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)

Effects of Sea Ice on the Development of Dandong Coastal Zone and Marine Species

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1. Background

UNDP/GEF is providing assistance through UNOPS to countries bordering Yellow Sea in support of their efforts to address among others the increasing trends of depleting fishery stocks, loss of coastal wetland, land and sea-based pollution and implementation of the Yellow Sea Large Marine Ecosystem Strategic Action Programme (YSLME SAP) adopted by China and RO Korea with support of DPR Korea. One of the assistance programs to implement the SAP is the UNDP/GEF/UNOPS project entitled 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, or the UNDP/GEF YSLME Phase II Project. The project will have the inception workshop on July 13, 2017, where the stakeholders will meet and build consensus on the project objectives and approaches, agree on the project workplan for 2017-2019, and discuss on the roadmap towards a sustainable arrangement for effective ecosystem-based management of Yellow Sea in accordance with YSLME Strategic Action Programme.

Component 4 addresses improving ecosystem carrying capacity with respect to supporting services. In Outcome 4.3 of Component 4 entitled “Adaptive Management mainstreamed to enhance the

resilience of the YSLME and reduce the vulnerability of coastal communities to climate change impacts on ecosystem processes and other threats identified in the TDA and SAP", Based on the project document, there is a need for further efforts to determine the impacts of climate change. With scientific and environmental information available, an appropriate regional strategy will be developed as a long-term goal. Major efforts on adaptive management in response to climate change will include preparation of regional strategies on adaptive management, site-based ICM plans established by PEMSEA to enhance climate resilience for selected sites in YSLME.

The impact of climate change in Yellow Sea is mainly reflected in the rising sea level, higher frequency and severity of various marine disasters, such as storm surge and sea ice. In the context of global climate change, China's coastal air temperature and sea temperature has kept rising, together with air pressure decrease and the sea level rise. From 1980 to 2014 (Fig 1), the sea level has kept rising at a rate of 3.0 mm / year, higher than the global average level over the same period (Chinese sea level Bulletin).

The occurrence of storm surge and sea ice is closely related to climate change. The width of fixed ice in the north Yellow Sea is about 0.2 ~ 2 km, in the estuaries and shoal areas can reach 5 ~ 10 km, the

drifting ice line is much the same as the 10 ~ 15 m contour. The annual sea ice occurrence is related to the frequency, intensity and times of cold wave from the north. The sea ice has impact on shipping, fishing and marine culture, while floating ice provides habitats for some marine species, such as spotted seals, birds, etc.

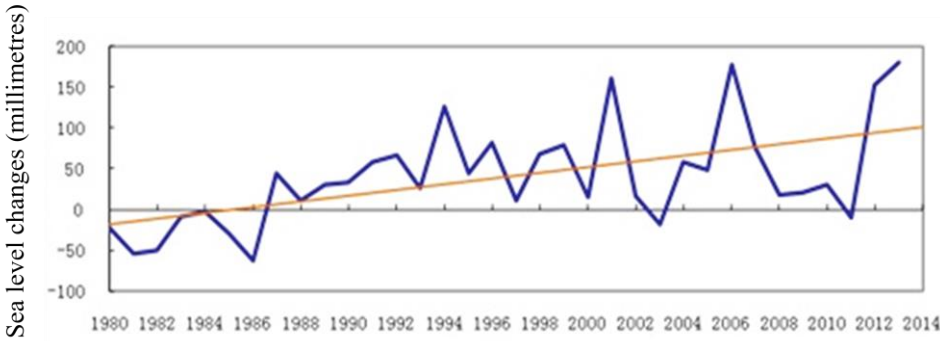

Fig. 1 The trend of the sea level of Bohai Sea and North Yellow Sea (1980-2013) (Chinese sea level Bulletin)

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

Dandong city locates in the north coast of Yellow Sea, facing DPR Korea across the Yalu River, the main urban area is built along the coast.

Most citizens will be facing the impact of Sea level rise. Vulnerability assessment of coastal zone is an urgent need for Dandong city.

Fig.2 The position of Dandong in Yellow Sea

Yalu river estuary is a very important station for the migration bird and an important part of the migratory Routes of East Asia-Australasia. 353 species of birds were recorded which belong to 18 orders, 63 families. According to the International Union for Conservation of Nature (IUCN) list, 11 are endangered (EN), 12 are vulnerable (VU), and 1 is critically endangered (CR). The sea level rising could have significant impacts of the food availability to wading birds. One demonstration about the migrating birds and intertidal benthos has been done in the first phase of YSLME, based on this project, more valuable work can be sustained.

Due to the situation now, the inclusive of DPRK for YSLME become a possible option. Yalu River is a boundary river between China and DPRK. The participation of DPRK and the joint adaptation management of the Yalu River Delta could be a potential outcome in the future.

The Coastal Vulnerability

Knowledge about climate change vulnerability is needed as a basis for appropriate, responsive planning of preparedness and adaptation measures. The proposed present assessment considers the particular climate-related vulnerabilities of

- households;
- cultivation systems;
- other production systems, livelihoods;
- infrastructure; and
- habitats and ecosystems.

Households are vulnerable to storms, erratic rainfall, floods, and saline intrusion, which directly affect important facilities such as access to safe water and sanitation. Also, many households are directly exposed to vulnerabilities of cultivation systems, which can affect food security and livelihoods. Cultivation systems are also vulnerable to storms, erratic rainfall, floods and saline intrusion. This, in turn, causes poor drainage, soil deterioration, and reduced yields (or failed crops).

