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FISHERIES AND MARICULTURE MANAGEMENT IN BOHAI SEA, CHINA

An Ecosystem-based Medium Term Strategy

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ABSTRACT

The Bohai Sea is one of the most important fisheries resources in China. Fisheries and mariculture are the main industries offering important food security by exploitation of migrating and stationary resources based on the same ecosystem in Bohai Sea. Understanding the potential bioeconomic interactions between fisheries and mariculture will provide the basis for fisheries and mariculture management. A medium term management strategy in Bohai Sea is suggested in this research.

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1. INTRODUCTION

Fisheries and mariculture in China are an important protein source for 1.3 billion people. Fisheries and aquaculture play a key role in enhancing food security for the population. Bohai Sea of China is one of the most intensively exploited areas in the world (Wigan 1998). China has increased total harvest by intensive exploitation of fisheries resources and by rapid development of aquaculture. Present trends suggest that fisheries are approaching their limits, and the increase in production will come from aquaculture (Zhong and Power 1997). According to the China Oceanic Information Centre (COI 2000), the output of fisheries and mariculture reported by the surrounding provinces and cities has increased in recent years. The catch from Bohai Sea reached about 1.6 million metric tons, and mariculture production was just over one metric ton in 1999. At the same time, the ecosystem in Bohai Sea has degraded because of overfishing and the adverse impacts of mariculture, in addition to pollution from other industries and city sewage (Anon. 1999a).

Fisheries and maricultute in Bohai Sea are not only providing a seafood source, but also sustaining the livelihood for numerous fishermen around Bohai Sea. Furthermore, Bohai Sea is a big spawning and nursery ground to migratory species from the Yellow Sea and East China Sea. It is estimated that 40% of the fisheries resources in the Bohai Sea, Yellow Sea and north area of East China Sea originate in Bohai Sea. Bohai Sea is the biggest mariculture base in China (Anon. 2001a). The ecosystem in Bohai Sea is fragile because of the nature of an inland sea with low flush. Both the excess fishing effort and the accumulating negative impacts from mariculture exert great pressures to the ecosystem. The fishing effort in terms of the number fishing vessels in China including Bohai Sea has increased dramatically over the years. Numerous unregistered or unlicensed fishing vessels and degrading ecosystem are the main problems in China fisheries. The illegal fishing and destructive fishing methods such as electricity, explosive, toxin and other illegal fishing methods are often used because the destructive fishing methods usually have higher efficiency.

Mariculture in Bohai Sea, as an alternative supply of seafood to the large population around Bohai Sea, is becoming more and more important. At the same time, the pollution from mariculture is accelerating by the spatial expansion of mariculture. Constructing mariculture areas damage the natural spawning grounds and habitats, which exert more pressures on the wild fish stocks. And the none-endemic species, including biologically modified species are also maricultured in Bohai Sea, and its threat to nature remains uncertain. Open-access fisheries and unregulated mariculture in Bohai Sea impede the economic progress and the sustainability of fisheries resource. The collapse of fish stocks in Bohai Sea shows that the stakeholders in fisheries and mariculture need a more conservation-oriented strategy in fisheries and mariculture management. The objectives of this project on fisheries and mariculture management in Bohai Sea are to:

- investigate the resources exploited by fisheries and mariculture
- present a rationale of combined management using theoretical analysis

- suggest management regimes to achieve the sustainable fisheries and mariculture

Fisheries and mariculture coexist in the Bohai Sea area, so understanding biological and economic interaction between fisheries and mariculture will be helpful in providing the basis for proper fisheries and mariculture management. This project originates from desk research using fisheries economics and policy analysis. It is assumed that negative impacts from other industries in the Bohai Sea are constant. This research presents an overview of the characteristics of the fisheries and mariculture in Bohai Sea, attempts to reconcile bioeconomic conflicts between fisheries and mariculture through a medium term ecosystem-based fisheries and mariculture management strategy.

2. LITERATURE REVIEW

Fisheries economics is a study which combines biological and economic perspectives to provide a theoretical basis for optimal exploitation of fisheries resources. Mariculture is directly associated with fisheries by bioeconomic links, the optimal resources allocation between fisheries and mariculture will be the focus of combined fisheries and mariculture management.

The long-term sustainable use of fisheries resources is the overriding objective of conservation and management, which is based on the best scientific evidence available to maintain or restore stocks at levels capable of producing maximum sustainable yield. Mariculture should undertake appropriate environmental assessment and monitoring with the aim of minimizing adverse ecological changes and related economic and social consequences resulting from water extraction, land use, discharge of effluents, use of drugs and chemicals, and other activities. The development of aquaculture should be ecologically sustainable and to allow the rational use of resources shared by mariculture, fisheries and other activities (FAO 1995).

When the number of fishing vessels exceeds the capacity of the fisheries resources, it is said to be over harvested. A simple and widely accepted model of open-access equilibrium in fishery is the Schaefer model. The model combines biological and economic aspects of fisheries. In open-access fishery, the fishery will move toward an equilibrium position at which the total revenue from the fishery equals the total cost. This is because new fisherman will be attracted to the fishery as long as they can make profit from their fishing operation. While the total cost exceeds the total revenue, there must be some fishermen losing money, and they will leave the fishery (Anderson 1986).

The Schaefer model shows that for the different levels of efforts in a fishery, sustainable yield will rise by increasing level of effort until a certain point is reached. Thereafter the yield will become smaller because of the continuous increasing levels of fishing effort. The fish stock cannot replenish itself, and in the end will be depleted. The model assumes a constant price of yield, which means that the fishery provides only small part in the social supply and variations in supply will not affect the local price of a certain species. Since the price is constant, by multiplying the price by the

total sustainable yield curve, the same shape of revenue curve will be derived from the yield curve. In terms of the costs, the model postulates that effort is increased by new fishing boats (or nominal fishing effort) entering in the fishery. As a result the cost will be a linear function of the fishing effort. Diagrammatically, the Schaefer model can be illustrated as Figure 1.

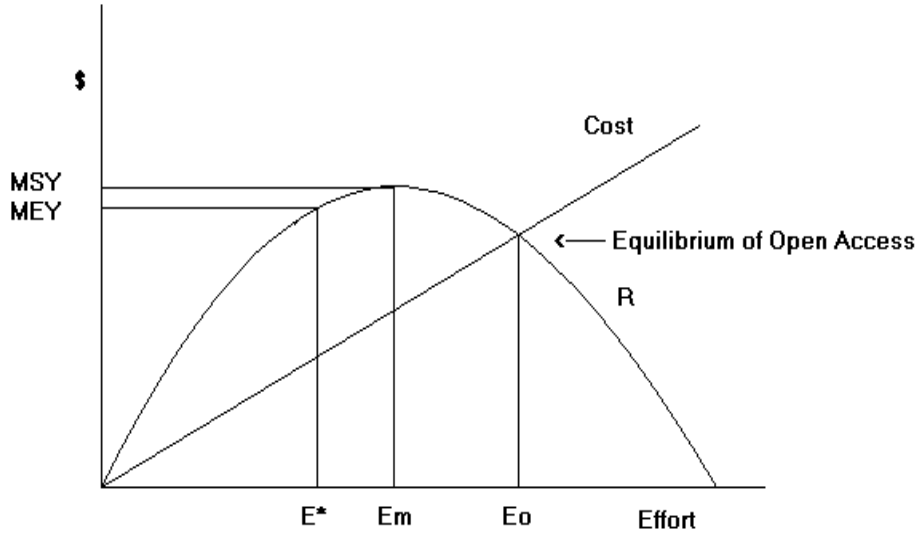

Figure 1: Open-access fisheries (E is fishing effort, R is revenue, MSY is maximum Sustainable Yield, MEY is maximum economic yield).

According to the Schaefer model, in open-access fisheries, the maximal economic sustainable yield (MEY) can be achieved at lower fishing effort level (E*). The excessive fishing effort in open-access fisheries should be managed by restricting access to the fisheries.

Fisheries management systems are designed to address economic, social, and environmental objectives such as fishermen's welfare, economic efficiency, the allocation of resources, and environmental protection. All these objectives could only be achieved on an ecologically sustainable basis (King 1999). The regulation in fisheries management could be classified into two categories: regulations that restrict access and regulations that deal with open access. The former includes overall quotas, fishing gear restriction, closed seasons, and closed areas; the latter includes taxation, licensing, and individual quotas (Cunningham *et al.* 1985). Over the past several decades, countries have shifted the management of ocean fisheries within two hundred miles of their coastline from open access to restricted access. Yet regulatory regimes largely have failed to stem the decline of fisheries because they do not alter the fundamental incentives that lead to overfishing (Runolfsson 2001).

Aquaculture has developed using a variety of production systems around the world, including ponds, tanks, raceways, cages or "netpens" (Emerson 1999). Many people look to aquaculture for future growth to relieve pressure on ocean fish stocks, most of which are now fished at or beyond capacity. The available scientific evidence indicates that some types of aquaculture are actually increasing the pressure on ocean fish populations on a destructive path that poses a threat not only to wild fish stocks but also to the aquaculture industry's own long-term potential. The balance between

farmed and wild-caught fish, as well as the total supply of fish available for human consumption will depend on future trends in aquaculture practices. Without clear recognition of its dependence on natural ecosystems, the aquaculture industry is unlikely to develop to its full potential or continue to supplement ocean fisheries (Naylor *et al.* 2001).

Aquaculture has grown rapidly in fresh water, brackish water and marine water. In 1996, the environment and societal issues (Table 1) in aquaculture were formally presented to the United Nations by representatives of a group of non-governmental organizations (NOGs) (Claude and Schmittou 1999).

Table 1: List of proposed actions arising out of concerns about environmental and societal effects of aquaculture and its sustainability presented by representatives of NGOs.

