THE BASE LINE REPORT ON THE ENVIRONMENT OF THE THREE DEMONSTRATION SITES

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1. **INTRODUCTION**

1.1 Task overview

According to the "Project Cooperation Agreement Between the United Nations Office for Project Services and Yellow Sea Fisheries Research Institute of Chinese Academy of Fishery Sciences of Ministry of Agriculture (YSFRI-CAFS-MOA), People's Republic of China" (PCA), the RWG-M group should support to demonstrate IMTA in three sites. The objective underlying PCA is to replicate IMTA to Haiyang and Sanggou Bay of Shandong and Zhangzi Island of Liaoning Province. However, the PMO and RWG-M group discussed the IMTA sites in November, 2017. The delegations thought it was important to demonstrate the IMTA in a regional scale in order to improve the efficiency of the funding. Another site in Sanggou Bay was supplemented and the site of Zhangzi Island of Liaoning Province was canceled. So all the demonstrate sites are in Shandong Provence, which are Rongcheng Rongjin Oyster Aquaculture Co., Ltd. in the west of Sanggou Bay, Rongcheng Chudao Aquatic Co., Ltd. in the southeast of Sanggou Bay and Haiyang Yellow Sea Aquatic Product Co., Ltd., a land based aquaculture area, in the south of Haiyang City. The IMTA has been demonstrated in the Sanggou Bay for many years. But some areas are still implementing monoculture. In this report the environment of the three demonstrate sites was determined before the IMTA demonstration, which gives data for the evaluation of the effects of IMTA demonstration in the YSLME phase Ⅱ.

1.2 Objectives

The evaluation of the environment in the three demonstrate sites before IMTA practice is prerequisite. The data will be used for identifying the suitable areas for IMTA demonstration in other part of Shandong Provence. Baseline report identifies interventions to replicate IMTA in three demonstration sites.

2. STUDY AREAS

2.1 Spatial boundaries and sample sites

2.1.1 Sanggou Bay

Sanggou Bay (37°01–37°09′ N, 122°24′–122°35′ E), located in Shandong Provence, China, is a well known typical IMTA area. There were more than 30 important aquaculture species of which shellfish and seaweed were the main cultured ones (Zhang et al. 2007). The investigation 21 sites were set around the whole bay area including three sites outside the aquaculture area (Fig. 1). There are two IMTA demonstrate sites in Sanggou Bay. The aquaculture area of Rongcheng Rongjin Oyster Aquaculture Co., Ltd. located at SG-19 and SG-14 sites. It is cultured oyster there as an oyster monoculture site. The aquaculture area of Rongcheng Chudao Aquatic Co., Ltd. located at SG-4 and SG-5 sites. The SG-5 site is the shellfish-seaweed IMTA area. The SG-4 site is kelp monoculture site.

