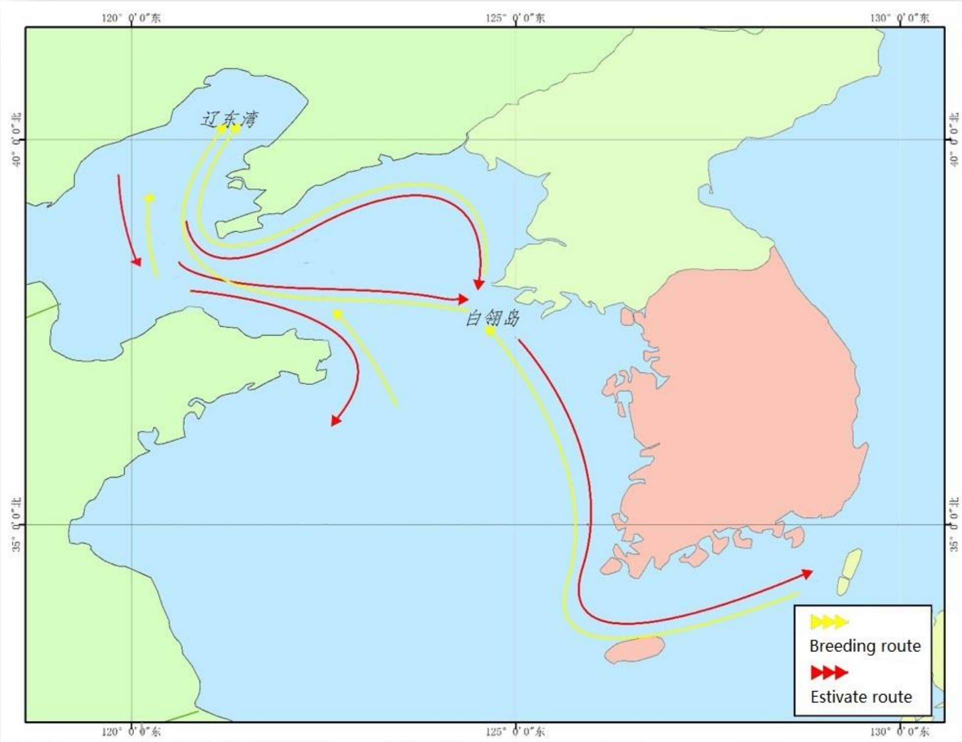

Fig. 2.18 The breeding and summer route of spotted seal (*Phoca largha*)

3.Management conditions and handicap

(1) Shortage of basic management and protection facilities

The shortage of basic management and protection facilities restricted the management of the protected area. According with the feature of the Marine Protected Area designated in YSCWM, we should define responsibilities and obligations of management, implement post responsibility system or target responsibility system respectively. A complete system related reward and punishment should be established in order to ensure the efficient operation of the organization for designating YSCWM as a new MPA.

(2) Contradiction between fishery and protection

Before conceiving as an MPA, fishery was one of most common traditional activities in the Yellow Sea, which supported considerable income of local society. Fishery was the livelihood of local coastal residents. If the process for establishing YSCWM as an MPA had been implemented, the profit of fisherman should be considered as one of the most essential issue, which referred to the people's livelihood in our society. The related government and organization should concern their opinion before implement restrict regulations in the Yellow Sea.

(3) Education and human resource

The management of MPA involved a wide range of professional knowledge, covering multiple research fields like biological science, ecology, environmental science, oceanography and other disciplines, which also bought challenges to establishing a professional team on management of MPA in the YSCWM. However, in the present education system, few universities or research institutes set up specialty of marine reserve management, so it was eager for the professional human resource on designing and managing the MPA in the YSCWM.

(4) Proposal

To solve the issue on the process, it was essential to strengthen intergovernmental cooperation on the procedure of establishing an MPA in the YSCWM. The cooperation was no only focus on the research and investigation, but also on the management of MPA in the YSCWM, like supporting facilities, restricting fishery and relevant education, etc.

4. Conclusion

In this report, EBSAs Criteria had been used to estimate the feasibility for designating YSCWM as a new MPA. Eight Criteria had been concerned as the evidence for establishing a new MPA in/ around the YSCWM, which referred to chlorophyll concentration, phytoplankton abundance, zooplankton abundance/biomass, benthos abundance/biomass, primary productivity, fishery resource, spawning, feeding and overwintering grounds, migration paths and habitat for endangered/threatened species, etc. There were ample evidences to prove that it was necessary to establish an MPA for protecting the ecosystem and environment in the YSCWM. However, despite many previous studies, long-term variation of the features of the YSCWM, like the variation of thermocline, boundary and the effects on marine organisms, is still unclear, and its driving mechanisms are poorly understood (Yang et al., 2014). Otherwise, some management handicaps would be in the way of promoting the process, like shortage of basic management and protection facilities, local fishery influence, education and human resource, etc.