1. Ensure that artisanal fisheries and dependant coastal communities, and their access to community resources, are not affected adversely by aquaculture development or operations, including extensive and semi-intensive as well as intensive aquaculture methods
2. Ensure the use of environmental and social impact assessments prior to aquaculture development and the regular and continuous monitoring of the environmental and social impacts of aquaculture operations
3. Ensure the protection of mangrove forests, wetlands and other ecologically sensitive coastal areas
4. Prohibit the use of toxic and bioaccumulative compounds in aquaculture operations
5. Apply the precautionary approach to aquaculture development
6. Prohibit the pollution of surrounding areas resulting from the excessive discharge of organic wastes
7. Prohibit the development and use of genetically modified organisms
8. Prohibit the use of exotic/alien species
9. Prohibit the use of salinization of freshwater supplies, including groundwater important for drinking or agriculture
10. Prohibit the use of feeds in aquaculture operations consisting of fish that is or could be used as food for people
11. Prohibit the wholesale conversion of agricultural or cultivable land to aquaculture use
12. Ensure that the collection of larvae does not adversely affect species biodiversity
13. Ensure that abandoned or degraded aquaculture sites are ecologically rehabilitated and that the companies or industry responsible bear the cost of rehabilitation
14. Ensure that aquaculture and other coastal developments are addressed in integrated coastal management planning, which includes the meaningful participation of all coastal user groups
15. Ensure the development of aquaculture in a manner which is compatible with the social, cultural and economic interests of coastal communities, and ensure that such developments are sustainable, socially equitable and ecologically sound
16. Ensure that multilateral development banks, bilateral aid agencies, the UN Food and Agriculture Organization and other relevant national and international organizations of institutions do not fund or otherwise promote aquaculture development inconsistent with the above criteria

Basically, the problems in aquaculture come from the adverse environmental impacts, which lead to social and economic problems. The new development of aquaculture technology and management regimes should be based on ecological and economic viability.

In spite of these negative impacts of aquaculture, there are still major aquaculture producing countries that do not have appropriate legal framework and policies for aquaculture. Governments fail to provide the needed economic, legal, and social support to ensure economic and environmental sustainability (Tisdell 1999). The aquaculture industry should be proactive and work towards developing and implementing systems of environmental management based on the best management practices (BMPs), which are based on environment impact assessment including effluent regulations, introduced and biologically modified species regulations, drug and chemicals, feed regulations, water use and aquaculture farm construction regulations (Claude and Schmittou 1999). The ecosystem paradigm is emerging as the dominant approach to managing natural resource; it has taken roots in government policy and planning in fisheries and mariculture (NOAA 2000).

Public goods, externalities, natural monopolies, and information asymmetries are the four commonly recognized market failures. Market failure arises in open-access case (fisheries) from the infeasibility of exclusion. Correction of the market failures to improve efficiency in the production, and the reallocation of opportunity and goods to achieve the distributional and other values are the rationales for public policy. An understanding of market failure helps us understand the nature of public policy problems (Weimer and Vining 1999).

Fisheries and aquaculture quite often coexist, and fish products of different species from fisheries and aquaculture usually have substitute relationship. Economists are interested in the degree of substitutability, which may exist among fish products of various species for both modelling and policy purposes (Clay and Gordon 1999). The aquaculture can have a positive effect on lowering the practice of fisheries by reducing its cost whether the aquaculture products are the same as the fisheries products or only a substitute (Ye and Beddington 1996). The market interactions between aquaculture and the traditional wild catch species may have implications on the management of both wild and farmed species. In unregulated fisheries, farmed production of a species that is also harvested in a capture fishery could result in a lower effort level in the fishery, lower price and overall increase in the supply of the product on the market, the effect of a certain species that acts as a substitute species is less pronounced (Pascoe *et al*.1999).

Bohai Sea is a component of Yellow Sea large marine ecosystem (LME). To achieve the sustainability of the renewable fisheries resource requires the implementation of a new paradigm aimed at greater integration of a highly sectorized approach to solving problems of coastal habitat degradation, marine pollution and overexploitation of fisheries. Economists and policy analysists will need to work closely with ecologists and other scientists to identify and evaluate management options that are both scientifically credible and economically practical (Sherman 1994).

3. CHINA MARINE FISHERIES AND MARICULTURE

China is a Pacific Rim country with its territory extending cross tropical, subtropical and temperate zones. Its southeast faces the Bohai Sea, Yellow Sea, East China Sea and South China Sea with the coastline of over 1800 km with numerous harbours and vast marine fishing grounds. The fishing grounds that have been developed in China's

sea cover 818,000 square nautical miles. More than 1700 marine fish species, plus thousands of other aquatic animal and plant species with economic value like shrimp, crab, shellfish, cephalopods and seaweeds are harvested (Anon. 2000a). Due to the large population, the fisheries and aquaculture are seen as an important protein source. China is the largest fishing nation in the world,
Japan is second and USA is third (Figure 2).

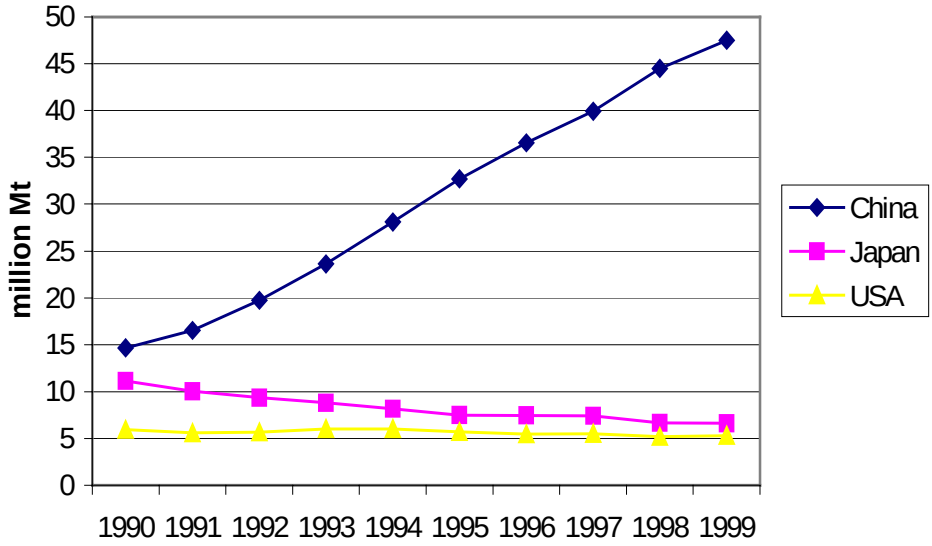

Figure 2: Total fisheries and aquaculture output of China, Japan and USA in 1990-1999 (FAO 2001)

3.1 Marine Fisheries

Chinese marine fishing grounds are mainly on the continental shelf, covering dozens of degrees in latitude with abundant fish species and resources. The main capture species includes the hairtail, round scad, Japanese mackerel, filefish, mackerel, pomfret, large yellow croacker, small yellow croacker, white herring, prawn, Chinese acetes, cuttlefish and jellyfish. The dominant fishery operations are longline, trawling, purse seining, drift netting, hooking and fixed netting. Catch by trawling accounts for over 40% of marine fishing (Anon. 2000a).

In 1997, there were 40 state-run marine fishing enterprises in China. They accounted for 10% of the total marine catch. Collective and cooperative economic organization, joint groups and individual fisherman are a major force of China's marine fishing. This sector employs over 1.05 million specialized workers. Catch by this sector accounted for 90% of marine fishing. China's distant water fishing is a newly emerged industry that started in 1985. China has established Chinese, joint venture companies or jointly managed fisheries enterprises which are mainly marine fishing cooperation in some countries and regions (Anon. 2000a). China is the largest fishing nation in the world. Catch in China compared with Japan and USA is showed in Figure 3.

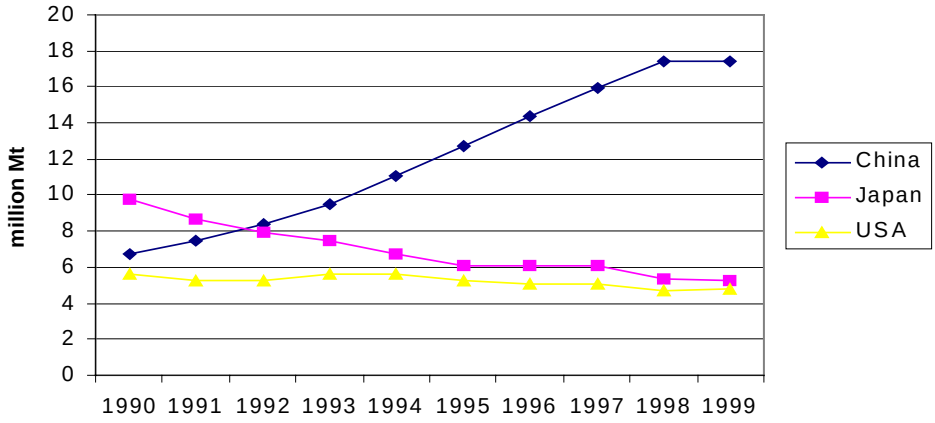

Figure 3: Marine catch of China compared to Japan and USA (FAO 2001).

3.2 Mariculture

Aquaculture is a large component of the fisheries in China. There are altogether about 2.6 million ha of shallow sea, mud flats and bays suitable for marine animal and plant culture in China (Anon. 2000a). The mariculture began developing rapidly in the 1980s. Until now, China is the only country in the world where the total output of aquaculture has exceeded the catch. In 1999, the production of aquaculture (including freshwater) is 23.96 million metric tons, which is 58% of the total output (Yang 2000). The Chinese government currently promotes mariculture as a growing industry. China is the biggest mariculture country in the world. Figure 4 shows the output of mariculture in China and Japan.

