The Evaluation for the Fisheries Resources in Bohai Sea

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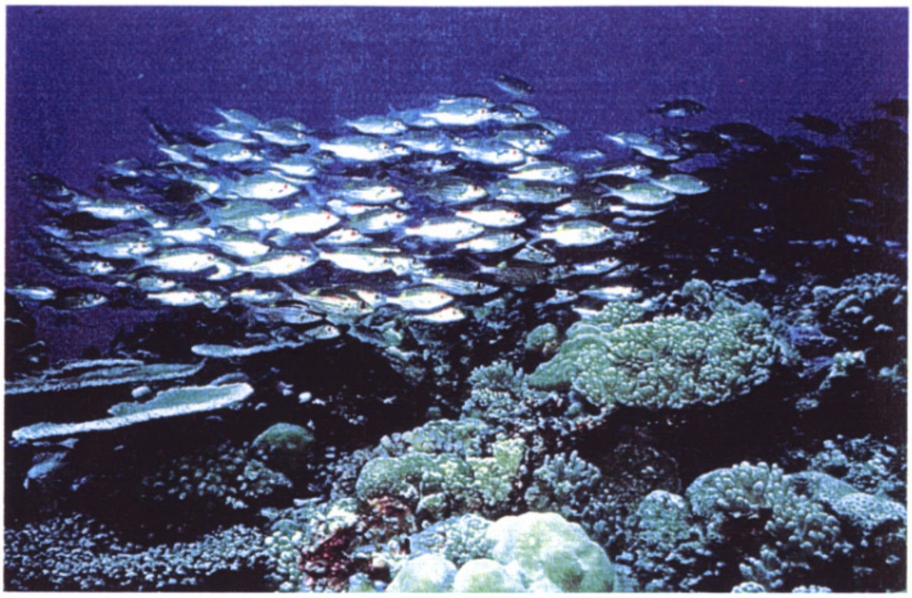

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ABSTRACT

Fisheries in Bohai Sea occur in an ecosystem, with different provinces conducting fishing activities on different species using different gears. Coordination of government actions continues to be a problem, as there exists many contradictions between different sectoral planning approaches. With the absence of a holistic institutional framework of management mechanism, coastal and marine resources are being destroyed. It has been found out in the study that fisheries resources in Bohai Sea, especially traditional high-valued species such as small yellow croaker, hair tail and Chinese prawn, have been over fished, and they have been replaced by some low-valued species, mostly primarily smaller pelagic species, such as Japanese anchovy, half-fin anchovy etc. The effects on trophic level changes have been caused by mainly due to impacts from human activities and the variation in natural environmental problem like pollution. The CPUE declined from 2.39 tons/ kilowatt in 1950's to 0.91 tons / kilowatt in 1990's. The Bohai Sea being an important spawning, nursery and feeding ground for many migratory species from the Yellow Sea and at the same time supporting an important penaeid shrimp fishery it deemed important to carry out this work. The paper is divided into six sections. The first section is a brief introduction of the physical and biological characteristics of the region. Following is the description of methodology used in this paper. The data used in this study are listed in third section. The next section describes the major fisheries and specie shifts in dominance, and examines of the causes of resource variability are given in section five. Suggestions for restoring the resources of this ecosystem are offered in the final section.

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1.0 INTRODUCTION

1.1 Fisheries in China

Fish has been a very important source of protein to the coastal populations for many generations, especially for these highly populated countries. They have had fisheries for many generations and the numbers of involved in artisanal fishing and small-scale fishing, commercial fishing have been, and still are, large.

1.1.1. Fisheries Resources

1.1.1.1 Marine Fisheries and changes

Resources China has its border on the sea in the east and south. The Bohai Sea, Yellow Sea, East China Sea and South China Sea have a total area of 35.473 million square kilometers. Among them 14.8 million square kilometers are continental shelves. There are over 6500 islands along with the coastline forming numerous fishing bays and fishing grounds. The tidal areas, about 18.783 million hectors, are good for aquaculture.

There are over 3000 marine species in the China seas.

Aquaculture To meet the growing national demand for high-value marine products, an increasing proportion of the available 2.6 million ha of inter-tidal mudflats, shallow seabed and bays is being developed for aquaculture. Between 1985-1995, the total area for mariculture rose in average by 10% per year from 277,000 ha to 715,000 ha. The annual expansion of mariculture increased to 13.4% between 1992-1995.

Between 1984 and 1995, the total tonnage from fresh, brackish, and marine waters reported as aquaculture increased 13.6%, 13.5% and 16.1%, respectively, and in 1995, The changes for marine products totaled 9.4 mn MT, 0.1 mn MT and 8.1 mn MT, respectively. During this period, the value of cultured aquatic products from freshwater, brackish water and marine water increased at an APR of 13.9, 13.4 and 17, respectively, and in 1995 reached values of US$ 84,000 million, 6,000 million and 73,000 million, respectively.

1.1.1.2 Inland Water Fisheries and changes the inland waters in China total 176,000 square kilometers, about 17.6 million hectors, including rivers, lakes, ponds and reservoirs. The rivers account for 39% of the total and the lakes contribute 42.2%. China has about 830,000 reservoirs with areas of about 2 million hectors and total capacity of 450 billion cubic meters. Fish ponds in China come to 1.27 million hectors. About 59% are in the east and most of them are located in the middle and lower reaches of the Yangtze River.

According to 1981 statistics, China has 709 freshwater fish species and 58 subspecies, excluding 64 species migrating between sea and inland waters.

Aquacultur*e* the aquacuture rapidly develops both marine and inland fisheries in China. It dominates the global production, of which it accounts for 67.8% in 1996. Freshwater finfish as main production showed a rapid growth since 1991 and is the largest aquaculture activity. In 1995, it accounts for 53% of total aquaculture products. Aquatic plant production stabilized after 1993, and in 1995 represented 27% of total production. Production of crustaceans, mainly fleshy prawns and freshwater crab, increased up to 1991. Among these growths, the production from inland aquaculture is evidently big. The species for inland aquaculture are changed, according to the need of markets and the prices of the species.

The production of inland aquaculture ranks first in the world. Its production accounts for 75.3% in the total inland aquaculture, while lake fish culture, river fish culture and reservoir fish culture make up 11.4%, 8.7% and 4.6%, respectively.

1.1.2 Fishing Catch

Available statistics on catch are incomplete. Over the past twenty years since China first embarked upon its economic reforms and open-door policy, Chinese total fisheries production has increased several times, from 4.3 mn MT in 1979 to reach 33 mn MT in 1996. 50% of total production comes from aquacuture that uses an area of 4,750 hectors. The fisheries sector's share of total agricultural production is from 8% in 1994 to 12% by the year 2000.

1.1.3 Fishing Fleets

Statistics of fishing vessels are also incomplete. The complete data are industrial and semi-industrial vessels, which are controlled by government. For artisanal vessels, the estimates are out of control. In 1992 total number was 384531, in which, the number of GT or HP was 10486. So small-scale vessels or artisanal vessels are the dominating fleets. The fishing industry in China involves more than 384,000 motorized fishing boats in 1996.

As regards gears, trawls, seines, gillnets, longlines and stationary fishing gears are employed. OF which, trawls, gillnets and longlines are stable fishing methods, and steadily increase with years. But seines and stationary fishing methods are declined over time.

1.1.4 Employment

The Chinese fisheries are labor intensive industry. Apparently the overall fisheries sector employs a work force of over 10 million people. And with the development of agriculture modernization, some surplus farmers move to coastal areas and begin fishing or engaging in fisheries related to activities.

1.1.5 The Principles for Management

According to Nie (2000), the principle for developing fisheries in China changed in decades.

Before 1957, the principles for fisheries developing was on the basis of recovering production in fisheries, focused on the recovery and promoting fishing industry in marine fisheries. Because marine fisheries at that period were underexploited, there was a big space to full-exploitation. The increase in fishing power accelerated utilization for resources without any destruction.

1958-1978, the principles for developing fisheries in China were “develop both in marine and freshwater fisheries, promote both in aquaculture and exploitation ”. But in practical works, focuses were put on marine fisheries and fishing industry, ignored freshwater fisheries and aquaculture. As the increasing of fishing power, the catches were getting exceed the renewability of resources. Although the quantity of catches was increasing, it was decreasing in labor productive ratio, economic gains and products quality. Fisheries resources were destroyed.

In 1979, the government advocated " To utilize resources reasonably, strongly develop aquaculture, focus on the quality of aquatic products ".

1985, "focus on aquaculture, promote aquaculture, fishing industry and processing industry, adjust focuses according to the practical conditions ".

1997, "accelerate aquaculture developing, preserve and reasonably utilize the inshore fisheries resources, actively develop offshore fisheries, take vigorous measures to promote fish processing and trade, strengthen legislating management ". During this period, aquaculture developed solidly. Fishing pressure on inshore fisheries was reduced in a certain extent because of development on offshore and further develops fisheries in long distant waters. But overexploitation on marine fisheries was not controlled effectively, because basic power on fishing efforts were still comparatively big, and individual fishing power developed very fast after 1980's.

1999, "zero increase" on catch in marine fisheries was put out. The outcomes from this principle were good. Fishing yields in marine fisheries in 1999 decreased 1.7% from the last year's yield.

1.2 Fisheries in Bohai Sea

1.2.1 Background

Geography the Bohai Sea is the largest internal sea in China and is one of twelve internal seas in the world. The Bohai Sea lies in northeast of China, it is between north latitude 37-41 degree, east longitude 117.5-122.5 degree, the coastline is about 1780 km. The surface area is

Figure 1 Bohai Sea connects with Yellow Sea by Bohai strait.

about 80 000 km^2 and a mean depth is 18 m. The deepest area is 70m. The Yellow river, the Hai river, the Huai river and Liao river flow into it. The annual runoff is about 83.36 billion cubic meters. A quantity of nutrition is brought into Bohai Sea by the runoff.

The Bohai Sea connects with the Yellow Sea through the Bohai Strait, which is 104 kilometres long, and with a number of small islands in it. The overall water exchange between those two seas takes 16 years, that means if the water environment in this area is polluted, the persistent pollutants will remain in this 'enclosed pond' for at least 16 years.

Economic position The Bohai Sea is a major economic and maritime hub in China. It is a maritime outlet for the Northeast and the Great West of China. It is a concentrated area both of harbor and industry in China that has rich natural resource and advanced transportation in aero-amphibious area. Based on the statistics, the gross industrial and agricultural value of output is 1187.7 billion-Yuan. Most of mainstay enterprises in Hebei Province, Shandong Province, Tianjing City, and Liaoning Province are along the coastline of Bohai Sea. Total coastal population is 46,560,000. Sections in this area are include iron and steel industry, machine production and operation, shipbuilding, electron tube instrument production, oil industry, chemical industry, textiles, light industry, metallurgical industry, food, processing, medicine, etc. and it accounts for one-third of the national ocean contribution to the gross domestic product.

Significance of fisheries The Bohai Sea is an important spawning, nursery and feeding ground for many migratory species from the Yellow Sea and supports an important penaeid shrimp fishery. The fluctuations of stocks from one of those two seas significantly influence another one.

Physical condition The eutrophication in the Bohai Sea is increasing year by year. The primary productivity determined is 100 g C/yr, equivalent to phytoplankton of 180 million t/yr. Temperature is mainly influenced by the seasonal change, the temperature in winter is lowest, and highest temperature occurs in summer (August). The temperature change is major cause for migratory species to move out in late autumn and move in spring. The variations of salinity, phosphate, silicate, inorganic nitrogen and PO_4 – P in Bohai Sea are influenced by the flowing capacity from onshore sources like Yellow River and the warm currents from Yellow Sea in higher salinity and higher PH.

1.2.2 Fisheries Resources

Fisheries Resources in Bohai Sea have typically tropical features. The relationship between multiple species, environment, inter and intro-ecosystem are very complicated. The impacts from human being make the resources more unpredictable. Due to the big fishing pressure and environmental fluctuation, the composition of fisheries and dominant species are successively changing.

1.2.2.1 Compositions of fisheries species and distributions in biomass

Compositions of fisheries species and distributions in biomass have been changing in decades. The results from the second scientific survey conducted in the time of 1982 to 1983 in Bohai Sea showed that the fishes caught belong to 46 species 100 subspecies. Main species are half-fin anchovy, Ray, Japanese anchovy, Red tongue sole, small yellow croaker (young fish), Spanish mackerel (young fish), Gizzard-shad and Left-eyed flounder. Comparing the catch with it in 1959, the main species in spring in 1959 was small yellow croaker, account for 39.9%, in autumn, hairtail was main species in 1959, accounted for 44.3%. The half-fin anchovy and Japanese anchovy were main species in 1982, it accounted for 27.5%.

1.2.2.2 The Food Chain of fisheries in Bohai Sea

Deng et al (1988) systemically studied the food relationship between different species in Bohai Sea fisheries, examined the importance of different type of food for predator species by using IRI (index of Relative Importance) (Hacunda, 1971) value, figure out and analysis the foodweb structure for the fishes in Bohai Sea.

According to the conclusion they made, the fishes in Bohai Sea can be divided into 3 trophic

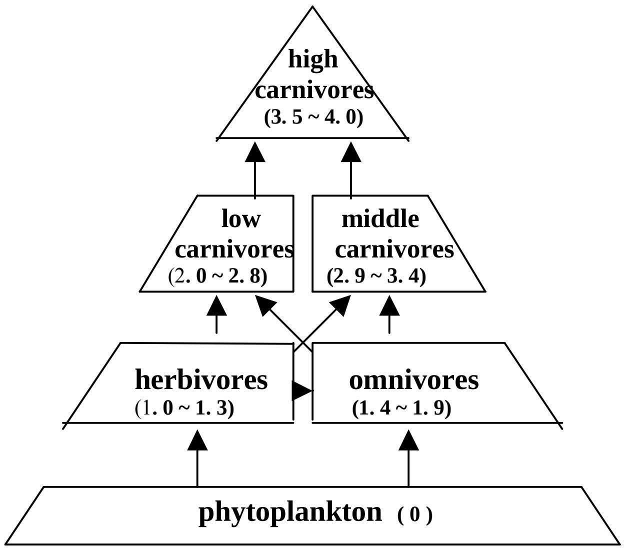


Fig 1. 2 The relation between trophic levels in food web

levels by the composition of foods:

1) Low carnivores.
2) Middle carnivores.
3) High carnivores.

The fishes in Bohai Sea are divided into 4 nutrition levels by using Odum and Heald (1978) standard.

• Zooplankton belongs to the first level (0 - level), the primary production in ocean is composed by zooplankton and phytoplankton;

• The Chines prawn (Fleshy prawn) studied in this paper is on second level , which includes herbivores (1.0-1.3) and omnivores (1.4-1.9), the fish in this level are mainly fed by zooplankton. Meanwhile, they are the food for the species on the third level;

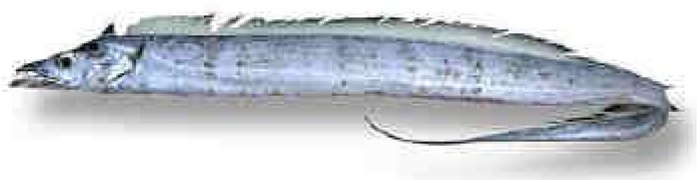
• The low carnivores (such as some sardine, Japanese anchovy, half-fin anchovy, herring and etc.) and middle carnivores (for example, small yellow croaker, seabream, perch, and some flounder) are included into the third level indicating number 2.0 ~ 2.8 and 2.9 ~ 3.4;

• The fourth level is comprised by some big carnivorous species like hairtail, Spanish mackerel, halibut. They depend on the some small pelagic fishes like Japanese anchovy and some shrimps as feeds. They occupy the top position on the foodweb.

The ratios between low, middle and high carnivores are 22: 19: 10. Most species are the low carnivores. Of the prey categories in the Bohai Sea, zooplankton, snapping shrimp (*Alpheus* spp). Brachyura, Japanese anchovy (*Engrilus japonicus)*, pinkgray goby (Chaeturichthys *hexanema)* and spotted fringemouth loach (*C. Stigmatis*) are the most important. They are on the very important stage on the energy flow from the primary productions to high carnivorous species.

1.2.2.3 Natural features for major species

Hairtail *(Trichiurus haumela)* the hairtail is a very silvery fish, eel-like body is all shiny chrome. Its size is up to 2.2 meters and 3.5 kg. Hairtail tend to more in schools.



Hairtail *(Trichiurus haumela)*

The hairtail is a strong carnivorous species with big body size. It has been a dominant resource in Bohai Sea for more than one decade, but now it nearly disappeared, it is the species that is very difficult to recover.

The hairtail is a highly productive demersal species (Chao et al. 2001). The hairtail showed two migratory aggregation behaviors (Misu & Shiokawa.1961). Hairtail migrate inshore and from south to north to reproduce and feed in the spring. In late autumn, the hairtail migrate back to the south to overwinter. The condensed fish schools are formed during overwinterinng and in the spawning season. (Misu, 1961).

Small Yellow croaker (*Pseudosciaena polyacti*)

Small yellow croaker is dermersal species with ability of making sounds. Small yellow croaker spawns in coastal areas between late May to June depending on the latitude (Chyung, 1977.

Small Yellow croaker (*Pseudosciaena polyacti*)

It appears in Bohai Sea for laying eggs and feeding from May to Nov. it belongs to warm water fish, mainly fed by fishes, others are mysid shrimp (*Mysidae),* Northern maoxia shrimp *(Acetes chinensis, Polychaet)* and a quantity of hilsa shad (*Macrura*).

Japanese anchovy (*Engraulis japonicus*) and Half-fin anchovy (*Setipinna taty*)

They are pelagic fishes with small size (about 50 cm maximum length; most species below 15 cm.). They occur in large schools near the surface, mainly in coastal waters and estuaries in tropical and temperate regions, but as far out as over 1,000 km from the shore. Tends to move more northward and inshore in spring and summer. Juveniles associate with drifting seaweed. The high minimum population doubling time is less than 15 months. They appear in Bohai Sea in May,

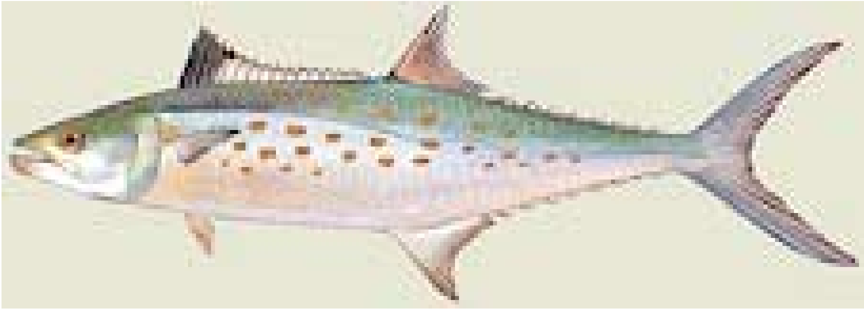
Japanese anchovy (*Engraulis japonicus*) sorted out from whale's stomach

Mainly filter feeding on zooplankton, such as copepod, but also on other small crustaceans like Northern maoxia shrimp (*Acetes chinensi)*, *Sagitta crassa*, mysid shrimp (*Mysidae)* and *Gammaridea*, molluscs larvae, fish eggs and larvae and diatoms, and a few piscivorous like juveniles.

Japanese anchovy and half-fin anchovy are commercially important species for marketed fresh and salted, processed into fishmeal and oil, and also used as bait.

Japanese anchovy is an important species on food web in Bohai fisheries, it is the segment that the energy from zooplankton flows into the biomass of economically big species such as hairtail, seabream, halibut and etc.

Spanish mackerel (*Scomberomoyus niphonius*) Spanish mackerel inhabits surface dwelling in inshore, nearshore and offshore waters, especially over grass beds and reefs, but they freely enter tidal estuaries. It is schooling fish with an ability of fast swimming that migrates over long distances in large schools along the shore northward in spring, returning to southerly waters when water temperature drops, and it appears in Bohai Sea from June to Nov.



Spanish mackerel (*Scomberomoyus niphonius*)

. It lives from five to eight years and females spawn by age two. Older fish may attain a weight of several pounds. It reaches a maximum age of 8 years.

Spanish mackerel consumes small fishes, shrimp and squid, and mainly feeds on fishes such as Japanese anchovy and *C. hexanema*.

It supports major commercial and sport fisheries

1. 2 Fishing Activities

Fishing in Bohai Sea is complex activities, which comprised by many types of gears. Marine fishing methods have remained mostly unaltered over decades. Trawling is the predominant form of fishing, followed by static fishing, gillnetting, purse seining, angling and setnet fisheries. In 1988, the trawlers withdrawn from Bohai Sea fisheries, and shrimp drift net became only gear to be conducted in this area.

Fishing power was limited on the original level. But fishing efforts were not controlled efficiently because of too big basic number on fishing power.

1.3 Previous Research and Research Gaps

1.3.1 Previous research

There are totally four times surveys for fisheries resources in Bohai Sea. The sampling stations covered the major distribution area with some seasonal differences according to the sea situation. These surveys are the survey in1959, in 1982 ~1983, in 1992 ~1993, and in 1998 ~ 1999. One haul for per sampling station, towing times are 1 hours. All catches were divided into fishes and economic invertebrate animals. All analysis are focusing on the catches caught respectively in Spring, Summer and Autumn, because there are e few species (local species) spending time in Bohai Sea during Winter.

1.3.2 Research gaps

Due to the financial constrains, there are only four times surveys in several decades, not continually, and the time intervals are very long. Therefor no systematic information were gained for fisheries changes in details, even sometime very big commercial catch happened, but no scientific analysis are available for such changes. But the scientific surveys in Norway, Canada, America and etc advanced countries are carried out every year, so they have built up complete fisheries information system. Quotas for catch are discussed in every certain time period, it is very useful for managing fisheries. But fisheries in Bohai Sea, because of no reliable data for setting up the quotas, lacking of multiple-model, so until now it is not available to know how much fishes should be caught, how much exists in the sea. The interactions between multiple-species still seem myths. The natural fluctuations in abundance of all species are very big, but the association of heavy rate of fishing and marked changes in species composition is not well documented.

