COASTAL ENVIRONMENTAL PROFILE OF XIAMEN

by the Integrated Task Team of the Xiamen Demonstration Project

GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas

MPP-EAS Technical Report No. 6

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Foreword

The primary objective of the Global Environment Facility/United Nations Development Programme/International Maritime Organization Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas is to support the efforts of the eleven (11) participating governments in the East Asian Region to prevent and manage marine pollution at the national and sub-regional levels on a long-term and self-reliant bases. It is the Programme's vision that, through the concerted efforts of stakeholders to collectively address marine pollution arising from both land- and sea-based sources, adverse impacts of marine pollution can be prevented or minimized without compromising desired economic development.

The Programme framework is built upon innovative and effective schemes for marine pollution management, technical assistance in the strategic maritime sectors of the region, and the identification and promotion of capability-building and investment opportunities to attract the public agencies and the private sector for funding and investment. The more specific Programme strategies are:

- Develop and demonstrate operational models on marine pollution reduction/ prevention and risk management;
- Assist countries in developing the necessary legislation and technical capability to implement international conventions related to marine pollution;
- Strengthen institutional capacity to manage marine and coastal areas;
- Develop regional network of stations for marine pollution monitoring;
- Promote public awareness on and participation in the prevention and abatement of marine pollution;
- Facilitate standardization and intercalibration of sampling and analytical techniques and environmental impact assessment procedures; and
- Promote sustainable financing for activities requiring long-term commitments.

One of the Programme's activities in articulating the mission statement is the establishment of demonstration projects. Located in the southern part of Fujian province, People's Republic of China and northwest of Taiwan Strait, Xiamen is one of the three demonstration sites of the MPP-EAS. Xiamen consists of the Xiamen island proper, Gulangyu Islet and the coastal part of the north bank of inland Jiulongjiang River. The Xiamen Municipality comprises six districts and one county, namely: Kaiyuan, Siming, Gulangyu, Huli, Jimei and Xinglin Districts and Tong'an County.

Xiamen Municipality is one of the five "special economic zones" (SEZ) approved by the State Council of the People's Republic of China. It has been transformed into a beautiful port city with fairly complete infrastructure and vigorous economic exchange, locally and abroad. The industrialization of Xiamen has accelerated in recent years, providing a variety of technologically advanced products that are very competitive in the international and domestic markets.

The pace of economic development in Xiamen compounded by population increase have exerted significant impacts on the coastal environment, especially those associated with pollution and resource-use conflicts. Traditional management approaches to mitigate those impacts have not been successful. The utilization of marine resources contributes a lot in the socioeconomic development of Xiamen. In order to achieve sustainable development of the coastal areas, it is necessary to shift to and adopt the integrated coastal management aproach (ICM).

The MPP-EAS selected Xiamen as a demonstration site since its Integrated Task Team adopts the ICM framework to address the effects and potential consequences of economic activities and marine pollution. The ICM approach provides the necessary framework, including options and measures with respect to environmental management, in dealing with cross-sectoral coordination and integration. Specifically, it aims to demonstrate how ICM can be applied to (a) prevent and manage land-based pollution sources in an area moving towards heavy industrialization; (b) encourage the active participation of industries with the city/municipal and provincial governments to minimize pollution risks from existing economic activities and future developments; and (c) involve non-government organizations as strong partners in the protection of the coastal and marine environments.

This Coastal Environmental Profile of Xiamen is one of the initial inputs of the Integrated Task Team of the Xiamen Demonstration Project (ITT-XDP). It is a synthesis of available information provided by or acquired from various government agencies, institutions and groups within the Xiamen. This *Profile* represents the Team's assessment on the environmental and socioeconomic status of Xiamen, including its institutional and legal characteristics from a multidimensional perspective. The purpose of this *Profile* is not simply to characterize Xiamen and its myriad activities but also to identify crucial management issues affecting or will affect it, including significant data gaps which could shed further light on the identified management issues. From there, recommendations are made on how to address the issues and achieve the overall strategic environmental management plan, as well as articulate the actions to address the management issues identified in this *Profile*. This *Profile* is not expected to be static and will be revised accordingly as the XDP progresses in its implementation of various activities over the next two years.

Chua Thia-Eng
Regional Programme Manager
Regional Programme for the Prevention
and Management of Marine Pollution
in the East Asian Seas

Preface

In 1993, the GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas (MPP-EAS), executed by the International Maritime Organization (IMO), was officially launched in Xiamen, China, through the signing of the Programme document by the participating East Asian countries at an intergovernmental consultative meeting.

An important activity of the Programme is the Xiamen Demonstration Project (XDP). The project objective is to strengthen Xiamen's capability to apply the integrated coastal management (ICM) system in the prevention, mitigation, and management of marine pollution on a self-reliant basis, and to demonstrate its workable experience to the countries of East Asia.

The Coastal Environmental Profile of Xiamen (hereinafter referred to as the *Profile*) covers the following:

- Natural environment and its relation to development;
- Marine resources and their development status;
- Urban socioeconomics and status of ecological environment;
- Status of coastal water quality;
- Characteristics of marine ecosystem and problems;
- Status of marine environmental legislation; and
- Status of marine environmental management.

The *Profile* focuses on the analysis of marine environmental quality and adequacies of institutional arrangements, e.g., organizational structures, functions, and activities in coastal management; existing legislation and enforcement of environmental laws and regulations; and inputs and sources of marine environmental fund. In short, the *Profile* depicts the management issues of the Xiamen coastal resources and environment, their causes, priorities, and consequences, in order to provide a scientific basis for developing a strategic management plan and other demonstration activities.

The data used were taken from studies made since the late 1980s, as well as some of the latest socioeconomic data. Over the past 20 years, research institutes and universities have carried out many investigations and studies on the Xiamen coastal and marine environment and ecology. Government agencies for environmental protection and marine management organized and implemented some marine environmental programs during the past 10 years. Information from these programs was used in the *Profile*.

The *Profile* represents a concise and illustrative introduction, and a synthesis of the existing studies on the features of coastal and marine environment, resources, and management. However, in its preparation, there had been few historical data about environmental management. Accordingly, additional efforts have been made in data gathering through interviews, discussions, and meetings.

The *Profile* was written by the Integrated Task Team of the XDP, including Professor Guo Yunmou for Chapter 1; the late professor Wu Yuduan for Chapter 2; Mr. Lin Wei for Chapter 3; Mr. Gu Deyu for the Preface, Summary, Chapter 4, Conclusions and Recommendations; Dr. Xie Haisheng for Chapter 5; Mr. Zhao Deming for Chapter 6; and Mr. Lin Hanzhong for Chapter 7. The whole draft was integrated by Mr. Gu Deyu.

These authors come from various scientific research and educational institutions, and relevant municipal governmental agencies for planning, land use, environmental protection, and marine management. The first draft of the *Profile* was revised according to the recommendations of the concerned governmental agencies and experts. The multi-disciplinary and cross-agency approaches have facilitated data collection, analysis, and summary of experiences relating to coastal and marine environment and, thus, increased the objectivity, completeness, and credibility of the information contained in the *Profile*.

The Integrated Task Team sincerely acknowledges the various research institutions, universities, and government agencies for providing the data and information, although their respective names are not listed herein. Special thanks also go to the Regional Programme Manager of the MPP-EAS, Dr. Chua Thia-Eng, and his staff for their policy guidance, technical advice, and substantial efforts in information validation, refinement, and editing.

The *Profile* was developed under the financial support from the MPP-EAS and the Xiamen Municipal Government. Contributions in kind were made by the Xiamen Municipal Planning Commission, Environmental Protection Agency, Land Planning Agency, Marine Management Division, Xiamen University, Third Institute of Oceanography, and Fujian Institute of Oceanography.

The Integrated Task Team of the
Xiamen Demonstration Project

Summary

This book covers the characteristics of the ecosystem, socioeconomic development and the changes in environmental quality of the coastal and marine areas in the Xiamen Demonstration Site (XDS). Related management problems are also analyzed and solutions suggested.

The XDS is located at the southern coast of the Fujian Province in the People's Republic of China. Its area is limited to the boundary of Xiamen Municipality's administrative jurisdiction, excluding the adjacent Jiulongjiang River, although it has impacts on the project area.

Xiamen has a history of over 1,000 years that dates back to the Song Dynasty. It has always been an important trading port in the southeastern coast of China. It has a population of 1.17 million, 47 percent of which live in urban areas. Xiamen Municipality has a total land area of 1,516 km^2, with Xiamen Island proper in the center, occupying a land area of 128.78 km^2, characterized mainly by hillocks composed of granite and volcanic rocks. The topography of Tong'an County and the districts of Xinglin and Jimei changes from low mountains and hillocks to coastal plains as one moves from west-northwest to east-southeast directions.

Ecosystem Features and Their Changes

The bathymetry of Xiamen's coastal waters ranges from 10 to 30 m with a surface area of 334 km^2. Its coastal waters are divided into several areas, namely: the West Harbor, Maluan Bay, Tong'an Bay, Jiulongjiang River Estuary, the Outer Harbor and the Eastern Channel. There is a 184-km long winding shoreline in XDS composed of rocky and sandy coasts, scarps and mud flats.

Jiulongjiang River is the major river influencing XDS. It flows into the sea with a runoff of 1.19×10^{10} m^3 per annum, carrying 2.69×10^6 tons per annum of sand into the sea. The Xiqi and Dongqi rivers in Tong'an County are the biggest in the region. The other rivers in XDS are small with low runoff.

Located at the south subtropic zone, XDS has crimson red and saline coastal soils. There are eight major soil groups which are of medium to low soil fertility. The present vegetations are secondary and artificial covering only about 28 percent of the total land area. Having a minimal forest cover, XDS's green area per capita is low at 7.57 m^2.

Due to subtropical oceanic climate, Xiamen has warm weather year-round, with an annual average air temperature of 20.9°C and precipitation of 1,143 mm concentrated during spring and summer. The annual evaporation reaches 1,910 mm. Northeast monsoon prevails from early autumn to early spring, while southeast monsoon prevails in spring and summer with an average wind speed that is weaker than in the northeast monsoon.

Xiamen has a normal diurnal tide with high tide averaging 4 m. The tidal current varies greatly at different areas and can reach up to 60-90 cm/s at deep navigation channels. The residual current is usually weak, with a magnitude of about 10 cm/s at the estuary.

Natural disturbances are relatively severe in the XDS where tropical storms and storm surges prevail. Typhoons or tropical storms usually visit Xiamen 5.44 times a year. In the past, Xiamen was disturbed by earthquakes occurring from the adjacent region.

In terms of spatial extent, Xiamen's coastal waters are relatively wide compared to its limited land area. Coastal erosion has become serious in recent years. Its freshwater resource is not rich; and its marine fisheries and resources have been nearly exhausted.

Before the 1980s, real estate and economic developments in Xiamen were concentrated only in the Xiamen Island proper and Xinglin District. However, toward the end of that period, Xinglin, Jimei and Haicang began to develop rapidly. Since then, Xiamen's socioeconomic development as a region has been very rapid. This has been manifested by major port constructions in the West Harbor and large-scale development of mariculture. Yet, these have resulted into a rapid increase in waste discharges, thus, posing a threat to the environmental quality of the West Harbor.

In due time, the environmental quality of the Xiamen coastal waters will gradually deteriorate in several areas, especially in Maluan Bay. This has become seriously polluted due to waste discharges from industrial and agricultural production and household and mariculture activities. Other coastal areas show organic pollution. Also seriously polluted are the waters surrounding the Baozhuyu Island which lies north of the West Harbor. Comparatively speaking, the environmental quality of Tong'an Bay is the best among all of Xiamen's coastal waters.

Organic wastes and nutrients are the major pollutants entering Xiamen's coastal waters. Thus, the main problem is organic pollution. In the West Harbor, the chemical oxygen demand (COD) content has significantly increased since 1982. Inorganic nitrogen concentration has also increased to some extent. Bacterial pollution is also a problem because domestic sewage is mixed with other waste waters before being discharged to the coastal waters as a result of the inadequacy of urban effluent treatment and management.

Except for Tong'an Bay, the concentration of fecal coliform in Xiamen's coastal waters has exceeded the National Seawater Standard. Eutrophication in its coastal waters is at a medium level, which may be characterized by a relatively high concentration of inorganic nitrogen and relatively low phosphate. However, several instances of red tide outbreaks occurred in the past.

Xiamen's subtropical coastal waters provide important habitats for various marine species with relatively high primary productivity (167 mg/m^2d). Preliminary statistics have recorded 2,369 marine species, which are mostly eurythermal, including 181 for phytoplankton, 192 for zooplankton, 248 for nekton and 731 for benthos.

After a period of rapid economic development, Xiamen's marine ecosystem experienced distinct changes. The reclamation of coastal beaches and the construction of causeways reduced and segmented its coastal water area. These have resulted into enclosed or semi-enclosed water bodies such as the West Harbor, Xinglin Bay, Maluan Bay, Dayu Bay and Yuan Dang Lake. The population of *Chaetoceros,* which was formerly abundant in the area, had decreased by 50 percent from 1954 to 1980 because of environmental change. In Yuan Dang Lake, the big reduction in marine species population points to serious pollution and the impacts of reclamation undertaken in the early 1970s. The environmental quality of Yuan Dang Lake significantly improved after comprehensive mitigation measures were taken. However, a new sign of contamination has been observed.

Admittedly, there are serious conflicts regarding the use of coastal lands and waters. This is especially the case in West Harbor where port construction, mariculture activities, urban construction, tourism and marine environmental protection contentiuosly vie for priority attention.

Management Issues and Constraints

Ideally, the legal framework for marine environment protection and management requires complementing policy support from the national, provincial and municipal levels.

In Xiamen, the absence of necessary legislations and the inadequacy of technical support hamper marine environment protection and management. Some existing local regulations and national laws and legislations need modifications and updating. Compliance with environmental laws is low and can be attributed to weak enforcement.

There are twelve government agencies directly involved in marine development and management operating at the central, provincial and local levels. Their overlapping functions cause confusion in the implementation of government programs and policies relating to marine pollution control and management. This is a situation that needs an effective mechanism that will facilitate coordination among these agencies and institutions.

In terms of financial support from the government, about 0.8 percent of Xiamen's Gross Domestic Product (GDP) is devoted to environmental protection and management programs and projects.

Infrastructure support for waste minimization and management is inadequate, with only the Yuan Dang Lake Sewage Treatment Plant in operation. As for oil and chemical spills, there is no master plan or technical capability to contain their occurrence.

The government's campaign on environmental awareness and education is commendable, but there is still a need to broaden its scope and implement it vigorously.

Information Uncertainties

There is an abundance of data on marine hydrology and biology. However, the database for comprehensive management, control and prevention of marine pollution remains inadequate due to the following reasons:

- The study scope is quite limited;
- Pollution sources are not well-studied;
- There are insufficient scientific studies on some critical marine pollution problems and environmental management issues;
- The analysis of a long-term systematic monitoring of changes in marine ecosystem and environmental quality is incomplete;
- Cross-sectoral marine environmental information system is lacking; and
- Data are kept by different institutions, thus access is inconvenient and difficult.

Future Directions

In Xiamen, the increase in human activities due to population growth and the unrelenting economic activities spurred by economic growth have caused significant increases in waste discharges, gaseous emissions and other pollutants.

For the next ten years, economic growth will largely occur on lands surrounding the West Harbor. Thus, it would possibly face serious pollution problems if no adequate pollution control and management measures are adopted. Wastewater treatment infrastructures remain inadequate. Whether they could keep pace with the increasing rate of waste discharges is indeed the question. With this situation, the future environmental quality of the West Harbor will be at stake and thus needs immediate attention.

List of Acronyms

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DDT	Dichlorodiphenyltrichloroethane
E	East
ECC	Environmental Carrying Capacity
EIA	Environmental Impact Assessment
ENE	East northeast
EPA	Environmental Protection Agency
EPD	Environmental Protection Device
GDP	Gross Domestic Product
GIS	Geographic Information Systems
ICM	Integrated Coastal Management
IMO	International Maritime Organization
LPG	Liquefied Petroleum Gas
MPP-EAS	GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas
MSG	Monosodium glutamate
NE	Northeast
NEPA	National Environmental Protection Agency
NIC	Newly Industrialized Country
NNE	North northeast
RMB	Ren Min Bi
RP	Reactive phosphorus
S	South
SE	Southeast
SEZ	Special Economic Zone
SSE	South southeast
TEUs	Twenty-foot equivalent units
TIN	Total inorganic nitrogen
TMDS	Tajiao Marine Dumping Site
UNCED	United Nations Conference on Environment and Development
XAEPS	Xiamen Association of Environmental Protection Science
XDP	Xiamen Demonstration Project
XDS	Xiamen Demonstration Site

Chapter 1:

Physical Endowments and Their Relation to Development

Extent and Boundary of the Xiamen Demonstration Site

Xiamen is located at the southern part of Fujian Province of the People's Republic of China and west of Taiwan Strait *(see Figure 1.1)*. It is composed of Xiamen Island proper, Gulangyu Islet, and the coastal part of the northern bank of Jiulongjiang River and southwest of Xiamen Island.

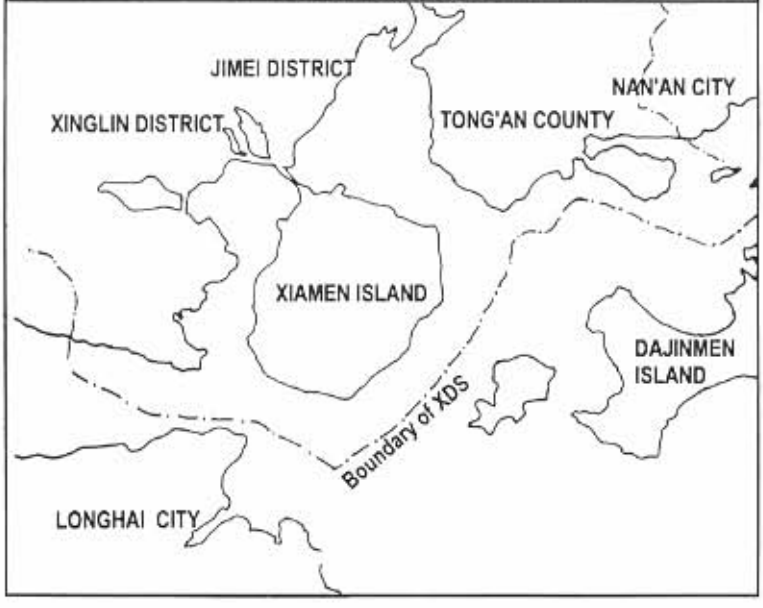
The Xiamen Municipality consists of six districts and one county, namely: Kaiyuan, Siming, Gulangyu, Huli, Jimei and Xinglin Districts, and Tongan County.

The total length of the coastline is 184.54 km characterized by cliff, rocky, sandy and silt-mud shores. Xiamen Municipality has a total area of 1,516 km^2 with Xiamen Island proper having an area of 128.78 km^2.

The Xiamen Demonstration Site (XDS) covers the waters on the southern coast of Fujian extending west of Taiwan Strait. The site's coastline is 57 km long from north to south and 68 km wide from east to west. For environmental considerations and manageability, the existing administrative boundary of the Xiamen Municipality is used as the limit of XDS, i.e., it covers all the administrative regions of Xiamen Municipality *(see Figure 1.2)*.

Figure 1.1. Geographical location of Xiamen Municipality

Figure 1.2. Geographical boundaries of the Xiamen Demonstration Site



The coastal waters of XDS include the Jiulongjiang River Estuary; the West Harbor, Maluan Bay and Xinglin Bay; the Outer Harbor; Tong'an Bay, consisting of Xunjiang in the south and Dongzhuigang in the north; the Eastern Channel to Xiamen Island; and the northern part of the Northern Channel to Jinmen Island. Following Xiamen's administrative jurisdiction,

the XDS boundaries lie in Qingjiao, Haicang at the Jiulongjiang River Estuary in the west, and at the central line between Jiyu Island and Dashiken of Longhai City in the south.

Its boundary at the Eastern Channel is the central line of Jinmen-Xiamen coastal waters, extending about 3-5 km.

The XDS includes the islands of Xiamen, Gulangyu, Dadeng, Xiaodeng, Tong'an County, extending 32 km northward; Jimei district, extending 23 km westward; and Xinglin District. The XDS boundary at Yunding Hill of Tong'an County in the north up to Dingdingwei Hill of Jimei District in the west corresponds to watershed areas.

In general, the area coverage of XDS, excluding the Jiulongjiang River, includes the basins that drain into Xiamen's coastal waters. However, the part of Jiulongjiang River which extends 300 km inland outside the boundary of Xiamen Municipality still has some impacts on the XDS.

Impacts from neighboring regions and adjacent coastal waters take the form of pollutants carried by Jiulongjiang River; mud and sand produced by the reclamation of coastal waters and beaches of Zhongyin Development Park at the southern coast of Jiulongjiang River Estuary; and water quality being exchanged around Jinmen Island at the entrance of Xiamen Bay.

Geography

Geomorphology — The hilly Xiamen Island, the major land body of Xiamen Municipality, is of igneous origin consisting of granite and volcanic rocks.

The island is characterized by narrow and short plains dotted by low hills that converge toward the center of the island. However, the land areas in the northwest are surrounded by mountains on three sides, with plains and low mounds scattered around them.

The Gaoqi-Jimei Causeway constructed northwest of Xiamen Island in 1956 and the Xiamen bridge built in 1991 had turned the island into an artificial peninsula.

Yuan Dang Lake, located west of Xiamen Island, was originally an inner bay wedged into the island's land mass before it became an artificial lake when a causeway was constructed in 1971.

There are 29 small islands and 58 ledges in the coastal waters around Xiamen Island. Huoshaoyu Island, Datuyu Island, Dayu Island and Jiyu Island in the south are *kopjes* (small hills) made of volcanic rocks. Baozhuyu Island in the northwest and Eyuyu Island and Dalimuyu Island in the north are also *kopjes* made of granite.

Gulangyu Island in the south, which is separated from Xiamen Island by a 500 m wide channel, has an undulating terrain where earthen hummock and granite are widely distributed. *Longtoushan* ("mountain like the head of a dragon") or Sunlight Rock, Gulangyu's highest location, is 92.7 m above sea level.

Xinglin Bay and Maluan Bay, located northwest of Xiamen Municipality, combine with the Jiulongjiang River Estuary in the south forming the three small peninsulas of Jimei, Xinglin and Haicang.

Tong'an County, located north of Xiamen Municipality and across Tong'an Bay, faces the bay but bounded by mountains at the interior. Dongzhuigang of Tong'an Bay cuts into its southeast coastal land. Situated in the east are three islets namely, Dadeng, Xiaodeng and Jiaoyu.

The county's topography changes in a northwest to southeast direction. The mountains in the east, west and north form the boundary between Xiamen Municipality and Quanzhou City. The mountains in the north are relatively higher than those in the southwest and the east where hills gradually become terraces to catsteps to coastal plains.

Xiamen Bay is a complex bay composed of Tong'an Bay, West Harbor, Jiulongjiang River Estuary, Eastern Channel and the Outer Harbor *(See Figure 1.3.)*

Figure 1.3 shows the location of Maluan Bay. It is separated from the West Harbor by a 1,685 m long Maluan causeway built in

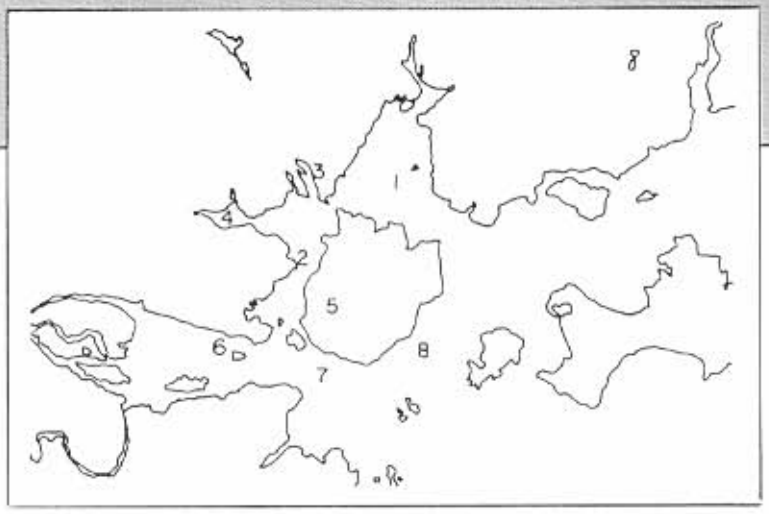


Figure 1.3. Geomorphology and divisions of Xiamen coastal waters

Legend:
1 - Tong'an Bay (TB)
2 - West Harbor (WH)
3 - Xinglin Bay (XB)
4 - Maluan Bay (MB)
5 - Yuan Dang Lake (YL)
6 - Jiulongjian River Estuary
7 - Outer Harbor (OH)
8 - Eastern Channel (EC)

Source: State Oceanic Administration et al. (1989)

1960. Its water surface area was reduced from 17 km^2 to 9 km^2 at the completion of the causeway, and further to about 7 km^2 at present. The bay has a maximum depth of 11 m and a minimum of 5 m. There is a flood gate with 7 holes and 4 sluice gates at the northern end of the causeway but the latter are closed most of the time. Nine streams entering Maluan Bay originate from the northwest hilly areas. The total drainage area is 123 km^2, providing an average runoff of $1.04 \cdot 10^8 m^3$ in a rainy year, $0.85 \cdot 10^8 m^3$ in an average year, and $0.37 \cdot 10^8 m^3$ in a dry year.

West Harbor is the central port of Xiamen. Before the Gaoqi-Jimei Causeway was constructed in 1956, West Harbor and Tong'an Bay used to be one water body. After the causeway was built, the West Harbor has become a semi-enclosed bay, with an entrance in the south where it combines with the Jiulongjiang River Estuary as they flow into the Outer Harbor.

Water channels of more than 10 m in depth are found in Dongdu south of Shihushan, Song-Gu and Xia-Gu and they follow a south-north or southwest-northeast direction. Dongdu Channel can be as deep as 30 m in some parts. Silty mud flats have formed on both sides of the channel.

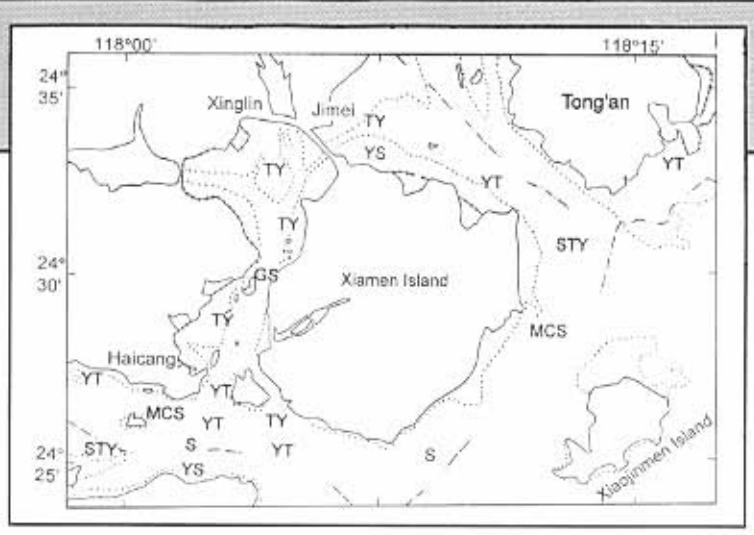
The waters east of Dalimuyu Island are 10-15 m deep with shallow areas in the west around mud flats. The Dongzhuigang has sandy sediment north of Eyuyu Island and sandy and silt-mud in the south *(see Figure 1.4)*.

Xinglin waters in north West Harbor and Houyu waters in the south are wide water bodies. For the past 30 to 40 years, tidal influxes have greatly reduced due to the construction of causeways and berths and large-scale reclamation of Maluan Bay, Xinglin Bay, Dongyu Bay and Yuan Dang Lake, leading to different levels of scouring or siltation. Some shallow waters and channels are heavily silted *(see Figure 1.5)*.

Jiulongjiang River Estuary is at the front edge of an underwater delta. The estuary, which connects the Jiulongjiang River to the sea, tapers from the middle toward its mouth. In the middle lies an underwater shoal around Jiyu Island. Near the estuary's south and north banks are found deep water channels with an average depth of more than 10 m. Sediment patterns such as medium-coarse sand, fine sand, muddy silt and silty mud vary from west to east.

The Eastern Channel and the Outer Harbor connect the Tong'an Bay, the West Harbor and Jiulongjiang River Estuary to the Taiwan Strait. The Eastern Channel is bounded by Xiaojinmen Island, Dada Island and Xiamen Island. Its water depth is often deeper than 10 m. However, there is a shallow portion with less than 2 m depth between Dada Island and

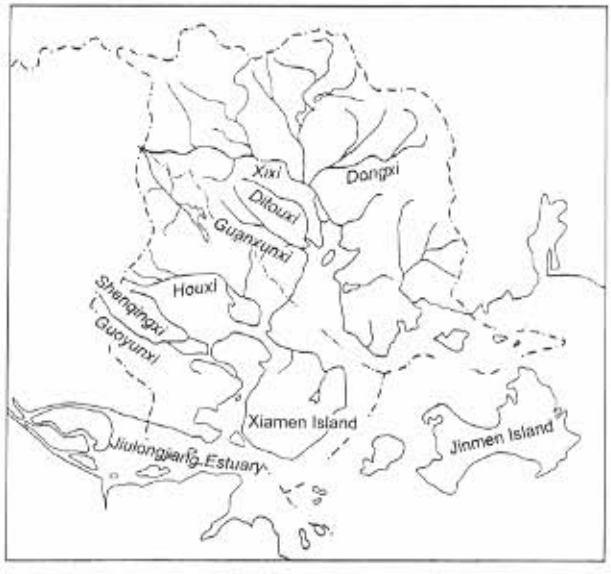
Figure 1.4. Sediment types in Xiamen coastal waters



Legend:
- *GS - gravelly sand*
- *MCS - medium-coarse sand*
- *S - sand*
- *YS - clayey sand*
- *STY - sand-silt-clay*
- *TY - silty clay*

Source: *State Oceanic Administration et al. (1989)*

Figure 1.5. Drainage areas of Xiamen Municipality



Source: *Nanjing Institute of Geography and Limnology et al. (1989)*

Baishi Fortress in Xiamen Island. Its sediment composition is mainly medium-coarse sand. However, there is a fine sandy beach extending 4.5 km long from the seaside resort in Xiamen University to Baishi Fortress.

The Outer Harbor, which is bounded by Gulangyu Island, Dada Island, Erda Island and Qingyu Island, has an entrance facing southeast. Its wide, flat seafloor is covered with silty-mud sediment. Qingyu Island Channel, which has a minimum water depth of 14-18 m and a maximum of 26 m is the navigational entry to Xiamen Port.

Drainage — The main streams in the Jimei and Xinglin districts are Houqi, Shenqingqi and Guoyunqi. Houqi flows into Xinglin Bay while the latter two into Maluan Bay.

The main rivers in Tong'an County are Xiqi, Dongqi, Guanxunqi and Litouqi and they enter into the coastal waters separately. Dongqi and Xiqi are the largest rivers in Xiamen. The four rivers are important sources of sediments for Dongzhuigang and Xunjiang of Tong'an Bay.

However, it is the Jiulongjiang River that significantly affects Xiamen's coastal waters. The river is the main source of sediments for the estuary and the Outer Harbor. The movement of suspended particles into the West Harbor is the main cause of siltation in the West Sea *(see Table 1.1 and Figure 1.6)*.

Soil — The zonal soils in Xiamen region belong to eight great soil groups, 11 soil subgroups, and 20 soil genuses. The fertility of the farm land is medium to low *(see Figure 1.7)*.