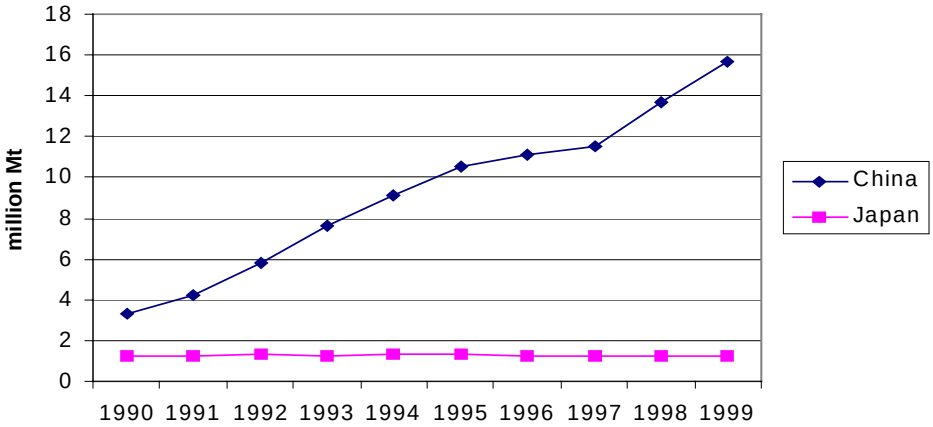

Figure 4: Mariculture output of China compared to Japan (FAO 2001).

3.3 Institutional framework

China attaches great importance to marine development and protection, and makes it the state's development strategy. It is strengthening comprehensive marine management, steadily improving its marine-related laws to achieve the sustainable development of marine economy. In 1982, National People Congress (NPC) Standing

Committee approved the Marine Environment Protection Laws, which is modified by NPC in December of 1999. The objective of this law was to protect the marine environment and prevent more damage to the marine environment. The marine-relevant laws are shown in the Appendix. In 1986, the Fisheries Law was enacted, and modified in 2000. In accordance with these basic fisheries laws there have been more than 500 regulations, rules and standards put into practices at the provincial and central governmental levels. The Fisheries Bureau, Ministry of Agriculture is responsible for the fisheries and aquaculture industries all over the country.

3.4 Marine fisheries management in China

Based on the current legal system in fisheries, fisheries management in China concentrates on the fisheries resources management, fishing vessels management and fishing port surveillance. These main management methods are implemented by fisheries administrative agency, fishing port surveillance agency and fishing vessels inspection agency. The fisheries management agencies are set up at the central government, province, municipal, city and prefecture levels, and even at the county level. Fishing licenses, closed seasons, closed areas, protected areas, fishing gear regulations, and stock rebuilding projects (sea ranching and artificial reef) are the currently practiced management approaches in the marine fisheries in China. There are more than 30,000 administrators engaging in the fisheries management and more than 1000 fisheries inspection boats. In recent years, a fisheries resources information system, fisheries environment monitoring, and inshore fishing security communication systems are being developed (Anon. 2001c). Fisheries management emphasizes the inshore fishing effort control, closed season management, closed areas management, illegal fishing control, fishing vessel management, fishing security and salvage management, distant-water fishing management, foreign fishing violation monitoring and control.

The social, economic and geographic environments make fisheries in China quite complicated. The fisheries management functions are not properly defined and coordinated between the management agencies. Due to economic and unemployment pressure, there is lack of fisheries management cooperation between local governments. Telecommunication and computer technology is not adequately applied in monitoring fishing and fishing vessels information management. Widely scattered fishing ports, landing points and large fishing areas help illegal fishing and illegal fishing vessels avoid fisheries inspection.

4. FISHERIES AND MARICULTURE SITUATION IN BOHAI SEA

4.1 Bohai Sea

Bohai Sea (Figure 5) is the only inland sea in China bordered with Yellow Sea and surrounded by the Liaoning, Hebei, Shandong Province and Tianjin Municipal. Bohai Sea is an about 97,000 km^2 with an average depth of 26 m. Total coastal population is 46 million, with population of 11 million along the coast of Liaodong, 21 million along the coast of Bohai Sea Bay, and 13 million along the coast of Laizhou Bay. The population density around Bohai Sea is 419 people/km^2 (Anon. 1999a).

Figure 5: Location of Bohai Sea

Bohai Sea and its surrounding area is an economic important region in China, and main marine industries in Boahai Sea contribute one third of the total output of marine industries in China (Anon. 2000b). Bohai Sea, a major multi-species fisheries area, is one of the world's most ecologically important water bodies. Bohai Sea is rich of fisheries and mariculture resources. In addition, Bohai Sea is the biggest mariculture base in China.Within Bohai Sea there are the three most important spawning grounds – Laizhou Bay, Bohai Bay and Liaodong Bay. It is estimated that 40% of the fisheries resource for Bohai Sea, Yellow Sea and north area of China East Sea originates in Bohai Sea (Anon. 2001a). Bohai Sea also offers breeding and over-wintering field for some mammal species such as the spotted seal. The fishery resources in Bohai Sea are important to China, Japan, North and South Korea.

4.2 FISHERIES AND MARICULTURE SITUATION IN BOHAI SEA

4.2.1 Fisheries in Bohai Sea

Fisheries resources in Bohai Sea have been dramatically decreasing since the 1980s. Compared with the fisheries resources in the early 1980s, the biomass of invertebrate animals in Bohai Sea reduced by 39% in 1992 and 1993 and the average weight of the spawning fish reduced by 70%. The biomass of the high value species such as Japanese sea bass, Chinese herring, Genuine porgy, Olive flounder, Chinese prawn and Swimming crab decreased by 71%, and the total biomass of low value species was 2.4 times as that in the early 1980s. The survey in 1998 indicated that the total biomass of fisheries reduced by 89% compared to 1992 (Qiao 2001). The over-exploited fisheries in the Bohai Sea are the result of failure to control the access to the

fisheries resource and failure to control the negative environmental impacts from mariculture. Inevitably, the fall in catch of high value species has been accompanied by a shift towards catches of low value pelagic species such as anchovies and sardines. The total catch from the Bohai Sea is increased in the 1990s (Figure 6) which is mostly due to the increasing fishing effort in Bohai Sea. In addition to the 75,000 locally registered fishing vessels and 290,000 fishermen from the Bohai Sea region, fishing vessels from other provinces further away (mainly Jiangsu Province, 16,460 Mt in 1999) can also conduct their fishing in Bohai Sea (Ministry of Agriculture 2000).

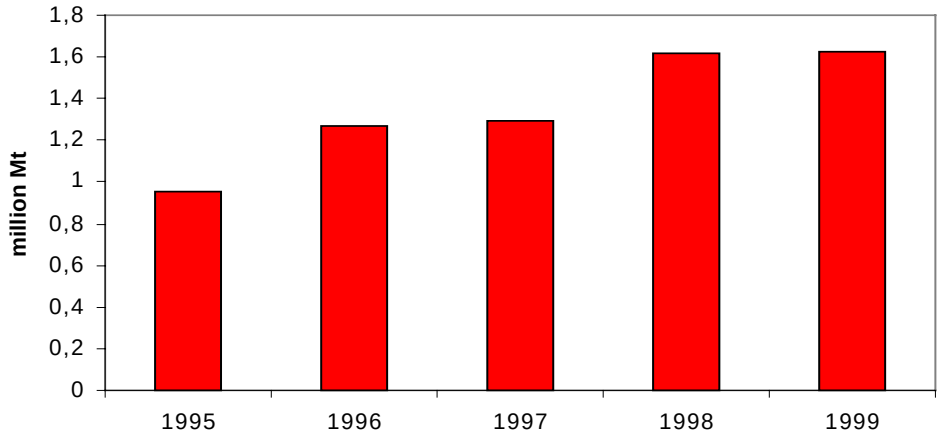

Figure 6: Total Catch in Bohai Sea, 1995-1999 (COI 2000).

However, another survey carried out by the Fisheries Bureau shows another trend in terms of the profit from the major fisheries enterprises (Figure 7). Although the catch was still increasing from 1996 to 1999, there is a net loss after 1996. Figure 7 shows the net revenue of the major fisheries enterprises around Bohai Sea in recent years, which mainly conduct their fisheries operation in Bohai Sea.

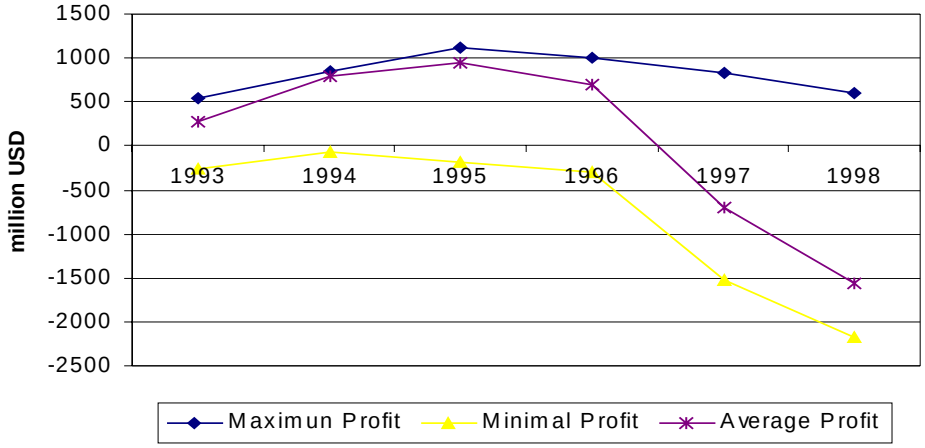

Figure 7: Maximum profits, minimal profit and average profit reported by capture fishing enterprises in the Bohai Sea Rim (Ministry of Agriculture 2000).

