INSTITUT NATIONAL GRONOMIQUE
PARIS - GRIGNON

CENTRE DE RECHERCHE EN
ECOLOGIE MARINE ET
AQUACULTURE

MEMOIRE

Présenté par : Benoît COLLAUDIN

Spécialisation : Sciences et techniques des productions animales

Sujet :

A FIRST APPROACH OF AQUACULTURE DEVELOPMENT IN THE JIAOZHOU BAY (P.R. CHINA)

Pour l'obtention du DIPLOME d'INGENIEUR AGRONOME
(de l'Institut National Agronomique Paris - Grignon)

Sous la responsabilité de :
Daniel Sauvant

Maître de stage :
Maurice HERAL

Enseignant responsable :
Catherine MARIOJOULS

soutenu le : 27 Septembre 1996

Acknowledgements

I would like to express my sincere thanks to the Chinese team who has warmly welcomed me, with first Mr. Chen Linhao from the State Oceanic Administration of Beijing who was always ready to help me and has made some arrangements in Beijing for me when I was in Qingdao or in L'Houmeau. I also would like to express my gratitude to Mr. Chao Jinxiang and Mr. Wang Liansheng from the Fishery Bureau of Qingdao for their friendship and co-operation, and all the people I have met thanks to them (fishermen, managers of the Fishery Agencies...). I truly would like to thank especially the whole team of the marine biology department of the First Institute of Oceanology, Mr. Zhu Mingyuan who welcomed me for the second time on his staff, Mr. Cheng Shan I have often requested to translate some papers, and Mr. Ji Rubao who has been working on this co-operation since the beginning, and who has helped me during those four months in China for both our investigations and my daily life.

I would like also to thank the whole team of IFREMER and CREMA L'Houmeau, Mr. Michel Houdart (from IFREMER Paris), Mr. Maurice Heral, Mr. Jean Prou, Françoise Mornet and Evelyne Richard for their help before and after my study in China.

A last I would like to thank my teacher Catherine Mariojouls for her precious advises and her help.

Summery of the Equations, Graphics and Tables.

SUMMERY

1. Introduction

One of the interesting problem to solve of the shellfish aquaculture is that it exist a threshold of density of stock over which the growth rate of the individuals decline as well as their survival rate. This is mainly due to the environment we are working on : the sea. Indeed, the shellfish (that almost can not move) live, breath and eat in only one environment : the sea water. As we can not control the physical and chemical characteristics of the sea water (excepted in ponds) we have to adapt the shellfish production to the environment. To switch from a small-scale production to a large scale one we need to think again about the distribution of the different shellfish productions according to the environment of the studied area. Before we start any studies on ecophysiology of shellfish to understand why they « do not want to grow anymore », or before we give our body and soul to modelling and to get by this way some answers to our questions, we need to take stock of the chosen area. This can be long, really long, but it is not conceivable to start any further investigations if we do not have in mind basic data such as : the different species living and produced in this area, their natural and breeding stocks, the exact location of those productions, the evolution of the physical and chemical characteristics (during the whole year) of the sea water and what are the socio-economic activities that can have an impact on the environment or on the management of the coastal area.

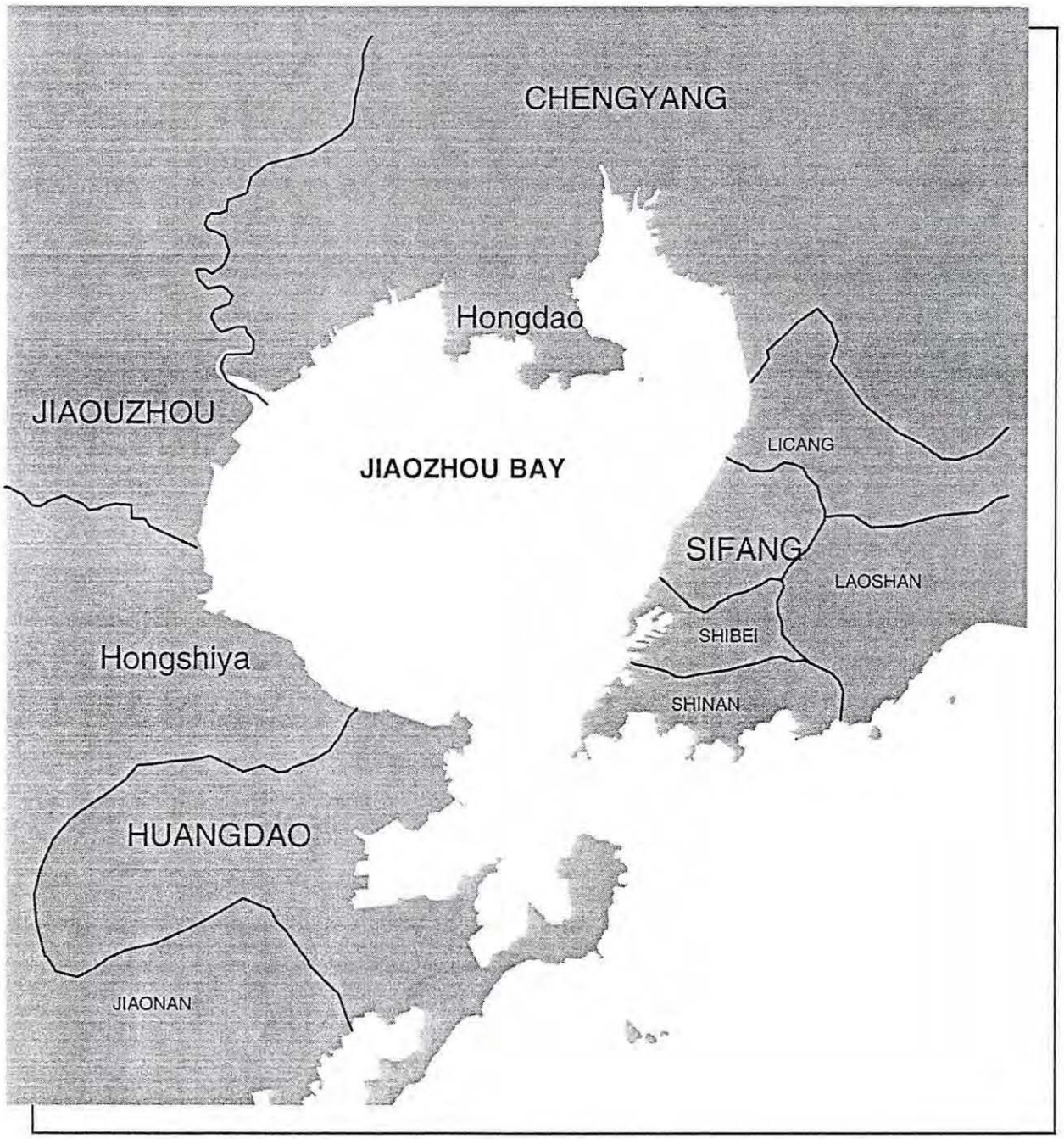
A Chinese French co-operation has been signed between two marine research institutes : the First Institute of Oceanology, State Oceanic Administration -F.I.O.- and the Institut Français pour la Recherche et l'Exploitation de la Mer -IFREMER-. The global program of this co-operation is to stop the decline of the productivity of the shellfish productions in the Jiaozhou bay (a Chinese bay turns towards the Yellow sea), to make those productions sustainable, to predict the ability of this bay

to support a shellfish production on a large scale and its optimum density of stock, and to work out an integrated coastal zone management of the Jiaozhou bay.

As a part of this Chinese French co-operation I went to China during 4 months (April July 1996) to gather historical data around the Jiaozhou bay about the aquaculture productions and to estimate the breeding stocks of scallops.

This paper present an overview of the Jiaozhou bay, the historical data I have collected (mainly) on shellfish productions, a description of the breeding structures of the suspended aquacultures, the breeding cycle of the scallops in this bay and an estimation of it stock.

Districts and areas around the Jiaozhou bay



DISTRICTS

Areas

2. An overview of the Jiaozhou bay

The Jiaozhou bay, located in the northern part of China, in the south-western tip of the Shandong peninsula, in the administrative division of Qingdao (cf. MAP 1, 2), turned towards the Yellow sea is a 400 km^2 semi-closed bay. With an average depth of 7 m, relative strong currents (15 cm / s with a maximum of 153 cm / s in the mouth of the bay), the half exchange of the sea water is quite fast (only 5 days), faster in the eastern part of the bay than in the western part.

The bay is surrounded by the county of Qingdao, that has an area of 10654 km^2 and a population of 6.785 million of inhabitants (cf. MAP 2). The city proper (districts of Shinan, Shibei, Sifang, Licang, Chengyang, Laoshan and Huangdao) covers 1305 km^2 with 2.149 millions of residents. On an administrative point of view the Jiaozhou bay should be divided onto 8 different areas or districts : Shinan, Shibei, Sifang, Licang, Chengyang, Jiaozhou, Hongshiya (this area belongs in fact to the district of Jiaonan), and Huangdao (cf. MAP 3). Each district (excepted Sifang) has its own Fishery Agency that manage both aquaculture and fishing, but the central administration (the Fishery Bureau) is based downtown (district of Shinan).

2.1. History of the evolution of the surface of the bay

During the beginning of the 60's (cf. MAP 4), the evolution of the bay was due to an advance of the land, new settlements have been built along the coast line, but after 1970 the production of salt and shrimps started so ponds have been built using concrete or stones on the beaches. After the beginning of the 80's the island of Huangdao has been linked, little by little, to the land. This new area is nowadays occupied by

Table 1 : Evolution of the surface and volume of the Jiaozhou bay from 1915 to 1995 Hou Guoben and al., 1993

	Total surface (km^2)	Surface bellow 0 m (km^2)	Volume of water (10^9 m^3)
1915	559	274	1.18
1935	559	274	1.18
1963	423	264	1.01
1988	390	257	0.92
1992	388	256	0.91

factories. The eastern part of the bay has also undergone some changes, last year a new highway has opened rectifying the profile of the coast line, but the evolution of the Jiaozhou bay is not finished. New shrimp ponds should be built in the north-west part of the bay to cover 1/3rd of the free inter-tidal area (inter-tidal area n°1, cf. MAP 5).

2.2. The rivers around the bay and the water supplying of the city proper

Many rivers (cf. MAP 6) are running into the bay. The volume of fresh water that runs to the bay fluctuate during the year because of the raining season (July and August, cf. annex, from Marine Science n°1). The most important river according to the flow of water (and sand) is the Dagu river (ANNEX I, II) located in the western part of the bay, it may have an impact on the salinity of the sea water nearby the mouth of the river and on the primary production, but more investigations are needed. The volume of sand released by this river (almost 100 m^3 / s on an average) can still have an effect on the profile of the coastline in the western part of the bay as it had before (cf. : Table 1 : Evolution of the surface and volume of the Jiaozhou bay from 1915 to 1995 Evolution of the surface and volume of the Jiaozhou bay from 1915 to 1935, p.7). The other rivers have also a real impact on the environment of the bay, not because of the volume of fresh water that they release but because of the quality of their waters. This is particularly true in the eastern part of the bay where the rivers are over polluted (cf. MAP 7, ANNEX III, III(A), III(B)).

Nowadays the daily water supply capacity of Qingdao (the city proper) is 500,000 m^3, and will be 1,050,000 m^3 before 2000 (Zhu Ban, 1995), when the channel between the Yellow river and Qingdao will be completed. Where will be released all this fresh water? That would be an interesting question to answer. The Chinese administration has made quite a lot to cure the pollution in the eastern part of the bay. A purification of water factory has opened last year, and 3 others are being built (one in Huangdao and 2 on the eastern coast of the bay), new tubes have been installed to collect the waste water on the eastern coast of the bay and on the south part of the district of Shinan. Obviously it is still not enough but on the right track.

2.3. The population around the bay

Nowadays the population (Table 2) is a reflection of the growth of the industrial activities. The eastern industrial area of the bay (districts of Shinan, Shibei, Sifang and Licang) and the western one (district of Huangdao) have the highest densities of population but little by little the industries settle in the northern part of the bay so the population of those areas increases year after year. But to have a good idea of the impact of the population on the ecology of the Jiaozhou bay we need to study Qingdao basin. Any way the wasted waters of more than 2.7 million of inhabitants living in this basin run every day into the bay.

Table 2 : Population around the Jiaozhou bay

Zhu Ban, 1995

District	Population
Shinan	28,000
Shibei	463,000
Sifang	60,000
Licang	11,600
Chengyang	411,900
Jiaozhou	729,000
Huangdao	974,500
TOTAL	2,678,000

As there is still not enough basic equipment in the district of Huangdao many people live in Qingdao and cross the bay every day to go working, but I think that soon more people will live there. The city hall of Qingdao has moved few years ago to the eastern part of the district of Shinan, new buildings are being built downtown in which offices settle so that the distribution of the population will soon change.

2.4. The industrial areas

The main industry areas are located in the eastern part of the bay in Sifang and Licang districts and in the Economic and Technological Development Zone of Huangdao. The main factories produce : textiles, light equipment, tobacco, refrigerators, chemical products, energy, metals, salt... A lot of pollution are released from those factories especially in the eastern part of Jiaozhou bay (cf. MAP 6, ANNEX III, III(A), III(B)).

Different kinds of industries are settled around the bay : private and public ones, big and small ones but the newest ones seems to be private and high-tech. The industrialisation of the bay is not finished, if in the eastern part the advance of the

factories is blocked by the shrimp ponds the land is still free in the western part (and it's no use to tell them twice).

2.5. Means of transport

By the same time the means of transport have increased. The harbour (MAP 8) of Qingdao city is now the 5th largest one of China, divided into two parts (that I will call : harbour of Qingdao and harbour of Huangdao) it has an annual capacity of 73 million tons. The harbours of Qingdao and Huangdao should be enlarge(MAP 8 bis), so that one part of the aquatic productions should disappeared before 2010) (from the local Fishery Agencies of Huangdao and Chengyang).

Hundreds of Chinese people cross the bay everyday from Qingdao to Huangdao thanks to a ferryboat that leaves the harbour every 30 minutes, to make this transit easy there is some talk about building a bridge (MAP 8 bis) that will be useful for both people and goods discharge from cargoes in Huangdao, and a subway that would also cross the bay (but I don't know that much about it). The second ferry is mainly used by tourists during the summer.

A new highways (opened in 1995) surround the bay and link the old city (Shinan) with Huangdao as well as a railway.

2.6. The marine cultures

If you have a look on a book that present the county of Qingdao, you will read that the only marine production in the Jiaozhou bay is salt. Indeed a lot of ponds in the north part of the bay are used to produce it (515,900 MT. in 1995, Zhu Ban, 1995) (cf. MAP 9). But if you ask in Beijing to people what is Qingdao famous for, they will answer either for its beer, for its beaches or for its seafood. Lets open a menu and have a Chinese meal in Qingdao. You will start with some fried shrimp (*Penaeus chinensis*), then you will have some clams (*Ruditapes philippinarum*) with a spicy sauce, some boiled scallops (*Chlamys farreri* or *Argopecten irradians* during the winter), some mussels on the shell (*Mytilus edulis*), and if you are still hungry you

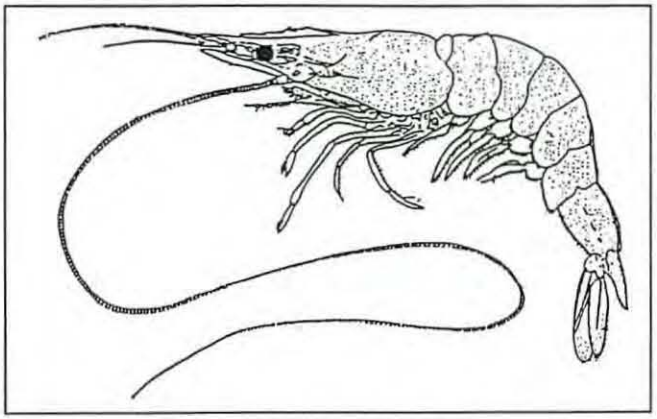
can order an oyster and algae soup (*Ostrea plicatula and Laminaria japonica*). By the time you will have an idea of what are the different aquatic productions in the Jiaozhou bay.

3. The aquaculture in the Jiaozhou bay

On the map n° 9 I have only mentioned the main productions. Other sea products are produced in the bay such as abalone, sea cucumber... on a small scale.

3.1. The productions in ponds

Since the beginning of the 60's ponds have been built in the inter-tidal areas, located in the north part of the bay (cf. MAP 10) those ponds are used to produced either salt[1] or sea products (mainly shrimps). *Penaeus orientalis* (also called *Penaeus chinensis*) is the main produced species. It has euryhaline characteristics (large salinity range), and a good sexual maturation in ponds without eyestalk ablation. It can tolerate low temperatures and may grow at 14°C. Gravid females are fished in the Yellow sea in November and kept in hatchery. After the induced spawning period the young shrimps are sold to farmers. The harvesting appends at the end of September, beginning of October.



Penaeus orientalis

[1] I will not deal with the production of salt, I have just established a map of the ponds to distinguish the saltmarshes from the shrimp ponds.

Photo 1 : The suspended aquaculture in the Jiaozhou bay (lines and floats)

Photo 2 : A shrimp-scallop mixed culture in the south west part of the Jiaozhou bay

The district of Jiaozhou

The district of Jiaozhou has 12,000 muland of ponds (15 muland = 1 ha = 10,000 m^2) that have produced in 1995 : 300-400 MT. (Metric ton). of shrimps (*Penaeus orientalis*). The data collected for the surface of ponds should only include the surface of the water. But we should add a production of 500 MT. of fish as a combined culture (From the Fishery Agency of Jiaozhou). The area for the fish-shrimp combined culture is not clearly defined but all those fish are produced along the Dagu river. Because some problems of diseases exist farmers do not change any more the water of the ponds after July but just add some fresh water from the Dagu river. As we will see in some other parts of the bay farmers are used to combined the shrimp culture with shellfish or others crustaceans, but those ones can not endure the fresh water so fish are the only solution for them. According to the farmers, the fish production is a good indicator of the water quality so if some fish die it means that it is time to harvest the shrimps before they all die.

