Activity 4 of output 3.1.2

Deliverable 12-3：

Assessment of the mariculture pollution and ships pollution in the Yellow Sea

National Marine Environmental Monitoring Center

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Content

1. Introduction

1.1 Mariculture and its pollution

1.1.1 Brief introduction of mariculture in China

Nowadays, aquaculture has been a fast-growing industry because of significant increases in demand for fish and seafood throughout the world (Gao et al., 2007). Aquaculture has shown great promise for meeting the increasing need for protein food sources and providing some relief to wild aquatic food species now threatened by over-fishing (Naylor et al., 2000). China has a long history in aquaculture. Since the 1970s, under the reform policies and driven by the economic benefits, the rapid development of China's aquaculture has been the focus of the world's attention. Now, China is the world's largest fishery nation in terms of total seafood production volume (Gao et al., 2007). The proportion of total aquaculture production of China to the world production was reached 60%. Mariculture is a major part of the aquaculture, which is well known as the major contributor to the increasing level of nutrients in the coastal area (FAO, 2018). The area and yield of mariculture of the recent ten years in China were shown as Fig.1. By the year 2017, in China, the total mariculture area and the yield have reached 208.41 million hectares and 2000.70 million tons, respectively (MAO, 2018).

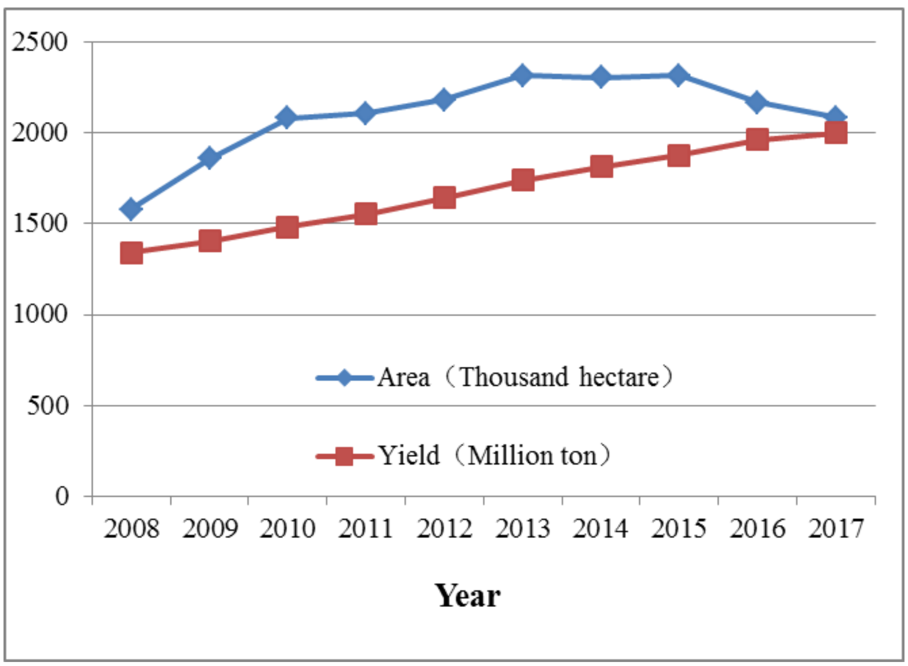

Fig.1 The area and yield of mariculture of the recent ten years in China

After years of development, there are various types of mariculture in China, including land-based factory culture, pond culture, raft culture, sowing and breeding in shallow sea and cage culture in shallow sea. Among them, land-based industrial culture and pond culture are in a relatively close environment, while shallow sea floating raft culture, shallow sea sowing and breeding and shallow sea cage culture normally belong to open environment. This difference lead to different effect to the marine environment.

The species of aquaculture are also diverse, including fish, shrimp and crab, large algae, shellfish and sea cucumber. From 2008 to 2018, the overall structure of mariculture species in China has not changed much (Fig. 2). Shellfish farming production accounts for the highest proportion of total mariculture production, with an average of about 73.3%. The second is algae, whose yield accounts for about 10.8% on average. In the past decade, fish and crustacean production has increased year by year, accounting for 6.4% and 7.6% respectively. Along with the development of the scale of mariculture, especially in China, concerns are evoked about the negative effects of the mariculture waste both on the culture system and on the ambient aquatic ecosystem (Cao et al., 2007).

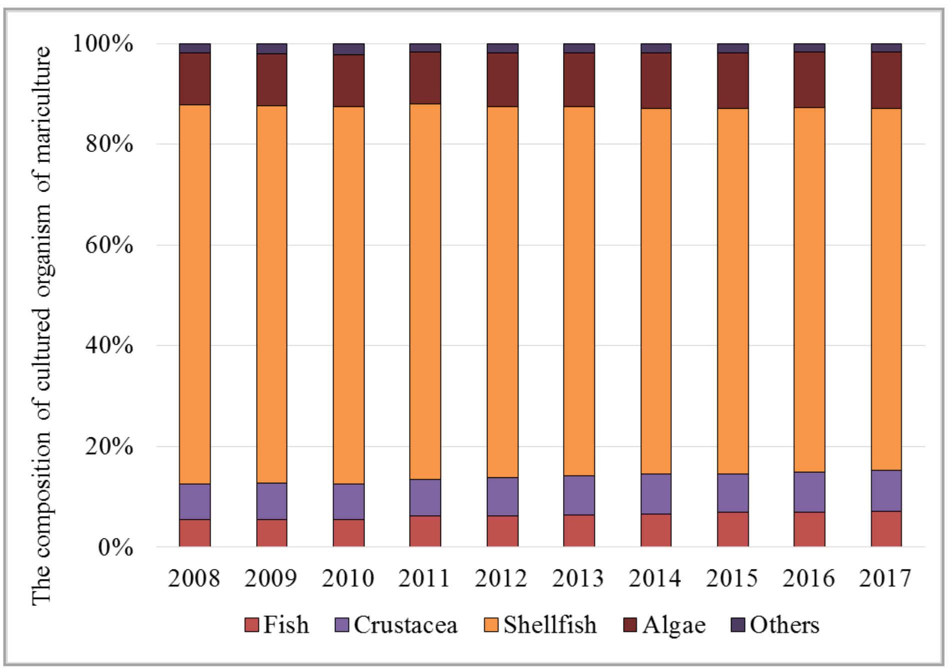

Fig. 2 The composition of cultured organism of mariculture in the recent years of China

1.1.2 Environmental impact of mariculture

The impact of mariculture on the environment mainly includes the pollution from mariculture and the negative impact on the ecological environment. Aquaculture pollution mainly includes nitrogen and phosphorus nutrients, drug residues and plastic waste produced in the process of aquaculture, and the pollutant emissions are closely related to the mariculture model. The main impacts of mariculture on the ecological environment include: changing the hydrodynamic forces of the sea area, destroying wetlands, invasion of alien organisms, etc.

1) nutrient pollution

In addition to floating raft algae culture, a large number of inorganic nitrogen and active phosphate are produced by physiological activities such as defecation and metabolism, such as non-feeding floating raft culture, shallow sea bottom seeding and proliferation, feeding land-based factory culture, enclosed pond culture and shallow sea cage culture. Zong et al. (2017) showed that the annual output of nitrogen and phosphorus in mariculture areas reached 293 000 t and 97 000 t, respectively. Among them, the total nitrogen and total phosphorus production of feeding aquaculture organisms (fish, crustaceans, etc.) reached 39 000 t and 6000 t respectively, and that of non feeding aquaculture organisms (Filter Feeding Shellfish) reached 254 000 t and 91 000 t, respectively. At the same time, the total nitrogen and total phosphorus production of mariculture has exceeded the discharge capacity of ammonia nitrogen and total phosphorus in the sewage from the outfall. Therefore, the self pollution of mariculture has become one of the important pollution sources in the coastal waters of China.