This suggests that the main reason of the contrast between catch and profit is caused by the collapse in the high value species. In addition, the contrast probably arises from

the small-scale fisheries sector around Bohai Sea. Although the catch shift from high value species to low value species, the small scale fishermen could still make money because of the low maintenance cost of the fishing vessel. Unfortunately, there is no data available to show the profit in the small-scale fisheries around Bohai Sea. The increased supply from mariculture as substitute products could lower the average price of the fish products. Mariculture in Bohai Sea might also reduce the total revenue from the fisheries by price competition. Mariculture is stimulated to expand in Bohai Sea because of the profit of mariculture and the promotion by local governments. The low value small sized pelagic species at lower level in the food web are important for the high-value species of higher level in the food web. Certain amount of catch is used as the feeding stuff for the mariculture species. The continuing intensive small-scale fisheries operation with low selectivity in Bohai Sea will keep the fisheries in Bohai at a low sustainable level.

4.2.2 Mariculture sector in Bohai Sea

The relative good climate and the shallow seawater in Bohai Sea provide great feasibility for marine animal and plant culture. Most of the high value species for example, Chinese prawn, abalone, sea cucumber, flounder and urchin can be cultured in Bohai Sea. Figure 8 shows the geographical expansion and the increasing of mariculture production in Bohai Sea from 1994 to 1999.

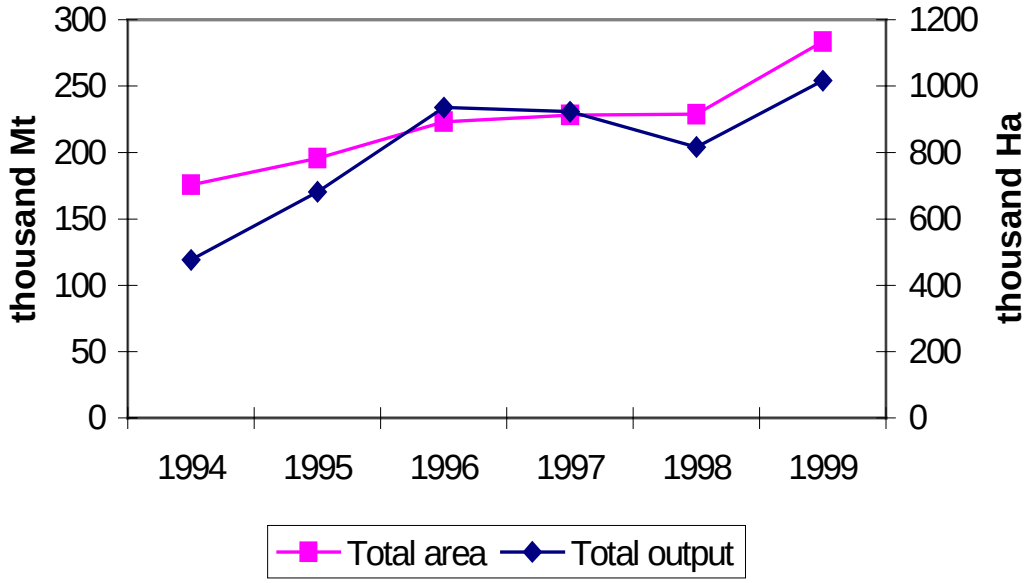

Figure 8: Mariculture area and output in Bohai Sea from 1994 to 1999 (State Oceanic Administration 2001)

The increase of mariculture output basically depends on the expansion in the mariculture area. Large-scale activities of reclaiming land from the sea by landfill have been executed in China. As a result, large areas of beach for aquaculture and many natural spawning grounds of marine life have disappeared, and imposed some serious negative impacts on the marine biological resources of the surrounding areas (Anon. 2001b).

Eutrophication of marine waters in some estuaries and semi-closed seas is noticeable with limited flushing and with very small tides and sensitive to the man's activities (Taivo 1993). Water exchange between Bohai Sea and Yellow Sea is through the narrow Bohai Strait situated at the southeast of Bohai Sea (Figure 5). Tide is the predominant driving force of the water circulation in the Bohai Sea (Anon. 1999b). Mostly sea-based and highly extended mariculture in China has exceeded the carrying capacity in shoal area. The traditional mariculture overlooked the importance of ecological stability and rational exploitation, which make the inshore water pollution increasingly serious, and increase the frequency of red tide (Zhan and Ma 2001). In recent years both the frequency (Figure 9) and proportion (Figure 10) of red tide occurrence in Bohai Sea are increasing. Actually the frequency in figure 9 is only the observed red tides, the actual frequency of red tide is higher in Bohai Sea (Anon. 2000b).

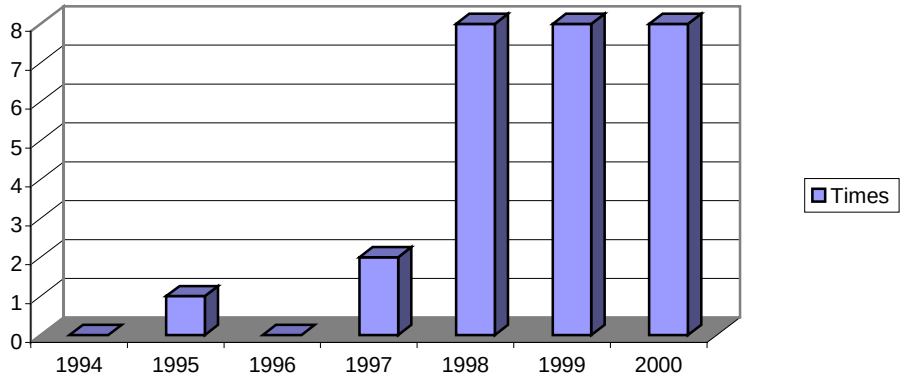

Figure 9: Frequency of red tide observed in Bohai Sea from 1994 to 2000 (SOA 2000)

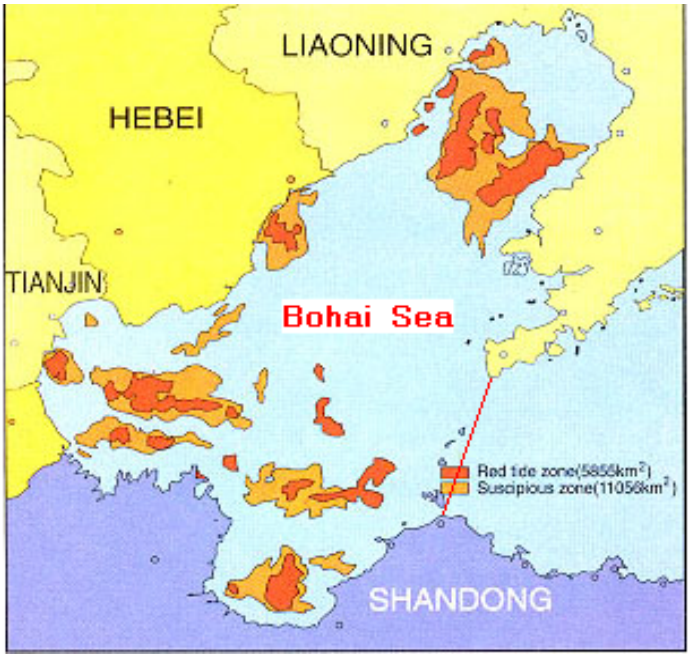

Figure 10: Satellite Remote Sensing of Red Tides in Bohai Sea August 1998 (Beijing Earth Station 1999).

Figure 10 shows the red tide distribution in Bohai Sea by satellite remote sensing in August of 1998. At that time, the confirmed red tide area is 5,856 km^2 and suspicious areas are 11,056 km^2. Although there is no research that shows that red tide solely depends on pollution from mariculture, high density of mariculture undoubtedly contributes to the eutrophication in the water body. According to Huang (2000), the bottoms of most of shrimp ponds are seriously polluted. The water quality of most shrimp mariculture areas is below the fisheries water quality standard or the national seawater quality grade 1. The water pollution is caused by the simplified mariculture technology without waste treatment facilities, overfeeding and high mariculture density.

Mariculture also suffers a lot from the eutrophication. Eutrophication stimulates diseases, parasites and oxygen-void from the algal blooms. Chinese Prawn and freshwater crab are the main high profit mariculture species. The production of crustaceans increased until 1991 and fell due to disease related problems and sub-optimal management (Figure 11). The decline in the shrimp production was offset by a subsequent increase in freshwater crab production (FAO 1997).

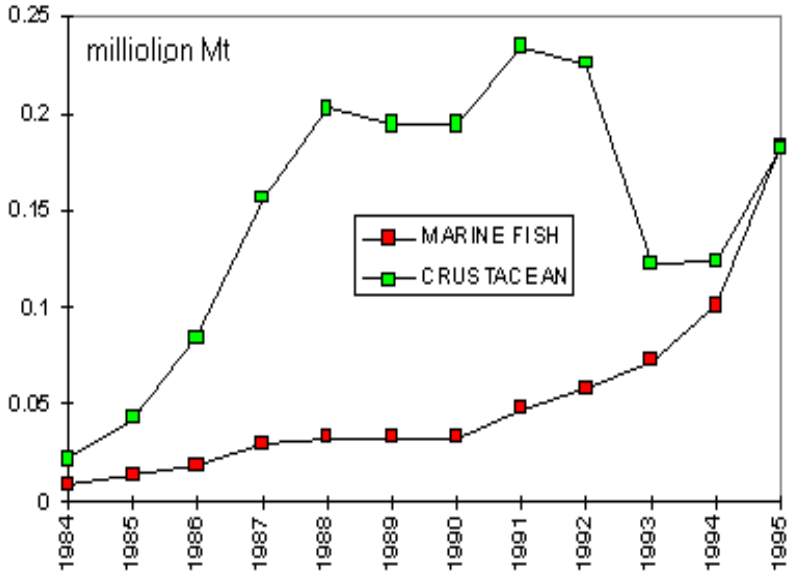

Figure 11: Production of major groups of aquaculture organisms in China (FAO 1997)

The shrimp mariculture is thought to be the most polluted mariculture. The Chinese prawn mariculture collapsed in 1993, at the same time there were 12 red tides blooms observed in the China Seas. The wild fisheries stock is also affected by the algal blooms in Bohai Sea. It is reported that that in Bohai Sea one billion jellyfish died during an algal bloom occurrence in August of 2000 (Anon. 2000c). In addition, the potential impacts of the breakout of diseases and the impacts of non-endemic species in mariculture on the wild stocks are still remain uncertain in the Bohai Sea.