Fisheries in Bohai Sea are owned by the state, all surveys are conducted for natural resources. No examinations are investigated for management. Actually, open access, inefficient top-down management and weak enforcement are so common. So it is very necessary to have a research in management system.

1.5 Problems Facing in Bohai Sea

In recent years, rapid development in Bohai-rim areas brought about serious damage to its ecological environment.

1.5.1 Resources Status

Due to the high levels fishing and environment pollution, the fisheries resources in Bohai Sea, specially some traditional high-valued species, i.e., yellow croaker and hairtail have been overfished, and that have been replaced by some low-valued species, primarily smaller pelagic species, such as anchovy half-fin anchovy (*Setipinna Taty*). The CPUE declined from 2.39 tons/ kilowatt in 1950's to 0.91 tons / kilowatt in 1990's. But the fishing efforts are still increasing continually, for example, the fishing vessels in 1999, Liaoning province has reached 32,330 (839,938 KW), and Shangdong province has reached 43,736 (1,262,302KW). The situation is very severe.

1.5.2 Chaostic Management

Fisheries in Bohai Sea are in an ecosystem, but fishing activities are conducted by different provinces. Coordination of government actions continues to be a problem. There exists many contradictions between different sectorial planning approaches, and in the absence of a holistic institutional framework of management mechanism, coastal and marine resources are being destroyed. Since no quotas have been set down, co-operations are not feasible for fishing and managing fisheries in this area, every sector try to catch as much as they can, even the fishing powers are limited by the central administration. But the enforcement of rules and entering the fisheries is very weak, fisheries in Bohai Sea actually are open access. Fisheries are managed by several province, everybody manage it, means nobody manages it - Fisheries in Bohai Sea with the features of open access and the more efficient system: co-management would be a prospective alternative.

Conflicts also exist between fishing fleets, ocean transportation, oil industry and aquaculture due to no clear property rights, sometime such conflicts may cause big accidents.

The policies were not implemented well in Bohai Sea.

1.5.3 Aquaculture and pollution

The overall water exchange between the Bohai Sea and Yellow Sea, through the Bohai Straits, takes 16 years. This means in most time the persistent pollutants will have to be ‘digested’ by this 'enclosed ponds' itself. It is reported that water quality in forty percent of the Bohai Sea was estimated to below national standards. The long-term sustainability of the Bohai Sea however is threatened by pollution.

Pollution in Bohai Sea mainly comes from three sources: 1) industrial discharge such as COD, wasting oil and some chemical material; 2) domestic sewage; 3) aquaculture, mainly comes from shrimps ponds.

Industrial and domestic discharge pollution from exploitation of oil fields in this area, like Shenli Oil Field, and producing of oil products in Chemical Factory, are major reason for the changes of environment, petroleum and COD are considered as the main pollutants (Tang, 1994). Indications of possible bilge pumping or ship dumping activity in the region were observed many times. The width of the slick features indicates the effect of wind spreading. Untreated wastewater from factories around Bohai Sea strengthens such pollution, and unfortunately, as the presence of natural slicks and the intensity of fishing activity increase makes such pollution more harmful and ‘indigestible’.

Aquaculture in China increased dramatically in the past decades, consumption of the world market and livelihood for Chinese people strongly benefit from aquaculture. Since 1980’s, shrimp aquaculture along coastline of Bohai Sea developed very fast in areas and in yield. The pollution from aquacultrue has been significantly growing also. The economic loss is impossible to be estimated. The explosion of red tide which mainly caused by marine pollution has brought disastrous outcomes. For example, such disaster has made the shrimp industry in China in 1994 nearly dies out from aquaculture. It is reported that red tide has occurred 20 times in past seven years (Jin, 2001).

1.6 The rationale and professional contribution of the research

1.6.1 Resource

In more than 40 years, the Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Science, have conducted surveys 4 times in Bohai Sea with a long time intervals, they have gained the primary information about changes of dominant species, fluctuation of abundance, reduction of species composition. All studies were focused on the biological and environmental aspects. The initial stock size is not known; year-class strength determination is deficient due to insufficient data, age (size) specific natural mortality is not known, and fisheries statistics are deficient. So the Virtual Population Analysis (VPA) is not fully applicable in the modeling fisheries in Bohai Sea. Therefor the scientists just focus on outcomes from surveys and to analysis the reasons of the changes in Bohai Sea's fisheries. No model and trends are available. This study will review the types, availability, and reliability of basic data of Bohai Sea fish and fisheries, suggest that a synthetic and holistic ecosystem approach in biology. Try to support scientific information to administrator to set up principles and measures for managing fisheries in Bohai Sea, to find some trends for giving scientific analysis and predication for rebuilding the fisheries in Bohai Sea.

Study results provide unique opportunity to quantitative and qualitative measure of user group's response and therefor offer reasonably excellent possibility for transfer of information. Researchers can use findings of study as a foundation to further research as they are in a manner responsive to both ecological and sociological needs. To do what Tang (1989) said: 'To restore the living resources of the Bohai Sea, setting up a model structure', then to find possible measures which adopt include establishing effective ecosystem management, and developing a restocking program.

1.7 Objectives of the study

● Review the fisheries resource in Bohai Sea: the historical changes; the present status. To analysis the reasons for causing the degradation of fisheries and environmental ecosystem in Bohai Sea. And to give some information about the MSY-maximum sustainable yield for some commercially important species by using the biological model.

● To evaluate the present fisheries management situation in Bohai Sea in order to study in terms of: natural resources use; human activities. The analysis will include an evaluation of the environmental impacts from industry and aquaculture.

● Identify the main constraints which concerning to improve the fisheries resource in Bohai Sea to a successful management.

● Support some rational management solutions, which base on sustainable use of natural resources and sustainable aquaculture in Bohai Sea.

2.0 METHODOLOGY

2.1 General overview

The study quoted some results from the surveys, which conducted by The Yellow Sea Fishery Research Institute, Chinese Academy of Fishery Science to scientifically illustrate the changes of fisheries in Bohai Sea. The study makes use of both qualitative and quantitative data collection procedures, including techniques were semi-structured questionnaires, semi-structured and unstructured interviews. Secondary data are based on official records. Various resource persons were consulted for gathering necessary information and for familiarization with the study area, research themes surveyed included observable indications such as dependency on resources, current situation of fisheries, sustainability, problems, management strategies, policies, future prospects of the fisheries, employment (From interview conducted with fisheries officers and scientists).

Interviews and structured questionnaires have been used to obtain information in the following aspects:

● Different types of fish species harvested for commercial industry and the changes over the years.

• Number of people, vessels and gears engaged in the fishery and the changes over years.

• Fish landings in relation to efforts (catch per unit effort, CPUE) over decades. The available data on fish stocks and assessment of the research

• Revenues of fish landings. Costs of fishing efforts.

• Different regulations both on local and governmental level that exist in the management of the fisheries resources in Bohai Sea, and investigate reasons of failure and success and possibilities of improvement.

2.2 Field work

Interviews, visits and conversations on lines were conducted to collected data during the period of June- August 2002.

Different fisheries officers in four fisheries bureaus which belong to the provinces around Bohai Sea, institutes which are doing research works for Bohai Sea, and markets were visited, in order to get first and second hand data on current research and management works strategies for fisheries futures management.

Interviews of fishermen and fisheries scientists in Bohai Sea were organized.

Information from newspaper and country reports was collected in order to obtain the response from society to find economic and social influences to fisheries.

2.3 Analysis of data

The data used for stock assessment are those three types:

- Fisheries statistics (catch and effort data) Data involves a time series of commercial catch and effort.
- Research surveys data.
- Biological studies.

The analytical framework involved both descriptive and computerized statistical techniques to analysis the results for the sources of data. Mathematical computer software including the MS- Excel software were used to statistically analyze the data and to compute the results.

2.3.1 Biological models

The two types of surplus production models have been used widely in managing fisheries largely because they are based on the assumption of the net growth rate of a stock is related to its biomass, and only catch and effort data needed to be used for the models.

In tropical fisheries, catches are always made up of many different species, the only practical option available for managing it to maximize economic yield may be to treat the component species as a single stock. Fisheries in Bohai Sea are analysis under such assumption.

The linear form of surplus - yield model (Graham, 1935. Schaefer, 1954, 1957, Ricker, 1975) assumes logistic population growth, resulting in: (1) a linear relationship between fishing effort and population size (catch per unit effort), and (2) a parabolic curve when yield is plotted against with population size or fishing effort.

But Gulland (1961), Garrod (1968), Wise and Fox (1970) found that the relationship between fishing effort and catch per unit effort in their statistics was best described by a curve. In this model, CPUE decreases in a curve with increasing fishing effort, rather than as the straight line by using natural logarithms:

$$\ln [\ CPUE\ ] = \ln [Y / f\ ] = a + b\, f \qquad (1)$$

$$Y = f \exp [a + bf] \qquad (2)$$

In which:

$$MSY = (-1 / b) \exp [a - 1] \qquad (3)$$

$$f_{msy} = -\ 1 / b \qquad (4)$$

2.3.2 Computation model

2.3.2.1 Model

The linear model y = α + βx + ε (α is the intercept, β is the slope, and ε is the error) is used to fit a line to the data. The predicted values of y (label ŷ) can estimated by ŷ = a + b x (α,β are labeled by a, b).

Sum of Squared Residuals (R^2) = $\sum_{i=1}^{n}(y_i - \bar{y})^2$

$$b = -\ \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

$$a = \bar{y} - b\bar{x}$$

2.3.2.2 Analysis of regression

Regression Statistics:

- ***R Squared* – coefficient of determination**, measures the percentage of variation in the values of the dependent variable that can be explained by the change in the independent variable. R^2 – values vary from 0 to 1.

- *Adjusted* R^2 – is used when performing a regression with several predictor variables, adjust the R^2 for determining whether adding the additional number of predictors.

- ***Estimated Variance*** – measures the size of a typical deviation of an observed value (x, y) from the regression line.

Analysis of variance (ANOVA table): analyzes the variability. The variability is divided into two parts: the first is the variability due to the regression line and second is due to random variability.

- ***SS*** – the sums of squares
- ***MS*** – the mean square
- ***F- ratio*** – displays the ratio of the mean square for the regression to the mean square error of the residuals. A large F-ratio indicates that the regression may be statistically significant, and a small value for this ratio indicates that much of variability in y is due to random error and is not due to the regression.
- ***P – value*** – is measured by the F- distribution. The regression is significant at the 5% level.

Parameter estimates:

- ***Coefficients*** - include the constant coefficient, or intercept, and the slope.
- ***SE – Standard Error*** - The ratio of parameter estimates to their standard errors follows a t-distribution with n – 2, degrees of freedom.
- ***t – Stat*** – the ratios for each parameter.

2.3.3 Computation tools

2.3.3.1 Mathematics

• Harvests plotting on efforts comprised different figures for different species in those four regions, which are used to describe the trends in catches, efforts and CPUE.

• Regression tools in mathematics are used to work out related parameters and analysis values.

2.3.3.2 MS-Excell package

• Histogram, area blocks, colored lines and smooth lines tools in MS-Excell tool package were used to plot the diagrams for describing the changes of yields, efforts and CPUE versus time series (1956 – 1998).

• Bar distribution was used to figure out the proportion of pollutants from different sources.

3.0 DATA PRESENTATION

The data plotted in this section give an overall information for the fisheries in Bohai Sea. The estimations from regression of data analysis will tell the reliability of data used in this study.

3.1 Commercial Fisheries Data

3.1.1 Data Sources

Before 1988 back to the time that the new China was established (1949), all works for data documented for fisheries are not systematical, so the commercial fishing data in those 40 years were collected in the book 'China Statistics Yearbook for 40 Years Fisheries ' (1949 ~1988). The book was edited by the Ministry of Agriculture, People's Republic of China and published in 1990. After 1990, the yearbooks for China's fisheries are announced annually, so the data after 1990, used in this study, were selected from the annual announcements.

3.1.2 Total marine catch

The fishing data begins to be recorded from 1951. No data are available before that time due to the very small catch ability and incomplete documented system.

Table 3.1 Marine fish yields in Coastline areas (tons)

Year	Tianjing	Hebei	Liaoning	Shandong	Total
1951	11563	50249	72078	124987	258877
1952	11520	59407	76334	131746	279007
1953	8752	25084	94998	131503	260337
1954	7959	21283	105857	130127	265226
1955	8753	27265	107013	152065	295096
1956	10501	21089	103764	157831	293185
1957	7600	18860	98623	165086	290169
1958	12002	29486	113110	164343	318941
1959	17076	23701	148294	180747	369818
1960	16093	32267	155954	181190	385504
1961	14186	19623	117757	143917	295483
1962	15022	20637	121759	146052	303470
1963	17518	25093	113237	102140	257988
1964	20299	28976	136657	118340	304272
1965	19628	38939	113934	128188	300689
1966	20047	37320	121967	124743	304077
1967	11970	29148	106940	114434	262492
1968	16124	37872	97259	160409	311664
1969	10592	17657	115292		143541
1970	20560	31603	147641	199556	399360
1971	16662	32800	188424	244752	482638
1972	12904	31666	211973	308941	565484
1973	12758	40647	239975	298597	591977
1974	18435	37150	253544	291749	600878
1975	20272	35194	278832	298990	633288

1976	21942	31185	291947	362080	707154
1977	24287	49499	268671	362810	705267
1978	19843	41251	261405	347885	670384
1979	14552	36454	249085	301752	601843
1980	12429	41938	220919	301882	577168
1981	11905	38909	226063	305389	582266
1982	18688	50377	278955	357874	705894
1983	15756	41702	260920	328832	647210
1984	22228	48579	268838	377365	717010
1985	19795	58578	267494	364849	710716
1986	18662	60590	276117	413985	769354
1987	22895	72398	307203	506422	908918
1988	20431	71274	318594	562942	973241
1990	22400	61800	303400	704100	1091700
1991	14800	49600	294800	769000	1128200
1992	10600	46100	319700	926300	1302700
1993	10000	46200	347600	962200	1366000
1994	10100	58800	403400	1095900	1568200
1995	13200	73000	477700	1111600	1675500
1996	14200	76800	666700	1218500	1976200
1997	13700	110500	717300	2104500	2946000
1998	9900	145700	842800	2241300	3239700

There are four regions along the Bohai Sea. The catches for Tianjing and Hebei just come from the Bohai Sea. But the fishing fleets in Liaoning and Shandong catch fish from both Bohai Sea and Yellow Sea. The total marine catch mainly comes from

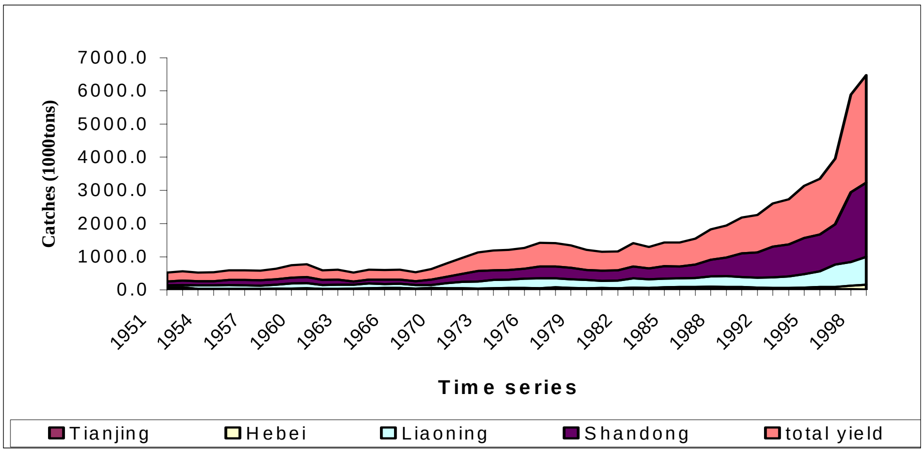


Figure 3.1 The catches for marine fishes in Bohai Sea

those tow regions (Figure 3.1).

The fisheries in Bohai Sea are tropic resources, the catches may include many species, but only some important commercial species were recorded. They are small yellow croaker, hairtail, blackgill croaker, Left-eyed flounder, red tongue sole, Red sea bream, pomfret, Japanese anchovy, Spanish mackerel, Japanese sardine and etc. This paper only study some most important species which have ever formed the fisheries industry in Bohai Sea.

3.1.3 Fishing Effort Data

Table 3. 2 Fishing effort in Bohai Sea (HP-horse power)

Year	Tianjing	Hebei	T + H	Liaoning	Shandong	L + S	Total
1956	1765	1608	3373	18983	20383	39366	42739
1957	1845	2080	3925	19429	24644	44073	47998
1958	3282	3010	6292	24442	30579	55021	61313
1959	3442	4030	7472	31771	32880	64651	72123
1960	4542	5190	9732	43765	39195	82960	92692
1961	11335	6565	17900	55186	47538	102724	120624
1962	21925	10838	32763	63797	69150	132947	165710
1963	20895	10931	31826	61008	32624	93632	125458
1964	20410	13678	34088	62480	34988	97468	131556
1965	21075	14380	35455	62675	37574	100249	135704
1966	21685	14280	35965	67375	43055	110430	146395
1967	22610	16465	39075	69309	47835	117144	156219
1968	23275	19605	42880	70058	47859	117917	160797
1969	22905	20765	43670	72016	58890	130906	174576
1970	22955	21700	44655	74196	103242	177438	222093
1971	22388	24375	46763	81138	119106	200244	247007
1972	27200	31051	58251	100853	149951	250804	309055
1973	35970	37886	73856	124190	187739	311929	385785
1974	42655	53995	96650	149540	218962	368502	465152
1975	47770	70088	117858	191784	249995	441779	559637
1976	58960	87623	146583	224969	289569	514538	661121
1977	63607	100336	163943	246874	321945	568819	732762
1978	71968	107672	179640	263521	347875	611396	791036
1979	71190	120519	191709	278895	388931	667826	859535
1980	71375	124031	195406	299748	426981	726729	922135
1981	67059	130224	197283	304336	453727	758063	955346
1982	68648	133402	202050	308431	483064	791495	993545
1983	66980	145787	212767	327586	496894	824480	1037247
1984	61650	156397	218047	357978	527819	885797	1103844
1985	56701	182954	239655	404530	591286	995816	1235471
1986	65052	212812	277864	509094	725438	1234532	1512396
1987	68212	241892	310104	547817	773729	1321546	1631650
1988	74827	279144	353971	591225	870830	1462055	1816026
1990	55246	314136	369382	703850	1016665	1720515	2089897
1991	74305	304325	378630	744328	1141860	1886188	2264818
1992	71354	310484	381838	775757	1226392	2002148	2383986
1993	68038	314049	382087	780473	1285630	2066103	2448190
1994	70715	325400	396115	796034	1239939	2035973	2432088
1995	63139	324829	387968	860953	1443592	2304545	2692514
1996	69917	354197	424114	895040	1612464	2507504	2931618
1997	61472	405903	467375	972097	1697313	2669410	3136785
1998	71733	407361	479094	1019090	1856097	2875187	3354281
1999	77871	460208	538079	1211995	1844990	3056984	3595063

The fishing power in Liaoning and Shandong are much bigger than it is in Tianjing and Hebei. The unit of efforts before 1988 is horsepower. The unit of the effort after that (1990-1998) is changed to K.W, when those data are used in this paper, all data are converted to horsepower: 1 horsepower = 735.5 W.

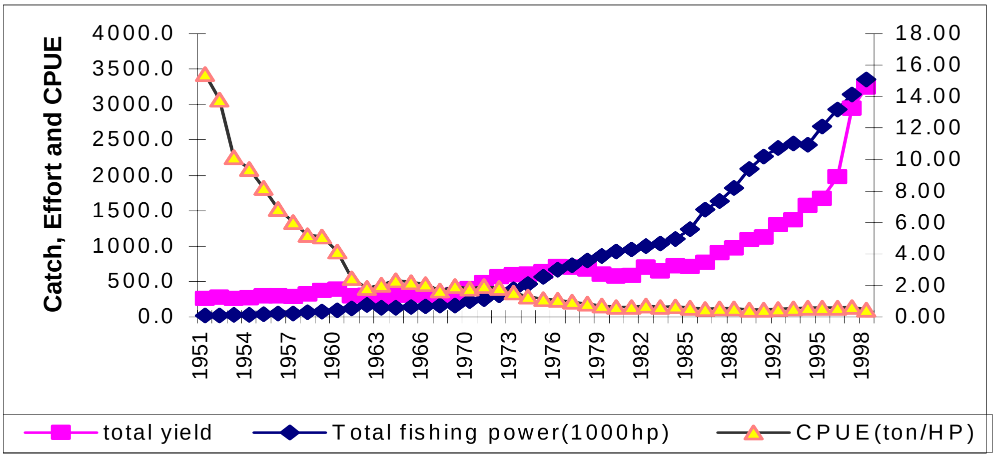


Figure 3.2 The trends of total marine catch (1000tonnes), effort (horse power) and CPUE (tonnes/hp)

The figure 3.2 is the comparison for the changes of marine fisheries in total catch, total effort and CPUE.

3.1.4 Catch data for small yellow croaker

Table 3. 3 Catches for small yellow croaker in different areas (tons)

Years	Tianjing	Hebei	Liaoning	Shandong	Total
1956	1236	3047	20023	25904	50210
1957	1473	2128	23287	32011	58899
1958	1572	1216	16429	24623	43840
1959	1889	1514	22371	20268	46042
1960	1989	1324	30428	20016	53757
1961	1669	406	22765	14278	39118
1962	1935	416	16939	8987	28277
1963	1621	852	20413	2959	25845
1964	1011	317	19740	2706	23774
1965	639		10060	1948	12647
1966	1135	3223	8826	621	13805
1967	800	4807	5573	1770	12950
1968	495	3861	2768	1792	8916
1969	242	2506	5430		8178
1970	184		4947	1913	7044
1971	133	52	2569	2124	4878
1972	26	110	755	623	1514
1973	15	35	1381	1091	2522
1974	62	56	5599	2575	8292
1975	377	98	6924	3453	10852
1976	176	60	8254	4402	12892
1977	48	62	8272	1798	10180
1978		3	2491	1621	4115
1979	1	70	3602	4243	7916
1980	34	324	11506	5647	17511
1981	269	324	9926	10119	20638
1982	203	120	8047	11361	19731
1983	200	97	4303	9112	13712
1984	2	12	2207	5658	7879
1985	97	146	3787	6079	10109
1986	5	7	2492	9064	11568

1987	4	192	1595	12914	14705
1988	203	406	1376	11377	13362
1990		22	3447	9797	13266
1991		32	3718	24669	28419
1992	17	15	3132	34232	37396
1993	165	550	4383	44724	49822
1994	78		4265	44779	49122
1995	6	922	6309	66400	73637
1996		25	9263	43851	53139
1997			13430	36769	50199
1998		3165	22885	45376	71426

The catches for small yellow croaker strongly fluctuate during year series. There are some blanks in table 3.3, particularly in the catch data for Tianjing and Hebei. No explanation could be found in the yearbooks. One can find that catches for Tianjing and Hebei dramatically decreased after late 1960's, but the catches for Liaoning and Shandong are influenced by the yields from Yellow Sea.