2）Drug contamination

In the stage of factory culture, cage culture and other culture methods, chemical drugs (such as antibiotics, therapeutic agents, disinfectants and preservatives) are often used to ensure the survival rate of cultured organisms and prevent and control diseases, which leads to the residues of these chemicals in the environment and enrichment in cultured organisms. The pollution of aquaculture drugs is more serious. Sulfa antibiotics can be detected in all sediment samples from two typical mariculture areas of Daya Bay and Yangjiang, with a content of up to 2.1-35.2ng/g; sulfadiazine, sulfamethazine and sulfamethoxazole residues with a maximum content of 150.0, 146.5 and 112.8ng/g were detected in liver tissues of seven kinds of cultured fish (He et al., 2014).

3） waste pollution

Mariculture facilities require a large number of plastic materials, such as cage culture nets, floating raft culture floating cage and cage, especially the traditional fishing rafts, which use very easily broken foam plastics and wood boards, resulting in pollution of sea drift garbage, and part of the sea area is faced with the pollution of plastic garbage.

4) hydrodynamic change

High density and large-scale shallow sea floating raft culture and shallow sea cage culture will significantly change the direction and flow velocity of the sea current due to the existence of breeding facilities, slow down the rate of sea water exchange in semi-closed sea areas, thus affecting the renewal speed of marine nutrients and food, increasing pollution risk and enhancing the difficulty of supervision. For example, the aquaculture activities in Sanggou Bay have developed rapidly. From 1983 to 2011, the average half exchange time of seawater in the whole bay has been prolonged by 71%.

5) destruction of wetland

Large scale aquaculture and land-based industrial aquaculture have brought negative impact on the structure, function and process of coastal wetland ecosystem, which is embodied in the huge changes in the pattern of coastal wetland, the maintenance of biological diversity and the structure of biological distribution. Through the reclamation of intertidal mudflat, the original inter-tidal habitat is transformed into artificial aquaculture pond, which occupies a large number of natural shoreline and tidal wetland, which is an important reason for affecting the health of typical marine ecosystems such as estuaries, bays and coastal wetlands.

6） invasion of alien organisms

Although the introduction of mariculture has strongly supported the development of mariculture industry in China, some improper introduction has not considered the invasion risk of alien species due to insufficient demonstration, and improper management in the process of aquaculture has led to the escape of alien organisms, which directly endangers the survival of indigenous marine organisms in the same or similar ecological environment.

1.1.3 Current management system of mariculture

1) spatial management of sea area

The spatial planning of mariculture is mainly based on the “sea area use management law”, “fisheries law” and “marine environmental protection law”. The administrative offices shall examine the application submitted by the mariculturists according to law, issue licenses and other certificates to the legal persons, and grant or confirm their legal qualifications or legal rights to engage in the licensed activities. The implementation of the aquaculture license system in China is to control the species, density, scale and mode of aquaculture. According to the reasonable aquaculture density determined by the aquaculture planning, the total amount of aquaculture scale is controlled through the issuance of aquaculture license. In addition, according to the “marine environment protection law”, an environmental impact assessment shall be carried out for the construction, reconstruction and expansion of mariculture farms.

2) pollutant discharge management

In terms of the management of the discharge of pollutants from mariculture, China implements the formulation of discharge standards. The discharge of aquaculture wastewater shall meet the discharge standards prescribed by the state. The "discharge requirements of mariculture water" issued by the Ministry of agriculture clearly stipulates the main pollution discharge standards and relevant measurement methods in the process of mariculture production. The implementation of the discharge standard of mariculture wastewater can provide legal and technical basis for the management of mariculture pollutant discharge, and the strict implementation of the standard can effectively reduce the pollution of mariculture to the marine environment.

3) seedlings and additives and management

The input products of aquaculture refer to the seedlings, feedstuffs, fishery drugs, etc. put in the process of aquaculture. The management of aquatic fry can improve the quality of aquatic fry and prevent the invasion of alien species; the management of aquatic feed can improve the utilization rate of bait and reduce the pollution of residual bait to the environment; the management of aquatic drugs can reduce the impact of the use of fishery drugs on the environment and ensure the edible safety of aquaculture products.

4) ecological environment quality management

Monitoring and evaluating the environmental indicators that have an important impact on the mariculture process and the main pollution indicators closely related to the quality of aquaculture products. Sea water indexes include: water temperature, pH, dissolved oxygen, COD, BOD, nitrogen, phosphorus, pathogen, coliform, heavy metal, sulfide, pesticide and other organic compounds, etc.; sediment indexes mainly include: pathogen, fecal coliform, coliform, organic carbon, sulfide, petroleum, heavy metal, pesticide, etc. The implementation of the environmental standard system of mariculture can provide legal and technical basis for the assessment of environmental quality and ecological risk of mariculture sea area.

1.1.4 Problems in pollution control of mariculture

1) Deficiencies in the regulatory management of pollutants discharge

The regulation of pollutant discharge of mariculture is mainly based on the current discharge requirements of mariculture water, which is the recommended industry standard issued by the Ministry of Agriculture in 2007. The limit of pollutant content in mariculture tail water is also limited to suspended solids, COD, inorganic nitrogen, active phosphate, zinc, copper and other indicators. For total nitrogen, total phosphorus, as well as the characteristic disinfectants in the tail water of mariculture Antibiotics, pathogens and other indicators lack of standard constraints. Most of the industrial aquaculture enterprises only monitor the water temperature, pH, dissolved oxygen of the aquaculture water to ensure the growth of the aquaculture organisms, but generally lack the monitoring of the nutrients, dissolved organic matters, suspended solids and pathogens produced in the aquaculture process.

At present, most of the mariculture outlets have not been included in the normal supervision and monitoring, but also lack of targeted monitoring of different pollutants produced by aquaculture. Because of the huge scale of mariculture and the lack of human and material resources, it is difficult to supervise the discharge of mariculture wastewater.

2) lack of supervision on pollution of open aquaculture at sea

The open culture mode, which is dominated by non baited shellfish, has not been regulated. Although there is no need to feed in the process of shellfish breeding, because of the large scale and high density of shellfish breeding, when the scale of shellfish breeding exceeds the tolerance range of environmental capacity of the local sea area, a series of potential pressures are brought to the marine ecological environment, such as the reduction of hydrodynamic force, the shortage of bait, the aggravation of self pollution of breeding, etc. At the same time, the mariculture wastes, represented by plastic wastes, which are produced by open mariculture at sea, have not been regulated.

1.2 Ships and their pollution

1.2.1 Development of ships and transportation

The shipping industry has experienced a rapid development over the past few years in the world, because shipping is the most cost-effective option for global transport of goods, and over 90% of world trade is carried by sea (Kilic and Deniz, 2010). Ships emissions could also lead to negative impacts on the environmental quality of ports, ship routes, and the coastal area. This is particularly in China, where with the significant development of the economy and shipbuilding industry, the total number of ships increases rapidly, and where pollution caused by ship emissions is becoming increasingly more serious (Zhang, et al., 2017). The main types of the ships are fishing vessel, passage ship, cargo ship, etc. By the year 2017, the total number of fishing vessel in China has reached 575,300 (MAO, 2018). The total number of coast ship was 103, 180, 000 and the ocean-going ship was 2, 306. The net dead weight of the coast ship was 7044.41 million tons and the ocean-going ship was 5457.50 million tons. The passenger capacity of the coast ships was 223600 and the ocean-going ship was 20800.

1.2.2 Pollution from ships

The discharge of pollutants produced in the normal navigation of ships and the accidents of ships in the ocean will lead to marine environmental pollution. The main pollutants produced by ships include oil, domestic sewage, garbage and toxic and harmful substances.