Ecological concern and better management in fisheries and mariculture are important to ensure sustainable development. Awareness of the bioeconomic interactions between fisheries and mariculture will provide the basis for developing a new adaptive management regime in Bohai Sea.

5. BIOECONOMIC JUSTIFICATIONS FOR COMBINED FISHERIES AND MARICULTURE MANAGEMENT IN BOHAI SEA

Small-scale mariculture and fisheries usually have low or negligible economic and biological impacts on the local economics and environment. On the other hand, open-access commercial fisheries and intensive mariculture will have great impacts on the local economy and environment. Accordingly, the biological and economic interaction between fisheries will become significant. Biological impacts of fisheries and mariculture on the ecosystem will affect growth, stock size and the carrying capacity for both fisheries and mariculture, which will also determine the further development of fisheries and mariculture. Fish products from fisheries and mariculture have substitute or close substitute relation, where the raw material for a particular product can come either from mariculture or from the fisheries. Changes in the price as a result of market interactions will affect the revenue of the fisheries and mariculture. The revenue change will have an economic impact on the level of fishing effort and mariculture production.

5.1 Open-access fisheries and opportunities in mariculture

According to the Schaefer model, fisheries can achieve MEY, MSY and open-access equilibrium by varying fishing effort. Open-access situation is far from ideal because the same level of sustainable yield could be obtained at low cost and lower fishing effort level. The excessive fishing effort in open-access fishery is wasteful in two ways: it causes unnecessary costs and results in a smaller catch. Employing people on boats that contribute nothing to the value produced in the fishery is pure waste, and employing people on boats that reduce the value produced in fishery is even worse. This does not mean that these people should be abandoned without any means to support themselves (Hannesson 1993). If the income from mariculture were higher than the income from fisheries, it would create the incentive for the fishermen to leave fisheries for mariculture. Even fishing facilities such as fishing boat and fishing port could be utilized for mariculture. Especially, in the labor-intensive fisheries and mariculture, the labour distribution between fisheries and mariculture will be meaningful in improving the efficiency of employment and facilities in fisheries and mariculture and increasing the income of the employees.

5.2 Mariculture Impacts on the Open Access Fisheries

Increasing mariculture production will probably counterbalance the difficulties of the supply of marine capture. The consumption in developing countries will expand because of the large population and growth of economies; accordingly the mariculture will be encouraged to grow to meet the demand because of the dwindling fisheries resource. It is likely that mariculture products will have great market impacts on the conventional commercial fisheries by affecting the total supply. This is due to diverse advantages of mariculture such as flexibility of approach, less social opportunity cost, relative regular and controlled quantity of production, and greater scope for the application of modern science and technology (Cunningham *et al*.1985).

5.2.1 Biological impacts of mariculture on open-access fisheries

The biological impacts of mariculture on the fisheries are generally negative, and the cumulative effects of these will be significant when it exceeds the capacity of the oceanic self-purification or ecosystem tolerance. The increasing negative impacts of mariculture will decrease the carry capacity of the ecosystem. The pollution from mariculture will also reduce the growth rate by increasing the natural mortality of fish. The increasing pollution from mariculture will also have great effects on mariculture itself by breakout of disease and brood stock degradation.

In open-access fishery, the negative impacts from mariculture leading to poor stock growth, ultimately, will lower the sustainable catch. According to the Schaefer model, fishermen respond to the profit by increasing or decreasing the fishing effort. Figure 12 shows the negative biological impacts from mariculture on the open-acess fisheries. Decline of growth rate and low environment capacity will reduce the sustainable revenue curve from **R** to **R1.** The decrease in growth and stock size will drive the open-access equilibrium from the level from right to left and fishing effort will reduce from **E to E1**. Catch from the fishery will decrease**.** **R2** shows even worse situation, which means that there will be net loss in commercial open-access fishery at any level of fishing effort due to the significant adverse biological impacts from mariculture on the fishery stock. However, the adoption of aquaculture technologies in fish stock rebuilding such as hatchery, breeding, feeding, sea ranching and artificial reef will help rebuild the carry capacity. Theoretically, that will move the revenue curves **R2** and **R1** toward **R**. **B**iological interference alone will actually improve the quality of the ecosystem, which will be in favour of the fish stock, but it cannot make the current open-access situation better. The improved fisheries resources will again increase fishing effort; it will move fisheries to a new open-access equilibrium. Although the fishing effort reduce to a new level **E1** and the fishery reach a new equilibrium, but there is no improvement in revenue, the cost still equal to the revenue. Regardless, the ecosystem is degraded by mariculture.

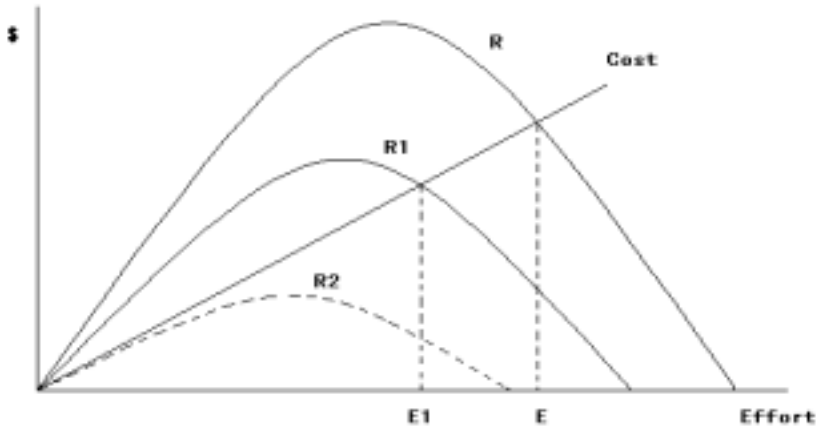

Figure 12: Bio-economic impacts of mariculture on fisheries

5.2.2 Economic impacts of mariculture on open-access fisheries

Economically, the interaction or competition between the commercial fisheries and mariculture is mainly price competition in local markets. Basically, both marine

fisheries and mariculture offer the fish products to fulfill the demand of seafood for the population. The price could decrease as the supply from mariculture increases. Figure 13 shows the change of open-access equilibrium because of the price competition from mariculture. The lower average price of fisheries products will lead to less revenue from fisheries, the open access equilibrium will move from right to left, the fishing effort will reduce from **E_1 to E** and the catch will increase. If the supply from the mariculture reduced because of pollution, disease, self-pollution and climate factors, the total supply of fish products will decrease, and the price of fish products will go up. The revenue curve will move from **R** to **R_2**. Nevertheless, in the open-access fishery, it will drive fishing effort from **E** to **E_2** and the open-access equilibrium will move from right to left.

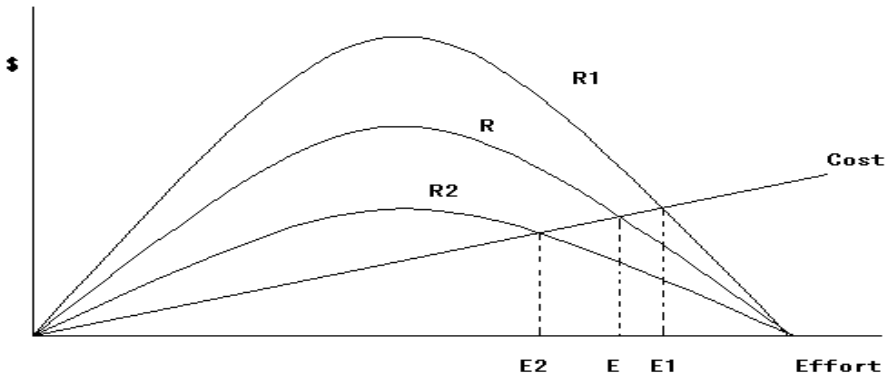

Figure 13: Supply from mariculture impact on the fishery

Demand and supply determine the equilibrium price and production. High market demand will stimulate the rise of price, which, in open access fishery will stimulate the investment in both fisheries and mariculture to increase the supply. In short run, the rise of price will increase marginal profit from fisheries, which will drive the fishing effort from the **E** to **E_1** and accordingly the open-access equilibrium will move from left to the right (Figure 14). If the market demand exceeds the supply, and if mariculture has approached the supply limit, as it has in this case, it will play a less important role in reducing the fishing effort.

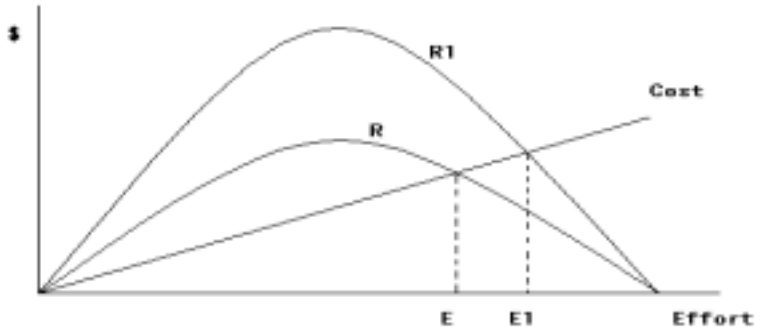

Figure 14: Impacts of market demand on the fisheries.