The district of Chengyang

I got better data for the district of Chengyang. In 1995 the total area was 23,000 muland that have produced 1,150 MT. of Shrimps (90 % of *Penaeus chinensis*, 7-8 % of *Penaeus japonicus* and 2-3 % of *Penaeus penicillatus*). Almost half of the surface of production is a mixed culture (cf.
Table 3, Table 4, MAP 11, Photo 2) shrimp-shellfish, shrimp-fish (also located nearby the rivers) or shrimp-crabs.

Table 3 : The different productions in ponds, in the district of Chengyang, their surface and total productions (1995)

From the Fishery Agency of Chengyang

kind of culture	Surface (muland)	Surface (ha)	Production of shrimps in MT.	Other product (MT.)
Shrimps-fish	6,000	400	360	fish : 600
Shrimps-shellfish	2,000	133	120	shellfish : 800
Shrimps-crabs	2,000	133	120	crab : 120
Shrimps (alone)	13,000	867	550	

Table 4 : Number of individuals of shrimps, scallops, oysters, clams, crabs and fish introduced per muland in ponds at the beginning of the breeding cycle in the district of Chengyang (1995)

From the Fishery Agency of Chengyang

	Individuals per muland	Individuals per ha	Production (kg) expected per muland
Shrimps (*Penaeus chinensis*).	10,000	15,000	50
Scallops (*Argopecten irradians*)	12,000-18,000	180,000-270,000	200-300
Oysters (*Ostrea plicatula*)	2,000-3,000	30,000-45,000	300-500
Clams (*Ruditapes philippinarum*)	8,000-15,000	120,000-225,000	150-300
Crabs (*Portunus trituberculatus*)	500-1,000	7,500-15,000	?
Fish (?)	200	3,000	100

Whatever can be the kind of shrimp culture (mixed or not), the density of shrimps after the enhancement of the ponds (in May) is always the same. the adults are harvested in October (if no diseases appeared). We have a semi-intensive production, feed only with artificial food (1.789.98 MT. equivalent dried weight for the all district of Chengyang in 1995) and a survival rate of 58 % (from the Fishery Agency of Chengyang).

3.2. The benthic productions

3.2.1. The production of clams

- Location and breeding cycle

The production of manila clams (*Ruditapes philippinarum)* between aquaculture and fishing, is mainly located in the shallow water of the north-east and the north-west part of the bay (cf. MAP 12) in the districts of Jiaozhou, Chengyang and Hongshiya.
In the district of Jiaozhou 80 % of the clams are produced in the sub-tidal area, 15 % in the middle and low tidal areas and 5 % in the high-tidal area. The harvesting method is a kind of hand dredging. A new method has appeared to enhance the swallow water, the fishermen use huge suction pumps to collect the clams from the

centre of the bay, and release them in their own area. Although this method is forbidden many boats have such an equipment. 30 % of the clams collected by this method die. Is this a real important fact ? Enough to be seen but it was difficult to get information about legal aspect so for illegal ones...

I would like to disgress for a moment to deal with the legal aspect of this production. It seems that some laws exist to control the exploitation of clams (each district has its own area), but during my stay in China I haven't seen a boat harvesting clams in a legal area (those areas, normally located nearby the coastline seem to be empty). if a fisherman is caught red-handed, his harvesting or a part of it (if there is too much!!!) is seized. Then he should give some money to the Fishery Administration (as a fine) when he go back to the harbour. I'm wondering : 1st why if several boats are caught only one of them has to give a part of its harvesting, 2nd if the fine is actually paid and 3rd if the seize that is not destroyed but distributed between the members of the administration is not the catalyst of this illicit exploitation.
Some fishermen buy some small clams (but not spats) from an other part of China (it should be from the Bohai sea, cf. MAP 1) to enhance their area of production.

- The historical data

More than 77,260 MT. of clams have been produced in the Jiaozhou bay in 1995 (cf. Table 5) (from the Fishery Agencies of Chengyang, Jiaozhou and Hongshiya) and the total production of the bay would have been 100,000 MT. in 1990, with a total breeding stock of 140000 MT. (September 1990) -From Marine Science Bulletin vol. 11 n° 3, June 1992).

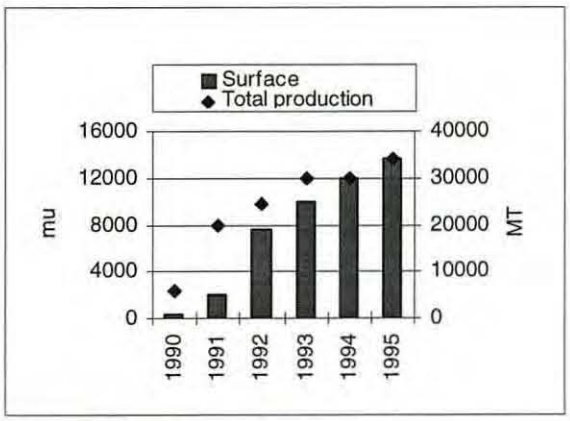
Table 5 : Surface, production and productivity of manila clams (*Ruditapes philippinarum*) in the districts of Jiaozhou Chengyang and Hongshiya (1995).

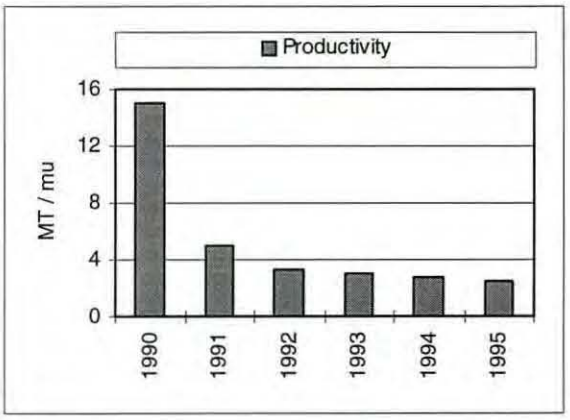
From the Fishery Agencies of Jiaozhou Chengyang and Hongshiya.

District	Surface (muland)	Production (MT.)	Productivity (MT./muland)
Jiaozhou	28,000	56,000	2.3
Chengyang	15,230	14,660	0.96
Hongshiya	14,025	6,600	0.47

The district of Huangdao

The total production of clams in the area of Hongdao (an area that belongs to the district of Chengyang) has increased (cf. Graphic 1, ANNEX IV) from 1990 to 1995 because the surface of production has increase. But during the same time the productivity has been divided per 4 and is still decreasing. Obviously this area is over exploited, year after year the clams are harvested more and more early. I think that the productivity in 1990 is too high (maybe because of an underestimation of the surface).so that the productivity hasn't decreased so much, but between 1991 and 1995 it has been divided per two.





From the Fishery Agency of Hongdao

calculated

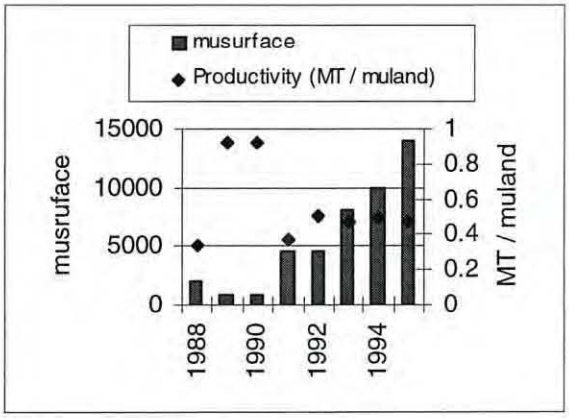
Ruditapes philippinarum

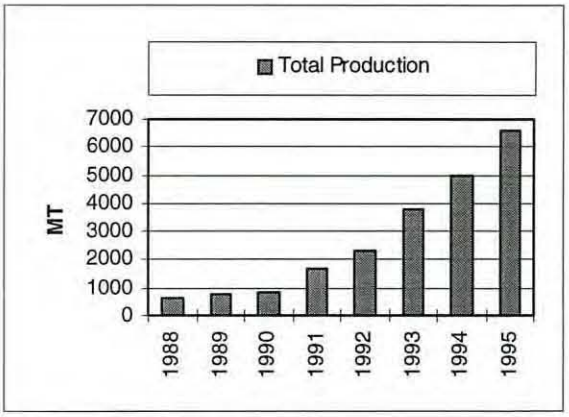
Graphic 1 : Evolution of the production of clams (*Ruditapes philippinarum*) in the area of Hongdao (that belongs to the district of Chengyang) from 1990 to 1995.

According to what we eared the breeding stock of the bay as changed a lot because of this over exploitation, 5 years ago the individuals were harvested after 2 years of growth whereas now they are harvested within a year.

The area of Hongshiya

The clams are here mainly produced in the middle and sub-tidal areas so that the productivity (cf. Graphic 2, ANNEX IV) is relatively low (less than 1 MT. / muland).





From the Fishery Agency of Hongshiya

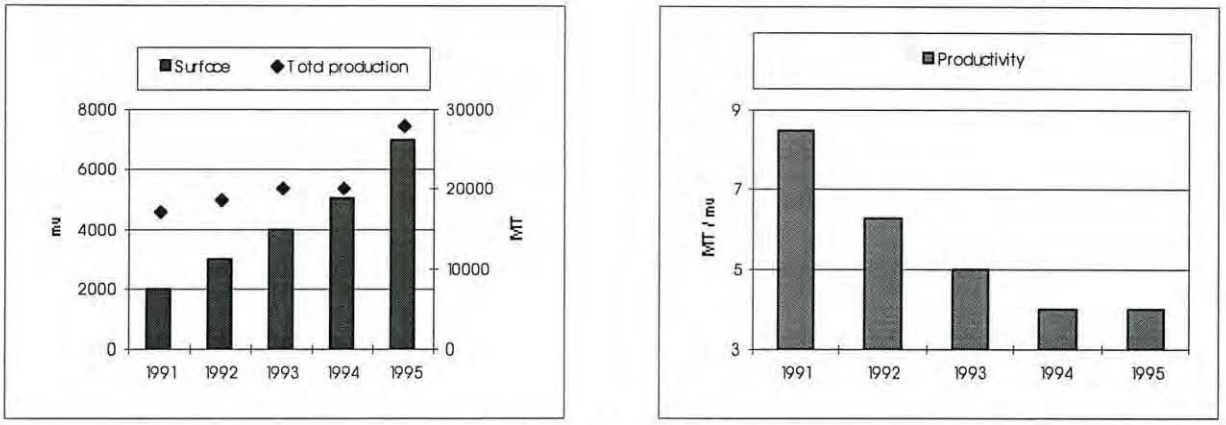
Calculated

Ruditapes philippinarum

Graphic 2 : Evolution of the production of clams (*Ruditapes philippinarum*) in the district of Hongshiya, from 1988 to 1995

3.2.2. The production of oysters

The south part of the peninsula of Hongdao is an area reserved for the breeding of oysters (*Ostrea plicatula*) (cf. MAP 12). The juveniles are collected from the rocks and released in the sea where they can grow bigger. The adults are dredged. 12420 MT. of oysters have been harvested in 1995 from the district of Chengyang (12420 muland of production) (From the Fishery Agency of Chengyang). I got other data from the Fishery Agency of Hongdao (cf. Graphic 3, ANNEX V).



From the Fishery Agency of Hongdao

Calculated *Ostrea plicatula*

Graphic 3 : Evolution of the production of oysters in the area of Hongdao.

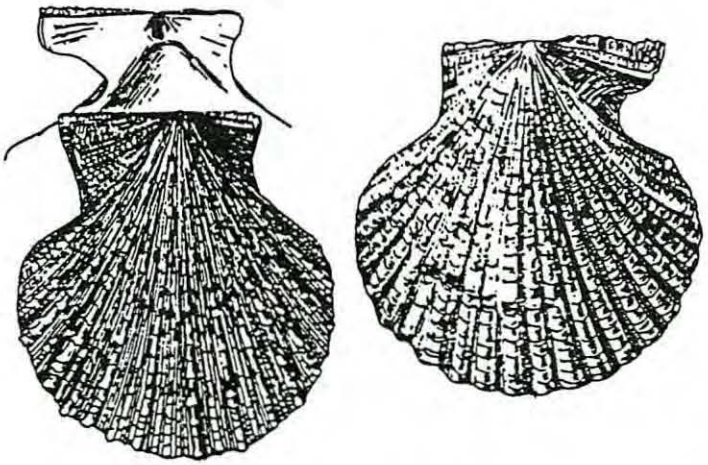
What to think about those data? The productivity seem to be so high! The production of oysters is even more important here than in the all district of Chengyang!!! Everybody around the bay agree to say that Hongdao is a really important area for the shellfish production in the Jiaozhou bay (people do not talk about the district of Chengyang but about Hongdao) so that the productivity in this area can be higher than in the other parts of the district, but the normal productivity of oysters in the bay is 1 MT. / muland.

3.3. The suspended productions

Two species of scallops [the local scallop, *Chlamys* (Azumapecten) *farreri* (Jones et Preston) and the bay scallop, *Argopecten irradians* irradians (Lamarck)], the main production in the Jiaozhou bay after the production of clams, one species of mussel (the blue mussel, *Mytilus edulis*) and one of algae (*Laminaria japonica*) are produced in this bay on a suspended way. (cf. Table 6, p.19, MAP 13) ! Mainly three districts are concerned by those productions (Sifang, Hongshiya and Huangdao). As there is no Fishery Agency in the district of Sifang, the information have been collected from Chengyang which is in charge of it. A small forth area of production of scallops exist in front of the harbour of Qingdao (Wuhao), I don't know that much about it as I have turned my mind on the biggest areas, but I will sometimes add some information about it.

3.3.1. the different species of scallops

I will not present here Mytilus edulis and Laminaria japonica as those species exit also in France



Graphic 4 : *Chlamys farreri*

The local species (C. farreri) is easy to recognise thanks to its little excrescence on the shell and to one of its ear that is hypertrophied. The colour of the shell is brown or red. It can reach 6-10 cm. The scallop can live more than 2 years (4 is a maximum). the sexes are separated and the sexual maturity occurs during the second year.

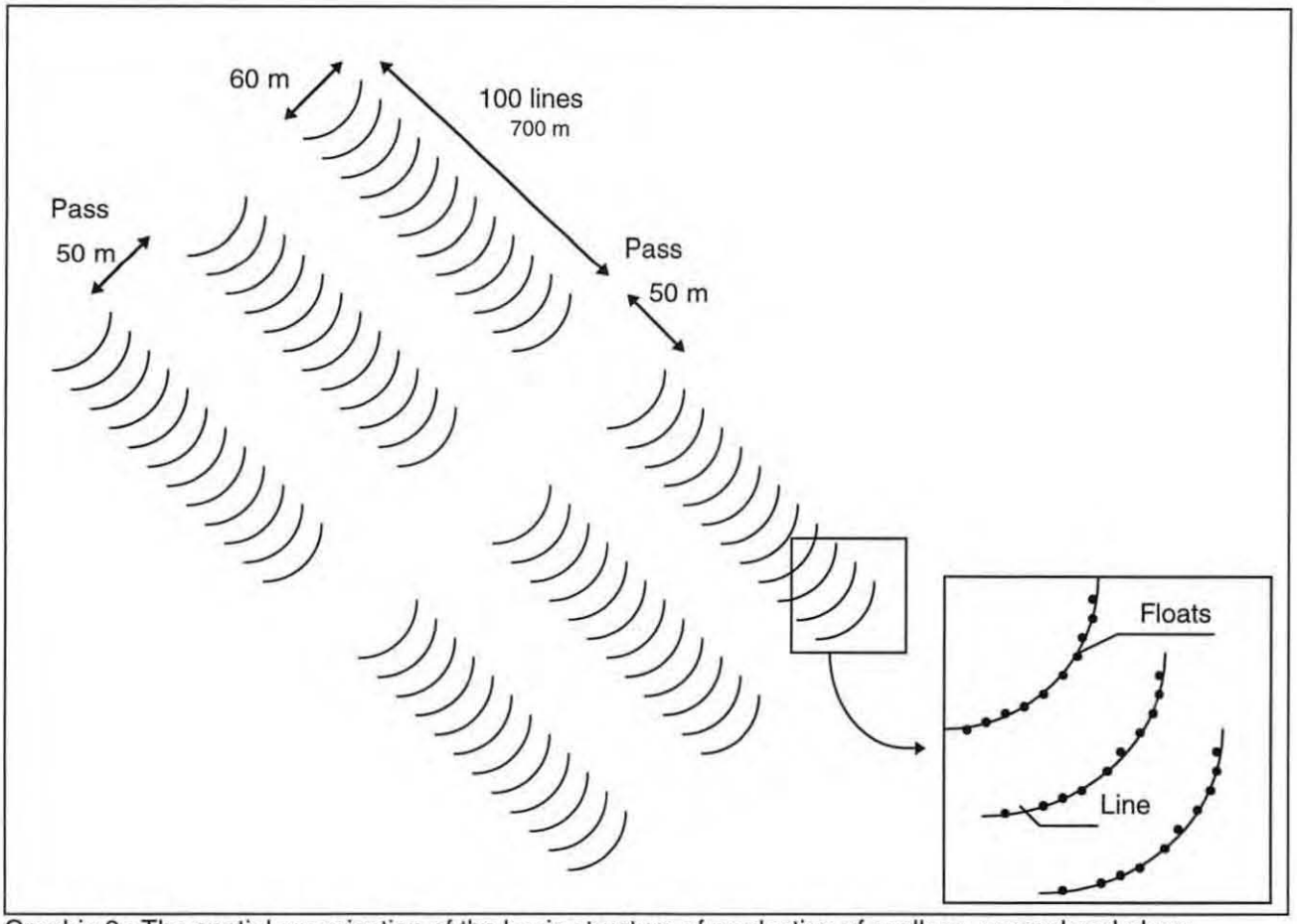
Graphic 5 : *Argopecten irradians*

The bay scallop has a grey convex shell, its commercial size is about 6 cm, with two small ears. It grow fast and reaches sexual maturity within a year. Its life span is about 12-16 months even if a few individuals can live up to 24 months but mass mortality appears during the first winter. Anyway, as it grows fast farmers can harvest them within a year.