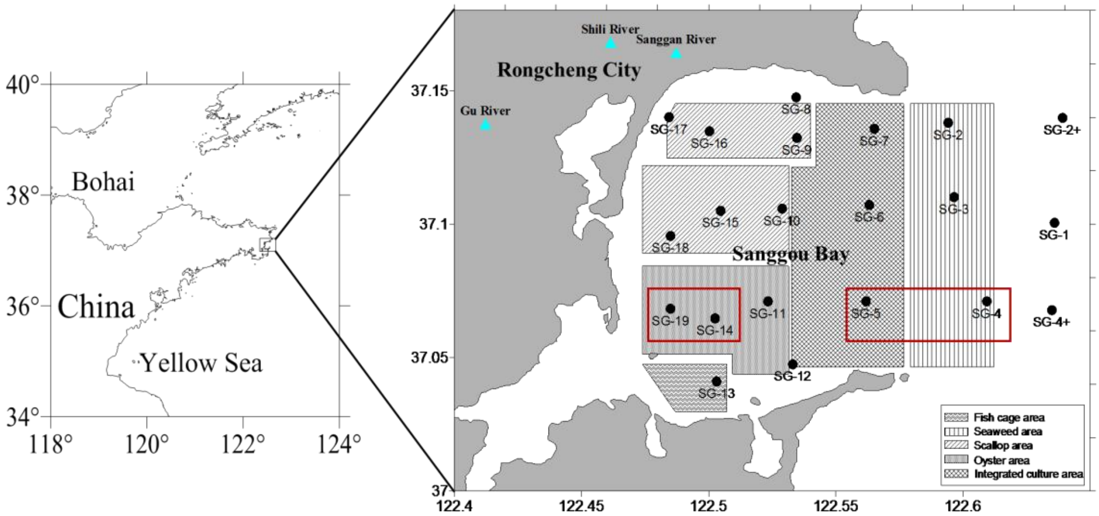

Fig. 1 The investigation sites and IMTA demonstration sites in the Sanggou Bay

2.1.2 Land-based aquaculture area

Haiyang Yellow Sea Aquatic Product Co., Ltd. was established in 1998. In 2004, it was run together with the Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences. It is a typical enterprise that combines scientific research with production. The company has 16000m^3 for indoor aquaculture, 30000 m^3 for demonstration aquaculture, 10000 m^3 for ecological demonstration aquaculture pond, and 140 ha^2 for pond aquaculture. The investigation in this report is the production and environment situation. The IMTA will be practiced in the pond outside the indoor areas (Fig. 2).

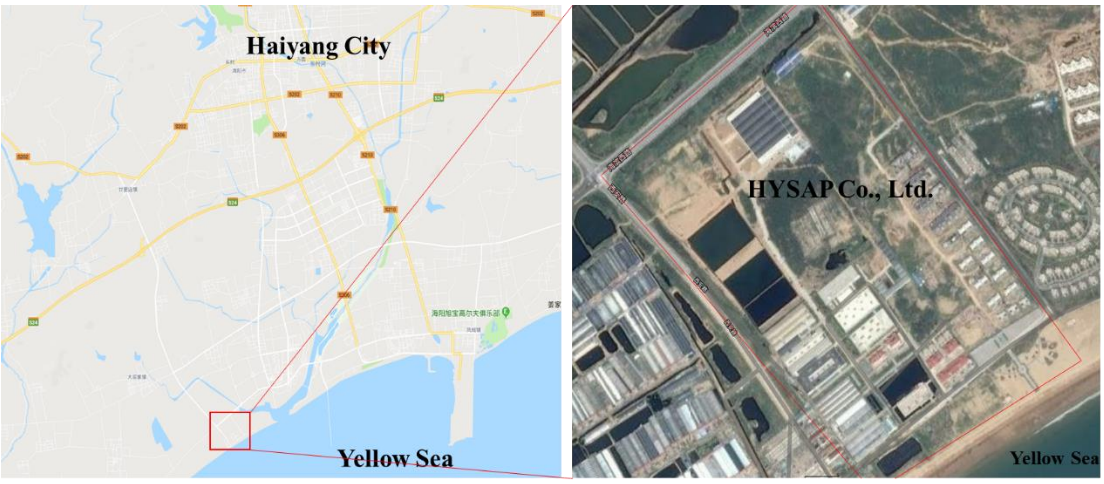

Fig. 2 The location of Haiyang Yellow Sea Aquatic Product Co., Ltd. (HYSAP Co., Ltd.).

3. **BACKGROUND**

The Yellow Sea (YS) ecosystem and its ecosystem carrying capacity (ECC) has changed dramatically since the 1st phase of the Project, for better or worse. Since the NSAPs were developed as the National Plans focusing on YS which were developed by China and Korea to assist in implementation of the regional SAP at the national level by including both national and transboundary issues, a bridging process of identification of gaps and updates on various areas listed in the NSAPs requires to review and update with information available by taking consideration of any changes made with updates available since the 1st phase including aquaculture techniques.

During the 1st phase of the project, the monoculture was the main model of aquaculture. There was no suitable scientific techniques, principle and policy to guide the farms. The experience learned from the fathers dominated the aquaculture production. Some of the aquaculture area exceeded the aquaculture capacity in the regional waters. Especially, the monoculture without scientific guidance usually induces environmental problems. In water areas with high shellfish aquaculture density (monoculture), lack of food and self-pollution have become a serious problem, which is particularly prominent in China (Cui Yi et al., 2005 (self-pollution); Deng, 2016(lack of food)). The decline in immune ability and condition index led to a decline in the production of economic shellfish (Zhang and Yang, 1999; China Association of Aquatic Products Circulation and Processing, 2018 meeting). Seaweed cultivation is an important environment-friendly culture method and plays an important role in reducing the degree of eutrophication in the sea (Troell et al., 2009). However, Large-scale algae cultivation induces the problem of nutrient restriction, which affects the community structure of phytoplankton, and thus affects the health of aquaculture ecosystems (Liu, 2002). With the expansion of the scale of kelp farming, Sanggou Bay, an important production area of kelp, the restriction nutrient changed mainly from nitrogen since the 1980s to the inorganic phosphorus and inorganic silicon at present (Liu, 2002).