5.3 Bioeconomic impacts of mariculture on the cost of open-access fisheries

The impacts of mariculture on the price of fish products, the potential negative biological or environmental impacts on the decreased fishery stock and reduced growth rate will reduce the stock size, which will increase the difficulty of fishing activity. The smaller stock size and lower growth lead to low catchability, some fishermen will invest in new fishing gear with high efficiency, which will increase the price per unit effort, and subsequently the cost curve will rise. Figure 15 shows the increase of cost per unit effort, the cost curve moves from **C** to **C1.** It will drive the open-access equilibrium from right to left, simultaneously, the fishing effort will decrease from **E** to **E1**, in the short run, the catch will increase a little bit, but thereafter the catch will decrease because of the continuous deteriorating of fish stock and increasing cost. If the fishermen adopted destructive fishing gear it will probably increase the catch in the short run and the total cost and cost per unit effort will reduce. In the long run, it will accelerate the depletion of the stock and catch will dramatically decrease.

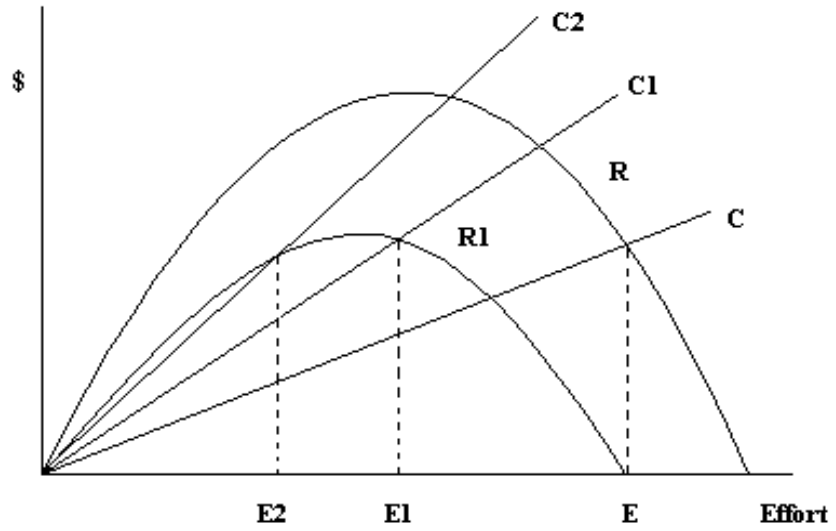

Figure 15: Mariculture impacts on the cost of fishing effort

5.4 Summary

In a nutshell, mariculture will generally have a negative biological or environmental impact on the wild fisheries. Unregulated mariculture will have a more substantial adverse effect on fisheries and mariculture itself. Healthy mariculture has to be promoted in an area where fisheries and mariculture coexist. Economically, the comparatively large production from mariculture will improve the total supply of fish for consumption, which will reduce the fishing effort in open-access fisheries by price competition. Therefore, mariculture will be helpful for the fisheries management in restricting the fishing effort. Furthermore, mariculture has employment potential to attract fishermen from fisheries to mariculture. Mariculture technology application in fisheries will also improve wild fish stock. All the above will not solve the economic

problems in open-access fisheries by proper mariculture management. Fisheries management aiming at reducing the fishing effort to the MEY level in fisheries is imperative. The control over access to the fishery will be the challenge in fisheries management. Both the government and stakeholders need to adopt conservation-oriented and ecosystem enhancement management measures to achieve the sustainable fisheries and mariculture.

6. CURRENT MANAGEMENT APPROACHES IN BOHAI SEA

6.1 The Goal of Current Fisheries Management

Fisheries management in China aims at sustainable development in fisheries. China Fisheries Law is a basic law to deal with fisheries and aquaculture activity and fisheries resources protection. Newly modified China Fisheries Law came into effect on December 1, 2000. The new law stipulates the principle that annual catch should be set below the annual natural growth. Based on the Fisheries Law, the policy of zero-growth in marine catch is formulated by the Ministry of Agriculture. As for individual fishermen, catch limits are not specified by variety nor are there any daily limits for total allowable catch.

However, under this policy, stocks could decrease because of increasing fishing effort in the already deteriorated fisheries resource. Continued, unregulated mariculture in Bohai Sea will also be a contributing factor in the zero-growth in catch, which will in turn probably reduce the catch in Yellow Sea and East China Sea. Furthermore, catch fluctuation in some species will affect the component of the total catch greatly. For instance, there is an annual crop of jellyfish in Bohai Sea, and the quantity and the size of jellyfish is dependant on varying ecological factors but not significantly upon the previous year's population, and the annual catch of jelly fish fluctuates greatly. The catch composition change by significant fluctuation of some species will lead to depletion of other species under the zero-growth policy. The numerous fishing vessels and landing points in marine fisheries make it very difficult to monitor the catch of each boat. The excessive fishing capacity is the most severe threat to the fish resource. In the short run, the zero-growth policy should focus on maintaining the same fishing effort. In the medium term, the fishing capacity should be reduced based on the available fish stock to achieve the maximum economic yield.

6.2 License

Fishing license is commonly adopted as a management method in fisheries management. In China, the fisheries license system includes the fishing license, vessel security inspection license, and vessel registration license. To date, the fishing capacity has increased greatly, exceeding the available fishing opportunities. The first national fishing vessels census of the marine fishing vessels was carried out by the Ministry of Agriculture in 2000, showing that there were 244,300 marine fishing vessels, with total tonnage exceeding 5,410,000 GRT, and total fleet engine power of 12,220,000 kW. Unregistered or unlicensed vessels were 48.3% of the total marine fishing vessels (Liu 2001). This is the result of the great economic development and employment pressure in relation with a competition among the local governments for better living condition for the people. The result of the fishing vessel census proves

that the current license system failed to keep the fishing capacity under control in terms of fishing vessels. An alternative management approaches to fishing capacity reduction is needed. An early record of the registered fishing vessels shows that there were 75,000 fishing vessels not including unregistered and unlicensed fishing vessels in Bohai Sea fisheries. The number of fishermen is 290,000 (Ministry of Agriculture 2000). Too many fishing vessels lead to degradation of resources, which limits the sustainability of fisheries. Hebei Province realized the minus-growth in marine catch before the end of July of 2000. However, it is reported that in the first quarter of 2001, 3047 fishing vessels out of 8283 in Hebei province stopped fishing in Bohai Sea due to the low level of fisheries resource (Anon. 2000d)

6.3 Closure season

The closure season allocates a certain period for fish to grow and spawn, it is a biologically effective approach to allow fish to grow and certain species to spawn without fishing disturbance. In Bohai Sea, the closure season has been practiced from 1995 between mid-July and mid-September with a small annual adjustment. The adjustment is mainly prolonging the closure season from 2 to 3 months. During the closure season, no fishing operation could be operated in Bohai Sea. However, after the closure season, the sudden increase of fishing operation will exert much more pressure on the fish stock because of the large quantity of fishing vessels. In addition, illegal fishing can often be detected even in the closure season.

In Bohai Sea, there is no specific fishing season, which means that the commercial fishing operation can be conducted all year round except for the closure season**.** The closure season could be in favor of some species whose spawning season fits the closure season and most species grow fast in this period. However, the current closure season cannot cover the spawning seasons of all the species of economic value. For example, Chinese prawn is a high valued migratory species, which migrate between Bohai Sea and Yellow Sea during its one-year life cycle. The spawning seasons of Chinese prawn in Bohai Sea is from April to June. The spawning seasons in the Bohai Sea of the primary pelagic species from Yellow Sea area are in May and June (Anon. 2001d). In this case the closure season can not effectively protect all of the spawning species from exploitation during the spawning seasons.

6.4 Protected and Closed Areas

In June 1989, a nature protected area system was set up in China. From 1989 to 1999, 60 marine protected areas protected areas at national and local level were established along the coastline. There are nine protected areas in Bohai Sea established before 1999. Table 2 shows marine protected areas around Bohai Sea. Basically, the protected areas focus on protecting the sustainability and bio-diversity of the ecosystem, and geographical physiognomy.

Table 2. Protected areas established in Bohai Sea before 1999 (SOA 2000).

No	Name	Area (m^2)	Location	Function	Level
1	Changli Golden Coast Protected Area	3,000,000	Hebei	Natural scenery and surrounding sea area	N
2	Tianjin Ancient Coast and Wetland Protected Area	2,118,000	Tianjin	Shell coast, ancient oyster beach vestige and wetland ecosystem	N
3	Yellow River Delta	15,300,000	Shandong	Protogene wetland ecosystem and valuable fowls	N
4	Shuangtaihe Waterfowls Protected Area	80,00000	Liaoning	Valuable fowls: red-crowned crane, white crane, swan etc.	N
5	Sanshandao Valuable Marine Creatures Protected Area	20000	Liaoning	Valuable shellfish: Scallop, abalone	L
6	Suizhong Grit Coast and Marine Ecosystem Protected area	N/A	Liaoning	Grit Coast and Marine ecosystem	L
7	Huangye Ancient Shell Mound Protected Area	10000	Hebei	Ancient shell mound, shell sand and vegetation	L
8	Miaodao Marine Protected area	5,25000	Shandong	Island ecosystem in variable zone	L
9	Jimo Marine Creatures Protected Area	91500	Shandong	Valuable marine economic creatures	L

Total protected areas in Bohai Sea cover only 15.04 km^2. Compared to the total area of Bohai Sea, the protected areas are only 0.2% including some land areas. The most important spawning grounds – Laizhou Bay, Liaodong Bay and Bohai Bay are not claimed as protected areas. In 1955, all the inshore areas in Bohai Sea, Yellow Sea and East China Sea were confined as closed areas by the State Council. Trawl net operation within the closed areas has been banned since then. The main objective of the closed areas is to protect the inshore ecosystem from the destructive trawl net fishing and alleviate the conflicts between artisanal fisheries and motorized trawl net fisheries. However, the relative plentiful fisheries resources allure more and more new small fishing vessels to conduct their fishing in closed areas. Because of the numerous fishing vessels, the fisheries monitoring, surveillance and control become inefficient to deter illegal fishing.