3.3.2. The basic structure of the suspended aquaculture

In each part of the Jiaozhou bay, 60 m long lines are used (Graphic 4, p 19), suspended under floats (40-80 floats), as a basic structure under which farmers fix different equipment according to what they produce (scallops, mussels, algae). I can

assume that the lines are grouped by 100. This structure is kept in the water even after the harvesting period (cf. Photo 1).



Graphic 6 : The spatial organisation of the basic structure of production of scallops, mussel and algae in the Jiaozhou bay.

3.3.3. Distribution of the different species

More than 90 % of the total surface is represented by the scallop production.

Table 6 : Distribution of the species produced on a suspended way in the Jiaozhou bay (1995 and 1996)

From investigations around the bay

	Chlamys farreri	*Argopecten irradians*	*Mytilus edulis*	*Laminaria japonica*
Sifang	✓		✓	✓
Huangdao	✓	✓	✓	
Hongshiya	✓	✓	✓	
Wuhao	✓			

3.3.4. The unit of surface

I would like you to be attentive to this problem, especially if you are looking for more information on aquaculture in China. I have already introduced the concept of mu (that I have called muland, but its real name is mu). This Surface unit (15 mu = 1 ha) refers to the land (agriculture, ponds, bottom cultures...). The problem is more complicated if we deal with the suspended aquaculture (cf. Table 7). Few years ago the only unit used to describe the production of scallops was the first one. Farmers got into the habit of putting those spats into 400 lanterns

Table 7 : Definitions of the unit of surface used in china for the suspended production of scallops, mussels and algae, and their estimated surfaces (m^2) for the Jiaozhou bay.

From the different Fishery Agencies

Production	Definition	Estimated surface (m^2)
Scallops	1 mu = 100,000 spats	4,000-6,000
	1 mu = 400 lanterns	
Mussels	1 mu = 300 ropes	3,300
Algae	1 mu = 400 ropes	5,800

Lantern and rope, cf. Graphic 7, 10, 11, p. 21, 24 and 25

so that the definition changed. But the lanterns have also changed as well as the number of individuals per tray, 1 mu nowadays do not equals to 100000 spats.

The surface of 1 mu for mussels and algae is constant in each part of the bay, we will see that this is not true for scallops. This surface depend on the breeding structure (cf. ANNEX VI). Different from the notion of surface (that refers to m^2) I will now use the words "musurface".

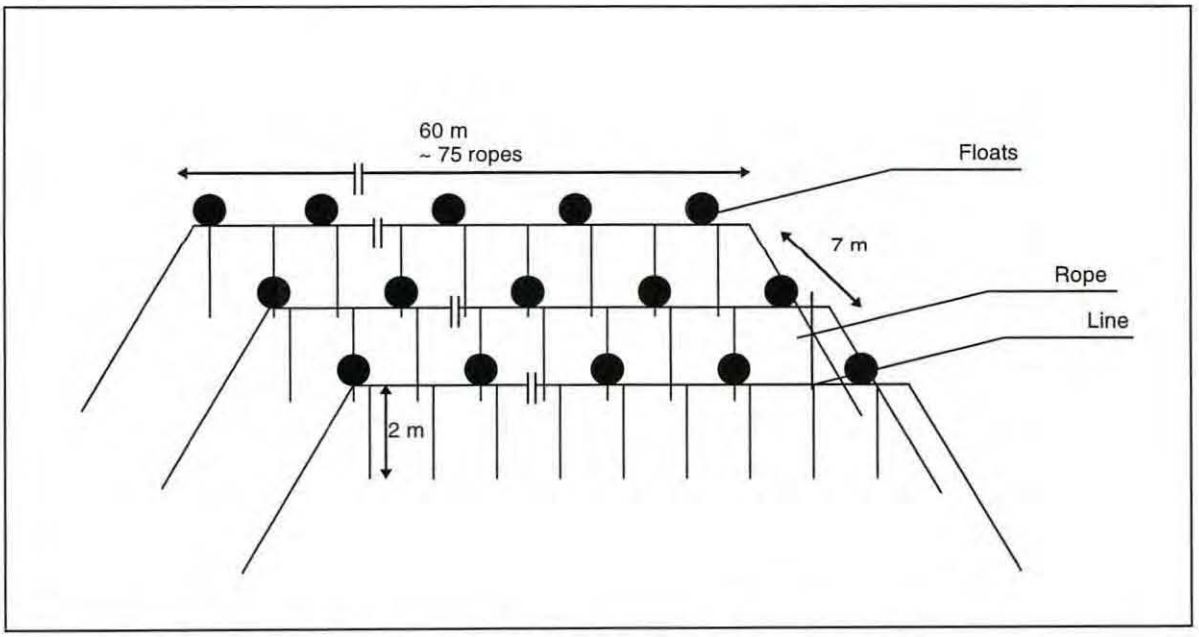
I would like also to draw your attention to the use of the hectare in the Chinese bibliography. Indeed since 1992 China has joined the western countries and use now the international units system trying to make disappeared, in publications, the mu. I can not assume that all the Chinese literature uses the word hectare in a wrong way but the data (in hectare) I have collected was obviously wrong, expressed in what I will call pentadecamu. On the land 1 mu = 1/15 ha, this ratio has been kept to convert the mu into hectares even for the suspended aquaculture. In this paper all the data have been corrected and converted back into mu.

As this unit (mu) means nothing by itself I will use "muland" as I already did (for a musurface that refers to the land, shrimp ponds, bottom cultures...), mumussel, mualgae and muscallop. For the last one, as two definitions exist mine will be : 1 muscallop equals to 400 growth lanterns (cf. growth lantern p.26).

3.3.5. The mussel culture

- The breeding structure

According to the Fishery Bureau the mussel culture is less and less important in the Jiaozhou bay. The spats are collected on ropes (from outside of the bay) which are bought by the farmers in early June. Normally two ropes are suspended between two floats (cf. Graphic 7). Within a year the mussels are harvested.



Graphic 7 : Breeding structure of mussels (*Mytilus edulis*) in the Jiaozhou bay

- Historical data

The district of Sifang

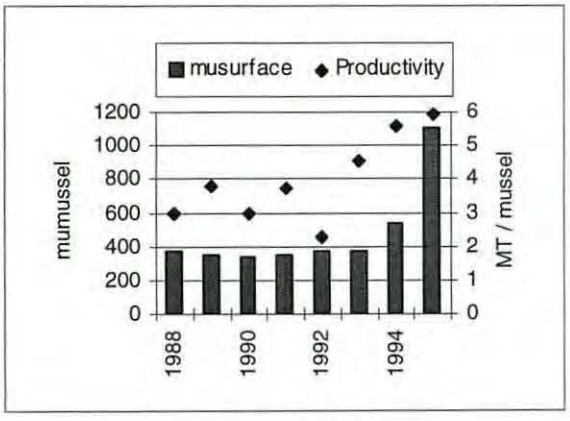
Tableau 8 : The musurface, the productivity and the total production of blue mussels (*Mytilus edulis*) in the district of Sifang in 1995

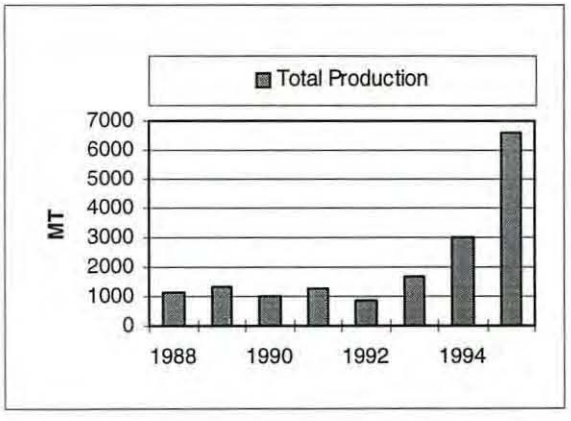
From the Fishery Agency of Chengyang

1995	Musurface (mumussel)	Productivity (MT./mumussel)	Production (MT.)
Blue mussel	1650	5	8250

The district of Hongshiya

The productivity of mussels (cf. Graphic 8, ANNEX VII) is still increasing in Hongshiya and is the highest one in the bay. To have an idea and to compare with a French productivity, I have calculated the productivity of mussels per meter of rope. In 1995 the productivity of blue mussels was 6 MT. / mumussel ~ 10 kg / m of rope. For the same species (*Mytilus edulis*) in the area of Pertuis Breton (nearby La Rochelle) we have 13 kg / m of rope (M. J. Dardignac, pers. com., IFREMER). Of course the water quality and temperature is not the same, but if I convert those data onto kg / ha the productivity becomes 18 MT. / ha in Hongshiya and 4.6 MT. in Pertuis Breton so that we can understand that the strategy of production is not the same (the density of ropes is higher in Hongshiya than in Pertuis Breton).



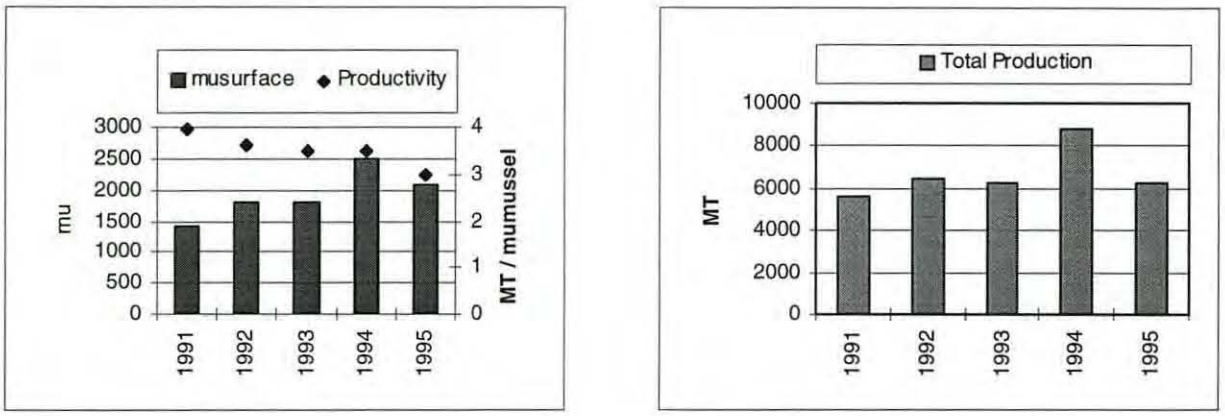


From the Fishery Agency of Hongshiya

Graphic 8 : Evolution of the musurface, total production and productivity of blue mussels (*Mytilus edulis*) in the district of Hongshiya from 1988 to 1995

The district of Huangdao

The productivity of the mussels production in Huangdao (Graphic 9, ANNEX VII) has been decreasing since 1991 and was in 1995 3 MT. / mu (half of the productivity of Hongshiya).



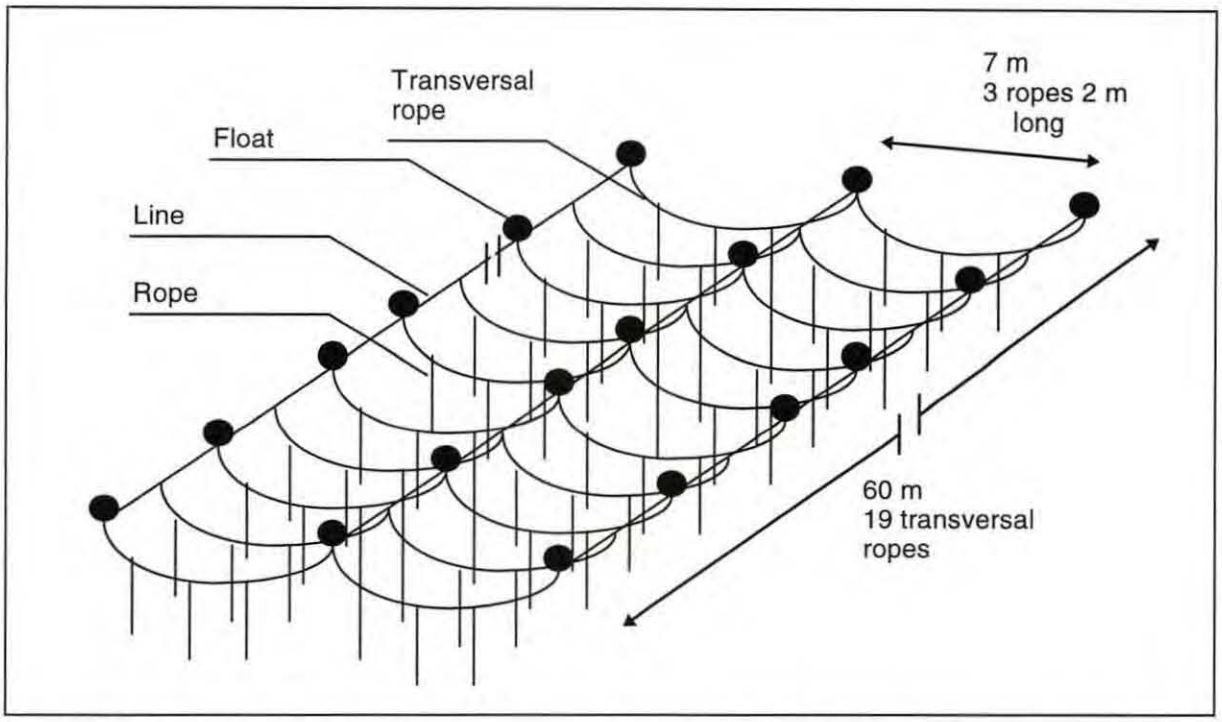
Graphic 9 :Evolution of the musurface, total production and productivity of blue mussel (*Mytilus edulis*) in the district of Huangdao

From the Fishery Agency of Huangdao

3.3.6. The algae culture

- The breeding structure

The structure of the algae production (cf. Graphic 10) is almost the same as the mussel one. Indeed the farmers use the lines of production of mussels or scallops (cf. : 3.3.7. The scallop, p. 24) to fix some transversal ropes. The vertical ropes are used as collectors on which the algae fixed naturally and grow. The main production is *Laminaria japonica* with a short life cycle (from January to April).



Graphic 10 : Breeding structure of algae (*Laminaria japonica*) in the Jiaozhou bay

- Historical data

The district Sifang

Table 9 : Musurface, productivity and total production of algae (Laminaria japonica) in the district of Sifang (1995).

1995	Musurface (mualgae)	Productivity (MT./mualgae)	Production (MT.)
Laminaria japonica	1,320	1	1,320

The productivity of algae in this district (cf. Table 9) is according to the scientist of the F.I.O. a normal one and is representative of the all production of the Jiaozhou bay.

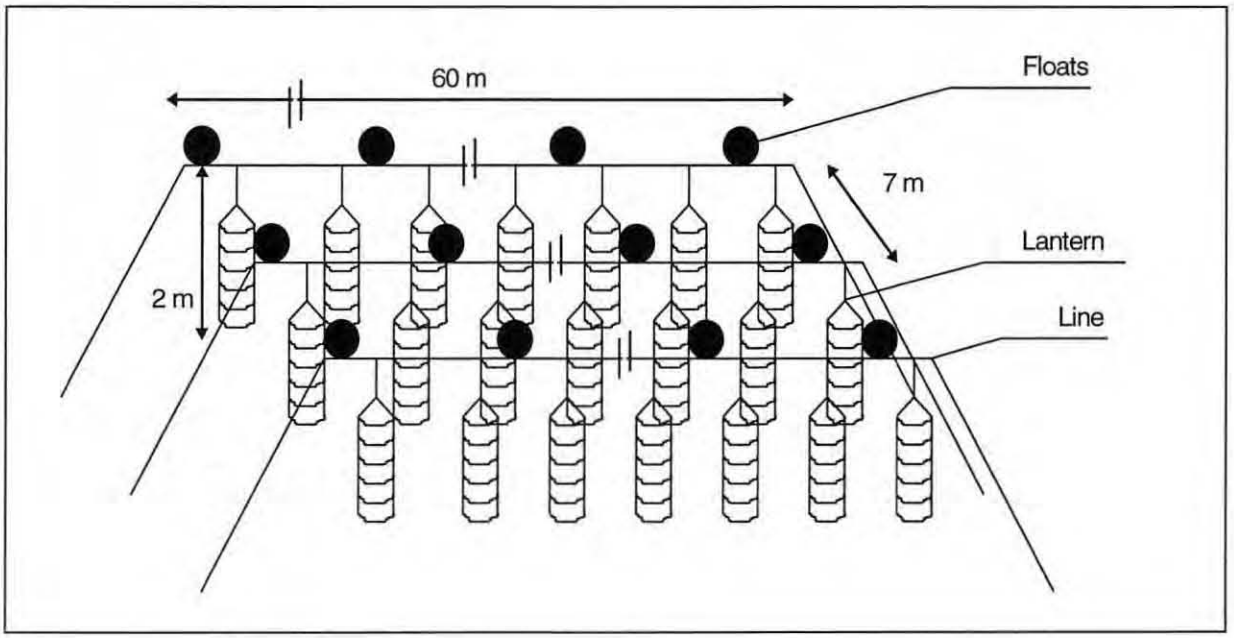
3.3.7. The scallop culture

- The breeding structures

As some variations exist from one district to an other I will just present here a general view of the breeding structures (cf. 3.2. for more details).

Photo 3 : Farmers dividing the spats (*Agopecten irradians*) from net bags to temperate growth lanterns

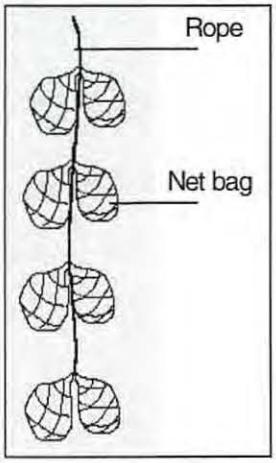
Photo 4 : Net bags with spats (Argopecten irradians)



Graphic 11 : Breeding structure of the scallops produced (for both species *Chlamys farreri* and *Argopecten irradians*) in the Jiaozhou bay

The breeding structures of the scallop production (cf. Graphic 9) is also based on lines suspended under floats (40-80 floats). It seems that the number of floats depend on the weight of the scallops, but more investigations are needed to confirm this fact. Under the long lines 3 kinds of structures are used, each one corresponding to one period of the breeding cycle. The structures are the same one for both species, *C. farreri* and *A. irradians*)

- String of net bags

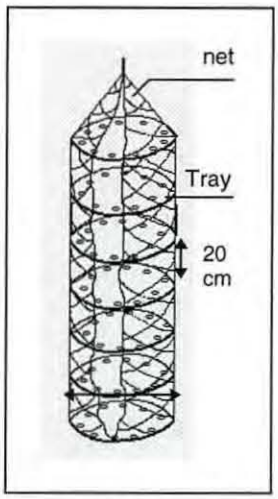


Graphic 12 : String of net bags

The farmers buy the spats in net bags (that contains 800-1000 individuals) from nurseries located either around the Jiaozhou bay (especially for the bay scallop) during the autumn and fix them onto ropes or in Rongcheng (west part of the Shandong peninsula). Their size is 1 cm and their cost is 1 fen per individual (1 fen = 0.006 Franc). Those net bags are fixed on ropes and put into the sea (cf. Graphic 12, Photo 4).