Studies have shown that the social, economic and environmental benefits of IMTA are significant. Using the 17 major measurement and valuation parameters by Costanza et al (1997), the conclusion was that the core services of marine aquaculture ecosystem in Sangou Bay are high in that total value per year per hectare of IMTA of kelp and abalone is 3-4 times higher than combined value of monoculture kelp and monoculture scallop. The total value per year per hectare of kelp + abalone + sea cucumber reached nearly RMB 1 million yuan, 5 times higher than the combined value of monoculture kelp and monoculture scallop. Study by other researchers also prove that IMTA can often be more profitable (in context of net present value (NPV)) than monoculture systems.

4. **METHODS**

4.1 Sampling and locations

In Sanggou Bay, the sampling time was in November, 2017 before kelp seeding. And the sampling time was the ending of oyster farming in the production cycle. All the sites were sampled surface water, bottom water (if the depth more than 10m) and sediment. The temperature, pH and salinity were determined by a YSI 6600 at the same time. The sediment underneath the farm were randomly taken in each sampling location using a Van-Veen grab. The sample on the surface 1-2cm was collected. At the demonstration sites, the sedimentation samples were collected by the sediment trap. The sediment trap consisted by a black tube (height 35cm, diameter 6 cm) and a black plastic bottle (height 15cm, diameter 6 cm) was used for sediment collection. Water samples were collected at every site.

For the land based aquaculture area, the production situation, the water quality of the indoor area, the water quality of the outdoor pond and the sediment of the pond were determined in May 2018. The temperature, pH and salinity were determined by a YSI 6600. In the IMTA demonstration pond, there were five sampling sites around the pond. The sediment in the land based pond was collected using a Van-Veen grab the same as in the sea.

4.2 Samples analysis

It was taken 2L water at each sampling site. Then 3 ml magnesium carbonate suspension solution was added. Then 800 ml from the 2L sample was filtered through a 0.45 μm cellulose acetate filter to determine the total concentration of Chl-a at each site. Another 800 ml water sample was filtered on 20 μm, 2 μm and 0.45 μm filter in order to determine the Chl-a concentration of three different size classes phytoplankton. The filtered samples were stored at -20℃. The filtered samples were extracted with 90% acetone for 24 hours. The concentration of Chl-a was measured with a spectrophotometer. There were three classes of phytoplankton: larger than 20 μm is microphytoplankton, 2-20 μm is microphytoplankton, and 0.45-2 μm is picophytoplankton. The determination of nutrient was according to the method in the "Principle for the Investigation of Oceans" (GB12763.4-2007), where phosphorus (TP), nitrogen (TN), dissolved inorganic carbon (DIC) were determined.

Deposition samples collected from the sediment traps (De), and sediment collected underneath the farm (Se) were first oven-dried at 70°C to define total dry weight (DW), and then the organic matter content (OM in ash free dry weight) was determined by a muffle furnace (SXL–1030, China) at 450 °C for 6 h. Prior to analysis for nutrient composition, sediment trap and sediment samples were weighed and homogenized. Subsequently carbon and nitrogen contents were determined using a Vario ELIII Elemental Analyzer (Elementar, Germany).

4.3 Data management and analysis

The distribution of the phytoplankton Chl-a, temperature, pH were generated using the Surfer 11 software.

5. RESULTS

5.1 Sanggou Bay

5.1.1 General chemistry

1. Temperature

The temperature in the bay was lower than that outside of the bay in November, 2017. The difference of temperature inside and outside of the bay was 2.7℃-4.0℃ (Fig. 3).