Table 1.1. Quantity of runoff and sand transported by rivers and streams into the sea

River	Length (km)	Area (km^2)	Station	Yrs.	Runoff ($10^8 m^3/a$)			Sand ($10^4 t/a$)		
					Ave.	Max.	Min.	Ave.	Max.	Min.
Xiqi, Tong'an	34	494	n.d	n.d.	3.7	n.d.	n.d.	6.0	n.d.	n.d.
Jiulongjiang	285	14,741	Punan	38	37	61.3	29.3	93.6	220	21.3
			Zhendian	38	82	139	50.7	176	464	61.6

Note: *Station is the place where runoff and sand content are observed. Yrs. are the time duration of data available. n.d. = no data*

Source: *Li Qingnian and Guo Yunmou (1984)*

Figure 1.6. Jiulongjiang River Basin

Source: *Nanjing Institute of Geography and Limnology, China Science Academy et al. (1989)*

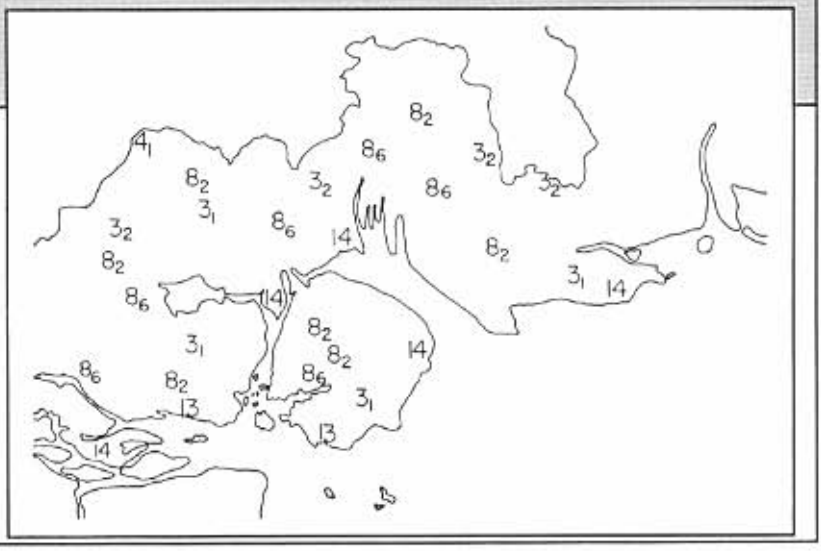
The soil types in Xiamen are as follows:

1. Crimson soil is found mainly in low hills and terraces, having an elevation of more than 300 m above sea level. It contains 1.65 percent organic matter with about 5.7 pH and of medium fertility. It is the major soil type for forestry, growing fruit-bearing trees and root crops. Erosion in some hills and terraces heavily affects crimson soil.
2. Rice soil is found in fluvial plains and marine depositions or in some terraces. Generally, it is thick and has medium to high fertility.
3. Coastal salty soil is deposited in tidal mud flats. It is suitable for mud flat aquaculture when it has a high content of organic materials.

Figure 1.7. Soil types in Xiamen Municipality

Legend:
- 3_1 - Crimson soil
- 3_2 - Crimsoney soil
- 4_1 - Rice soil
- 8_2 - Rice soil (water logging type
- 8_6 - Rice soil (salinized type)
- 13 -Weathered sandy soil
- 14 -Coastal salty soil

Source: *State Oceanic Administration et al. (1989)*



4. Red soil is found especially in hills with an elevation of less than 300 m above sea level in both Tong'an County and northwest Xiamen Island and also in forested areas. It contains 1.81 percent organic matter and is heavily affected by erosion.
5. Wind-weathered sandy soil characterized the beaches in southeast Xiamen Island and the coastal catsteps east of Xiamen port. Its organic material content is low.

Vegetation — The zonal vegetation in Xiamen is dominated by perennial *Laurisilvae*, a typical flora in the forest ecosystem of the South Subtropic Zone. However, secondary vegetations have replaced the original or old-growth forest.

Among the existing flora, the Royal poincinna, masson pine and China fir grow well and are widely distributed in hills and terraces. On sandy beaches, oak trees were planted to serve as windbreakers and for shore protection. A small number of mangrove areas can be found in mud flats of high and middle tidal zones. On low hills and barren lands usually grow thin bushes, woods and grasses *(see Figure 1.8)*.

Rice, vegetable and fruit-bearing plants along with other crops such as sweet potatoes and peanuts are widely cultivated. The fruit-bearing *longyan* tree(*Euphoria longan)* is commonly grown in the region.

Vegetation cover has an average of 27 percent with a large spatial variation. The maximum is 44-49 percent and the minimum is 0.7-18 percent *(see Figure 1.9)*.

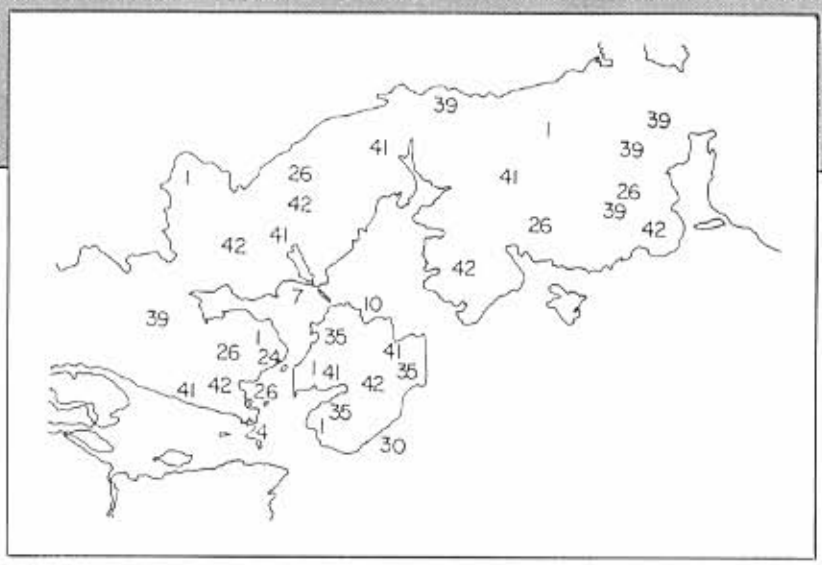
Climate

Air Temperature — Xiamen has a southern subtropical climate characterized by a long period of high air temperature and a small temperature variation. It has no severe winter or intense summer.

Its average temperature over the years is 20.9°C. The highest average monthly temperature is 28.4°C in July; the lowest at 12.6°C in January and February, with an annual variation of 15.8°C and a diurnal variation of 7.0°C. The recorded maximum temperature was 38.5°C and the minimum was 2.0°C *(see Figure 1.10)*.

Precipitation — The average precipitation is 1,143.5 mm. Precipitation is high in spring and summer but low in fall and winter. The average relative humidity is 74 percent. Spring and summer are humid; while autumn and winter

Figure 1.8. Vegetation of Xiamen Municipality



Source:
State Oceanic Administration et al. (1989)

Legend:

1 - masson pine
7 - Kendelia candel
24 - Helicteres angustifolia
26 - masson pine, Acacia rachli
35 - Acacia rachli
36 - horsetail tree
39 - longyan
41 - paddy field crops
42 - dry field crops

Figure 1.9. Vegetation cover of Xiamen Municipality

Legend: Vegetation Cover (%)

≥44 (44-92) 23 - 24 ≤18 (18-0.7)

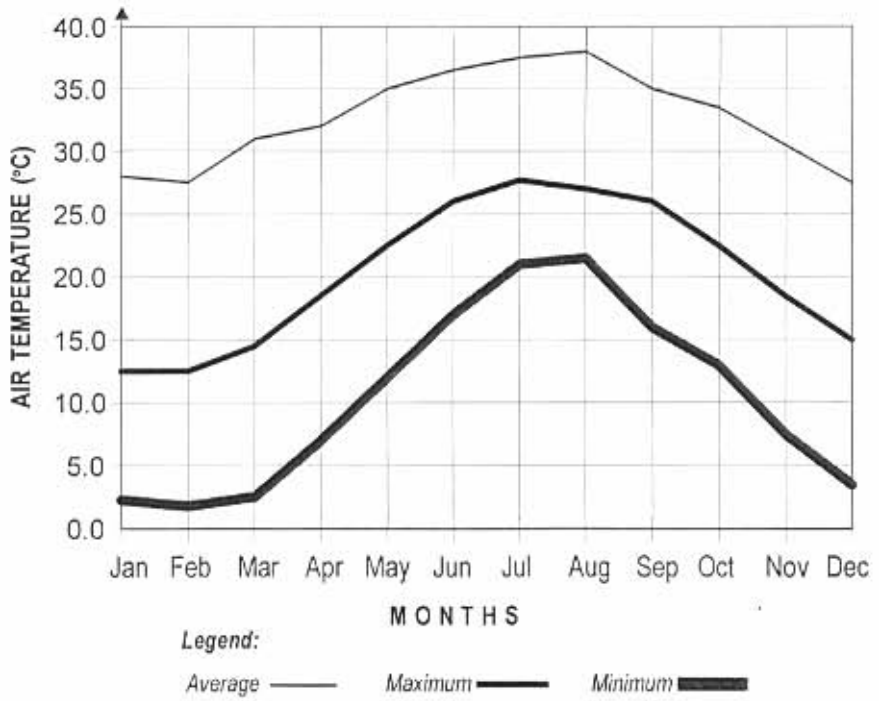
are dry. The average evaporation is 1,910.4 mm, the highest of which is in summer and autumn, and the lowest is in winter and spring *(see Figure 1.11)*.

Wind — There is a distinct seasonal change in monsoon circulation. Wind velocity is high during the northeast monsoon that usually lasts from September to March. Low wind velocity prevails during the southeast monsoon which occurs from April to August. The average wind speed is 3.4 m/s and is often in the NE direction at a frequency of 15 percent.

Hydrology

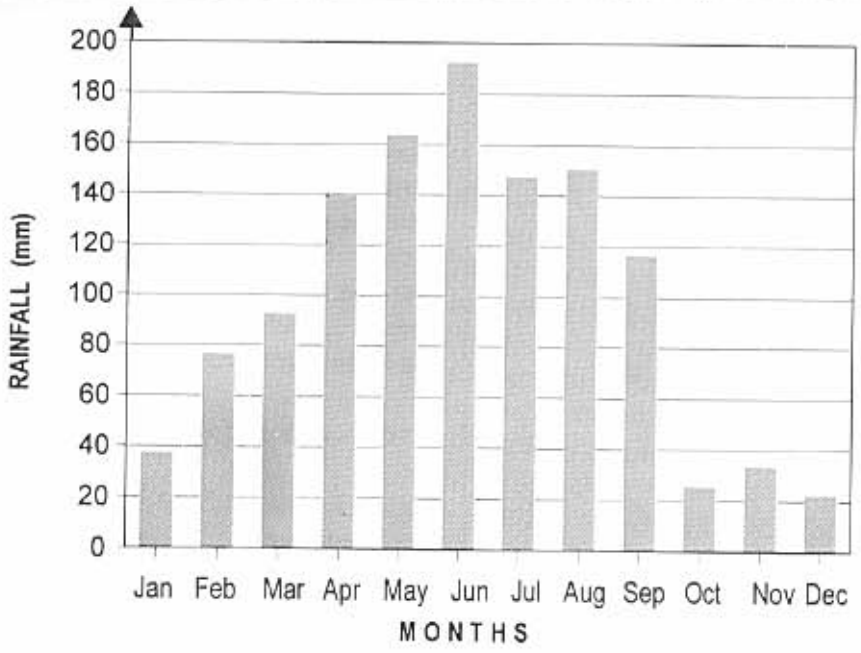
Water Temperature and Salinity — The temperature of Xiamen coastal waters ranges from 14.2°C to 16.2°C in February, with an average of 14.8°C, and from 27.2°C to 28.9°C in September, with an average of 27.8°C. The salinity ranges from 22.91 parts per thousand (ppt) to 31.08 ppt, with an average of 28.69 ppt in February, and from 13.95 ppt

Figure 1.10. Monthly variation of average air temperature in Xiamen Municipality



Source: *Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)*

Figure 1.11. Monthly variation of average precipitation in Xiamen Island (1952-1990)



Source: *Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)*

to 32.40 ppt in September, with an average of 30.06 ppt.

Tide — Xiamen's coastal waters have a normal semi-diurnal tide of high range, as shown in the following table. The average sea level is 0.30 m above the Huanghai Sea *(see Table 1.2)*.

Tidal current — Xiamen's coastal waters have a strong bifurcated tidal current of the semi-diurnal type. However, the direction and velocity of the tidal current vary from place to place due to differences in geomorphology. The velocity usually decreases from the entrance to the upper part of the bay, and also from deep channel to the shore. The narrow sections of Dongdu Channel in the West Harbor, between Songyu and Gulangyu islands, between Gulangyu and Xiamen islands; the channels in the east coast of Houyu Island, and in the north coast of Jiyu Island; and the waters of Autou-Wutongdao at the entrance of Tong'an Bay have a strong tidal current reaching a maximum of 60-90 cm/s, with a record of instant velocity above

Table 1.2. Tidal patterns

Ave. high tidal level	5.68	Max. tidal range	7.78
Ave. sea level	3.58	Ave. tidal range	3.99
Ave. low tidal level	1.89	Min. tidal range	0.99
Max. tidal level on record	7.78	Ave. flood duration	6 hrs. 8'
Min. tidal level on record	-0.06	Ave. ebbing duration	6 hrs. 10'

Source: *Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et. al. (1994)*

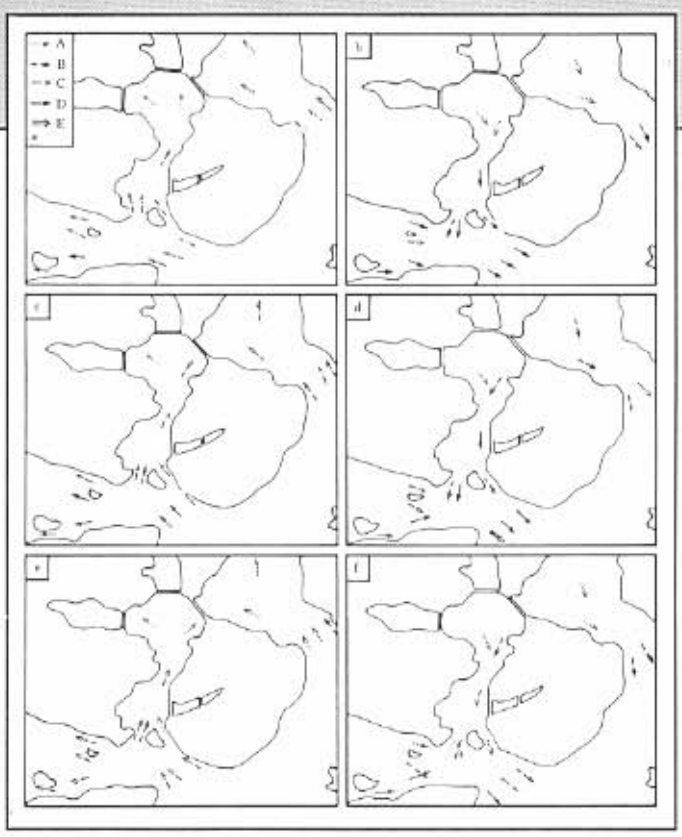


Figure 1.12. Maximum tidal current patterns in Xiamen coastal waters

Legend:

A - *weak*
B - *medium*
C - *medium-strong*
D - *strong*
E - *very strong*
a - *surface flood tide*
b - *surface ebb tide*
c - *5-m layer flood tide*
d - *5-m layer ebb tide*
e - *bottom flood tide*
f - *bottom ebb tide*

Source: *Third Institute of Oceanography, SOA (1988)*

100 cm/s. The recorded maximum tidal current at Dongdu Channel is 152 cm/s. Elsewhere in the region, tidal currents are below 40 cm/s. The slowest current speed occurs in the wide and shallow waters around Baozhuyu Island in Xinglin Bay and north of West Harbor *(see Figure 1.12)*.

The current velocity at flooding and ebbing phases in the Xiamen waters varies. Usually, waters with a strong tidal current have an ebbing velocity faster than the flooding tidal current, favoring a seaward transportation of the suspended materials or pollutants. However, in Xiamen there is not much difference between the flooding and the ebbing tidal currents in weak tidal areas. In addition, the ebbing tidal current of surface layer in the Xiamen waters generally lasts 20-50 minutes longer than the flooding current, with a maximum time difference of 1 hour and 50 minutes between flooding and ebbing.

Residual Current — Due to the strong effect of runoff by Jiulongjiang River, the residual currents in the Outer Harbor, in the estuary, and in the West Harbor are strong and often larger than 10 cm/s. On the other hand, the residual currents near Xinglin, in the upper part of the West Harbor, and in Tong'an Bay are weak. The residual current direction at Dongdu Channel is similar to that of its ebbing tidal current. However, its direction to the north of Jiyu Island; in the western Songyu-Gulangyu Channel; to the west of Huoshaoyu Island; and off the north coast of Tong'an Bay is similar to that of the flooding tidal current. Elsewhere, the residual current of the upper layer usually flows in the ebbing direction and of the lower layer in the flooding direction. The residual current at the culvert of Gao-Ji Causeway flows from the West Harbor to Tong'an Bay at 10-40 cm/s *(see Figure 1.13)*.

Wave — Waves from Taiwan Strait strongly influence Xiamen's offshore waters. The most frequent wave moves toward the east (E) direction and the less to the east-northeast

(ENE) direction. The strongest wave is in the southeast (SE) direction. The maximum wave height reaches 6.9 m, and the ratio of wind wave to swell is 42/58, indicating a stronger roll by the swell.

In its coastal waters, on the other hand, the waves weaken gradually from the Outer Harbor to the inner waters due to the sheltering effects of the island chain composed of Dajinmen, Xiaojinmen, Dada, Erda, Qingyu and Wuyu. The maximum wave height at the east and southeast coast of Xiamen Island, particularly in the West Harbor, ranged at 4-5 m and as low as 1.3 m. The waves in the east and southeast coasts of Xiamen Island contribute to the receding of the coastlines and the formation of sandy beaches.

In West Harbor, the wind wave that dominates has a ratio of 89/11 wind wave to swell. In the same place, waves are usually weak due to short fetch and have the following characteristics *(see Figures 1.14 and 1.15)*:

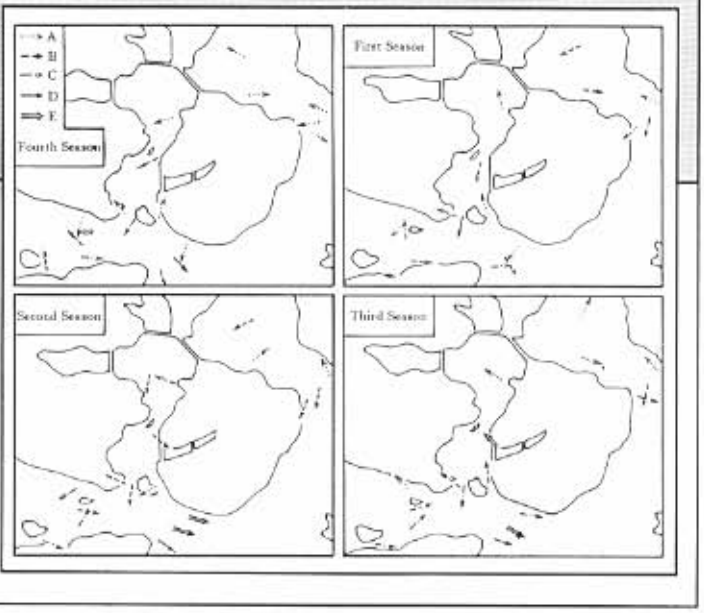
- prevailing wave direction — NE
- secondary prevailing wave direction — ENE
- strong wave direction — NNE and N
- maximum wave height — 1.3 m
- secondary strong wave direction — SSE
- maximum wave height — 1.2 m
- yearly average wave height — 1.2 m
- average period — 3.4 seconds
- frequency of 0-2 wave at sea scale — 99.6%
- seasonal variation — indistinct
- more strong waves in summer and NNE ENE waves in the other three seasons.

Xiamen Bay's southeast entrance allow the easy dominance of waves with southeast direction. During typhoons, southward winds and SE wind waves usually affect a large area of Xiamen waters.

Currents of Offshore Waters — In the XDS offshore waters, current circulation in Taiwan Strait is jointly influenced by the Zhejiang-Fujian coastal current, the Kuroshio branch and the South China Sea warm current. The prevailing current direction is the NE direction with distinct seasonal variations.

In summer (June to September), on the one hand, the strait is influenced by the northeast warm current of high salinity and temperature, which consists of the southern warm current and Kuroshio branch entering the strait in the south.

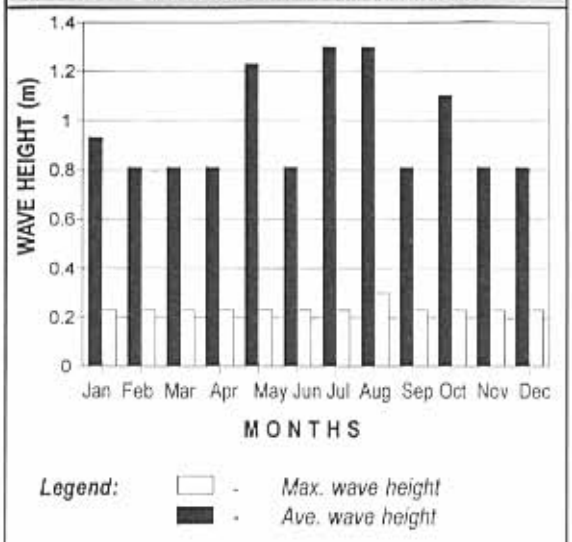
Figure 1.13. Seasonal pattern of surface layer residual and bottom layer currents in Xiamen coastal waters



Legend:
A - *weak*
B - *medium*
C - *medium-strong*
D - *strong*
E - *very strong*

Source: Third Institute of Oceanography, SOA (1988)

Figure 1.14. Annual variation of waves at Dongdu Station in the West Harbor



Source: Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)

In winter (October to May), on the other hand, the southward Zhejiang-Fujian coastal current affects all or part of the upper layer of western strait up to the Xiamen Harbor and Lishi Islands in the south.

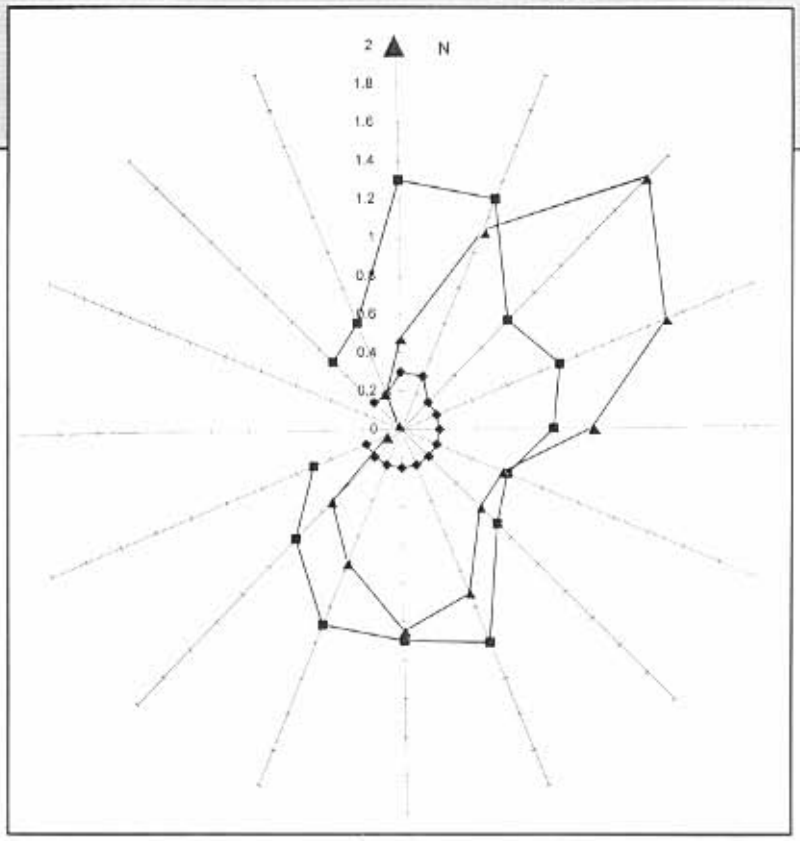
However, the northward Kuroshio branch and South China Sea warm current of NE direction affect the eastern upper layer and both the middle and bottom layers. Since Xiamen Harbor is a semi-enclosed bay, which has a narrow mouth and a large body, offshore water currents have minor influence.

Marine Natural Ecosystem

Being in the subtropic zone, Xiamen coastal waters provide important habitats for a wide diversity of species that have scientific or economic value.

The concentration level of chlorophyll *a* in the water column ranges from medium

Figure 1.15. Wave rose at Dongdu Station in the West Harbor



Legend:
Ave. wave length
Max. wave length
Wave direction frequency
1 cm = 0.25 cm
1 cm = 10%

Source: Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)

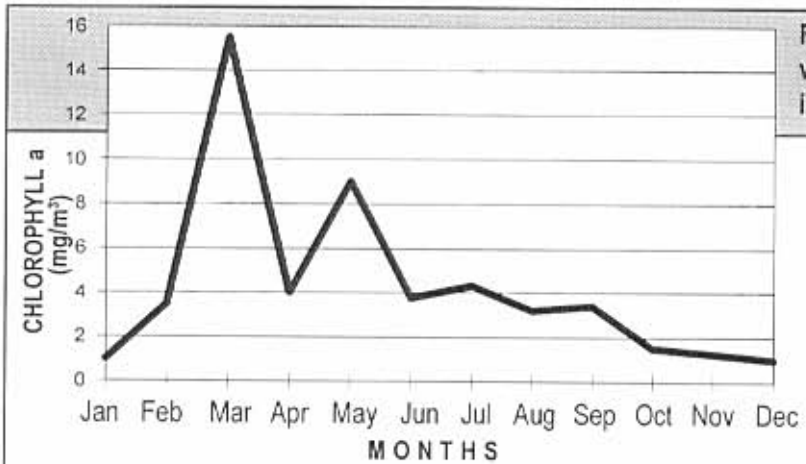


Figure 1.16. Monthly variation of chlorophyll *a* in Xiamen coastal waters

Source: Chen et al. (1993)

to high with an annual average of 4.6 mg/m^3. The primary productivity is 167 mgC/m^2. There is a distinct monthly variation of chlorophyll *a* concentration, with the maximum variation in spring and the minimum in winter equivalent to an eight-fold difference *(see Figure 1.16)*.

There is also a clear spatial variation of chlorophyll *a*. The concentration of chlorophyll *a* in Tong'an Bay is high all year-round, indicating an active primary production *(see Figure 1.17)*.

Studies done by various agencies showed (*see Table 1.3*) that there are 181 species of phytoplankton, 192 species of zooplankton, 248 species of nekton, 731 species of benthos, and 817 intertidal zone species. (The names of the dominant species are listed in Annex 1).

These different groups of marine species have significant spatial and temporal variations *(see Figures 1.18 - 1.23)*. Studies from 1991 to 1992 show a record of 150 species of fish, 127 species of crustaceans and 59 species of algae.

However, accounts show that *Sousa chinensis, Branchiostoma belcheri* (lancelet), and egret are becoming rare and endangered in Xiamen coastal waters as indicated by a serious reduction in their numbers in the past 40 years.

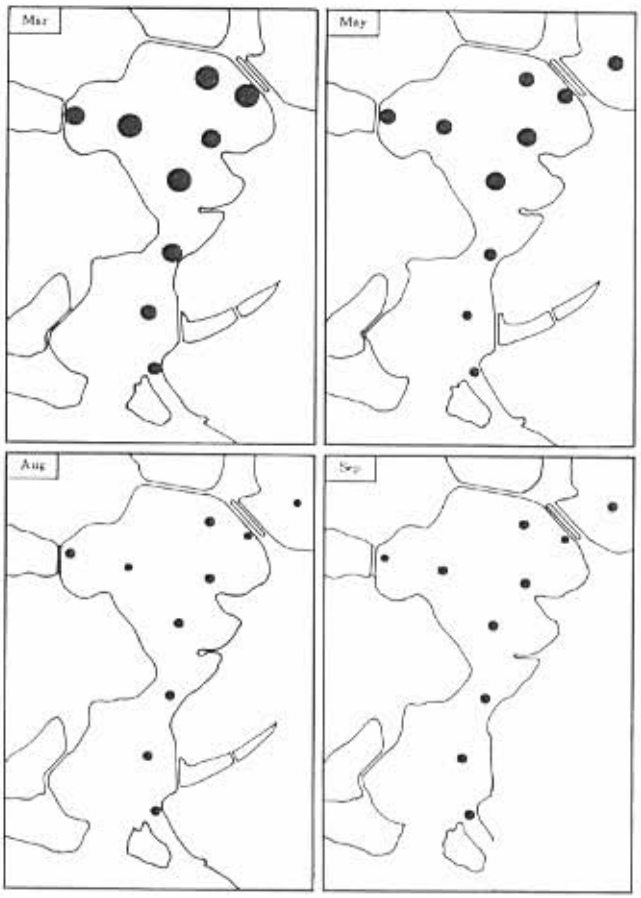
Table 1.3. Numbers of marine species in Xiamen coastal waters

Phytoplankton		Zooplankton		Nekton		Benthos	
Group	No.	Group	No.	Group	No.	Group	No.
Bacillariophyta	164	Medusa	75	Fish	157	Polychaeta	248
Pyrrophyta	16	Copepoda	73	Shrimp	42	Crustacea	175
Cyanophyta	1	Ostracoda	3	Crab	32	Mollusca	146
		Decapoda	4	Squid	4	Echinodermata	43
		Amphipoda	1	Cephalopoda	13	Demersal fish	84
		Mysidacea	8			Others	35
		Euphausiacea	1				
		Chaetognatha	11				
		Tunicata	5				
		Others*	11				
Total	181		192		248		731

Legend: * = *including larval plankton and ichthyoplankton*

Source: *Data of plankton and benthos are from the Third Institute of Oceanography, SOA (1988). Data of nekton are from the Office of Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)*

Figure 1.17. Spatial variation of chlorophyll *a* in Xiamen coastal waters



Source: Chen et al. (1993)

Six mangrove species grow in Xiamen: *Kandelia candel, Avicennia marina, Aegiceras comiculatum, Acanthus ilicifolius, A. ebracteatus* and *Excoecaria agallocha*. However, their quantities have greatly decreased. Presently, they are found mainly in the west shallow flats of Haimen Island, in the estuary and high tidal zone north of Caobotou and in Fugong Town of Longhai City, outside of Xiamen Municipality. Within the XDS, mangroves are found in small numbers in Haicang, Dongyu and west of Jiyu Island *(see Figure 1.24)*.

Natural Hazards

Earthquake — The XDS is situated in the middle of the Quanzhou-Shantou fault zone, the most active fault zone in the southeast coast of China. Seismic movement is strong in the east, south and north zones, but weak in the west and middle zones. Xiamen Island appears being wedged by these two active faults. Historical records show that earthquakes stronger than intensity 7 on the Richter scale have occurred in the eastern part of Taiwan Strait causing some damages in Xiamen *(see Table 1.4)*. Medium to strong earthquakes with a magnitude of about 6 can occur in the Quanzhou-Shantou active fault zone in the next 100 years and may cause extensive damages in the urban areas of Xiamen *(see Figures 1.25 - 1.26)*.