Consequently, it was essential to strengthen intergovernmental cooperation on the procedure of establishing an MPA in the YSCWM. The cooperation was no only focus on the research and investigation, but also on the management of MPA in the YSCWM, like supporting facilities, restricting fishery and relevant education, etc.

References

Castilla, J. C., Roles of experimental marine ecology in coastal management and conservation. Journal of Experimental Marine Biology and Ecology, 2000, 250: 3–21.

Chen, D. X., Marine Atlas of Bohai Sea, Yellow Sea, East China Sea: Hydrology. China Ocean Press, Beijing, 1992: 61-133.

Chiappone, M. et al., Marine reserve design criteria and measures of success: lessons learned from the Exuma Cays Land and Sea Park, Bahamas. Bulletin of Marine Science, 2000, 66: 691–705.

Claudet, J. et al. Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean marine reserve: Identifying community-based indicators. Biological Conservation, 2006, 130(3):0-369.

Dai et al., Variations of fishery resource structure in the Yellow Sea and East China Sea. Progress in Fishery Sciences, 2019,1- 12

Fu, M. Z. et al., Size structure and potential export of phytoplankton primary production in the southern Huanghai (Yellow) Sea, Acta Oceanologia Sinica (in Chinese), 2009, 31(6): 100- 109

Halpern, B., The impact of marine reserves: do reserves work and does reserve size matter? Ecological Applications, 2003, 13: S117–S137.

Harmelin, J. G., Mediterranean marine protected areas: some prominent traits and promising trends. Environmental Conservation, 2000, 27: 104–105.

Jacobs, G.A. et al., Yellow and East China Seas response to winds and currents. J. Geophys. Res. 2000, 105 (C9): 21947–21968.

Li et al., Status, problems and optimized management of spawning, feeding, overwintering ground and migration route of marine fishery resources in Bohai Sea and Yellow Sea. Transactions of Oceanology and Limnology (in Chinese), 2018, 5: 147- 157.

Ma, J. et al., Effects of the Yellow Sea Warm Current on the winter temperature distribution in a numerical model. J. Geophys. Res. 2006, 111, C11C04.

Moon, J.H. et al., Comparison of wind and tidal contributions to seasonal circulation of the Yellow Sea. J. Geophys. Res. 2009, 114 C08016.

Park, S. et al., Interannual-to-interdecadal variability of the Yellow Sea Cold Water Mass in 1967–2008: characteristics and seasonal forcings. J. Mar. Syst. 2011, 87 (3): 177–193.

Pauly, D. et al., Towards sustainability in world fisheries. Nature, 2002, 418: 689–695.

Quan Q et al., Seasonal variations of several main water masses in the southern Yellow Sea and East China Sea in 2011. Journal of Ocean University of China, 2013, 12(4):524-536.

Sumaila, U.R. et al., Addressing ecosystem effects of fishing using marine protected areas. ICES Journal of Marine Science, 2000, 57: 752–760.

Teng, S.K.et al., Global international waters assessment: Yellow Sea. GIWA Regional Assessment, 34 University of Kalmar, Sweden. 2005.

Wang, R. et al., The Yellow Sea cold bottom water-an over summering site for *Calanussinicus* (Copepoda, Crustacea). J. Plankton Res. 2003, 25 (2): 169–183.

Wei, H. et al., Interannual and long-term hydrographic changes in the Yellow Sea during 1977–1998. Deep Sea Res. II, 2010: 57, 1025–1034.

Wei, Q. S. et al., Observation of seasonal evolution of DO, chlorophyll maximum phenomena and nutrient accumulating in the Southern Huanghai (Yellow) Sea Cold Water Mass Area. Acta Oceanological Sinica (in Chinese). 2013, 35(4): 142- 154.

Won, C., et al., Abundance, seasonal haul-out patterns and conservation of spotted seals Phoca largha along the coast of Bak-ryoung Island, South Korea[J]. Oryx, 2004, 38(01):109---112.

Xu, D. et al., The baroclinic circulation structure of Yellow Sea Cold Water Mass. Sci. China Ser. D 2003,46 (2): 117–126.

Yang, H. W. et al., Interannual variation of the southern limit in the Yellow Sea Bottom Cold Water and its causes. Journal of Marine Systems, 2014, 139:119-127.

Zhang, P. H. et al., Comparison in microbenthic community composition inside and outside the cold-water mass in the southern Yellow Sea in summer. Oceanologia et Limnologia Sinica (in Chinese) 2017, 48(2): 312-325

Zhang, S.W. et al., Observation of the seasonal evolution of the Yellow Sea Cold Water Mass in 1996–1998. Cont. Shelf Res. 2008: 28 (3), 442–457.