Infrastructure - roads, dykes, canals, water gates, drainage systems, and water and power supplies is vulnerable to storms, floods and sea level rise. Such pressures cause structural damage and a variety of consequential, severe social and economic impacts.

The coastline stability is vulnerable to increased sea level, storms, and floods. Near the coast, the wave height is limited by the water depth. A higher sea level will allow for higher waves near the coast, and higher wave-generated erosion. Coastal erosion, enhanced by a sea level rise, can cause loss of land (including recreational beaches), habitats and coastal structures (such as dykes). The eroded material can end up elsewhere along the coast where it can damage coastal habitats, increase the flood risk and impede drainage. Healthy marine ecosystems can provide protection against coastal erosion.

Habitats and ecosystems include precious assets such as marine habitats (e.g. sea grass beds), coastal habitats, inland aquatic habitats (wetlands and active floodplains) and forests. The marine ecosystems are affected by increased temperatures, and increased storm frequency. The inland ones are, from place to place, affected by storms, floods, and saline intrusion (as well as pollution).

The vulnerabilities are related. They interact with other vulnerabilities in the socio-economic situation. Also, from place to place, the coastal area are affected by increased generation of sewage and

solid waste, adding to surface water pollution, caused by pesticides and fertilizers.

2. Overview of Dandong

Dandong, a prefecture-level city, located in the southeastern part of Liaoning Province. Dandong is bordered by Xinyizhou City of the Democratic People's Republic of Korea in the east, the Yellow Sea in the south, Anshan in the west, Dalian in the southwest and Benxi in the north. Geographical coordinates range from 123°22’to 125°42’E and 39° 43’ to 41°09’N. The largest transverse distance between East and West is 196 kilometers, the largest longitudinal distance between North and south is 160 kilometers, the coastline is 120 kilometers long, and the total area is 15222 square kilometers. It has three municipal districts, one Autonomous County and two county-level cities under its jurisdiction. In 2016, the total population was 23.779 million.

Dandong, the center of Northeast Asia, is the northern starting point of China's coastline. It is an important intersection point of Northeast Asia's economic circle with the economic circle around the Bohai Sea and the Yellow Sea. It is a riverside, coastal and border city with industry, commerce, logistics and tourism as its main body. It is a national border cooperation zone and a key development and Opening-up along the border of the whole country. The pilot area and

coastal open city have five types of ports, railways, highways, pipelines and airports, 10 ports, and a Sino-Korean border trade area. They are the largest port city for China's trade with DPRK, and the tourist city for the DPRK under state franchise. It is the only city in Asia with border ports, airports, high-speed rail, River ports, seaports, highways and regional circulation nodes.

Dandong is located in the mid-latitude zone of the east coast of Eurasia and belongs to the warm temperate sub-humid monsoon climate. The annual average rainfall is between 800 and 1200 millimeters, which is the most rainfall area in northern China. 2/3 of the precipitation is concentrated in summer. The annual average temperature is 8-9℃in the South and 6-7℃ in the north. Under the influence of the monsoon, the seasonal variation is obvious and the four seasons are distinct. It is the warmest and wettest place in Northeast China. Winter is the longest, followed by summer, and the transition season between spring and autumn is the shortest. Dandong has the most precipitation in Northeast China, accounting for 70% of Liaoning Province's precipitation, and has abundant water resources. The annual average precipitation is 881.3-1087.5 mm. Two-thirds of the annual precipitation is concentrated in summer, and the rainstorm concentration period is from mid-July to mid-August.

Dandong area has dense rivers, mainly Yalu River, Ocean River and

coastal water system. There are 944 large and small rivers over 2 kilometers in the whole area, of which 4 rivers and 4 rivers are Yalu River, Hunjiang River, Gao River and Dayang River, with basin area exceeding 4983 square kilometers. Dandong has a total flow of 9.36 billion cubic meters, excellent water quality, total water hardness, PH value, biological protoplasm and transparency are superior to international standards; the water per capita occupies 3968 cubic meters, which is four times the water per capita of Liaoning Province, and 1.5 times the water per capita of the whole country, which provides good conditions for the development of industrial and agricultural production. The coastline of Dandong City is 328.9 kilometers long, of which 93.3 kilometers (excluding 32.5 kilometers of island line). The sea area is 3,500 square kilometers, 12 million hectares sea area within the 10-meter contour line, 2.44 million hectares of beach area in the intertidal zone, 0.8 million hectares of shrimp can be raised above the intertidal zone, and 1.8 million hectares of reed can be planted. Dandong City has 235.6 kilometers of riverbank and more than 1,600 rivers.

There are many kinds of marine organisms in Dandong coast, which can be divided into swimming organisms, plankton and benthic organisms. There are 118 species of marine fish, 21 species of shrimp, 13 species of crabs, 16 species of jellyfish and more than 30 species of

marine algae.

Dandong Port is the Deep water ice-free port at the northernmost end of China's coastline. It is connected with the Eastern Railway of Northeast China. It radiates more than 30 million people in 13 cities and more than 40 counties. The transshipment of grain, coal, ore, steel and other commodities into the sea promotes the economic development of the eastern part of Northeast China.