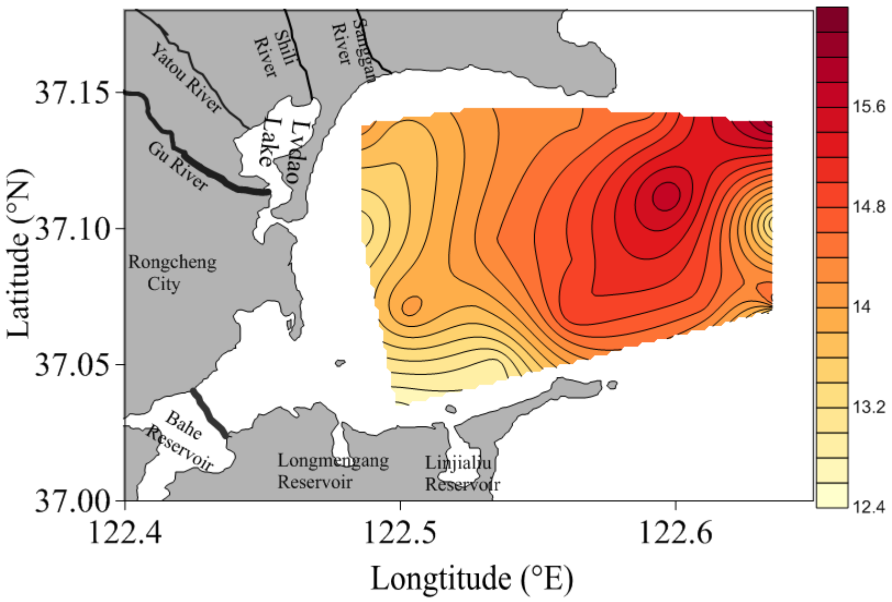

Fig. 3 The temperature of surface water in Sanggou Bay in November, 2017.

2. Salinity

The fluctuations of salinity in different sites were little, which were among 30.20-30.94.

5.1.2 Nutrients

1. Dissolved inorganic nitrogen (DIN)

The DIN of the surface water in Sanggou Bay was relevant low. It was among 0.5-10.2μmol/L. The highest DIN in the shellfish aquaculture area. And the seaweed area and the IMTA area were lower than shellfish area (Fig. 4).

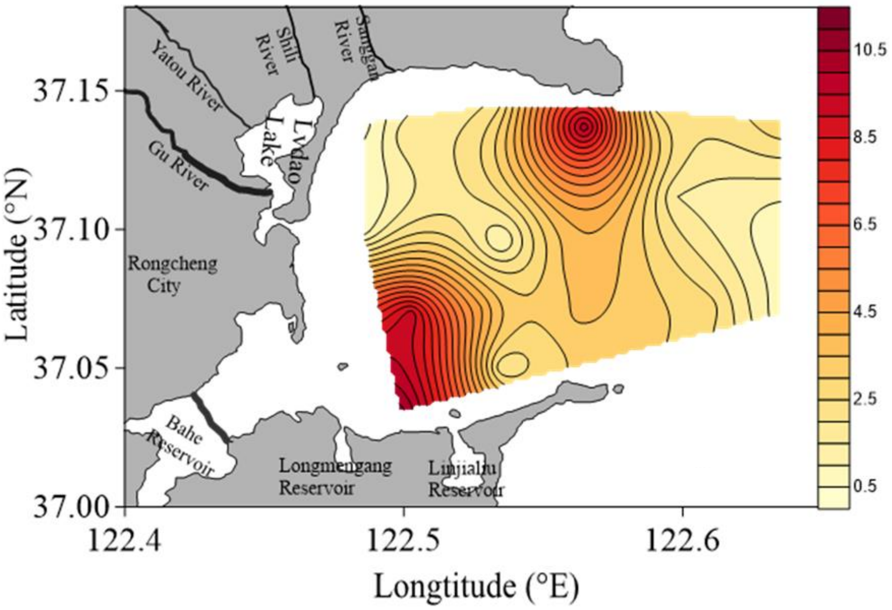

Fig. 4 The Dissolved inorganic nitrogen (DIN) of surface water in Sanggou Bay in November, 2017.

2. Phosphorus

The phosphorus was highest in the oyster and fish monoculture area in the southwest of the bay. The lowest phosphorus concentration was in the northeast of the bay where is the water input area. The IMTA area is lower than oyster monoculture area (Fig. 5).