1) oil pollution

The oil pollution caused by ships mainly includes the discharge of oily sewage and oil spill caused by various accidents during normal navigation. The sources of oily sewage in normal navigation mainly include ballast water, tank washing water and bilge water. The water content of oil pollution in the bilge of a ship is related to the carrying capacity of the ship. The oil content of the oily sewage in the bilge of different tonnage ships is about 2-20mg / L. In addition, due to accidents at sea, such as ship collision, grounding, and other accidents, oil leakage will also cause greater pollution to the marine environment

2) domestic sewage

Domestic sewage pollution of ships refers to the waste water and waste formed by the daily life of crew members, passengers and animals carried on ships, such as the waste water discharged from medical rooms, toilets, laundry rooms, etc. The output of domestic sewage is related to the type and use of ships. The output of domestic sewage of ocean going ships is about 50-200L/person/day. Ship sewage contains more nitrogen, phosphorus and other nutrients, which will lead to eutrophication of seawater. At the same time, there are a lot of bacteria, parasites and pathogenic microorganisms in ship sewage, which will cause serious pollution to the water body.

3) toxic and harmful substances

In recent years, with the increasing number of ships transporting dangerous chemicals, the pollution caused by harmful and toxic substances is more and more serious. When the ships carrying toxic and harmful substances have accidents, they often lead to a large number of toxic and harmful substances leakage, which results in local sea area pollution. In addition, the ships carrying harmful and toxic substances in the normal shipping process will also cause pollution of the marine environment.

4) ship garbage

Ship garbage refers to the wastes from various sources constantly or regularly disposed by the ship during the navigation process. These wastes mainly include work supplies, such as machine parts, packaging materials, peeling paint residue, oil cotton yarn, food residues, and other daily consumer goods produced in the life of the crew and passengers. When ocean going ships transport general bulk cargo, there is an average of 1t waste per 100t to 150t cargo, and 70kg waste per 100t cargo in bulk. If these wastes are discharged into the sea without treatment, it will have a serious impact on marine organisms and marine eco-environment.

1.2.3 Management of pollution from ships

At present, the management of marine pollution is mainly based on the “environmental protection law”, the “water pollution prevention law” and the “marine environmental protection law”, as well as some management regulations formulated on its basis, such as the regulations on the management of marine environmental pollution from ships. The above laws and regulations have clear provisions on the discharge of marine pollutants. According to the “water pollution prevention law”, the discharge of oily sewage and domestic sewage shall conform to the standards for the discharge of pollutants from ships. The residual oil and waste oil of a ship shall be recovered and shall not be discharged into a water body. It is forbidden to dump ship garbage into the water body. When carrying oil or toxic goods, the ship shall take measures to prevent overflow and leakage, so as to prevent water pollution caused by falling of the goods. "

In the specific practice and operation level of ship pollution prevention and control, the national ship water pollutant emission control standard (GB 3552-2018) was officially promulgated in 2018. Compared with the original discharge standard, the requirements for sewage discharge control of ships containing toxic liquid substances have been added; in terms of domestic sewage discharge control, six indicators, such as pH value, ammonia nitrogen and total phosphorus, have been added; the classification scheme and discharge control requirements of ships' garbage have been adjusted; the standard monitoring methods for oil sewage and domestic sewage at the machine have been clarified.

1.2.4 Problems of pollution control of ships

(1) The pollutants produced in the normal shipping process of the ship mainly include oily sewage, domestic sewage, toxic and harmful substances, ship garbage, etc. Different kinds of ship pollutants make the treatment of ship pollutants more difficult.

(2) The pollutants discharged into the marine environment by the ship can not be limited to a certain area. Because of the mobility of sea water, the pollutants will also diffuse with the flow of sea water, which causes many inconvenience for the treatment of ship pollution.

(3) Oil, plastic waste and other pollutants are difficult to degrade and transfer independently after being discharged into the ocean, which will slowly accumulate in the ocean, thus damaging the marine ecological balance. Some toxic and harmful substances can be enriched in marine organisms, and then affect human health through the food chain.

(4) Due to the change of water volume, turbulence and other ship's own environmental factors, the traditional pollutant treatment technology is not easy to implement.

1.3 Evaluation methods

1.3.1 Mariculture

Now, the cultured organisms were usually divided into two types for the evaluation of self-pollution of mariculture, the artificial-feeding organisms (mainly fish, shrimp, crab, etc.)

and the non-feeding organisms (mainly filter-feeding bivalves, such as mussels, oyster, scallops, etc.). For the artificial-feeding organisms, the evaluations of self-pollution are mainly determined by the method of chemical analysis, material balance, or improvement methods of them. The method of chemical analysis is usually used to estimate the pollution of pond culture. The concentration difference of nitrogen and phosphate in the intake and outlet water combined with the water discharge of the pond to evaluate the amount of nitrogen and phosphate discharged from the cultured organisms**.** The nitrogen and phosphate discharge will be calculated as the equation（Zhang et al., 2003）:

$$P=Q\times(C_{out}-C_{int})\times10^{-6}$$

where

P —— the nitrogen or phosphate discharge (t);

Q —— water discharge of the pond (L);

C_{out} and C_{int} —— the concentrations of the water in the outlet and intake of the pond (mg/l).

For the method of material balance, the amount of the diets, the yield of the cultured organisms, the contents of N and P in the cultured organisms are used to estimate the self-pollution of the mariculture. The method of material balance is usually used to estimate the self-pollution of the net cage culture. It will be calculated as the following equation(Zhao et al., 2004):

$$P=S-W$$

where

P —— the nitrogen or phosphate discharge;

S —— the contents of N and P in the diets;

W —— the contents of N and P in the cultured organisms.

For the non-feeding organisms (mainly filter-feeding bivalves, such as mussels, oyster, scallops, etc.), the amount of nitrogen and phosphate discharged from the cultured organisms were evaluated by in situ determination. The key parameters which were biodeposition rate and excretion rate of dissolved nitrogen or phosphate will be obtained from the in situ experiment. Biodeposits were collected by traps. Biodeposition traps were randomly hung the cultivation raft by ropes (Fig.3). The material in the traps was allowed to settle before carefully siphoning off the overlying water. Nitrogen and phosphate excretion rates of shellfish were measured in closed respiration chambers with rubber plugs containing field seawater. Chambers were hung the raft by net cages and immersed in seawater to maintain constant ambient water temperature. After cultivation the chambers were taken out, the test shellfish were removed and water samples of every chamber were collected immediately. All the samples collected in the field after cultivation were transplanted to the laboratory for determination.

The key parameters obtained from the field experiment combined with the yield of the cultured organisms and the cultured period of the cultured organisms to obtain the amount of nitrogen and phosphate discharged from the cultured organisms.

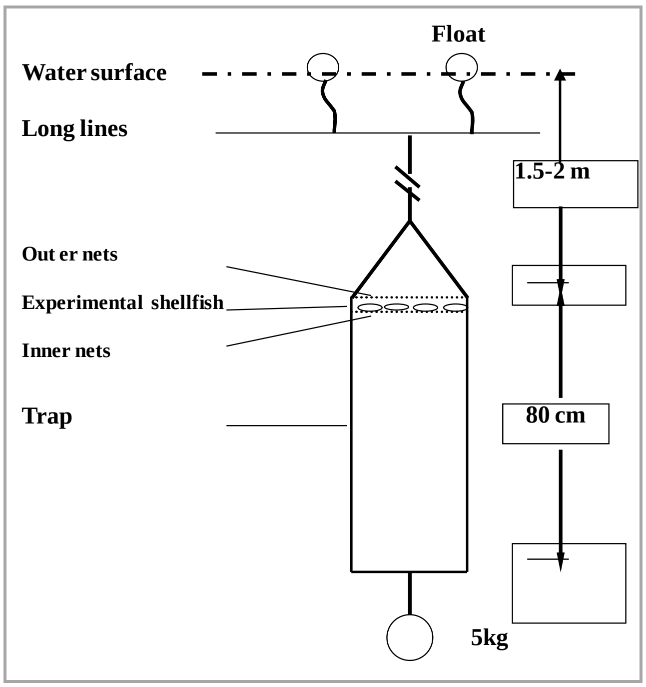

Fig.3 Schematic diagram of the biodeposition trap

The biodeposition rate of the non-feeding organisms will be calculated as the equation (Yuan et al., 2010):

$$R_b=(W_b-W_c)/N\cdot T$$

where

R_b —— the biodeposition rate (g/ind/d);

W_b —— the biodeposit collected in the trap containing shellfish (g);

W_c —— the sediments collected in the traps without shellfish (control) (g);

T —— the time of the measurement period (d);

N —— the number of animals in the trap (ind).