3. Annual situation of sea ice in Dandong

The Yellow Sea and Bohai Sea are located in the mid-latitude monsoon climate zone, which is one of the lowest ice-forming areas in the world. Sea ice occurs annually in the Bohai Sea and Northern Yellow Sea in winter (Tang et al., 2012). Among them, the Bohai Sea has the most serious sea ice because of its unique geographical environment (Zheng et al., 2015). The Bohai Sea is a typical inland shallow sea with an average water depth of 18 m, small heat capacity and low salinity (27-31). Therefore, the freezing point is relatively high (-1.7 ~ -1.4℃) (Lu et al., 1993). In winter, under the frequent invasion of cold waves, the heat loss in the Bohai Sea is very great, and the water temperature decreases rapidly, and then freezes. The Bohai Sea is one of the lowest latitudes of ice in winter on the earth. There are different degrees of ice phenomena every year. The ice period is about three months.

Generally, the Bohai Sea began to freeze in early December, and the sea ice disappeared in mid-March of the next year, with a glacial period of 3-4 months. In January and February, the ice condition is the heaviest. Taking Liaodong Bay with the highest latitude as an example, the thickness of sea ice can reach 50cm in the perennial ice year, the outer ice line is about 80 nautical miles offshore, and the speed of sea ice movement can exceed 1.5m/s. The grade of ice regime in the Bohai Sea is determined according to the range and thickness of ice in the Bohai Sea in winter, which reflects the ice regime in the Bohai Sea (Ding, 1999, Zhang, 1986). Ice grade is divided into 5 grades: 1 grade is light ice year, 2 grade is light ice year, 3 grade is constant ice year, 4 grade is heavy ice year, 5 grade is heavy ice year. There are significant inter annual and inter decadal variations in the ice regime of the Bohai Sea (Fig. 3) .

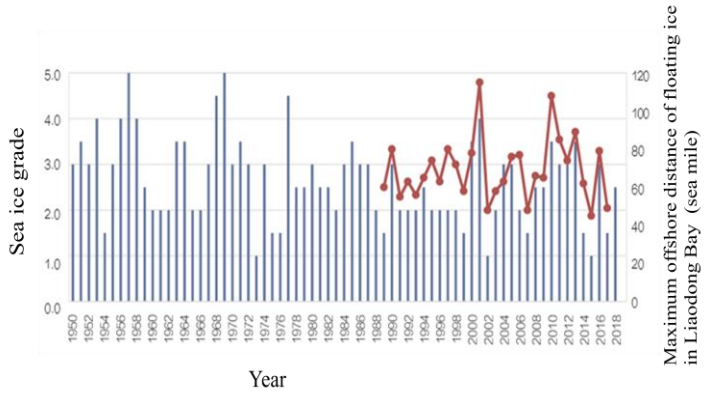

Fig.3 Sea ice grade Ice grade since 1950 and maximum offshore distance of floating ice since 1989

Fig. 4 is the maximum entropy spectrum analysis. The results show that the main periods of ice regime are 2.6a, 4.0a, 5.8a, 6.8a and 11.0a, respectively. The sea ice in the Bohai Sea not only has an inter annual variation period of 2-7 a, but also has an inter decadal variation period of 11 a.