Tropical Storm — It is considered as the most hazardous weather disturbance in Xiamen. According to statistics, an average of 5.4 tropical storms affect Xiamen region every year *(see Table 1.5)*. Tropical storms usually occur in July, August (it has the most number of storms) and September. Storms that pass Xiamen and Guangdong coasts and then inland to Fujian Province are the strongest. During typhoons, the largest wind force period can reach 8 and above on the wind scale with a maximum instant wind speed of 60 m/s (e.g., No. 590 Typhoon), and the average rainfall of 100 mm can reach a maximum of 510 mm (No. 9009 Typhoon).

Storm Surges — In Xiamen, storm surges, which are caused mainly by typhoons, usually occur in summer and autumn. During surges, water level may increase by an average of 50 cm. Its amplitude is from 1.50 to 2.00 m, with

Table 1.4. Major earthquakes near Xiamen

	Year	Epicenter	Magnitude	Epicenter distance (km)	Influence Intensity
1	1105	Zhangzhou	6.5	38	six-seven
2	1445	Zhangzhou	6	41	six
3	1600	Zhangzhou	7	13	six
4	1604	offshore Quanzhou	8	163	seven-eight
5	1906	offshore Jinmen	6.1	56	six
6	1918	Nan'ao	7.3	133	seven
7	1986	Hualian, Taiwan	7.6		five

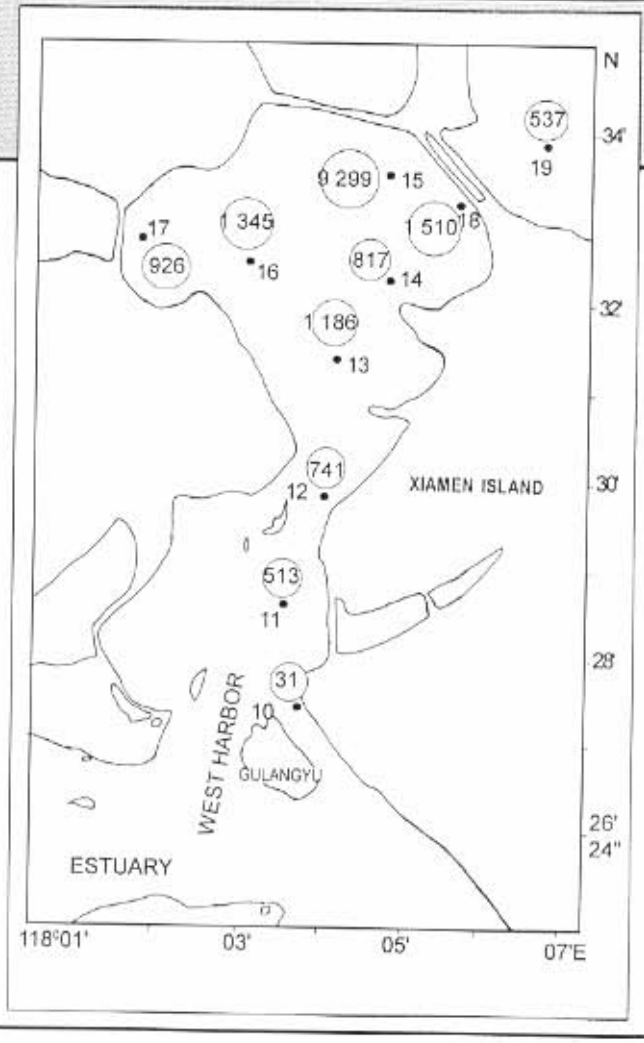
Source: Ye Qing (1992)

Table 1.5. Frequency of tropical storms in Xiamen (1952-1990)

Month			5	6	7	8	9	10	11	Total		Ave.
nus.	I	typhoon	6	12	31	33	38	10	6	136		
		storm	1	5	16	19	5	2	0	48	184	4.8
	L	typhoon	0	1	5	9	8	1	0	24		
		storm	0	0	1	0	0	0	0	1	25	0.5
%	I		4	9	26	28	23	7	3		100	
	L		0	4	24	36	32	4	0		100	

Source: Office of Steering Group for Comprehensive Investigation of Xiamen Island Resource et al. (1994)

Figure 1.18. Spatial distribution of average cell count of phytoplankton in surface layer



Legend:
Cell count of phytoplankton (10^3 ind/dm^3) ○

Note: *The quantity of phytoplankton shows patched distribution pattern with maximum value (926x10^3 ind/dm^3) in areas northwest of West Harbor and minimum in areas north of Gulangyu (31x10^3 ind/dm^3). Some medium-high values are scattered in other parts of the West Harbor and Tong'an Bay.*

Source: *Zhang Shuijin (1993)*

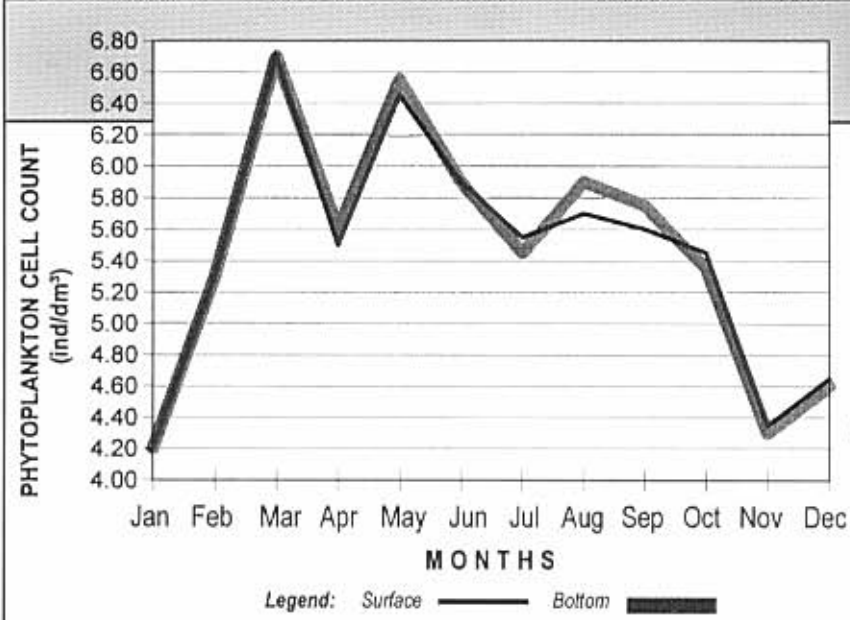
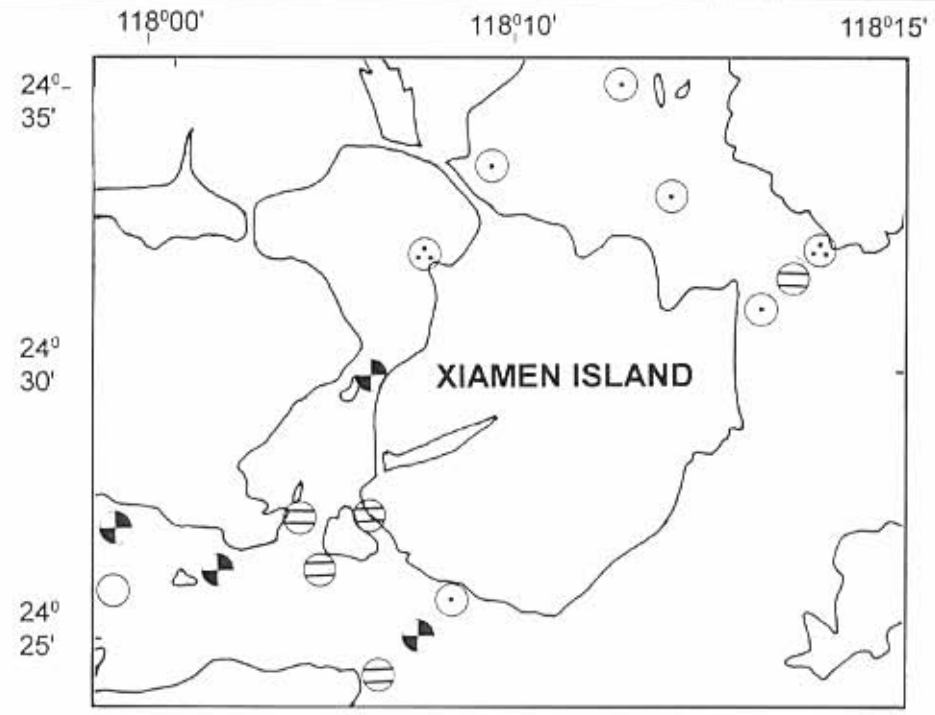


Figure 1.19. Monthly variation of phytoplankton

Note: *It is shown here that phytoplankton activity has distinct temporal variations, with high values from early spring to middle autumn and low values in late autumn and winter. There is not much difference in their concentrations at surface and bottom layers.*

Source: *Zhang Shuijin (1993)*

Figure 1.20. Spatial distribution of zooplankton biomass



Source: *Third Institute of Oceanography, SOA (1988)*

Note: *The annual average values of zooplankton biomass are high at Jiulongjiang River Estuary, where they reached over 500 mg/m³; medium values appeared at the West Harbor with range of about 151-500 mg/m³; and low values at Tong'an Bay with about 75-150 mg/m³.*

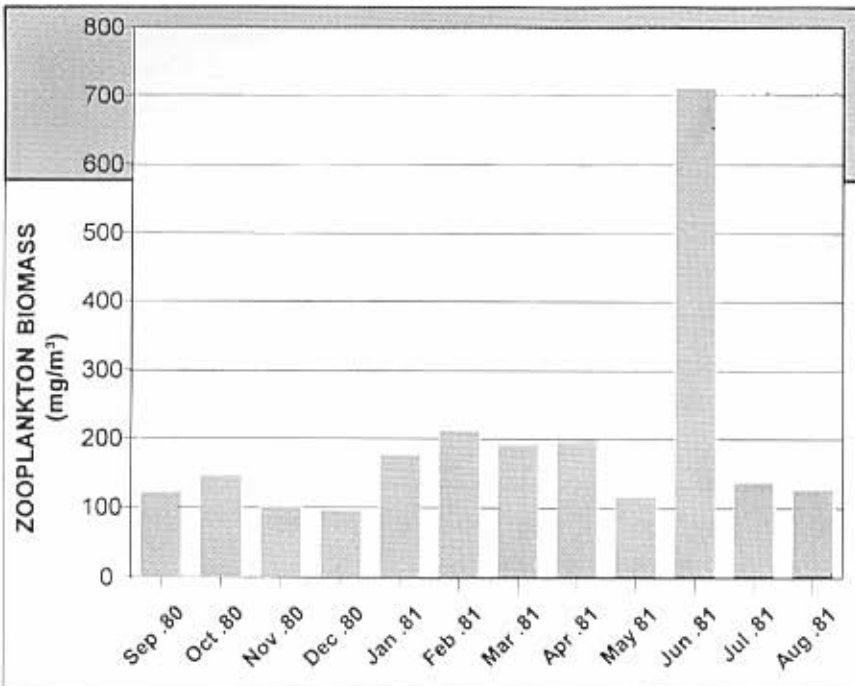
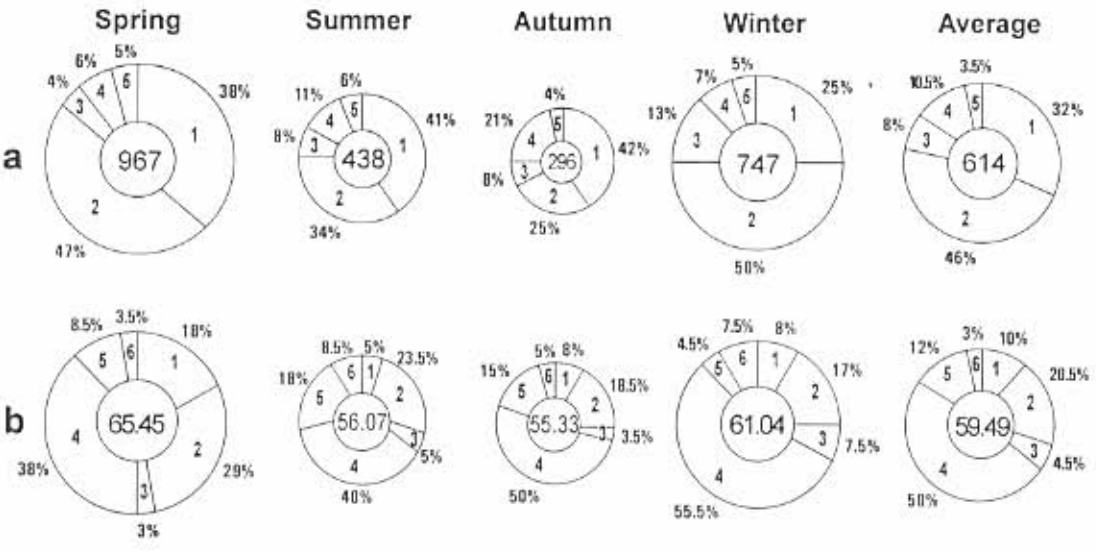


Figure 1.21. Seasonal variation of zooplankton biomass

Note: *Zooplankton biomass shows a larger temporal variation than phytoplankton with a single peak in June.*

Source: *Third Institute of Oceanography, SOA (1988)*

Figure 1.22. Percentage of density (a) and biomass (b) of different benthos



Note: *This figure illustrates the composition of benthos by percentage of different groups. The numbers in the middle cycle of* ***a*** *and* ***b*** *indicate the total density and biomass in ind/m² and g/m², respectively. It can be seen that for density, Mollusca nearly consists about half of the total, while for biomass Echinodermata occupies large portion of the total.*

Source: *Third Institute of Oceanography, SOA (1988)*

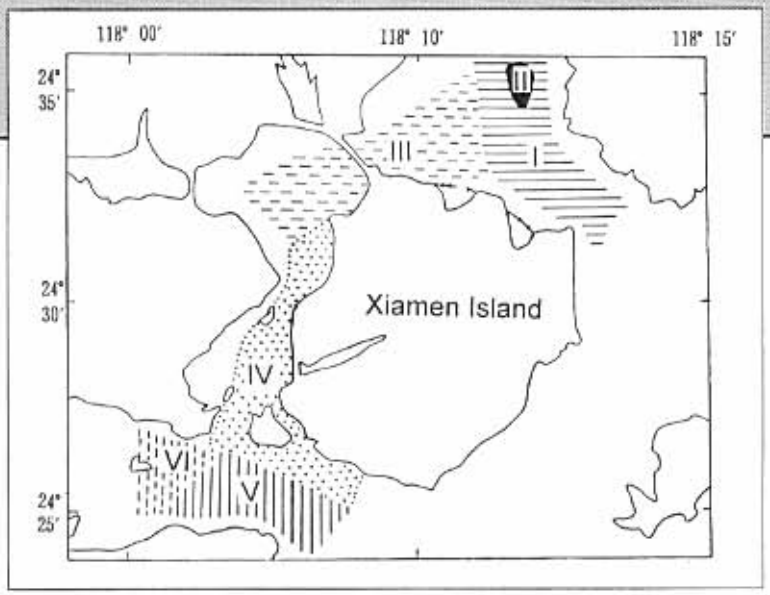


Figure 1.23. Spatial distribution of benthic communities

Source: *Third Institute of Oceanography, SOA (1988)*

Legend:

- ***I*** - *Euniphysa aculeata-Pherudsa plumosa community*
- ***II*** - *Brachiostoma belcheri community*
- ***III*** - *Poecilochaetus paratropicus-Haploscoloplos spp. community*
- ***IV*** - *Saccella cuspolotana-Episiphon kiechowwaanense community*
- ***V*** - *Protankyra bidentata-Eulina maria-Hexapus anfractis community*
- ***VI*** - *Prionospio malmagreni-Prionospio pinnata community*

Figure 1.24. Mangrove distribution in Xiamen

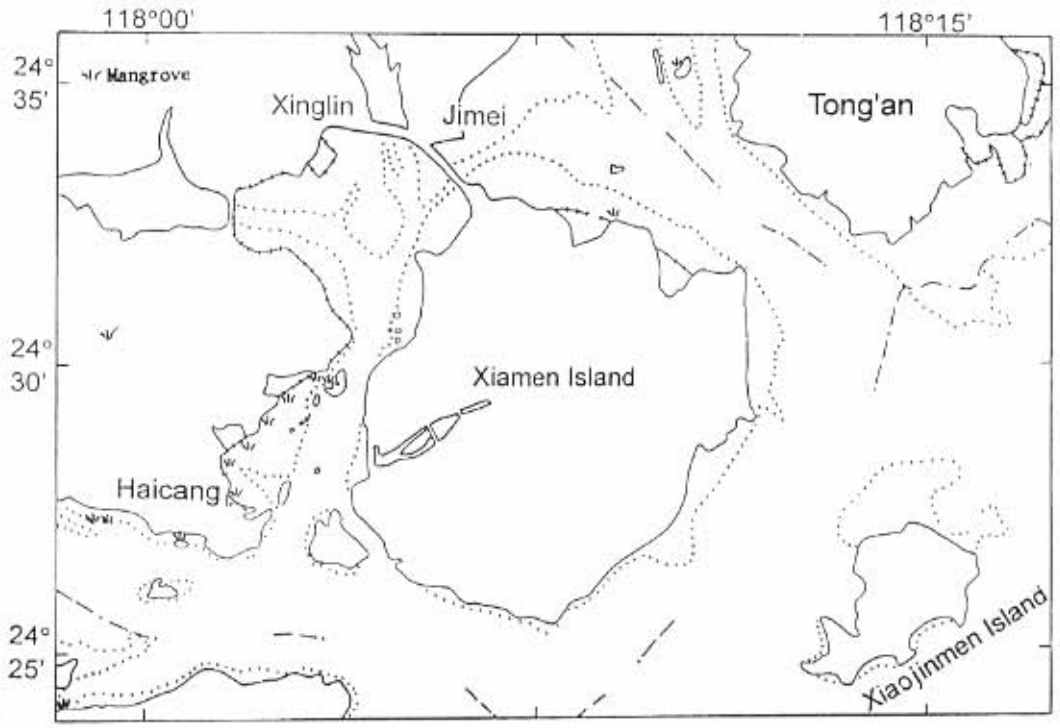
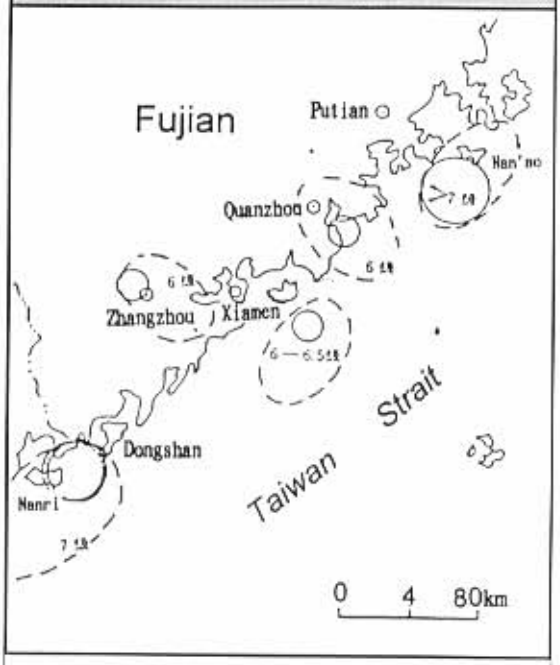


Figure 1.25. Location of seismic activities near Xiamen Municipality



Legend: M = magnitude

M>8.0 8.0>M>7.0 7.0>M>6.0 Potential Source

Source: *Ye Qing (1992)*

a maximum usually at 1.80 m. In addition, the maximum level relative to high tide can reach 1.31 m.

Storm surges are often accompanied by rising tides and waves, exceeding the allowable level and thereby causing seawater flooding. In the past, Xiamen had been hit by such type of flooding notably in 1603 (9 September), 1721, 1917 (26 July) and 1959 (23 August), resulting in heavy losses in terms of lives and properties.

Drought — Rainfall in Xiamen is minimal; while freshwater sources are insufficient. Drought usually occurs in summer when rainfall is at most minimal. The average inter-annual frequency of drought occurrence is 79 percent for summer, 63 percent for spring, and 55 percent each for autumn and winter.

Other weather conditions such as gales and low temperatures may also bring some adverse impacts on the economy and society as a whole. While rains are a boon to agriculture, they also help aggravate marine pollution as heavy rains can carry a large amount of pollutants from urban surroundings via canals or sewers directly to coastal waters.

Beach Erosion — Coastal erosion in Xiamen is also a major cause for concern. About half of its shorelines have been eroded or receded at different rates.

An example of serious erosion has occurred at the cliff shore section of the north and northeast coasts of Xiamen Island, corresponding to a length of around 19 km from Gaoqi to Hechuo. This section has been under constant pressure from strong northeast winds and waves.

Also, a 3-km long coast from Yinchuo to Aoguan (west of the West Harbor) and a 2-km long shoreline (west of Tong'an Bay) have been seriously eroded. The erosion rates of these shorelines range from 1 to 2 m per year and can reach 2-3 m per year in some places, e.g., the Tapu-Huangchuo span in Xiamen Island.

Another example of major erosion occurred on the sandy shores in the east and southeast coasts of Xiamen Island and affected a 16-km long shoreline stretching from Hechuo to Xiamen University. But the most visible proof of coastal erosion appears on the shores of Zenchuo'an and at the seaside resort of Xiamen University. From June 1991 to July 1992, the beaches of Xiamen University were eroded at 32.5-63.1 cm. The high and medium tidal beaches of Zengchuo'an were eroded by an average of 50 cm. Aside from wave action, other major causes of erosion in Xiamen shores are sand quarrying and poorly planned construction projects *(see Figure 1.27)*.

Coastal erosion has caused damages on infrastructure (e.g., roads, causeway, bridges, underwater cables and houses), large-scale soil and field erosions, accelerated port siltation, farm land flooding and the reduction of environmental integrity.

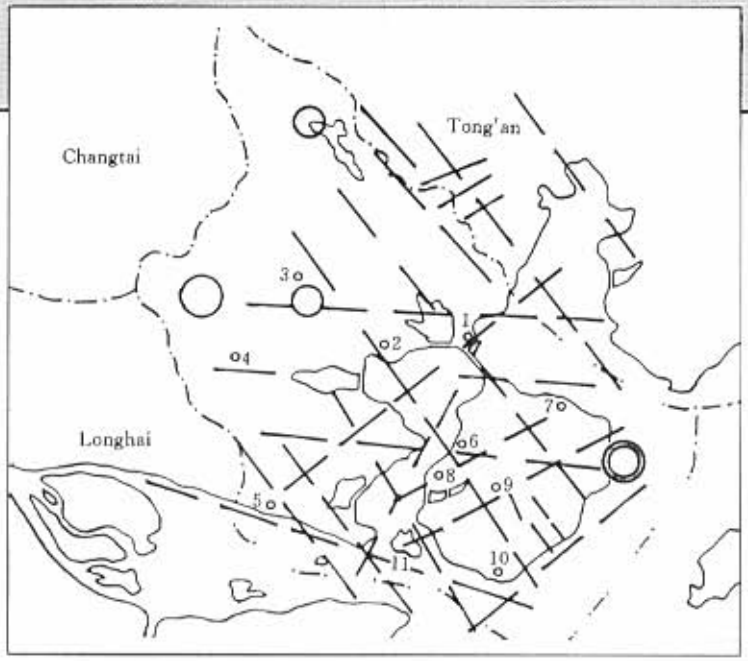


Figure 1.26. Map of fault systems in Xiamen

Fault

Seismic Magnitude

$3.0 \leq M$ $2.0 \leq M < 3.0$

Legend:

1. *Jimei*
2. *Xinglin*
3. *Guankou*
4. *Dongfu*
5. *Haicang*
6. *Huli*
7. *Zhongzhai*
8. *Dongdu*
9. *Lianban*
10. *Zengcuo'an*

Source: *Ye Qing (1992)*

Figure 1.27. Occurrence of coastal erosion in Xiamen

Legend:

1 *bed rockcape*
2 *lateral platform*
3 *sandy plain*
4 *river mouth*

Chapter 2:

Marine Natural Resources and Their Development

Xiamen marine environment and resources can be classified into several types. These are based on their economic uses and purposes as largely dictated upon by their individual characteristics. *Table 2.1* shows their basic characteristics and status of development.

Marine Biological Resources and Their Development

Being rich in fish and other aquatic resources, fishing and mariculture are the two major sources of income in Xiamen's coastal areas *(see Figure 2.1)*.

In the 1980s, marine fish production grew steadily. In fact, the 20,388-ton fish production in 1981 was doubled to 41,193 tons in 1989. In the early 1990s, however, it temporarily declined to about 40,000 tons per year. In 1993, it bounced back to a high of 42,229 tons as the combined production of 10,531 fisherfolk and workers using 2,663 fishing boats.

The breakdown for the total number of fishing boats used in 1993 is as follows: 27 enclosure net boats, 162 angling net boats, 262 trawlers, 784 set net boats, 1,172 drift net boats and 486 paddle-driven boats (lesser compared to the 779 in 1990). In general, marine fishing and mariculture production show an increasing trend *(see Table 2.1)*.

The improvement in the number of fish storage facilities was minimal. In 1993, only one storage facility was added to the 21 already existing in 1992 with 1,101 total workers but the resulting total number of workers was less at 1,093.

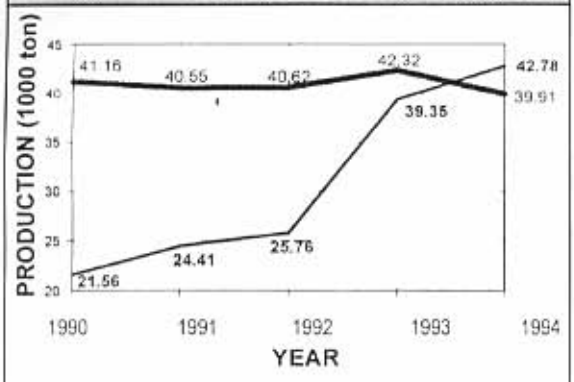
Fish processing, on the other hand, experienced a significant improvement. In 1993, another processing plant with 103 workers capable of producing 1,438 tons of processed fish products was established adding to the two processing plants with 553 workers and 5,265-ton production built in 1992. For aquaculture, the production of feeds for fish greatly decreased from 20,000 tons in 1990 to only 251 tons in 1993.

Table 2.1. Summary of Xiamen's marine natural resources

Type	Basic characteristics/use	Development status
Harbor	27.4 km shoreline, deep water, over 40 berths of 10,000-50,000 tonnage; 72 km shoreline, medium-shallow water, over 30 middle-small berths; total handing capacity can be 5-8 million tons	handling capacity of 11.4 million tons in 1994
Tourism	10 types, 26 subtypes, 79 spots including seaside, famous mountain, historical spots	5.5 million tourists in 1992
Area	798 km² coastal zone, 137 km² tidal flat	
Marine resources	432 economic species, 127 km² tidal flat and shallow waters for mariculture	mariculture occupied 75 km² in 1992
Brine	salt pond of 0.257 million areas	0.12 million tons salt produced in 1992
Tidal energy	potential capacity of 1.1 million kw	untap
Seawater	as coolant, sanitary use	not planned

Source: *Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)*

Figure 2.1. Marine fishing and mariculture in 1990-1994



Source: *Xiamen Statistics Yearbooks, 1991-1994.*

Fish for consumption and processing are caught mainly from Xiamen's offshore waters. In 1986, fishing activities within the XDS coastal waters provided 1,300 tons of marine products and 10 tons of eel fry. The major fish catch consists of juveniles and fingerlings in winter and spring, and small trash fish, shrimps and cephalopods in summer and autumn. Fishing relies largely on set net, drifting gill net and post net methods as angling is being less resorted to.

Mariculture development gained its momentum from the late 1980s toward the early 1990s. As a result of increased attention given to mariculture as a viable economic activity, production increased from 1988 to 1992 by about threefold *(see Tables 2.2 and 2.3)*. However, *Tables 2.2 and 2.3* show that while mariculture areas expanded rapidly, production did not increase proportionally. Mariculture already covered about 60 percent of the designated culture areas *(see Figures 2.2 and 2.3)*.

In addition to harvesting fresh marine products for food, pharmaceutical and health products derived from marine sources have also been explored and developed. For example, pharmaceutical products derived from China horseerab have been produced and marketed.

Figure 2.2. Distribution of mariculture areas in West Harbor

Source: *Center of Environmental Science Study (1994)*

Table 2.2. Status of mariculture in Xiamen Municipality

Location	Tidal areas (mu*)				Labor force in mariculture				Production status		
	Total	Total area suitable for mariculture	Extent of use		Specialized	Others	Total	% of population	Output ton/a	Output ton/a/person	Ratio of mariculture to fishing
			area	%							
Xiamen Island					150	1,670	1,820	0.5	2,669	1.47	
Xinglin	271,665	59,852	40,169	67.1	879	1,772	2,651	4.6	4,926	1.73	
Jimei					464	1,169	1,633	1.1	3,212	1.97	0.602
Tong'an	214,883	129,704	65,590	50.9	7,923	10,020	17,943	3.6	13,605	0.76	

Legend: * 15 mu = 1 hectare
Note: *Data for Xiamen Island include Gulangyu.*
Source: *Center of Environmental Science Study (1992)*

Table 2.3. Mariculture production in 1988-1992

Species		1988			1989			1990			1991			1992		
		Area	p	kg/u	Area	p	kg/u	Area	p	kg/u	Area	p	kg/u	Area	p	kg/u
Shellfish	r	155	108	98.2	2,190	2,105	984	2,585	2,600	1,046	2,620	2,627	1,003	4,055	3,289	811
	rp	6,335	3,290	755	555	4,576	973	5,605	5,183	1,025	6,295	6,024	1,029	7,508	6,640	884
	b	20	10	500	300	290	1,000	320	290	906	320	290	906	250	200	800
	o	17,670	2,649	150	55,709	8,449	158	56,371	9,187	165	60,198	95,006	158	60,633	9,211	152
	m				120	120	1,000	150	165	1,100	380	470	1,238	540	1,510	2,790
	f										2,000	367	184			
	m							17	567							
a	s			5	5	1,000	5	10	2,000	10	10	1,000	110	165	1,550	
	l	80	13	163	5,320	636	120	5,470	682	125	6,120	814	133	9,000	1,208	134
Fish		1,477	62	42	1,228	104	87	1,275	98	77	1,445	100	69	1,596	161	101
Soya		70	60	1045	155	63	417	168	63	377	204	98	492	699	157	224
Prawn		9,547	971	102	25,970	3,317	128	25,385	3,262	129	26,167	4,112	157			
Total		35,314	7,162		96,552	19,770		97,364	21,557		105,759	24,412		113,571	25,862	

Legend: *r* = *razor clam*; *rp* = *Ruditapes philippinarum*; *b* = *blood clam*; *o* = *oyster*; *m* = *mussel*; *kg/u* = *kilogram per unit*; *f* = *fan shell*; *a* = *algae*; *s* = *sea tangle*; *l* = *laver*; *p* = *production (kg)*

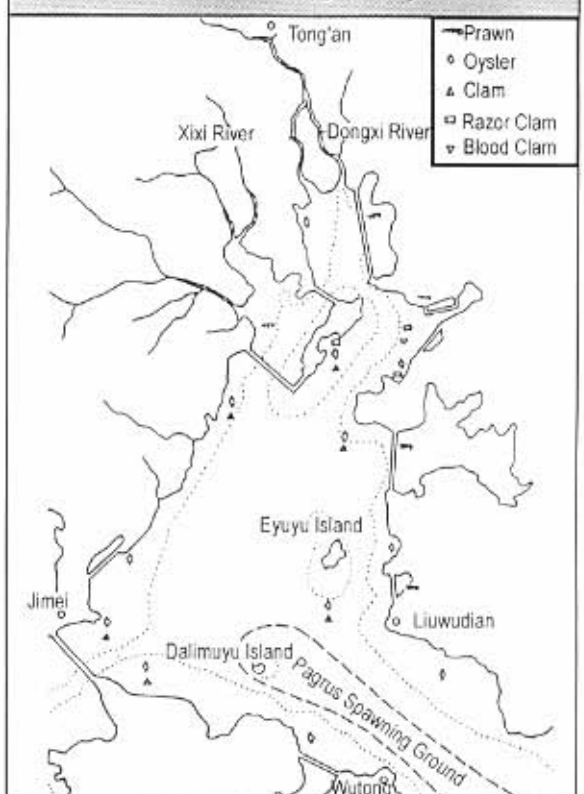
Fish includes rock, cod, perch and red porgy which are raised mainly in cage net.