The excretion rates of dissolved nitrogen and phosphate of the shellfish will be calculated as following:

$$R_e = \frac{(C_{t1} - C_{t0}) \times V_r}{N \times (t1 - t0)}$$

where

R_e —— the ammonium or phosphate rate of dissolved nitrogen and phosphate (mg/ind/d);

$t0$ and $t1$ —— the beginning and end times of the measurement period (h);

C_{t1} and C_{t0} —— the ammonium and phosphate concentrations in water at the time $t1$ and $t0$ (mg/l);

V_r —— the volume of respiratory chamber (L);

N —— the number of shellfish in the chamber (ind).

1.3.2 Ships

Ship emissions mainly include domestic sewage, oil, which will affect the marine environmental quality in the coastal area. The total amount of the domestic sewage discharged from the ships was in correlation with the daily output per capita of the domestic sewage, the number of the people in the ships, and quantity of the ships (Dong, et al., 1999; Liu, et al., 2009). It can be calculated as the following equation:

$$Q = n \times q \times 10^{-3}$$

where

Q —— the annual discharge amount of the domestic sewage (m^3);

n —— the number of the people in the ship (ind);

q —— the average daily output per capita of the domestic sewage (L/ind·d).

The amount of each pollutant discharged from the ships was related to the concentration of the each pollutant in the domestic sewage. The parameters mentioned above can be obtained by in situ determination and empirical coefficient, or from the related standards based on the type of the ships.

The amount of oily sewage discharged from the ships depending on the daily output of oily sewage, quantity of the ships, and the navigation days. And the amount of oil discharged from the ships can be calculated when the concentration of the oil in oily sewage was obtained (Huang, et al, 2008). It can be simplified as the equation:

$$Q = P \times D \times C \times 10^{6}$$

where

Q —— the annual discharge amount of the oil (t);

P —— the daily output of oily sewage (t/d);

D —— the average navigation days (d);

C —— the concentration of the oil in oily sewage (g/m^3).

In Activity 4 of Output 3.1.2 entitled “Reduced pollutant levels by enforcement and control in demonstration sites”, the project will support for monitoring and acquisition of data for sharing on pollutants from atmosphere-based, fertilizer use and sea-based sources, and production of data products of Yellow Sea. One of the main tasks in the project is the assessment of the mariculture pollution and ship-based pollution in the Yellow Sea in PR China. It specifically seeks to assess the total amounts of pollutants discharged from mariculture and ships in coastal areas of the Yellow Sea, which is the basis for management actions to control pollutants in this region, and to present management actions to reduce the sea-based pollution. The methodologies established here are supposed to be applicable to the whole Yellow Sea Region.

2. Background

2.1 Mariculture in coastal area of Yellow Sea

The coastal areas of Yellow Sea include coastal area of Jiangsu province and parts of Shandong and Liaoning province in north China. The scales of the mariculture of Shandong and Liaoning province were much larger than other provinces in China, the mariculture productions of which was reached 519 and 308 million tons, respectively. Mostly mariculture zones of Shandong and Liaoning province were located in coastal area of the Yellow Sea. The mainly mariculture zones and their mainly culture organisms, culture types in coastal area of Yellow Sea were shown as Tab.1.

Tab.1 The mainly mariculture zones in coastal area of Yellow Sea

Mariculture zone	**Culture organism**	**Culture type**
Liaoning Dandong mariculture zone	Manila clam, Meretrix meretrix	Bottom culture
Liaoning Donggang mariculture zone	Manila clam, Meretrix meretrix	Bottom culture
Liaonning Dalijia mariculture zone	Scallop	Floating raft culture
Liaonning Zhuanghe bottom culture zone	Manila clam	Bottom culture
Liaonning Zhangzidao mariculture zone	Scallop, Sea cucumber	Floating raft culture, Bottom culture
Liaoning Changhai mariculture zone	Scallop, Sea cucumber, Mussel	Floating raft culture, Bottom culture
Shandong Penglai mariculture zone	Scallop, Sea cucumber	Floating raft culture, Bottom culture
Shandong Changdao mariculture zone	Scallop, fish	Floating raft culture, Net cage culture
Shandong Muping mariculture zone	Scallop, Sea cucumber	Floating raft culture, Bottom culture
Shandong Weihai mariculture zone	Scallop, Sea cucumber, Oyster	Floating raft culture, Bottom culture
Shandong Rongcheng mariculture zone	Sea cucumber, Oyster, Fish	Floating raft culture, Bottom culture, Net cage culture
Shandong Wendeng mariculture zone	Oyster, Manila clam	Floating raft culture, Bottom culture
Shandong Rushan mariculture zone	Oyster, Manila clam	Floating raft culture, Bottom culture
Shandong Haiyang mariculture zone	Manila clam, Razor clam	Bottom culture
Shandong Rizhao mariculture zone	Mussel, Scallop, Oyster	Floating raft culture
Shandong Lingshan Bay mariculture zone	Mussel, Scallop, Manila	Floating raft culture, Bottom culture

Mariculture zone	Culture organism	Culture type
	clam	
Shandong Aoshan Bay mariculture zone	Mussel, Oyster, Manila clam	Floating raft culture, Bottom culture
Jiangsu Haizhou Bay mariculture zone	Mussel, Oyster	Floating raft culture
Jiangsu Qidong shellfish culture zone	Meretrix meretrix	Bottom culture

2.2 Ships in coastal area of Yellow Sea

The impact of ship pollutant discharge on the ecological environment of the Yellow Sea should be concerned. Among the top 10 ports in terms of cargo throughput in China, ships of 7 ports need to pass through the Yellow Sea. Every year, there are 3 039 792 ships passing through the Yellow Sea in Liaoning, Shandong and Jiangsu, with a cargo throughput of 2 686 382 897 tons and a passenger transport volume of 92 639 995. The information of ships entering and leaving ports in Liaoning, Shandong and Jiangsu provinces is shown in Table 2. In addition, the fisheries in Liaoning, Shandong and Jiangsu provinces are relatively developed. The number of motorized fishing boats in the three provinces is about 35 000, and the annual operation time of motorized fishing boats at sea is basically more than 200 days.

Tab.2 The information of the ships in/out port in the coastal of the Yellow Sea

	Liaoning Province	Shandong Province	Jiangsu Province	Yellow Sea
The amount of the ships	521510	583377	1934905	3039792
Tonnage	1372336186	2607887934	3539224925	7519449045
Deadweight capacity (t)	1556206605	3482170965	15002576542	20040954112
Cargo throughput (t)	535595346	1062246322	1088541229	2686382897
Passenger traffic	10888330	25754326	55997339	92639995

3. Objective and contents

The objective underlying the proposed consultancy is to establish the assessment model of nutrients discharged from mariculture, pollutants discharged from ships and assess the total amounts of nitrogen and phosphate in various forms discharged from mariculture and pollutants discharged from ships in coastal areas of the Yellow Sea.

The main research contents of this demonstration activity are as follows:

(1) Establish the assessment model of nutrients (nitrogen and phosphate) in discharged from different culture systems of mariculture in coastal areas of the Yellow Sea.

(2) Investigate the yield of different cultured organisms as well as its nutrients discharge coefficient in the cage culture and raft culture systems during the cultured period in coastal areas of the Yellow Sea.

(3) Investigate the yield of non-feeding organisms and the content of nitrogen and phosphate in vivo, then, assess the amounts of nitrogen and phosphate uptake from the marine environment in the Yellow Sea during cultured period by the organisms.

(4) Assess the amounts of nitrogen and phosphate discharged from mariculture in the Yellow Sea based on the established assessment model and the investigation data.

This report is expected to deliver the following results:

(1) Methodologies for monitoring and assessment of nutrients discharged from mariculture and pollutants discharged from ships;

(2) An assessment report of the amounts of nutrients discharged from mariculture and pollutants discharged from ships in the Yellow Sea.