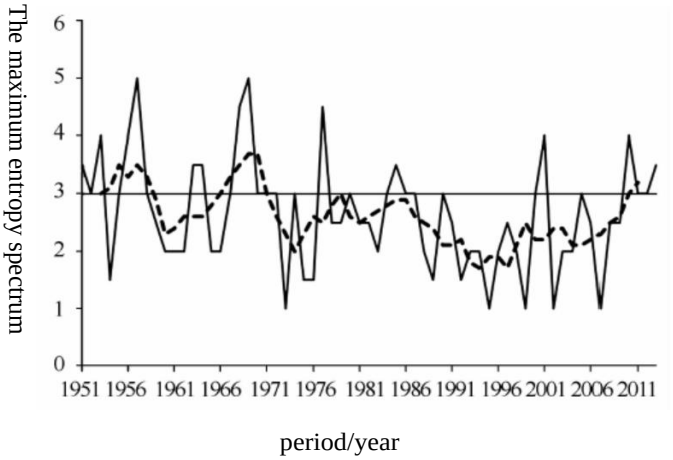

Fig.4 The maximum entropy spectrum for the sea ice grade in the Bohai Sea

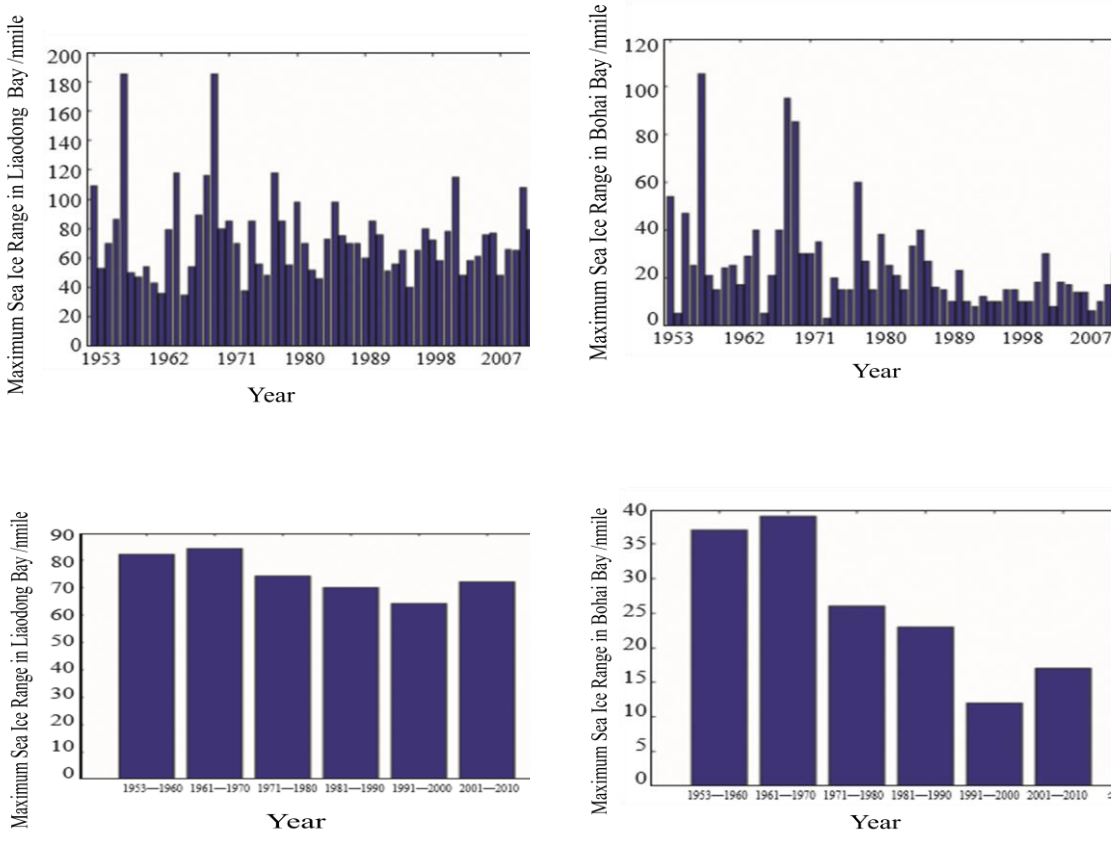

Fig.5 Annual Maximum Sea Ice Range in Bohai Bay and Liaodong Bay from 1953 to 2011

In the winter of 2014-15, the ice condition in the northern part of the Yellow Sea is light ice year (grade 1.0). The maximum area of sea ice is 10519 square kilometers. The maximum area of sea ice in Liaodong Bay is 8545 square kilometers, and the maximum distance from the outer line of floating ice is 45 nautical miles offshore; there is only a small amount of floating ice in Bohai Bay and Laizhou Bay; the maximum area of sea ice in northern Yellow Sea is 3502 square kilometers, and the maximum distance from the outer line of floating ice is 20 nautical miles (Chinese Marine Disaster Bulletin) (Table 1).

Table 1 Ice regime in the Bohai Sea and Northern Yellow Sea in the winter of 2016-17

sea area	Maximum Distribution Area of Sea Ice (Square kilometers)	Maximum offshore distance of floating ice (miles)	General Ice Thickness	Maximum Ice Thickness
Liaodong Bay	10519	45	5-15	25
north of yellow sea	3502	16	5-10	20

In the winter of 2015-16, the ice condition in the northern part of the Yellow Sea of the Bohai Sea is of the normal ice year (grade 3.0), with a maximum sea ice area of 39,284 square kilometers. The largest area of sea ice in Liaodong Bay is 21594 square kilometers and the maximum distance from the outer line of floating ice is 79 nautical miles; the largest area of sea ice in Bohai Bay is 7936 square kilometers and the maximum distance from the outer line of ice is 23 nautical miles; the largest area of sea ice in Laizhou Bay is 5086 square kilometers and the

maximum distance from the outer line of floating ice is 34 nautical miles. The maximum area of sea ice in the north is 6216 square kilometers, and the maximum distance from the outer edge of floating ice is 20 nautical miles (Chinese Marine Disaster Bulletin) (Table 2).

Table 2 Ice regime in the Bohai Sea and Northern Yellow Sea in the winter of 2017-18

sea area	Maximum Distribution Area of Sea Ice (Square kilometers)	Maximum offshore distance of floating ice (miles)	General Ice Thickness	Maximum Ice Thickness
Liaodong Bay	21594	79	10-20	35
Bohai Bay	7936	23	5-15	25
north of yellow sea	6216	20	5-15	25
Laizhou Bay	5086	34	5-15	25

In the winter of 2016-17, the ice condition in the northern part of the Yellow Sea is light ice year (grade 1.5). The maximum area of sea ice is 15201 square kilometers. The maximum area of sea ice in Liaodong Bay is 10515 square kilometers, the maximum area of sea ice in Bohai Bay is 440 square kilometers, and the maximum area of sea ice in northern Yellow Sea is 4686 square kilometers(Chinese Marine Disaster Bulletin)（Table 3）.