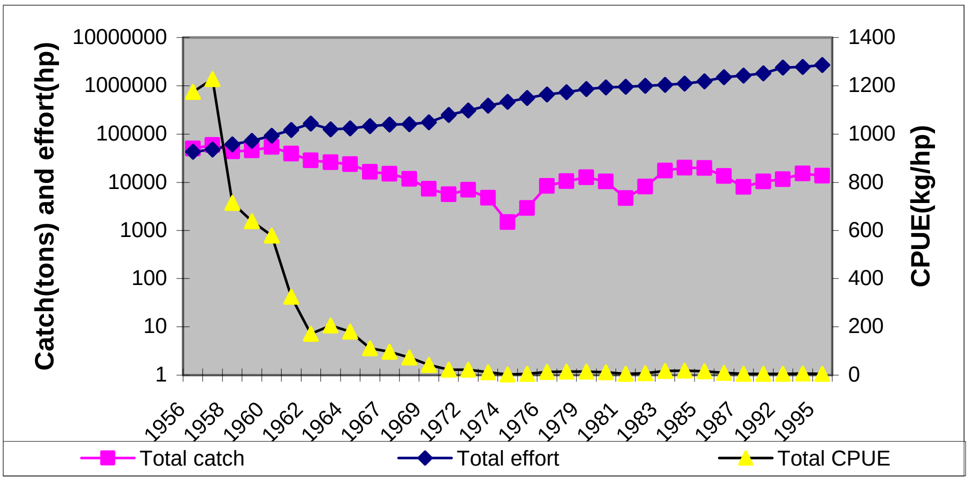


Figure 3.3 The changes for small yellow croaker in Bohai Sea

The figure 3.3 illustrated the trends in total catches, total fishing power and CPUE for small yellow croaker. The figure was made by logarithm to clearly show the changes for those three types of values.

3.1.5 The changes for hairtail

The hairtail and small yellow croaker had formed the main fisheries industry in 1950s and 1960s in both Bohai Sea and Yellow Sea. In general speaking, those two species

Table 3. 4 Catches for hairtail in different area (tones)

Year	Tianjing	Hebei	Liaoning	Shandong	Total
1956	108	459	23678	41042	65287
1957		884	16025	47415	64324
1958	474	567	14664	33449	49154
1959	541	1155	12005	31434	45135
1960	1719	1360	30454	31946	65479
1961	1809	983	19682	33961	56435
1962	1940	1735	22527	32968	59170
1963	1584	939	17649	12377	32549
1964	1109	321	12243	8753	22426
1965	1561		11371	4983	17915
1966	2303		8481	8111	18895
1967	1173		8752	4083	14008
1968	1034		2272	1866	5172
1969	393		6601		6994
1970	657		8234	13702	22593
1971	1756	285	9240	19628	30909
1972	361	95	5444	9306	15206
1973	675	731	16893	27675	45974
1974	2122	439	19249	27466	49276
1975	1647	724	15937	26656	44964
1976	1220	529	16298	23220	41267
1977	2456	1405	15305	24084	43250
1978	1560	920	10249	19229	31958
1979	1350	664	11557	16503	30074
1980	1849	1831	21256	29586	54522
1981	2722	1828	24501	26993	56044
1982	5556	2312	25133	40049	73050
1983	5459	2410	28892	25179	61940
1984	5967	1948	36791	36319	81025
1985	4462	1186	30609	21584	57841
1986	2789	836	25213	14513	43351
1987	2748	1546	17161	17376	38831
1988	3087	1686	11411	18234	34418
1990	1860	1094	13616	21296	37866
1991	905	891	8490	25078	35364
1992	485	593	11201	32485	44764
1993	1864	182	3012	29575	34633
1994	800	52	5438	40878	47168
1995	2994	79	6939	50135	60147
1996	2300	30	6535	50457	59322
1997	1000	197	9587	51156	61940
1998	500	130	15508	94027	110165

experienced two periods: dramatically decline in abundance in 1950s-1960s, the slow and uncertain recovering period followed later, although the catch in table 3.4 showed the increase in catch, the fisheries for those two species are quite unstable.

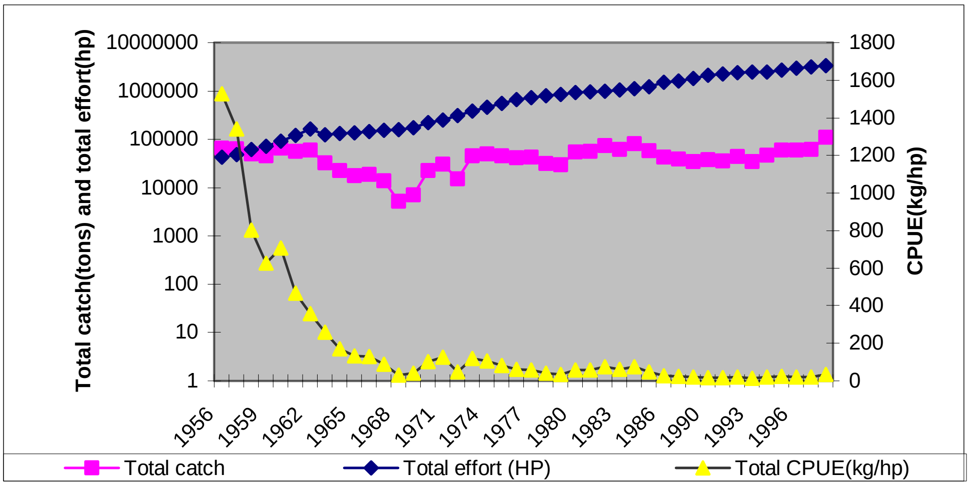


Figure 3.4 The trends for hairtail in Bohai Sea

3.1.6 The changes for Chinese prawn

Table 3. 5 Catches for Chinese prawn in different areas (tons)

Year	Tianjing	Hebei	Liaoning	Shandong	Total
1956	7777	7635	5429	15940	36781
1957	1700	1737	3047	9910	16394
1958	2547	2005	2697	6470	13719
1959	5021	3408	3875	7821	20125
1960	1786	1635	4000	2409	9830
1961	1921	1223	1913	2031	7088
1962	1760	965	3482	4752	10959
1963	2102	1006	4612	2306	10026
1964	2585	1338	8093	3251	15267
1965	2586	1225	8712	4496	17019
1966	1888	968	6672	5312	14840
1967	652	532	5559	3110	9853
1968	422	391	4345	3692	8850
1969	1054	654	4046	1860	7614
1970	797	573	3497	6152	11019
1971	877	440	3104	5224	9645
1972	783	546	3787	6032	11148
1973	2315	1801	11282	14740	30138
1974	3425	3063	11596	19836	37920
1975	2409	2486	6944	15384	27223
1976	878	563	2545	4997	8983
1977	2047	1245	6305	12561	22158
1978	3181	1948	10226	16007	31362
1979	3437	2904	14693	21692	42726
1980	2128	2261	9064	18097	31550
1981	781	868	5103	14047	20799
1982	398	341	2421	3790	6950
1983	1046	1088	4771	8213	15118
1984	460	821	1982	4196	7459
1985	1054	2029	5873	11475	20431
1986	534	2117	5550	8263	16464
1987	276	1566	3625	3782	9249
1988	633	3343	6767	8629	19372
1990	380	2795	2046	3041	8262
1991	270	1474	4082	4109	9935
1992	493	2266	2376	4303	9438
1993	202	1461	541	3401	5605
1994	154	774	1037	2532	4497

1995	399	1298	664	2005	4366
1996	459	1006	847	2201	4513
1997	234	841	1809	2618	5502
1998	116	553	1759	3467	5895

The product form Chinese prawn fishery is mainly for exporting. After being fishing down in wild biomass in 1960s, the auqaculture industry for this species rapidly grew up. The succeed of artificial breeding further accelerated the increase in aquaculture which is one of main sources of pollution in Bohai Sea. The wild resource of this species is often threatened by the pollution and disease from aquaculture. The product from aquaculture for this species has exceeded the catch from wild resource. The Table 3.6 shows the growth of Chinese prawn in aquaculture in both area and yield.

Table 3.6 Chinese prawn culture along the Bohai Sea coast

	Area (hm^2 x 10^3)	**Products(tons)**
1983	5.706	1414
1984	9.062	3908
1985	18.216	12275
1986	30.808	29201
1987	47.378	62821
1988	68.809	90780
1989	67.876	80571
1990	65.034	78127
1991	62.896	84480
1992	57.115	79631
1993	60.008	26117
1994	60.964	19033

Source: From ' The cause of recruitment variation of Penaeus chinensis in the Bohai Sea', (Deng, J. 2001)

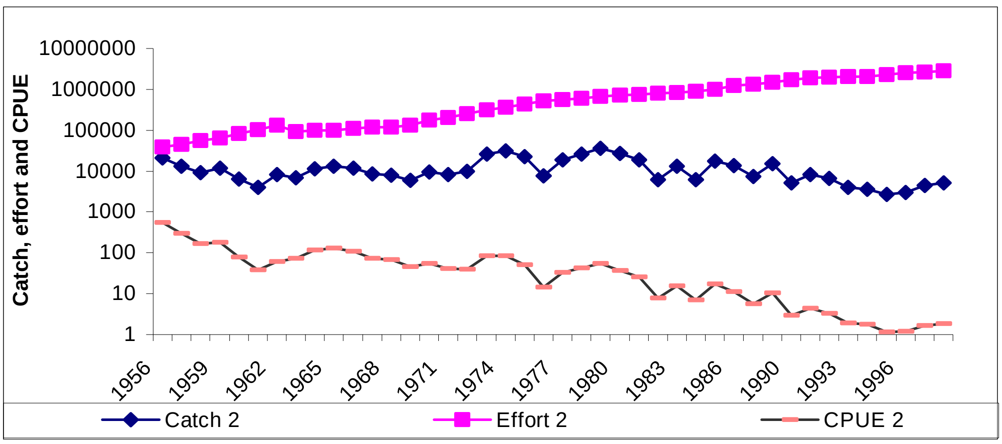


Figure 3.5 (logrithms) The changes of Chinese prawn in Bohai Sea

The logarithms are used to plot the figure 3.5 showing clearly the fluctuations in catches and CPUE for wild Chinese prawn as fishing efforts increased.

3.1.7 The Changes for Japanese anchovy

Table 3.7 Catches for Japanese anchovy in different areas (tons)

Year	Tianjing	Hebei	Liaoning	Shandong	
1990			483	903	1386
1991		473	26666	38798	65937
1992		2500	40436	117115	160051
1993		23	55702	192218	247943
1994		613	62849	266800	330262
1995		278	66395	354741	421414
1996		1234	84554	537437	623225
1997	1743	20955	133541	870862	1027101
1998	25		24925	870128	895078

The data for Japanese anchovy are limited, because the catch for this species was very low in 1950s and 1960s while big size demersal species were dominant, so no available data were documented before it grew up in 1980s. The commercial catch data began in 1990.

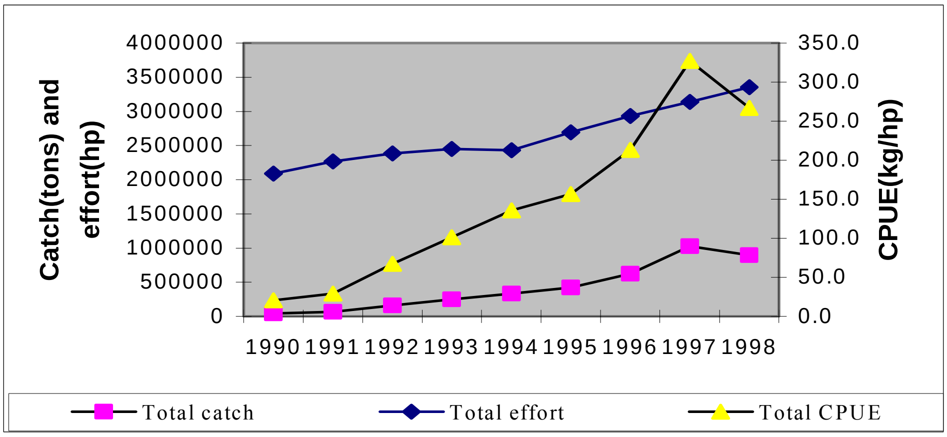


Figure 3.7 The changes for Japanese anchovy in Bohai Sea

The Fig. 3.7 shows the increases in catch, effort and CPUE.

3.1.8 The changes for Spanish mackerel

Table 3.8 Catches for Spanish mackerel in different areas (tons)

Year	Tianjing	Hebei	Liaoning	Shandong	Total
1978	1086	1119	8841	19955	31001

1979	1117	1497	7762	25167	35543
1980	815	1932	9789	20667	33203
1981	609	812	7749	23741	32911
1982	1098	1381	13521	18905	34905
1983	486	603	14846	29606	45541
1984	99	540	10096	35164	45899
1985	428	367	15879	33501	50175
1986	202	680	15188	42914	58984
1987	663	485	11851	53643	66642
1988	682	1091	13088	90068	104929
1990	1656	2005	32696	81135	117492
1991	792	1270	23956	52652	78670
1992	108	880	8998	59487	69473
1993	9	515	3616	93379	97519
1994	109	17	7775	88083	95984
1995	4	514	5835	119036	125389
1996	48	2403	18243	137072	157766
1997	150	5374	27302	234093	266919
1998	481	8236	30512		39229

The Spanish mackerel as new predator developed, and probably formed a new relationship of predator and prey with half-fin anchovy and Japanese anchovy when previous predators disappeared or decreased. So the data for Spanish mackerel are available after mid 1970's.

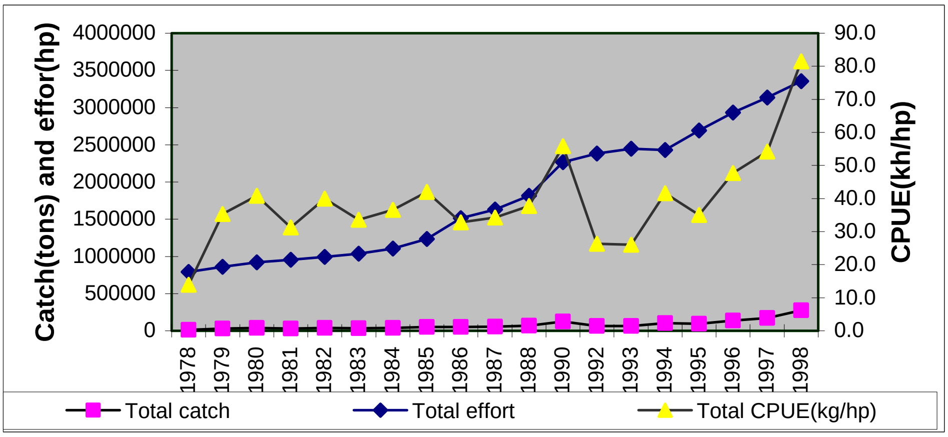


Figure 3.7 The changes for Spanish mackerel in Bohai Sea

The basic impression for Japanese anchovy and Spanish mackerel in catch is both of them increased form the first documented until reached the peak points, then both of them suddenly have big drops and happened accordingly in the same year.

3.2 Presentation of Regressions

Regression results: 1956 - 1998 (missing 1989)

Table 3.9 Parameters for different species in areas of Tianjing and Hebei (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
Small yellow	-2.49399	-0.01749	0.58072	0.56719
Hair tail	-2.33746	-0.00775	0.74515	0.73743
Chinese prawn	-1.89968	-0.00984	0.68323	0.67531
Japanese	-23.14990	0.04289	1.00000	Indeterminate
Spanish	-4.56685	-0.00241	0.05932	0.00705

Table 3.10 Parameters for different species in whole Bohai Sea (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
	-2.20383	-0.00130	0.33776	0.31568
Hair tail	-1.47339	-0.00102	0.65204	0.64149
Chinese prawn	-2.21155	-0.00150	0.84391	0.84000
Japanese anchovy	-7.65380	0.00208	1.00000	Indeterminate
Spanish mackerel	-3.51641	0.00015	0.20535	0.15860

In general, the catch and effort for Chinese prawn fit very well, The adjusted R^2 means 84% variation in catch is due to the variation in effort. The regression for Japanese anchovy is indeterminate because of the limitation of data, and the catch and effort for Spanish mackerel don't fit at all.

3.2.1 Small yellow croaker

The regression between catches and efforts for small yellow croaker is not very good, it's overall R^2 value is just 0.31568, it means that 31.57% of the variation in the catch

Table 3.11 Parameters for small yellow croaker in different areas (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
Tianjing	-1,25527	-0.09742	0.70728	0.69868
Hebei	-3.41931	-0.01670	0.42767	0.41177
Liaoning	-2,02987	-0.00409	0.50892	0.49664
Shandonng	-3,00973	-0.00081	0.08524	0.06178

index can be explained by the change in mean effort. The variation of regressions between catch and effort for small yellow croaker in different areas is very big. The one fits well is the data for this species in Tianjing, the worst one is 0.06178 in Shandong, the latter means it almost could not make change in catch if you change effort.

3.2.2 Hairtail

Table 3.12 Parameters for Hairtail in different areas (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
Tianjing	-2,26658	-0.02020	0.33586	0.31883
Hebei	-2,55969	-0.01421	0.74292	0.73536
Liaoning	-1,38031	-0.00390	0.75654	0.75045
Shandonng	-1,49610	-0.00167	0.46882	0.45520

The regression for hairtail in whole area is 0.64149. It means there is 35.85 % uncertainty in the changes between catches and efforts. The regressions for different areas vary between 0.31883 and 0.75045. The catch data match effort data well in Hebei and Liaoning, the regressions are comparatively high.

3.2.3 Chinese prawn

The regression between catch and effort for Chinese prawn is 0.84000. The

Table 3.13 Parameters for Chinese prawn in different areas (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
Tianjing	-0,83649	-0.05938	0.70309	0.69566
Hebei	-2,36825	-0.01062	0.58793	0.57762
Liaoning	-2,28960	-0.00490	0.87295	0.86977
Shandonng	-2,30683	-0.00278	0.83162	0.82741

regressions in different areas vary between 0.57762 and 0.86977. General impression for this species is the 84 % variation in catch can be explained by the variation of effort, only 16 % variation in catch is presumed to be due to random variability.

3.2.4 Japanese anchovy

The relationships between catch and yield for Japanese anchovy in whole sea is uncertainty. The lowest value is only -0.00195. It seems impossible.

Table 3.14 Parameters for Japanese anchovy in different areas (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
Tianjing	-37.7665	0.487361	0.08914	-0.00195
Hebei	-19.086	0.03883	0.46638	0.35965
Liaoning	-9,00492	0.00685	0.20823	0.09512
Shandonng	-9,84561	0.00547	0.59377	0.53574

The main reasons for such results maybe because the data for this species are limited

3.2.5 Spanish mackerel

Table 3.15 Parameters for Spanish mackerel in different areas (1956-1998)

Areas	Best Fit		R^2	Adjusted R^2
	A	B		
Tianjing	-7,23149	0.02497	0.00705	-0.04811
Hebei	-4,87489	-0.00255	0.03999	-0.01335
Liaoning	-3,06411	-0.00118	0.23323	0.19063
Shandonng	-3,20246	0.00040	0.42868	0.39508

The catch data also don't fit the effort data for Spanish mackerel. The highest value is just 0.39508, some of them even are negative, it is not reasonable.

4.0 RESULTS

4.1 Trends

4.1.1 Total marine catch

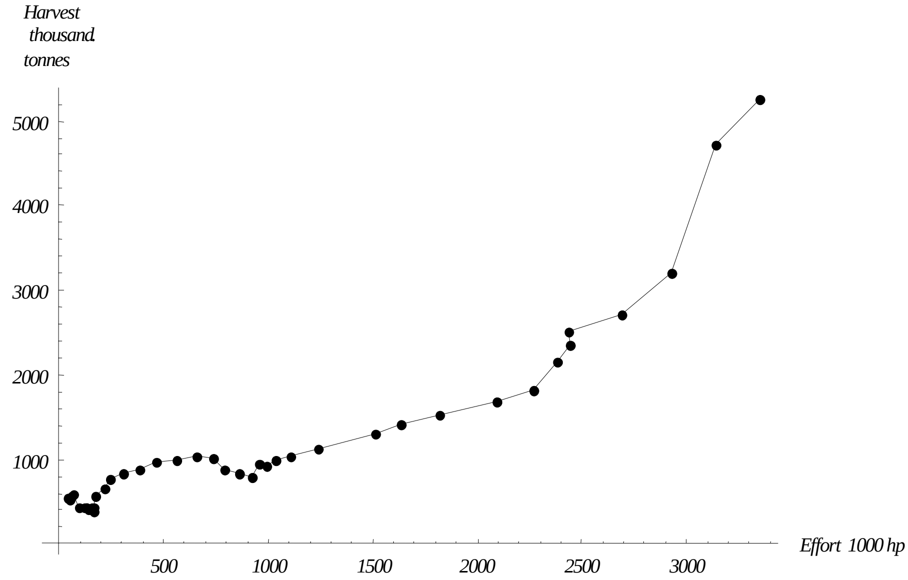


Fig. 4.1 Total marine catch versus effort

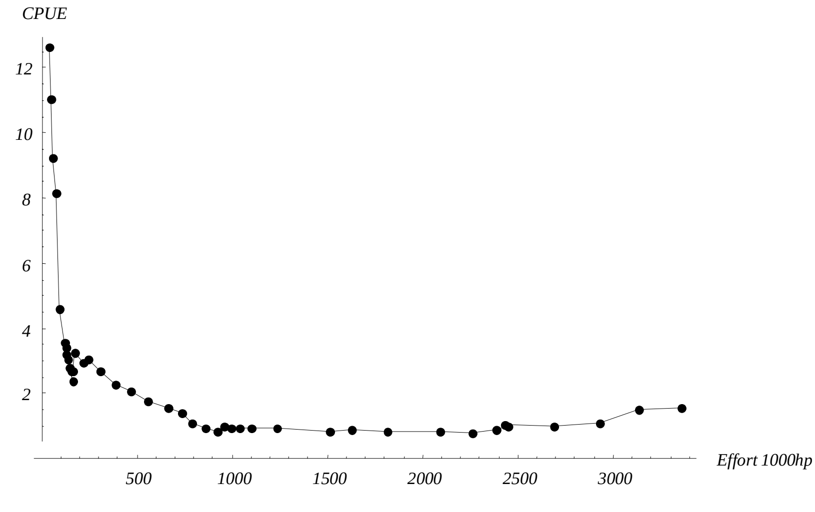


Fig. 4.2 CPUE of total catch versus effort

Figure 4.1 shows the general trend of total catch for all species in Bohai Sea. As fishing efforts increasing, total catch raised also. When the effort exceed 2300 hp, catch curve flip upward suddenly, by the end of 1997, the total catch almost reached the highest yield 5× 10^6 tons. But the CPUE (Fig. 4.2) for total catch showed the changes in three periods: firstly suddenly dropped down, secondly gradually decreased, and finally kept comparatively constant. More catch was gained by adding more effort, but the income didn't get a big change.