4. Method description

4.1 Workflow

According to objectives given above, workflow as Fig.4 will be adopted. Detail content of works for each task is described in the following.

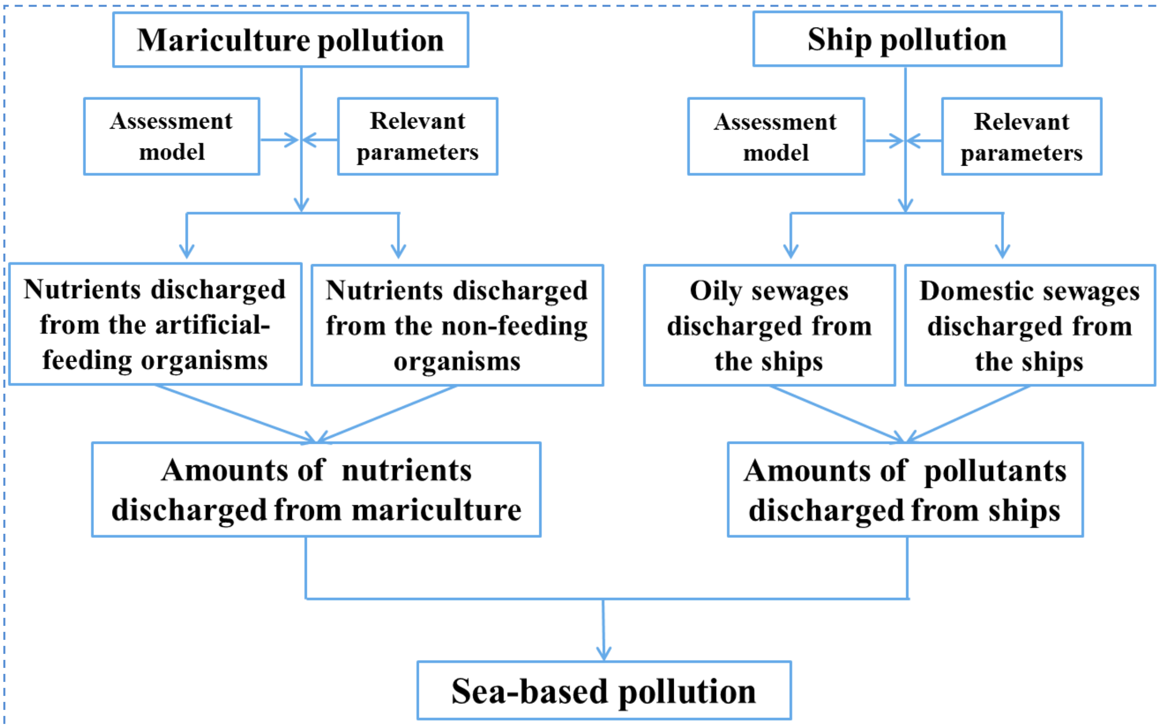

Fig.4 Diagram of workflow

4.2 Mariculture

Based on above, in order to assess the nutrients discharged from mariculture, the cultured organisms will be classified as two types: artificial-feeding organisms and non-feeding organisms. The N or P discharge coefficients of the artificial-feeding organisms were investigated in the First China Pollution Source Census based on different culture types and different areas by the methods of chemical analysis and material balance. It is fit for the evaluation of the mariculture pollution of large areas in China, including the Yellow Sea. So, the assessment method of artificial-feeding organisms will be established based on N or P discharge coefficients. The pollutions of non-feeding organisms in north China were studied by many researchers including the team of this project. Thus, the assessment methods will be established based on our research and literatures. Detail equation for the assessment is described in the following.

- The self-pollutant loading of the artificial-feeding organisms will be calculated as the equation (Zong et al., 2017):

$$L_a=R_a\times W\times 10^{-3}$$

where

L_a —— the total amounts of N or P discharge from the cultured organisms (t);

R_a —— the N or P discharge coefficient of the cultured organism (kg/t);

W —— the yield of the cultured organism (t).

- The self-pollutant loading (N and P) of the non-feeding organisms will be calculated as the equations:

$$L=L_p+L_d$$

$$L_p=N\times R_b\times C_i\times T\times 10^{-6}$$

$$L_d=N\times R_e\times T\times 10^{-9}$$

where

L —— the total amount of N or P discharge from the cultured organisms (t);

L_p —— the amount of particulate N or P (t);

L_d —— the amount of dissolved N or P (t);

N —— the number of cultured organisms (ind);

R_b —— the biodeposition rate (g/ind/d);

C_i —— the content of N or P in the particulate matter (%);

T —— the time of the cultural period (d);

R_e —— the excretion rate of dissolved N or P (mg/ind/d).

- The nutrients (N and P) uptake amount of the non-feeding organisms will be calculated as the equation:

$$L_n=R_n\times W$$

where

L_n —— the uptake amount of N or P by the cultured organisms (t);

R_n —— the content of N or P in the cultured organisms (%);

W —— the yield of the cultured organisms (t).

4.3 Ships

Assessment method for the pollutants in the domestic sewage and oil discharged from the ships will be established based on the methods mentioned above. The demanded parameters can be obtained by in situ determination and empirical coefficient, or from the related standards based on the type of the ships. The amounts of pollutants from the ships can be assessed as the following equations.

- The total amount of pollutant in the domestic sewage discharged from the ships will be calculated as the equations:

$$Q = N \times P \times D$$

$$W_i = C_i \times Q \times 10^{-9}$$

where

Q —— the annual discharge amount of the domestic sewage (L);

N —— the number of the ships;

P —— the average daily output of the domestic sewage of the ship (L);

D—— the average navigation days in coastal area of Yellow Sea (d);

W_i —— the annual discharge amount of each pollutant in the domestic sewage (t);

C_i —— concentration of the each pollutant in the domestic sewage (mg/L).

- The total amount of oil discharged from the ships will be calculated as the equation:

$$Q = D \times N \times C \times 10^{-6}$$

where

Q —— the annual discharge amount of the oil (t);

P —— the daily output of oily sewage of each ship (t/ind·d);

D —— the average navigation days in coastal area of Yellow Sea (d);

N —— the number of the ships;

C —— the content of the oil in oily sewage (‰).

5. Results and discussion

5.1 Pollutants discharged from sea-based mariculture

5.1.1 The self-pollutant loading of the artificial-feeding cultured organisms

1) cultivation production

According to the field survey and the statistical results of "2018 China fishery statistical yearbook", there are a large number of aquaculture species in the Yellow Sea coastal waters, basically including all aquaculture species in China, and the biological yield of mariculture is shown in Table 3. Among all the mariculture organisms (fish, crustaceans, etc.) in the Yellow Sea, the highest yield of sea cucumber is 130000 tons. The next are *Penaeus vannamei* and snails, while the sea bream and grouper are less cultured in the Yellow Sea. The highest yield of fish culture is *Paralichthys olivaceus*, reaching about 70000 tons.

Table 3 Annual yield of the artificial-feeding cultured organisms in the coastal area of Yellow Sea (t)

Organisms	Liaoning Province	Shandong Province	Jiangsu Province	Yellow Sea
Weever	5342	11219	1562	18123
Left-eye flounder	35084	29254	6409	70747
Red drum	-	2880	-	2880
Snapper	4	184	89	276
Grouper	-	58	10	68
Pufferfish	2553	3714	183	6450
Right-eye flounder	-	3547	2337	5884
Swimming crab	3031	10593	32569	46193
Green crab	-	-	1972	1972
White-leg shrimp	8918	65616	21248	95782
Tiger prawn	-	265	8664	8929
Chinese shrimp	8871	5595	6652	21118
Japanese shrimp	5383	14960	757	21100
Sea cucumber	61269	71742	351	133362
Sea uechin	1850	-	3919	5769
Jelly fish	50519	788	5331	56638
Abalone	1708	9656	-	11364

Snail	-	11942	67038	78980

"-": NO this species in the province.