Table 3 Ice regime in the Bohai Sea and Northern Yellow Sea in the winter of 2016-17

sea area	Maximum Distribution Area of Sea Ice (Square kilometers)	Maximum offshore distance of floating ice (miles)	General Ice Thickness	Maximum Ice Thickness
Liaodong Bay	11515	49	5-15	30
Bohai Bay	440	2	5	10
north of yellow sea	4686	16	5-15	25

In the winter of 2017/18, the ice condition in the Bohai Sea and the northern Yellow Sea was slightly lighter than that in the perennial period (grade 2.5). The maximum area of sea ice was 29071 square kilometers. The maximum area of sea ice in Liaodong Bay is 18,041 square kilometers and the maximum distance from the outer line of floating ice is 74 nautical miles; the maximum area of sea ice in Bohai Bay is 5,426 square kilometers and the maximum distance from the outer line of ice is 12 nautical miles; the maximum area of sea ice in Laizhou Bay is 2,386 square kilometers and the maximum distance from the outer line of floating ice is 19 nautical miles. The maximum area of sea ice in the northern Yellow Sea is 7 896 square kilometers, and the maximum distance offshore from the outer edge of floating ice is 21 nautical miles (Chinese Marine Disaster Bulletin) (Table 4).

On January 25, 2018, due to the continuous low temperature of more than 20 degrees below zero, the ice situation in the coastal waters and beaches of the North Yellow Sea aggravated. Some huge sea ice near Dandong, Liaoning Province, even reached nearly one meter thick (Fig 6).

Table 4 Ice regime in the Bohai Sea and Northern Yellow Sea in the winter of 2017-18

sea area	Maximum Distribution Area of Sea Ice (Square kilometers)	Maximum offshore distance of floating ice (miles)	General Ice Thickness	Maximum Ice Thickness
Liaodong Bay	18041	74	7-20	35
Bohai Bay	5426	12	5-10	15
North of yellow sea	7896	21	10-15	25
Laizhou Bay	2386	19	5-10	15

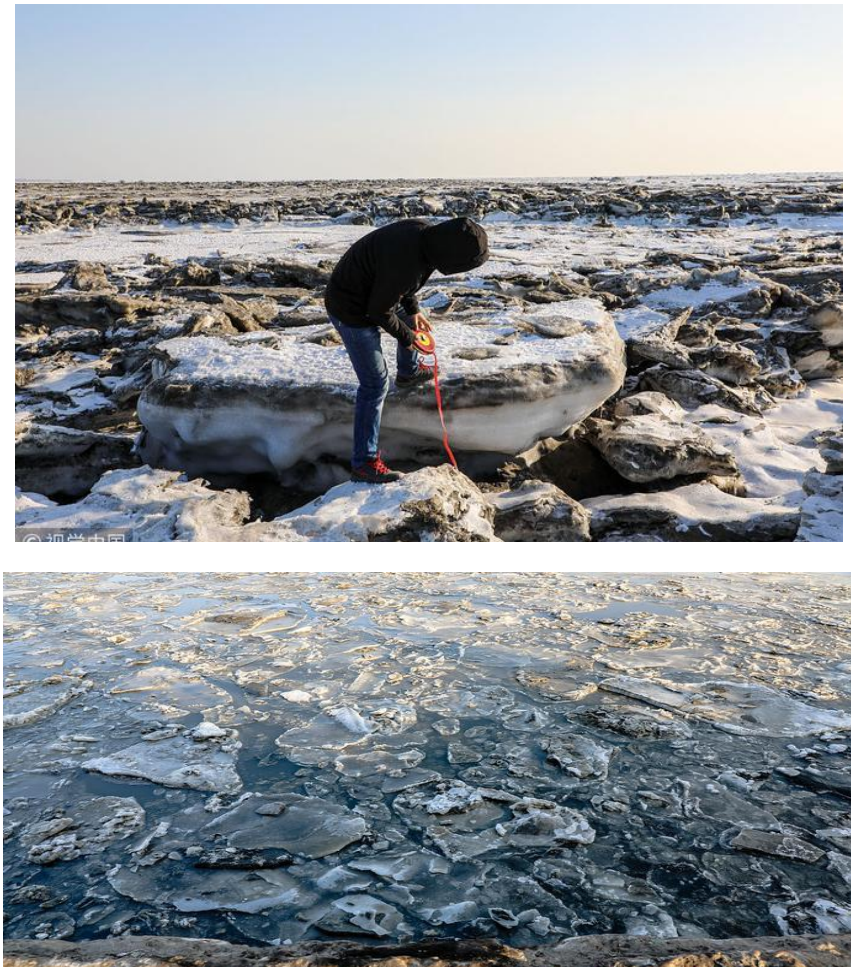

Fig.6 Sea ice near Dandong, Liaoning Province on January 25, 2018

4. The Impact of Sea Ice Change on Dandong's Economic Development

4.1 Impact of sea ice on marine transportation, marine engineering construction

Generally, sea ice occurs every year in Liaodong bay and Bohai Bay, but there are not many years of heavy ice. There is a serious ice condition in about 10 years (Tang et al., 2012). The coastal areas of the

Bohai Sea have different degrees of icing every year, which has a great impact on fishing and shipping (Pang et al., 2018). The ice condition varies greatly every year, which threatens the marine production activities, and even causes serious disasters when the ice condition is serious. In the winter of 2009-2010, the most severe ice condition occurred in the Bohai Sea in the past 30 years. Due to the early occurrence, rapid development and long ice age of severe ice, the social and economic losses of the Bohai Sea and its coastal areas have been seriously affected. According to statistics, the economic losses caused by the ice disaster are nearly 6.6 billion yuan. The ice disaster affected the operation of several ports in the Bohai Sea and the northern Yellow Sea, and even resulted in the closure of some ports (Jiang and jiang, 2013）. In addition, sea ice is also one of the battlefield environment factors closely concerned by military activities at sea and national defense construction. The experimental training of naval vessels in the Yellow Sea and Bohai Sea in winter is largely restricted by the ice conditions in the Yellow Sea and Bohai Sea.