Source: *Center of Environmental Science Study, Xiamen University et al. (1992).*

As marine biological resources provide numerous opportunities for viable economic activities, there are, however, some problems in their development and management as noted in the following:

1. Conflicts on resource-use and competition for space among mariculture, port construction, maritime transportation and beach reclamation.
2. In the 1980s, a sharp increase in seafood prices and the free use of coastal waters provided the impetus for large-scale mariculture activities. In turn, mariculture stimulated not only areal expansion but also the development of new farming species and methods, such as oyster farming using stone stack and suspended feeding in shallow waters and large-scale caged-fish farming. However, these efforts did not significantly increase production but even lowered it. In addition, a large number of marine areas were occupied during the height of mariculture boom but were eventually left idle when production began to decline. Some made good profits from mariculture without considering its social and ecological impacts.

Figure 2.3. Distribution of mariculture areas in Tong'an Bay



Source: *Center of Environmental Science Study et al. (1992)*

3. Pollution degrades the quality of water and sediments for mariculture resulting in the reduction of production and quality of mariculture products. For example, the massive pen shellfish kill in Gaodie sea farm and the 80 percent oyster mortality around Baozhuyu Island have been attributed to marine pollution. The pollutant concentration in biota and the environmental quality of mariculture waters are shown in *Tables 2.4* and *2.5*.
4. The use of destructive fishing gear types and methods, such as electricity and explosives, to increase catch resulted in declining fish population.
5. Pollution due to wastewater from mariculture hampers its own development.

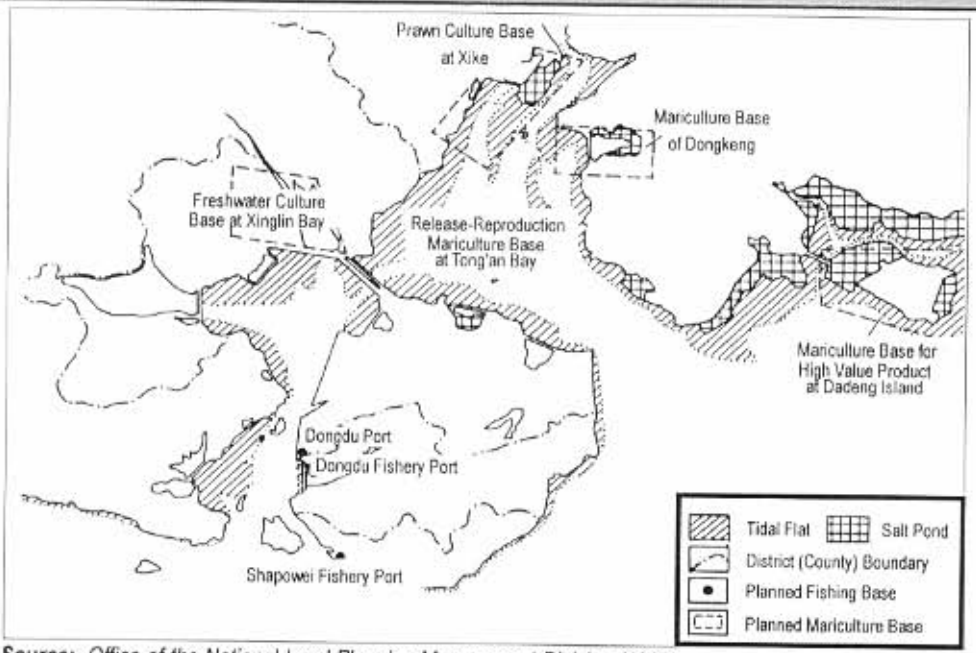
The Planning and Zonation of Fisheries Development — In order to develop sustainable marine biological resources in Xiamen, a zone plan was formulated to manage fisheries and mariculture development in the region *(see Figure 2.4)*. The plan aims to identify areas for specific types of fisheries development: freshwater aquaculture in Xinglin, shrimp mariculture in Xike and Dongken, high-value sea production in Dadeng Island, and experimental mariculture techniques on reproduction and sea farming in Tong'an Bay.

Port Resources and Their Development

In Xiamen, deep harbors and navigational channels are important resources for port development. Deep harbors, on the one hand, are located mainly in the coasts west of Xiamen Island proper; near Paitou, Dayu Island; and from Songyu to Qianyu Island. Deep channels, on the other hand, are located in waters, where current velocity is high, between Xiamen and Gulangyu; Sonyu and Gulangyu; Huoshaoyu and Paitopu; and Jiyu and Qianyu *(see Table 2.6)*.

Development Status and Problems — Port construction and development began in the 1980s. The first phase of the Dongdu port project was finished in 1984; the second phase in 1994. Since then port handling capacity has doubled *(see Table 2.7 and Figure 2.5)*. The number of berths has been

Figure 2.4. Pattern of fishery development



Source: *Office of the National Land Planning Management Division (1993)*

Table 2.4. Pollutant concentration (parts per million) of intertidal benthos in Xiamen

Area	Species	Item	Copper	Lead	Cadmium	Zinc	Total Mercury	666	DDT
West Harbor	oyster	range	17.3-111.0	0.183-0.726	0.407-0.878	13.6-80.7	0.0090-0.0148	0.00095-0.00122	0.0093-0.0245
		ave.	74.9	0.326	0.584	64.4	0.0667	0.00108	0.0169
	rp	range	1.13-7.12	0.165-0.186	0.066-0.085	10.3-14.7	0.0101-0.0150	0.00051-0.00127	0.0036-0.0484
		ave.	3.20	0.174	0.075	13.0	0.0119	0.00089	0.0042
	razor clam	range	3.61	0.186	0.069	15.5	0.0150	0.22214	0.0110
	d.w.	range	41.2	0.363	0.093	29.4	0.0340	ND	ND
Tong'an Bay	oyster	range	6.6-25.6	0.072-0.159	0.401-0.659	14.9-54.1	0.0280-0.0470	0.00039-0.00138	0.0026-0.0322
		ave.	13.1	0.120	0.579	30.5	0.0390	0.00088	0.0158
Gulangyu	oyster	range	2.6-57.0	0.191-0.295	0.561-0.879	53.5-743.0	0.0121-0.0402	0.00100-0.00742	0.0344-0.4480
		ave.	37.4	0.226	0.777	329.0	0.0236	0.00234	0.1600
Dadeng Island	oyster	range	11.9-30.7	0.140-0.390	0.256-0.657	8.8-154.0	0.0088-0.0447	0.00070-0.00108	0.0130-0.0838
		ave.	16.5	0.240	0.455	93.8	0.0272	0.00089	0.0378
	snail	range	4.8-106.0	0.139-0.648	0.051-1.070	13.7-50.8	0.0109-0.0509	0.00032-0.00524	0.0236-0.0335
		ave.	30.3	0.320	0.371	32.0	0.0288	0.00169	0.0267
Standard (mollusk)*			100	10	5.5	250	0.3	2.0	0.2

Legend: *rp* = *Ruditapes philippinarum; d.w.* = *dog whelk*
* = *The standards are defined as those in the Concise Specifications for National Comprehensive Investigation of Sea Island Resources.*
ND = *not determined*

Note: *The average concentration in the table indicates that zinc content in oyster and snail samples from the West Harbor and Dadeng Island exceeded the standard. Concentration of pesticides were very low since their production and use have stopped, the results were the residues from their historical application.*

Source: *Center of Environmental Science Study (1992)*

Table 2.5. Assessment of environmental quality for mariculture

	Water quality			Sediment quality			Biota (oyster)			EQI	Composite assessment
	A		q	A		q	A		q		
	COD	IP		OM	Cu		Cu	OCP			
W.H.	0.40	1.40	0.90	0.59	0.76	0.68	0.75	0.09	0.42	0.65	fairly clean
T.B.	0.28	1.20	0.74	0.35	0.54	0.45	0.13	0.08	0.11	0.45	clean
G.I.	0.32	0.73	0.53	0.55	0.81	0.68	0.37	0.81	0.59	0.62	fairly clean
D.I.	0.40	0.73	0.57	0.24	0.44	0.34	0.17	0.19	0.18	0.30	clean

Legend:

A = *ratio of observed data to standard*
q = *quality index of water, sediment, biota*
COD = *chemical oxygen demand*
IP = *inorganic phosphate*
OM = *organic matter*
Cu = *copper in sediment and biota*
W.H. = *West Harbor*
T.B. = *Tong'an Bay*
G.I. = *Gulangyu Island*
D.I. = *Dadeng Island*
EQI = *index of environmental quality*
OCP = *organochloro pesticides in biota*

increased to 66 to handle the yearly increase in the volume of passengers and goods.

Some problems and issues on port development exist including:

1. The insufficient flushing of deep navigational channels is due to the reduction of seawater influx by about a magnitude of $1.2 \times 10^8 m^3$. This was the result of reclamation projects and the construction of causeways and jetties. The increase in sand input into the coastal waters was brought about by soil erosion and improper approach in construction in coastal areas. Hence, some anchorage grounds and navigational channels have become silted *(see Figure 2.6)* creating shallow sections with a depth of less than 8 m and are obstacles to navigation;
2. The development of mariculture and the use of small set net in the West Harbor were not guided by scientific planning. For example, some mariculture areas are very near navigational channels, posing problems on navigation and safety; and
3. Wastes discharged from berths and vessels pollute the waters of West Harbor. Oil slicks and floating rubbish are often observed on water surface.

Port Development Plan — At present, major port construction includes the third phase of the Dongdu port project, special berths at Songyu and Haicang, and medium-small berths at Tong'an. There is a plan to build additional 14 berths with a handling capacity of 15 million tons, enabling the total handling

Table 2.6. Distribution of deepwater harbors in Xiamen shoreline

Location of deepwater harbors			Shoreline length (km)
Xiamen	Xiamen Island	Dungshang	1.4
		Wutong	5.0
		Shihushan - south fishing port	6.0
		Xiamen Is. side facing Lujiang	3.0
	Jimei Xinglin	west to Xiangbishan - Neikeng	4.0
		north to Xiangbishan	0.3
		Songyu - Dayu	1.0
		north of Shuitou - north to Paitou	0.6
	Islands	north of Dayu	0.6
	Tong'an	Liuwudian	0.5
Longhai	Gangwei Village	Dashikeng	1.6
		Yuziwei	2.7
Total			**26.7**

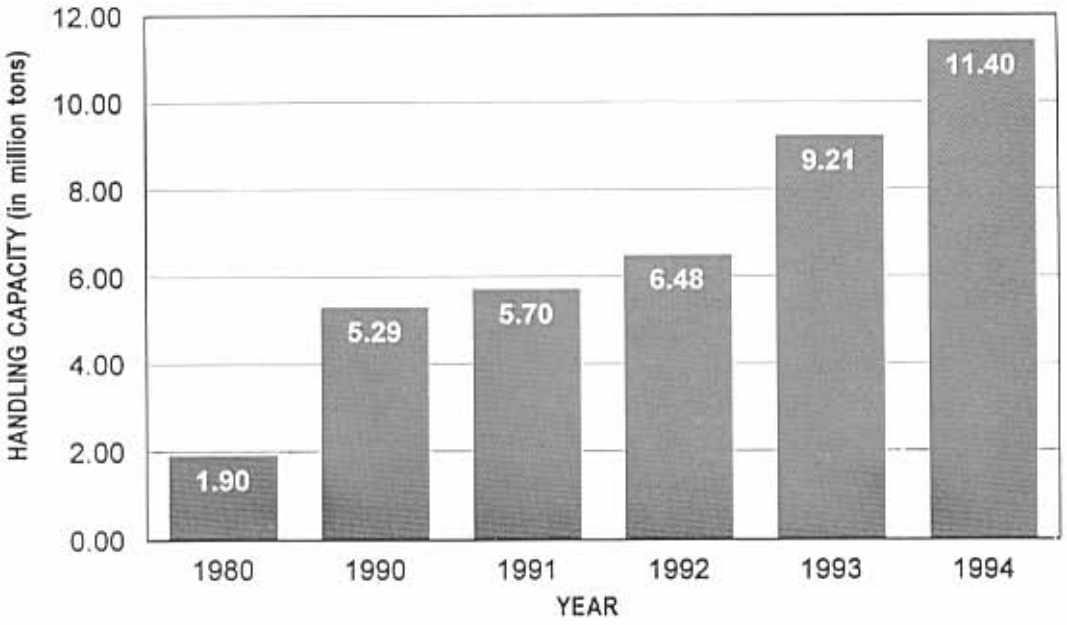
Note: *For convenience, shoreline at Gangwei village is listed here; refer to Table 3.5.*
Source: *Office of the National Land Planning Management Division (1993)*

Table 2.7. Transport of passengers and goods in Xiamen Port for the past 40 years

	Passengers (10,000)	**Goods** (10,000 tons)
1952	22.1	8.2
1980	110.0	82.7
1989	193.3	210.6
1993	206.7	347.6

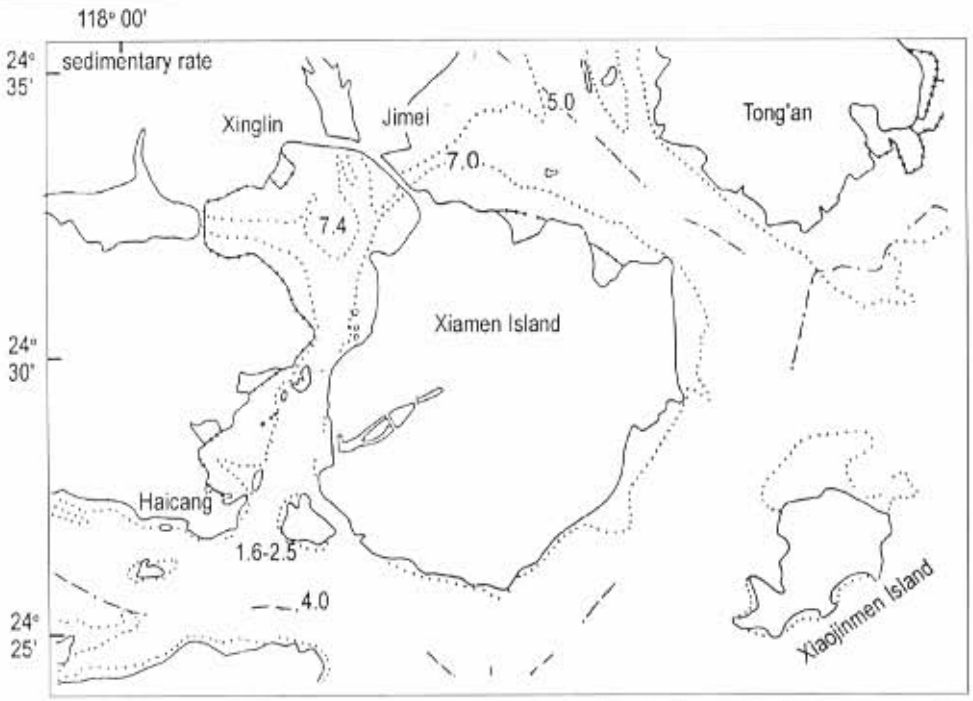
Source: *Statistics Bureau (1994)*

Figure 2.5. Development of handling capacity of the Xiamen Port in 1980-1994



Source: *Xiamen Statistics Yearbooks, 1991-1994.*

Figure 2.6. Areas of siltation in Xiamen coastal waters



Source: *Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)*

capacity to reach 26 million tons by year 2000. The handling capacity will reach 50 million tons by 2010. *Figure 2.7* shows the distribution of port shoreline and berths according to the plan.

Tidal Flat Resources and Their Development

Mud or tidal flats in the region are quite extensive with a total area of 136.77 km^2. *Table 2.8* shows their distribution and areas in relation to other lands of various uses.

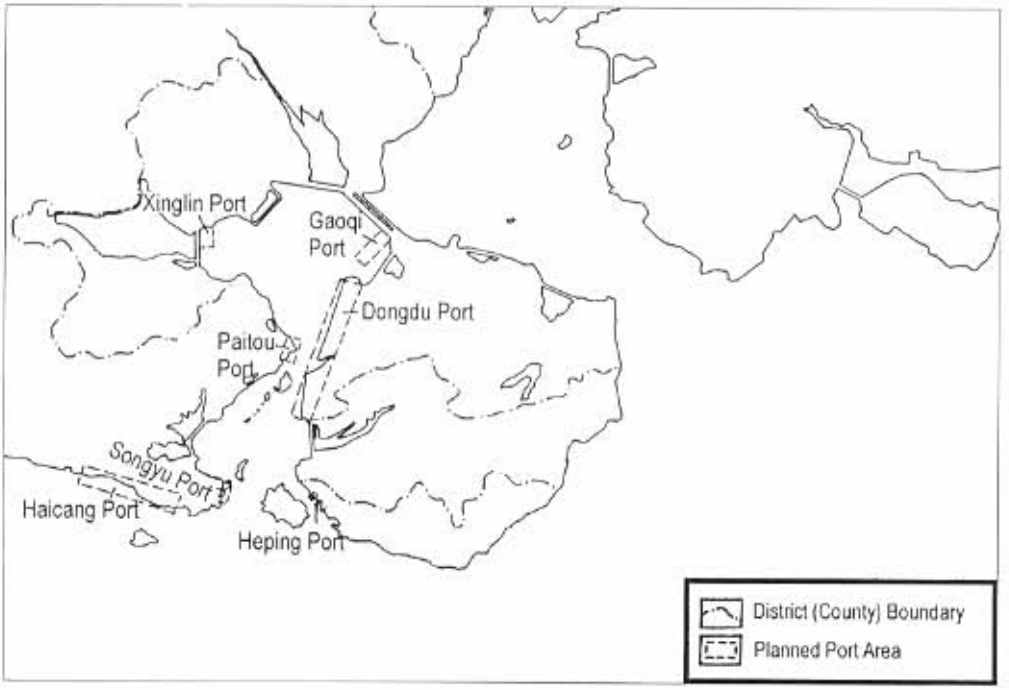
In the region, their distribution is as follows: 15.08 km^2 in Xiamen Island; 98.31 km^2 in Tong'an, Xinglin and Jimei; 24.36 km^2 in Dadeng Island; and only 1.02 km^2 in Gulangyu Island.

In West Harbor, tidal flats are mainly distributed in its northern coast and in the coast of Haicang. They are also found in the southwest, west, north and northeast coasts of Tong'an Bay.

The north coast of Xiamen Island is characterized mainly by mud flats, but with some minor sandy beaches of about 8.8 km long within an area of 6.6 km^2. In the west, the beach is also a mud flat, extending to about 11.5 km long with an area of 4.3 km^2, where the port areas (from Shihushan to Pier No. 1) are located. In Xiamen Island, there are rocky, sandy and muddy beaches with width ranging from 100 to 2,000 m *(see Figure 2.8)*. Other rocky beaches exist southeast of Xiamen Island and east of Gulangyu. Sandy beaches are located in the south and southeast coasts of Xiamen Island, and in the south and southwest coasts of Gulangyu Island. The coasts from the east to the south of Xiamen Island are mainly sandy and mud-sandy beaches of about 20 km long with an area of 4 km^2. Most of the sandy beaches have become resorts or oyster farms such as the one in Hechuo.

Development Status and Problems — Most of the mud flats in north West Harbor and Tong'an Bay including those in the north of Dondu port area; in the north beach outside of Maluan Causeway; around Paitou and west of Dayu

Figure 2.7. Distribution of ports and berths



Source: *Office of the National Land Planning Management Division (1993)*

Table 2.8. Land use classification in Xiamen Municipality

Areas	Total (km^2)	Farm land	Tidal flat	Forest	Industry	Water	Special	Transport	Garden	Grasses
Whole City	798.58	423.27	136.77	87.30	73.06	47.92	10.35	7.62	5.76	1.53
Urban	476.35	230.12	65.28	71.53	43.46	44.95	9.52	7.17	2.79	1.53
Tong'an County	322.23	198.15	71.49	15.77	29.60	2.97	0.83	0.45	2.97	-

Source: *Office of the National Land Planning Management Division (1993)*

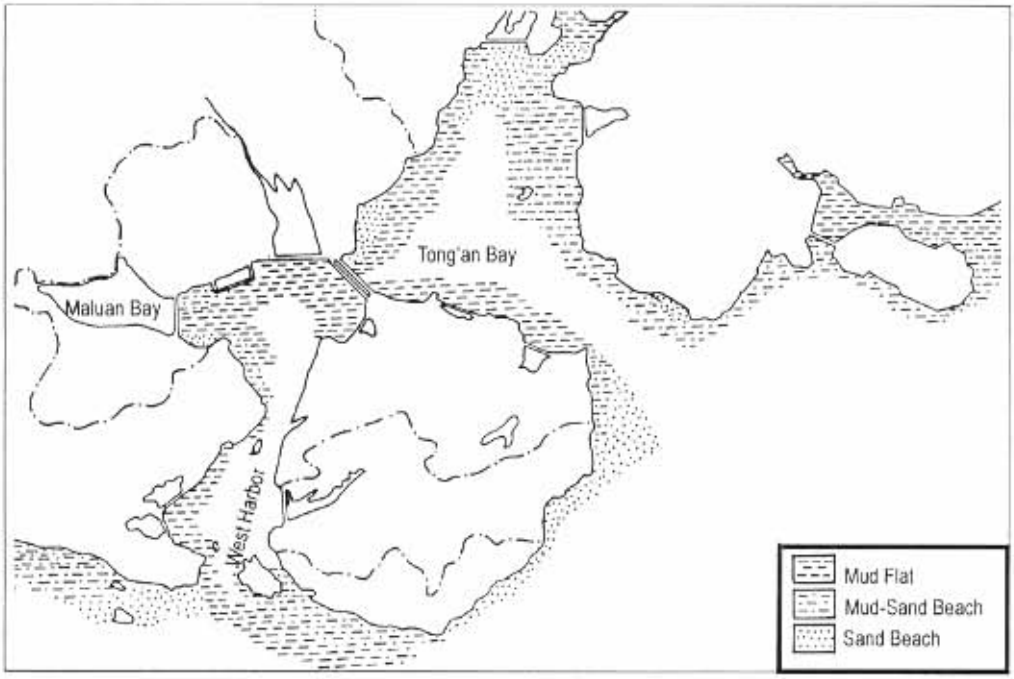
Island; and in the north of Songyu pier area have been used for mariculture. Conflicts on coastal land use exist among port construction, mariculture and coastal engineering projects. Some conflicting activities (e.g., land development and reclamation of beaches in West Harbor) have resulted into hydrologic changes, marine pollution and disruptions in the ecosystem *(see Figure 2.9)*.

Freshwater Resources and Their Development

Freshwater resources and supply in Xiamen Municipality are not abundant, coming mainly from the waters of Jiulongjiang River. Underground water is hardly suitable for drinking and for other related purposes due to its high salinity.

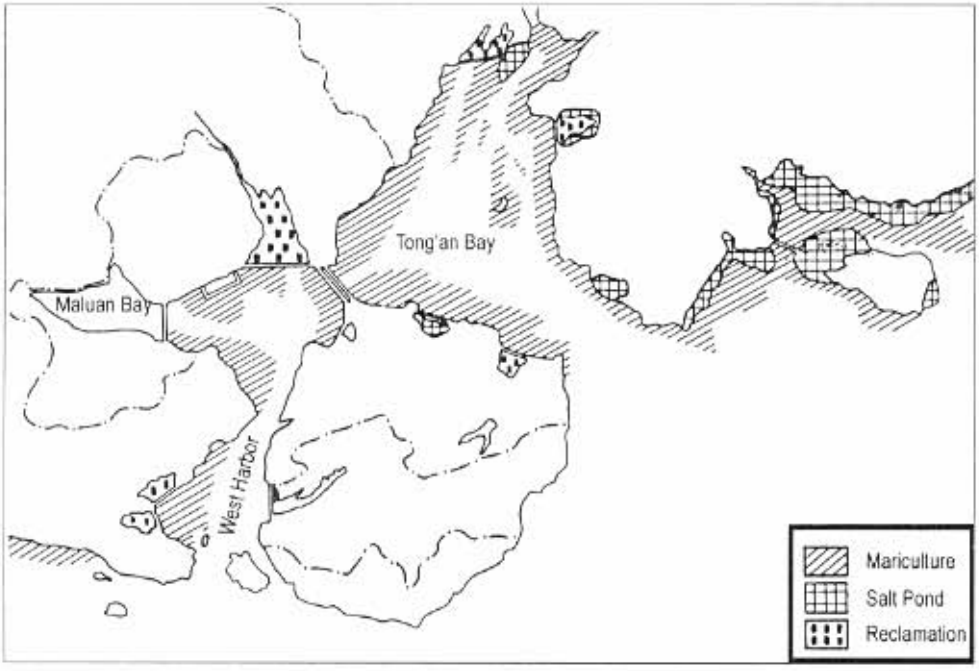
In Xiamen City, the average annual runoff is 12.35 x $10^8 m^3$; the average runoff per capita is 1,200 m^3, an average that is lower than the national and provincial averages, and even lesser than the world's average of 12,900 m^3 in 1977. Freshwater resources in Xiamen Island proper are scarce with an average runoff of 0.79 x $10^8 m^3$. Hence, a large part of freshwater supply comes from Jiulongjiang River, which supplies about 3.75 x $10^8 m^3$ per annum, as well as from other sources outside the municipality.

Figure 2.8. Distribution of different tidal flats in Xiamen



Source: *Center of Environmental Science Study (1992)*

Figure 2.9. Status of tidal flat uses in Xiamen



Source: Center of Environmental Science Study (1992)

Tourism Resources and Their Development

Tourist attractions in Xiamen, which include the Gulangyu-Wanshisan national park, are ample. The location and distribution of natural sceneries, seaside resorts and artificial attractions are shown in *Tables 2.9, 2.10* and *2.11*, respectively.

Development Status and Problems— In Gulangyu Island, tourism resources have been fully utilized, yet their environmental quality remains good. Its seaside resort are accessible all year-round. Elsewhere, the environmental quality of some beaches has been deteriorating due to the impacts of land-based wastewater discharges, rubbish dumping and oily wastewater discharges from ships, aside from inadequate management. About one-third of the sandy beaches around Xiamen Island proper is affected by microbial contamination and oil pollution.

Development Plan of Tourism Resources— New tourist sites were planned to be located particularly in northeast Tong'an Bay, Xinglin Bay and Huoshaoyu Island in West Harbor *(see Figure 2.10)*.

Table 2.9. Natural sceneries and tourist attractions in Xiamen

Type	Subtype	Location
Island	1. national level mountain	Wanshiyan, Sunrock
Hill	2. city level mountain	Hongjishan, Wulaofeng, Yupingshan, Hongshan, Huweishan
Island scenic spot	3. sea stacks	southeast of Xiamen Island, Gulangyu, Jiyu
	4. sea caves	southeast of Xiamen Island, Gulangyu, Huoshaoyu, Baozhuyu
	5. sea erosion-arch-bridge	Gulangyu, Jiyu, Eyuyu
	6. sea erosion group	southeast of Xiamen Island, Eyuyu
	7. wind shaking rock	Xianyueshan at Xiamen Island, Huajing Garden
Beach dune	8. sandy beach (swimming)	east coast of Xiamen Island, Gulangyu, Dadeng Island, east coast of Xiamen Island
	9. dune	
Island reef	10. islands	Gulangyu, Huoshaoyu, Jiyu, Baozhuyu, Eyuyu
	11. reefs	east coast of Xiamen Island, south coast of Gulangyu
Channel	12. channel	Xiamen-Gulangyu channel
Bay	13. bay	Xinglin Bay, Yuan Dang Lake, Xiamen Bay, Tong'an Bay
Spring	14. mineral spring	east Longsheshan, southeast Wulaofeng
	15. hot spring	Zhongzhai
Geological site	16. tectonic landscape	Xiamen Island, Gulangyu, Huoshaoyu, Jiyu,
	17. sea eroded landscape	Dadeng Islands, east coast of Xiamen Island
Ecosystem	18. coastal protected forest	east coast of Xiamen Island, Wanshi rock at Xiamen Island, Subtropic Plant Institute
	19. coastal ornamental plants	Gulangyu Plant Introduction, northwest of Dayu, Eyuyu, Jiyu, Dayu, Xiamen Island and Yuan Dang Lake, Xinglin Bay
	20. mangroves	Huoshaoyu
	21. egret	Xiamen Harbor
	22. dolphin	Amphioxus (Eyuyu, Dadeng, Xiaodeng, Huangcuo)
	23. valuable seafood	Mitella (Tuyu)
Lake	lake	Yanwu pool and confederate rose lake (ancient Lagoon), Yuan Dang Lake
Reservoir	reservoir	Shangli, Dongshan, Wanshiyan, Hubian Reservoirs

Source: *Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)*

Table 2.10. Status and impacts of seaside resorts and marine parks in Xiamen

Area		Capacity x 10,000 persons	Status x 10,000 persons	Environmental impacts
Gulangyu		0.4/d, 146/a	>1/d at peak	minimal
Aoyuan park		0.35/d	0.16/d	minimal
Wanshi park		800/a	0.3-0.5/d	deteriorating
Nanputuo		6/d, 580/a	0.3/d, 5.5/d at peak	safety problem
Hulishan barbette		2/d, 73/a	0.1-0.2/d	minimal
Yundingyan		n.d.	dozens of hundred/d	minimal
Qingjiao		n.d.	4/month in 1993	minimal
Seaside	Gulangyu	0.2-0.6/d	n.d.	deteriorating
	Xiamen University	0.2/d	>1/d at swimming season	sand beach erosion, seawater pollution
	Hulishan-Baishi barbette	1/d, 190/a	underdeveloped	high potential impacts

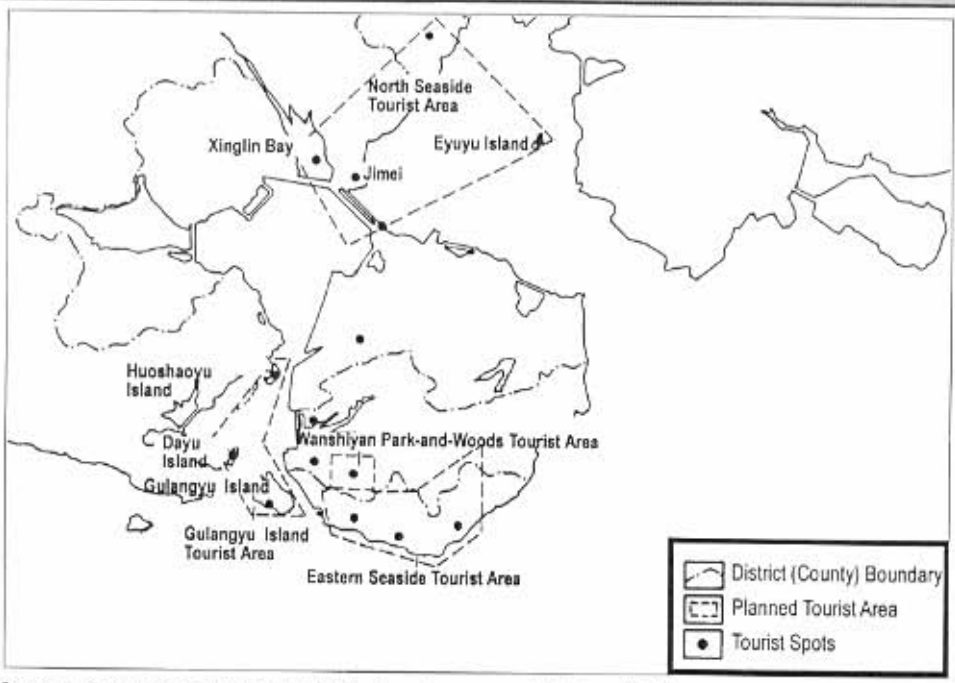
Legend: *n.d. = no data available*
Source: *Center of Environmental Science Study (1994)*

Table 2.11. Historical and artificial tourist sites in Xiamen

Type	Subtype	Location
Archeological ruins	1. neolithic ruins	Xiangyu coast, Shijiantou
	2. museum of mankind	Museum of Mankind of Xiamen University
Historical sites	3. stone tablet, stonecutting	Nanputuo Temple, Wutong ferry, Wanshiyan, Sunlight rock
	4. ancient town/barbette	Hulishan barbette, Baishi barbette
	5. temple, church	Nanputuo Temple, masjid, Xinjie church, Qingjiaochiji Temple
Garden	6. cemetery and park	Cemetery of Xiamen revolutionary martyr, Shuzhuang Garden and Ming Garden at Gulangyu
Cultural sites	7. memorial hall	Museum of Overseas Chinese, Zhengchenggong memorial hall, Luxum memorial hall, Jimei cultural village
Island attractions	8. salt ponds	Zhongzhai at Xiamen Island and Dadeng Island
	9. mariculture sites	north and northeast coast at Xiamen Island and Huoshaoyu, Dadeng, Xiaodeng, Dalimuyu
Sea port	10. modern port	Dongdu port, Heping berth
Sea food	11. fresh seafood	Xiamen Island, Gulangyu
	12. local flavor snacks	Xiamen Island
Tourist shopping	13. carved stone handicrafts	Stone-carving factory
	14. native products	Xiamen carved lacquerware, pearl embroidery sites
Causeway	15. causeway	Gao-Ji causeway, Dadeng causeway
Bridge	16. bridge	Xiamen Bridge

Source: Office of the Steering Group for Comprehensive Investigation of Xiamen Island Resources et al. (1994)

Figure 2.10. Spatial distribution of areas for tourism development



Source: Office of the National Land Planning Management Division (1993)

Chapter 3:

Urban Socioeconomic and Ecological Status

Xiamen evolved from a lowly rural settlement in 980 AD to a modern seaport at the beginning of the 1980s. Since the 17th century, it has already been one of China's international trading port.