Photo 5 : A farmer dividing the scallops (*Chlamys farreri*) after the temperate growth period.

Photo 6 : The growth lanterns are filled with scallops.



Graphic 13 : Chinese lantern

- Temperate growth lanterns

After few months spent in net bags the juveniles are transferred into temperate growth lanterns (cf. Graphic 13, Photo 3), this is the first dividing period (spring). The mesh size of those lanterns is 3 mm. Two kinds of lanterns exit : 6 or 9 trays on an average (the number of trays can vary from 5 to 10). From 900 to 3000 of juveniles are put per lantern, without any relation between the number of individuals and the number of trays (cf. 4.2 Cycles of production and breeding structures of scallops in the districts of Sifang, Hongshiya and Huangdao, p. 33).

- Growth lanterns

After a second dividing period (end of the spring beginning of the summer, cf. Photo 5) other lanterns with a bigger mesh size (10-20 mm) are used. The number of trays fluctuate from 9 to 10 and the number of individuals per lantern from 250 to 400 (cf. Photo 6).

- The historical data

The breeding of *Chlamys farreri* (the local species) started not only in the Jiaozhou bay but also in the Yellow and Bohai seas during the 70's, because the international demand (Japan, USA..) existed and the mariculture of several major fishery culture species (such as kelp and mussel) suffered in China from drastic decrease in market price. During the beginning of the 80's (1982) the bay scallop (an American species : *Argopecten irradians*) was successfully introduced in the Jiaozhou bay. This species

has a shorter life cycle and grow faster than the local species so that it can be harvested within a year. During the 80's more and more bay scallops were produced in the Jiaozhou bay. In 1990, 100% of the scallop production was represented by this species (From the Fishery Bureau). After 1990, things started to change, the problem raised is a diminution of the growth due to a lack of the renewal of the genetic (only 26 individuals have been successfully introduced in 1982). In 1994 new individuals from Canada (also *Argopecten irradians*) were introduced, experiments carried out by the First Institute of Oceanology of Qingdao have « shown » a better growth and a better survival rate (ANNEX VIII) of the Canadian species. I just want to notice that the experiments were not carried out during the same year !
Since 1995 none American bay scallops has been cultivated in the Jiaozhou bay but Canadian ones.

The district of Sifang

Sifang is a new area as the suspended aquaculture has started in 1995. There is no Fishery Agency in this district and according to the people working there, there won't be anyone in the future (the area will be erased before). The district of Chengyang collect the data (cf.
Table 10)

Table 10 : Musurface, productivity and total production of scallops (*C. farreri* and *A. irradians*), blue mussels (*Mytilus edulis*) and algae (*Laminaria japonica*) in the district of Sifang (1995)

From the Fishery Agency of Chengyang

1995	Musurface (mu)	Productivity (MT./mu)	Production (MT.)
Scallops (50% of each species)[2]	650	3.64	2366
Blue mussel	1650	5	8250
Laminaria	1320	1	1320
Total surface	3620		
available surface for the scallop production	61450		

From those data we can realised how important it is to paid attention to the musurface. Indeed, having in mind that the muscallop is different from the mumussel

[2] Farmers agree to say that there is none a bay scallop in this district, and I haven't seen one.

and from the mualgae, and that the surface of production of algae is in fact included in the two other ones, how can a total musurface be equal to three different ones? An other question is what is the real unit of the available surface (we have to remember that this data include Chengyang, Sifang and obviously Licang). I don't know where are the administrative limits of the districts (in the bay) but if I convert those 61450 mu into km^2 using the surface of one mu (anyone) the available surface is larger than 200 km^2 (remember that the surface below 0 m of the bay was 256 km^2 in 1992). But if I say : the available surface is 61450 muland then we have a 41 km^2 available area, this is maybe one answer ?

The size of the fresh muscles of scallops (beginning of the harvesting period of 1996) :

Farmers are used to sell their scallops according to the size of the muscle of the scallop. The criterion used is the number of muscles that half a kilogram can contain so that the bigger this number is the smaller are the scallop muscle.

North part of the area of Sifang : 130 muscles per half a kilogram.

South part of the area of Sifang : 80 muscles per half a kilogram.

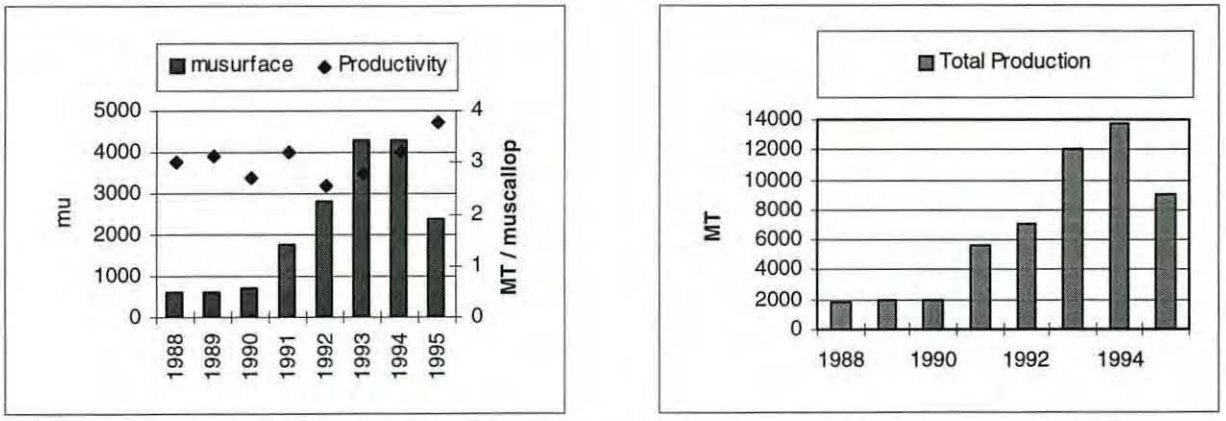
If we look at the tidal currents (cf. ANNEX IX, Ding Wenlan, 1992) we can see that their orientation is the same as the area of production. The density of this area is may be too high to have a sustainable production from the north to the south. An other explanation can be that as a lot of pollution come from the north east part of the bay (cf. MAP 7) the growth rate of the northern scallops is may be more affected than the one of the southern scallops.

The district of Hongshiya

From 1989 to 1993 the musurface of the scallop production in the district of Hongshiya (cf. Graphic 14, ANNEX X) has increased by the same time as the total surface. After this period people started to realise that the density of production was too high so that in 1994 not the musurface but the surface has increased. The drastic drop of the musurface in 1995 is due to two reasons. The first one is an administrative one. The limits of the district of Hongshiya have changed in 1995. A

small area, that include 800 muscallops, has been given to the district of Huangdao (the nearest area of production of scallops, north from the harbour of Huangdao, cf. MAP 18). The second reason is that the musurface has decreased (but not the surface).

Hongshiya is the only district where the productivity is still increasing. The reason why is to my mind a better management of the suspended aquaculture and a better control of the area. The Fishery Agency of Hongshiya has been the only one where people said that the density (of production of scallops) was too high so that they have reduced the musurface of the area.

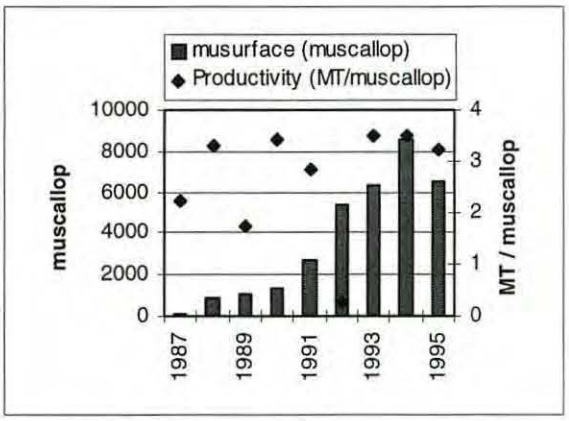


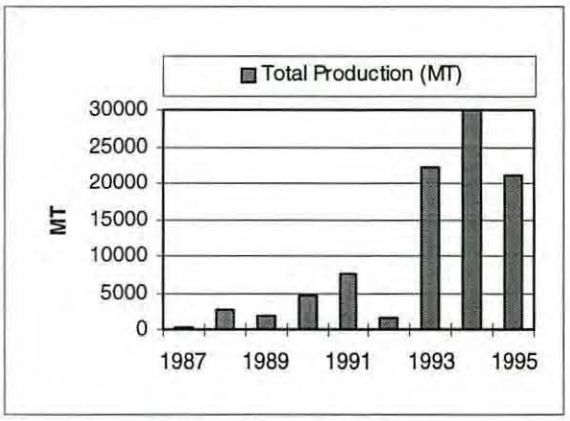
Graphic 14 : Evolution of Musurface, productivity and total production of scallop (*A. irradians* and *C. farreri*) between 1988 and 1995 in the district of Hongshiya

From the Fishery Agency of Hongshiya

The district of Huangdao

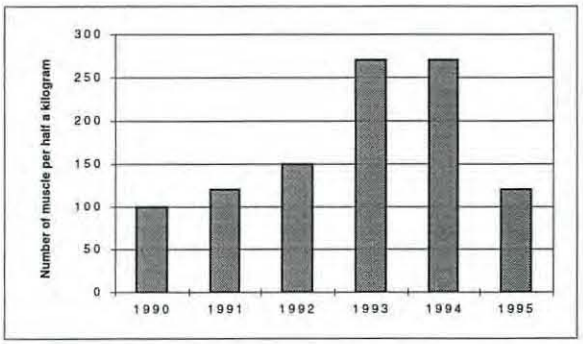
Excepted the drop occurred in 1992 (due to storms), the productivity of scallop (cf. Graphic 15, ANNEX X) has increased from 1990 to 1994 thanks to the development of a new area outside of the bay (4000 muscallops in 1994). But this hides in fact a diminution of the growth of the scallops, (cf. Graphic 16) the size of the muscle has been divided by two from 1990 to 1994.





Graphic 15 : Evolution of the musurface, productivity and total production of scallop (*A. irradians* and *C. farreri*) between 1990 and 1995 in Huangdao district.

From the Fishery Agency of Huangdao



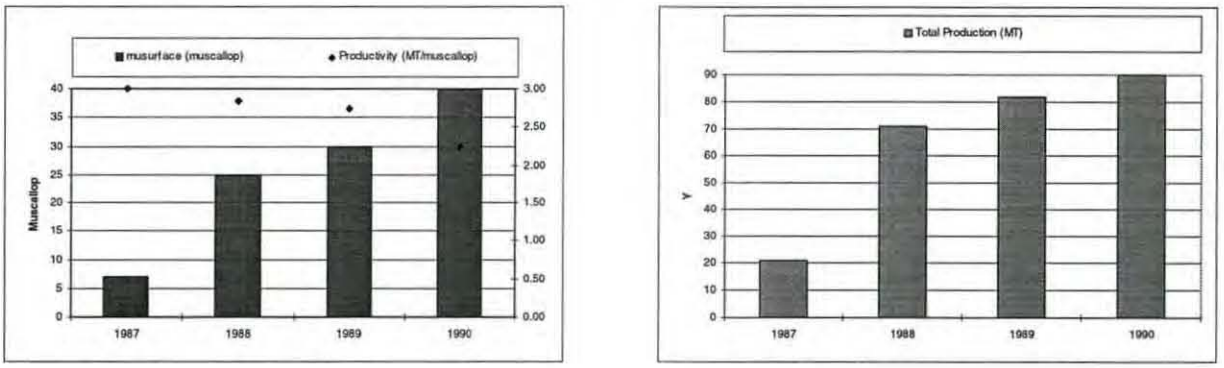
Graphic 16 : Evolution of the criterion of size of the fresh muscle of scallops (*Chlamys farreri*) in the district of Huangdao.

The reason raised by the Fishery Agency of Huangdao to explain the diminution of the musurface in 1995 was the construction of the Harbour of Huangdao. This is obviously wrong, the harbour was already built in 1993 as we can see it on the satellite spot image we have (the picture has been shot in 1993, cf. MAP 14).

The productivity has also decreased in 1995 whereas the criterion of the size of the scallop muscle was better (two times better). My feeling is that the criterion of the size of the muscles do not reflects the reality, the problem is that we don't know who has measured this data, and if the Fishery Agency got it from a processing industry or from a trade company, it means that this data is available for the biggest scallops of this district (as only the biggest ones are exported).

The area of Wuhao

Even if this area located in front of the harbour of Qingdao has produced 90 MT. of scallops in 1990 (cf. Graphic 17, ANNEX X) this is a really small area (according to Chinese people). The productivity has decreased between 1987 and 1990, whereas the musurface and the total production has increased.



Chlamys farreri

Graphic 17 : Evolution of the musurface, productivity and total production of scallops (Chlamys farreri) between 1987 and 1990 in the area of Wuhao.

From 1987 to 1990 (From the First Institute of Oceanology, personal communication)

4. Estimation of the breeding stock of scallops in the Jiaozhou bay

Even if I will give here some data about the breeding stock of scallops this is just an approximation to qualify (and not to quantify) what is going on in the Jiaozhou bay. Under no circumstances those data are good enough to carry out any serious work on marine management in the Jiaozhou bay.

For each district according to each breeding structure I have calculated the evolution of the number of individuals per muscallop, and estimated the occupied surface per muscallop. Then with some data I have collected from the literature I have estimated the evolution of the breeding stock.

4.1. The different areas of production and their estimated surface.

The district of Sifang

This area has been clearly (cf. MAP 15) located by GPS (Geographic Position System) so that we have a good idea of the total surface (14. km^2).

The district of Huangdao

It was difficult to establish the real surface of this area, as you can see on the MAP 16 only few points, using GPS, have been located. We got a map from the Fishery Agency of Huangdao (cf. MAP 17). The MAP n°16 presented here is a combination between the map I got, the few points I have collected and what I have seen from the ferryboats and the coast line.

According to the map I have established (cf. map) the total surface of the suspended production of the district of Huangdao (only the area inside of the bay) is 20 km^2.

The district of Hongshiya

The map (cf. MAP 18) of the area of production of scallops in the district of Hongshiya has been established using few points I have located using a GPS, a map I have consulted in China and what I have seen from the boat. The total surface of the suspended aquaculture is about 17 km^2.

The area of Wuhao

This small area has a total surface of 0.5 km^2 (cf. MAP 15).

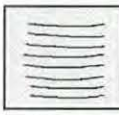
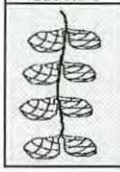
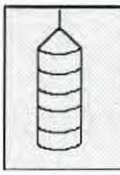
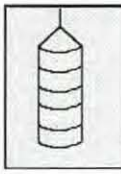
4.2. *Cycles of production and breeding structures of scallops in the districts of Sifang, Hongshiya and Huangdao*

The information that follow have been collected from different Fishery Agencies around the Jiaozhou bay and from some fishermen the administration has let us talk to.

The district of Sifang

Table 11 : Cycle of production and breeding structures for the year classes N-1, N and N+1 of *C. farreri* in the district of Sifang

From the Fishery Agency of Chengyang

Sifang			
	Lines		1 muscallop = 5 lines - 4125 sq m
Structure	Period	Species	Date (month)
	Juvenils in net bags	C. farreri	9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 1 N 1 N+1 1 bag = 2000 individuals 1 rope = 25 bags = 50000 individuals 1 line = 120 strings of net bags = 6000000 individuals
	Scallops in temperate growth lantern	C. farreri	9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 N N+1 1 tray = 500 individuals 1 lantern = 6 tray = 3000 individuals 1 line = 80 temperate growth lanterns = 240000 individuals
	Scallops in growth lantern	C. farreri	9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 N-1 2 N 2 N+1 1 tray = 30 individuals 1 lantern = 10 trays = 300 individuals 1 line = 80 growth lanterns = 24000 individuals

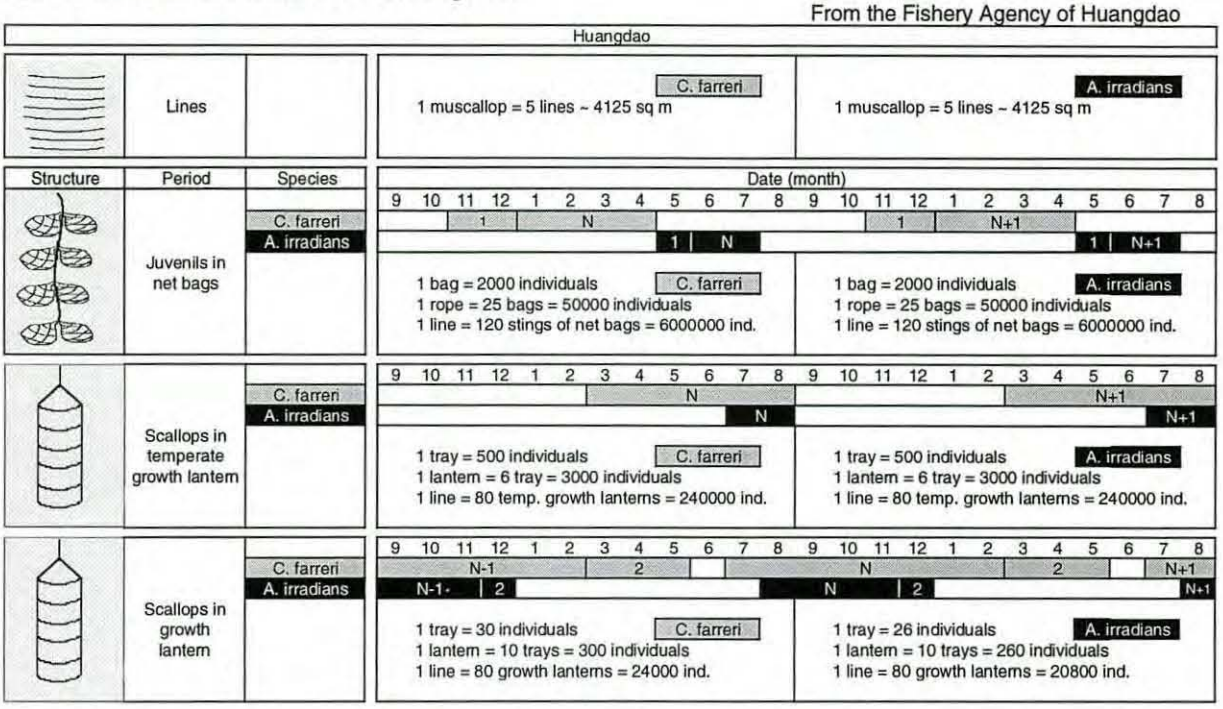
1 : enhancement

2 : harvesting

The district of Huangdao

Table 12 : Cycle of production and breeding structures for the year classes N-1, N and N+1 of *C. farreri* and *A. irradians* in the district of Huangdao.