6.5 Enforcement

The numerous fishing vessels and wide distribution of fishing port around Bohai Sea are the main difficulties in fisheries enforcement. In China, 72.2% of unregistered or unlicensed fishing vessels are less than 12 meters. Most of them are not equipped with GPS system and are made of wood and could not be detected by land-based monitoring. Widely distributed fishing ports and transboundary fishing operation increase the difficulties of fishing port surveillance. Small wooden fishing craft are almost impossible to monitor since the fishing craft need no landing facilities and landing points for them are changeable. High cost of field inspection lower the efficiency of enforcement greatly.

All the fisheries management methods practiced in Bohai Sea aim at protecting the fisheries from being depleted. Inefficient and ineffective enforcement hinders the full activity of current management system. The fisheries inspectors are often from the same fisheries area and quite familiar with fishermen, which makes it difficult for the inspectors to enforce the regulations. The frequency of infringement is high, and enforcement is considered unfair, which leads to low compliance of the regulations.

High penalties can be effective in deterring fishermen from breaking the regulation. However, the regulation enforcement dilemma shown in Table 3 restricts the implementation of fisheries regulations. In some areas, the fine from the offence is the main source of the inspectors' salary. The dependent relation between inspectors and fishermen is the fundamental concern of the enforcement dilemma. High penalty will be effective in eradicating infringements, and at the same time will cut off the inspectors' source income. Low penalties will keep a constant income by legal and illegal means. Fishing gear, fishing vessel, and license confiscation is difficult to enforce because it will lead to direct conflicts between fishermen and fisheries inspectors. On the other hand, the fisheries inspectors could not benefit from the confiscation directly. From the fishermen's perspective, low penalty could still make their illegal fishing activity profitable, but they are reluctant to accept the high penalty because it will make their illegal fishing unprofitable. Obviously, the eradication of illegal fishing will upgrade the ecosystem greatly; the frequent infringements and low penalty will lead to inefficient and ineffective management as well as the degradation of the ecosystem.

Table 3: Dilemma of fisheries regulation enforcement

	Fisherman	Inspector	Ecosystem
High Penalty	Unaccepted	Un-incentive	Upgrade
Low Penalty	Accepted	Incentive	Degrade

7. RESTRUCTURED FISHERIES AND MARICULTURE IN BOHAI SEA

7.1 Fisheries Sector

7.1.1 Fishing Capacity Cutback

Fisheries difficulties in Bohai Sea can be attributed to too many fishing vessels, illegal fishing and the deteriorating ecosystem. From the fisheries perspective, the recovery and improvement of fisheries resources could be achieved by reducing the fishing effort and stock enhancement projects. Substantial improvement can only be achieved by the gradual approach to cutback the fishing capacity. The dramatic cutback in fishing effort will lead to the sudden increase of unemployment, which will lead to political and administrative difficulty.

Multiple measures have been devised to restrict the fishing effort in fisheries. Fishing licenses, protected areas, closed areas, closure seasons and fishing gear regulation

setc. have played their roles in Bohai Sea. Within these management measures, improving fishing license system will have the main function in reducing overcapacity. Overcapacity in Bohai Sea, featured with numerous, widely scattered fishing vessels, weakens the fisheries regulations enforcement. Therefore, the protected areas, closed areas, closure seasons and fishing gear regulations can not play their full roles in controlling fishing effort.

A reduction in total fishing capacity can not be achieved by a single province or municipality. Cooperation of local government is needed to control total fishing capacity. Temporary fishing effort reduction will not eliminate the threat of depletion to fish stocks. The closure season could reduce the fishing effort in the dimension of time; closed areas and protected area could only restrict the fishing effort in the dimension of territory. Fishing gear regulation could only restrict the intensity of fishing operation. A fishing capacity quota system imposes more effective control over access to fisheries. Access rights could be more equitably distributed to fishermen among the littoral provinces and municipalities. Optimal fishing capacity (effort) needs be determined in Bohai Sea.

A capacity quota system could be put in place based on the current proportion of fishing vessel distribution in terms of engine power and tonnage to fix the proportion of the fishing capacity distribution for the future management. In addition, no new entrant would be allowed. There should be a certain percentage of fishing vessels scrapped in the following years. The fishing capacity quotas could be fixed at province (municipal), city, prefecture, county and even village levels. Since all current fishing licenses will expire in five years, a license auction system could be established for the annual license renewal. A certain percentage of fishing vessels would lose the access right in fisheries. Current fishing vessel security inspection system could also reduce the fishing capacity. The quality of fishing vessels is related to the fishing security. The function of security inspection is to improve the security of fishing operations. The security inspection should be emphasized on the wooden boats. It could not be monitored by remote monitoring system and destructive fishing is often conducted by small wooden craft. The government could declare that all of the wooden boats should be scrapped within 10 years. The security inspection will help restructure the component of fishing vessels since, in the long run, only vessels equipped with remote monitoring devices would be allowed to enter fisheries. The application of monitoring technology will improve the effectiveness and efficiency of enforcement and the cost of fisheries enforcement will be greatly reduced.

If the proportion of unregistered or unlicensed fishing vessels is the same for all areas in China, there should also be a relative large proportion of unregistered and unlicensed vessels in Bohai Sea. It is impossible to confiscate all unregistered or unlicensed vessels, and dramatic reduction will lead to severe social problems. The unregistered or unlicensed vessels could be legalised by security inspection and auction system. Since the first thorough marine fishing vessels census was finished in China on October 31, 2000, the local government could take this chance to legalise all the fishing vessels around Bohai Sea by pilot experiment in license auction. The vessels that do not pass the security inspection will be scrapped and a certain percentage of vessels will be scrapped by license auction. A holistic and detailed fishing vessel information system should be established after the legalisation of the fishing vessels.

7.1.2 Fishing Effort Control

Since it is not realistic to reduce fishing capacity dramatically, an integrated license system along with other management measures will help to reduce the fishing effort in different dimensions.

- **Protected Area**

The spawning season of most marine fish species in Bohai Sea is between March and September. Prolonging the current closed season in Bohai Sea gradually to protect more species from the fishing disturbance could improve the stock. The length of closure season should be compatible to the existent fishing capacity. The closure season regulation enforcement can be implemented by fishing port surveillance. The efficiency and effectiveness of enforcement is relatively higher, and the cost of enforcement is relatively lower. Progressed fish stock and income of fishermen by closure season will improve the compliance of the fisherman to the regulations of closure season.

As a part of Yellow Sea LME, Bohai Sea is an important spawning ground to the fisheries in Yellow Sea and East China Sea. So if at the central government level claims Bohai Sea as a large protected area it will improve the fisheries stock in Bohai Sea, Yellow Sea and East China Sea. Within Bohai Sea, the three main spawning grounds - Laizhou Bay, Liaodong Bay and Bohai Bay should be claimed as permanent protected areas.

Overfishing is not the only factor contributing to the current decline in fisheries. Environmental degradation of coastal areas that is caused by other human activity is a long-term threat to aquatic productivity. Improvement of the whole environment, especially, the water quality will be the premise for the protected areas to enhance the productivity in Bohai Sea.

7.1.3 Fisheries Enforcement

Fisheries enforcement will determine the result of a certain management regime. Strict enforcement will help the fisheries regulation achieve management objectives in fisheries. In addition to the application of dynamic monitoring technology, the cost of enforcement and incentives and behaviors of the inspectors will be the dominant factor in fisheries enforcement.

- **Fishing Port Surveillance**

According to the current fishing vessel management, all fishing vessels belong to a certain fishing ports. By banning wooden vessels, remaining fishing vessels will need a certain landing facility in fishing port; the fixed number of landing ports will improve the efficiency and effectiveness in size limitation and fishing gear regulation by land-based surveillance. A ishing port administration agency should be responsible for recording the catch of each fishing vessels. Fishing port inspection is relatively more cost-effective than field inspection.

- **Tax on catch**

A tax could be put on the catch in terms of species and tonnage, which would increase the cost of fishing effort. In open-access fisheries, increasing fishing cost will reduce the fishing effort. In the enforcement perspective, the salary of the inspector could consider to be dependent on how much is taxed from the catch, which will stimulate the inspector to control the landing even on the illegal landing points. In the fisherman's perspective, in terms of a certain species, the small-sized fish should pay the same tax as the big-sized fish, which will encourage the fishermen to target big-sized mature fish. In the short run, a high tax on the high value species will help the stock recover.

- **Inspectors**

Local fisheries inspectors have a deep-rooted relationship with the local fishermen, and sending the inspectors to different areas will improve the efficiency and effectiveness of enforcement. The regulation-infringement record will be taken as the basis of next year's fishing capacity quota for the area. It will encourage the inspector to detect the illegal fishing in their area. A comprehensive appraisal and regulation system for inspector should be set up. Cutting off the connection with the fine from the rule-violators, to some extent, could avoid the enforcement dilemma. The allowance and promotion could only depend on the detection of infringement and the improvement of fisheries resources. High penalty should be given to the inspector who does not properly implement the existent by taking bribes and other offences.

- **Infringement reporting**

Fishermen are usually familiar with the fishing area and fishing vessels - they know who is doing what. There is a competitive relationship between the fishermen because of the open-access fisheries in Bohai Sea. Accordingly, an infringement reporting system could be established. The reward for reporting an infringement of regulation could be priority standing when the next fishing licenses are issued. The reporting system will greatly increase the efficiency and effectiveness of field inspection, which could offset the inadequate application of monitoring technology in fisheries management in short run. The public awareness of ecosystem protection and cooperation among fishermen should be promoted. Fishermen's incentive of ecosystem protection for better income will greatly improve the compliance to fisheries regulation enforcement.

- **High penalty**

Since a high fine is not easy to collect from fishermen, penalties should focus on fishing boats, fishing license and fishing gear confiscation, which will reduce the regulation violation greatly. Making serious offences, a criminal would deter the violation as well, because it is a great dishonour according to Chinese traditional culture.