Xiamen's economic development gained momentum in the 1980s notwithstanding a parallel rise in its population. In 1992, it ranked 10th among the top 35 cities of China in terms of socioeconomic development.

Its current direction for socioeconomic development is being provided by a plan dubbed as the "Development of the National Economy of Xiamen Municipality in the Next 20 Years."

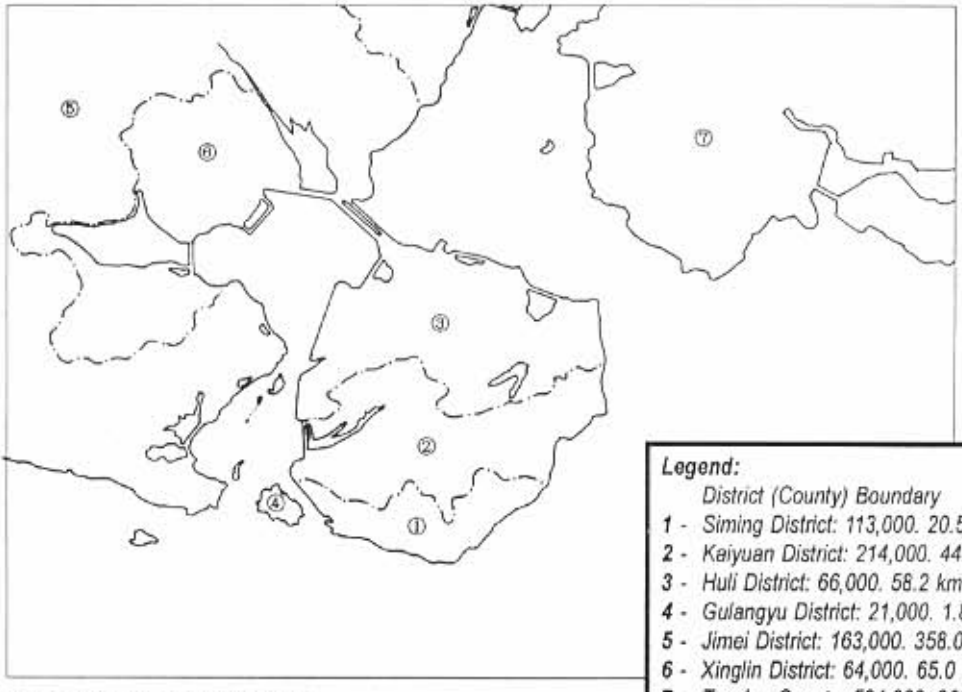
Since sustainable development and socioeconomic growth are crucial in maintaining Xiamen's position as an important seaport—its communities have been actively involved in protecting and managing the marine waters.

Basic Facts on Society and Economy

Demography and Population — There are six districts and one county under the jurisdiction of Xiamen Municipality, namely: Shiming, Kaiyuan, Gulangyu, Huli, Xinglin, and Jimei Districts; and Tong'an County.

The municipality's population reached 1.1749 million at the end of 1993, of which 1.0924 million were permanent residents and 0.40 million were transients or visitors. Many non-Xiamen-born Chinese and their relatives live in Xiamen. On the other hand, a number of Xiamen-born Chinese live in Hong Kong, Macao and Taiwan *(see Figure 3.1)*. In terms

Figure 3.1. Population and land areas of districts and county of Xiamen Municipality



Source: *Statistics Bureau (1993)*

of ethnic distribution, the Hans comprise the majority with 99.9 percent of the total population. There are more than 20 ethnic groups that include the Hui, Man, Zhaung, She and Gaoshan groups among others.

Table 3.1 shows that Xiamen's population remained at some 0.15 million between the middle of the 17th century and 1941. This, however, was doubled to 0.285 million from 1950 to 1980. It increased further to 1.18 million from 1980 to 1993.

It is projected that its population will reach 1.50 and 2.20 million by the years 2000 and 2010 with annual growth rates of 3.71 percent and 3.9 percent, respectively. The average life expectancy is 70 years *(see Figure 3.2)*.

At present, its population density is about 11,700 persons/km^2. According to statistics, the urban area expanded 2.5 times and reached 49.1 km^2 from 1980 to 1993. Residential houses cover 8.48 million m^2, with 8.4 m^2 per capita.

Economic Development — Xiamen has figured prominently in the economic history of China. It has been one of the important cities along the southeast coast of China since the 17th century. It was one of the five ports designated for international trade after the First Opium War.

However, its development slowed down before the founding of the People's Republic of China in 1949. The creation of the Huli Special Economic Zone (SEZ) in 1980 provided the impetus for its rapid economic growth. In 1984, the SEZ was expanded to cover the whole Xiamen and Gulangyu islands. Economic development reached new heights when the Foreign Investment Zones at Haicang, Xinglin and Jimei were set up in 1989-1991.

Urban Infrastructures and Facilities— For Xiamen's water supply, there are five tap water plants with a total capacity of 0.521 million tons per day, a total actual water supply of 0.3254 million tons per day, and a pipe line stretching 636 km long.

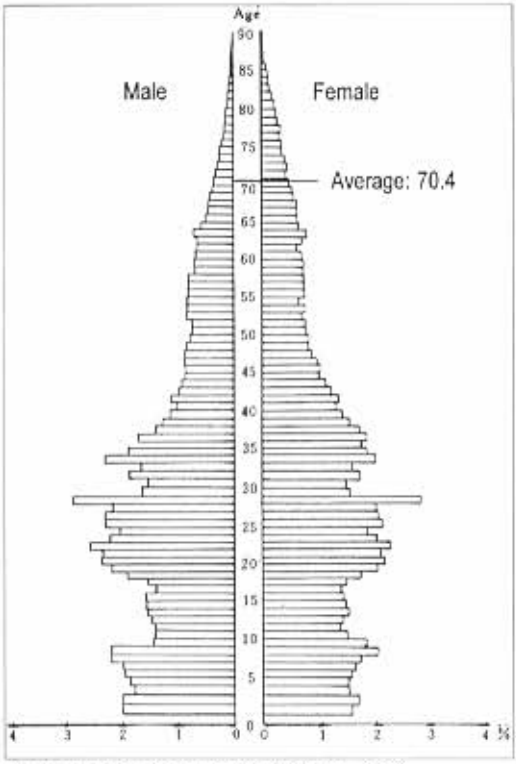
In contrast to the improvements in water supply, electricity supply remains to be improved. Nevertheless, more than 1.6 billion kwh of electricity are consumed annually. Liquid gas supply reaches 17,840 tons annually for the 0.261 million population, contributing to the reduced household

Table 3.1. Historical development of Xiamen Municipality

Epoch	Features	Population	Highlights
980 (Yuan Dynasty)	rural settlement	6,000	under Tong'an County, Quanzhou Prefecture
1394 (early Ming Dynasty)	military base	16,000	construction of Xiamen town to resist Japanese invasion
1516 (middle Ming Dynasty)	small trading town	16,000	as outer harbor of Yue Harbor in Zhangzhou
1650 (end Ming Dynasty)	military port	12,000	Zhengchenggong's base to resist Qing Dynasty and recover Taiwan; for sea defense; with commercial activities
1684 (early Qing Dynasty)	trading port	145,000	start of customs, commercial and trade activities
1842 (end Qing Dynasty)	trade port	145,000	one of the five trade ports; with commercial and trade activities
1936 (R.C.)	commercial port	160,000	prosperous commercial activities
1948 (R.C.)	commercial port	120,000	economic depression times
1950 - 1980 (P.R.C.)	industrial city	130,000	construction of modern industries, urban area expanded from Xiamen Island to Xinglin industrial area and Jimei cultural village
		285,000	
since 1980	special economic zone	480,300	ample development of industry, business, tourism, real estate etc.

Source: Commission of Urban and Rural Reconstruction of Xiamen Municipality, Urban Planning and Management Agency of Xiamen Municipality (1991)

Figure 3.2. Age structure of Xiamen's population in 1990



Source: Data of Population Statistics, 1990.

consumption of coal thereby decreasing the source of sulfur dioxide pollution.

The drainage system remains ineffective. There has been no functional system of drainage pipelines. There is only one sewage plant with a treatment capacity of 61,000 tons per day or 28 million tons per year; while about 50 million tons of industrial and domestic wastewaters are discharged directly into the coastal waters. Only about 42.3 percent of the industrial wastewater are treated before being discharged. In 1993, about 92 million tons of wastewater were discharged.

Communications and transportation occupy important roles in the economic development of China. The telecommunication system has been greatly improved and has reached a total telephone exchange capacity of 0.1678 million units. Direct-dialing connections from Xiamen cover not only more than 400 cities nationwide but also 188 nations and regions abroad.

For land transportation, there are 89,000 motor vehicles plying the 454 km urban roads. However, pollution from automobiles is becoming a major concern. In 1993, railway transportation moved 4.02 million passengers and 6.76 million tons of goods.

For air transportation, about 2.15 million passengers and 33,000 tons of goods were transported in 1994, ranking fourth in the country. There are five regular flights from Xiamen to international destinations such as Manila, Singapore, Jakarta, Penang, Kuala Lumpur and Hong Kong, plus 43 domestic flights.

Water transportation includes oceanic, coastal and riverine navigations. Oceanic transportation covers a number of international destinations such as Bangkok (Thailand); Singapore; Jakarta and Surabaya (Indonesia); Manila (Philippines); Osaka, Nagoya and Hokkaido (Japan); Seoul (Korea); and San Francisco (United States). The coastal and riverine navigations cover the cities and towns along China's coasts and Jiulongjiang River.

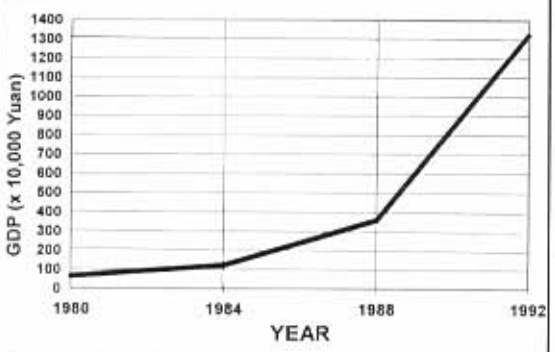
Being one of China's major ports, the handling capacity of the Xiamen port hit 11.4 million tons and 0.225 million TEUs (twenty-foot equivalent units) of containers in 1994.

Travel and tourism facilities have significantly improved with 33 hotels of 4,519 rooms and 9,199 beds, 150 tea houses, and amusement centers. In 1993, around 0.28 million foreign tourists came to Xiamen contributing a revenue of 460 million Yuan; while domestic tourists totaled five million. Xiamen has a scenic national park with an area of 4.05 km^2, of which 2.7 km^2 is open for tourism. Totally, there are 20 parks that comprise a small area of 168 ha.

The number of business establishments and commercial centers have increased. At the end of 1992 alone, there were already 20,000 retail, food and beverage stores.

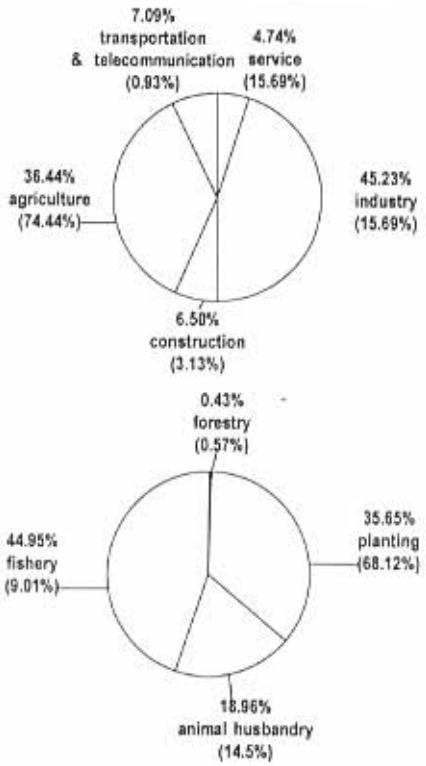
Economic Facts — The period 1980-1993 was an opportune time for Xiamen's rapid economic growth. In 1993, the Gross Domestic Product (GDP) of Xiamen

Figure 3.3. Gross Domestic Product in 1980-1993



Source: China Statistics Press (1994)

Figure 3.4. Production chart of Xiamen's rural areas in 1980 and 1993



Note: *The percentages given in bracket are for 1980; the non-bracketed ones are for 1993.*
Source: *Statistics Bureau (1993)*

Municipality was estimated at 13.2 billion Yuan from a 35 percent increase in 1992 and about eight times higher than that in 1980. *Figure 3.3.* shows the GDP performance from 1980 to 1993.

The sustained development of market economy and the emergence of small enterprises have gradually changed the structure of rural economy. In 1993, the rural GDP of Xiamen Municipality reached 4.298 billion Yuan. From 1980 to 1993, the total rural industrial production increased from 15.69 percent to 45.23 percent; while agricultural production decreased from 74.44 percent to 36.44 percent *(see Figure 3.4)*. During the same period, fisheries production increased from 9.01 percent to 44.95 percent.

The total industrial production at the township level and above reached 17.349 billion Yuan in 1993, of which light industry contributed 12.413 billion Yuan (71.44 percent) and heavy industry, 4.938 billion Yuan (28.45 percent). *Figure 3.5* shows the contribution in production of eight different industries.

Basically, Xiamen is a light-industry municipality. From 1980 to 1993, the annual production of light industries was consistently higher than those of the heavy industries. Agricultural production, which was the lowest, fluctuated with a relatively higher average as against heavy industry's average fluctuation.The latter's production increased from 26 percent in 1980 to 30 percent in 1988 *(see Figure 3.6)*.

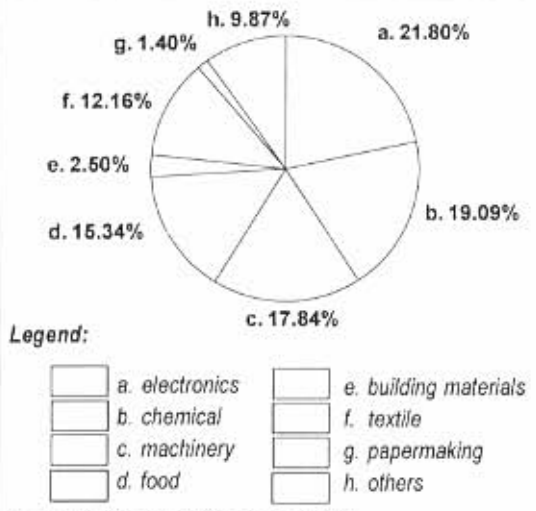
International trade has played an important role in Xiamen's economy. In 1993, the total value of import and export reached US$4.1 billion, ranking fourth among 35 large and medium cities in China. Xiamen's exports represent 75 percent of the total exports in the south Fujian Province.

Socioeconomic Features and Their Development Trends

Socioeconomic Development — From 1980 to 1993, Xiamen's economy grew by an annual rate of more than 20 percent *(see Table 3.2)*.

The rapid economic development of Xiamen Municipality is attributed to its port advantages, hospitable subtropical climate,

Figure 3.5. Percentage shares of eight industrial productions in 1993



Source: China Statistics Press (1994)

natural sceneries and strategic geographical location near the Taiwan Strait. With the establishment of the special economic zone (SEZ) in 1980, Xiamen has built up its industrial base capable of producing electronics, machineries, textiles, chemicals, construction materials and processed food products.

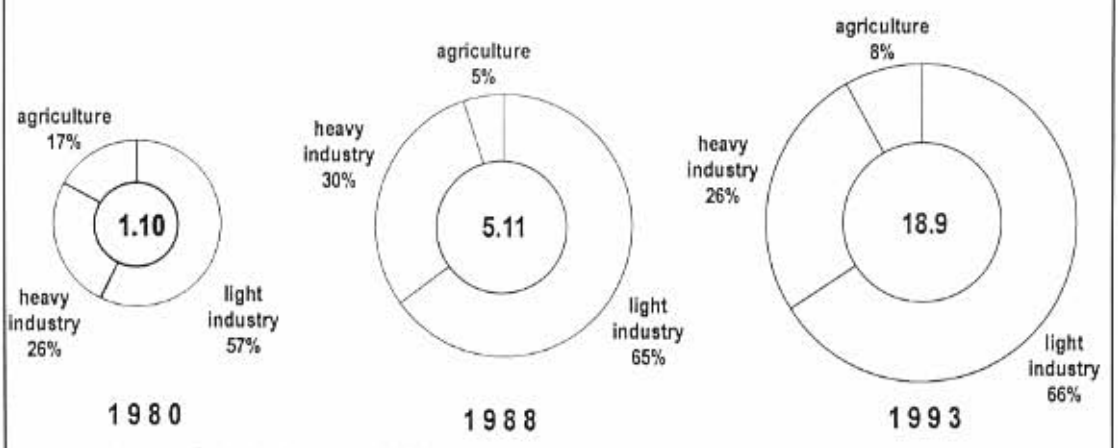
Broad economic and trade connections with more than 100 nations and regions abroad have been established. In Xiamen, there are more than 300 trade offices representing different provinces and cities of the country. Xiamen takes the lead in drawing foreign investments, advanced technologies and facilities, and foreign banks into its shores. It also encourages the establishment of foreign-funded enterprises.

There are more private-owned enterprises than state-owned ones. Since 1989, combined production by foreign-funded enterprises, joint ventures and cooperatives have surpassed that of the state-owned enterprises. In 1993, the gross production of private enterprises represented 62.6 percent of the total industry production at township level or above. Since 1993, the government has approved the applications of 2,290 foreign-funded enterprises but only 1,520 are operating. High productivity in private, state-owned and foreign-funded enterprises is attributed to a committed labor force and flexible management.

Xiamen's rapid economic growth is also attributed to its reliance on science and technology as being pursued through its educational system. The nine-year compulsory education program was enforced in 1994.

There are 17 universities and colleges and 420 institutions for scientific research, technological development and business and trade. Around 15 percent of its residents have received university and college education,

Figure 3.6. Production from agriculture, light and heavy industries since 1980



Source: Xiamen Statistics Yearbook (1992)

Table 3.2. Economic indicators of Xiamen Municipality for 1980 and 1993

	1980 (Yuan RMB)	1993 (Yuan RMB)
Gross value of social products (services)	135,135	1,895,481
Gross industrial products	91,604	1,329,765
Gross agricultural products	19,388	124,981
Gross domestic products	64,000	1,093,609
primary industry	13,834	93,334
secondary industry	37,015	590,942
tertiary industry	13,154	409,333
GDP per capita (Yuan RMB/person)	689	9,406
Number of retail stores	1,252	(1992) 23,517
Investment in fixed assets for the whole society	12,612	644,586
Port handling capacity (10,000 tons)	190	920
Aviation passengers (10,000 persons)	----	155

Source: *Statistics Bureau (1994)*

putting the average educational level of Xiamen residents above the national average.

At present, Xiamen is executing a policy of free port to create better economic environment and attract more investments.

Socioeconomic Trends — Xiamen's socioeconomic development plan has been the basis in making Xiamen a modern city with an international seaport and a scenic environment. For this purpose, planners have adopted an "area-by-area and gradual" development strategy. The West Harbor and its adjacent lands were chosen as the main areas for new development projects doubling Xiamen's area by the end of the 20th century *(see Figure 3.7)*.

A. Direction and Focus of Economic Sectors

The primary sector, i.e. agriculture, focuses on the stabilization of cereal, edible oil and sugar production as the first component; it also aims to increase forestry, livestock, poultry and fisheries production as the second component. The ratio of the first component to the second one was 1:2.13 in 1995 and increasing to 1:2.6 by the year 2000.

The secondary sector, which is represented by manufacturing and construction, is geared towards the creation of superior industries, technical advancement, international market expansion and economic efficiency. This sector focuses on the development and production of machineries, electronics, electrical and petrochemical products, and the strengthening of the construction industry. From 1995 to 2000, total production is expected to increase from a value of 28 to 69 billion Yuan at an average annual rate of 23.2 percent.

The tertiary sector, which is represented by service-oriented establishments, will account for 48 percent of the GDP by year 2000 and a 40 percent share of the total number of people employed in all sectors. Its development focus will be on three aspects. The first aspect concerns infrastructures (e.g., telecommunications, transportation, scientific research, education, public utilities, etc.) which have fundamental impacts on economic development.

The second aspect concerns sectors closely related to economic development and personal affairs and welfare (e.g., business and trade, financing, insurance, tourism, environmental protection, real estate, arts and culture, education, social services, etc.)

The third aspect focuses on new sectors related to the advancement of science and technology, including those directly or indirectly linked with production and livelihood, such as various technical and information services.

Figure 3.7. Overall development plan of Xiamen Municipality

Legend:

1 - Residential land, Class 1
2 - Residential land, Class 2
3 - Land for public facilities
4 - Land for education, culture & science
5 - Industrial land, Class 1
6 - Industrial land, Class 2,3
7 - Land for storage uses
8 - Land for bonded industries
9 - Land for civil facilities
10 - Land for greens and tourism
11 - Land for ecological greens
12 - Land for plant nursery
13 - Land for outward transportation
14 - Land for special uses
15 - Beach-bathing resort

Source: Planning Service of Xiamen City

B. Pattern of Sector Development

In the Xiamen Island proper, an integrated system of scientific research, technical development, test production and marketing will be developed through the construction of the highly technological sector development parks, such as the China Development Institute of Science and Technology in Xiamen and the Xiamen International Commercial Town of Science and Technology. While financing, trading and business activities are being promoted, they will be monitered and regulated to make the island unpolluted, with low-energy consumption, and highly oriented to science and technology.

The Haicang area will concentrate on the production of heavy machineries, petrochemicals, vehicles, metals, chemical fibers and plastics, aside from raw materials.

Urban development and construction will be based on functional zonation and the requirements of a modern urban center as there is a plan to make Haicang a new modern urban area in the 21st century. Development will be accelerated in areas such as the Xingyang Industrial Park, the new Haicang District, the Haicang Farm and the Songyu Area.

Xinglin District will replicate highly technological sectors in Xiamen Island and the large industrial projects in Haicang to improve and expand its production capacity

and product lines. The industrial zones of North Xinglin, South Xinglin, Beitou, Maluan and Zhongya will each become a center of electronics, chemicals, textiles and machineries production based on functional zonation.

Jimei District, which is located between the Special Zone (to be developed later as a free port) and the non-special zone, will take advantage of the interaction of the two zones by focusing on the development of the tertiary sectors such as tourism, retail trade, light industries and arts and culture.

Business development in the new districts of North Jimei, the Dong'an Industry Zone, New Dongfu Zone, Industry Zone of South Guankou and Zhongming Town Industry will be promoted. The construction of the Jimei-Tong'an Road will make the new industrial corridor favorable to the economic development of the suburbs.

For Tong'an County, its main development target is to pursue an export-oriented economy based on well-developed industries, stable agriculture, prosperous tertiary sector and sound ecological condition. It also has a plan to establish a satellite town.

For the county's industrial zones, their specific production targets are as follows: Chengdong Industrial Zone for food processing; the Chengnan Industrial Zone for light industry, manufacturing and machineries; and Pantu and Huangjin for highly technological products. Likewise, pottery and the production of other construction materials will also be given attention in view of the abundance of granite and kaolin.

To generate revenues from tourism and other tertiary services, golf courses, resorts, amusement parks and other recreational facilities will also be developed, particularly, in Pantu, Dingxi and Dadeng Islands.

C. Pattern of Town Development

There are three areas that follow a specific pattern of town development. The first pattern, a one hundred-year modern development plan, covers the downtown areas of Xiamen and Gulangyu Islands. Projects that entail large supplies of water and electricity, vast tracts of land, big volumes of transportation and those with large pollution potential will be strictly regulated. Aside from highly technological projects, other areas of focus are light industries and tertiary sectors such as financing, business, trading, tourism and arts and culture.

The second pattern is concerned with the development of satellite towns at the suburbs, including those along the Xiamen coastal waters such as Liuwudian, Jimei, Xinglin, Maluan and Haicang. Jimei and Xinglin have well-known cultural and scenic spots and are important industrial areas of the Xiamen Municipality. In the plan, an industrial park will be set up in Liuwudian; a light-industry park in Maluan; and a heavy industry base and a transit port in Haicang. Their development plans will also address the issues of population, land use, water supply, electricity, communication systems and environmental protection.

The third pattern covers the small towns in the far suburbs concentrated around Datong of Tong'an County. Aside from supplying agricultural products, the tertiary sector will also be developed. Labor-intensive industries are planned due to the absence of large tracts of land and the presence of a large population *(see Table 3.3)*.

Port Sector

In addition to the discussion in Chapter 2 on port sector and development, further details are given below.

Geographical Advantage — The Xiamen port has a geographical advantage, being prominently and strategically located within the three bustling economic and trade centers.

Firstly, in the Fujian Province, the Xiamen port is located at the Xiamen-Zhangzhou-Quanzhou trade triangle which is the most important port for foreign trade. With the presence of communication

Table 3.3. Basic facts on Xiamen districts

Districts		Urban land (km^2)	Characteristics of the district	Population (10,000)	Development plan
Xiamen Island	west	48.2	city center, administration, resident, business, culture	64.78	in plan
	east	42.5	tourist spot, high-tech, tertiary industrial trade with Taiwan	39.20	long-term
all Xiamen Island		90.8	city center of politics, economy and culture	103.98	
Jimei		8.0 (10.9)	culture, education, tourist spot	7.84 (15.50)	in plan
Xinglin		23.3 (27.7)	industry, transportation center	27.13 (35.0)	in plan
Maluan		41.6 (44.7)	middle-low processing industries, secondary resident	43.78 (52.03)	in plan
Haicang	new town	46.8	resident, upper reach industry	43.78 (52.03)	in plan
	Songyu		power, harbor		
	Paitou		harbor, tourist		
Dongdu		7.4	middle-low reach industry, transportation	11.92	long-term
Guankou		36.3	middle-low reach processing industries, secondary resident	53.45	long-term
Houxi		12.2	transportation, center, resident, industry	20.43	long-term
Gulangyu		1.64	scenic tourist area	1.5	in plan
separate zone		22.2 (29.0)	ecological protection, municipal passage		

Source: *Planning Bureau of Xiamen City*

networks and all means of transportation, Xiamen has become an important hub of commercial, financial and cultural activities in the region. Xiamen port has important links to several areas adjacent to the Xiamen Municipality such as Longyan, Quanzhou, Zhangzhou, Yong'an, Datian, Qingliu and Niuhua; Sanming and Nanping of Fujian Province; the east and south of Jiangxi Province; east of Guangdong Province; and south of Hunan Province, among others.

Secondly, Xiamen is in the middle of Shanghai and Guangzhou, China's two leading trade and economic centers. Shanghai is the center of economic development in the Changjiang River delta as Guangzhou is in the Pearl River delta. Xiamen is 381 nautical miles away from Guangzhou, 564 from Shanghai, 267 from Hongkong and very near Taiwan.

Finally, Xiamen belongs to the dynamic East Asian region, the home of newly-industrialized countries (NICs) or economic tigers such as Taiwan, Singapore, among others. Important trading areas in its northern focus are Japan, Korea and the economic belt around the Bohai Sea of China; in its southern sights are the fast developing Southeast Asian countries, Hongkong and the Pearl River economic zone of China. It is also China's important gateway to the bigger Asia-Pacific economic belt.

A. Handling Capacity

In 1994, the handling capacity of the port reached 11.4 million tons *(see Figure 2.5)* by operating 66 berths that included a 35,000 and a 10,000-tonnage container berths, a 5,000-tonnage berth, a 25,000-tonnage coal berth and four 10,000-tonnage bulk berths. In 1993, the port handled 894 ships with a total tonnage of 124,000 and 1,474 ship visits.

B. Collection and Distribution

The collection and distribution capabilities of the port have been significantly improved by the establishment of important transportation networks in 1994, such as the following: the Yin-Xia railway line with a capacity of 14 million tons; a shipping route that includes the cities along the south,

southeast, North China coast and the Jiulongjiang River; a road network consisting of three state highways and many provincial and county roads; and an air transport network that can handle 33,300 tons of goods and 2.15 million passengers.

C. Warehouses and Stock Yards

In 1990, there were seven warehouses with a total area of 39,915 m^2 which can store 57,904 tons of goods; 19 stock yards with a total area of 244,114 m^2 for 31,445 tons; and three container yards with a total area of 36,600 m^2 good for 1,744 containers *(see Table 3.4)*. Phase II of the Dongdu Port adds 21,014 m^2 for container capacity; 34,236 m^2 for bulky and other goods; 28,692 m^2 for front operations; 3,198 m^2 for front-warehouse operations; 9,345 m^2 for warehouses; 14,066 m^2 for supporting operations; and 32,758 m^2 for coal storage.

D. Port Inspection

Joint inspections of foreign ships using Xiamen port have been carried out by the Maritime Safety Superintendency, the Customs, the Frontier Inspection Station, the Inspection of Import and Export Commodity, the Sanitary Quarantine and the Animal and Plant Quarantine.

Development Trend — To meet the economic development goals through trade, port modernization is being undertaken. The planning phase has given important consideration to such concerns as port development, residential, tourism, beach resort development, sewage discharge and mariculture and salt pond areas *(see Table 3.5 and Figure 3.8)*.