From the Fishery Agency of Huangdao

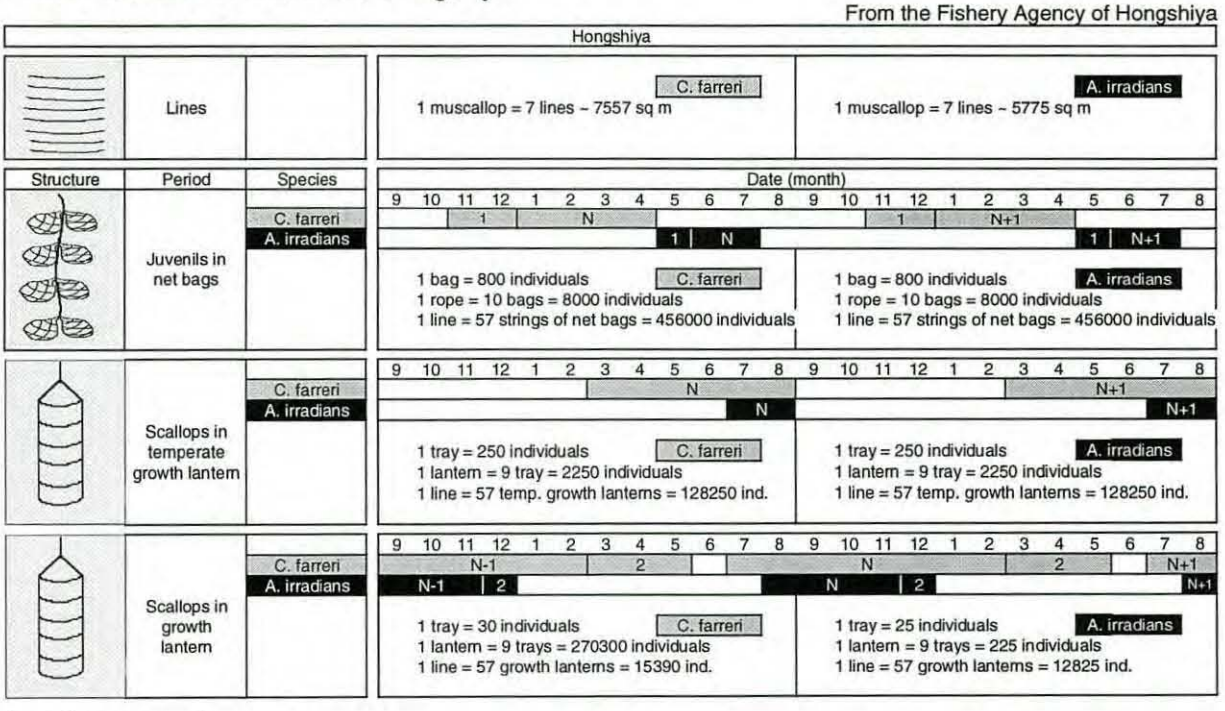


1 : enhancement
2 : harvesting

The district of Hongshiya

Table 13 : Cycle of production and breeding structures for the year classes N-1, N and N+1 of *C. farreri* and *A. irradians* in the district of Hongshiya.

From the Fishery Agency of Hongshiya



1 : enhancement
2 : harvesting

4.3. The estimated musurfaces of the scallop production

Having in mind the estimated total surface of the suspended aquaculture, an estimation of the surfaces of the mussel production, and the estimated surface of one muscallop for each district I have calculated the different musurfaces of the scallop production.

The district of Sifang

The surface of production of blue mussels in this district (cf. map) is 1 km^2 so that the total surface of production of scallops is 13 km^2.

↳ The total musurface of the scallop production is 3150 muscallops.

The district of Huangdao

As I don't know what is the musurface of the mussel production for 1996 I have kept the data collected for 1995 (2100 mumussels = 6.93 km^2) and I have considered that 1/3rd (~2 km^2) is inside of the bay (the same ratio as for the musurface of the scallop production). So that I can assume that the total surface of production of scallops is 18 km^2.

↳ The total musurface of the scallop production is 4364 muscallops.

The area of Hongshiya

As I did for the district of Huangdao I have used the data of production of blue mussels in 1995 (1110 mumussels ~ 4 km^2) so that the total surface of the scallop production is 13 km^2.

↳ The total musurface of the scallop production is 2251 muscallops.

The area of Wuhao

As I don't know that much about this small area I have considered that the only production is a scallop one.

↳ The total musurface of the scallop production is 121 muscallops

4.4. The mupoint

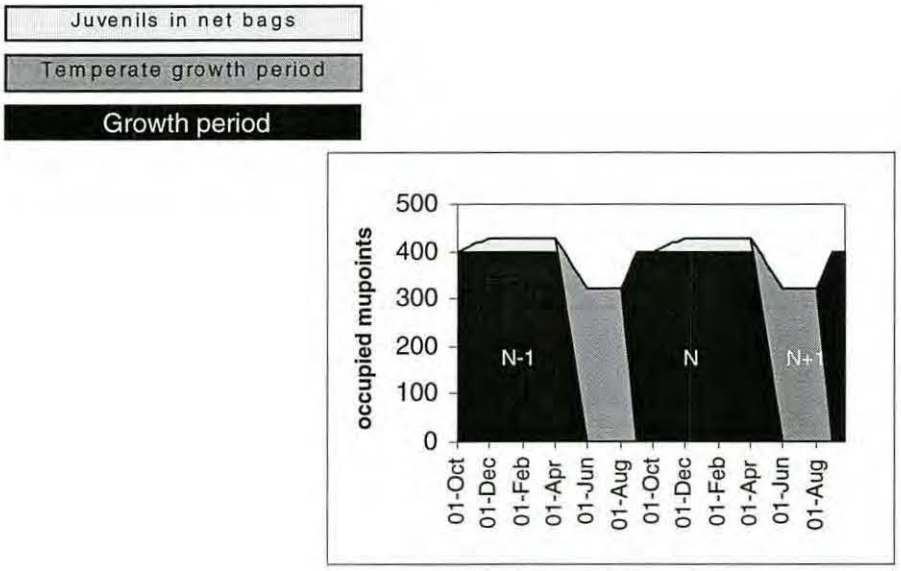
My estimation of the breeding stock of scallops in the Jiaozhou bay is based on an estimation of the musurface of the scallops production and on an estimation of the density of production. As the breeding cycle of the local species (*Chlamys farreri*) is one year and a half the problem is to know if farmers have to divide their area of production into two parts (one for each year class) or not ? Indeed I haven't told you yet but for the scallops production the historical data of the musurface you can get

from Fishery Agencies or farmers, represent in fact the number of the **harvested** growth lanterns divided by 400. As the bay scallop is harvested within a year there is no problem for this species.
So I have established the evolution of the occupied surface by the scallops during the period of production. The unit of the occupied surface used is the mupoint. As the breeding structure changes during the year (sometimes 40 lanterns per line, sometimes 80...) in the Jiaozhou bay I have enlarged the definition of the muscallop : 1 muscallop = 400 mupoints. The idea is to divide 1 muscallop onto 400 units or mupoints, each one is occupied during the growth period by one growth lantern.

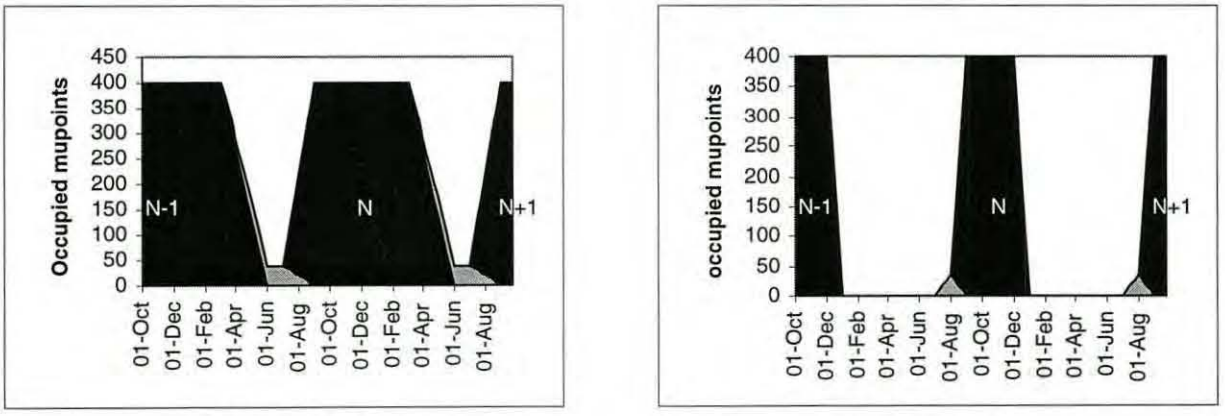
4.5. The evolution of the occupied mupoints per muscallop

I have calculated for each species the number of scallops per muscallop (400 growth lanterns) and the surface occupied by those scallops in growth lanterns temperate

growth lanterns and in strings of net bags according to the breeding cycle of each districts. The number of the occupied mupoints do not always equals to the number of temperate growth lanterns or strings of net bags. For example, in the district of Sifang farmers fix 40 temperate growth lanterns per line (whereas there are 80 growth lanterns during the growth period on this line). So in this district one line equals to 80 mupoints, but during the temperate growth period 40 mupoints are empty on this line, as farmers will not fix further breeding structures on them I have considered that 80 mupoints are occupied.

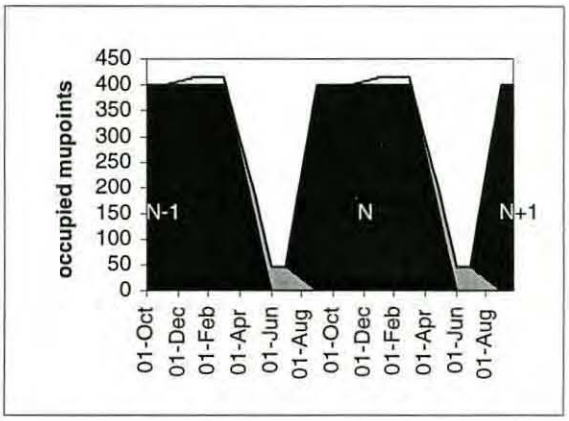


Graphic 18 : Evolution of the occupied mupoints per muscallop by Chlamys farreri (for the year classes N-1, N, N+1) in the district of Sifang

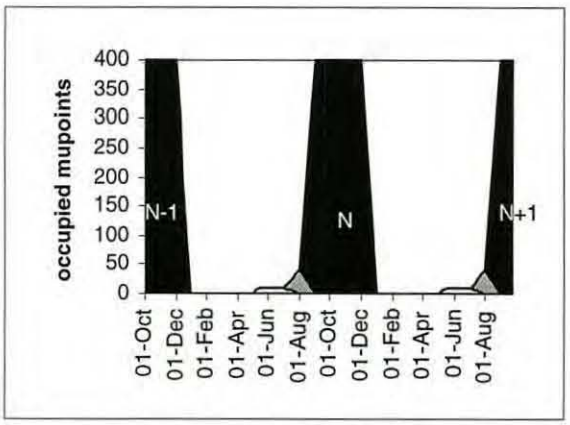


Chlamys farreri *Argopecten irradians*

Graphic 19: Evolution of the occupied mupoints per muscallop by *C. farreri* and *A. irradians* in the district of Huangdao for the year classes N-1, N, N+1.



Chlamys farreri



Argopecten irradians

Graphic 20 : Evolution of the occupied mupoints per muscallop by *C. farreri* and *A. irradians* in the district of Hongshiya for the year classes N-1, N, N+1.

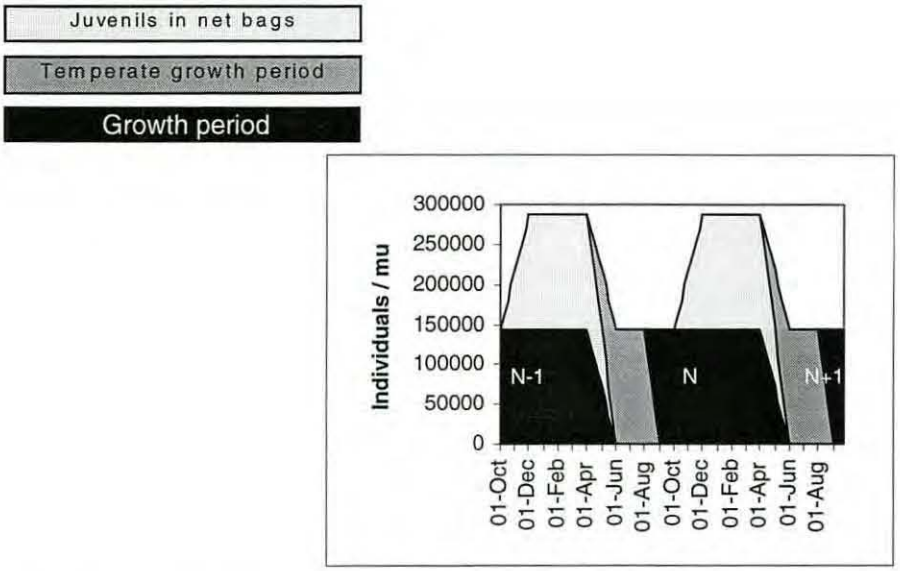
- Although farmers do not spend two months to harvest one muscallop I have homogenised the breeding cycle of each area on the breeding cycle of one muscallop.
- Hongshiya and Huangdao, the two oldest area have almost the same breeding cycle (we will see that the densities are a little bit different). In the district of Sifang the farmers use a low density of individuals per mupoint during the temperate growth period.

If farmers want to produce one muscallop of local scallops they need in fact more than one musurface (cf. Graphic 18, Graphic 19, Graphic 20) (413 mupoints in Hongshiya, 428 mupoints in Sifang and 402 mupoints in Huangdao per muscallop). But the breeding structure for juveniles in net bags is not so clearly define and depend on each farmer. If farmers need some space to fix their strings of net bags they just need to harvest few lanterns, it is what they should do as we can find scallops at the market during the whole year. An other solution can be to fix more net bags per ropes. In fact this period of the breeding cycle represent less than 7% of the global surface, so according to the precision of the estimations we can neglect this problem.

4.6. Evolution of the density of individuals per muscallop

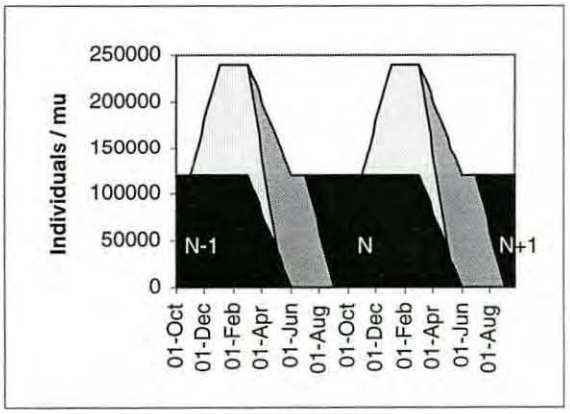
As you can see on the Graphic 21, Graphic 22 and Graphic 23, Hongshiya has the lowest number of individuals per muscallop of the Jiaozhou bay, the highest density

per muscallop occurs in the district of Sifang. We can also notice that between the bay scallop and the local scallop, the American species is always produced on a lower density.

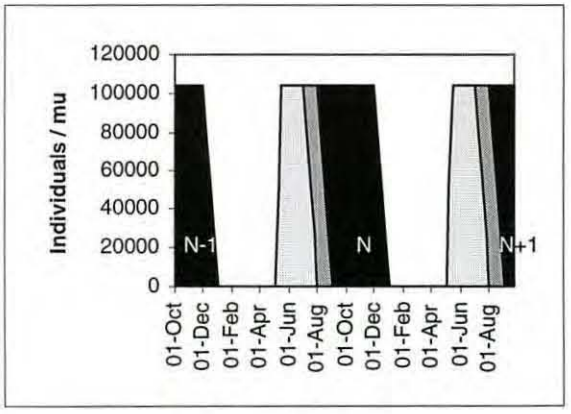


Chlamys farreri

Graphic 21 : Evolution of the number of individuals per muscallop by *C. farreri* and *A. irradians* in the district of Sifang for the year classes N-1, N, N+1.