2）emission coefficient

The emission coefficient used to evaluate the pollutant emission in the process of feeding aquaculture is obtained from "manual of aquaculture pollution source production and emission coefficient" of the first national pollution source census according to the main cultivation mode and different cultivation sea areas of aquaculture organisms. TN and TP emission coefficients of different feeding species are shown in Table 4. It can be seen from table 4 that the TN and TP emission coefficients of different aquaculture organisms are quite different. The largest emission coefficient is grouper, and the TN and TP emission coefficients are 76.472 and 12.774 kg /t respectively. The TN and TP emission coefficients of prawn and sea cucumber were relatively small.

Table 4 TN and TP discharge coefficient of the artificial-feeding cultured organism in the coastal area of Yellow Sea (kg/t)

Organisms	Liaoning Province		Shandong Province		Jiangsu Province	
	TN	**TP**	**TN**	**TP**	**TN**	**TP**
Weever	11.552	0.642	17.330	0.963	17.330	0.963
Left-eye flounder	2.052	1.309	1.508	0.962	1.508	0.962
Red drum	-	-	17.330	0.963	-	-
Snapper	17.33	0.963	17.330	0.963	17.330	0.963
Grouper	-	-	76.472	12.774	76.472	12.774
Pufferfish	12.772	0.709	12.772	0.709	17.330	0.963
Right-eye flounder	-	-	2.059	1.314	2.059	1.314
Swimming crab	2.450	1.062	1.655	0.718	2.449	1.062
Green crab	-	-	-	-	2.841	0.114
White-leg shrimp	0.866	0.316	0.288	0.105	2.119	0.353
Tiger prawn	-	-	0.875	0.320	2.122	0.353
Chinese shrimp	0.875	0.320	0.596	0.218	2.116	0.352
Japanese shrimp	0.666	0.243	0.666	0.243	2.122	0.353
Sea cucumber	3.000	0.071	1.331	0.031	4.975	0.117

Sea uechin	4.975	0.117	4.975	0.117	-	-
Jelly fish	3.152	0.355	4.035	0.455	4.035	0.455
Abalone	8.791	0.749	8.791	0.749	-	-
Snail	-	-	8.791	0.749	8.791	0.749

3）pollutant discharge level

According to the yield and emission coefficient of different feeding aquaculture organisms in Table 3 and table 4, the TN and TP emissions of various aquaculture organisms in the Yellow Sea coastal waters are shown in Table 5. It can be seen from the table that, in 2017, the annual emissions of total nitrogen (TN) and total phosphorus (TP) of feeding aquaculture organisms in the Yellow Sea were 2092.9 t and 285.3 t respectively. Among them, the highest TN emission (snail) is 694.3 t, accounting for 33.2% of the TN emission of feeding aquaculture organisms; the second is fish, the TN emission of all kinds of fish is 564.2 t, accounting for 27.0% of the TN emission of feeding aquaculture organisms. The highest TP emission of *Paralichthys olivaceus* is 80.2 t, which accounts for 28.1% of the TP emission of feeding culture organisms; the second is snail, which accounts for 59.1 t, which accounts for 20.7% of the TP emission of feeding culture organisms. The TN and TP emissions of shrimps and sea urchins were relatively low.

Tab.5 Annual amount of TN and TP discharge from the artificial-feeding cultured organisms in the coastal area of Yellow Sea (t)

Organisms	Liaoning Province		Shandong Province		Jiangsu Province		Yellow Sea	
	TN	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**
Weever	61.7	3.4	194.4	10.8	27.1	1.5	283.2	15.7
Left-eye flounder	72	45.9	44.1	28.1	9.7	6.2	125.8	80.2
Red drum	-	-	49.9	2.8	-	-	49.9	2.8
Snapper	0.1	0	3.2	0.2	1.5	0.1	4.8	0.3
Grouper	-	-	4.4	0.7	0.8	0.1	5.2	0.8
Pufferfish	32.6	1.8	47.4	2.6	3.2	0.2	83.2	4.6
Right-eye flounder	-	-	7.3	4.7	4.8	3.1	12.1	7.8
Swimming crab	7.4	3.2	17.5	7.6	79.8	34.6	104.7	45.4
Green crab	-	-	-	-	5.6	0.2	5.6	0.2

White-leg shrimp	7.7	2.8	18.9	6.9	45	7.5	71.6	17.2
Tiger prawn	-	-	0.2	0.1	18.4	3.1	18.6	3.2
Chinese shrimp	7.8	2.8	3.3	1.2	14.1	2.3	25.2	6.3
Japanese shrimp	3.6	1.3	10	3.6	1.6	0.3	15.2	5.2
Sea cucumber	183.8	4.4	95.5	2.2	1.7	0	281	6.6
Sea urchin	9.2	0.2	-	-	19.5	0.5	28.7	0.7
Jelly fish	159.2	17.9	21.5	2.4	3.2	0.4	183.9	20.7
Abalone	15	1.3	84.9	7.2	-	-	99.9	8.5
Snail	-	-	105	8.9	589.3	50.2	694.3	59.1
Total amount							2092.9	285.3

5.1.2 The self-pollutant loading of the non-feeding cultured organisms

1) cultivation yield

The non baited aquaculture organisms in the Yellow Sea coastal waters are all kinds of filter feeding shellfish. The aquaculture production is obtained from the 2018 China Fisheries statistical yearbook. The production of various aquaculture organisms is shown in Table 6. It can be seen from Table 6 that the yield of clams in the Yellow Sea is the highest, reaching 2.36 million tons, followed by scallops, with a yield of 1.05 million tons. The output of clam is the least, only 55 000 tons. In addition, it can be seen from the statistical results that the total yield of non baited culturing organisms in the Yellow Sea is far greater than that of baited culturing organisms.

Tab.6 Annual yield of the major non-feeding culture organisms in the coastal area of Yellow Sea (t)

Organisms	Liaoning	Shandong	Jiangsu	Yellow Sea
Oyster	167335	655693	48185	871213
Clam	952188	1035020	377306	2364514
Arca	27399	1835	25347	54580
Mussel	47334	321844	45031	414209
Scallop	349450	708636	48	1058134
Razor clam	37678	118038	60220	215936

2) emission coefficient

The average individual size of all kinds of filter feeding shellfish required for pollutant emission assessment is obtained by market purchasing. The individual quantity per ton of various non baited culture organisms was calculated based on the cultivation yield. Table 7 shows the biological deposition rate and ammonia nitrogen and active phosphate excretion rate of various filter feeding shellfish in the Yellow Sea, which are obtained through field investigation and relevant references. According to the number of individuals harvested per ton and the discharge rate of dissolved and non dissolved N and P, the discharge coefficient of filtered shellfish can be calculated by using the evaluation model we constructed (Table 8).

Tab.7 The average biodeposition rates, ammonia and phosphate excretion rates of the major non-feeding cultured organisms in China

Organisms	Biodeposition rate ($g·ind^{-1}·d^{-1}$)	Ammonia excretion rate ($mg·ind^{-1}·d^{-1}$)	Phosphate excretion rate ($mg·ind^{-1}·d^{-1}$)	Ind/t
Oyster	2.76	1.57	0.33	7072
Clam	0.61	0.17	0.13	74074
Bay scallop	1.67	0.95	0.11	41494
Japanese scallop	1.75	1.02	0.75	16639
Mussel	1.10	0.78	0.07	34843
Arca	0.88	0.69	0.08	23474
Razor clam	0.61	0.17	0.13	49261

Tab.8 The pollutants discharge coefficient of the major non-feeding cultured organisms (kg/t)

Organisms	TN	TP
Oyster	12.602	3.937
Clam	18.948	9.157
Bay scallop	44.739	12.618
Japanese scallop	26.707	6.948
Mussel	24.387	10.656

Arca	14.960	3.950
Razor clam	16.218	7.087

3) pollutant discharge

According to the cultivation yield and TN and TP emission coefficient, the TN and TP emissions of filter feeding shellfish in one cultivation cycle can be calculated (Table 9). The annual TN and TP emissions of filter feeding shellfish in the Yellow Sea were 122 350 t and 45392 t, respectively. The TN and TP emissions of non feeding organisms in the Yellow Sea accounted for 48.1% and 49.7% of that of non feeding organisms in China, respectively. The results show that the cultivation scale of filter feeding shellfish in the Yellow Sea is large and the cultivation yield is high, which is the main production area of filter feeding shellfish in China.