The current port development includes the preparatory works for the Phase III of Dongdu Port and the construction of a 100,000-tonnage petroleum transshipment berth in Songyu and a 50,000-tonnage coal berth in Haicang. In the long-term plan, seven ports with a total handling capacity of 50 million tons will be constructed in seven areas, namely: Heping, Dongdu, Gaoqi, Xinglin, Paitou, Songyu and Haicang (*see Figure 2.7*).

Urban Environmental Quality

In general, the present environmental quality of Xiamen Municipality is good. The air is clean, thus, satisfying Class II requirement of the National Air Environmental Standard.

In terms of water quality, Bantou reservoir is good while Xinglin Bay satisfies Class III of the Surface Water Quality Standards. Coastal waters, except for the inner bays such as Maluan Bay and the northern part of the West Harbor, meet Class II of the National Seawater Quality Standards.

However, noise pollution caused by vehicles and restaurants is getting serious, prompting many complaints from residents. Also, domestic garbage and construction debris are produced in large quantities and have adverse impacts on the environment.

Xiamen's urban environmental quality depends on three factors. One is the presence of environmental laws and programs. The municipal government has already enacted a number of environmental laws and regulations aside from implementing its own environmental programs and projects.

Another factor is Xiamen's geographical location, which gives rise to strong environmental assimilation. The atmospheric dispersion is helpful, except for the inner bays and waters. Oceanographic dynamics, which provide strong current for pollutant dilution and dispersion, are significant in the southern part of the West Harbor, the Outer Harbor, the Eastern Channel and the entrance of Tong'an Bay. However, biological degradation is active due to the year-round high temperature.

Lastly, the industrial structure indicates whether or not there exist serious pollution sources. There are no heavy-pollutive industries, such as those producing metal and petrochemical products.

Table 3.4. Xiamen Port: berths, warehouses and stockyards

Port	Jetty name	Date of operation	Structure	Berths: Forebottom height Design	Berths: Forebottom height Actual	Berths: Capacity	No. of jetties: d	No. of jetties: m	No. of jetties: s	L	Warehouse & yard areas: Ware.	Warehouse & yard areas: Yards	Comprehensive capacity: Cargo	Comprehensive capacity: Passenger	Cargo type
										m	m²	m²	mt	mp	
	total						7	4	29	2,217	39,915	241,114	2.67	0.30	
DD	s-total						4	3		976	17,576	105,266	1.54		
DD-II	35,000 ton container	1994.6		-12.2		35,000	1			303	9,345	21,014	1.00		container
	20,000 ton sundry	1994.6		-10.6 -6.9		40,000	2	1		347 205		34,236	1.00		sundry
	25,000 ton coal	1994.6		-10.2		25,000	1			270		32,758	1.50		coal
Old port	s-total								10	573.3	3,611	4,721	0.55	0.30	
	berth no.1	1966	slope steamer		-2.0	50			1	32					c-p
	berth no.3	1930	gravity quay		+2.0	100			1	25					b-s
	berth no.5	1981	mixed		+2.0	100			2	55			0.10		p-s
	berth no. 6	1940	slope-steamer		+2.0	50			1	5.3					p-s
	Mazhugong	1967*	gravity quay		-2.0	300			1	50			0.10		c-p
	Heping #1	1987*			-7.0	10,000	1			100			0.17	0.10	c-p
	Heping #2	1987*			-7.5	10,000	1			100			0.08	0.20	c-p
Gaoqi	Heping #3	1987*			-9.0	10,000	1			120			0.10		c-p
	Yuhui	1930	gravity quay		-1.0	100			1	75					b-s
	Datong	1950	reinforcement brick long piled		-0.5	50			2	0					coal
	Huangjiadu	1940	slope-steamer		-0.5	50			1	3					b-s
	s-total								10	660		22,590	0.48		
	#1=#2	1970	reinforcement brick jetty		+2.0	100			2	6					coal
	#3=#6	1970	gravity quay		+2.0	100			4	100			0.20		b-s
	#7=#13	1970	gravity quay		+2.0	50			7	135					coal
	#11	1970	gravity quay		+2.0	100			1	40					b-s
	small craft	1988	low-piled		+2.0	+2.0	200			4	150			0.20	p-s
suburb	Jimei	1978	simpel		+3.0	50			1	35					b-s
	Liuwudian	1989	reinforcement brick pile		-4.6	-4.6	1,000		1		114			0.10	p-s

Legend:
DD - *Dongdu Port*; *DDII* - *second phase project of Dongdu Port*
d - *deepwater berth*; *m* - *medium water berth*
s - *small craft pier*; *L* - *length of the jetty*
mt - *million tons*; *mp* - *million passengers*
c-p - *cargos and passengers*; *b-s* - *bulky sundry*
p-s - *package sundry*

Source: *Planning Bureau of Xiamen City*

In general, population density, industrial and agricultural outputs, pollution discharge per unit area, etc. have been considered in classifying the urban environmental quality of the Xiamen Municipality *(see Figure 3.9)*.

A high level of economic development but with low environmental quality exists in the west-northwestern part of the Xiamen Island, where the old downtown, Yuan Dang New district and Huli Industrial Zone are located. In contrast, the Bantou Reservoir and its adjacent area in northern Xiamen are less developed but with high environmental quality. The status of environmental quality for the rest of Xiamen is intermediate.

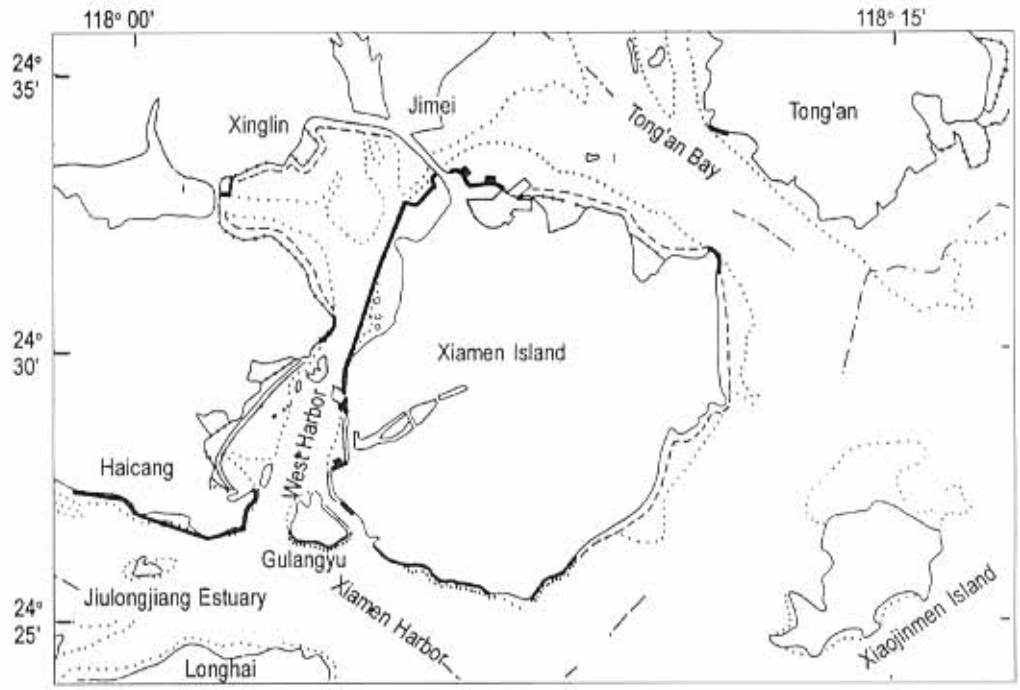
This pattern shows that Xiamen's environmental quality is very much influenced by economic activities and levels of development. The degradation of environmental quality can be prevented by timely government interventions, effective law enforcement and adequate investments in environmental protection and management.

Table 3.5. Resource use plan for shoreline and port

Location	Length	Depth	Use Status	Shoreline Plan	Remarks
Xiamen Island (subtotal)	49.0				
Gaoqi - Airport	4.1	s	salt, mariculture, airport	others	
Airport - Dalimuyu	2.3	s	mariculture	mariculture	
Dalimuyu - Wutongdao	4.5	s	mariculture	commercial port	reserved for future
Wulongdao - North Heouo	5.0	s	mariculture	reclamation & mariculture	
North Heouo - Xiamen University	16.2	s	mariculture, most is undeveloped	tourist, resident	clean yellow sand beach
Xiamen University - South Heping berth	2.3	m	navy, fishing boat base, rescue ship	other	including rescue jetty
South Heping berth - North Heping berth	0.4	d	Heping berth for business	commercial port	passenger traffic center
South Heping berth - berth No. 1	1.1	s	riverine passenger, ferry, small rural craft, seaside park, urban living	small craft jetty to be moved	urban activities
Berth No. 1 - Hubingnan Road	0.1	s	small jetty for rural, small shipyard	urban activities	foreign related sectors (the Customs, joint inspection, port, frontier defense), small movable craft
Hubingnan Road - South fishing port	2.1	s	Tongyi jetty, cold storage for foreign trade, Yuan Dang causeway	urban activities, others	including rural small craft pier
South fishing port - South Shungshishan	0.6	d	fishing port	fishing port	
South Shuangshishan - South Shihushan	5.6	d	4 berths of Phase 1 of Dongdu commercial port, other remained	commercial port	Dongdu port area
South Shihushan - North Luyong oil jetty	1.2	m	stone materials works, precast concrete yard, Luyong oil jetty	others	
North Luyong oil jetty - Gaoqi	2.3	s	commercial port-Gaoqi operation district, other remained	commercial port	Gaoqi port district, fuel pier
Gaoqi (South Gaoji causeway) - Wencuo	(12.8)				
South Gaoqi causeway - West Xingji causeway	5.25	s	causeway, mariculture	others	
West Xingji causeway - North Maluan causeway	5.87	s	mariculture	mariculture, commercial port	Xinglin port district
North Maluan causeway - Wengcuo	1.67	s	causeway, jetty for polyester fibre plant and glass works	others	
Wengcuo - Qing Jiao, Haicang	(26.9)				
Wengcuo-Yincuo	1.7	s	mariculture	tourist	
Yincuo - North Jingtaiyu	4.2	s	mariculture	mariculture	
North Jingtaiyu - South Paitou	1.3	d	remained	shoreface industry	shipyard
South Paitou - South Liushan	1.85	s	mariculture	shoreface industry	
South Liushan - Dongyu	1.5	s	mariculture	urban activity	
Dongyu - Songyu	3.65	m	partly mariculture, ferry	reserved	
Dayu	2.2	d	remained	reserved	
Songyu - West Yadanshan	2.55	d	navy fuel jetty, most remained	industry, commercial port	Songyu oil jetty
West Yadanshan - Gongqiangshan (Aotou)	2.5		ship-breaker, mariculture, most remained	industry, commercial port	Haicang port, power plant pier
Gongqianshan - Qingjiao	5.45		mariculture	industry, urban activity	U-excavated port in plan, industrial port
Tong'an Bay (Jimei-Tong'an)	(42.7)				
Liuwudian - Aotou	5.3		Liuwudian jetty, mariculture	industry, commercial port	small piers for towns along Tong'an Bay, unplanned
Total	131.4				

Legend: *Length in km; s - water depth below 6 m; m - water depth between 6-10 m; d - water depth over 10 m*
Note: *Other shorelines include jetties, causeway, navy, and special purpose.*
Source: *Third Institute of Oceanography, SOA (1994)*

Figure 3.8. Shoreline and port use plan of Xiamen Municipality



Legend:

port shoreline — *tourist shoreline* — *mariculture shoreline*

residential shoreline — *special shoreline*

Source: *Planning Service of Xiamen City.*

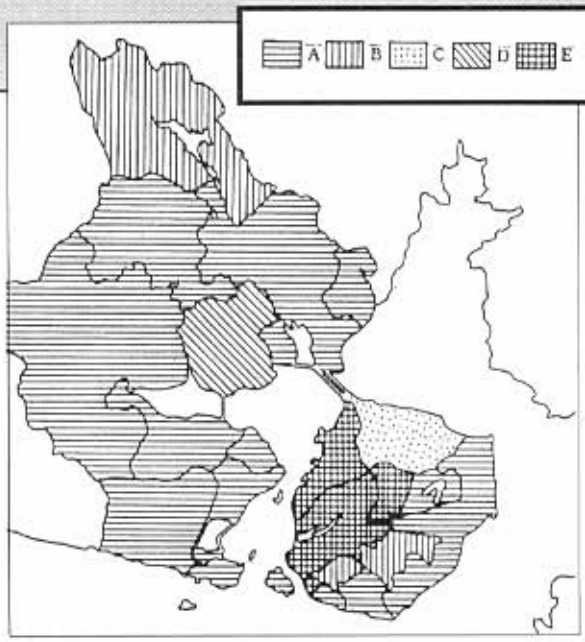


Figure 3.9. Classification of urban environmental quality of Xiamen Municipality

Legend:

A - Development above average with high environmental quality

B - Development below average with very high environmental quality

C - Development at average and environmental quality at above average

D - High development level with average environmental quality

E - Very high development level with environmental quality below average

Note: *Levels of development and environmental quality are set at five different grades as below:*

Development Stages	***Environmental Quality***
very high	*very high*
high	*high*
above average	*above average*
average	*average*
below average	*below average*

Source: *Center of Environmental Science Study et al. (1992)*

Chapter 4:

Status of Marine Pollution

A review of the marine environmental quality of Xiamen indicates that the marine waters of Maluan Bay and those near Baozhuyu Island are seriously polluted. The other parts of Xiamen coastal waters are relatively good, meeting the requirements of Classes I and II of the Seawater Quality Standards of the country. Eutrophication events are increasing. Oil pollution is localized and contaminations by heavy metals, radioactive wastes and biocides are slight.

Marine Environmental Quality

To determine Xiamen's marine environmental quality, studies have been made on its coastal waters. *Table 4.1* shows the levels of concentration of some pollutants as discussed below.

Organic Pollution, Eutrophication and Red Tide — Organic pollution is the most serious pollution problem in Xiamen coastal waters. The main sources are urban domestic effluents, industrial and mariculture wastes. The Chemical Oxygen Demand (COD), an indicator for organic pollution, has increased since 1982 *(see Figure 4.1)*, showing a distinct spatial gradient in the Xiamen coastal waters *(see Figure 4.2)*.

The COD in Maluan Bay is within the range of Classes III and IV of the Seawater Quality Standard; elsewhere, the COD falls within Classes I and II. The COD contents of Tong'an Bay and Outer Harbor are the lowest and meet Class I of the standard. For the West Harbor and the Estuary, their CODs are slightly higher, falling between Classes I and II of the standard.

The concentrations of sulfide and organic matters in the surficial sediment are the results of the accumulated organic materials from the water body. It reflects the long-term organic pollution in the water column. The concentrations of the two parameters in Maluan Bay are the highest; decreasing from West Harbor, Estuary and Outer Harbor to Tong'an Bay, sharing the same trend as COD. *Figures 4.3* and *4.4* show the spatial distribution of sulfide and organic matters in surficial sediments.

Due to high concentrations of COD, sulfide and organic matters, as shown in *Figures 4.1* to *4.4*, Maluan Bay has serious organic pollution. These organic pollutants are brought by land-based waste discharges, waste from intensive mariculture, domestic effluents and poor hydrodynamic conditions.

Xiamen coastal waters show a medium level of eutrophication due to inorganic nitrogenous nutrients. The amount of dissolved inorganic phosphate in most of the Xiamen coastal waters fall within Class I of the Seawater Quality Standards, except for that very high concentration found at the bottom water of Maluan Bay. *Figures 4.5* and *4.6* show the spatial variation of reactive phosphorus and total inorganic nitrogen (TIN). In their temporal variation, *Figure 4.7* shows that inorganic nitrogen has increased while reactive phosphate has decreased slightly since 1987.

Major red tide outbreaks due to *Gymnodinium* and *Eucampia zoodiacus* occurred in 1986 and 1987 in the West Harbor, particularly in the north coasts of Dongdu-Huoshaoyu Island. In 1986, a *Gymnodinium* red tide outbreak in Xia-Gu Channel extended to the offshore waters of Hulishan Fortress, forming a red tide belt.

The results of the study on red tide in Xiamen coastal waters indicate that red tide occurrence follows a complex process triggered by the following conditions: eutrophication; the sudden change in weather, especially during spring and

Table 4.1. Concentrations of some pollutants in Xiamen coastal waters
(Units: OM in %; fecal coliform in ind/l and others in mg/l)

Date	Areas	DO	COD	BOD	RP	3IN	S^{2-}	OM	OIL	Fecal coliform	
										Planning	Sea islands
Jun-Dec 1982	W.H.		1.24								
Jan-Dec 1987	W.H.	7.16	1.38		0.015	0.21					
Mar 1987 - Feb 1988	W.H.	7.22	1.33		0.015	0.22	118	1.82		TC < 54,000, 30% exceeding standard	3,914
Mar-Oct 1989	W.H.	6.68	1.50		0.013	0.26		2.40	0.012		
Apr 1989-Mar 1990	W.H.		1.81		0.011	0.34	284			69% exceeding standard**	
1992	W.H.								0.026		
	M.B. S	9.37	4.32	3.29	0.003	0.29			0.058	646	
	B	3.45*	7.72	3.50	0.161	0.08	1,636	3.51		(20-5,420)	
	E+OH S	7.24	1.53	0.88	0.016	0.41			0.015	5,136+	1,800+
	B	6.87	1.03		0.015	0.24	147	1.74	0.015	1,610++	1,187++
	T.B. S	8.15	1.08	0.89	0.012	0.21	31	0.99	0.012	108	
	B	8.19	0.93		0.012	0.17				(20-1,700)	
	E.C.										2,806

Legend:

DO = *dissolved oxygen*
COD = *chemical oxygen demand*
BOD = *biological oxygen demand*
RP = *reactive phosphate*
TIN = *total dissolved inorganic nitrogen*
S^{2-} = *sulfide at surfacial sediment*
OM = *organic matter at surfacial sediment*
** = *based on the FC standard of 2,000 ind/l*
* = *dissolved oxygen was not detected for some stations; data in bracket are range of determination*
B = *bottom water*
S = *shallow water*
W.H. = *West Harbor*
M.B. = *Maluan Bay*
E+OH = *Estuary and Outer Harbor*
T.B. = *Tong'an Bay*
E.C. = *Eastern Waters*

Sources:

Institute of Environmental Science Study, Xiamen City (1990)
Office of the Steering Group for Comprehensive Investigation of Resources in Xiamen Islands (1994)
Third Institute of Oceanography, SOA (1983, 1993a, 1993b, 1993c, 1994)
Xiamen Management Region, SOA (1990)

Figure 4.1. COD concentrations in Xiamen coastal waters from 1982 to 1990

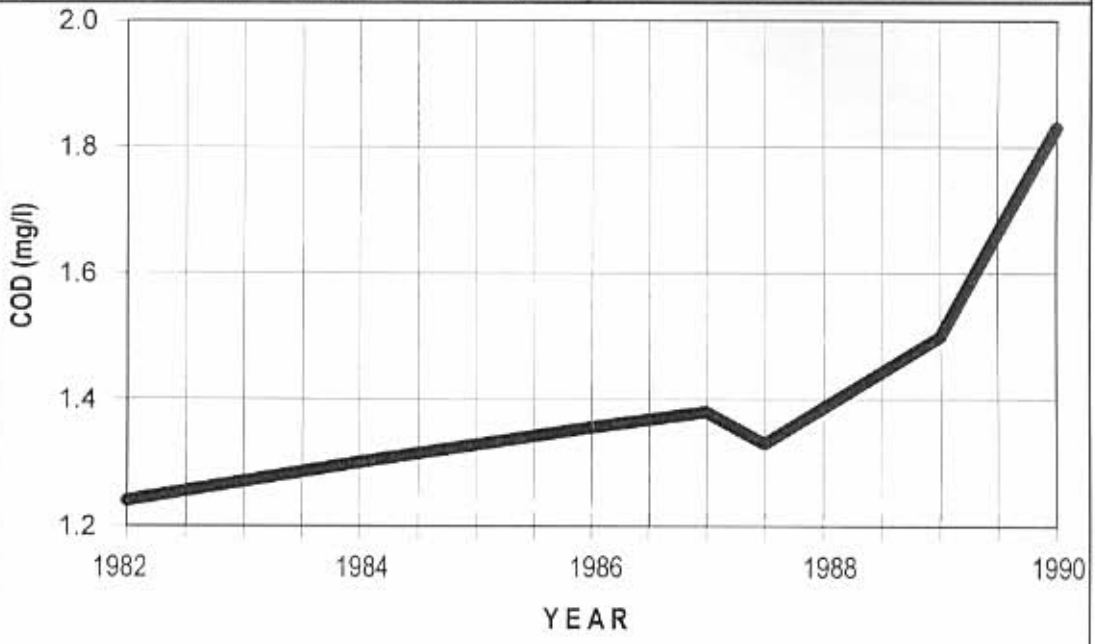


Figure 4.2. Spatial distribution of COD concentrations in Xiamen coastal waters

Legend:

1 - *Tong'an Bay*
2 - *West Harbor*
3 - *Maluan Bay*
4 - *Jiulongjiang River Estuary*
5 - *Outer Harbor*
6 - *Eastern Channel*

0.93-1.03 mg/l
1.03-1.53 mg/l
1.38-1.81 mg/l
4.32-7.72 mg/l

Figure 4.3. Spatial distribution of sulfide concentrations in the surface sediment of Xiamen coastal waters

Legend:
1 - Tong'an Bay
2 - West Harbor
3 - Maluan Bay
4 - Jiulongjiang River Estuary
5 - Outer Harbor
6 - Eastern Channel

31 mg/kg
147 mg/kg
284 mg/kg
1,633 mg/kg

Figure 4.4. Spatial distribution of organic matter in the surface sediment of Xiamen coastal waters

Legend:
1 - Tong'an Bay
2 - West Harbor
3 - Maluan Bay
4 - Jiulongjiang River Estuary
5 - Outer Harbor
6 - Eastern Channel

0.99%
1.74 %
2.40 %
3.51 %

Figure 4.5. Spatial distribution of reactive phosphorus (mg/l) in Xiamen coastal waters

Legend:
1 - Tong'an Bay
2 - West Harbor
3 - Maluan Bay
4 - Jiulongjiang River Estuary
5 - Outer Harbor
6 - Eastern Channel

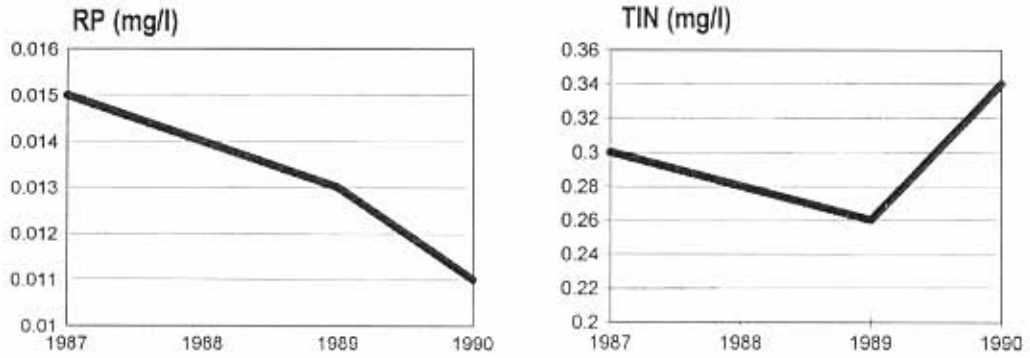
0.012 mg/l
0.015-0.016 mg/l
0.011-0.022 mg/l
0.003-0.161 mg/l

Figure 4.6. Spatial distribution of total inorganic nitrogen (mg/l) in Xiamen coastal waters

Legend:
1 - Tong'an Bay
2 - West Harbor
3 - Maluan Bay
4 - Jiulongjiang River Estuary
5 - Outer Harbor
6 - Eastern Channel

0.08-0.20 mg/l
0.17-0.21 mg/l
0.21-0.34 mg/l
0.24-0.41 mg/l

Figure 4.7. Variation of reactive phosphorus (RP) and total inorganic nitrogen (TIN) in Xiamen coastal waters since 1987



summer; the release of large amounts of nutrients into the water during storms; the rapid transformation of nutrients; the subsequent transportation of sedimentary organic matter during warm season; and the photosynthesis of blooming red tide species as aided by clear or sunny weather after the rains *(see Figure 4.8)*.

No red tide occurrence has been detected in the West Harbor since 1987. This is probably due to the large-scale shellfish culture which consumes large amounts of nektons and thereby inhibits the growth of red tide species, or the occurrence was simply undetected. Further study is needed.

Figure 4.8. Red tide areas in 1986 and 1987

Source: *Third Institute of Oceanography, SOA (1993a)*

Bacterial Pollution — The results of monitoring coliform population in Xiamen indicate the varying degrees of bacterial pollution in different sea areas. Fecal pollution is quite serious in the West Harbor where the concentration of fecal coliform reaches 3,914 individuals/l and exceeds the standard for recreational seawater (2,000 ind/l). This has been caused by large amounts of domestic wastes from land-based sources.

The fecal coliform content in the Eastern Channel is lower than in the West Harbor but still exceeds the standard; the case is the same with the Jiulongjiang River Estuary. Tong'an Bay has a low fecal coliform content, which makes it suitable for shellfish culture for domestic consumption.

Figure 4.9. Spatial distribution of fecal coliform in Xiamen coastal waters

Legend:

1 - Tong'an Bay
2 - West Harbor
3 - Maluan Bay
4 - Jiulongjiang River Estuary
5 - Outer Harbor
6 - Eastern Channel

112 ind/l
646 ind/l
1,187 ind/l
1,800 ind/l
2,306 ind/l
3,914 ind/l

It is interesting to note that the fecal coliform content of Maluan Bay ranges from 20 to 5,240 ind/l, with an average of 646 ind/l. The bay is seriously polluted by organic substances from mariculture rather than from domestic wastes *(see Figure 4.9)*.

Oil Pollution — Generally, oil pollution is not a major problem in Xiamen coastal waters, but this is not a reason to loosen guard on potential sources.

According to available monitoring data, oil contamination is most serious in Maluan Bay, with 0.058 mg/l concentration in the water column, exceeding the standard of Class I. This might be due to the oily wastewater discharged from numerous small boats used for mariculture, and the limited water exchange between the bay and West Harbor. West Harbor is second to Maluan Bay in terms of oil contamination *(see Figure 4.10)*.

Since 1985, marine pollution surveillance has observed floating oil on the sea surface in addition to the dissolved and dispersed oil. In 1989, 21 oil slick incidents affecting over 500 m^2 were recorded from Dongdu Port to southeast of Gulangyu Island, where similar cases were found in 1990 and 1991. From 1984 to 1992, several oil spills occurred, of which some were detected as originating from factories along the coastlines and others from illegal ship discharges.

In the West Harbor, oil pollution has been directly caused by oil spill; and its high oil content has been due to the increase in oily water discharges from sea vessels and motorized fishing boats. In recent years, however, prevention and management of oil pollution have improved considerably.

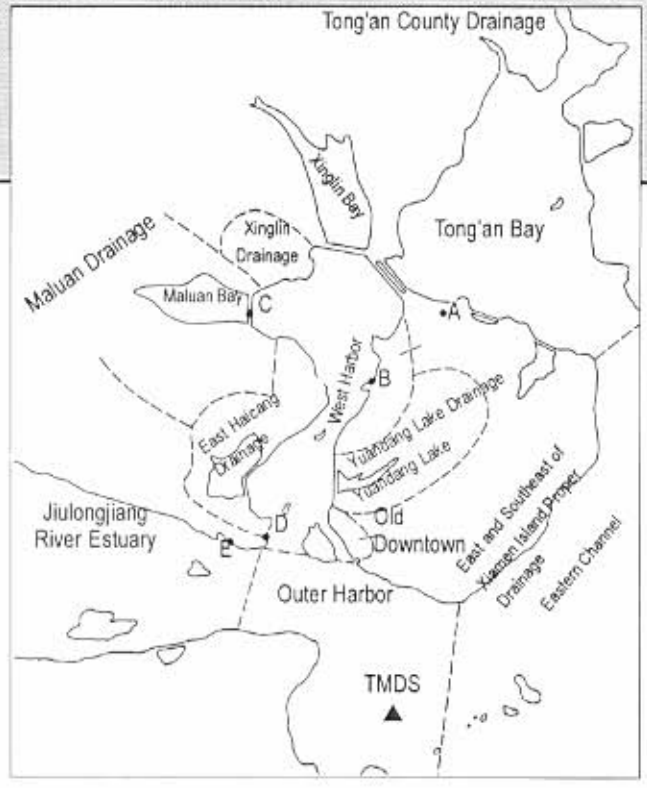
Sea Dumping and Disposal of Solid Wastes — The major wastes dumped at sea are Class III dredged materials from jetties, port basins and navigation channels. The dumping sites are located at Zhenghai Jiao and Tajiao *(see Figure 4.11)*. The Tajiao site was opened in

Figure 4.10. Spatial distribution of dissolved and dispersed oil (mg/l) in Xiamen coastal waters

Legend:
1 - Tong'an Bay
2 - West Harbor
3 - Maluan Bay
4 - Jiulongjiang River Estuary
5 - Outer Harbor
6 - Eastern Channel

0.93-1.03 mg/l
1.03-1.53 mg/l
1.38-1.81 mg/l
4.32-7.72 mg/l

Figure 4.11. Sketch map of potential sources of environmental accidents in Xiamen Municipality



Legend:
A - Airport
B - Jetty and tank area for fuel and liquified gas near Shihushan
C - Pier at Maluan for chemicals used by chemical fiber plant at Xinglin
D - Petroleum transshipping jetty at Songyu
E - Coal jetty for power station at Haicang
▲ - Tajiao marine dumping site (TMDS)

Source: *Institute of Environmental Science Study (1990)*

1990 and was closed in 1995. No significant adverse impacts have been found thus far. Since 1990, around 0.325 million tons of wastewater from monosodium glutamate (MSG) production have been dumped at such sites. However, no adverse impacts have been detected.

The volumes of dumped wastes are listed in *Table 4.2*, showing annual variations with each total amount below one million tons per year. The amount of wastes from MSG production dumped at sea varied according to levels of production. All industrial solid wastes and domestic garbages were disposed of at designated landfills. Rubbish such as plastic bags, bottles, etc., which come mainly from households, recreational and tourist facilities, and sea vessels, usually litter the shores and offshore waters, especially after a storm. Floating wastes in a belt formation reaching several kilometers had also been observed.

Environmental Accidents — As mentioned earlier, several oil spill incidents have occurred in recent years. Xiamen's rapid economic development has been accompanied by an increase in the use of petroleum and fuel products (e.g., LPG) and chemicals. Consequently, the potential for environmental damage also increases. For example, there is an increased risk for Zhaishang Village where jetties and depots of fuel oil and petroleum are located. Other potential sources of environmental accidents include the airport fuel depot area, the chemical jetties in Xinglin District, and the petroleum transshipment jetties in Haicang.

Yet, adding to the potential of these real dangers is the lack of an emergency response system for oil and chemical accidents. The responsibility to prevent and respond to such incidents rests solely with the Environmental Protection Agency and the Fire Department. This indicates that the traditional response approach is still reactive rather than preventive.

Sediment Deterioration and Secondary Pollution — The sediments in Maluan Bay are seriously polluted, thus becoming a secondary pollution source *(see Table 4.1 and Figure 4.3)*. Its sulfide content exceeds 1,636 mg/kg, giving off a foul smell during summer and winter. Its organic matter content is as high as 3.51 percent. The levels of both substances exceed the standards. The eutrophication of sediment is below zero, indicating its reduced condition. In addition, the high content of organic matter in the sediment poses as a potential source for eutrophication. Also, the concentration of mercury in the surface sediment has reached 0.107 mg/kg becoming a secondary pollution source.