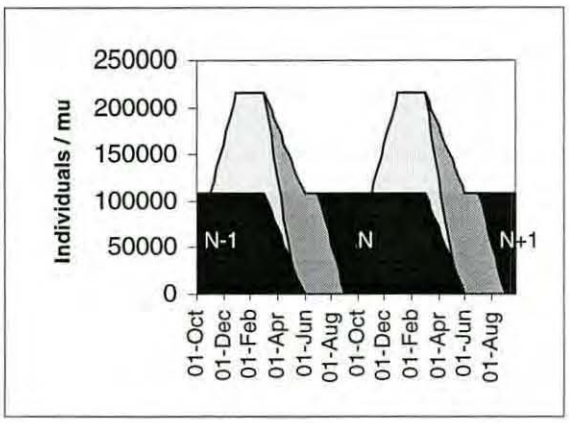


Chlamys farreri

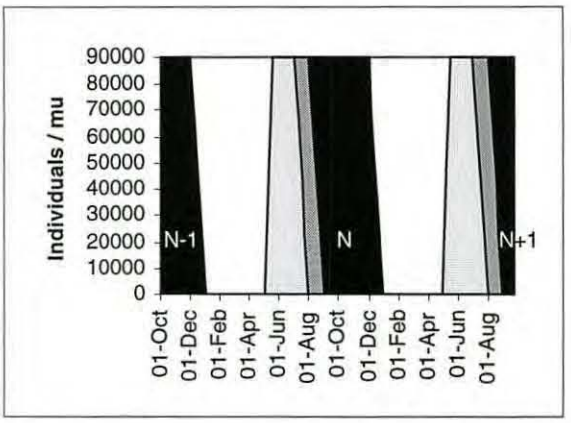


Argopecten irradians

Graphic 22 : Evolution of the number of individuals per muscallop by *C. farreri* and *A. irradians* in the district of Huangdao for the year classes N-1, N, N+1.



Chlamys farreri



Argopecten irradians

Graphic 23 : Evolution of the number of individuals per muscallop by *C. farreri* and *A. irradians* in the district of Hongshiya for the year classes N-1, N, N+1.

4.7. The growth rate of the two species of scallops

As this is one of the most important data we need to qualify the evolution of the breeding stock of scallops during the year I have calculated it using few data I have collected from the literature. I do agree that those calculations are not so good but remember that for lack of better information I'm trying to qualify what is going on in the bay

- *Chlamys farreri*

Equation 1 : Relation between the size of the shell (height) and the Weight of the dried muscle (*C. farreri*).

Wang Rucai, Wang Zhaopin, Zhang Jianzhong.

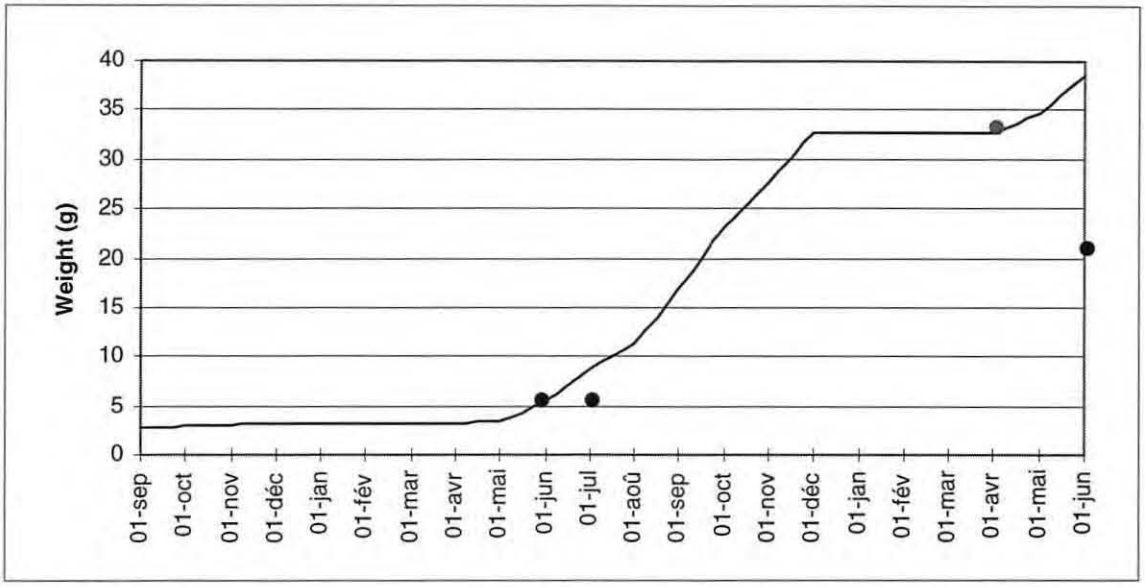
$$Weight_{(g)} = 2.8995*10^{\wedge(-3)}*High_{(cm)}{}^{\wedge 3.5}$$

Equation 2 : Relation between the weight of the Dried muscle and the Total fresh weight (*C. farreri*).

Wang Rucai, Wang Zhaopin, Zhang Jianzhong

$$D.m._{(g)} = -0.11767+0.04281* T.f.weight_{(g)}$$

Thanks to works carried out by searchers of the Ocean University of Qingdao we got a relation (Equation 1, Equation 2) (Wang Rucai, Wang Zhaopin, Zhang Jianzhong, 1993) between the total fresh weight of the scallops and the weight of the dried muscle, and a relation between the size of the shell (height) and the total fresh weight. Some works from the Ocean University of Qingdao (Zhang Qixin, Yong Qingming, 1989) give us the evolution of the size of the shell (height) of the scallops in the Jiaozhou bay 'cf. ANNEX XI) so I have calculate the evolution of the weight of the scallops during the period of production (cf. Graphic 24).



Graphic 24 : Evolution of the total fresh weight of Chlamys farreri (calculated, measured : blacks and grey points)

When I was in Qingdao we started some experiments to establish the growth rate of the dried muscle , gonad, flesh and shell and the evolution of the shell size. Those monthly experiments were carried out with 60 scallops (*Chlamys farreri*) from the district of Sifang. I just have now few data (cf. annex, and marks on the Graphic 24), the experiments will keep going on for one year and a half. The black points on the Graphic 24 are the results of the two first samplings we did. During the first one in early June two different year classes have been collected. I have calculated from the dried muscle weight the total fresh weight using the relation of Wang Rucai (Equation 2) and then pointed them on the graph. As you can see there is one point out of the curve, but we have to think that those scallops have been collected after the spawning period (during May) so that a lot of energy has been used for this and especially energy from the muscle, and that the curve has been established from the

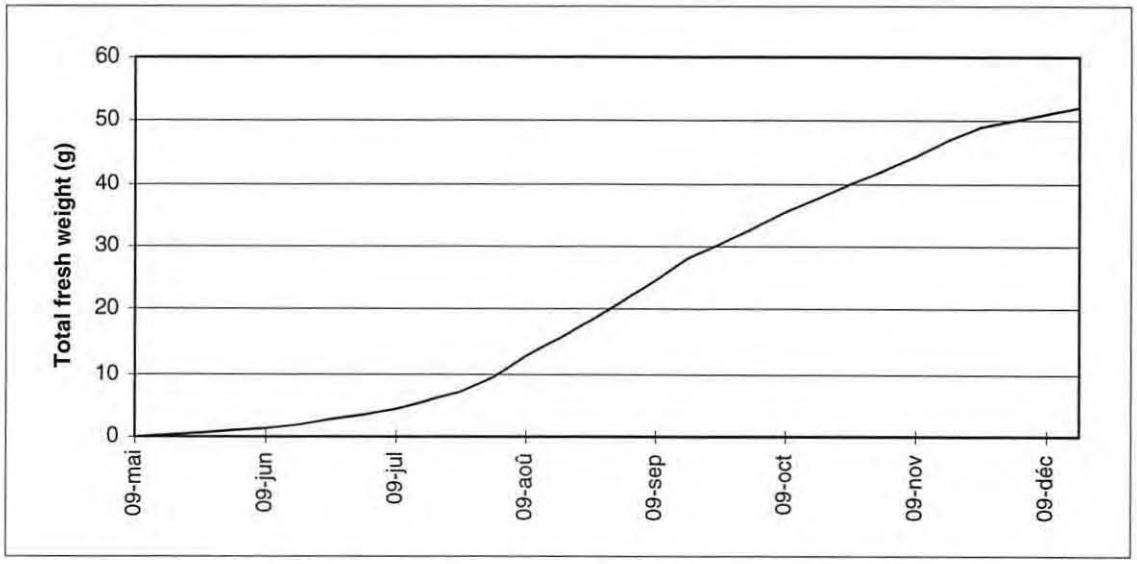
evolution of the shell size (that means : not so much influences of the spawning period on it). But there is an other fact : indeed all the studies carried out in the Jiaozhou bay on scallops do not deal with the district of Sifang as it is a really new area. The breeding cycle is different, the density of production is higher, the quality of the water is not good, many factors that can have an influence on the growth rate of the scallops. The grey point represents the first data we got, this is the average of the measured total fresh weight of 50 scallops (second year class, collected from a small harbour in Hongshiya) after the harvesting period.

- *Argopecten irradians*

Equation 3 : Relation between The total fresh weight and the length of the shell (*A. irradians*). Von Bertalanffy (1981)

$$Weight_{(g)} = 0.2604 * Length_{(cm)}^{\wedge 2.9827}$$

Extracted from works carried out in the Jiaozhou bay (ANNEX XII) I also have found the evolution of the height of the bay scallop (the American species but not the Canadian one). In the province of Zhejiang (south from Shanghai) the professor Zhang Yorong (Zhang Yorong) has shown than there was a good correlation during 13 months of experiments (on 1500 bay scallops) between the measured total fresh weight of the bay scallop and the estimated one thanks to the equation of Von Bertalanffy (Equation 3). As I couldn't find any better data I have used this equation and estimated the evolution of the total fresh weight of the bay scallop in the Jiaozhou bay. But I can not believe that there is no better data (for both kind of bay scallops : the American species and also the Canadian one) as the bay scallop has been introduced in China two times in Qingdao, and a lot of experiments were carried out as its introduction represents an economical interest.



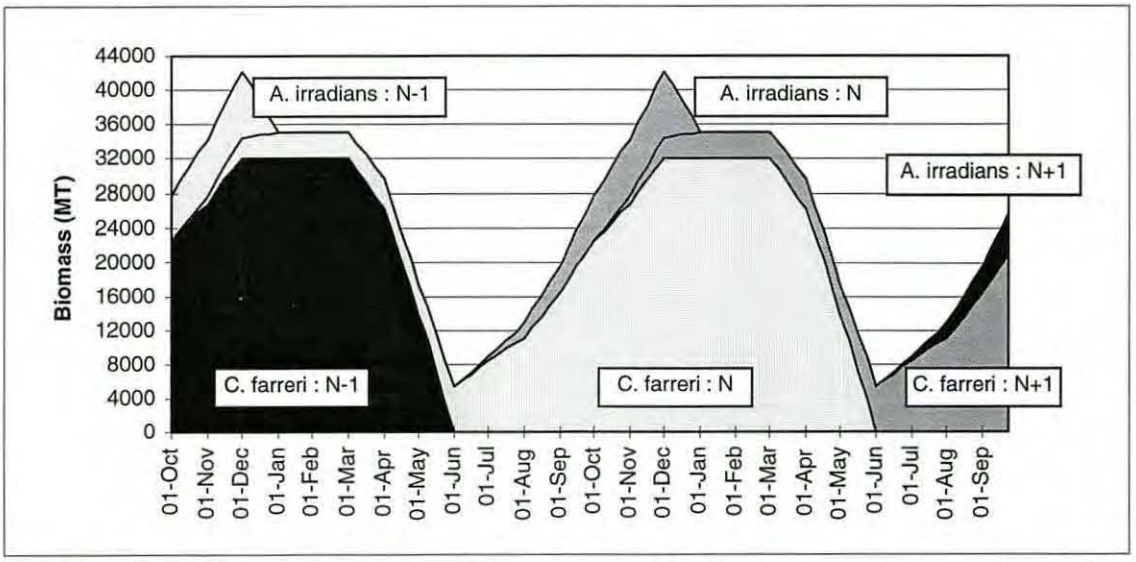
Graphic 25 : Evolution of the weight of *Argopecten irradians* (calculated).

4.8. Result

To estimate the breeding stock of scallops in the Jiaozhou bay, I have used the musurface I have calculated from the estimated surfaces. Having in mind the evolution of the number of individuals per muscallop, the growth rate of the scallops and the musurface of production of each district I have estimated an evolution of the breeding stock (cf. Graphic 26). Since the presentation of the location of the suspended breeding structures in the Jiaozhou bay you should have noticed that there is a small area just nearby the harbour of Qingdao, called Wuhao, that also produces scallops (I have considered that *Chlamys farreri* is the only species produced in this area). In 1987 it was with the area of Huangdao the only part of the Jiaozhou bay registered as producing scallops (from the different Fishery Agencies). I have used for Wuhao the breeding structure of Huangdao and estimated the evolution of its breeding stock.

To give an idea of the variations of the breeding stock of scallops in the Jiaozhou bay I would say that it fluctuates between 4000 MT. and 40000 MT. This breeding stock is mainly represented by the local species (*Chlamys farreri*) (cf. Graphic 26) that cover more than 75 % of it (Farmers agree to say that the price of the bay scallop is not interesting for them and restaurant owners say that the taste is not so good, and we can also notice that in the district of Sifang -a new area- there is none a bay

scallop). Whereas the breeding stock sharply decreases from March to June because it is the harvesting period, from June to December it increases because of the growth of the scallops.



Graphic 26 : Evolution of the estimated breeding stock of scallops in the Jiaozhou bay for both species Chlamys farreri and Argopecten irradians and for the year classes N-1, N, N+1.

- Limit of this estimation

  - I haven't got any available growth rate of the two species of scallops.
  - I have calculated two growth rates (to have an idea of what could be the evolution of the breeding stock in the bay) and used them without taking into consideration the variations that can occur from one district to an other (different densities, different water qualities, different breeding cycles...) and even in one district (cf. variation of the fresh muscle weight of the scallops in the district of Sifang). I have considered that the small area located in the northern part of Huangdao that belongs to Huangdao since 1995 has the same breeding structure as the other parts of this district even if the farmers are still the same.
  - There is obviously a big difference for the district of Huangdao between the musurface declared by the Fishery Agency of Huangdao and the musurface I have estimated (two times bigger as the official one). Different explanations can be suggested :

⇒ I have made a mistake drawing the area, as you have seen on the map only few points have been located by GPS.

⇒ From the historical data we got we need to subtract 4000 muscallops located outside of the bay. Is it really 4000 muscallops or less ?

⇒ I have made a mistake in the ratio surface/musurface. If it is the case, as no samplings have been done, it means that the breeding structure declared by the Fishery Agency is wrong. If I want my surface to represent the musurface declared I need a 8000 m^2 muscallop (instead of 4125 m^2 estimated). Remember that the musurface in this district has decreased in 1995 and we don't really know why. It has been presented in fact has a drop of the surface (with no changes in the breeding structures). According to what I have seen the construction of the harbour hasn't changed so many thing (You can find lines of production less than 100 m far from the harbour so that it is not the main reason.

⇒ There are some illegal exploitation in the district of Huangdao, that can explain why it has been so difficult to investigate in this area.

5. Comments

The filtration rate of Chlamys farreri is about 4.4 l / h / individuals (Kuang Shihuan, Fang Jianguang, Sun Huiling, Lifeng) on an average during a whole day in September in Rongcheng (Eastern part of the province of Shandong). To have an idea of what can be the total volume of water filtered by the scallops in the Jiaozhou bay I have used this data for both species. I know that the water temperature in Rongcheng is more cold than in the Jiaozhou bay so that the filtration rate can be

different in this area, but that is the only data we got. I also realise that the filtration rate of *A. irradians* should be different from the one of *C. farreri*.

In September we have about 1 200 000 000 individuals in the Jiaozhou bay, the harvesting period is finished for the second year class -*C. farreri*-, the one year class scallops are going to over pass the winter, and the bay scallop is not yet harvested. According to this data, $166*10^6$ m^3 of water are filtered per day by the scallops. Remember that the total volume of water of the Jiaozhou bay was $0.91*10^9$ m^3 in 1992, that means that the whole water of the bay is filtered in 5.5 days (this is almost the half exchange time -5 days- of the water of the bay). Having this in mind, we easily understand that if any serious diseases appear, the sustainability of the scallop production in the Jiaozhou bay would have a lot of problems. We have also to remember that the living stock of clams is over 60 000 MT. in the bay, that means that we have to consider both clams and scallops for the further works.

As you should have notice, there are a lot of imprecision in the data I have collected and in the estimated ones, first the estimation of the musurfaces especially in the district of Huangdao, the number of individuals per muscallop that depend a lot on the breeding structure (especially in this paper), and last the growth rates of the two species of scallops. Excepted for the growth rate I do think that the sampling I went to China for is the only solution to reduce the imprecision of the estimations and to have an idea of the deviation of the estimated values. Unfortunately I haven't been allowed to do any sampling on scallops.

I would like here to settle again the background of this Chinese-French co-operation, and to comment how we can include my work in this program. The aim this co-operation is to work out a model on the Jiaozhou bay that will be useful to predict the ability of this bay to support the intensive shellfish aquaculture in a global program of the integrated coastal zone management. The tools we should use for this, are the carrying capacity modelling and the Geographic Information System (GIS). But this are just tools. Modelling and GIS are just like a telephone box : if nobody has a telephone card no one can use it. In our case the problem is more complicate because one phone card is not enough, we need one for the historical data, one for the physical and for the chemical variations of the sea water of the Jiaozhou bay,

one for the speed currents, one for the breeding stocks..... I would say that we have now some of those cards but some of them are a little bit too old. Having a phone call the more telephone cards you have the more details you can have about a story, it is the same for modelling. The more information we have and the more precise those information are, the more useful will be the results. If we haven't really find any new cards during my stay in China I think that we know now where to find them.

- For the historical data I got, I think that we need to clarify some data (especially in Hongdao), and to complete some others. A farmer has told us that he have to pay some money each year as a tax so that the administration (maybe the different city halls around the bay) should have really precise data for the total number of farms, of farmers, of boats, of the total exploited musurfaces... (if by chance there are not too much illicit productions).
- For the estimation of the breeding stocks of scallops, nothing good and serious will be done without any sampling, because :

  We are trying to estimate the real value of the total number of scallops in the Jiaozhou bay and not the number of the officially produced scallops (cf. the scallop production in Huangdao). This problem also exit in France, it is sometimes difficult to believe what the administration declare, we have to think about it and never ignore it. We have also to remind that we are working on this project as scientists and not as jurists.