4.1.2 Small yellow croaker

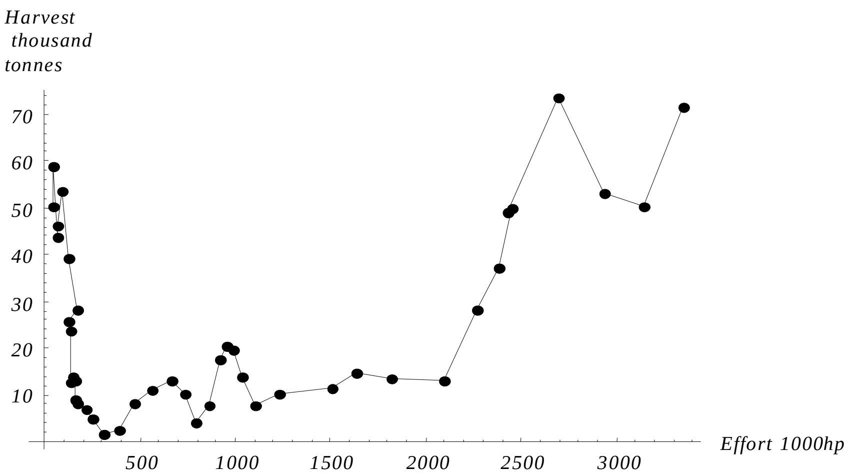
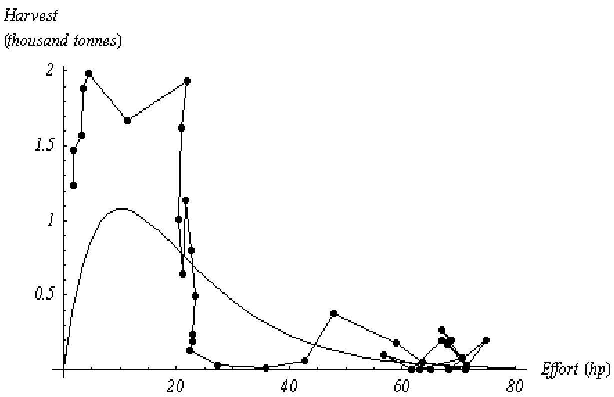


Figure 4.3 Catch for small yellow croaker versus effort

Fig.4.3 All catches for small yellow croaker started at very high points when efforts were very small, then rapidly dropped to the bottom, then fluctuate at those low levels with slight increases. The total trend shows that it has the same phenomenon, when the effort exceed 2100 hp, the catch risen sharply and reached the highest point, then give a big jerk and reverse. Let’s look at the catches in different areas for small yellow croaker.



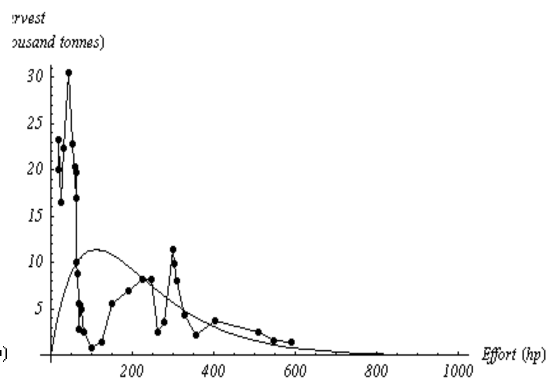


Fig. 4. 4 Catch curve for SYC in Tianjing

Fig. 4.5 Catch curve for SYC in Liaoning

Figure 4.4 and 4.5 showed the changes of catches in Tianjing, Liaoning. In general, both of them give the same impression that at the only beginning, the catches are much higher than maximum sustainable yields, then dropped down to the bottom points sharply, then hesitating at a very low level for a long time with slight increase. The observed catch in Liaoning has reached the predict point, then return to the very low level again. The situation in Tianjing area seemed different, the catch curve stayed at high points where are much higher MSY for a longer period with a bending, then jump down.

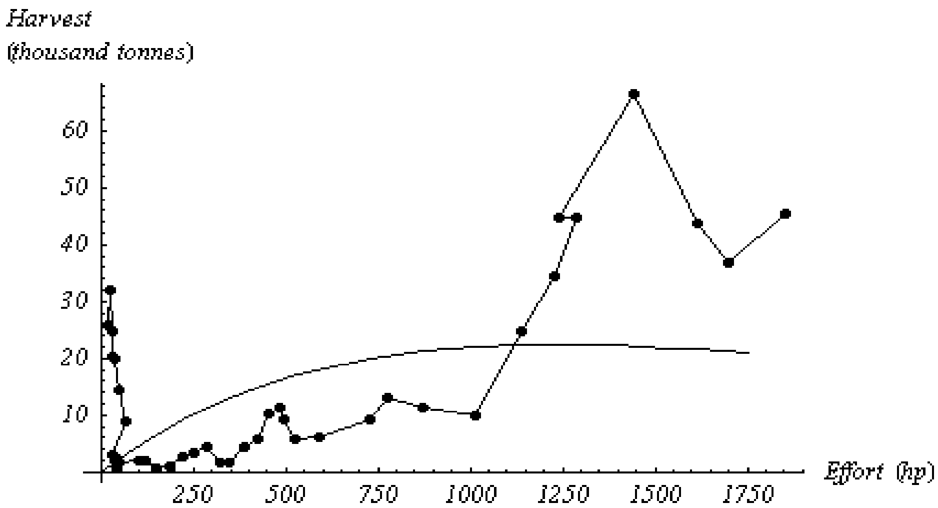


Fig. 4.6 Catch curve for SYC in Shandong

to the almost bottom point suddenly, and stay there for comparative longer time, then turn up over the predict catch point and turn down again. Finally stopped there with running circles at that low level. Figure 4.4 showed above for Tianjing seems reasonable, but the catch curve for small yellow croaker in Shandong seems very strange. The catch curve was fluctuating under the predicted curve for a long time except in first several years. After effort reached 1000 hp, it suddenly rose up and jumped over the MSY until the highest point, then jerk down again. It seems the catch of small yellow croaker got good gains in several good harvesting years, and suddenly suffered the bad situation like bad weather influence.

4.1.3 Hairtail

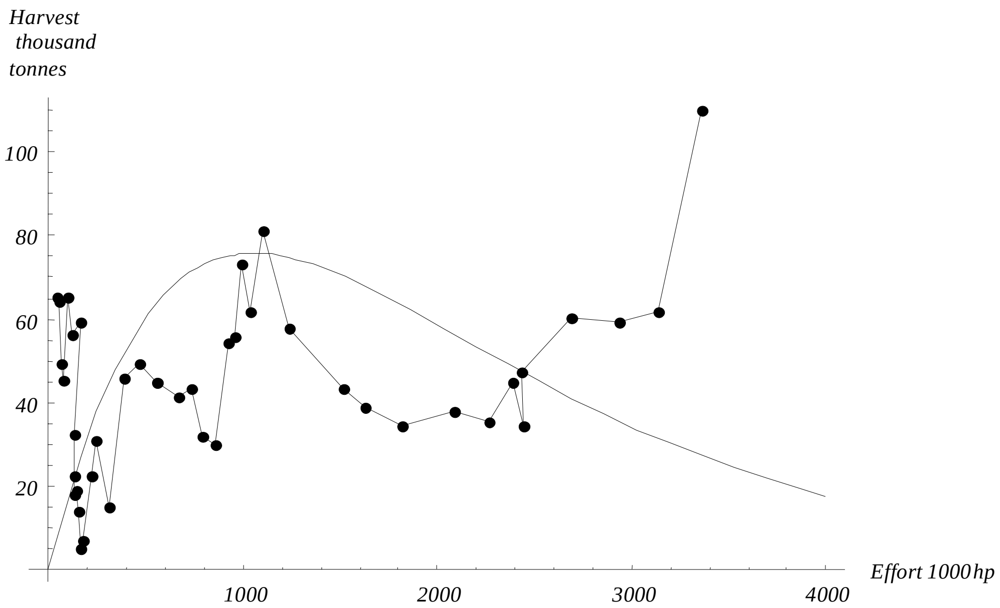
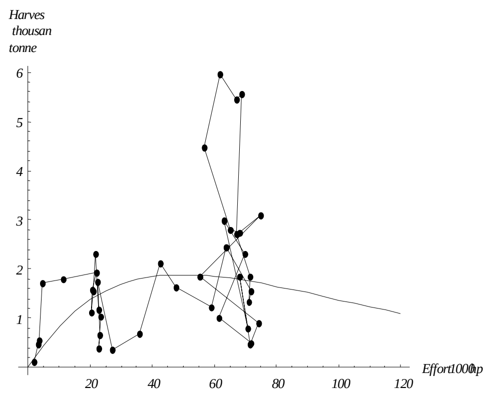


Figure 4. 7 catch for Hairtail versus effort

Figure 4.7 showed a general trend for total catch of hairtail in Bohai Sea. The same thing happened in hairtail also, the higher catches occurred at the beginning, then suddenly dropped down to the bottom point.



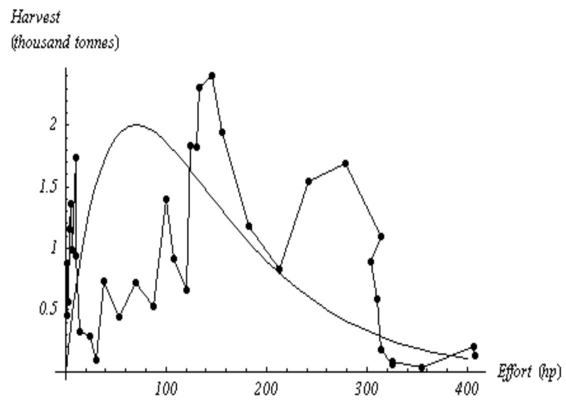


Fig. 4.8 Catch curve for HT in Tianjing Fig. 4.9 catch curve for HT in Hebei

The difference for hairtail comparing with small yellow croaker is the catches fluctuately increased, after reached MSY point, then turn back to a low level.

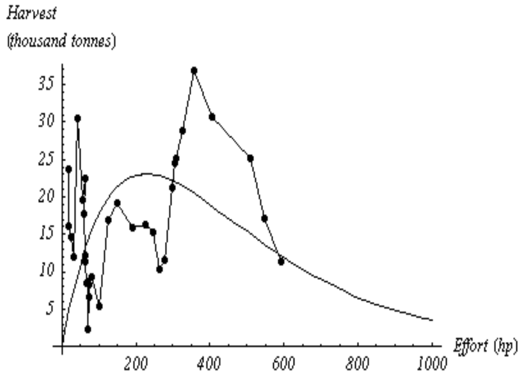


Fig. 4.10 Catch curve for HT in Liaoning

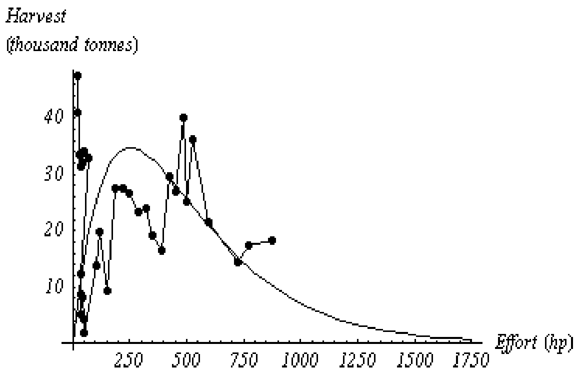


Fig. 4.11 Catch curve for HT in Shandong

fluctuating at the low level until suddenly rise when the effort approached 2600 hp. Let's look at the detailed information.

Figures 4.8, 4.9 show big differences in catches for hairtail in Tianjing and Hebei. In general, all observed catches in different areas at the beginning are higher than the predict catches. When the efforts increased, they dropped to the bottoms suddenly except catches in Tianjing which stopped at higher level a little bit longer (Fig. 4.8). Fig. 4.9 also show that after dropping down to the bottom, they arose again and then reached and exceed the MSY, experienced another reverse down irregularly up and down changes occurred. Figure 4.10 and 4.11 showed that the observed catches curves up and down with increase under predicted curves when using more efforts, but none of them reached MSY points when MSY efforts were given. Afterwards they sharply increased in catches, then dropped down dramatically with several fluctuations.

4.1.4 Chinese prawn

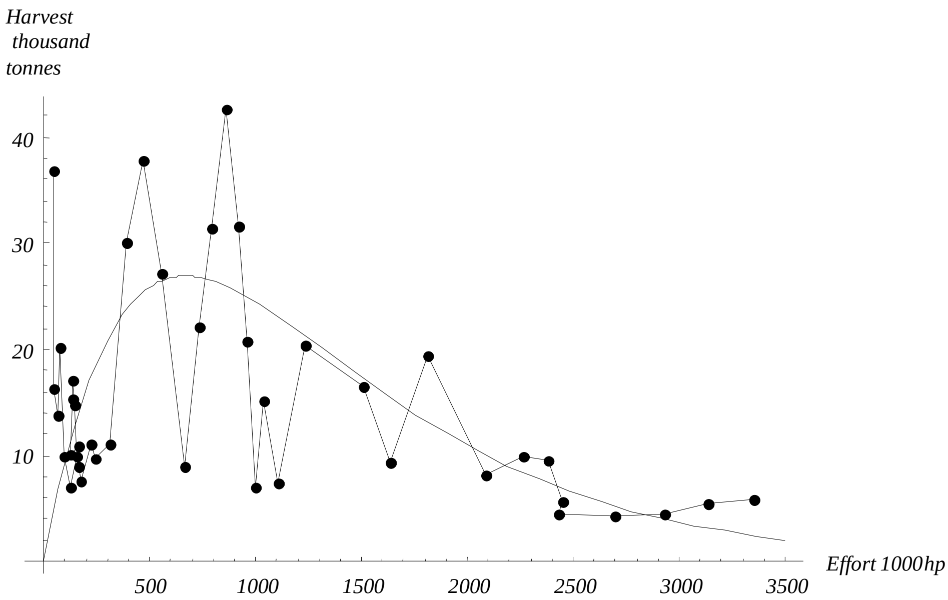
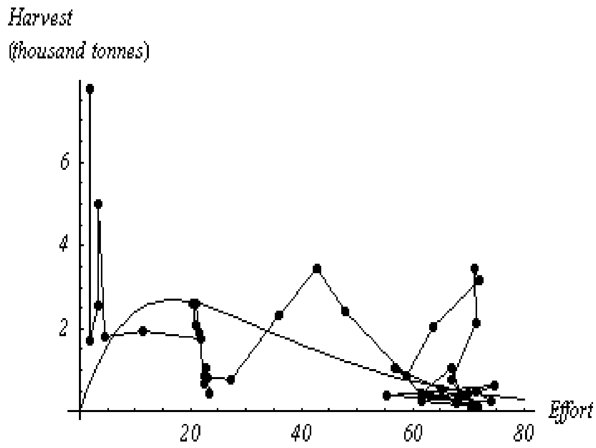


Figure 4.12 catch for Chinese prawn versus effort

Figure 4.12 showed the obvious features that after first dropping, dramatic up and down movements were running between the peak and bottom, and such movements gradually decreased and ended with a slight increase. Fig. 4.15 and 4.16 show the similar trends



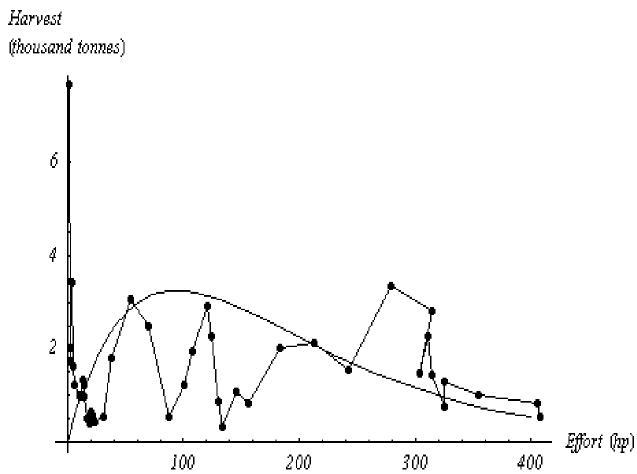


Fig. 4. 13 Catch curve for CP in Tianjing

Fig. 4. 14 Catch curve for CP in Hebei

for catches in Liaoning and Shandong with total catch curve for Chinese prawn in Bohai Sea.

Figure 4.13 and 4.14 showed the catch curves for Chinese prawn in Tianjing and Hebei, both of them dropped down from the high points at the beginning. The catch curve for Tianjing demonstrated very unique characters, the first one is the catch curve stayed at the level where the first drop occurred for a long time. Second one is that the catches seemed independent from efforts in periods of those the efforts were

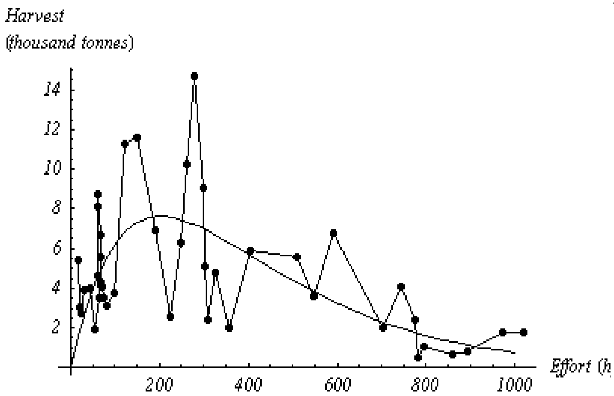


Fig. 4 15 Catch curve for CP in Liaoning

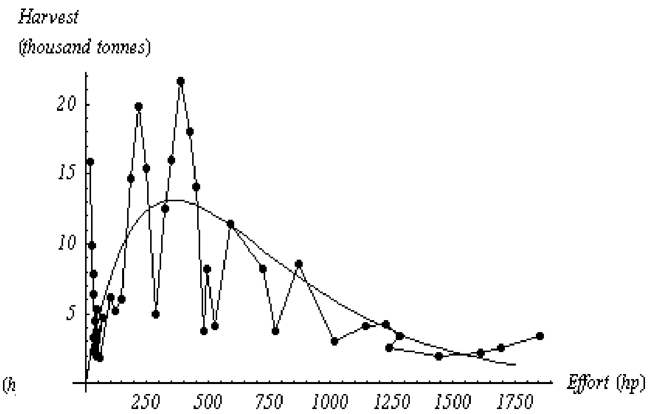


Fig. 4. 16 Catch curve for CP in Shandong

around 20 khp and 70 khp. The catches around in those two periods for long time. The catch curve for Shandong increased first dropping until slightly exceed the predict point, then decreased again with several fluctuations under the predict level until the effort reached around 260 Khp where the catches jumped up suddenly, after that catches decreased gradually.

4.1.5 Japanese anchovy

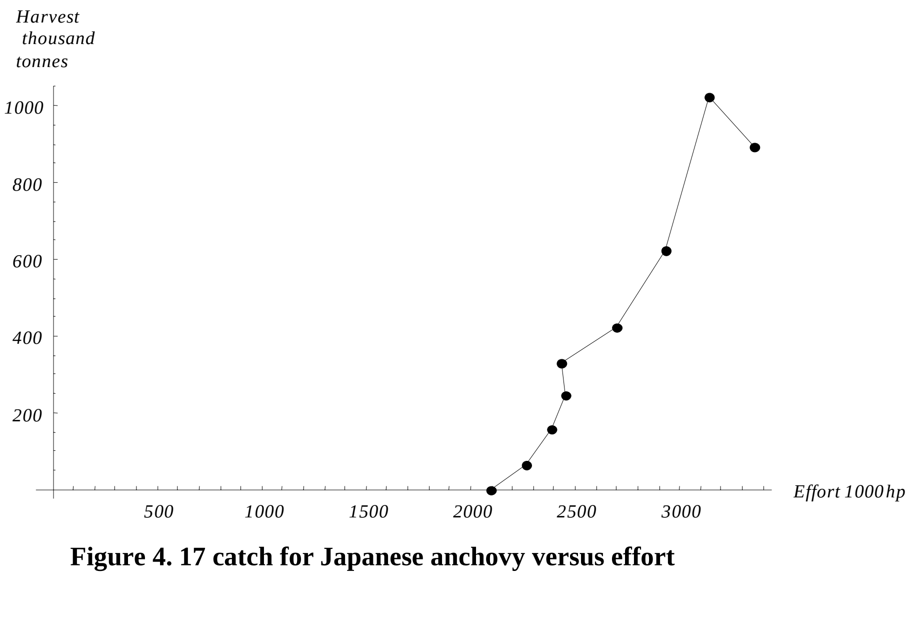


Figure 4. 17 catch for Japanese anchovy versus effort

In contrast, catch curves for Japanese anchovy showed opposite direction, which is the catches are low at the first period, then arise as the fishing power increasing, after reaching the highest point, dropped down.