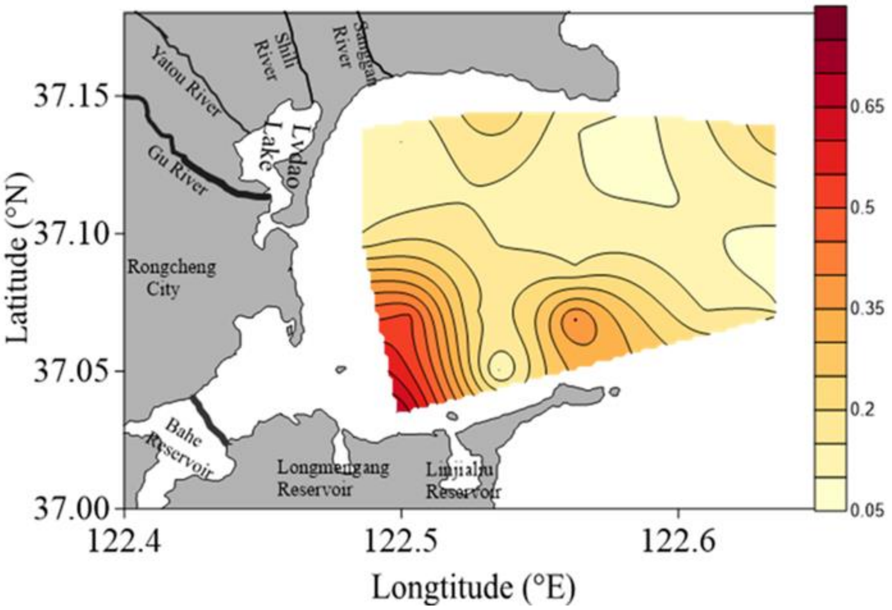

Fig. 5 The Phosphorus of surface water in Sanggou Bay in November, 2017.

5.1.3 Carbon

1. pCO_2

The distribution of pCO_2 in surface seawater of Sanggou Bay was shown in Fig. 6. The pCO_2 in surface seawater is gradually reduced from inside to outside. The highest value was found in the cage culture area with a pCO_2 value of 382.56 μatm. The difference of pCO_2 between different culture areas was significant ($P<0.05$).

The range of pCO_2 in surface waters of Sanggou Bay was between 323.42 and 382.56 μatm. The CO_2 exchange flux values at each site in different culture sea areas were shown in Table 1. The fluxes in the control area (no aquaculture area outside of the bay), seaweed area, shellfish-seaweed area, shellfish area, and cage area were -3.30±0.35, -15.40±1.28, -4.32±1.41, -1.02±0.83 and 8.14, respectively. In addition, all areas were identified as carbon sink area except for the cage area. The F value of the seaweed area was the largest followed by the IMTA area. And the shellfish area was the lowest.

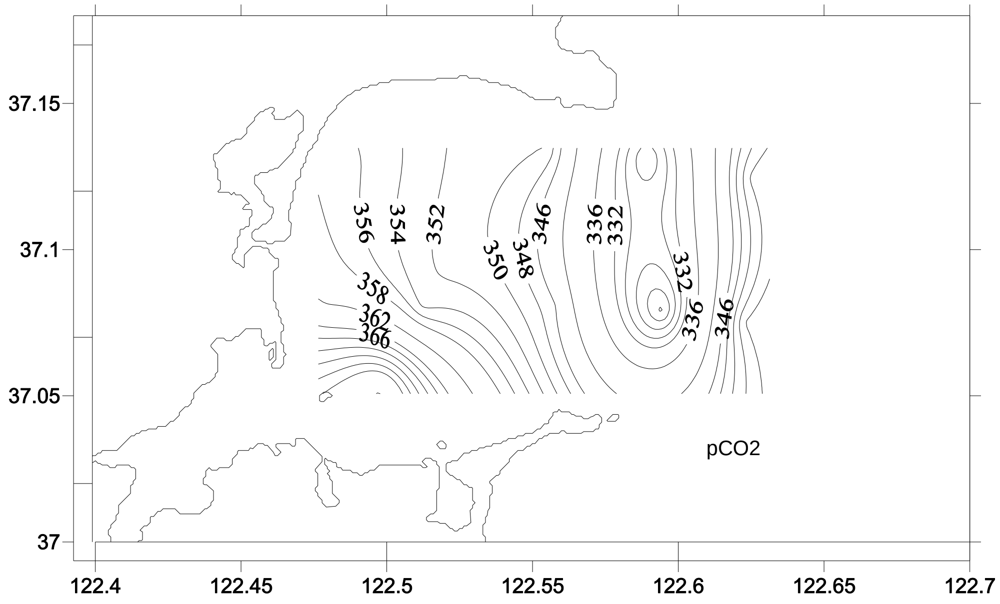

Fig. 6 The pCO_2 of surface water in Sanggou Bay in November, 2017.