In recent years, with the rapid development of the economic zone around the Bohai Sea, oil and gas development, shipping, fisheries and other activities in the Bohai Sea are becoming more and more active. Many oil platforms and ports have been established in the ice-covered sea area, and sea ice has brought different degrees of impact on these

marine economic activities and offshore facilities.

The ice condition in the early glacial period near Dandong Port has little influence on navigation safety, but the influence in the peak glacial period is greater. There are more ice floes in the melting period. Sea ice will cause damage to ships, especially to propellers and rudders. We should pay attention to avoiding when sailing. When ships navigate in areas with high concentration of ice floe, there will be some phenomena, such as speed drop, steering difficulty and maneuverability decline, especially for small vessels. When a ship encounters a large scale ice plate, if the relative speed is relatively high, the ship will deviate from the course or even get stuck in the ice out of control. When no-load small and medium-sized ships without internal circulation enter and leave the port, the broken ice in the sea water will easily block the entrance of the seabed circulating water and make the main engine seawater cooling system not work properly. Forced parking; in addition, when mooring in ice, special attention should be paid to the possibility of anchoring, and the anchorage position should be measured frequently. When there are more ice floes in berth area, especially when the wind blows up, the ice floes will concentrate on the front of the wharf. When the ship is berthing and moving, a large amount of sea ice will be accumulated between the ship and the wharf. If the ice is hard, it will affect the ship's berthing. If the ice is hard, the gap between the ship and

the wharf will be large, which will make the gantry crane unable to carry out the loading and unloading operation normally (Fig 7). When leaving berth, more ice floes will make it difficult to turn around and the ice pressure is too high to leave the wharf.

Fig.7 Impact of sea ice on fishing vessels and fishing industry

4.2 Impact of sea ice on aquaculture

The Bohai Sea and Liaodong Bay area is an important mariculture area in China. Sea ice disaster has a great impact on the aquaculture industry. If the freezing period of heavy ice year is advanced, the harvest period of scallops and other seafood will lead to the death of a large number of shellfish and other seafood. In addition, most of the salt will precipitate during the formation of sea ice, so the salt content of sea ice is only about 1/5 of the salinity of frozen sea water. A large amount of sea ice melting in the end-glacial period will lead to a decrease in the salinity of sea water, which will affect the normal growth of marine organisms in the next year（Zhang et al., 2009）.

5. Effects of sea ice on coastal species in Dandong

5.1 Effects on Population Distribution and Reproductive Habits of Spotted Seals

The Bohai Sea is the only breeding ground for spotted seals in China. Every winter, spotted seals migrate across the Yellow Sea to the Bohai Sea from offshore waters, most of which are concentrated in the Liaodong Bay of the Bohai Sea. As the lowest winter temperature in Liaodong Bay can reach - 30 C, sea ice sheets and long ice age, it has

become an ideal area for spotted seals to breed, inhabit, breast-feed and change their hair. The gestation period of spotted seals is about one year. Every year after November, spotted seals cross the Bohai Strait and enter the Bohai Sea one after another. In the next year, the female spotted seals give birth in January-March. In addition, the lactation period of spotted seals lasts for 24-30 days (Zhang, 1993; Wang, 1980), and then they enter the reproductive mating period. After the reproductive period in late May, the female spotted seals give birth. Most of the spotted seals then drift off the Bohai Sea and return to other offshore waters (Han et al., 2013)

The geographical location of the Bohai Sea is 37 degrees 07'-41 degrees 00'N and 117 degrees 35'-121 degrees 10' E. Located in the northeastern end of the mainland of China, it is surrounded by land on three sides and belongs to a typical semi-closed inland sea. It connects with the Yellow Sea through the Bohai Strait. The sea area reaches 77,284 km^2, and the coastline is 2,668 km long with an average depth of 18 M.

Spotted seals in Liaodong Bay are the only fin-footed marine mammals that breed in Liaodong Bay of China at present. The total number of them is about 2000, and they are indicative species of ecological health in the Bohai Sea. The breeding ground of spotted seals in Liaodong Bay is located at 40°00’N, 120°6. ’The drift ice zone between

121°40 ’E to 40°40’N, 121°10 ’and 121°50’E. The seals'wool exchange area is located on the West Bank of Shuangtaizi River, Panshan County, about 10 km away from the estuary, i.e. near 121, 48, 40, 56, and 3 km north of Xiaodaozi Fishing Port. Therefore, several important periods of seals 1-year life cycle, reproduction and wool exchange, are concentrated in the northern waters of Liaodong Bay. Every year from January to February, spotted seals travel thousands of kilometers from the Bering Sea to give birth on the ice of Liaodong Bay in the Bohai Sea. The area of ice floe and the amount of ice floe are the main factors affecting the ice condition in the pupae area of spotted seals. Extreme sea ice phenomena under global climate change will affect the reproduction of spotted seals.