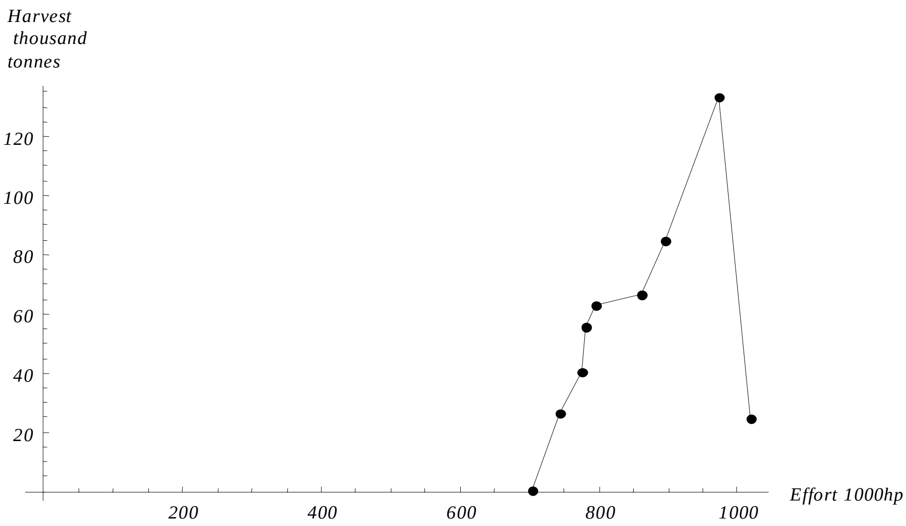


Fig. 4. 18 Catch curve for Japanese anchovy in Liaoning

Figure 4.17 showed that as the effort increasing, the observed catch curve is increasing until the highest point then gives a sudden reverse, and drop to a very low point.

Both Figures 4.17 and 4.18 showed the big drops after reaching the highest points.

4.1.6 Spanish mackerel

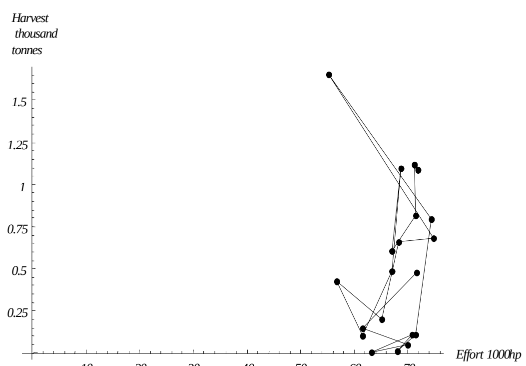


Fig. 4. 19 Catch curve for SM in Tianjing

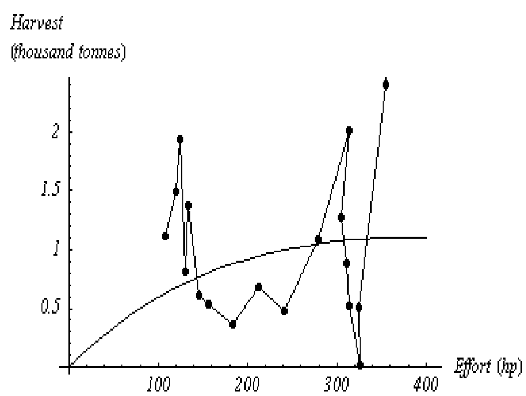


Fig. 4. 20 Catch curve for SM in Hebei

Figure 4.19, 4.22 showed the catch trends for Spanish mackerel in Tianjing and Shandong. They look quite opposite - it seems the catch in Tianjing is very independent from effort and the catch in Shandong really relies on the effort. When the effort are around 63 KHP, the catches in Tianjing pull up and down sharply. But the situation in Shandong is mostly like, as fishing effort increase, catches rise, and there is a big predicted rise at the ending point.

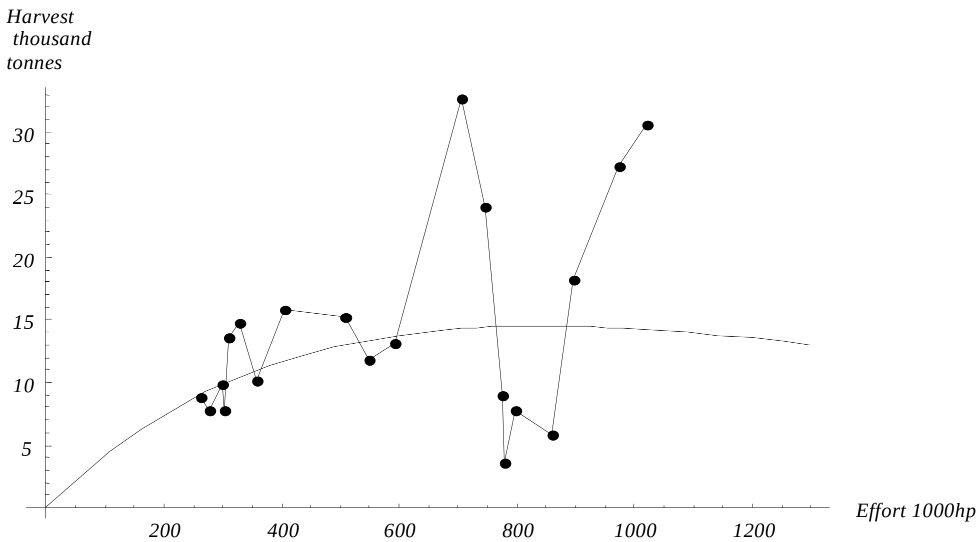


Fig. 4. 21 Catch curve for SM in Liaoning

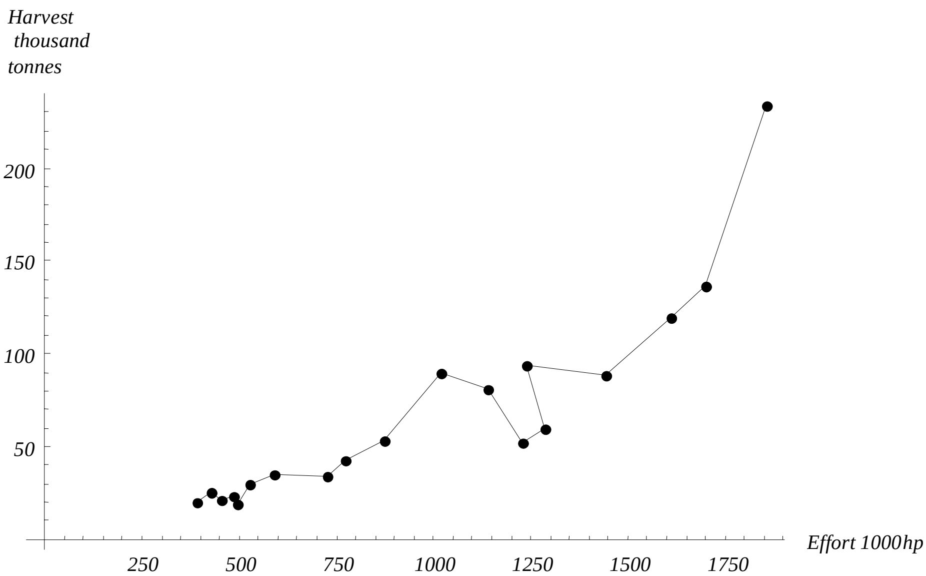


Fig. 4.22 Catch curve for SM in Shandong

The catch curves of Spanish mackerel for Hebei and Liaoning are different (Fig. 4.20 and 4.21). In general, both of them jumped up and down around the predicted curves, and both of them have big in crease at the ending points.

4.2 Estimations of parameters by applying the models

By applying the Fox model, the MSY for small yellow croaker, hairtail and Chinese prawn in different areas were gained (listed in table 4.1). Another pelagic species Le yu (Chinese name) is in the table as a contrast.

By using the linear model, we obtained the R^2, F_{Ratio}, and P-value. R^2 values tell us the regression between catch and effort, then one can estimate the reliability of MSY. According to the F_{Ratio} (large F-ratio indicates that the regression may be statistically significant) and P-value (the regression is significant at the 5% level), one can to determine to accept or reject the values of MSY.

Table 4.1 Estimations of MSY by using the model

Species	Small yellow croaker		hairtail		Chinese prawn		Le yu	
	MSY	R^2	MSY	R^2	MSY	R^2	MSY	R^2
Tianjing	1.076	0.6987	1.888	0.3188	2.684	0.6957	0.602	0.8488
Hebei	0.721	0.4118	2.002	0.7354	3.245	0.5776	0.506	0.7762
Liaoning	11.805	0.4966	23.736	0.7505	7.613	0.8698	0.621	0.5899
Shandong	22.336	0.0618	49.392	0.4552	13.155	0.8274	5.896	0.7545
Sum: (T+H+L+S)	35.938		77.018		26.697		7.625	
The whole area	31.344	0.3157	82.780	0.6415	26.909	0.8400	5.307	0.7609
Sum:(T + H)	1.737	0.5672	4.582	0.7374	5.593	0.6753	0.998	0.7220

MSY: thousand tons; T + H = MSY for (Tianjing + Hebei)

4.2.1 MSY for small yellow croaker

From the table 4.1, the overall value of MSY for small yellow croaker is 31344 tons, the values of MSY for those four regions were also obtained, sum them up, the total MSY is 35938 tons, the difference between those two values is 4594 tons. By examining the R^2, F_{Ratio} and P-value, the MSY (22336 tons) for small yellow croaker in Shandong has to be rejected, because it's R^2 is 0.0618, F_{Ratio} is 3.63397 and P-value is 0.064.

4.2.2 MSY for hairtail

The overall MSY for hairtail is 82780 tons, the value by summing up the MSY of hairtail for different areas is 77018 tons, 5762 tons difference between those two values. All values of the R^2, F_{Ratio} and P-value are in the acceptable range, therefor the values of MSY for hairtail are accepted.

4.2.3 MSY for Chinese prawn

It seems the values of MSY for Chinese prawn are much reliable, because the difference between the overall value and the value obtained by summing up MSY for this species in different regions is very small, just 212 tons. The values of the R^2, F_{Ratio} and P-value are well, so the results of MSY for this species are acceptable, the MSY value should be in 26697 ~ 26909 tons.

4.2.4 MSY for Japanese anchovy and Spanish mackerel

The values of MSY for Japanese anchovy and Spanish mackerel are not acceptable. The values of the R^2, F_{Ratio} and P-value are listed in table 4.2.

Table 4.2 F_{Ratio} and P-value for Japanese anchovy and Spanish mackerel

Areas	Japanese anchovy		Spanish mackerel	
	F_{Ratio}	P-value	F_{Ratio}	P-value
Tianjing			0.127853	0.724827
Hebei	4.36995	0.090849	0.749779	0.397941
Liaoning	1.84099	0.216962	5.47498	0.031014
Shandong	10.23160	0.015093	12.7557	0.002349

From the table 4.2, one may find that all values of F_{Ratio} for those two species are small, and almost all P-value are higher than 5% significant level except the values for those two species in Shandong region. Therefore the MSY for those two species are not obtainable by the data we have had.

5.0 DISCUSSIONS

Summary the fisheries in Bohai Sea, one may find that the fisheries in Bohai Sea have been undergoing such experience 'Due to unsustainable exploitation patterns, long-lived, piscivorous species with high trophic levels are replaced by short-lived planktonivorous and invertebrate species with low trophic levels in a time series of landings'. Then ' top predators are depleted'. Hence, ' decline in mean trophic level'. (Pauly *et al.* 1998).

The effects caused the changes in trophic level mainly come from two aspects: impacts form human activities and variations in natural environment. Meanwhile, fisheries in Yellow Sea and Bohai Sea have mutual influence with each other, Bohai Sea provides nursery and feeding ground to Yellow Sea, and Yellow Sea supports recruitment in fisheries to Bohai Sea. Such species shift happened in fisheries in both Bohai Sea and Yellow Sea. Tang (1989) analysis the reasons for the changes in Yellow Sea: The cause of decline in abundance for most demersal species in the Yellow Sea is due to extreme overfishing, the fluctuations in abundance for some demersal species may be affected by both natural and anthropogenic factors.

5.1 Impacts from Human Activities

5.1.1 High Fishing Intensity

Fishery is as vulnerable to human impacts, as any other environmental elements. One of the most important factors caused the decrease in fisheries abundance in Bohai Sea is the increase of fishing power. In 43 years (1956 ~ 1999), total fishing power in Bohai Sea increased by 84.12 times from 42739 hp to 3595063 hp. Under such incredible pressure, the yields could be pulled up in some extent although they didn't increase as much as the efforts did, and the catches could be much higher than their MSY under the precondition of sacrificing the resources. So under such extremely big fishing pressure, it is certain results that the resources in Bohai Sea have not been destroyed. Therefore, the reason caused change in species biomass in year’s series in Bohai Sea is the increase in fishing efforts. The fisheries resource in Bohai Sea has degraded seriously. The results from 4 times surveys (Jin & Tang, 1998 and Jin, 2001), conducted by the Yellow Sea Fishery Research Institute, Chinese Academy of

Fisheries Science respectively in 1959, 1982-83, 1992-93, 1998-1999, evidently show that fisheries in Bohai Sea have changed significantly in species, biomass and foodweb.

5.1.2 MSY and Commercial Catches

5.1.2.1 Total Marine Catch and Total Effort

Generally, the marine catch in Bohai Sea fisheries steadily increased in the whole period. The yields arrived at the highest point 3239700 tones in 1998. Because the efforts were steadily increasing. In 43 years from 1956 to 1999, total fishing power in Bohai Sea increased by 84.12 times, but the catch increased by just 12.51 times. Among those four areas, effort in Hebei is the biggest one with 286.20 times in increase, the average increase for those four areas in fishing power is 121.17 times. Under such fishing pressure, the catches were pushing up, simultaneously the shifts in dominant species following from small yellow croaker to Japanese anchovy. For instance, the yield for Japanese anchovy from both Yellow and Bohai Seas increased sharply in 1990's; the yields in 1997 and 1998 exceeded 1,000,000 tons, and became the single-species with highest yield in Chinese marine fisheries. According to investigation by acoustic estimation, the recruitment for Japanese anchovy in Bohai and Yellow Seas changed in a big decrease.

The values of f_{MSY} and MSY for small yellow croaker, hairtail and Chinese prawn listed in table 5.1 below are used to explain the reasons of changes for those species.

Table 5.1 Comparisons between the values of efforts and catches

Species		Tianjing	Hebei	Liaoning	Shandong	T+H+L+S	Whole area	T + H
Small yellow croaker	f_{MSY}	10.265	59.869	244.292	1231.42	1545.846	771.901	70.134
	MSY	1.076	0.721	11.805	22.336	35.938	31.344	1.737
	C_{LAST}	0.006	3.165	22.885	45.376	71.426		3.171
	$C_{HIGHEST}$	1.989	4.807	30.428	66.400	71.426		6.796
Hairtail	f_{MSY}	49.512	70.369	256.545	599.383	975.809	981.988	119.881
	MSY	1.888	2.002	23.736	49.392	77.018	82.780	4.582
	C_{LAST}	0.500	0.130	15.508	94.027	110.165		538.079

	$C_{HIGHEST}$	5.967	2.410	36.791	94.027	110.165		8.377
Chinese prawn	**f_{MSY}**	16.842	94.186	204.277	359.107	674.412	667.804	111.028
	MSY	2.684	3.245	7.613	13.155	26.697	26.909	5.593
	C_{LAST}	0.116	0.553	1.759	3.467	5.895		0.669
	$C_{HIGHEST}$	7.777	7.635	14.693	21.692	42.726		15.412
Sum up f_{MSY}		**76.619**	**224.424**	**705.144**	**1081.632**	**3196.067**	**2421.693**	**301.043**
f_{LAST}		77.871	460.208	1211.995	1844.990	3595.063		538.079

5.1.2.2 MSY and Small yellow croaker

According to the results listed in table 5.1, the MSY for small yellow croaker should be in 31344 ~ 35938 tons. If the fishing catch could be maintain in this level, the resource of small yellow croaker may biologically be harvest in a sustainable level in long term. But in practical work, the highest catches are about 2 times (1.99 - 2.28 times) higher than the values of MSY. Check those highest catches for those four regions, one may find no one is lower than their values of MSY, the resource of small yellow croaker was overexploited. So in 16 years from 1956 to 1972, the yields dropped by 48696 tons, 96.98% decrease, and the catch in 1972 just account for 3.02% of it in 1956.

The catches began to arise in catch in 1990's until reached the highest point 71426 tones (Fig. 4.3) in 1998. It seems the resource of small yellow croaker recovered in Bohai Sea, but when catches in different areas were figured out, one may surprisingly find the increase in total catch for this species is just caused by the catch in Shandong (Fig. 4.5). The fleets in this region were fishing from both Bohai Sea and Yellow Sea. The catch flipped downward in 1995 - 1996 with 20498 tones, 27. 84% decrease on the level of 73637 in 1995, such drops mainly happened in Tianjing and Hebei, and no catch was available in Tianjing since then. For the catch data for Tianjing and Hebei are mainly from Bohai Sea, so one can think those data give a real illustration for the fishery status of small yellow croaker in Bohai Sea.

From those data, one also can find, the resource of small yellow croaker dramatically changed by the end of 1990's, mainly attribute to the big fishing effort.

5.1.2.3 MSY and Hairtail

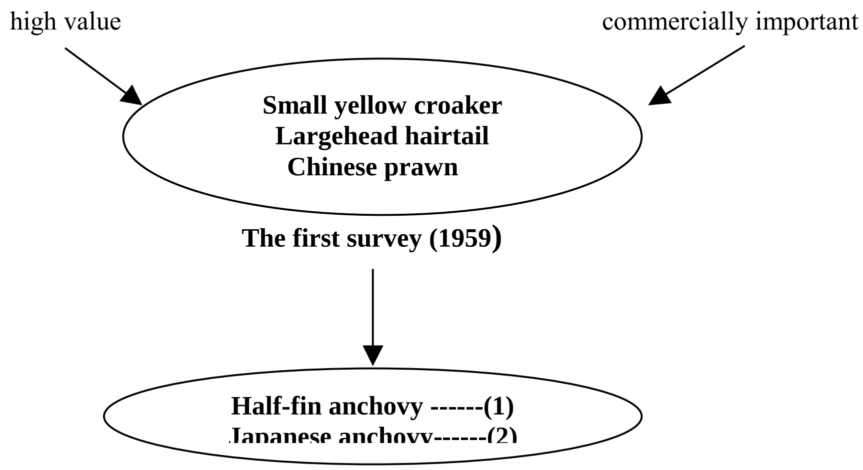
The values of MSY we caculated for hairtail should be in 77018 ~ 82780 tons, but the results tell us the observed values are much higher than MSY, the number of catch by summing up the catches of the four regions is by 33147 tons, 43.04% higher than MSY. Under such fishing intensity, overexploitation is a certain outcome, the abundance of this species decreased. The last catches for this species give evidences, the alst catch in Tianjing is only 500 tons, but the catch in Shandong is still exclusive example. The highest efforts in those four areas are last efforts which come along with last catches, but the last catches shored in Fig. 4.8, 4.9, 4.10, 4.11 are far more lower than the values of MSY.

5.1.2.4 MSY and Chinese Prawn

The estimation for Chinese prawn tells us that the value of MSY should be in 26697 ~ 26909 tons, but the highest catch for those four regions is by 1.6 times, 16029 tons higher than MSY. Checking the catches for those four areas, one may find that all of them are much higher the values of MSY, particularly the catch in Tianjing, it is 2.90 times higher than it's MSY. The resource of Chinese prawn has obvously been overexploited, so the last catch for those four regions is only 5895 tons, it is far away from the estimating value, all catches for those four areas decreased to a very low level. The Chinese prawn industry which has been so strongly supporting the fisheries in past time in Bohai Sea now lost the significance.

5.1.3 Evidences from Scientific Surveys

5.1.3.1 Dominant Species Shift in Decades



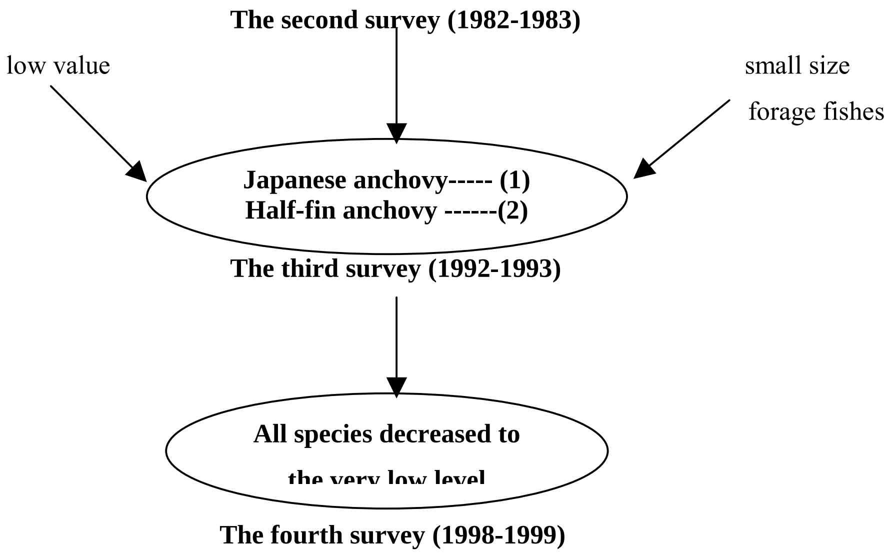
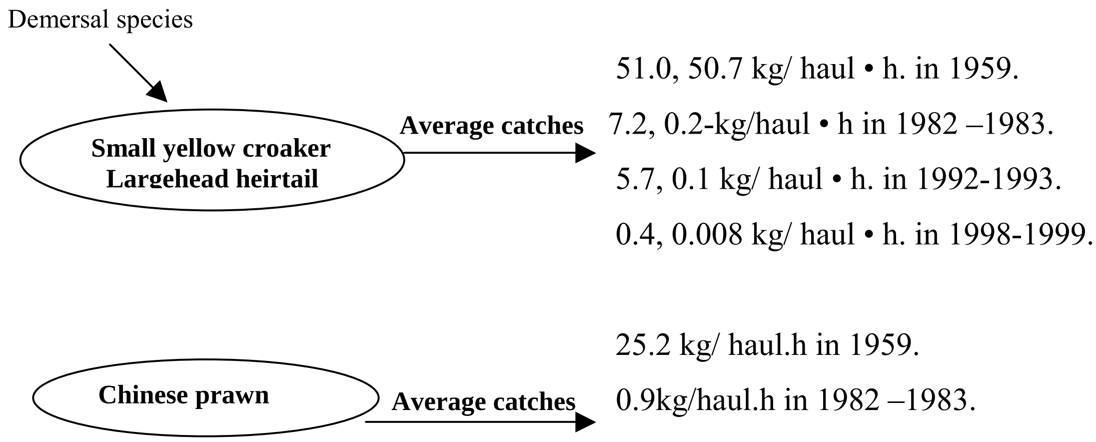


Figure 5. 1 the shifting of dominant species in Bohai Sea

Under extremly big fishing pressure, the fisheries resources in Bohai Sea, specially some traditional high-valued species, small yellow croaker, hairtail and Chinese prawn, have been overfished, and that have been replaced by some low-valued species, primarily smaller pelagic species, such as Japanese anchovy, half-fin anchovy. The CPUE declined from 2.39 tons/ kilowatt in 1950's to 0.91 tons / kilowatt in 1990's. And as the fishing efforts were increasing further, the species shift is still going on, the future of fisheries in Bohai Sea became unpredictable.