Pollutant Sources

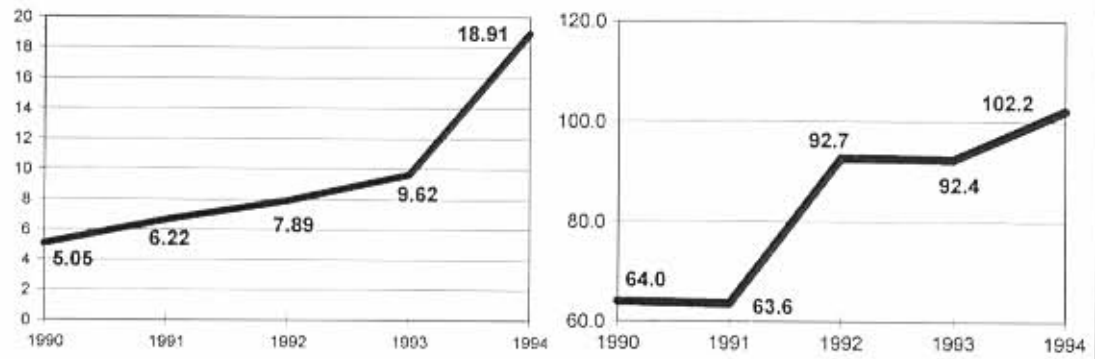
Land-based Pollution Sources — Land-based wastewater discharges had increased by about 50 percent from 1991 to 1992, reaching about 20 million tons in 1994 *(see Figure 4.12)*.

The lands that surround West Harbor are centers of industrial and urban activities, posing as major sources of pollution. Tong'an Bay receives pollutants from Datong Town, Dongxi and Xixi Streams in Tong'an County.

Table 4.2. Amount of wastes dumped in Xiamen coastal waters

	1990	1991	1992	1993	1994
Dredged materials ($x10^4 m^3/a$)	-	45.6	78.4	41.8	75.1
Monosodium glutamate waste ($x10^4 t/a$)	2.7	10.8	8.1	8.2	4.7

Figure 4.12. Wastewater discharges A and GDP from 1990-1994



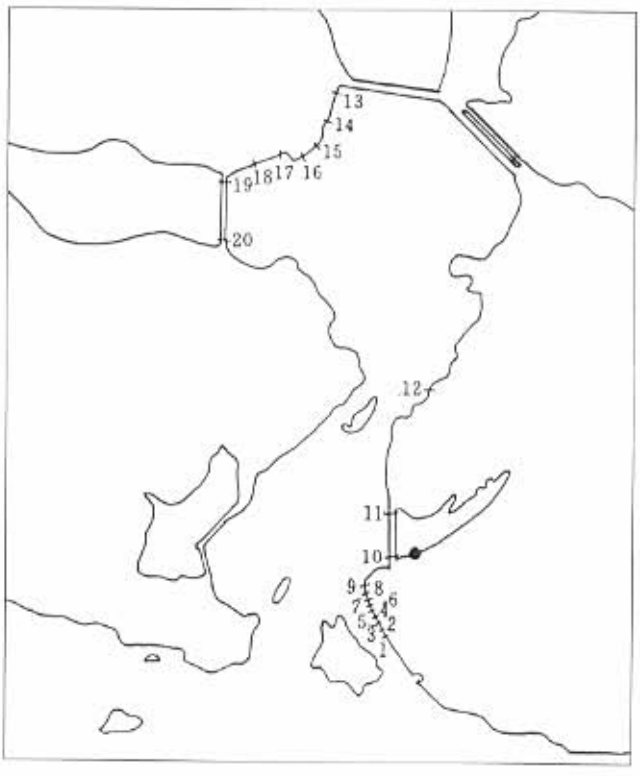
Source: Xiamen Statistics Yearbooks, 1990-1994.

In Jimei and northeast Xiamen Island, industrial discharges have significantly increased. In the Eastern Channel, soil erosion from farmlands, domestic effluents and non-point discharges are the major pollution sources. Nonetheless, the environmental quality in this area is still considered good due to the low level of developments in nearby areas considering their proximity to the open sea.

Land-based pollution sources are divided into several areas according to their geographic characteristics and socioeconomic development *(see Figure 4.11)*. The land-based sources of pollution in the West Harbor were investigated in 1989, showing 20 outfalls of industrial and domestic effluents *(see Figure 4.13)*. On the other hand, the non-point sources have come from among the 46 agricultural units in four subdistricts, 18 units of forestry and barren lands, animal husbandry and township industries, etc. The amount of wastes from land-based sources surrounding the West Harbor is shown in *Table 4.3*.

Commercial and residential buildings are mainly concentrated in the old town of Xiamen. About 95 percent of the wastewater discharged from this area are domestic sewage, entering the sea directly through nine outfalls.

Figure 4.13. Location of outfalls around West Harbor



Legend:

• *Yuan Dang Sewage Treatment Plant* **1-20** *Outfalls*

Source: *Institute of Environmental Science Study (1990)*

Table 4.3. Land-based pollution sources in Xiamen

1989#	Drainage	Waste-water		Amount of pollutants fron various sectors (t/a)									
				COD_{cr}		BOD_5		TN		TP		IP	Oil
		Ind. x10^4(m^3/a)	Dom. x10^4(m^3/a)	Ind.	Dom.	Ind.	Dom.	Dom.	Agr./ Nat.	Dom.	Agr./ Nat.		
	N. W. Old Downtown	11	347	27	1,380	24	692	134		27		17	
	Yuan Dang Lake	993	1,087	9,242	9,229	3,366	4,500	435		87		54	
	West Huli	284	190	369		165		48	30	6.2		0.002	
	Xinglin	421	103	113	405	62	203	39	0.1	7.8		2.9	
	Maluan	45		63		53			717		0.1	0.06	
	East Haicang					7			171		0.01	0.01	
	Jiulongjiang River*	148,000		34,000					5,220 (IN)			265	440
	Tong'an (92)	362		2,668		1,070							
	E. & E.S. Xiamen Is.												
	Subtotal**	2,116	1,727	12,113	11,014	4,582	5,395	656	918	128	0.11	74	
	Total**	3,843		23,127		9,977		1,574		128.11		74	
1993+	TOTAL	3,726	5,695	7,514									16.7

Legend:

 # = Data for 1989 are from the Investigation and Prediction of Pollution Sources for West Harbor Water Column, Part 1 of the Environmental Capacity and Water Quality Control Planning for West Harbor, Xiamen. Xiamen Environmental Science Institute, June, 1990, pp. 1-56.

+ = Data for 1993 are from the Xiamen Environmental Statistics, 1993.

** = Pollutants carried by Jiulongjiang River are not divided into categories of industrial, domestic or agricultural/natural and are calculated according to A=CxQ, where A is the amount of pollutants, C the concentration of the individual pollutant in river water, Q is the average runoff of Jiulongjiang River.*

*** = Subtotal and total do not include the quantity carried by Jiulongjiang River.*

TN = total nitrogen
TP = total phosphorus
IP = inorganic phosphorus
Agr. = agriculture
Nat. = nature
IN = inorganic nitrogen
COD_{cr} = chemical oxygen demand
BOD_5 = biological oxygen demand
Ind. = industrial wastewater
Dom. = domestic wastewater

The Yuan Dang Lake has a drainage area of 37 km^2, and its lakeside area is rapidly becoming a new downtown area due to extensive development activities. The amount of industrial wastewater is almost at the same level as domestic sewage and are discharged to the sea through two outfalls.

The Yuan Dang Sewage Plant has primary and secondary treatment capacities of 37,000 and 34,000 tons per day, respectively. Wastewater (about 13 million tons per year) after secondary treatment, on the one hand, is discharged to the sea through the Yuan Dang Lake. On the other hand, wastewater amounting to about 15 million tons a year is directly discharged after primary treatment.

Wastewater produced in the Huli area comes from industrial and domestic effluents and agricultural wastes. The industrial and domestic effluents are discharged to the outfall in this district.

In Xinglin district, wastewater comes mainly from industries, households and farmlands. Most industrial and agricultural wastewater is discharged into Maluan Bay, except that from the Xiamen Sugar Refinery which is discharged into Xinglin Bay. In recent years, wastewater produced in this area has amounted to 17 million tons a year, and could reach about 21 million tons yearly in the next few years. However, only one sewage plant with primary treatment capacity of 30,000 tons per day has been under construction.

The Maluan Bay drainage system covers an area of 157 km^2. Industrial and agricultural wastewater in the area is discharged into the West Harbor through two outfalls.

In Eastern Haicang, pollution from non-point sources is a major concern and point source pollution has been increasing in recent years.

The Jiulongjiang River, being the second largest river in Fujian Province, brings large amount of pollutants estimated at 34,000 tons of COD per year in 1986-1987. It carries huge amounts of organic materials, inorganic phosphorus and nitrogen exceeding the sum from all other drainage areas.

Tong'an County, lying in the suburb of Xiamen, produces 3.92 million tons of industrial effluents, together with an unknown amount from non-point sources. However, no study has been made on land-based sources in the northeast, east and southeast Xiamen Island.

The Yuan Dang Lake drainage has accounted for 75 percent of total COD, 67 percent of total BOD, 68 percent of total phosphorus and 34 percent of total nitrogen discharged into the sea. The Maluan drainage accounts for 21 percent of total nitrogen discharge.

Phosphorus pollution comes mainly from domestic effluent and less from soil erosion. The largest contributor of phosphorus to the West Harbor is the Yuan Dang area with 87 tons a year or 68 percent of the total (128 tons). The second largest contributor (21 percent) is the northwest part of the old town *(see Table 4.4)*.

Land-based solid wastes come mainly from civil and engineering works and households. Large amounts of construction debris have been reported, but no data are available.

In 1993, industrial solid wastes consisting of coal ash, slag, chemical residues and metallurgical discards were estimated at 0.25 million tons in 1993. However, 90 percent of these wastes were recycled, leaving a small amount for disposal. In addition, some 0.24 million tons of domestic garbage on land were gathered and disposed of in sanitary landfills.

Some chemical fertilizers and biocides are used in the suburbs of Jimei, Xinglin and Huli. However, no study has been done on their impacts to coastal environment *(see Table 4.5)*. Reclamation without cofferdam contributed to siltation in some areas, but its impact on mariculture needs further assessment.

Sea-based Pollution Sources — The most significant sources of sea-based pollution are ports, ships and mariculture. Sea dumping is of secondary significance. No detailed study

Table 4.4. Amount of major pollutants entering Xiamen coastal waters

Drainage	Wastewater (x 10^4t/a)	Amount of pollutants (x 10^4t/a)					
		COD	BOD	TN	TP	IP	Oil
N.W. Old Downtown	358	1,406	716	134	27	-	-
Yuan Dang Lake	3,672	7,166	2,426	435	87	-	-
West Huli	474	369	165	78	6.2	-	-
Xinglin	524	518	265	39	7.8	-	-
Maluan	45	63	53	717	0.1	-	-
East Haicang	-	-		171	-	-	-
Jiulongjiang*	148,000	34,000	-	5,220(IN)		265	440
Tong'an	-	-	-	-	-	-	-
E. & E.S. Xiamen Island	-	-	-	-	-	-	-
Total**	5,065	9,522	3,625	2,102	101	280	440

* calculated according to river runoff and pollutant concentrations
** pollutants carried by Jiulongjiang River are not included

Table 4.5. Quantity (ton) of chemical fertilizers and biocides used in Jimei, Xinglin and Huli districts in 1990

N	P	K	Composite	Biocides#
5,540	2,167	1,650	953	155.9

Legend: *# = for pesticides and fungicides, 1605 Powder and Derosal are most often used, respectively. Organochloro, biocides such as DDT and 666 have been banned.*

Source: *Center of Environmental Science Study, Xiamen University (1992)*

has been carried out on the distribution and quantity of these sources. *Table 4.6* gives some preliminary statistics for 1988 and 1992 (excluding the data on Tong'an County).

There are inadequate data on mariculture as an important sea-based source of pollution. Based on the 1994 mariculture production of 42,725 tons, it was estimated that about 10,000 tons of organic wastes from mariculture were discharged into the sea in the same year.

Table 4.6. Pollutant discharges from ports and ships in Xiamen

	Ships no.	Hand. capacity (t)	Oily water (x10^4t/a)	Oil (t/a)	Sewage 10,000 (t/a)	BOD (t/a)
1988#	13,539	431	7	28	-	30
1992*	-	920	10.1	202	9.2	37
1994	-	1,140	-	-	-	-

Source:
 # = from the Institute of Environmental Science Study, Xiamen City (1990)
** = from the Environmental Impact Report for the Second Phase Project of Dongdu Port, Xiamen, undistributed report (1992)*

Marine Pollution Trends

Changes in Coastal Water Quality — By the year 2000, according to Xiamen's socio-economic development plan, wastewater discharge will range at 0.51-0.62 million tons per day. Population will also increase by 1.5 times *(see Table 4.7)*. The preceding projection will only compound the problems in Maluan Bay, including the sea areas of Baozhuyu Island and West Harbor, which are already highly polluted, if no countervailing measures are adopted. Thus, the improvement of water quality in these areas will require the breaching of the Maluan Causeway and the construction of the Xinglin Wastewater Treatment Plant.

The pollution potentials in south Baozhuyu Island, Gulangyu Island, and in the Jiulongjiang River Estuary need sufficient attention. In the long run, the increase in wastewater discharges will end up largely in the West Harbor.

In 1990, the environmental carrying capacity (ECC) of the West Harbor was computed at 48 t/d for COD and 0.92 t/d for total phosphorus. Sewage treatment will significantly reduce the COD to a level lower than the phosphorus amount. However, this estimate did not consider inputs from the Jiulongjiang River and other sources.

Environmental degradation in the West Harbor can be prevented through comprehensive planning and management, enforcement of regulations and construction of treatment facilities. These require adequate inputs of labor, material and financial resources.

Since the ECC study in 1990 was conducted for the West Harbor only, impact assessments need to be done for Tong'an Bay, Jiulonjiang River and the Eastern Channel to provide more information on the extent of marine pollution in Xiamen's coastal waters.

Table 4.7. Projection on population and waste water discharge in Xiamen Municipality

Area	Population				Wastewater production (x10⁴t/d)		
	1992	2000	2010	Beyond	2000	2010	Beyond
Xiamen Island	381,636	542,000	792,000	1,025,000	34.7	51	66
Gulangyu	22,294	21,400	20,000	15,000	1.0	1.0	0.7
Jimei, Houxi, etc.	58,523	93,300	182,000	419,000	4.5	8.7	20.1
Guankou, Dongfu	62,346	72,300	107,000	724,000	3.5	5.1	34.8
Xinglin	53,407	82,000	116,000	311,000	3.9 (6.0)	5.6 (12)	14.9
Xinyang	9,638	19,000	44,000	240,000	0.91 (5.0)	2.1 (10)	11.5
Paitou	2,853	5,600	13,000	30,000	0.3	0.6	1.4
Haicang new town	11,362	22,300	73,000	122,000	1.1 (5.0)	3.5 (10)	5.9
Haicang, 20 km²	22,724	38,500	87,000	97,000	1.8	4.2 (10)	4.7
Songyu subarea	2,274	6,000	10,000	17,000	0.3 (0.6)	0.5 (1.0)	0.8
TOTAL	627,057	902,400	1,444,000	3,000,000	51 (62)	82 (109)	160

Source: *Third Institute of Oceanography, SOA (1994)*

Chapter 5:

Marine Ecosystem Features and Problems

In Xiamen, the inner bays, artificial lake, estuary, outer harbor, intertidal zones consisting of rocky shore and sandy shores, mud flats, islands and islets serve as the habitats for a wide diversity of marine species. The high input of nutrients is responsible for the relatively high primary productivity in its coastal waters.

Ecosystem Changes and Their Causes in the West Harbor

Change of Habitats — The land around the West Harbor has long been the focus of development and still is in the next 10 to 20 years. This situation along with increased human activities have affected and caused some changes in the ecosystem of the West Harbor.

The reclamation of lands from shallow waters, and the construction of causeways in Gao-ji, Ji-Xing and Maluan since 1955 have reduced the water surface area of the West Harbor by 36 km^2 and influx by 40 percent ($1.2 \times 10^9 m^3$). The present water surface area of the West Harbor during low tide is only 22.5 km^2.

The present Yuan Dang Lake was created by a causeway built across a natural bay in the early 1970s. Reclamation and causeway construction have brought adverse impacts on the marine ecosystem of the West Harbor, changing not only the features of habitats for marine species but also the hydrodynamic conditions.

Change in Ecosystem — The change in habitats and the accumulation of pollutants in the harbor have transformed the biological community structure, and reduced the number of species sensitive to environmental change. The results of the phytoplankton studies in 1954 and 1980 on the West Harbor showed that the total cell counts of phytoplankton at Xia-Gu channel had increased; while the quantity of *Chaetoceros*, which are sensitive to the environmental change, had decreased from 5.58×10^5 ind/m^3 to 2.80×10^5 ind/m^3 *(see Table 5.1)*.

The community structure of zooplankton showed a similar pattern *(see Table 5.2)*. The number of species of planktonic Copepoda decreased from 35 in 1980 by about one-fourth to 27 in 1987. There was a reduction of species diversity index (H') from 2.04 to 1.76, although their abundance increased in the same period. In contrast, the physical conditions changed very little *(see Table 5.3)*.

Apart from the changes in marine community structure, the *Merismopedia warmingiana*, a species whose presence indicates lake water pollution, was found off the Yuan Dang Lake causeway in 1980. This could be an evidence of change in the water quality of Yuan Dang Lake, having received a large amount of urban effluents after its reclamation.

During a study on red tide in 1987, the *Oithona brevicornis*, an estuarine species with a strong pollution tolerance, was recorded in the waters of West Harbor, thus suggesting the impacts of land-based waste discharges. In West Harbor, the benthic community structure has also changed due to waste discharges from land, mariculture and ships.

The number of benthic species (84 benthos species recorded in four stations) in the harbor's upper part where pollutants have accumulated and water exchange is less than in the harbor's southern part. In its area from the middle to mid-south, the community structure is considered disturbed.

Large-scale red tide outbreaks caused by *Gymnodinium* and *Eucampia zoodiacus* took place in June 1986 and May 1987 in the sea areas around Baozhuyu Island in the north of West Harbor.

Table 5.1. Comparison of phytoplankton counts in Xia-Gu Channel for 1954 and 1980

	August			November			February			May		
	1954		1980	1954		1980	1954		1980	1954		1980
	08/16	08/30	08/12	11/13	11/27	11/26	02/05	02/20	02/18	05/50	05/20	05/20
	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.	H.T.
Skeletonema costatum	3,450	475	9,800	0	0	1,960	420	0	0	0	1,360	0
Melosira sulcata	0	150	1,260	0	150	4,620	720	1,510	10,360	1,506	1,200	5,040
Coscinodiscus	925	550	3,500	350	100	1,540	670	360	420	1,200	350	700
Biddulphia	200	725	140	25	25	140	70	40	140	100	0	140
Chaetoceros	3,975	200	840	0	263	0	0	0	140	0	25	140
Rhizosolenia	1,350	25	8,400	0	172	140	0	0	560	0	0	140
Nitzschia	0	125	9,520	50	25	1,120	20	0	700	50	0	1,260
Thalassionema nitzschioides	675	3,225	5,460	25	0	280	0	0	1,680	25	50	1,680
	15,275		58,100	775	450	14,980	2,170	2,980	24,360	3,150	3,150	13,720

Legend:
H.T. = High Tide

Note: *Data in 1954 were results from sea areas between Shuixiangong and Gulangyu; data in 1980 were for station 78 in Xia-Gu Channel, i.e., the same sea areas of the former study.*

Source: *Third Institute of Oceanography, SOA (1988)*

Table 5.2. Comparison of species abundance and diversity of planktonic Copepoda in the West Harbor (1980 and 1987)

	Number of species	Total abundance	H' average	*Oithoma* spp. (ind/m³)	Annual average water temp. (°C)	Annual average salinity (ppt)
August 1980 - July 1981	35	158	2.04	0.2	22.6	28.7
February 1987 - January 1988	27	168	1.76	3.0	22.2	28.3
Variation	8	10	0.28	2.8	0.4	0.4

Source: *Lian Guangshan and Lin Yuhui (1993)*

Table 5.3. Number of phytoplankton, zooplankton and benthic species in Maluan Bay (1994)

Phytoplankton		Zooplankton		Benthos	
Bacillariophyta	39	Copepoda	19	Polychaeta	4
Pyrophyta	2	Medusa	2	Crustacea	2
		Lucifer	1	Mollusca	6
		Amphipoda	1		
		Euphausiacea	1		
Total	**41**		**24**		**12**

Source: *Third Institute of Oceanography, SOA (1994)*

Ecosystem Changes and Their Causes in Maluan Bay

Environmental Characteristics — Maluan Bay has become an enclosed water body, having little water exchange with the West Harbor. The dilution effects from freshwater runoff have gradually decreased water salinity with an average of 23.4 ppt over the years. In 1993, it ranged from 2.5 to 26.74 ppt. The low salinity in the bay suggests poor water exchange and pollutant accumulation.

Community Structure — Species in Maluan Bay are few. Only four groups of species have been recorded thus far *(see Table 5.3).* Despite the small number of species, the phytoplankton population has remained high at 1.62×10^9 ind/m^3. The dominant species are *Nitzschia delicatissima, Cyclotella comta, Skeletonema costatum* and *Chaetoceros affinis.* Their seasonal variation is shown in *Figure 5.1.*

The dominant benthic species are *Neanthes donghaiensis, Nectoneanthes oxypoda, Nectoneanthes multignatha, Dendronereis pinnaticirris, Mytilopsis sallei, Musculista senhausia, Ruditapes philippinarum, Potamocorbula ustulata* and *Sermyla riqueti.* The density and biomass of benthic species in Maluan Bay are shown in *Figures 5.2, 5.3* and *5.4.*

Major Ecological Problems — The presence of a small number of species with simple structure suggests that the marine ecosystem of Maluan Bay has been altered. In some parts of the bay, no benthic species were found but their water columns had been observed to be high in phytoplankton. These are partial indications of eutrophication.

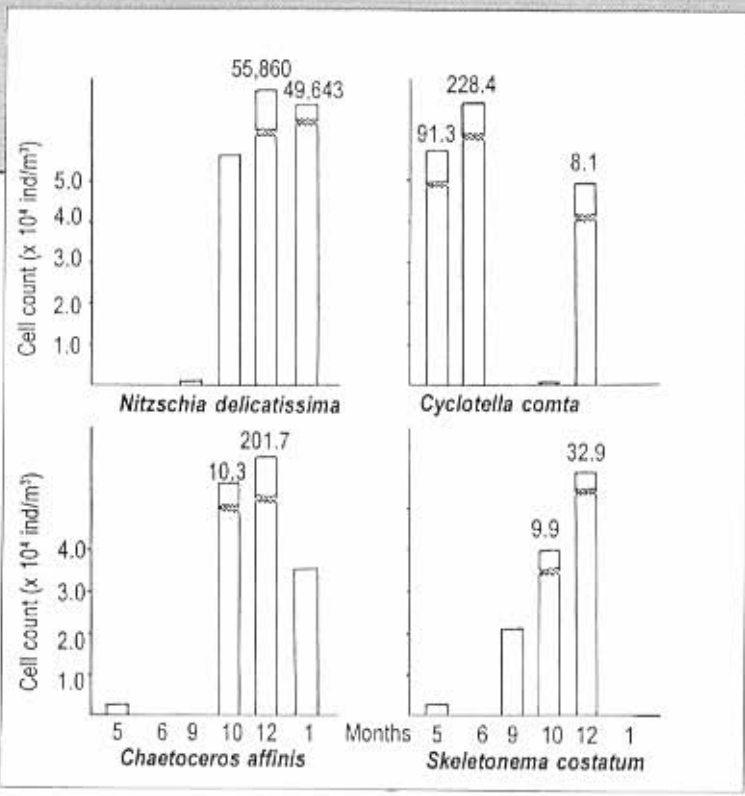
The construction of the Maluan Causeway and intensive mariculture in the bay have caused some impacts on its ecosystem. The causeway itself have reduced the water surface area by half. The sluice gates of the causeway are usually closed year-round, thus blocking water exchange between the bay and the West Harbor. In addition, the water between the causeway and Baozhuyu Island is stagnant with weak tidal currents of only 10 cm/s in the upper portion of the West Harbor and 20 cm/s in the channel southwest of Baozhuyu Island. In place of weak tidal current, a local eddy current allows suspended particulate materials to deposit in the sea area.

In recent years, mariculture nearly covered a large part of Maluan Bay. The intensive mariculture activities have generated a large amount of organic wastes (including uneaten feeds and fecal matters) resulting in the bay's poor environmental quality.

Ecosystem Changes and Their Causes in Tong'an Bay

Environmental Characteristics — For Tong'an Bay, the quality of both water and sediment is good and falls within Class II of the National Seawater Quality Standards although they contain high concentrations of the total inorganic nitrogen and phosphorus.

Figure 5.1. Seasonal variation of dominant phytoplankton in Maluan Bay



Source: *Third Institute of Oceanography, SOA (1994)*

Community Structure — Many species are found in Tong'an Bay *(see Table 5.4)*. The phytoplankton cell count shows a distinct seasonal variation, with an average of 9.13×10^6 ind/m^3, a high of 3.33×10^7 ind/m^3 in May and a low of 6.8×10^4 ind/m^3 in June *(see Figures 5.5 and 5.6)*.

The dominant species are *Chaetoceros affinis, C. curvisetus, C. debilis, Thalassionema nitzschioides, Leptocylindrus dannicus, Nitzschioides pungens, Bacillaria paradoxa, Asterionella japonica, Dactyliosolen mediterraneus, Bacteriastrum hyzalinum, Biddulphia sinensis, Coscinodiscus centralis, C. jonesianus, Ditylum brightwellii, Skeletonema costatum* and *Ceratium fusus*.

Their main ecotypes include those of eury-thermal-salinity, eurythermal-low-salinity, high-thermal-high-salinity, high-thermal-low-salinity and freshwater. The zooplankton cell count also shows a distinct seasonal variation, with an average biomass of 302 mg/m^3, a high of 966 mg/m^3 in May, and a low of 109 mg/m^3 in January.

The dominant species are *Oithona brevicornis, Labidocera euchaeta, Centropages tenuiremis, Acartia pacifica* (Copepoda), *Pleurobrachia globosa, Clytia folleatun* (Medusa), *Sagitta enflata* (Chaetognatha), *Pseudeuphausia sinica* (Euphausiidae), and *Lucifer hanseni* (Decapoda). Their main ecotypes include nearshore warmwater, estuarine low-salinity, nearshore warmwater, and eury-high-thermal-salinity.

About 208 sublittoral benthic species were identified *(see Table 5.4)*. However, the dominant species are: *Sternaspis scutata, Euniphysa aculeata, Terebellides stroemi, Lumbrineris nagae, Diopatra chiliensis, Tharyx marioni, Haploscoloplos* (Polychaeta); *Saccella cuspidata, Trigonothraccia jinxingae, Nucula nucleus* and *Musculista senhausia* (Mollusca); *Neoxenophthalmus obscurus* and *Xeno-phthalmus pinnotheroides; Amphioplus laevis, Dougaloplus echinatus, and Acaudina molpadioides* (Echinodermata).

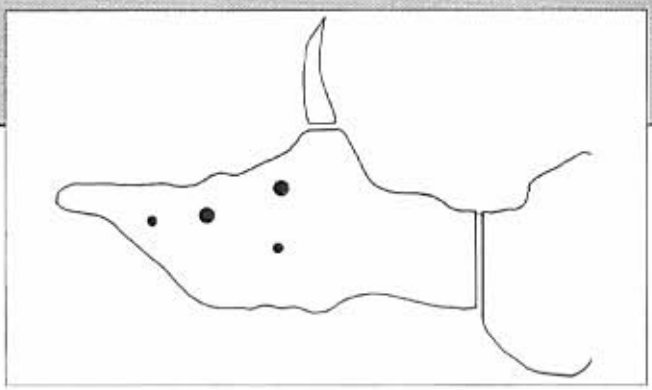


Figure 5.2. Spatial distribution of benthos in Maluan Bay

Legend *Spp. nos.*
- *1 - 5*
- *6 -10*

Source: *Third Institute of Oceanography, SOA (1993c)*

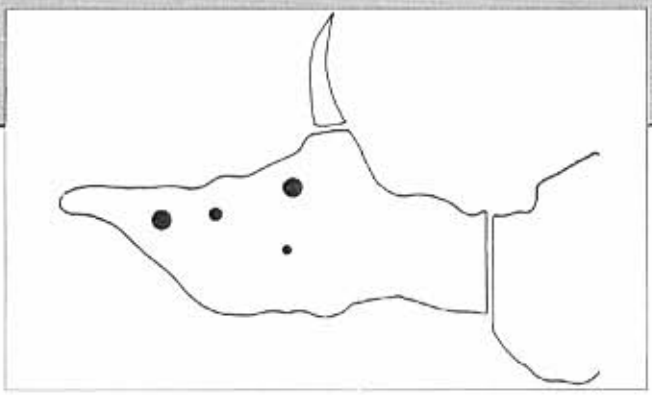


Figure 5.3. Spatial distribution of benthic density in Maluan Bay

Legend:
- *10 - 25 ind/m²*
- *50 - 100 ind /m²*
- *1,000 - 2,500 ind/m²*

Source: *Third Institute of Oceanography, SOA (1993c)*

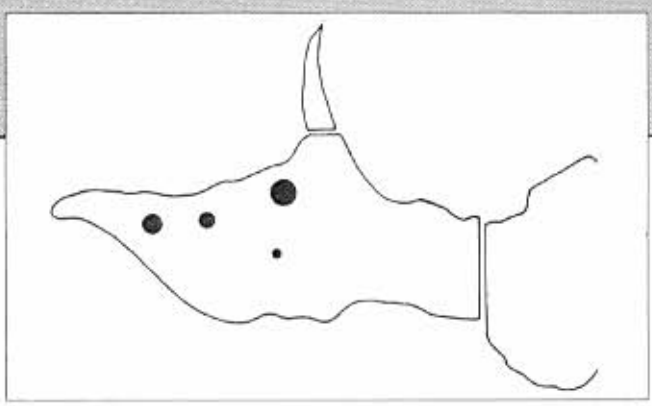


Figure 5.4. Spatial distribution of benthic biomass in Maluan Bay

Legend:
- *<1 g/m²*
- *25-50 g/m²*
- *100-250 g /m²*
- *250-500 g/m²*

Source: *Third Institute of Oceanography, SOA (1993c)*

Average biomass and total density of the above benthos are measured at 127 g/m^2 and 642 ind/m^3, respectively. The distribution by species and biomass is shown in *Figures 5.7, 5.8* and *5.9.*

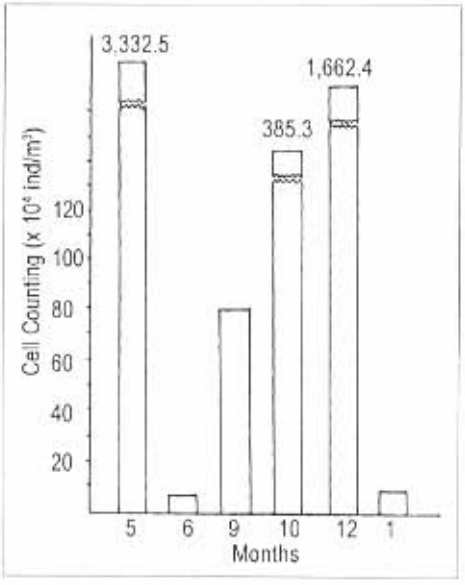
Table 5.4 shows 233 intertidal benthic species, with an even spatial distribution. The dominant species are: *Ceratonereis erythraeensis, Sternaspis scutata, Glycera subaenea, Cerithidae cingulata, Nassarius* spp., *Retusa boenesis, Musculista senhausia, Laternula marilina, Macrophthalmus japonicus, Uca* (Deltuca) *arcuata, U.* (Celuca) *lactea lactea, Ilyoplax tansujiensis* and *Macrophthalmus tomentosus.*

Table 5.4. Number of phytoplankton, zooplankton and benthic species in Tong'an Bay

Phytoplankton		Zooplankton		Benthos		Benthos of intertidal zone	
Bacillariophyta	80	Copepoda	37	Polychaeta	74	Polychaeta	75
Pyrophyta	14	Medusa	21	Crustacea	40	Crustacea	43
		Lucifer	3	Mollusca	51	Mollusca	72
		Amphipoda	2	Echinodermata	14	Echinodermata	12
		Euphausiacea	1	Benthic fish	19	Algae	5
		Chaetognatha	6	Others	10	Others	26
		Mysidacea	2				
		Acetes	1				
		Ostracoda	1				
		Larval plankton	10				
Total	**94**		**84**		**208**		**233**

Source: *Third Institute of Oceanography, SOA (1994)*

Figure 5.5. Seasonal variation of total phytoplankton cells in Tong'an Bay



Source: *Third Institute of Oceanography, SOA (1993b)*

The quantity and biomass of soft bottom intertidal benthos by major groups in Pantu and Houtian of Tong'an Bay are shown in *Figures 5.10* and *5.11*.