  Even if the mussel production is not that important compare with the scallop one, as from the boat we are not able to distinguish which line produces mussels which line produces scallops, a sampling strategy could give us a good idea of this.

  At last some sampling will enable us to define the exact ratio of *C. farreri / A. irradians* in the different areas (Huangdao and Hongshiya).

To finish with the sampling subject, I would say that having in mind the different breeding cycles in the different areas, the best times to sample would be first on October as *A. irradians* is not yet harvested and only one year class (the first one) of *C. farreri* should be in the water at that time, and second in July during the dividing period of the two species (to have an idea of the distribution of the scallops during

the temperate growth period). Just a precision, we can not spend two months on the same sampling period as the breeding structures change.

As I have already said, we have started with the study of the growth rate of *Chlamys farreri* in the district of Sifang, but the second sample was not good as it has also been collected during a dividing period (one month after the first one) so that the size of the scallops hasn't changed. We need to be able to choose the scallops we want, that means it is not the duty of the Fishery Bureau to choose the strategy of the sampling. The best way would be to deal always with the same fisherman. Unless further experiments have been carried out on the growth rate of the scallops (and I am sure that some data exist) we need to do the same work on the two species and on the other districts (Hongshiya and Huangdao). Of course that using a good model we could be able to estimate those growth rates, but that imply that we have a good idea of the ecophysiology of the two species, that we know what are evolution of the physical and chemical characteristics of the bay (recent data and good ones), that we know what can be the effects of the fluctuations of the environment on the growth rate of the scallops, that we have an better idea than I have about the densities of production for each district.....

At last we have collected some water in the Jiaozhou bay in order to analyse it (cf. annex). The results of the French analyse, using a Manifold (an autoanalyser continuous flow system), is different from the Chinese ones. The samples I have brought back have been frozen and warmed up two times but the total nitrogen couldn't have disappeared. How to explain this ? I don't know!!!

There is still a lot to do and we need to think about the aims of this program, but the most important think is to know which are the data we need to have a chance to succeed and how to get them.

6. Conclusion

In 1994, whereas the suspended aquatic productions were not yet settle in the district of Sifang, the total production of scallops (for both species *C. farreri* and *A. irradians*) in the Jiaozhou bay was 44,000 MT.

In 1995, the scallop production started in the district of Sifang (2,366 MT.), but during this year the total production in the Jiaozhou bay dropped to 25,000 MT. The main reasons are a decrease of the total musurface and a lower density of production.

But in 1996, the estimated breeding stock raised back to 40,000 MT. (that almost represent the total production) because of the increase of the musurface of the scallop production in the district of Sifang and because the estimated musurface in the district of Huangdao is two time as big as the official one.

According to the estimated value of the breeding stock of scallops in the Jiaozhou bay, the total volume of water of this bay is filtered by the scallops in a little bit more than 5 days. Until now, farmers are confronted with a decline of the productivity « only » due to the density of production that is too high. fortunately the shellfish production do not suffer yet from diseases as it has been occurring in the shrimp production around the bay for more than one year.

The study of the physical characteristics of the Jiaozhou bay and a model of its carrying capacity could help us to estimate the influences that can have the development of the scallop production in the district of Sifang on the ones in the districts of Huangdao and Hongshiya. It could also help us to predict the optimum shellfish density and their optimum location. We need now to go and see the scallops (the clams, the shrimps....) in the water and I do not mean : to have a look, but to work, unless good experiments have already been carried out.

7. References

A comprehensive Environmental investigation and the studies on the Jiaozhou bay and coastal areas (in Chinese), June 1992, Marine Science Bulletin, Vol. 1 N°3, special issue. Incomplete reference.

Cheng Xiangshu, 1991, investigations on environmental pollution in the Jiaozhou bay (in Chinese), Marine Science Bulletin 10(4) : 72-78.

Ding Wenlan, 1992, Current characteristics of the Jiaozhou bay, in : Ecology and living resources of the Jiaozhou bay. ed. : Liu Ruiyu, Beijing, 459 p.

Hou Guoben, Dingdong, Liu Xuexian, Dec. 1993, Harbours in the Jiaozhou bay (in Chinese), ed. Ocean publication, Beijing.

Kuang Shihuan, Fang Jianguang, Sun Huiling, Lifeng, Seasonal variation of filtration rate and assimilation efficiency of the scallop *Chlamys farreri* in Sanggou Bay (in Chinese), Yellow sea fisheries Research institute, Chines Academy of Fishery Sciences Qingdao. Incomplete reference.

Marine Science n°1, Jan 1992. Incomplete reference.

Wang Rucai, Wang Zhaopin, Zhang Jianzhong, 1993, Production of marine shellfish, ed. Ocean University of Qingdao, 397p.

Wu Yaoquan and al., 1992, Ecology and living resources of the Jiaozhou bay (in Chinese), ed. Liu Ruiyu, 460 p.

Zhang Qixin, Zhang Qixin, Yang Qingming, 1989, Primary study of the optimum harvesting period of scallop (in Chinese), in : Technology of scallop aquaculture, ed. Institute of Oceanology, Academia Sinica, Nov. 1989, 106 p.

Zhang Yorong, Zhejiang provincial Marine Fisheries Research Institute. Incomplete reference.

Zhu Ban, 1995, Qingdao year book (in Chinese), People's Republic of China, Qingdao, 329 p.

INSTITUT NATIONAL GRONOMIQUE
PARIS - GRIGNON

CENTRE DE RECHERCHE EN
ECOLOGIE MARINE ET
AQUACULTURE

MEMOIRE

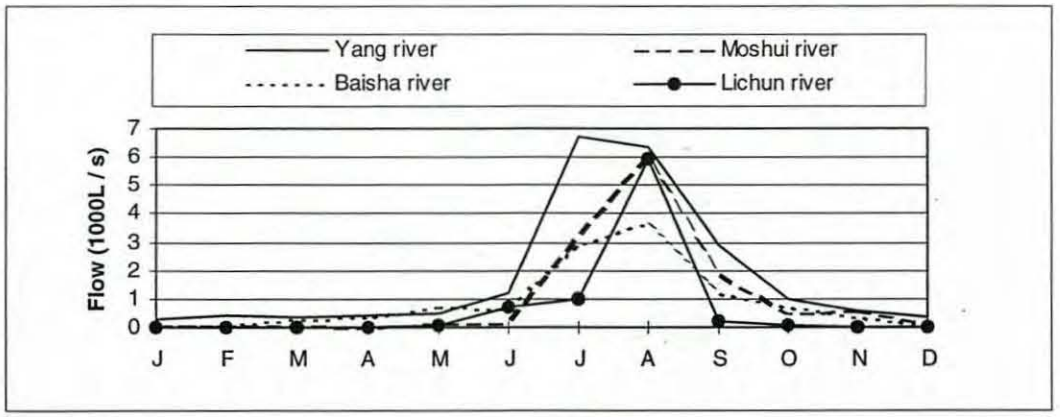
A FIRST APPROACH OF AQUACULTURE DEVELOPMENT IN THE JIAOZHOU BAY
(P.R. CHINA)

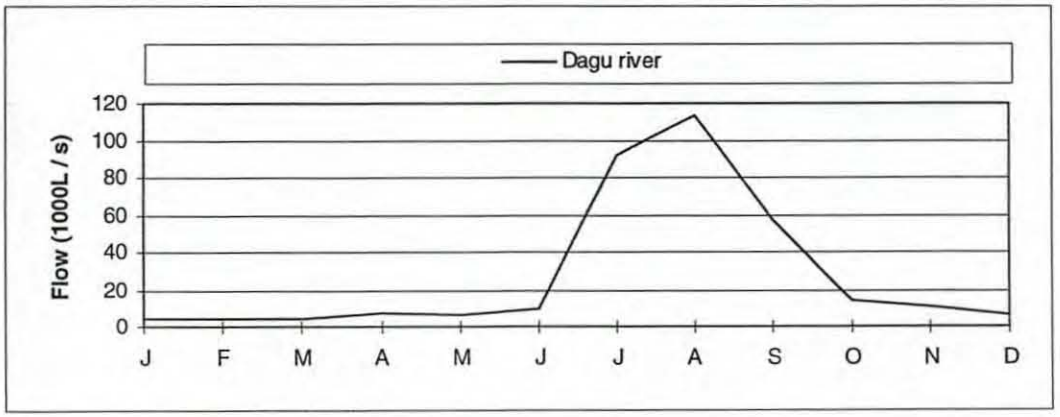
ANNEXES

ANNEX I

Volume of water running into the Jiaozhou bay from rivers (1991)

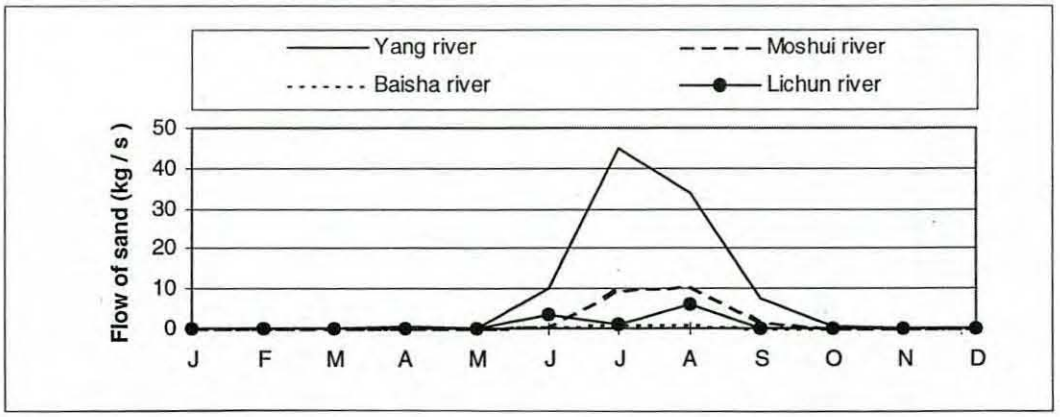
*1000 L/s	Months												
Rivers	J	F	M	A	M	J	J	A	S	O	N	D	Average
Yang	0.278	0.395	0.373	0.455	0.513	1.176	6.75	6.361	2.891	1.01	0.531	0.349	1.78
Moshui	0.068	0.068	0.045	0.023	0.14	0.133	3.168	5.99	1.853	0.51	0.591	0.123	0.923
Baisha	0.06	0.07	0.28	0.34	0.71	0.62	2.93	3.68	1.2	0.7	0.35	0.07	0.92
Lichun	0	0	0	0.001	0.04	0.737	0.973	5.94	0.213	0.047	0	0	0.34
Dagu	4.016	3.966	4.555	7.158	6.286	9.577	91.637	113.04	57.578	13.995	10.355	6.485	27.736

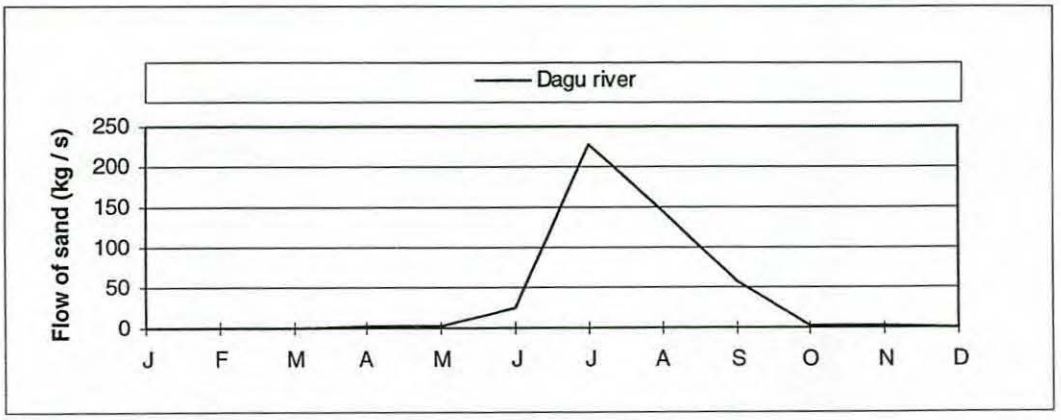




Volume of sand carried by the rivers running into the Jiaozhou bay (1991)

kg/s	Months												
Rivers	J	F	M	A	M	J	J	A	S	O	N	D	AVERAGE
Yang	0.009	0.063	0.037	0.395	0.0708	10.188	44.825	33.699	7.819	0.625	0.081	0.01	25.81
Moshui	0	0	0	0.075	0.03	0.33	9.657	10.402	1.617	0.121	0.098	0	4.76
Baisha	0	0	0	0	0.09	0.32	0.77	1.16	0.09	0.01	0	0	0.51
Lichun	0	0	0	0	0.003	3.74	1.073	6.14	0.07	0.06	0	0	2.94
Dagu	0.08	0.13	0.28	2.52	2.76	23.79	226.71	145.78	57.77	3.25	1.92	0.25	123.28





ANNEX III

Pollution released by the rivers into the eastern part of the Jiaozhou bay (1991)

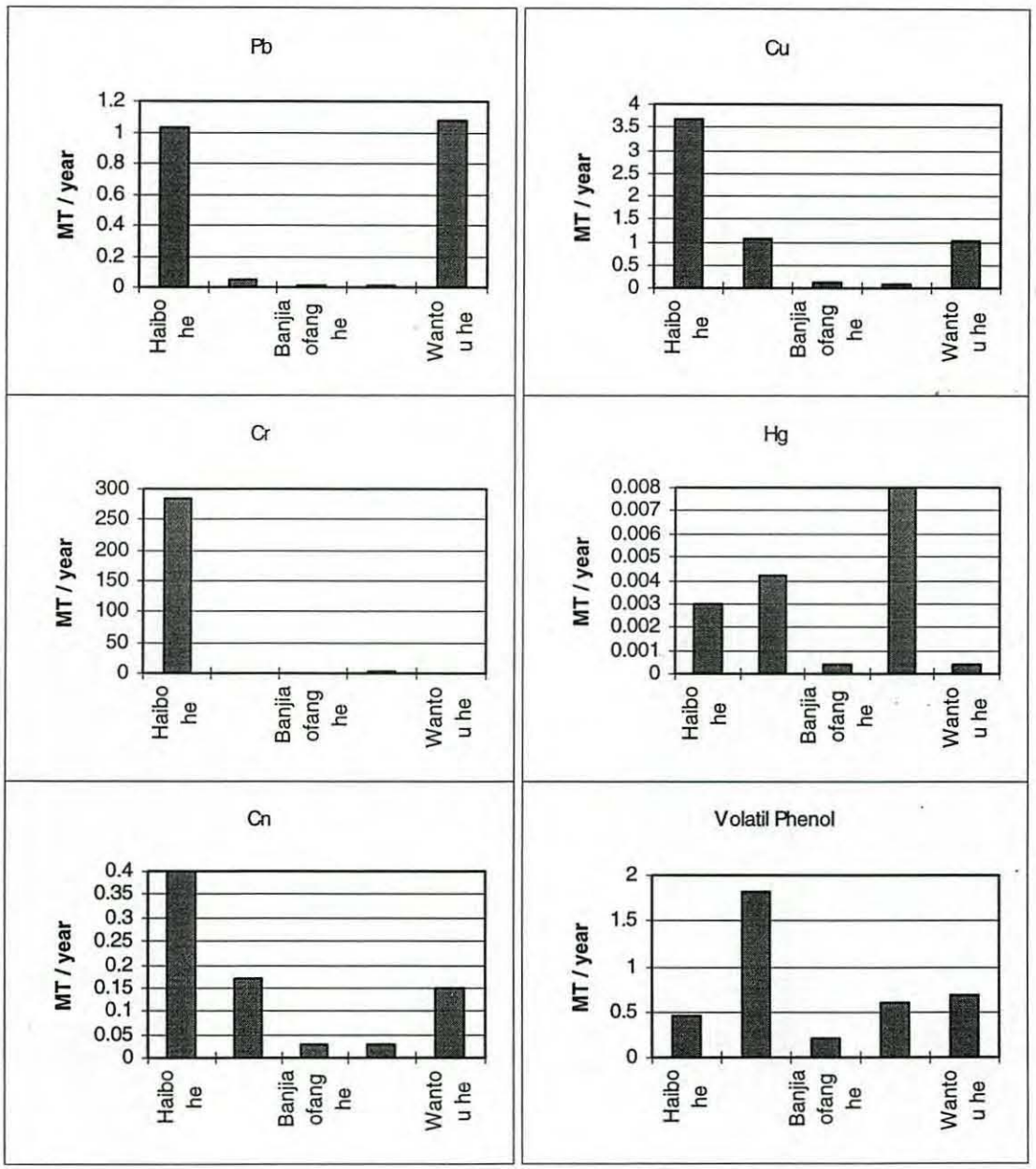
Total pollution released per year (MT./a) by the rivers