5.1.3.2 Biomass Decreased Remarkably

In accordance with the species shifting, the population, distribution and the whole ecosystem in Bohai Sea have been entirely changing also, eventually all species in abundance decreased to a very low level.



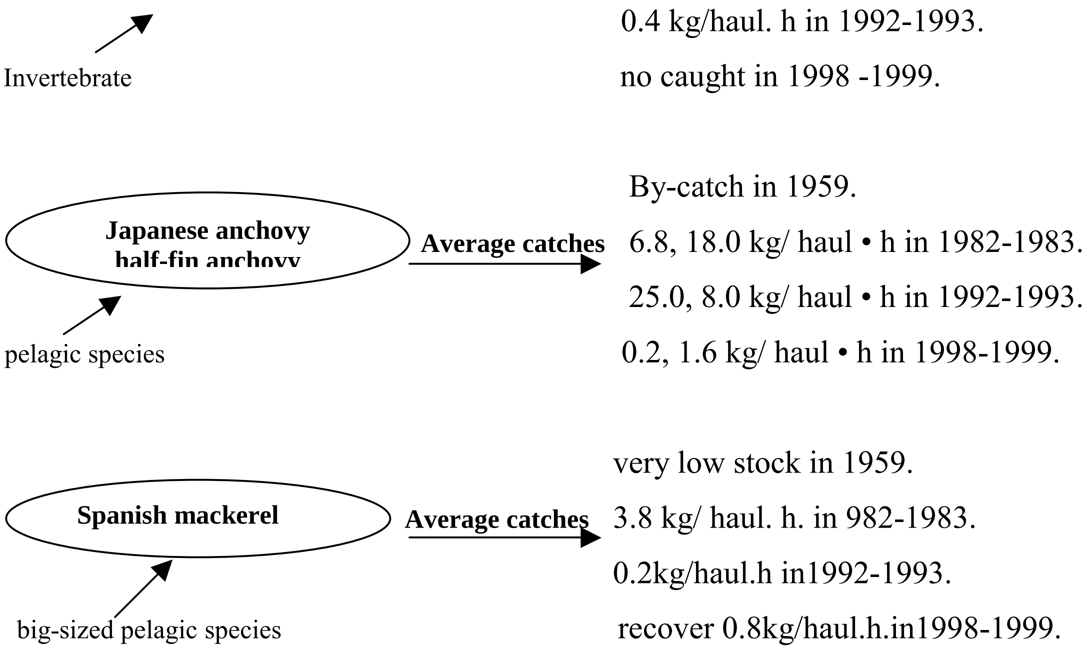


Figure 5. 2 the changes in biomass

5.1.3.3 Destruction of Some Food Chain

The species on the top of food chain system in Bohai Sea were some big sized demersal species, like hairtail, but it was fishing down under big pressure of fishing effort, and replaced by small sized, lower level, pelagic and forage species like Japanese anchovy - feed for many carnivorous species. In such situation, fishing forces had to change their target to those species, and once more those species decrease to a very low level, many carnivores species like Spanish mackerel, which fed by those pelagic species, decrease due to their food system broken

5.1.4 Factors Behind Fishing Intensity

Do we need to put so much fishing power to our fisheries resources? More yields can be gained by adding more fishing efforts? Obviously the answer is no, but why did it happen?

5.1.4.1 Policies and Fisheries Development

In the period of 1958-1978, the principles for developing fisheries in China were "promote both in marine and freshwater fisheries, develop fisheries both in aquaculture and exploitation". But in practical works, focuses were put on marine fisheries and fishing industry, freshwater fisheries and aquaculture were ignored.

During this period, the fishing effort in Bohai Sea increased from 61313 to 791036 hp, almost 13 times bigger than it is in 1958 in 20 years, the similar things happened in other seas in China then, so the proportion of catch from marine fisheries in national yield occupied for than 60% before 1980s (Nie, 2001). But the fisheries resources status in Bohai Sea were not clear, because only one scientific survey was given during 1958 - 1988. As the ' blind ' increasing of fishing power, the catches were getting exceed the renewability of resources, the resources of small yellow croaker, hairtail and Chinese prawn were quickly fishing down during this period, as such overexploitation happened on other species in other China's seas. Although the quantity of catches was increasing, it was decreasing in labor productive ratio, economic gains and catch quality. Fisheries resources were destroyed.

5.1.4.2 Failure in Top-down Management and Beaucratic System

In order to stop further collapse of the fisheries stock, the inshore trawl fishery has been suspended since 1982. A license system was also introduced to stop further increasing of fishing effort, but those measures didn't work well due to the weakness of administration (Ye, 1996).

Traditional approaches of fisheries management have been established by national governments in fishery laws and regulations. But they have been proved in inadequacy for the management of coastal fisheries. With the top-down management regime, fishery resources are under common property or open access and are often subjects to overexploitation and degradation, due to over-capitalization, efficient technologies and lack of proper management (Pomeroy, 1998). As the role of the government in fisheries management is strengthened, the function of local level control through traditional, informal management and customs has been diminished correspondingly. As a result that many laws and regulations have been in weak enforcement or been compromised. Such circumstances in Bohai Sea are not exclusive.

In China, the coastal lines along those four seas are 18,000 kilomiles, the economic zones are 3,540,000 square miles, and all those resources belong to the state. Under the top-down management, fisheries resources actually are common properties, all companies and individuals who have ability to access the fisheries can share such 'common resources', although Chinese government has issued the relative laws and regulations. Weakness in enforcement and beaucratic system made those laws and regulations at a loss, examples come from those aspects following:

The limiting of fishing power Chinese Agricultural Ministry had given the regulation in limiting fishing boats (for instance, number of fishing boats, boats size, engine power and etc.) in inshore fisheries in 1987. But 32,000 new boats, 880,000 fishing power were still out of control and joined in national fisheries that year. According to the national plan, the fishing power in all China's Sea in 1990 should be 88,029 in fishing boats, 3,659,000 hp in fishing engine. But in fact, the number of those in that year were 169,400 in fishing boats, 6,345,000hp in fishing engine, with the increased of 92.4 % in the number of boats and 73.4% in fishing power (Nie, 2001). Management was out of control.

The system of fishing license The licensing systems for joining fishing and new boats building began to carry out in 1980, but because of lacking of management and enforcement, a quantity of boats and companies, which do not have licenses, have been undertaking their businesses. It is reported by He (1999) that there were just 4 manufactures in Hainan which had license to build new boats, while more than 100 boats were built or repaired by more than 80 factories which didn't get any permission. Meanwhile, those people who did not have right to run such business handed out more than 100 new boats in Guangdong province.

Most of these problems encountered with the fishery are related to the enforcement of policies and management under the top-down regime in fisheries development. Governments play the roles of supervisors without the local preferences or small – scale fishers participated in management. The people who are struggling with livelihood and mostly in the driving of benefits in continuous competition for the resources due to effort increasing and resources degradations are people who likely break the laws and regulations by using of dynamite, crushing of corals or destroying of mangroves.

It is increasingly recognized that the responsibility for management should not rest with governments alone but rather be a shared responsibility, involving those operating in the fisheries sector as well as others who consider they have a right to participate in decisions concerning humanity's natural heritage (FAO, the state of world fisheries and aquaculture, 1998).

5.1.4.3 Population, Employment and Livelihood

The coastal zone is home to the majority of the world's population. As much as 66 percent of the world's population lives within 40 miles of the shore, and coastal populations are growing faster than the global population as a whole. Migration from rural to urban areas in China has led to heavy population concentrations and the development of industry in coastal areas. An estimated 40% of population lives along coasts, and 60% of China's GDP is produced in coastal areas.

Bohai Sea is continental sea surrounded by several big provinces that have big populations concentrated. The total coastal population along Bohai Sea is 46,560,000, the population density is 419 people/km^2, and the density for sea surface covers 582 people / km^2 (total surface area in Bohai Sea is 80,000 km^2). Under such population pressure, any fish stock could be 'eaten out' if without any limitation. For example, forage fishes in other developed countries could be feeds for carnivorous species and other animals. But in Southeast Asia, small pelagic fishes, such as mackerel, anchovy and sardines, provide an important protein source for people. The demand for small pelagic fish for direct human consumption is likely to increase with population growth in the developing country[1].

For most people in coastline of Bohai Sea, particularly local fishermen and the labors released from agricultural mechanization in inland, fisheries are their livelihood; fish provide them the essential protein. So in some way, one may say the fisheries are their life, if fisheries collapsed, they would lose their resources for life they rely on.

These heavy concentrations of human settlement, intensive employment and industrial activity along coastal areas have placed enormous pressure on marine ecosystem.

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[1] (http://www.earthvoice.org/animal.habitat/coastal.ecosystems.htm)

With more and more people crowding next to the shorelines, the growing threat to coastal ecosystems is particularly acute. And the loss of its biodiversity may have repercussions beyond our worst fears[2].

5.2 Causes from Environmental Changes

It is now realized that overexploitation has been the main cause of shifts in resource population in the Bohai Sea ecosystem. However, the changes of natural conditions may have had an important effect on the long-term changes in dominant species in biomass and distribution. The changes in abundance of the species of different ecological types are correlated with environmental variability (e.g. temperature) (Tang, 1989).

There are two types of species shift: one is systematic replacement; the other is ecological replacement (Xia, 1978). In systematic replacement, when one dominant species declines in abundance or is depleted due to overexploitation, another competitive species like Spanish mackerel in Bohai Sea or species which have been depressed when other species are dominant now released from such pressure like forage species Japanese anchovy and half-fin anchovy, and would have an opportunity to use surplus food and vacant space to increase its abundance. In ecological replacement, minor changes in natural environment can have major consequences for stock abundance, especially for pelagic species. In the long run, the effects of the two may be mingled, for instance, Peruvian sardine which disappeared under both factors of big fishing pressure and environmental changes.

So decrease in biomass and the shift in dominant species in Bohai Sea could be caused by the factors from those two aspects. In such situation, the cause of changes in population becomes impossible to pinpoint (Tang. 1989).

5.2.1 The Temperature Factor

In Bohai Sea, the animals are mainly warm-temperate species, with some cold-temperate components (Chen. 1997), so water temperature is the major factor

[2] (http://www.earthvoice.org/animal.habitat/coastal.ecosystems.htm

influencing the migration of fish in the Boahi Sea (Deng *et al. 1988a;* Liu*, et al., 1990).*

As we have known, the mean depth in Bohai Sea is only 18m; seasonal changes in natural condition such as temperature are very obvious in a year. The isobaths in Yellow Sea run chiefly in the north-south direction and the central part of the sea is traditionally called the Yellow Sea depression with depths in the range of 70m-to 80m. This is the major overwintering ground for most fish and invertebrates from both Yellow Sea and Bohai Sea. Most fisheries species in Bohai Sea are migratory, particularly small pelagic species are sensitive to the some marine ecosystem variations. So many species in Bohai Sea have such regular migration between Yellow and Bohai Seas during years.

As a rule, the migratory species gradually reach the Bohai Sea in spring for spawning, feeding and growing, and then completely move out when the temperature decreases close to their thermal tolerance limit in late autumn. The resident species remain in the Bohai Sea for wintering, and the number of species is reduced. Therefore, seasonally different demersal fish assemblages with respect to species richness, diversity, evenness, composition and biomass are mainly caused by changes in bottom temperature. The temperature variation appears to have a considerable effect on the population distribution (Chao, 2001)

If it is in normal condition, such seasonal migration is regular. As the pollution in marine environment in Bohai Sea is increasing, the fishes migrated out of Bohai Sea do not come back again. So at present, seasonal biomass just accounted for 3.5% - 22.5% in the same seasons in 1992-1993 (Jin, 1998). Small pelagic species, such as Japanese anchovy, which has been most important species in yield, has had big drop, it now is just 0.8% of yield in 1992. Other pelagic species, like half-fin anchovy, have decreased in a certain proportion also.

5.2.2 The Factor from Fisheries Resource

Comparing with other countries' marine resources, the characteristics of marine fisheries resources in China are:

♦The number of species in inshore are more than it in offshore, because the distribution of plankton in China shelves is that the biomass inshore is higher than it in offshore, especially the highest dense occurs in estuarine, so the fisheries in inshore have more species than offshore.

♦ There are more demersal species rather than pelagic species in China’s fisheries. The traditional fishing species like giant yellow croaker, small yellow croaker, hairtail, pomprey and etc. are demersal, carnivorous species with long-life in inshore fisheries, so they are easily overexploited and cause the degradation in resources.

♦China fisheries are characterized of complex ecosystem with more species and small biomass in each species, due to the lacking of the exchanges of strongly cold currency and warm currency and deficiency of upwelling currency.

The primary productivity in American Jorge Bay and Barents Sea are 300-470g C/ m^2/yr. and 200 g C/m^2/yr.. The primary productivity in Bohai Sea is 90-112 g C/m^2/ yr. (Deng, 1988), the level is lower. According to the report (1987) by Chinese Academy of Fisheries Science, annual average catch in China's seawater shelves is only 3.8 tones /square mile.year, but it is 11.8 tones in Japanese coastal fisheries, 18.2 tones in the South Pacific Ocean, and 4.7 tones in European Northern sea. The energy exchanges in Bohai Sea is lower also.

Cui, Y. et al (1996) studied the status of biological and physical environment in Bohai Sea and gained the conclusion that the nutrition level in Bohai Sea is low or moderate.

Summary the characters above, one of reasons for fisheries overexploited easily in Bohai Sea could attribute to the condition of natural resources.

5.2.3 The Influence from Recruitment

Because of a strait connecting to Yellow Sea and Bohai Sea, the changes in fisheries resource in Yellow Sea directly influence the biomass and distribution of fisheries resource in Bohai Sea. And the fluctuation of fisheries in Yellow Sea gives important influence to the recruitment for the Bohai Sea resource.

The stock of Japanese anchovy in the Yellow Sea has dramatically increased in the late 1980s when most large-sized species have been overfished. Fisheries highly depend on the small-sized pelagic species, particularly Japanese anchovy with yearly increase of catch by 20-83% in the Yellow Sea in recent years must influence the spawning stock migrating into the Bohai Sea. The anchovy fishery has shown considerable increase in proportion of one year fish, more than 90% of catch from the Yellow Sea was recruitment in spring in Bohai Sea in 1998 (Li, 1998), indicating a dangerous situation for this stock that may cause recruitment failure in the Bohai Sea. In addition, most other commercially important species in the Yellow Sea have been overexploited that can reduce the spawners into the Bohai Sea. Lacking spawning stocks would result in significant decline of biomass in Bohai Sea.

Due to the great increase in fishing effort, especially after the late 1950s, the area fished came to encompass the entire Yellow Sea, and by the mid 1960s nearly all the major stocks were heavily fished. Since then, fishery resources in the sea have greatly changed (Xia, 1978; Liu, 1979; Chikuni, 1985). Overexploitation has led to decline in abundance or depletion of many major stocks in the Yellow Sea, especially of demersal species such as small yellow croaker, hairtail, large yellow croaker, flatfish, and cod. The proportion of the catch for these target species to the total decreased from 35% tin the 1950s to about 10% in recent years (Tang, 1989).

The situation in Bohai Sea is that the dominant species, which mainly are low-valued pelagic fishes in 1980's, have replaced the carnivorous species, which are high-valued benthic fishes such as small yellow croaker and bighead hairtail in 1950’s- 1960’s. The dominant species in these small pelagic fishes are still continually shifting.

Such variations in abundance and dominant species are in accordance with the changes in Yellow Sea.

Small yellow croaker is the most commercially important demersal species in Yellow Sea. The catch reached about 200,000 Mt in 1957. However, as young fish were heavily exploited in the overwintering ground, the catch of young fish accounted for 40-60% of total catch of this species during the period 1957-1964. The catch has sharply decreased since the mid 1960s (Tang, 1989). The present catch is only 30,000-40,000 Mt in which young fish aged 0-1 year account for 80% (Lee, 1977; Liu, 1979; Anonymous, 1986b).

And the catch for small yellow croaker in Bohai Sea has been 58899 tones in 1957. But the yield in 1972 is 1514 tones, just accounting for 2.57%, one-thirty ninth of it in 1957. Such sharp decrease in catch simultaneously happened in Bohai Sea in the mid 1960s.

Hairtail is the second commercially important demersal species in Yellow Sea. The catch of this species reached peak of 64,000 Mt in 1957. But due to the increase in fishing effort and intensive fishing of spawning stock and young fish during the late 1950s and early 1960s, the catch has declined sharply since 1964. Stock in the 1970s was estimated to be only one-thirtieth of its previous level) (Tang, 1989). And since 1965, in fact, the hairtail stock in Yellow Sea has become a non-target species. Hairtail caught there is a feeding stock migrating from the East China Sea in autumn (Lin, 1985)

The catch of hairtail in Bohai Sea has reached 65287 tones in 1956, it became 5172 tones in catch in 1969, the reduction is more than 11 times in 13 years, only one-twelfth of its original level in 1956.

In addition, the hairtail species is resource that can afford a bigger fishing pressure. The disappearance of hairtail stock in Bohai Sea seem not completely attributing to the overexploitation, the distribution in ecology could be one of factors (Deng, 1988).

The pelagic species shifts in dominance in Yellow Sea are also outstanding. Environmental conditions are the primary cause of fluctuations in recruitment (Tang, 1989). The dominant species in the 1950s and early 1960s were small yellow croaker and hairtail, when pacific herring and chub mackerel become dominant during the 1970s. Some small-bodied, fast-growing, short-lived, and low-value forage fish (e.g., half-fin anchovy, and scaled sardine) increased markedly around 1980 and have taken a prominent position in the ecosystem.

Such phenomena occurred in Bohai Sea in accordance with it in Yellow Sea. It can be explained by the theory of predator-prey. The bimass of those small-size pelagic species as prey were controlled by the big stock of predator species when they are dominant. After predators are fishing down, the pressure on prey species is released, the biomass of prey species expanded. And usually such replacement is not reversed until another predators appear occupying the position of original predator species. As a result, some large –sized and high trophic level species were replaced by those small-bodied and lower trophic level species, causing the fishery resources in the ecosystem to decline in quality (Tang, 1989).

Spanish mackerel as a new predator in both Yellow Sea and Bohai Sea have tended steadily to increase both in abundance and catch since the species began to be utilized. Available data (1978-1997) for this species in Bohai Sea show such increasing trends, the catch 31001 tones in 1978 roused until it is 266919 tones in 1997, 8.61 times growth in 20 years, it could be thought a big increase for predator species. The reason for this is due to an unusual combination of natural and social-economic conditions (Tang, 1989). The disappearance of depression from original predator and the expanse of food fish species could be other reasons.

5.2.4 Pollution

Many studies have found that pollution can reduce diversity of fish community (Wilhm and Dorris, 1968; Bechtel and Copeland, 1970). One possible reason for the reduces of diversity in the 1992-1993 in the Boahi Sea was due to the increase of pollution caused by coastal mariculture of shrimp. Large-scale shrimp aquaculture has developed rapidly (10-fold in area) over the past ten years. A great quantity of waste of feedstuffs and excrements of shrimp has been drained directly to the sea, and this has often been associated with frequent appearance of red tide (Liu, 1993). In addition, the increasing pollution from coastal chemical and marine petroleum industry (Tian *et al.* 1991; Zhang, 1993) maybe another important source though the effect of mechanism of pollution on the community structure.

The decreases of dominant species and variation in species composition are indications that the ecosystem has degraded. Composition of fisheries is comprised by the species that can adapt bad environment and life –circle is shorter, size becomes smaller.

There are two sources for pollution in Bohai Sea:

- ♦ The pollution comes from industry disposal and domestic sewage.
- ♦ The pollution comes from marine aquaculture

5.2.4.1 Industry Disposal and Domestic Sewage

The remarkably reduced biomass in the Bohai Sea may correspond to high fishing intensity but can not be all attributed to it, pollution from industry disposal (such as from chemical factories, oil industry) and domestic sewage could be the factor for the inevitable compromise between conservation and exploitation in fisheries.

Pollution loadings are greatest near the coast. It is reported (Beijing Youth Daily, 2001) that 6.1 billion tons of domestic sewage and 5.6 billion tons industrial disposal flow into the Bohai Sea in the year 1999. If those numbers are divided by the area of Bohai Sea, the degree of pollution in Bohai Sea are obviously highest. The Figures 5.1 and 5.2 following show the degrees of pollutants drained into the seas.