Table 1 Flux of CO_2 (F) in different areas of Sanggou Bay

Area	F
Control area	-3.30±0.35
Seaweed area	-15.40±1.28
Bivalves and seaweed area (IMTA)	-4.32±1.41
Bivalves area	-1.02±0.83

2. Dissolved Inorganic Carbon (DIC)

The DIC ranged from 2120.74 to 2284.13μmol/L, with an average of 2213.91±43.05 μmol/L. It was decreasing from inside to the outside of the bay. There was a significant increase in DIC of the control area (no aquaculture area outside of the bay). The lowest DIC was in the seaweed area, and the highest DIC was in the shellfish area. The difference between highest DIC and the lowest DIC was 164μmol/L (Fig. 7).

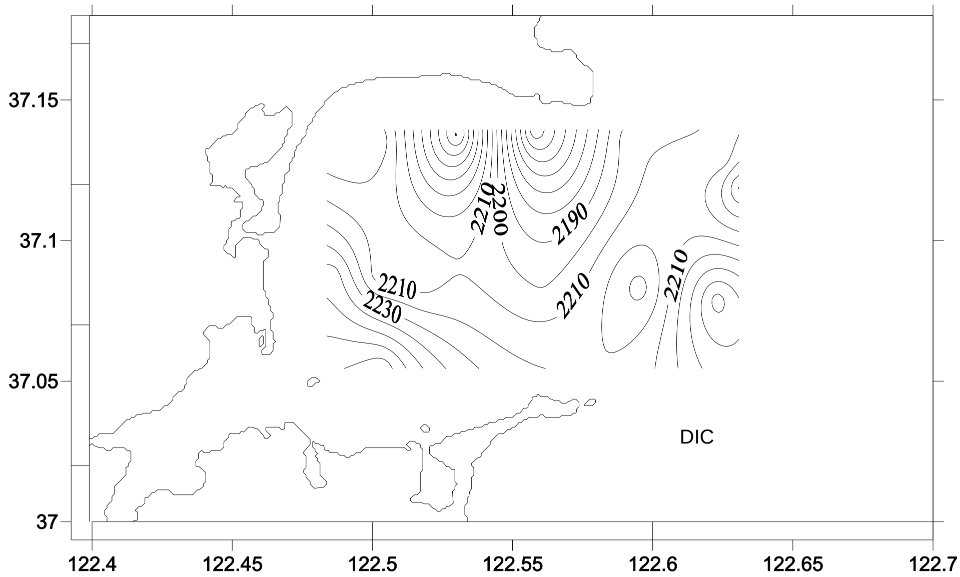

Fig. 7 The DIC of surface water in Sanggou Bay in November, 2017.

5.1.4 Chl-a

1. Chl-a (Total)

The total Chl-a was high in the coastal waters especially in the southern area of the bay. The total Chl-a (standing for phytoplankton) were showing a downward trend from inside to the outside of the bay. The total Chl-a was similar in the vertical distribution (Fig. 8).