Tab.9 Annual amount of TN and TP discharge from the non-feeding cultured organisms in the coastal area of Yellow Sea (t)

Organisms	Liaoning Province		Shandong Province		Jiangsu Province		Yellow Sea	
	TN	TP	TN	TP	TN	TP	TN	TP
Oyster	2108.8	658.8	8263	2581.5	607.2	189.7	10979.0	3430.0
Clam	23221	10146.5	25241	11029.2	9201.4	4020.6	57663.4	25196.3
Arca	409.9	108.2	27.4	7.2	379.2	100.1	816.5	215.5
Mussel	1264.2	328.9	8595.5	2236.2	1202.6	312.9	11062.3	2878.0
Scallop	6621.4	3199.9	31703.7	8941.6	2.1	0.6	38327.2	12142.1
Razor clam	611.1	267	1914.3	836.5	976.6	426.8	3502.0	1530.3
Total amount							122350.4	45392.2

5.1.3 The uptake amount of TN and TP by of the non-feeding cultured organisms

The content of TN and TP in various filter feeding shellfish was obtained by actual determination and related references (Table 10). The total amount of TN and TP absorbed by all kinds of filter feeding shellfish from the marine environment can be calculated by combining the cultivation yield and evaluation model (Table 11). This part of nitrogen and phosphorus can be removed from the marine environment by shellfish harvest. It can be seen from table 11 that the annual removal of TN and TP from the marine environment of filter feeding shellfish in the Yellow Sea is 45746 t and 2677 t respectively.

Tab.10 The content of TN or TP in vivo of the cultured organisms (%)

Organisms	TN	TP
Oyster	0.436	0.025
Clam	0.996	0.048
Arca	0.763	0.049
Mussel	0.633	0.068
Scallop	0.935	0.067
Razor clam	0.677	0.051

Tab.11 The uptake amount of TN or TP by the non-feeding cultured organisms
in the coastal area of Yellow Sea (t)

Organisms	Liaoning Province		Shandong Province		Jiangsu Province		Yellow Sea	
	TN	TP	TN	TP	TN	TP	TN	TP
Oyster	729.6	41.8	2858.8	163.9	210.1	12.0	3798.5	217.8
Arca	209.1	13.5	14.0	0.9	193.4	12.5	416.6	26.8
Mussel	299.6	32.4	2037.0	220.0	285.0	30.8	2621.6	283.1
Scallop	3265.6	233.3	6622.2	473.0	0.4	0.0	9888.3	706.3
Clam	9483.8	458.4	14317.8	692.0	3758.0	181.6	27559.5	1332.0
Razor clam	255.0	19.3	798.9	60.6	407.6	30.9	1461.5	110.8
Total amount							45746.0	2676.8

5.1.4 Summary

The total annual discharge of TN and TP from mariculture in the Yellow Sea is 144443 t and 45678 t respectively. TN and TP discharged from non-feeding cultured organisms accounted for 98.3% and 99.4% of total discharge, respectively. After deducting the total amount of non-feeding aquaculture organisms removed from the marine environment, the net emissions of TN and TP in the offshore aquaculture of the Yellow Sea were 78697 t and 43000 t respectively. Compared with the assessment results in 2014, the total annual discharge of TN and TP from mariculture in the Yellow Sea is relatively large, accounting for 48.9% and 50.0% of the total discharge of mariculture in China, respectively.

5.2 Pollutants discharged from ships

5.2.1 The total amount of pollutant in the domestic sewage discharged from the ships

The ships sailing in the Yellow Sea mainly include motor fishing boats, cargo ships, passenger ships and other large transport ships. Among them, large transport ships are equipped with sewage treatment equipment, and the treated domestic sewage is discharged according to the limit value in China's standards for the control of discharge of water pollutants from ships. However, due to the small size of the fishing boats, there is normally no sewage treatment equipment at present, and the domestic sewage is directly discharged into the sea.

1) Fishing vessels

The discharge coefficient of domestic sewage and COD average content of different size motorized fishing boats are shown in Table 12. It can be seen from these data that the discharge coefficient of domestic sewage from fishing boats is related to the size of the ship. The smaller the ship is, the smaller the discharge coefficient of domestic sewage is. The discharge amount of domestic sewage from different fishing boats is between 30-100 L/ind/day. However, COD content in domestic sewage is basically the same, with an average content of about 400 mg/L.

According to “2018 China Fisheries Statistical Yearbook”, there are 34581 motor-driven fishing vessels in the Yellow Sea, most of which are small vessels with engine power below 441 kW, accounting for 98.9% of all fishing vessels. Among them, the most fishing boats with power less than 44.1kw are 20952, accounting for 60.6% of all fishing boats. According to the survey results, the number of days a year for fishing boats to sail in the Yellow Sea is about 230 days. Table 14 lists the annual discharge of domestic sewage and COD from the motor-driven fishing boats in the Yellow Sea. It can be seen from the table that the annual discharge of domestic sewage from the motor-driven fishing boats in the Yellow Sea is 3.97 × 108 L, and the annual discharge of COD is about 158.8 t. Most of them are discharged by small fishing boats with engine power below 441 kW. The discharge of domestic sewage and COD accounts for more than 97% of the total discharge of all fishing boats.

Tab.12 The discharge coefficient of domestic sewage and the concentration of COD in the domestic sewage of various ships

Power of the fishing vessel (kw)	Domestic sewage (L/ind·d)	Concentration of COD in the domestic sewage (mg/L)
<44.1	30	400
44.1~441	80	400
>441	100	400

Tab.13 The total amount of different fishing vessels in the coastal area of Yellow Sea

Power of the fishing vessel(kw)	Liaoning Prov.	Shandong Prov.	Jiangsu Prov.	Yellow Sea
<44.1	8993	9344	2615	20952
44.1~441	3844	5403	4016	13263
>441	150	200	17	366
	Total amount			34581

Tab.14 The total amount of domestic sewage and COD from different fishing vessels

Power of the fishing vessel(kw)	Domestic sewage (L)	COD (t)
<44.1	14.5×10^{7}	57.8
44.1~441	24.4×10^{7}	97.6
>441	0.8×10^{7}	3.4
Total amount	3.97×10^{8}	158.8

2) Other vessels

Pollutants discharged from other large transport ships are calculated according to the number of personnel (including passengers and crew) entering and leaving the port. The investigation results show that the domestic sewage output of large transport ships is 100 L/ person, and the COD in domestic sewage is 125 mg / L according to the discharge standard for water pollutants from ships. The discharge of domestic sewage from large transport ships in the Yellow Sea is about 1.03×10^{10} L, and the discharge of COD is about 2580.0 t.

3) total discharge

The annual discharge of domestic sewage from ships in the Yellow Sea is 1.07×10^{10} L, and the annual discharge of COD is about 2738.8 t. Among them, the annual discharge of domestic sewage and COD from large-scale transport ships is far greater than that from motorized fishing boats, accounting for 96.3% and 94.2% of the total discharge respectively.

5.2.2 The total amount of oil discharged from the ships

Table 15 showed the discharge coefficient and oil content of different types of motor fishing boats, which data are from the field investigation and relevant references. The results show that the discharge coefficient of oily sewage from fishing boats is related to the power of engines. The smaller the power is, the smaller the discharge coefficient of oily sewage is, while the average content of oil in sewage is the same. According to the investigation parameters, combined with the number and operation time of mobile fishing boats in the Yellow Sea, the annual discharge of oil-bearing sewage and oil from fishing boats can be calculated by using the model. The assessment results show that the annual discharge of oil-bearing sewage from motor fishing boats in the Yellow Sea is 859931 T and that of oil is 2579.8 t (Table 16).