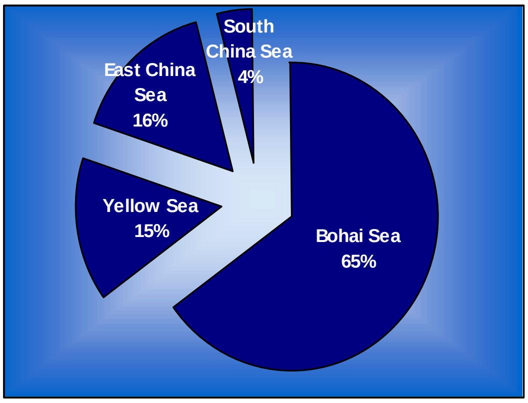

Fig. 5.1 The proportions (%) of domestic pollution comparing with sea area

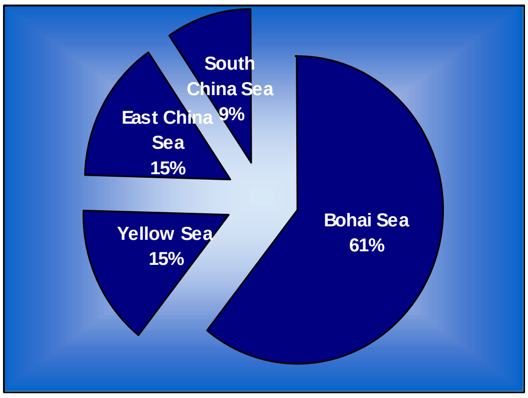

Fig. 5.2 The proportions (%) of industry pollution comparing with sea area

The main pollutants include organics, petroleum, peroxide, chloride and inorganic nitrogen and metals. Of the metals, zinc, arsenic and chromium are the most prevalent. The bottom sediment concentrations are at seriously high levels (She, 1998).

Since the water exchange in Bohai Sea takes 16 years, this suggests that the Bohai Sea has a very limited capacity for assimilating the industrial pollutants those may contain some toxic contaminants. These contaminants may have been linked with mortality, malformation, reduced hatching success, growth and mobility, development a normality and chromosome aberrations in fish eggs and larvae contaminated at the surface, and reproductive problems and reduced immune and endocrine systems in marine mammals. The effects on marine communities of chronic exposure to the high concentrations of contaminants can disrupt the metabolic regulatory, or disease defense systems of an organism, eventually compromising its survival or reproduction.

No scientific investigation was carried out for examining the effects on marine lives linked with those pollutants in Bohai Sea, but some indirect evidences have showed that many species have suffered, and some have disappeared, especially in spawning and nursery grounds. The ecosystem in Bohai Sea has been changing, the diversity has been reducing. Examples are given below for illustrating the reduction in diversity of species in Bohai Sea since 1959:

Reduction in diversity - 71 species in 1959.
- 61 species in 1982.
- 53 species in 1992.
- 32 species in 1998.

From the viewpoint of evolution, the biological assemblages have moved to low-mature species assemblage. Another characters, which indicated that the ecosystem in Bohai Sea has changed, is reduction in diversity. For instance, there were 71 species in summer in 1959, 61 species in 1982, and 53 species in 1992, 32 in 1998. The destroying of some food chains is one of characters that indicated that the ecosystem has changed. The biomass of Japanese anchovy, which is feeding for many carnivorous fishes, decreased. The decrease of Japanese anchovy in biomass caused big decline in yield for many carnivores species that depend on the Japanese anchovy as feeding, such as Spanish mackerel obtained bad growth and a big mortality.

The result of continuous decrease of species richness, diversity and evenness since 1983 indicates a non-linear correlation to the fish resources and fishing intensity.

(Jin, 2001), so it may be the results from pollution.

5.2.4.2 The Impacts from Aquaculture

Aquaculture could be a possible solution, because aquaculture production can alleviate pressure on wild fisheries stocks (Naylor *et al,* 2000). Aquaculture also provides more employment, especially for these highly populated countries that are mostly developing countries. The products from aquaculture play a growing part in providing food for our expanding global population, and it is particularly important for those who depend on the fisheries as livelihood. So global production of farmed fish and shellfish has more than doubled in the past 15 years.

The aquacuture rapidly develops both marine and inland fisheries in China also. It dominates the global production since 1990s, of which it accounts for 67.8% in 1996. Since the wild Chinese prawn was fishing down in China, the products of Chinese prawn from aquaculture increase rapidly, and yield has exceeded the catch from oceans.

The development of aquaculture in the coastal areas along Bohai Sea is remarkably fast. In 1956, the area for aquaculture along the Bohai Sea is only 2940 hectares and the total yield is 6059 tons. In 1988, the area for aquaculture increase to 154160 hectares, and the total yield reaches 493209 tons. In 32 years, there are 52.44 and 81.40 times increase respectively in area and yield. The areas for shrimp aquaculture increased from 5700 hectors in 1983 to 70, 000 hectors in 1989, account for 45% of total aquaculture areas, the yields were increasing from 248 kg/ h to 1400 kg/h.

Aquaculture has a number of economic and other benefits, like aquaculture production will compensate for the shortfall in ocean harvests as ocean fisheries deteriorate. For instance, the export quantity of frozen prawn was 47.269 tones, which took 8.9 percent of the total aquatic export quantity in 1993 in China, valued at US & 308.57 million, or 20.2 percent of the total value (FAO. 1994). Fish farming will restore wild populations by relieving pressure on capture fisheries, but if it is done without adequate environmental safeguards, it can cause environmental degradation. Aquaculture also can be a contributing factor, to the collapse of fisheries stocks worldwide (Naylor *et al.* 2000).

Aquaculture, or fish farming, which is often touted as a panacea for the problems of fisheries over-exploitation, may have many negative effects in environmental and economic aspects. The main environmental effects of marine aquaculture can be divided into the following five categories

Reduction of forage fish resources

Most of species cultivated in aquaculture need to use large quantity of wild-caught fish as feed ingredients, even compound feeds for herbivorous and omnivorous finfish can also contain low to moderate levels of protein from fish and terrestrial animals. The results from such use are that reducing food to wild carnivorous species**,** depleting the feeding fisheries resource, and thus indirectly effect marine ecosystem.

Organic pollution, eutrophication and red tide

Some aquaculture systems contribute to nutrition loading through discharges of fish waste and uneaten commercial feed, and give the pollution to the water. This may results in serious depletion in dissolved oxygen supplies needed by marine animals, and makes seaweed and sea grass sick or die due to hypoxia or anoxia, result the loss of habitats (e.g. sea grasses and coral reef).

The excessive use of fertilizers, herbicides, and pesticides that run from farmland into rivers, combined with detergents and human wastes, can trigger excessive alga growth, depleting the oxygen levels of the sea.

The explosion of red tide can cause disastrous outcomes. For example, such disaster has made the shrimp industry in China in 1994 nearly dies out from aquaculture, a 3,000 square mile dead zone has been found in the Gulf of Mexico near the mouth of the Mississippi River caused by red tide[3]. And it is reported that China experienced 280 red tides between 1980-1997, and red tide has occurred 20 times in Bohai Sea in past seven years (Jin, 2001). The accumulative area from 28 red tides in 2000 is more than 10, 000 square miles, and the loss in fisheries caused by just two big red tides in Liaoning and Zhejiang is nearly 3 billions RMB (Beijing Youth Daily, 2001)

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[3] (http://www.earthvoice.org/animal.habitat/coastal.ecosystems.htm)

Biological pollution

Exotic species: fish that escaping from aquaculture facilities may harm wild fish populations through competition and interbreeding or displace native species. Sometime, introduced species may transform marine ecosystems. The negative influence to wild recruitment stock in long term development is considerably big.

'Every time we introduce a species, we run the risk of radically transforming marine ecosystems, with tremendous ecological, economic and social consequences.' says Dr. James Carlton, professor of marine science at Williams College-Mystic Seaport, Connecticut[4].

Destruction of the juvenile resource

The capture of wild fingerling from oceans destroy the juvenile resource and give negative influence to recruitment in long-term. Shrimp or some of other species culture have been long dependent on wild seed stocks, by collecting fry in shallow estuaries or by capturing live gravid females. Because such capture may cause big mortality on wild seed stock after a series operations and transportation. Meanwhile, By-catch for other untargeted species from such fingerling capture would be very big also.

Pathogen invasions and disease outbreak

Introduction of new species may bring new disease source to native ecosystem, and results pathogen invasions, because local species may have weak ability in defending such disease. Meanwhile, overstocking and overmedication may degrade the immune system of aquatic animals, and then cause the outbreak of disease. The decline in world production in 1993 was largely due to disease outbreaks damaging two thirds of the Chinese shrimp crop and also affecting many Indonesian and Ecuadorian shrimp farms[5].

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[4] (http://www.emagazine.com/january-february_1998/0198feat1.html)

[5] http://www.emagazine.com/january-february_1998/0198feat1.html

Habitat destruction

The construction of aquaculture facilities can result in the loss and fragmentation of habitats. For example, the destruction on the mangroves for building shrimp ponds may result in loss of essential ecosystem services, generated by mangroves, including the provision of nursery habitat, coastal protection, flood control, sediment trapping and water treatment. And sea grasses are also vital breeding, feeding and nursery areas for fish and shellfish species, home to a variety of wildlife species, and important protection and shelter against storms and coastal erosion

In China, 50% wetlands were lost and 66% mangroves near shore were destroyed in the past 30 years (Beijing Youth Daily, 2001).

Share or compete for many ecosystem services

Because no clear property right for using seas, conflicts happened between different users in different fields, like between aquaculture, fishing ground, transportation and oil industry. Dalian harbor is one of important harbors along the coastal line of Bohai Sea, but due to the occupation of waterways by aquaculture, it has been called 'the area with potentially big accidents ' before 1998. A Russian ship was entangled here for 7 days by nets, and such accidents have ever happened on German and Korean ships also (Beijing Youth Daily, 2001).

Connell (1978) summarized that diversity is highest when disturbances are intermediate in intensity or size and low when disturbances are at either extreme. The disturbance of fishing effort and pollution on the fish assemblage of the Bohai Sea was low in 1959, and increased along with the development of fisheries and coastal industries. As the combined effect of fishing intensity and pollution on the Bohai Sea ecosystem continuously increased, that eventually led to a decrease in diversity thereafter, and further increase in such compound disturbance will result a collapse in fisheries in Bohai Sea.

5.3 Factors Behind the Increase of the Total Catch

There is a remarkable phenomenon in total catch, the catch for small yellow croaker, and the catch for hairtail, that it seems the fisheries in Bohai Sea are recovering and expanding, because the total catch seems increases (fig. 3.1), especially significant rise occurred in 1990s. And the catches for small yellow croaker and hairtail (table 3.3 and table 3.4) after dropping to the bottom points in 1960s have been increasing, until respectively reached peaks 71426 and 110165 tones in 1998, both of them have surpassed the catches in 1956, 50210 and 65287 tones. Does it mean the fisheries in Bohai Sea are developing? The results from scientific survey have completely denied those. Why are there so big differences between scientific survey and commercial catch data?

Let's look at the total catch and total effort. The total effort increased from 42739 hp in 1956 to 3354281 hp in 1998, 78.48 times increase in 42 years. But the total catches increased from 293185 tones in 1956 to 3239700 tones in 1998, just 11.05 times bigger the it's original level. so it is not strange that total catch was pulled up by strong increase in fishing effort, and certainly it is reasonable the CPUE for three of them dropped to the bottoms without reverse around 1970. Therefore it is not an expanding fishery in Bohai Sea.

5.3.1 Ecosystem Changes from Eutrophication

According to the results (Deng, 1988) from scientific surveys conducted in 1959-1960 and 1982-1983, the number of phytoplankton are $361 \times 10^4 / m^3$ and $637 \times 10^4 / m^3$, the 76% increase has been gained in about two decades, and the composition of phytoplankton species also remarkably changed. In accordance changes with Phytoplankton, the biomass of zooplankton increased also, from 107.1 in 1959 to $125.0 \ mg / m^3$. Such data were obtained under the circumstance that the pelagic species which mainly fed by zooplankton, like half-fin anchovy, Japanese anchovy, herring and etc. had a big increase in Biomass, so actually the quantity of zooplankton in 1982 was estimated much higher than it was in 1959. It is possible for the stress to be propagated into the plankton through its connections with either the benthos (Sammarco, 1983) or pelagic (Willianms, 1983) components. Bradbury *et al.* (2001) also pointed out that the effect could be confounded to an unknown extent by the observed patchiness of the plankton in space and time, and resultant anisotropy of its coupling with the other two components.

As it is known, the pollution in Bohai Sea was steadily increasing, the level of eutrophication could be getting higher and higher. Such increase on another hand could be a basic factor for pelagic species increase by connecting to the increase of plankton, so that could be a foundation for increase in total catch in Bohai Sea in last 20 years.

5.3.2 Changes in History Pattern

5.3.2.1 The main compositions of species in catch

The shifts from high-value species, like small yellow croaker and hairtail, to lower-value species like half-fin anchovy and Japanese anchovy, the quality of the catch has entirely decreased. According to the investigation in 1982-1983, the catches for some small pelagic species like Japanese anchovy and half-fin anchovy have accounted for 60% in total biomass in the fisheries in Yellow Sea and Bohai Sea. The reduction on nutrition level has a big influence on fisheries yields (Deng, 1988). According to the theory of energy transformation and the position of food chain, the abundance of predator should be smaller than it of prey. Mous (1969) pointed out that the energy transformation between carnivorous species like tuna: Zooplankton-filter species like sardine: Zooplankton: Phytoplankton = 1kg: 8kg: 70kg: 200kg. The means the disappearence of 1kg tuna brings the growth of 8kg sardine. The ratios between low, middle and high carnivores are 22: 19: 10 (Deng *et al.*, 1988). Fig. 1.2 in section 1.0 clearly showed the positions of those species, the ratio between hairtail and Japanese anchovy is 10 to 22.

After fishing down predator, the biomass of prey expands over the quantity of the original predator, in such period, the total catch could be bigger, and shows it in expanse. But behind such expanse, the values for these fisheries totally decline. trophic level dropped to a lower level also. And such expanse cannot last long under big and still increasing fishing pressure. The results from the fourth survey in Bohai Sea for half-fin anchovy and Japanese anchovy have proved such expanse, they have dropped down to a very low level in abundance.

In generally, the increase by the average level of 146530 tones per year succeeds until reached the highest point 1027101 tones in 1997. The catch for Japanese anchovy in 1990 is 1386 tones, comparing with total catch, it is just one-seven hundred eight seven. But 7 years late, the catch accounted for nearly one-third of total catches that is 2946000 tones in 1997. Then big drop happened in 1998, it is 895078 tones in catch, by 132023 tones, 14.75% decrease. In this year, it accounted for 27.63% in total catch (3239700 tones) in 1998.

Chen et al (1997) in the research of setnet fisheries in Yellow and Bohai Seas also found that the quality of catch decreased continuously, with species such as croakers and flatfishes, which made up more than 20% in the catch in the past, contributing only 2% today.

5.3.2.2 The composition of species size

The decline of the species was accompanied by the substantial reduction in its distribution (Otaki and Shojima, 1978), increase in growth and earlier maturation (Mio and Shinohara, 1975), and a decrease in the mean age and body length of spawning stock.

Tang (1989) described the fisheries in Yellow Sea that about 78% of the biomass in 1985 was composed of fish below 20cm and the mean body length in the catches of all commercial species was only 12cm, while the mean body length in the 1950s and 1960s was over 20cm. The results from catches in Bohai Sea show the similar events. The investigation in 1992-1993 show that the average weight for the stock of spawner is just 30% of it in 10 years ago. In the report (Liu, 1990), the age distributions of spawners for small yellow croaker in Bohai Sea in 1957 ranged from the age 2 ~ 20 years, the age 2-5 years were main groups, accounting for 69.0%. Average age was 4.94 years; average body length was 225 mm. But by the year of 1982, the age distributions of spawners reduced to the age 1-5 years, and accounting for 86.9%. Average age reduced to 1.90 years, average body length decreased to 182 mm. It was also estimated that spawning stock size for small yellow croaker in Yellow Sea in the early 1980s was only one-twentieth of its previous level (Mao, 1983).

Although exploitation of spawning stock in the western Yellow Sea has been prohibited since 1980, there has been no definite indication so far of a recovery of this species (Tang, 1989.). According to such trend, if no practical strategy for changing it, eventually it could go to the extinctive fisheries.

5.3.3 Policy Reason

In order to protect and rationally utilize fishery resources, the Chinese government has attached great importance to establishment of fishery related laws. 1) In 1979, the State Council formally approved the regulations on Fishery Resources Propagation and protection. 2) In 1980, the fishing license system was established to ensure the registration of fishing vessels before starting any kind of fish operation. 3) In 1985 and 1986, the Fishery Law of People's Republic of China and the Detail Roles of the implementation on the Fishery Law were issued respectively. 4) In 1988, The trawler was withdrawn from inshore fisheries. 5) In 1991, the Ministry of Agriculture approved the regulations on Fishery Resources Propagation and Protection in Bohai Sea. 6) From 1995, fishing was forbidden from 1st July to 31st Aug. in Bohai Sea, Yellow Sea, and East China Sea annually. 7) From 1999, fishing was forbidden from 1st June to 1st Aug. in South China Sea. 8) In 2000, the Fishery Law of People's Republic of China was re-edited. 9) TAC (total allowing capture) system will be acted from 2001.

From the description above, one can estimate that the function from policies could be great for fisheries in Bohai Sea. Especially the policies about trawler and seasonally closure could be one of good reasons for recovering of fisheries in Bohai Sea, so it could be a positive factor for such growth in catch in Bohai Sea in 1990's. On the other hand, weakness in implement of policies and the development of individual fisheries could be negative factors for protecting fisheries in this area, and such factors helped the catch data increasing.

5.3.4 Changes in Fishing Efficiency and Data Error

The increase in yield would involve into many factors, such as invention of new gears, stock recovered, some good nature conditions and etc. It is very possible that new technology would bring a big progress in fishing efficiency, so the utilization of some new devices like acoustic monitor and satellite search device could be a revolution in harvest technology. The effects it brings into fisheries would be great on both social- economic and biological aspects. During those 40 years, China's fisheries have been growing up under different new technology facilitated, and it is very confirmed that new technology gave a big push in fishing efficiency, and responded in increase of the catches.

In the process of data analysis, one may find there are many flips upwards in the data of total catch and catches for different species. After checking fishing efforts, no big changes in effort correspond with such drastic increase in catch. For instance, the total catch was pulled up from 1976200 tones to 2946000 tones in 1996-1997, 969800 tones, 49.07% increase was caught in one year. But only 217496 hp, 6.93 % in crease of effort responded such upper pull. Such big change could be caused by the number factor, including the changes in fishing efficiency and data errors.

In developing countries, data documented is a very hard and very complex work due to sophisticated society and unsystematic data documented management. Or some time, the data could be recorded due to different purposes, like political reason. For instance, according to the policy, the goal for marine fisheries in 1999 is to reach 'zero increase', so the catch for 1999 decreased 1.7% (Nie, 2000), but checking effort, it is found 240782 hp, 7,2% increase in 1998-1999. Those noticeable data seem doubtful.

China is a big country both on catch and aquaculture in fisheries. But management is lagging of the growth of fisheries, messes linked with different aspects, including data documented, such unusual data could be caused by error data recorded.

As to fisheries in Bohai Sea, so many different fishing gears and so big fishing employment involved into the catch in different fishing seasons and catching different species in this tropic fisheries, and for artisanal vessels, the estimates are out of control. It is impossible to make data collection completely accurate.

6.0 Conclusion and Recommendations

6.1 Conclusion

Overexploitation and environment degradation have broken down the Bohai Sea ecosystem, and reduced its resilience and stability (Ryder *et al.,* 1981). The whole ecosystem becomes unpredictable in quality and quantity of fisheries in Bohai Sea.

Top-down management does not work efficiently. Although Chinese government made great effort for protecting and recovering fisheries, fisheries in Bohai Sea eventually are still in the risk of collapse due to too big fishing pressure and weak implement enforcement.

6.2 Recommendation

The conclusion drawn from the discussion that excess fishing effort is the major cause of overfishing, the pollution accelerates the degradation of ecosystem in Bohai Sea. The present investigation and study gave basic estimations of MSY for some commercially important species, reviewed some problems in management. It is therefore recommended that some strategies should be used as short-term and long-term measures to sustain the fishery.

Short-term measures include:

● As an immediate measure, the number of fishing vessels from the industrial fleets should be reduced in order to reduce effort and fishing mortality. However, this strategy could be less expensive to management but could be costly to the industrial since most fleets would be non-operational.

● A continuation of strict regulation measures is essential, and intensification of conservation of young fish and spawning stock species would be the most important task in ecosystem management

Long-term measures include:

● Building a system of responsible aquaculture to control the pollution from aquaculture.

● Introducing legislating management in controlling industry pollution.

● An urgent task is to establish an effective monitoring system of ecosystem resources in the Bohai Sea. Give intensive attention to the changes of dominant species and environment, study MSY for the dominant species, and establish the TAC system to limit the landings.

● Establishing a co-management system for fisheries, and strengthening the enforcement of laws and regulations. The conditions for setting up co-management system have been existing, the key issue is decentralization.

● Public awareness campaigns should be done through video shows, posters, radio and through visits and training of the fishers. These campaigns will help the fishers to know the status of the fishery and can appreciate that its indeed overexploited so they can cope with any strategy put in place by the government.

References

Anonymous. 1986b. Marine fishery resources in China. Fishery Resources. *Investigation and Division* 6(2). In Chinese.

Anon.1990. China Statistics Yearbook for 40 Years Fisheries (1949-1988). Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1991. China Fishery Statistics Yearbook 90. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1992. China Fishery Statistics Yearbook 91. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1993. China Fishery Statistics Yearbook 92. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1994. China Fishery Statistics Yearbook 93. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1995. China Fishery Statistics Yearbook 94. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1996. China Fishery Statistics Yearbook 95. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1997. China Fishery Statistics Yearbook 96. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1998. China Fishery Statistics Yearbook 97. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.1999. China Fishery Statistics Yearbook 98. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon.2000. China Fishery Statistics Yearbook 99. Beijing, Bureau of Fisheries, Ministry of Agriculture, People's Republic of China.