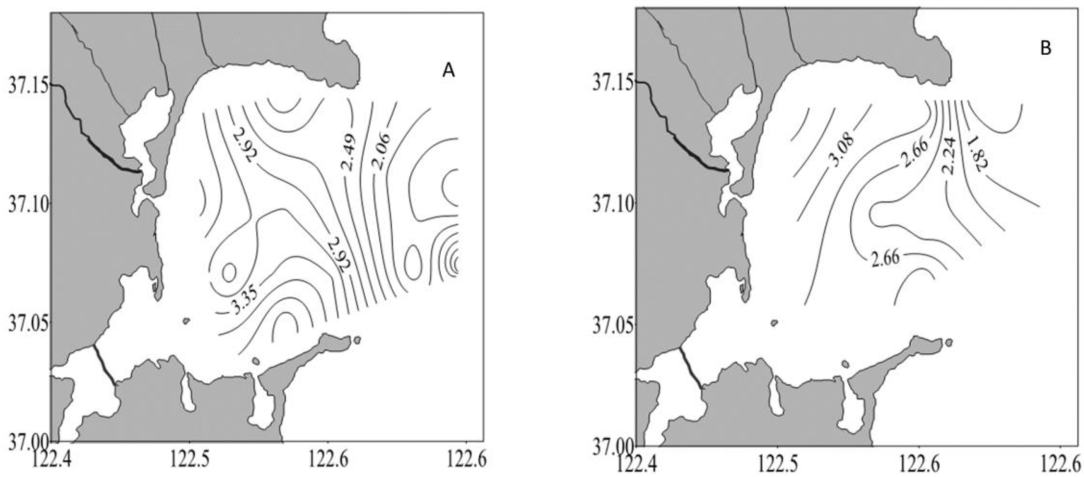

Fig. 8 The total Chl-a of surface (A) and bottom (B) water in Sanggou Bay in November, 2017.

2. Chl-a (size classes of phytoplankton)

The Chl-a of microphytoplankton ranged from 0.10 to 0.46 μg/L with an average of 0.20 μg/L. It was mainly distributed in the western coastal waters and the bay mouth, with a concentration of 0.32 μg/L. The Chl-a of microphytoplankton in the central waters of Sanggou Bay was relatively low. The Chl-a of nanophytoplankton ranged from 0.66 to 2.94 μg/L with an average value of 0.57 μg/L. The high concentration appeared in the nearshore of the southern bay. The concentration at the bay mouth was relatively low. The Chl-a of picophytoplankton was 0.19-2.18 μg/L with an average value of 0.98 μg/L. Picophytoplankton were mainly distributed in the southeast of the bay (Fig. 9).

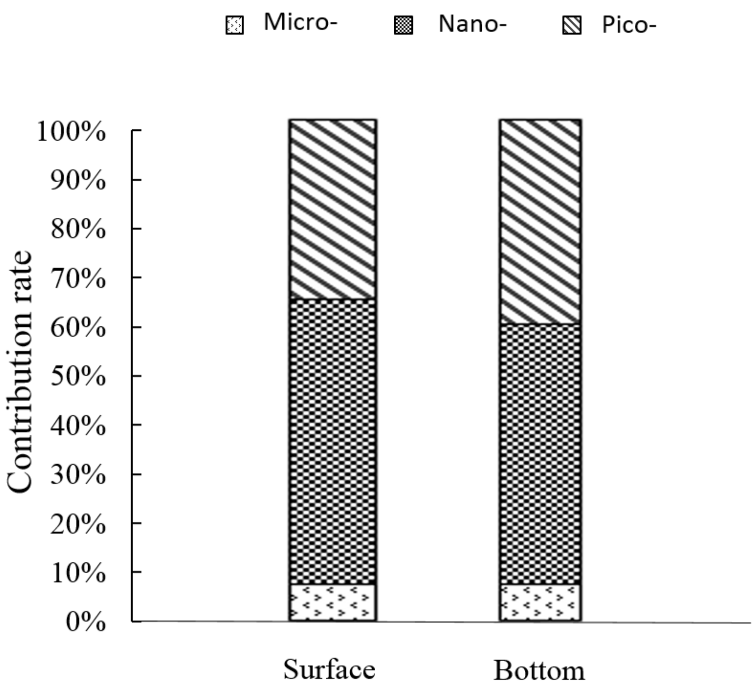

Fig. 9 The Chl-a of size classes of phytoplankton in Sanggou Bay in November, 2017.

5.1.5 Sediment

The nutrients of deposited material was also significantly different from the sediment collected underneath both areas; carbon, nitrogen and organic content were respectively 2.6, 4.1 and 4.1 times higher for the material collected with sediment traps (Table 2). This was also reflected by the nutrients of the deposited material, which was generally lower for the IMTA area.

Table 2 Nutrients of the deposited material (sediment traps) and sediment (grab samples) underneath the monoculture area and in the IMTA area.