It is rich in marine fishery resources such as fish and shrimp. Every year from early December to mid-February of the next year is the glacial period in the Bohai Sea. Spotted seals climb onto the sea ice to give birth. Like other migratory animals, migration is an important part of the life cycle of spotted seals in order to ensure favorable survival and reproductive conditions for the population, and its ice life has obvious periodicity. Every year after November, spotted seal populations enter the Liaodong Bay of the Bohai Sea through the Bohai Strait from offshore waters for foraging and breeding (Won et al, 2004).

Sea ice is an indispensable carrier for the survival and reproduction

of spotted seals. Each year, spotted seals are attracted to a series of activities such as foraging, mating and Wool Exchange at the edge of the ice floe (Trukhinetal, 2003; Mizuno et al, 2002). Liaodong Bay in the Bohai Sea is the only area in China that can retain sea ice for a long time and in a large scale, so it is the most suitable breeding place for spotted seals in the Bohai Sea.

Sea ice is an important support for the reproduction and rest of spotted seals. Around the 1960s, the area of sea ice in the Bohai Sea was relatively large and decreased in the 1990s. It is not conducive to the habitat and reproduction of spotted seals because of its small frozen area, thin ice layer and short frozen period. However, since the 21st century, the area of sea ice in the Bohai Sea has tended to rebound again. In order to facilitate the analysis of the variation of winter sea ice extent in Liaodong Bay of Bohai Sea in the past half century, the maximum coverage of sea ice can be measured by the distance from coastline to the outer edge of sea ice along the central axis of the Bay (Tang Maoling et al., 2012). The results are shown as follows: from 1960s to 1970s. The sea ice coverage in Liaodong Bay of Bohai Sea is relatively large, which has decreased since 1980s, but has gradually recovered since the 21st century (Fig 8, 9) (Wang and Ding, 2019). At present, the maximum sea ice coverage has gradually restored to the level of 1980s. Overall, the maximum sea ice coverage in Liaodong Bay of Bohai Sea is

compared with the past half century. It declined slightly, but did not change much. The rise of sea ice area is conducive to the survival and reproduction of spotted seals, thus creating an objective condition for the increase of the number of spotted seals.

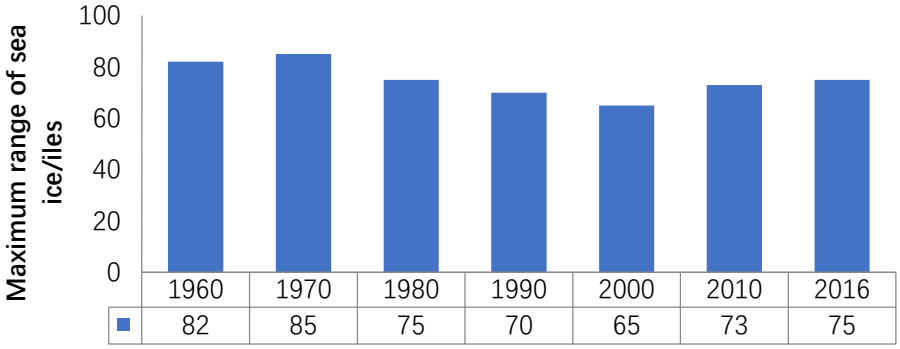

Fig.8 Maximum Coverage of Sea Ice in Liaodong Bay, Bohai Sea, in Winter

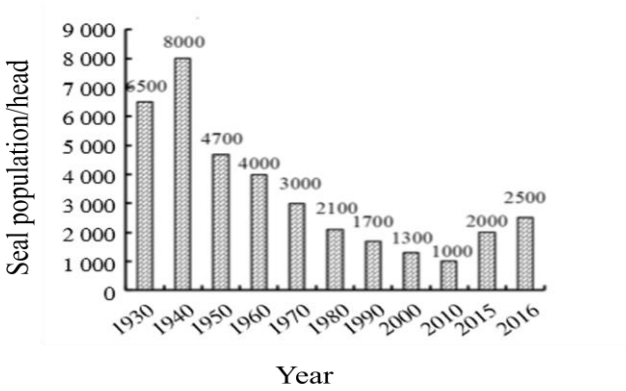

Fig.9 Statistics of Seal Number Change in the Bohai Sea

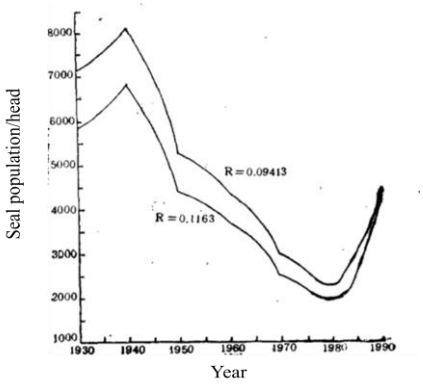

Fig. 10. Population dynamics curve of spotted seals in Liaodong Bay

Estimated changes in population size of harbour seals during the period 1930- 1990 at exponential rates of increase at 0.09413 and 0.116. Fig. 8 shows the population dynamics of spotted seals in Liaodong Bay from 1930 to 1990. If the population turnover rate of 0.1163 is used, the population size is about 5,758 in 1930, 6,930 in 1940, the smallest in 1979, about 1,908. If the population turnover rate of 0.09413 is used, the population size is about 7100 in 1930, the largest in 1940, about 8,137 and the smallest in 1979about 2,269 heads. The number of historical populations estimated by the two indices indicates the same trend of development. From 1930 to 1940, the population rose slowly and reached its peak in 1940; from 1940 to 1979, the population declined several times, with the largest decline in 1940 to 1950, the lowest in 1979, with only 1,908 heads (R-0.1163), from 1979 to 1982, the population increased slightly, but the range was very small, almost at the same level. After 1982, the population increased sharply. It is not difficult to see from Fig. 10 that the number of spotted seals in 1990 was equal to that in 1959 (R-10.09413) and 1949 (R-0.1163), both of which were about 4,500, and the population was restored (Dong and Shen, 1991).