7.2 Mariculture sector

7.2.1 Mariculture regulation

The sustainability and biomass yields of living marine resources can be enhanced by the implementation of a more holistic and ecologically based strategy for accessing, monitoring, and managing coastal ecosystems (Sherman 1994). In Bohai Sea, mariculture is mainly conducted in inshore areas. The increment of negative impacts from mariculture could irreversibly deteriorate the ecosystem. The direct adverse impacts on the ecosystem could have more significant effects on the sustainability of the wild fish stock. The frequent breakout of disease and red tide will be a fatal factor to mariculture and fisheries. The feeding stuff and fish fry in mariculture from wild stock will stimulate overfishing in Bohai Sea. Geographical expansion of mariculture could be in direct conflict with the fishermen in fishing areas. The management strategy in Bohai Sea should account for economic and environmental cost. Well-divided function zones could help to deal with Bohai Sea as a holistic ecosystem for rational exploitation by all stakeholders.

Bohai Sea could be divided into different function zones depending on the environmental feature of particular areas. The functional zones could overlap, although the main function of each zone should be specified. The function zones should mitigate the conflicts on the resource exploitation by different stakeholders. Any operation praticed in the function zone should be compatible with conditions of the ecosystem. Mariculture could only be carried out within a mariculture zone. Appropriate examination of potential beneficial and adverse impacts must be undertaken before further mariculture is undertaken in Bohai Sea. The environmental economic assessment should take the Bohai Sea as a holistic large marine ecosystem where its main function is a spawning ground for fisheries. Between mariculture and fisheries, the spawning ground protection zones should be emphasized, which provide the habitat of original brood stock to both fisheries and mariculture. The mariculture profit at the cost of wild fisheries is not economically efficient, the benefit from mariculture should balance off its cost in environment and fisheries. In the spawning area, only low environmentally modified and environment-friendly mariculture could be allowed. The mariculture species and methods in different locations will have different impacts on the environment. The mariculture management could resort to the spatial management base on the environmental economics assessment to minimize the adverse impacts.

Mariculture development has become a priority of local government to compensate the declining fisheries. Currently there are almost no restrictions or limitations on location, species and system used for mariculture. This will make mariculture exceed sustainable limits in Bohai Sea. The geographical expansion of mariculture in Bohai Sea indicates that considerable exclusive rights of access to mariculture should be implemented in Bohai Sea. Combined territory users right and license regulation could be adopted in mariculture management.

Anyone who carries on the business of mariculture in Bohai must hold a mariculture licence to operate mariculture based on the newly modified China Fisheries Law. The issue of licences for mariculture operations should go through environmental access according to the farm location, species and the mariculture system. Local

environmental assessment of a mariculture farm should take the ecosystem in Bohai Sea into consideration subject to the main function of the divided function zones. Location, species and mariculture system should be specified in the license. The local governments are authorized to suspend or revoke licence, in addition to all other available penalties, if the holder violates the mariculture regulations.

7.2.2 Mariculture Research Development

Technological innovations in mariculture will play a key role to improve the productivity in mariculture and alleviate the adverse impacts on the environment. The hatchery breeding and grow-out technology on new species, which have been harvested in fisheries, could be more effective in reducing the fishing effort in open-access fisheries. Application of artificial feeding stuff instead of the natural feeding stuff will reduce the fishing pressure on the wild stock.

The research in mariculture should give attention to the most effective use of the limited mariculture resources in Bohai Sea through environmental assessment. Mariculture affects the environment in many different ways, and it is not easy to determine. Research in mariculture is needed to develop a set of scientific standards for mariculture management purposes.

7.3 Combined Management in Fisheries and Mariculture

The present problem structure in coastal waters is more comprehensive and complex than the situation was some decades ago when the regulatory system was established. Public regulations and public authorities are responsible to end the conflicts over the limited resource to secure its sustainability. It needs institutional change in order to meet the regulative needs in a local and regional context. An administrative body may be established on a more permanent or on a holistic basis to deal with the Bohai Sea problems to conduct management at the local level. A plan of the mariculture and fisheries should be worked out. More comprehensive and effective enforcement should be carried out at different local levels.

In Bohai Sea the legal system, especially in the field of aquaculture, should be strengthened. Conflicts-avoid in vertical and horizontal legacy system would be critical to the implement the enforcement. Combined and compatible management in mariculture and fisheries will mitigate the adverse bioeconomic conflicts between fisheries and mariculture. For example, fry and feeding stuff from wild fish in the mariculture will stimulate the fishermen to violate the fishing gear and size limitation regulation and increase the fishing effort.

In Bohai Sea, environment degradation is not only caused by the fisheries and mariculture exploitation. Other industry and stakeholders should be responsible for the Bohai Sea ecosystem. In a long run, the improving ecosystem and security would benefit all the people in different industries. Ecosytem-based management of fisheries and mariculture need the participation of all stakeholders.

8. RECOMMENDATIONS

For the future of Bohai Sea, it is imperative for the local authorities to realize the importance of local cooperation. Many of the problems in Bohai Sea can be solved only through the ecosystem-based combined management with local cooperation among the provinces and municipalities around Bohai Sea. Local governments in the regions should be convinced that they would be at least no worse-off by cooperating than by competing both in fisheries and other industries relevant to the ecosystem in Bohai Sea. All of the local governments will play a crucial role in the development of Bohai Sea with the focus on the proper exploitation of the resources. In fisheries aspect, the governance of Bohai Sea should focus on the sustainable fisheries and mariculture management with reducing the fishing pressure and negative mariculture impacts to the ecosystem to achieve optimal socioeconomic benefits and sustainable ecosystem.

The cooperative activity between the local governments should include the measurements of stock size, productivity for carrying capacity determination and environmental economic assessment. The total allowable catch based on the stock assessment and the carrying capacity determination provides the improving analysis of socio-economic benefits in relation to the medium term sustainable fisheries and mariculture. As to the mariculture, the consideration should be given to the carrying capacity of mariculture and the adverse impacts assessment. Combining the sustainable management both in fisheries and mariculture will help to optimise the management options in Bohai Sea region.

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APPENDIX
A List of Laws and Regulations Related to Fisheries and Aquaculture

1. **The Fishery Act of People's Republic of China**, approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China on December1, 2000, is a basic law modified from the Act of Jan. 20, 1986 dealing with national principle for fishery management including aquaculture, fishing and fishery resource enhancement, utilization and conservation.
2. **The Detailed Rule for Implementing The Fishery Act of People's Republic of China**, approved by the State Council and issued by the Ministry of Agriculture on Oct. 19, 1987, is a supplementary regulation for The Fishery Act of People's Republic of China.
3. **The Wild Animal Conservation Act of People's Republic of China**, approved by the National People's Congress on Nov. 8, 1988, is the first law in China dealing with wild animal conservation.
4. **The Water Act of People's Republic of China**, approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China, is a law for management, utilization and protection of water resources.
5. **The Environment Protection Act of People's Republic of China**, approved by the Standing Committee of National People's Congress on Dec. 26, 1989, is a basic law for comprehensive environment protection.
6. **The Marine Environment Protection Act of People's Republic of China**, modified and approved by the Standing Committee of National People's Congress on 25 December 1999, is a law especially for marine environment protection.
7. **The Water Pollution Control Act of People's Republic of China**, approved by the Standing Committee of National People's Congress and issued by the president of People's Republic of China on May 1, 1984, is a law dealing with inland water pollution control.
8. **The Animal and Plant Import & Export Quarantine Act of People's Republic of China**, approved by the Standing Committee of National People's Congress on Oct. 31, 1991, is a law preventing animal and plant disease and pest infection.
9. **The Food Hygiene Act of People's Republic of China**, approved by the Standing Committee of National People's Congress on Nov. 19, 1982, is a law preventing unhealthy food from endangering people's health.
10. **The Export Food Hygiene Management Regulation of People's Republic of China**, issued by the State Commodity Inspection Bureau and the Ministry of Health on July 16, 1984, is a law to guarantee the quality of exported food.
11. **The Marine Petroleum Exploitation and the Environment Protection Regulation of People's Republic of China**, issued by the State Council on Dec. 29, 1983, is a detailed and supplementary rule for the Marine Environment Protection Act.
12. **The Marine Waste Disposal Management Regulation of People' Republic of China**, issued by the State Council on March 6, 1985, is a detailed rule for implementing the Marine Environment Protection Act.
13. **The Regulation for Controlling Marine Pollution by Inland Pollutants, People's Republic of China**, issued by the State Council on June 22, 1990, is a detailed rule for the Marine Environment Protection Act.
14. **The Regulation for Preventing Marine Pollution from Ship, People's Republic of China**, issued by the State Council on Dec. 29, 1983, is a detailed rule for the Marine Environment Protection Act.
15. **The Regulation for Preventing Marine Pollution from Coastal Construction, People's Republic of China**, issued by the State Council on May 25, 1990, is a detailed rule for the Marine Environment Protection Act.
16. **The Charter of the Ship Inspection Bureau of People's Republic of China**, approved by the State Council on Oct. 7, 1963, is a rule suitable to all kinds of ships except military ship, sport boat, tourism boat and small wooden boat.
17. **The Regulation on Making and Clearing Fishing Port, People's Republic of China**, issued by the Ministry of Agriculture on Jan. 26, 1990, is a detailed rule for fishing vessels.
18. **The Fishing Vessel Registration Charter, People's Republic of China**, issued by the Ministry of Agriculture on Nov. 9, 1985, is a detailed rule for both domestic and foreign fishing vessels.
19. **The Regulation on the Security of Agricultural Trans-genetic Application,** issued by the Ministry of Agriculture on May 23, 2001, is a rule suitable to all kinds of agricultural trans-genetic application, including aquaculture.