Tab.15 The discharge coefficient of the oily sewage and the content of the oil in oily sewage of different fishing vessels

Power of the fishing vessel (kw)	Discharge coefficient of the oily sewage (t/ind·d)	Content of the oil in oily sewage (‰)
<44.1	0.08	3
44.1~441	0.15	3
>441	0.20	3

Tab.16 The total amount of oily sewage and oil discharged from different fishing vessels (t)

Power of the fishing vessel (kw)	Oily sewage	Oil
<44.1	385508	1157
44.1~441	457574	1373
>441	16850	51
Total amount	859931	2579.8

6. Conclusion

The project evaluates the discharge of TN and TP from mariculture and the discharge of domestic sewage, COD, oily sewage and oil from ships in the Yellow Sea.

For pollutants from the mariculture, the results show that:

1) The total annual discharge of TN and TP from mariculture in the Yellow Sea is about 144443.3t and 45677.5t, respectively.

2) TN and TP accounted for 98.3% and 99.4% of the total emissions respectively, which was related to the large scale of filter feeding shellfish culture in the Yellow Sea.

3) The removal of TN and TP from the marine environment in the Yellow Sea was about 45746.0 t and 2676.8 t, respectively.

It should be noted that the self pollution in the cultivation process of filter feeding shellfish is only aimed at the local sea area of the cultivation area. For the whole marine ecosystem, nitrogen and phosphorus can be removed from the environment by harvesting.

For pollutants from the ship, the results show that:

1) The annual discharge of domestic sewage from ships in the Yellow Sea is about 1.07 × 107 L, and the annual discharge of COD is about 2738.8 t. Among them, the annual discharge of domestic sewage and COD from large-scale transport ships is far greater than that from motorized fishing boats, accounting for 96.3% and 94.2% of the total discharge respectively.

Most of the pollutants discharged by motor fishing boats are from small fishing boats with engine power below 441 kW. The discharge of domestic sewage and COD accounts for more than 97% of the total discharge of all motor fishing boats.The annual discharge of oil-bearing sewage and residual oil from motor fishing boats in the Yellow Sea are 859931 t and 2579.8 t, respectively.

7. Advice on management actions to reduce the pollution.

7.1 Mariculture

1) scientifically select the restricted and prohibited mariculture areas; strictly implement the national environmental assessment system and the sea area use management system, and conduct the environmental assessment demonstration and sea area use and approval for the construction, reconstruction and expansion of mariculture areas.

2) encourage aquaculture enterprises to develop environmentally friendly mariculture modes such as non feeding aquaculture, reduce feeding aquaculture mode, and encourage the development of ecological and healthy aquaculture mode.

3) strengthen the supervision of wastewater discharge from land-based industrialized aquaculture and enclosed aquaculture. The wastewater from mariculture shall be discharged after treatment and conform to relevant discharge standards.

7.2 Ships

1) establish and improve the laws and regulations on the prevention and control of ship pollution, and strengthen the supervision and management of ship pollution.

2) strengthen publicity and education to make the crew fully realize the importance of protecting the marine environment and enhance their awareness of marine environment protection.

3) accelerate the construction of port and wharf environmental protection equipment, strengthen the ship's pollutant treatment capacity, and effectively deal with the pollutants produced by the ship.

References

Cao L., Wang W., Yang Y., Yang C., Yuan Z., Xiong S., Diana J., 2007. Environmental impact of aquaculture and countermeasures to aquaculture pollution in China. Environmental Science and Pollution Research-International 14(7): 452-462.

Chart Online. 2017. Global ship data, http://www.enclive.cn/News/NewsDetail.html?-ID=30332&u=Trade (in Chinese).

Dong L.F., Zang Z.J., 1999. Assessment on the Yangtize River Ship Domestic Sewage Pollution. Journal of Xi 'an Highway University 19(suppl): 75-77 (in Chinese).

FAO, 2018. The State of World Fisheries and Aquaculture. FAO, Rome.

Huang X.Q., Wang J.H., Jiang X.S., 2008. Study on marine environmental capacity and contaminant gross control of Xiangshan Port. China Ocean Press, Beijing (in Chinese).

Kiliç A., Deniz C., 2010. Inventory of shipping emissions in Izmit Gulf, Turkey. Environmental Progress & Sustainable Energy 29(2): 221-232.

Liu X.D., Yao Q., Wang P., Tang L.L., Wang S.Y., Hu J., 2009. Calculation on Pollution Load of Inland River Ships in Taihu Lake. Environmental Science & Technology 32(12): 129-132 (in Chinese).

MAO, 2018. China Fishery Statistical Yearbook. China Agriculture Press, Beijing (in Chinese).

Naylor R.L., Goldburg R.J., Primavera J.H., Kautsky N., Beveridge M.C.M., Clay J., Folke C., Lubchenco J., Mooney H., Troell M., 2000. Effect of aquaculture on worldfish supplies. Nature 405: 1017-1024.

SOA, 2016. Bulletin of Marine Environmental Status of China. SOA, Beijing (in Chinese).

Yuan X., Zhang M., Liang Y., Liu D., Guan D., 2010. Self-pollutant loading from a suspension aquaculture system of Japanese scallop (Patinopecten yessoensis) in the Changhai sea area, Northern Yellow Sea of China. Aquaculture 304(1-4): 79-87.

Zhao Q., Zhang L.P., 2004. Study on quantitative methods of self-pollution of mariculture. Marine Environmental Science 23(3): 77-80 (in Chinese).

Zhang Y., Yang X., Brown R., Yang L., Morawska L., Ristovski Z., Huang C. 2017. Shipping emissions and their impacts on air quality in China. Science of the Total Environment 581: 186-198 (in Chinese).

Zhang Y., Hong H.S., Chen N.W, Zhang L.P., Ding Y.H., Huang J.L., 2003. Discussion on Estimating Nitrogen and Phosphorus Pollution Loads in Aquaculture. Journal of Xiamen University(Natural Science) 42(2): 223-227 (in Chinese).

Zong H.M., Yuan X.T., Wang L.J., Yu L.M., Hu Y.Y., Huo C.L., Zhang Z.F., 2017. Preliminary evaluation on the nitrogen and phosphorus loads by mariculture in China. Marine Environmental Science 36(3): 337-342 (in Chinese).

王闰. 船舶污染对海洋环境的影响及防治对策分析. 中国水运(下半月), 2018, 18(9): 102-103.

林伟龙, 刘贝贝, 黄伟彬. 海洋环境陆源污染及船舶污染防治建议研究. 中国资源综合利用, 2018, 8:123-125.

笪靖, 陈勇, 陈新响. 浅谈船舶污染途径与现状分析. 世界海运, 2015, 5: 65-67.

韩香举. 浅谈船舶污染现状及防治对策. 科技与创新, 2017, 15: 81-81.

袁秀堂, 张升利, 刘述锡, 等. 庄河海域菲律宾蛤仔底播增殖区自身污染. 应用生态学报, 2011, 22(3): 785-792.

毛玉泽. 桑沟湾滤食性贝类养殖对环境的影响及其生态调控. 青岛：中国海洋大学, 2004.

全国污染源普查水产养殖业污染源产排污系数测算项目组. 第一次全国污染源普查: 水产养殖业污染源产排污系数手册. 北京：2009.

赵清, 张珞平. 海水养殖自身污染的定量化研究. 海洋环境科学, 2004, 23(3): 77-80.

吴亦九. 船舶污染防治的法律体系初探. 世界环境, 2018, No.171(02): 89.

何秀婷, 王奇, 聂湘平, 杨永涛, 程章. 广东典型海水养殖区沉积物及鱼体中磺胺类药物的残留及其对人体的健康风险评价. 环境科学, 2014, 35(7): 2728-2735.

薛利建, 徐汉祥, 许文军. 逃逸美国红鱼在浙江海域生长特性的初步研究. 海洋水产研究, 2008, 29(2): 17-22.