5.2 Effects of sea ice on other species along Dandong coast

There are microorganisms and algae living in the ice of the Bohai

Sea, and various marine organisms living in the subglacial sea water (Yan et al., 1997). The Bohai Sea ice is the southernmost ice in the northern hemisphere. It is one year ice. The water depth in the ice zone is shallow and the ice condition is complex. Therefore, the ice in the Bohai Sea has a unique impact mechanism on the marine community in the ice area. For example, in the Antarctic and Arctic ice regions, the long winter is the reserve stage of ice algae. In spring, when sea ice melts, ice algae thrives on phytoplankton in seawater. However, the characteristics of the ice in the Bohai Sea determine that its contribution to phytoplankton may be different from that in Antarctica and Arctic (Li et al., 1997). Extreme ice events (ice weakening or aggravating) under the conditions of global climate change may also change this difference. Benthic shellfish grow in the ice zone along the coast of Bohai Bay. The influence of sea ice on the growth of benthic shellfish is mainly manifested in the direct influence of sea water on the transmittance, oxygen content and temperature of water. At the same time, ice may occur in offshore waters. Benthic organisms are directly exposed to sea ice environment and interact with ice bodies, causing damage to organisms (Xu et al., 2019).

Ma et al. (1997) have shown that there are obvious differences in intertidal animal communities between glacial and non-glacial periods in the ice zone off shore in Liaodong Bay. The number of species in glacial period is 1/2 of that in non-glacial period, and the species composition is

obviously different. There are only mollusks and polychaetes in glacial period. In addition to the above two types, there are crustaceans, newts, mollusks and echinoderms in non-glacial period. Crustaceans were the dominant species in the non-glacial period, while molluscs dominated the glacial period. The habitat density and biomass of benthic animals in the glacial period were lower than those in the non-glacial period, 29% and 40% respectively (Ma et al., 1997).

6. Future Prospects and Countermeasures

At present, global climate change is at the peak of fluctuation, and extreme weather is more likely to occur. In the early stage of ice formation, sea ice is mainly affected by extreme weather (the number, intensity and frequency of cold wave). Sea ice is more sensitive to global climate change. Therefore, the frequency and amplitude of random fluctuation of ice will increase, and extreme ice will be more sensitive to extreme weather (biased year). The greater probability of occurrence of heavy ice years increases the risk of sea ice. Existing studies have shown that although the ice in the Bohai Sea has a general trend of weakening under the background of global climate change, extreme events occur from time to time (Chinese Marine Disaster Bulletin, 2017; Qin, 2017). Based on the data of ice grade from 1950 to 2018 (Chinese Marine Disaster Bulletin, 2017), it is concluded that under the influence of global

climate change, the overall ice condition in China is gradually weakening, but extreme ice conditions above grade 3.5 occur occasionally. The ice area of the Bohai Sea reached 33,000 km2 in the year 2015-2016 (grade 3.0), which exceeded 40% of the total area of the Bohai Sea.

When the ice condition is serious, for ships with insufficient main engine power and poor ice breaking ability, the decision to terminate entry and exit from the port should be made resolutely according to the actual situation of the ship. Blind operation should not be avoided, especially in the glacial period and the melting period. Full attention should be paid to the anti-freezing of water tanks, water pipes, especially seabed valves. At work, the water volume of each tank should not exceed 90%, the ship must keep a certain draft, so that the propeller and rudder are unmanned to a certain depth in the water. Before leading a ship into or out of the harbour, it is necessary to know the basic information of the ship in detail, and to prepare anchors when navigating the channel to prevent the ship from being stranded due to ice entrainment deviating from the channel. For small and medium-sized ships, if the depth and width of the channel permits, the pilots who can circumvent large ice blocks should fully understand and grasp the characteristics of Dandong Port's ice age, drive cautiously, and ensure the safety of ice navigation.

Previous studies on sea ice mostly focused on the methods of ice extraction, inter annual variation and influencing factors. There were relatively few studies on sea ice prediction and dynamic generation and disappearance, which still need to be further strengthened. As one of the main economic development zones in China, the Bohai Rim has developed economy, busy shipping, abundant resources and flourishing mariculture. As a result, the sea ice disaster has become one of the most serious marine disasters in the Bohai Sea. Therefore, accurate prediction of the spatial and temporal distribution of sea ice has important practical significance for the prevention and Application of sea ice disasters. As far as sea ice observation means are concerned, for a long time, they mainly rely on fixed observation stations, Coastal Sea Ice Survey and cruise survey of icebreakers. Although these means can obtain more detailed sea ice information in a certain area, it is difficult to obtain real-time and large-scale observation data. These real-time and large-area observation data are the important basis for early warning and prediction of sea ice disasters. Therefore, other technologies, such as satellite remote sensing, can be fully introduced into the early warning, prediction and monitoring of sea ice disasters.

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