River	Chemical Oxygen demand	S	Petrol	Suspended Material	Volatile Phenol	Cn	Hg	Cr	Cu	Pb	Cd
Haibo	8889.07	89.15	10.9	6773.88	0.445	0.4	0.003	284.54	3.67	1.03	0.06
Lichun	10690	64.79	7.8	11220	1.81	0.17	0.0042	1.22	1.07	0.052	0.05
Banjiaofang	1540.08	6.372	1.674	464.4	0.21	0.03	0.0004	0.1206	0.1296	0.0126	0.0018
Lousha n	2623.82	8.24	2.48	1202.88	0.6	0.03	0.008	2.95	0.068	0.0155	0.069
Wantou	953.4	8.76	12.68	2692.35	0.69	0.15	0.0004	0.15	1.028	1.083	0.016

pollution released (mg/l of fresh water) by the rivers

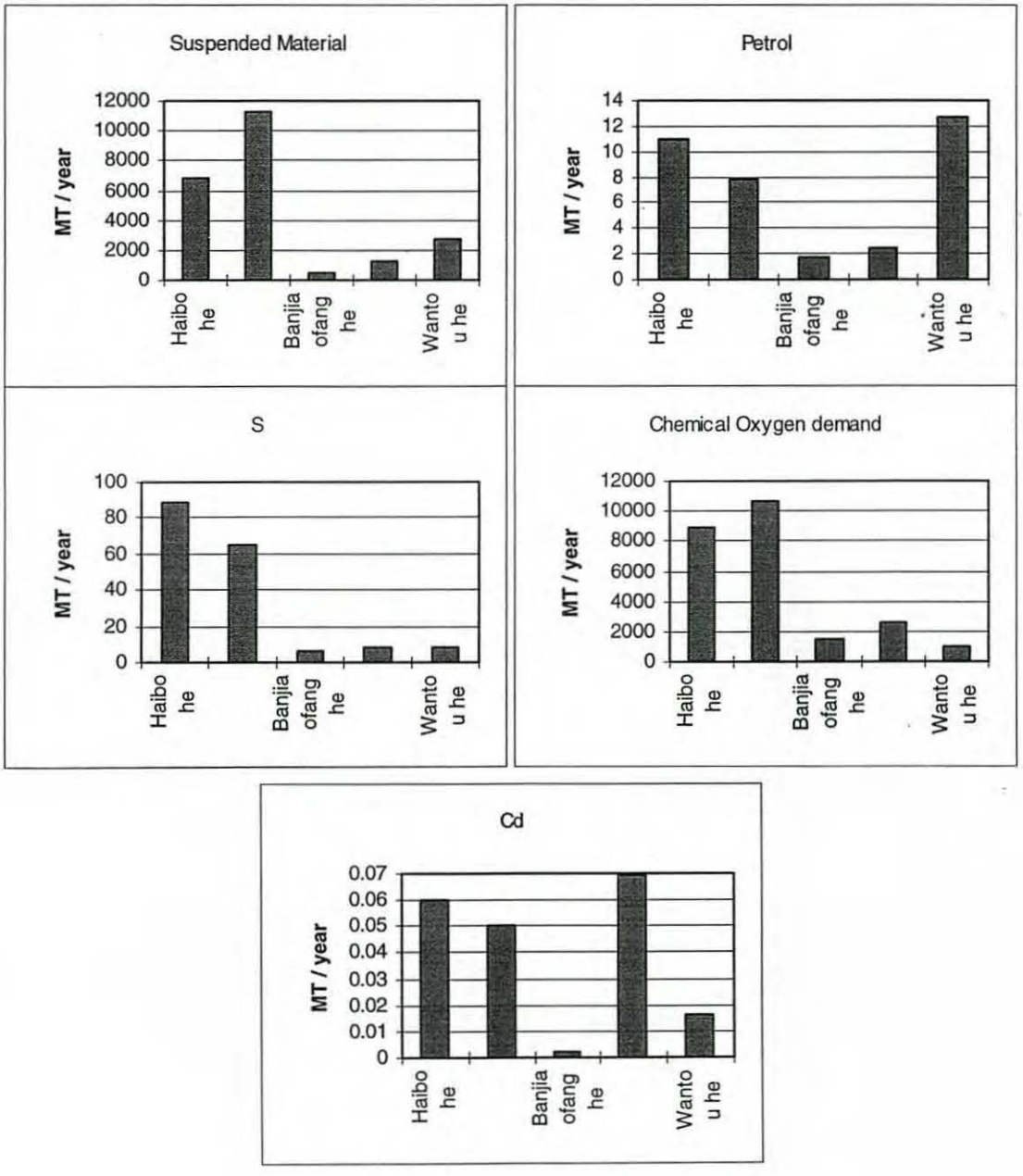
River	Chemical Oxygen demand	S	Petrol	Suspended Material	Volatile Phenol	Cn	Hg	Cr	Cu	Pb	Cd
Haibo	942.2	9.45	1.155	718	0.472	0.0429	0.00035	30.16	0.389	0.109	0.00658
Lichun	1521.4	9.22	1.11	1596	0.258	0.0249	0.0006	0.174	0.152	0.074	0.00727
Banjiaofang	855.6	3.54	0.93	258	0.117	0.014	0.0002	0.067	0.072	0.007	0.001
Lousha n	2342.7	7.36	2.211	1074	0.538	0.026	0.0007	2.634	0.0607	0.0138	0.0616
Wantou	244.82	2.25	3.257	640	0.176	0.038	0.0004	0.0377	0.264	0.278	0.004

Pollution released by the rivers into the eastern part of the Jiaozhou bay (1991)



ANNEX III (B)

Pollution released by the rivers into the eastern part of the Jiaozhou bay (1991)



ANNEX IV

Evolution of the production of clams (*Ruditapes philppinarum)* in the areas of Hongdao and Hongshiya.

Area of Hongdao (district of Chengyang)

Year	Musurface (muland)	Productivity (MT./muland)	Total production (MT.)
1990	400	15	6000
1991	2000	5	20000
1992	7500	3.25	24375
1993	10000	3	30000
1994	12000	2.75	30000
1995	13600	2.5	34000

Area of Hongshiya (district of Jiaonan)

year	musurface (muland)	Total Production	Productivity (MT./muland)	Total income (10000 yuan)	Total cost (10000 yuan)
1988	1950	651	0.334	134	
1989	799.5	740	0.926	242.7	
1990	900	830	0.922	270	
1991	4500	1650	0.367	768	
1992	4500	2278	0.506	1139	
1993	8010	3755	0.469	3755	2976
1994	10005	5000	0.5	3598	1500
1995	14025	6600	0.471	7863	3560

1 Yuan = 0.6 Franc

ANNEX V

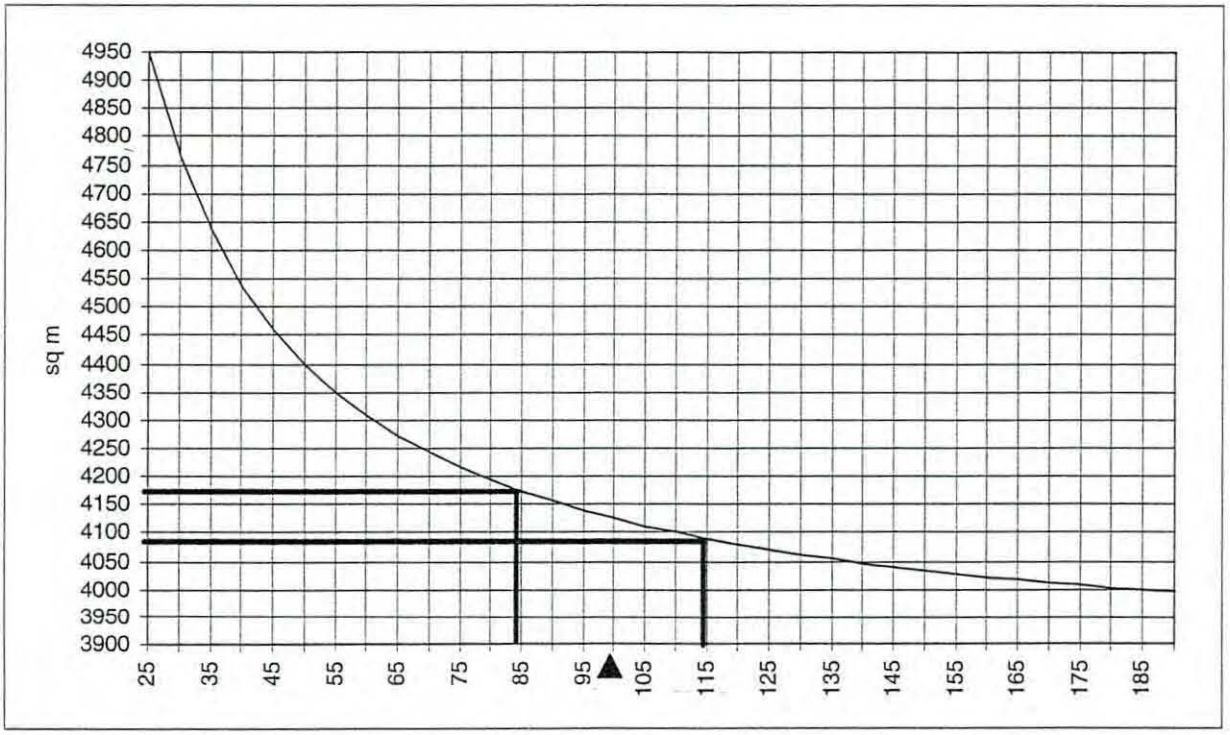
Evolution of the production of oysters (*Ostrea plicatula*) in the area of Hongdao from 1991 to 1995.

Year	Musurface (muland)	Productivity (MT./muland)	Total production (MT.)
1991	2000	8.5	17000
1992	3000	6.25	18700
1993	4000	5	20000
1994	5000	4	20000
1995	7000	4	28000

From the Fishery agency of Hongdao

ANNEX VI

Relation between the number of lines between two passes (cf. Graphic 6) and the surface (m^2) of one muscallop



I have estimated that the number of lines between two passes is 100, but we need more investigations to confirm this.
A 15 % mistake on the estimation of the number of lines between two passes equals to a 5 % mistake on the estimation of the surface of one muscallop.

ANNEX VII

Evolution of the productions of blue mussels (*Mytilus edulis*) in the area of Hongshiya and the district of Huangdao

Area of Hongshiya

year	musurface (mumussel)	Total Production (MT.)	Productivity (MT./mumussel)	Total income (10000 yuan)	Total cost (10000 yuan)
1988	375	1120	2.987	45	
1989	349.5	1330	3.805	52.8	
1990	340.5	1010	2.966	30.3	
1991	349.5	1300	3.72	55	
1992	370.5	850	2.294	42.6	
1993	375	1700	4.533	85	70
1994	540	3025	5.602	121	85.5
1995	1110	6600	5.946	475	234

1 Yuan = 0.6 Fr.

District of Huangdao

year	musurface (mumussel)	Total Production (MT.)	Productivity (MT./mumussel)	total income (10000 yuan)
1991	1410	5587	3.962	335.2
1992	1800	6488	3.604	389.3
1993	1800	6274	3.486	376.4
1994	2508	8742	3.486	874.2
1995	2100	6300	3	630

1 Yuan = 0.6 Fr.

ANNEX VIII

Comparison between the American bay scallop (*Argopecten irradians*) and the Canadian one of the growth, the mortality rate, and the ratio weight of the fresh muscle/total fresh weight.

Comparison of the growth of scallops between the American and the Canadian bay scallop (Argopecten irradians) in the district of Huangdao.

(FIO)

	American bay scallop			Canadian bay scallop	
Date	Size (cm)	Weight (g)	Date	Size (cm)	Weight (g)
1993/Sep/25	4.2	19.5	1994/Sep/18	4.57	21.3
1993/Nov/26	5.35	32.8	1994/Nov/18	5.50	35.1

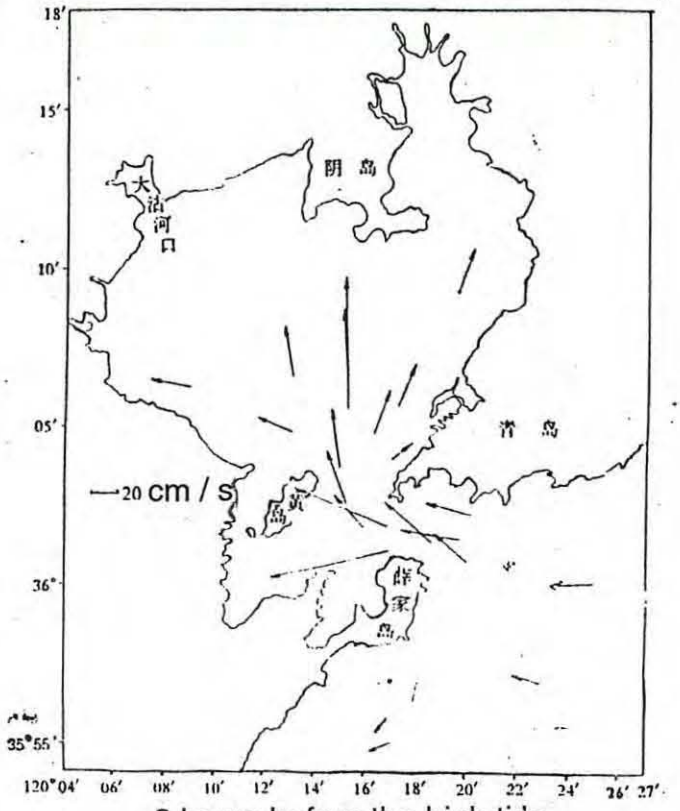
Comparison of the mortality rate between the American and the Canadian bay scallop (*Argopecten irradians*) in the district of Huangdao.

	American bay scallop		Canadian bay scallop
1993/Sep/15	16.8 %	1994/Sep/14	5.1 %
1993/Nov/21	21.6 %	1994/Nov/18	7.7 %

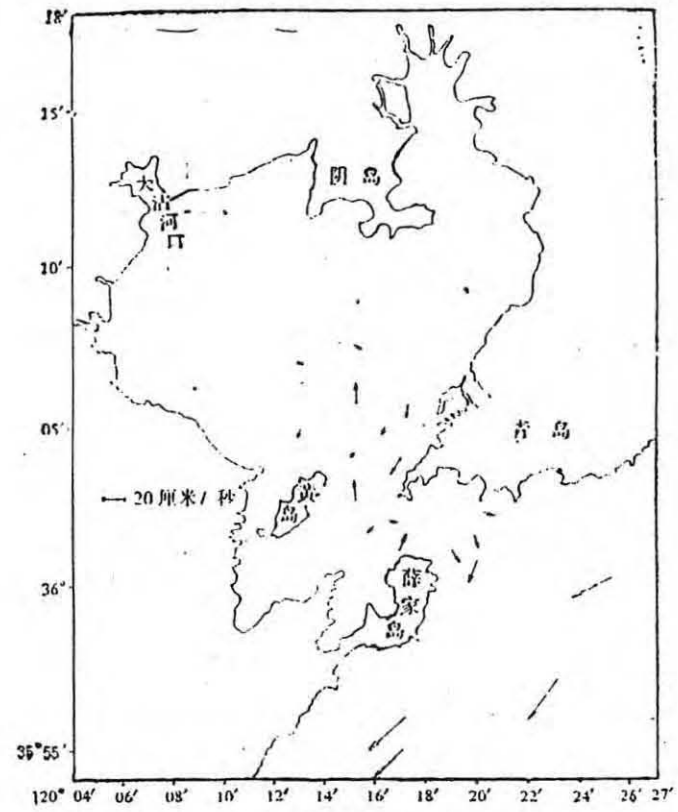
Comparison of the ratio weight of the fresh muscle/total fresh weight between the American and the Canadian bay scallop (*Argopecten irradians*) in the district of Huangdao

	American bay scallop (Nov. 1993)	Canadian bay scallop (Nov. 1994)
Fresh muscle weight / Total fresh weight (%)	9.2	9.6

Tidal currents in the Jiaozhou bay



3 hours before the high tide



High tide

Evolution of the production of scallops (*Argopecten irradians* and *Chlamys farreri*) in the district of Huangdao and the areas of Hongshiya and Wuhao

Area of Hongshiya

year	musurface (muscallop)	Total Production (MT.)	Productivity (MT./muscallop)	Total income (10000 yuan)	Total cost (10000 yuan)
1988	600	1800	3	490	
1989	640.5	2003	3.127	329.3	
1990	720	1944	2.7	349.9	
1991	1750.5	5600	3.199	2012.5	
1992	2809.5	7130	2.538	1830	
1993	4305	12019	2.792	1922	1715
1994	4305	13751	3.194	1704	1640.5
1995	2400	9015	3.756	2636	2000

1 Yuan = 0.6 Fr.

District of Huangdao

year	musurface (muscallop)	Total Production (MT.)	Productivity (MT./muscallop)	total income (10000 yuan)
1987	70	156	2.228571429	
1988	825	2716	3.292121212	
1989	1083	1885	1.740535549	
1990	1330	4563	3.430827068	912.6
1991	2704.5	7691	2.844	1845.8
1992	5431.5	1544	0.284	370.5
1993	6300	22050	3.5	5733
1994	8560.5	30000	3.504	6174
1995	6499.5	21000	3.231	6300

1 Yuan = 0.6 Fr.

Area of Wuhao

year	musurface (muscallop)	Total Production (MT.)	Productivity (MT./muscallop)
1987	7	21	3.00
1988	25	71	2.84
1989	30	82	2.73
1990	40	90	2.25

ANNEX XI

Evolution of the shell size, and total fresh weight (calculated) of *Chlamys farreri* in the Jiaozhou bay

	Size (cm)	dried muscle (g)	Total fresh weight per individual (g) calculated
1979-01-Sep.	0.7	0.00	2.8
01-Oct.	1.3	0.01	2.9
01-Nov.	1.6	0.02	3.1
01-Dec.	1.8	0.02	3.2
1980-01-Jan.	1.8	0.02	3.2
01-Feb.	1.8	0.02	3.2
01-Mar.	1.8	0.02	3.2
01-Apr.	1.8	0.02	3.2
01-May.	2.0	0.03	3.5
01-Jun.	2.9	0.12	5.6
01-Jul.	3.6	0.26	8.7
01-Aug.	4.0	0.37	11.4
01-Sep.	4.6	0.61	16.9
01-Oct.	5.1	0.87	23.0
01-Nov.	5.4	1.06	27.5
01-Dec.	5.7	1.28	32.7
1981-01-Jan.	5.7	1.28	32.7
01-Feb.	5.7	1.28	32.7
01-Mar.	5.7	1.28	32.7
01-Apr.	5.7	1.28	32.7
01-May.	5.8	1.36	34.6
01-Jun.	6.0	1.53	38.6

Average on 100 local scallops in the Jiaozhou bay.

From Zhang Qixin, 1992

ANNEX XII

Evolution of the shell size of *Argopecten irradians* in the Jiaozhou bay

Date	size (cm)
91/07/20	1.33
91/08/04	2.08
91/08/19	2.67
91/09/03	3.09
91/09/18	3.5
91/10/03	3.65
91/10/18	4.08
91/11/02	4.37
91/11/17	4.65
91/12/02	4.88
91/12/17	5.05
92/01/01	5.17
92/01/16	5.23
92/01/25	5.23
92/02/25	5.35

Average on 1500 bay scallops in the Zhejiang province (South from Shanghai).

From Zhang Yorong