Anon. 1997. Aquaculture development and prospects in southern China. World Fish Report 39:3-5. Heping, A. 1995. Country Report: People's Republic of China, p.91-112. In report on a regional study and workshop on the environmental assessment and management of aquaculture development (TCP/RAS/2253). NACA Environment and Aquaculture Development Series No.

Bangkok, Network of Aquaculture Centres in Asia-Pacific.

Bradbury R. H. and C. N. Mundy. 1989. Large – Scale Shifts in Biomass of the Great Barrier Reef Ecosystem. in the book Biomass Yields and Geography of Large Marine Ecosystems,

Chao H C, Kawasaki, Chiang K P and Ho C H (2001). Estimated distribution and movement of hairtail (*Trichiurus lepturus*) in the Aru Sea, based on the lohbook records of tralers. *Fisheries Science 2001, 6:3-13*

Chen, D. G., 1991. Fisheries Ecology in the Yellow and Bohai Seas, Marine Press, 410 pp. (in Chinese).

Chen, D., Liu, Q., Zeng, X., Su, Z. Catch composition and seasonal variation of setnet fisheries in the Yellow Sea and Bohai Seas. *Fisheries Research.* 32: (1997) 61-68.

Chikuni, S. 1985. The fish resources of the Northwest Pacific. *FAO Fish. Tech.* Paper 266.

Deng J, Zhu J, Cheng J and Hua D. (1988). Main Invertebrates in the Bohai Sea and their fishery Biology. *Marine Fisheries Research.*

Deng J, Han G and Ye C (1982). The study of Chinese prawn () death in Bohai Sea. *Journal of Fisheries of China.* Vol. 6, No. 2.

Deng J and Zhuang Z (2001). The cause of recruitment variation of Chinese prawn (*Penaeus chinesis*) in Bohai Sea. *Journal of Fisheries Science of China,* Vol. 7, No.4: 125-128

Deng J, Zhu J and Ren S (1996). The Study of Dynamics of Chinese Prawn (*Penaeus orientalis*) on Muture Biomass and Recruitment (SRR). *Journal of Fisheries Science of China.*

Deng. J., Ecological bases of marine ranching and management in the Bohai Sea. *Marine Fisheries Researc, vol. 9, Aug. 1988. 1-10.*

Hong S (1980). A Study on the Age and Growth of the Hairtail (*Trichiarus haumela*) in the Bohai Sea and Yellow Sea. *Journal of Fisheries of China.*

Larkin, P.A. and W.Gazey. 1982. Applications of ecological simulation models to management of tropical….

Liu, X. 1979. Status of Fishery resources in the Bohai and Huanghai Seas. *Mar. Fish.Res.* Paper. 26:1-17. In Chinese.

Liu, X. et al, 1990. China Oceanic Fisheries Division. Jejiang Science Technical Press.

Lee, J. 1977. Estimation of the age composition and survival rate of the yellow croaker in the Yellow Sea and Esat China Sea. Bull. *Fish. Res. Dev.* Agecy, Busan, 16:7-31.

Lin, J. 1985. Hairtail. *Agriculture Publishing House*, Beijing. In Chinese.

Jin X. The dynamics of major fishing resources in the Bohai Sea. *Journal of Fishery Science of China,* 2001, 1(7): 22-26.

Jin, X., Changes of fish biomass and assemblage structure in the Bohai Sea. *The Yellow Sea, vol. 5. Dec.1999. 14-18*

Jin X (1996). Variations of Coomunity Structure, Diversity and Biomass of Demersal Fish Assemblage in the Bohai Sea. *Journal of Fishery Science of China*. Vol. 3 No. 3: 31-47.

Jin, X. Changes in the Community Structure of the Lazhou Bay. *Asian Fisheries Science.* 18 (2000): 215-224*, Asian Fisheries Society.* Manila, Philippines

John S. Hacunda, 1981. Trophic Relationship Among Demersal Fishes in a Coastal Area of the Gulf Marine. *Fishery Bulletin,* Vol. 79, No. 4, 775-788.

Kenneth N. Berk & Patrick Carey. 2000. Data Analysis with Microsoft Excel, updated for Microsoft office 2000. Duxbury. Thomson Learning.

Hu, J. and Zu, D., 1986. Hairtail. In: Fisheries committee of the East China Sea (Editors), Survey and Division of Fisheries Reseaources in the East China Sea. *Teachers University of the East China Press,* Shanhai.

Misu H. Studies on the fisheries biology of the ribbon fish in the East China and the Yellow Seas. (3) Distribution, migration and consideration of population. *Bull. Seikai. Fifh. Res. Lab.* 1961; 24: 115-131.

Marr.J.c., 1982. The realities of fishery management in the Southeast Asian region. P.299-307. In Pauly, D. and G. I. Murphy (eds) Theory and management of Tropical Fisheries….

Michael King. 1995. Fisheries biology assessment and management. *Fishing News Books.* UK.

Mio, S. and Shinohora, F. 1975. The study on the annual fluctuation of growth and muturity of principal demersal fishes in the East China Sea and the Yellow Sea. *Bull. Seikai Res. Fish. Res.* Lab. 47: 51-95.

Mao, X. 1983.Status of the yellow croaker stocks. In condition of fishery resources in the huanghai Sea and East China Sea. *East China Sea Fish. Res. Inst.*

Nie S.M. 2000. Study on the Overfishing Problem of Marine Fisheries in China.
The Thesis of Master Degree.

Otaki, H., and Shojima, S. 1978. On the reduction of distribution area of the yellow croaker resulting from decreas of abundance , *Bull. Seikai Res. Fish.Res.* Lab.51:111-121.

Pauly, D., Christensen, V., Dalsgaard, J., Emese, R. & Torees, F.1998. Fishing down marine webs. *Science.* 279:860-863.

Ryder R A, S R Kerr, W Taylor, et al. Community consequences of fish stock diversity (J) *Can J Fish Aquat. Sci,* 1981, 38: 1856-1866.

R. J. Goldberg, M. S.Elliot, R. L. Naylor, 2001. Marine Aquaculture in the United State: Environmental Impacts and Policy Options. *Pew Oceans Commission. Arlington,* Virginia.

Simpson, A. C. 1982. A review of the database on tropical multispecies stocks in the Southeast Asian Region. P 5-32. In pauly, D. and G. I. Murphy (eds) Theory and management of tropical fisheries.

Tang, Q. 1989. "Changes in the Biomass of the Yellow Sea Ecosystem," in Kenneth Sherman and Lewis M. Alexander (eds.), Biomass Yields and Geography of Large Marine Ecosystems, (Boulder: Westview Press) AAAS Selected Symposium 111, pp.7-35.

Tang J (1994). The Main Source and Distribution Characteristics of Pollution in Laizhou Bay. *Journal of Oceanography of Huanghai and Bohai Seas.* Vol. 12. No.: 16-20.

The reconstruction of Northeast Asian Order. October 12-13, 2001. International Conference Hall, IFES, Seoul, Korea.

Xia, S, 1960. Fisheries of the Bohai Sea, Huanghai Sea, and East Chins Seas.*Mar. Fish. Res. Pap.* 2:73-94. In Chinese.

Xia, S. 1978. An analysis of changes in fisheries resources of the Bohai sea. Huanghai Sea, and East China Sea. *Mar. Fish. Res.* Pap. 25:1-13. In Chinese.

Yi Cui et al, 1996. The study of biological and physiological environments in Bohai Sea. *Journal of Fishery Science of China.*

Ye Y and Beddinton J(1996). Modeling interactions between inshore and offshore fisheries: the case of the East China Sea hairtail (*Trichiurus haumela*) fishery. *Fisheries Research* 27:153-177

Ye C, Deng J and Hua G (1987). Estimate of the Stock Abundance of the Chinese Prawn (*Penaeus orientalis kishinouye*) in Bohai Sea with Cohort Analysis. *Oceanologia et Liminologia Sinica.* Vol.18, No.6: 540-547.

Ye C, Tang O and Qin Y (1980). The Huang Hai Herring and Their Fisheries. *Journal of Fisheries of China.* Vol.4, No. 4:339-351.

Yimin Ye, John Beddington, 1996. Modeling interactions between inshore and offshore fisheries: the case of the East China Sea hairtail (*Trichiurus haumela*) fishery. *Fisheries Research* 27(1996): 153-177.

Reference cited:

Wilhm. J. L., 1968. Use of biomass units in Shannon's formula. Ecology. 49: 153-156.

Wilhm. J. L., and Dorris, T.C., 1968. Biological parameters for water quality criteria. *Bioscience,* 18: 477-481.

Shiokawa T (ed). *Management of RibbonFish Resources in the Central Japan Sea.* Japanese Fisheries Resources Conservation Association. Tokyo. 1988.

She, Jun, 1998. "Pollution in the Yellow Sea Large Marine Ecosystem: Monitoring, Research, and Ecological Effects," in Q. Tang and K. Sherman (eds.), Large Marine Ecosystems of the Pacific Rim.

Tang, Qisheng and Xianshi Jin. 1998. Ecology and Variability of Economically Important Pelagic Fishes in the Yellow Sea and Bohai Sea. In Q. Tang and K. Sherman (eds.), Large Marine Ecosystems of the Pacific Rim (in press, 1998).

Anonymous. 1986a. Marine fishery environment in China. Fishery Resources Investigation and Division 5(2). In Chinese.

Anonymous. 1986b. Marine fishery resources in China. Fishery Resources Investigation and Division 6(2). In Chinese.

Deng, J., and Zhao, Q. (eds). 1991. Marine Fisheries Biology. China: Agriculture Press.

Lui, X. 1979. Status of fishery resources in the Bohai and Huanghai Seas. Mar. Fish. Res. Paper 26:1-17. In Chinese.

Lui, X. (ed.) 1990. Investigation and Division of the Yellow Sea and Bohai Sea Fishery Resources. Beijing, China: Ocean Press.

Yang, J. 1985. Estimates of exploitation potential of marine fishery resources in China. In Proceedings of the strategy of ocean development in China. Pp.107-113. China Ocean Press, Beijing.

Zhao, Q. (ed). 1990. Marine Fishery Resources of China. Zhejiang, China: Zhejiang Science and Technology Press.

Appendices

AppendixⅠ The list of major fish species in Bohai Sea

Common name	Scientific name	Pattern
Small yellow croaker	*Pseudosciaena polyacti*	D,R
hairtail	*Trichiurus haumela*	D,R
Ray	*Raja porosa*	D,R
Scaled sardine	*Harengula zunasi*	P
Gizzard-shad	*Clupanodon punctatus*	P
Japanese anchovy	*Engraulis japonicus*	P
Rednose anchovy	*Thrissa kammalensis*	P
Half-fin anchovy	*Setipinna taty*	P
Long-tailed anchovy	*Coilia mystus*	P,R
White fish	*Salanx acuticeps*	R
Lizzard fish	*Saurida elengata*	D
Brawn barracuda	*Sphyraena pinguis*	D
Mullet	*Mugil so-iuy*	D,R
Common sea bass	*Lateolabrax japonicus*	D,R
Vertical striped fish	*Apogonichthys lineatus*	D
Spotted maigre	*Nibea albiflora*	D
White croaker	*Argyrosomus argentatus*	D
Small yellow croaker	*Pseudosciaena polyactis*	D
Blackgill croaker	*Collichthys niveatus*	D,R
Spinehead croaker	*Collichthys lucidus*	D,R
Red sea bream	*Pagrosomus major*	D
Eel-pout	*Enchelyopus elongatus*	D,R
Smallhead hairtail	*Trichiurus muticus*	D
Spanish macherel	*Scomberomorus niphonius*	P
Pomfret	*Stromateoides argenteus*	P
Sharp-tailed spiny goby	*Acanthogobicus hasta*	D,R
Finespot goby	*Chaetorichthys stigmatias*	D,R
Snailfish	*Liparis tanakae*	D,R
Left-eyed flounder	*Paralichthys olivaceus*	D,R
Right-eyed flounder	*Pseadopleuronectes yokonamae*	D,R
Red tongue sole	*Cynoglossus joyneri*	D,R

Appendix Ⅱ

Table 1. The Yields from aquaculture in the areas along Bohai Sea (tons)

Years	Tianjing	Hebei	Liaoning	Shandong	Total
1956		85	2203	3771	6059
1957		47	7058	6452	13557
1958		200	5102	2502	7804
1959		315	19867	7115	27297
1960	1500	271	27014	18757	47542
1961	684	271	16049	11846	28850
1962	244	360	14213	11998	26815
1963	301	283	11185	10909	22678
1964	579	181	8304	8386	17450
1965	608	99	11585	11360	23652
1966	371	469	16410	20054	37304
1967	108	401	18013	38424	56946
1968	374	139	15852	35835	52200
1969	281	210	18300	43214	62005
1970	689	334	21787	46731	69541
1971	362	116	36142	64196	100816
1972	368	108	41515	83781	125772
1973	73	332	45910	62883	109198
1974	150	389	43350	86415	130304
1975	86	363	59010	100442	159901
1976		467	74682	108174	183323
1977	24	992	103158	177334	281508
1978	113	1509	106703	189947	298272
1979	43	817	98406	148465	247731
1980	72	1046	112731	154040	267889
1981	129	624	624	133214	134591
1982	146	641	641	134095	135523
1983	230	599	599	157740	159168
1984	650	1577	1577	168250	172054
1985	1417	5914	5914	197591	210836
1986	2730	13229	13229	206710	235898
1987	4715	26205	26205	265531	322656
1988	6645	37988	37988	410588	493209

Appendix III

Table 2. The areas for aquaculture along Bohai Sea (unit: x10^4 mu)

Years	Tianjing	Hebei	Liaoning	Shandong	Total
1956		1.94	1.31	1.16	4.41
1957		1.94	8.45	1.32	11.71
1958		7.19	13.69	2.47	23.35
1959	5.02	6.67	63.03	4.81	74.51
1960	10.66	7.9	52.15	7.17	67.22
1961	7.41	5.44	17.87	4.6	27.91
1962	6.31	4.24	5.03	3.01	12.28
1963	4.21	5.95	3.58	2.8	12.33
1964	5.68	5.64	5.68	2.54	13.86
1965	9.36	5.73	21.03	2.67	29.43
1966	6.4	8.9	35	36.8	80.7
1967	4.15	3.13	28.42	29.47	61.02
1968	7.8	2.9	25.85	33.53	62.28
1969	10.15	0.07	23.57	16.51	40.15
1970	10.3	2.3	30	23.4	55.7
1971	3.49	0.29	32.77	36.86	69.92
1972	6.39	1.25	66.07	35.26	102.58
1973	11.33	8.9	63.86	35	107.76
1974	9	8.5	64	33.3	105.8
1975	2.11	7.5	60.76	33.75	102.01
1976	2.7	11.1	57.8	32.69	101.59
1977	1.95	10.56	47.5	36.55	94.61
1978	1.69	8.37	40.9	26.8	76.07
1979	0.12	10.85	48.45	26.55	85.85
1980	0.77	12.23	50.4	28.5	91.13
1981	0.85	12.7	49.9	28.66	91.26
1982	0.69	12.96	55.2	35.18	103.34
1983	1.21	13.65	59.3	32.3	105.25
1984	2.01	14.21	73.52	37.73	125.46
1985	4.07	14.33	83.59	49.58	147.5
1986	4.66	17.54	89.44	56.7	163.68
1987	6.25	22.29	94.53	70.87	187.69
1988	6.81	27.52	99.45	104.27	231.24

1 hectare = 15 mu

Appendix Ⅳ Regression

gomT = Regress[makegom[Drop[catchT, 7], effortT], {1, x}, x]

{ParameterTable →

	Estimate	SE	TStat	PValue
1	8.46203	0.123313	68.6227	0.
x	-0.0375326	0.0024022	-15.6242	2.22102×10^{-18}

RSquared → 0.862248, AdjustedRSquared → 0.858716, EstimatedVariance → 0.155029,

ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	37.8452	37.8452	244.117	0.
Error	39	6.04612	0.155029		
Total	40	43.8913			

}

gomH = Regress[makegom[Drop[catchH, 7], effortH], {1, x}, x]

{ParameterTable →

	Estimate	SE	TStat	PValue
1	8.36457	0.178056	46.9772	0.
x	-0.007376	0.000967644	-7.62264	2.58515×10^{-9}

RSquared → 0.592272, AdjustedRSquared → 0.582079, EstimatedVariance → 0.665492,

ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	38.6682	38.6682	58.1046	2.58515×10^{-9}
Error	40	26.6197	0.665492		
Total	41	65.2879			

}

gomL = Regress[makegom[Drop[catchL, 7], effortL], {1, x}, x]

{ParameterTable →

	Estimate	SE	TStat	PValue
1	8.03427	0.114736	70.0241	0.
x	-0.00163272	0.000256505	-6.36526	1.44918×10^{-7}

RSquared → 0.503208, AdjustedRSquared → 0.490788, EstimatedVariance → 0.260735,

ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	10.5641	10.5641	40.5166	1.44918×10^{-7}
Error	40	10.4294	0.260735		
Total	41	20.9935			

}

gomS = Regress[makegom[Drop[catchS, 7], effortS], {1, x}, x]

{ParameterTable →

	Estimate	SE	TStat	PValue
1	8.13563	0.127353	63.8827	0.
x	-0.000911537	0.000175566	-5.19201	6.40943×10^{-6}

RSquared → 0.402601, AdjustedRSquared → 0.387666, EstimatedVariance → 0.363241,

ANOVATable →

	DF	SumOfSq	MeanSq	FRatio	PValue
Model	1	9.79185	9.79185	26.9569	6.40943×10^{-6}
Error	40	14.5296	0.363241		
Total	41	24.3215			

}

Appendix V

Table 9 Parameters for different species in Tianjing (1956-1998)

Species	Best Fit		R^2	Adjusted R^2
	A	B		
Small yellow croaker	5.65249	-0.09742	0.70728	0.69868
Hairtail	4.64117	-0.02020	0.33586	0.31883
Chinese prawn	6.07126	-0.05938	0.70309	0.69566
Japanese anchovy	8.95990	-0.04886	0.08914	-0.00195
Spanish mackerel	-0.32374	0.02497	0.00705	-0.04811

Table 10 Parameters for different species in Hebei (1956-1998)

Species	Best Fit		R^2	Adjusted R^2
	A	B		
Small yellow croaker	3.48844	-0.01670	0.42767	0.41177
Hair tail	4.34806	-0.01421	0.74292	0.73536
Chinese prawn	4.53951	-0.01062	0.58793	0.57762
Japanese anchovy	-12.17825	0.03883	0.46638	0.35965
Spanish mackerel	2.03287	-0.00255	0.03999	-0.01335

Table 11 Parameters for different species in Liaoning (1956-1998)

Species	Best Fit		R^2	Adjusted R^2
	A	B		
Small yellow croaker	4.87789	-0.00409	0.50892	0.49664
Hairtail	5.52744	-0.00390	0.75654	0.75045
Chinese prawn	4.61815	-0.00490	0.87295	0.86977
Japanese anchovy	-2.09717	0.00685	0.20823	0.09512
Spanish mackerel	3.84365	-0.00118	0.23323	0.19063

Table 12 Parameters for different species in Shandong (1956-1998)

Species	Best Fit		R^2	Adjusted R^2
	A	B		
Small yellow croaker	3.89803	-0.00081	0.08524	0.06178
Hair tail	5.41165	-0.00167	0.46882	0.45520
Chinese prawn	4.60093	-0.00278	0.83162	0.82741
Japanese anchovy	-2.93786	0.00547	0.59377	0.53574
Spanish mackerel	3.70529	0.00040	0.42868	0.39508

Appendix Ⅵ

Table 3.9 Parameters for different species in whole Bohai Sea (1956-1998)

Areas	A	B	f_{MSY}	MSY
Small yellow croaker	-2.20383	-0.0013	771.901	31.3443
Hair tail	-1.47339	-0.00102	981.988	82.7804
Chinese prawn	-2.21155	-0.0015	667.804	26.9085
Japanese anchovy	-7.6538	0.00208	-479.948	-0.0837329
Spanish mackerel	-3.51641	0.00015	-6507.63	-71.1165

MSY (thousand tonnes)

Table 3.10 Parameters for small yellow croaker in different areas (1956-1998)

Areas	A	B	f_{MSY}	MSY
Tianjing	5.65249	-0.09742	10.2646	1.0762
Hebei	3.48844	-0.0167	59.8693	0.7210
Liaoning	4.87789	-0.00409	244.292	11.8047
Shandonng	3.89803	-0.00081	1231.42	22.3359

MSY (thousand tonnes)

Table 3.11 Parameters for Hairtail in different areas (1956-1998)

Areas	A	B	f_{MSY}	MSY
Tianjing	4.64117	-0.0202	49.5119	1.8882
Hebei	4.34806	-0.01421	70.3694	2.0016
Liaoning	5.52744	-0.0039	256.545	23.736
Shandonng	5.41165	-0.00167	599.383	49.3924

MSY (thousand tonnes)

Table 3.12 Parameters for Chines prawn in different areas (1956-1998)

Areas	A	B	f_{MSY}	MSY
Tianjing	6.07126	-0.05938	16.8419	2.6842
Hebei	4.53951	-0.01062	94.1863	3.2447
Liaoning	4.61815	-0.0049	204.277	7.6131
Shandonng	4.60093	-0.00278	359.107	13.1549

MSY (thousand tonnes)

Table 3.13 Parameters for Japanese anchovy in different areas (1956-1998)

Areas	A	B	f_{MSY}	MSY
Tianjing	8.9599	-0.04886	-2.0519	-2.9928
Hebei	-12.17825	0.03883	-25.753	4.8707
Liaoning	-2.09717	0.00685	-146.045	-0.0066
Shandonng	-2.93786	0.00547	-182.801	-0.0036

MSY (thousand tonnes)

Table 3.14 Parameters for Spanish mackerel in different areas (1956-1998)

Areas	A	B	f_{MSY}	MSY
Tianjing	-0.32374	0.02497	-40.0465	-0.0107
Hebei	2.03287	-0.00255	392.334	1.1021
Liaoning	3.84365	-0.00118	844.427	14.5058
Shandong	3.70529	0.0004	-2483.37	-37.1479

MSY (thousand tonnes)