	Deposited material		Sediment	
	Monoculture area	IMTA area	Monoculture area	IMTA area
Organic matter (%)	10.7 ± 0.0	6.5 ± 0.2	2.6 ± 0.1	2.2 ± 0.1
Carbon (%)	2.7 ± 0.0	2.0 ± 0.0	1.1 ± 0.0	0.7 ± 0.1
Nitrogen (%)	0.3 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.1 ± 0.0

Notes: Data differ significantly between monoculture area and IMTA area ($P < 0.05$).

5.2 Land based aquaculture area

5.2.1 Production situation

The flat fish is the dominant species in the Haiyang Yellow Sea Aquatic Product Co., Ltd. (HYSAP Co., Ltd.). They also produces prawns and sea cucumbers. The yield production is 500 tons. The average feeding rate is about 1.2. So the feed consumption is about 600 tons. The average conversion rate of feed is 30%. So most of the elements are discharged into the environment. There are about 70% nitrogen, carbon and phosphorus of the feed into the water. The nitrogen, carbon and phosphorus contents of the feed are 8%, 45% and 1.2%, respectively. So the discharged nitrogen, carbon and phosphorus from indoor aquaculture to the environment are 28 tons, 157.5 tons and 4.2 tons every year. However, there are several ponds outside. The materials will be discharged into the ponds outside. There are many kinds of aquatic organisms in the pond, which could consume the waste matters. The species in the pond outside are shrimp, fish, sea cucumber and other wild species. Because lack of aquaculture carrying capacity evaluation, the species were randomly cultured without scientific technique guidance.

5.2.2 General Chemistry

Most of the seawater used in HYSAP Co., Ltd. is from underground. The temperature is about 7-26℃ during the year. pH is 8.0-8.1. Salinity is 28-30.

5.2.3 Nutrients and carbon in the water

The average nitrogen content, carbon content and phosphorus content in the discharged water from indoor area were 5.95 mg l^{-1}, 3.71 mg l^{-1}, and 29.76 μg l^{-1}. The discharged elements in the water accounted 53% of the total elements in the indoor elements. And the discharged elements in the sediment accounted 17% of the total elements in the indoor elements.

5.2.4 Sediment

The total phosphorus (TP) in the dried sediment was 0.093-0.124% in the pond. The average TP was 0.112%. The total nitrogen (TN) in the dried sediment was 0.07%-0.21% in the pond. The average TN was 0.17%. The H_2S in the sediment was 3.64-10.41μmol l^{-1}. The average H_2S was 6.21μmol l^{-1}. The total organic carbon (TOC) in the dried sediment was 0.25%-1.37%. The average TOC was 0.75%.

6. **CONCLUSIONS**

1. The water quality and sediment environment of monoculture area were adversely affected. The discharged water from the land based aquaculture area is a serious problem for the environment. The IMTA could be a solution for the environmental protection and keeping the economic profit.

2. The respiration and excretion of shellfish cause some environmental problems. The monoculture of shellfish will have a negative impact on the environment. The high density of shellfish aquaculture might induce the shellfish culture area to be the source of CO_2. So the IMTA can effectively protect the water environment and increase production and reduce negative environmental impact.

3. The exchange of water in the bay was improved in the autumn and the nutrients were supplemented. However, the water temperature decreased in the autumn. In addition, the biomass of shellfish in the bay was the largest in the year. The feeding stress of shellfish inhibited the biomass of phytoplankton in autumn. Therefore, the monoculture of shellfish could reduce the primary production of the sea.

4. The phytoplankton are mainly distributed in the coastal waters of the bay. The lower concentration of phytoplankton was outside of the bay. It was because that the seaweed such as kelp and *Gracilaria lemaneaformis* had been harvested and the water exchange conditions in the bay had been improved. The element input of the rivers

increased a large amount of nutrients in the bay, which resulted in a higher Chl-a concentrations along the coast.

5. The monoculture of seaweed would reduce nutrients, which might cause the lower production of phytoplankton. The monoculture of shellfish would consume phytoplankton and produce nutrients, which could change the structure of the phytoplankton. The land based aquaculture would produce large amount of organic waste, which could induce environmental problems around the farm. So it is very important to integrated different species to benefit each other and reduce the adverse effects of the monoculture species. The IMTA practice should be strengthened in those Investigation areas.

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