In general, the biodiversity and biomass of intertidal and sublittoral benthos in Tong'an Bay are higher than those of other waters, thus indicating its better environmental quality.

Main Ecological Problems in Tong'an Bay and the Protection of *Branchiostoma belcheri* — The construction of the Gao-Ji Causeway, the reclamation of mud flats and mariculture are the major issues concerning their effects on Tong'an Bay ecosystem. However, the impact of waste discharges is not considered significant.

The construction of Gao-Ji Causeway and its accompanying reclamation reduced the navigable area by 30 km² and another 35 km² by mariculture. These activities have polluted the water causing some adverse effects on marine ecosystem.

The population of *Branchiostoma belcheri* commonly known as lancelet has declined and its habitats have moved outward. Also, the increase in mariculture, especially shellfish culture which consumes large quantities of phytoplankton in Tong'an Bay, has reduced the biomass of phytoplankton in that area.

The lancelet, a rare warm water benthic species found in coarse, sandy sediments in the middle and sublittoral intertidal zones of Xiamen's coastal areas, is an ideal specimen for the study of the evolution and development of Chordata. It is listed in Category II of plants and animals which need government protection.

In terms of Xiamen's fishing grounds, the one near Liuwudian, Tong'an Bay, had an area of 22 km² before 1956 with an annual

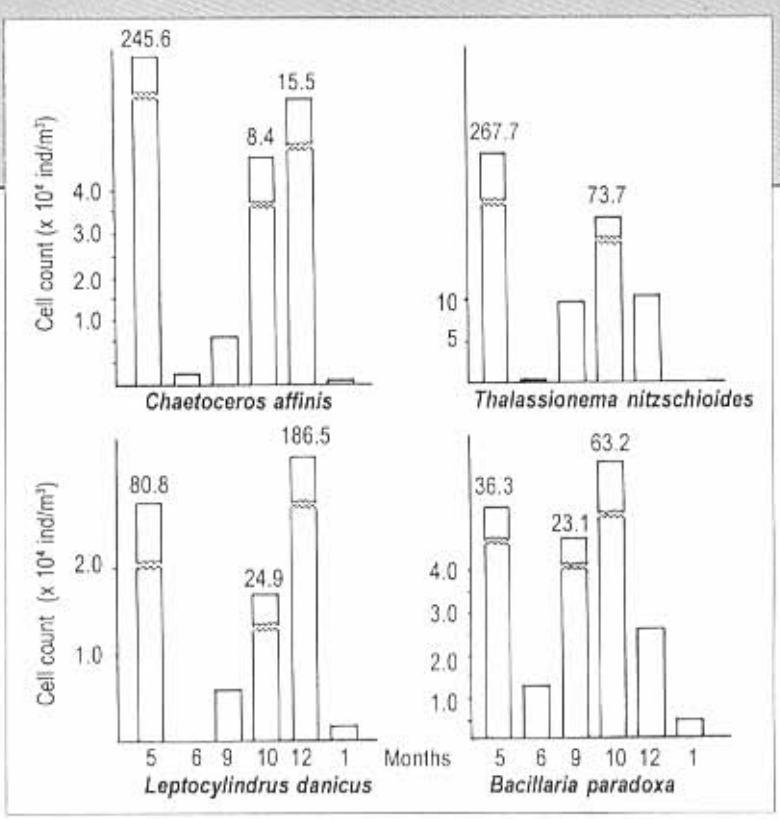


Figure 5.6 Seasonal variation of dominant phytoplankton cells in Tong'an Bay

Source: Third Institute of Oceanography, SOA (1993b)

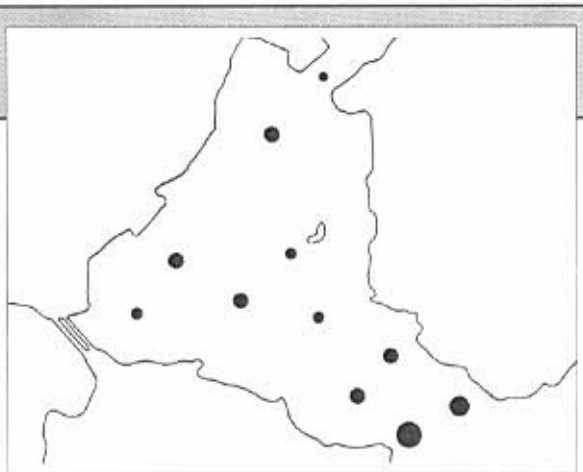


Figure 5.7. Spatial distribution of benthic species in Tong'an Bay

Legend	*Spp. nos.*
•	*5 -10*
•	*11 - 20*
•	*21 - 30*
•	*31 - 40*
•	*41 - 50*

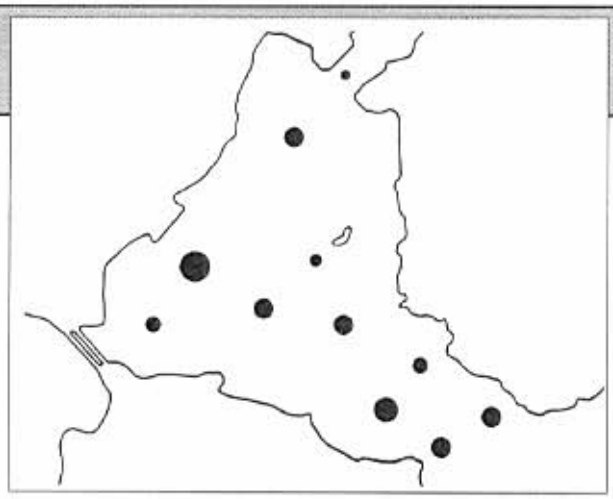
Source: Third Institute of Oceanography, SOA (1993.c)

production of 70-150 tons and the highest yield at 282 tons. Since 1970, fish catch has drastically declined to only about a ton. The change from sandy into silty sediment due to reclamation near Liuwudian and overfishing in Tong'an Bay were attributed to the depletion of *Branchiostoma belcheri*. To prevent further decline in their population, the Xiamen Municipal Government approved the establishment of protected areas for lancelets *(see Figure 5.12)*.

Ecosystem Changes and Their Causes in the Estuary and the Outer Harbor

Environmental Characteristics — The Jiulongjiang River Estuary, which is administered by both the Xiamen Municipality and Zhangshou City, has a narrow mouth and a large inland body. Its harbor, the Outer Harbor, has a water depth

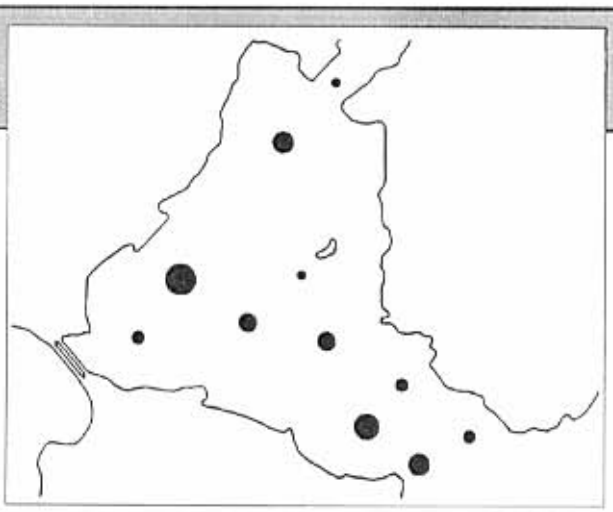
Figure 5.8. Spatial distribution of benthic density in Tong'an Bay



Legend:
- *25 - 50 ind/m²*
- *50 - 100 ind/m²*
- *250 - 500 ind/m²*
- *1,000 - 2,500 ind/m²*
- *>2,500 ind/m²*

Source: *Third Institute of Oceanography, SOA (1993c)*

Figure 5.9. Spatial distribution of benthic biomass in Tong'an Bay



Legend:
- *1-5 g/m²*
- *5-10 g/m²*
- *10-25 g/m²*
- *25-50 g/m²*
- *50-100 g/m²*
- *> 500 g/m²*

Source: *Third Institute of Oceanography, SOA (1993c)*

of 7-20 meters and its northern side faces the golden beaches of Gulangyu Island, the Hulishan and the Baishi fort.

The water of the estuary is hyposaline at the surface and saline at the bottom. The water column is a mixture of 55 percent offshore water and 45 percent freshwater.

Dissolved oxygen, COD, inorganic phosphorus and oil contents fall within Classes I and II of the National Seawater Standards. However, the inorganic nitrogen concentration usually exceeds Class III standard. The fecal coliform count is high, exceeding 1.0×10^4 ind/l at the mouth of the estuary and below 1.0×10^4 ind/l in the Outer Harbor during flood season in May and June.

The quality of sediment is generally good except in the northern coast of Jiyu Island and in the southern coast of Haicang. The levels of sulfide and organic substances in sediments have not exceeded the standard.

Community Structure — Species recorded in the area (in the estuary and Outer Harbor) are listed in *Table 5.5.*

Phytoplankton cell count has an average of 1.06×10^6 ind/m^3 and a minimum of 5.90×10^6 ind/m^3 in the month of May *(see Figures 5.13 and 5.14).*

The dominant species are *Chaetoceros curvisetus, Skeletonema costatum,* and *Thalassionema nitzschioides.*

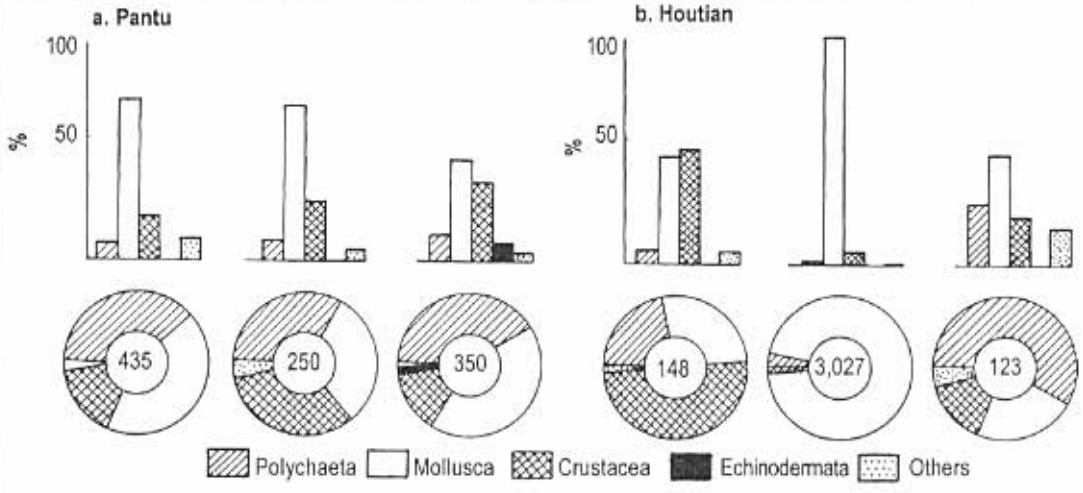
For zooplankton cell count, the maximum total biomass and density have reached 626.7 mg/m^3 and 462.0 ind/m^3, respectively in the month of May. The dominant species are *Labidocera*

Table 5.5. Number of phytoplankton, zooplankton and benthos species in the Jiulongjiang Estuary and the Outer Harbor

Phytoplankton		Zooplankton		Benthos	
Bacillariophyta	97	Copepoda	34	Polychaeta	60
Pyrophyta	19	Medusa	23	Crustacea	36
Cyanophyta	1	Lucifer	3	Mollusca	46
Chrysophyta	1	Amphipoda	5	Echinodermata	5
Chlorophyta	1	Euphausiacea	1	Benthic fish	19
		Chaetognatha	7	Others	18
		Mysidacea	5		
		Acetes	1		
		Ostracoda	3		
		Cladocera	2		
		Pteropoda	1		
		Leptocchela	1		
		Larval plankton	10		
Total	**119**		**96**		**184**

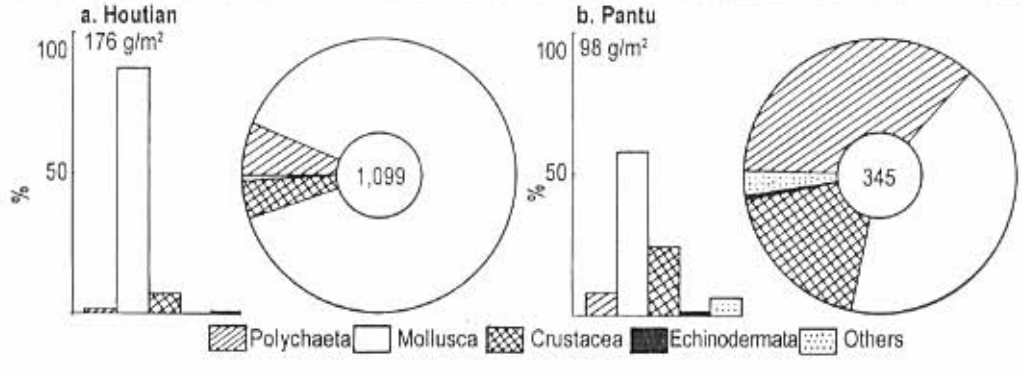
Source: *Third Institute of Oceanography, SOA (1994)*

Figure 5.10. Vertical distribution and composition of benthos in soft bottom intertidal zone of Tong'an Bay



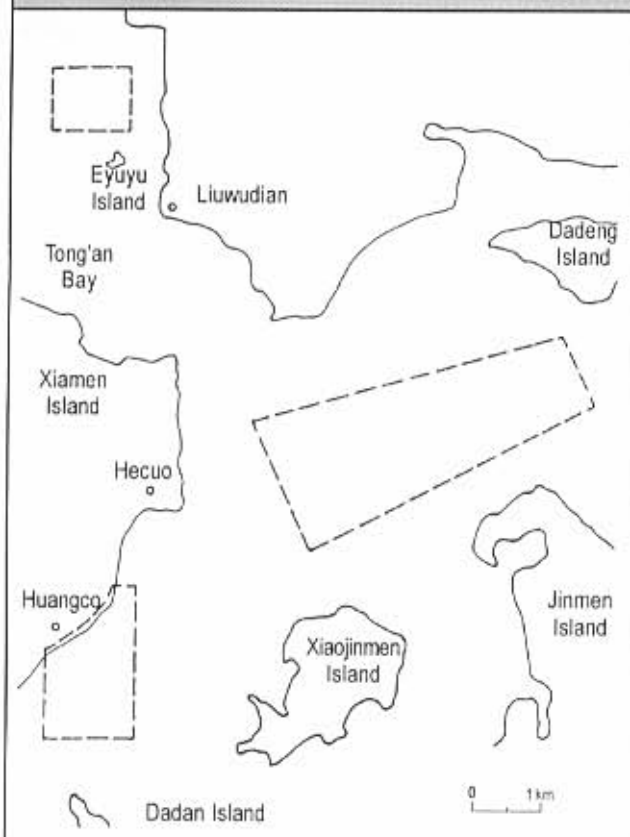
Source: *Third Institute of Oceanography, SOA (1993c)*

Figure 5.11. Distribution of biomass of benthic communities in soft bottom intertidal zone of Tong'an Bay.



Source: *Third Institute of Oceanography, SOA (1993c)*

Figure 5.12. Sketch map of Xiamen nature reserves for *Branchiostoma belcheri*



euchaeta, Schmacheria poplesia and *Pleurobrachia globosa*. The nearshore warmwater species are the most abundant.

Out of 163 benthic species, the dominant ones are: *Sternaspis scutata, Mediomastus californiensis, Diopatra chiliensis, Tharyx marioni, Ophelina acuminata, Glycera chirori, Trigonothracia jinxingae, Nassarius succinctus, Hexapus anfractus, Neoxenophthalmus obscurus, Xenophthalmus pinnotheroides, Eriocheir leptognathus, Amphioplus laevis,* and *Protankyra bidentata*. The number of species, biomass and density of benthos are shown in *Figures 5.15, 5.16* and *5.17*.

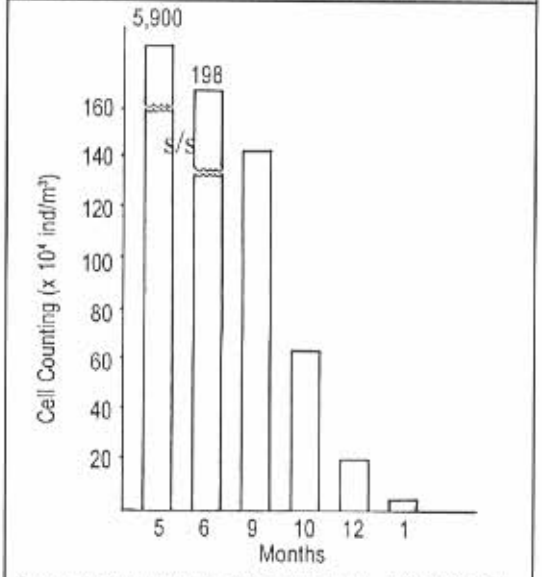
The number of benthic species has decreased as their distribution moved from the Outer Harbor to the estuary. There are fewer benthic species in the estuary and its Outer Harbor than in Tong'an Bay.

The distribution of benthic biomass varies with high values in the southeast coastal waters of Jiyu Island (with an average of 290.6 g/m^2) and around Yuziwei (with an average of 111.8 g/m^2). Low value, on the other hand, is found in the western coastal waters of Jiyu Island with a range of 1-5 g/m^2.

The total density decreases from the Outer Harbor inwards. Density values are 100-2,500 ind/m^2 in areas east of Jiyu Island; 50-100 ind/m^2 in areas west of Jiyu Island; and 15 ind/m^2 in other areas. Biodiversity index, with an average of 2.85, is higher in the Outer Harbor and lower in the estuary.

Major Ecological Problems and the Protection of the Chinese White Dolphin and Mangroves — Port development, marine fishing, mariculture and land-based waste discharges affect not only the waters within XDS, but also beyond, including Zhangzhou City, the upper basin of Jiulongjiang River and Jinmen Islands. Four jetties with a loading capacity of at least 10,000 tons are

Figure 5.13. Seasonal variation of total phytoplankton cells in the Jiulongjiang Estuary and the Outer Harbor



Source: *Third Institute of Oceanography, SOA (1993b)*

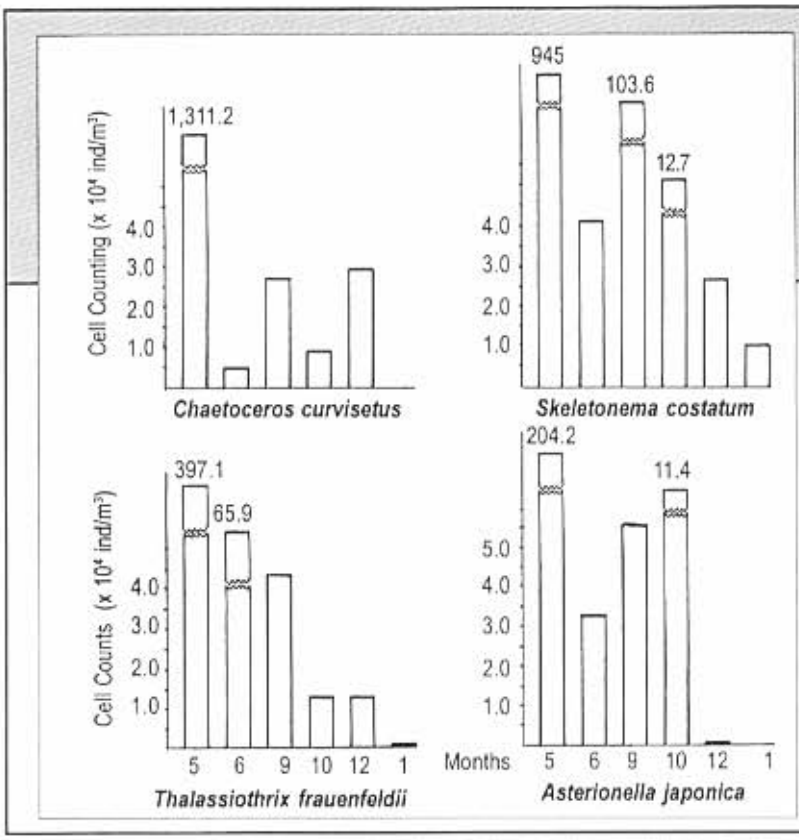


Figure 5.14. Seasonal variation of dominant phytoplankton cells in the Jiulongjiang Estuary and the Outer Harbor

Source: Third Institute of Oceanography, SOA (1993b)

Figure 5.15. Spatial distribution of the number of benthic species in the Jiulongjiang Estuary and the Outer Harbor

Legend: Spp. nos.
- *1 - 5*
- *6 - 10*
- *11 - 20*
- *21 - 30*
- *31 - 40*

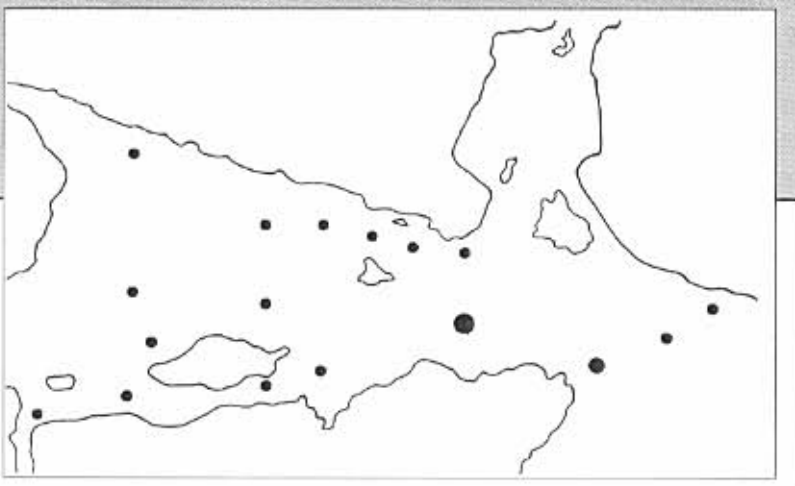
Source: Third Institute of Oceanography, SOA (1993c)

being constructed at Songyu, Qianyu and Dashiken at the southern coast of the estuary.

Mariculture is concentrated in areas under the jurisdiction of Zhangzhou City. Cultured species include prawn, oyster, razor clam and *Porphyra* with a total annual production valued at 20,000 Yuan from an area of 12.58 km^2 alone but including 6.5 km^2 for oyster culture. The mariculture area under the administration of Xiamen Municipality is less than 1 km^2.

Mariculture has become an important source of income for the local residents. Another is fishing which employs small fishing boats to catch shrimps, crabs, small trash fish and eel fry. Although eel fry is the main catch of the locals, its serious depletion has prompted the authorities to impose measures to sustain eel fry resources.

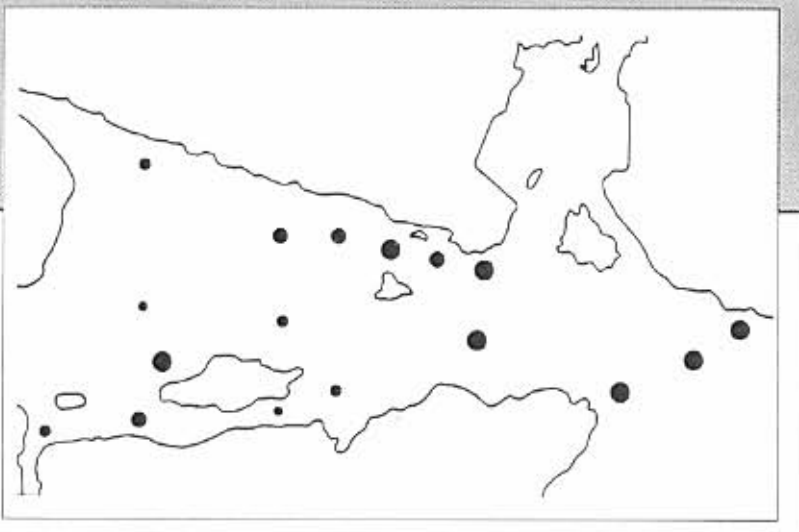
Figure 5.16. Spatial distribution of benthic biomass in the Jiulongjiang Estuary and the Outer Harbor



Legend:
- < 100 g/m²
- 100-250 g/m²
- 250-500 g/m²

Source: *Third Institute of Oceanography, SOA (1993c)*

Figure 5.17. Spatial distribution of benthic density in the Jiulongjiang Estuary and the Outer Harbor



Legend:
- 10-25 ind/m²
- 25-50 ind/m²
- 50-100 ind/m²
- 100-250 ind/m²

Source: *Third Institute of Oceanography, SOA (1993c)*

In terms of wastewater discharges, the economically-developed areas of Qianyu, Gulangyu Island and the Zhongyin Development Zone are projected to produce combined wastewater discharges amounting to 740,000 t/d by 2010.

Although the estuary and the Outer Harbor have good water exchange, such projected amount of discharge could have serious implications. It is important, therefore, to assess their possible impacts and formulate strategies to counter such impacts. The impact-laden activities (i.e., land-based waste discharge, mariculture, etc.) already mentioned affect not only the estuary and its Outer Harbor but also areas outside the XDS, such as Zhangzhou City, the upper basin of Jiulongjiang River and Jinmen Island.

The Chinese white dolphins *(Sousa chinensis)* found in the waters of the Outer Harbor and the estuary are included in the list of protected species. It is said that dolphins discourage sharks from attacking swimmers. Because of this, the local people consider the white dolphins as the *Treasure of the Port*. In the 1990s, unfortunately, their number has declined, and they can be found only in Xiamen's offshore waters.

Mangroves are mainly found near Haimen Island outside of the XDS. However, the areal extent of 100 ha has significantly decreased from the former area of 300 ha. Small groups of mangroves within the Xiamen Municipality can be found in Haicang, Dongyu Island and near Jiyu.

Chapter 6:

Legal Framework on the Protection and Management of Xiamen's Coastal Waters

Legislations definitely play a vital role in the protection of marine environment. Their importance is dictated by the legal necessity to determine and define management structure, processes and modalities; marine environmental quality standards; major measures for the prevention and mitigation of pollution to ensure these standards; the legal liabilities resulting from violation of the marine environmental protection laws and regulations; and the rights and procedures for environmental management and enforcement of laws.

However, previous experiences clearly show that enacting environmental laws with all the accompanying penalties is one thing; enforcing and implementing them is another. More often than not, the problem lies in the enforcement.

Legislations are effective inasmuch as they are adequate. Their provisions are clearly defined and strictly enforced. However, laws or regulations are certainly not enough. The presence of sufficient means and logistics to prevent or mitigate marine pollution is equally important.

Marine Environmental Legislation

Under Article 58, Item 1 of Articles 89, 90 and 100 of the *Constitution of the People's Republic of China*, the National People's Representative Congress and Its Standing Committee, the State Council and its administrative departments and commissions, and the Local People's Representative Congress and its Standing Committee have the power to enact laws relating to marine protection and management.

National People's Representative Congress and Its Standing Committee — The National People's Representative Congress and Its Standing Committee is the Government's lawmaking body that has the power to enact laws for the State. Thus, the application and scope of the marine environmental laws it has passed cover the whole nation.

The State Council and Its Marine Administrative and Environmental Protection Agencies — According to the Constitution of China, the State Council is the organ tasked to pass administrative measures and rules, promulgate decisions, and issue orders. The measures passed by the State Council are mainly administrative in nature.

In case of conflict between the laws passed by the National People's Representative Congress and its Standing Committee and those enacted by the State Council, the former shall override the latter.

The State Council's marine environmental administrative agencies, such as the State Oceanic Administration (SOA), the Environmental Protection Agency (EPA), and others, shall—in accordance with relevant laws, administrative rules, decisions and orders—issue orders, instructions and regulations known as *Department Rules* within their jurisdictions.

The Department Rules shall not contradict the laws and administrative regulations passed by the State Council. In addition, their legal applications cover only those subjects administered within the department authority and other departments or agencies as may be authorized by the State Council.

Local People's Representative Congress and Its Standing Committee — The People's Representative Congress and its Standing Committee of provinces and municipalities are directly under the Central Government. Provinces and other municipalities, with a higher level of autonomy, have the power to

enact local laws and regulations provided these are not in conflict with existing national laws. The laws passed by this body are registered by the Standing Committee of the National People's Congress.

The power to enact laws for the Fujian Province, of which Xiamen is part, belongs to the province's People's Representative Congress and Its Standing Committee.

The Xiamen People's Representative Congress, Its Standing Committee, and the Xiamen Municipal Government — On 20 March 1994, the Xiamen People's Representative Congress and Its Standing Committee obtained the mandate to enact laws at the municipal level. It was further authorized by the National People's Representative Congress to pass laws and regulations covering the Xiamen Special Economic Zone. At the municipal level, this body can pass laws relating to the protection and management of Xiamen's coastal waters. It was also empowered to determine the administrative jurisdiction of the XDS.

National Policies on Marine Environmental Protection

There are pertinent laws and regulations on marine protection and management promulgated from 1983 to 1990. These laws, which are mostly national in scope, are listed in *Table 6.1.*

The Scope of National Policies on Marine Environment

Territorial Scope — The *Marine Environmental Protection Law of the People's Republic of China,* as provided for in Article 2, shall apply to China's internal waters, territorial seas and other waters under China's jurisdiction.

As provided for in Item 3 of Article 2, the law also applies to the discharge of harmful substances and the dumping of wastes in sea areas beyond the jurisdiction of the People's Republic of China but have caused pollution to spread to its territorial waters.

Table 6.1. Laws and regulations on marine environment

Title	Date of promulgation
1. *The Marine Environmental Protection Law of the People's Republic of China*	23 Aug. 1982
2. *Regulations of the People's Republic of China Concerning Environmental Protection in Offshore Oil Exploration*	29 Dec. 1983
3. *Regulations of the People's Republic of China Concerning the Prevention of Pollution in Sea Areas by Vessels*	29 Dec. 1983
4. *Regulations of the People's Republic of China Concerning the Dumping of Wastes at Sea*	6 Mar. 1985
5. *Fisheries Law of the People's Republic of China*	1 Jan. 1986
6. *Regulations for the Implementation of the Fisheries Law of the People's Republic of China*	14 Oct. 1987
7. *Regulations of the People's Republic of China Concerning the Prevention of Environmental Pollution by Ship-breaking*	18 May 1988
8. *Rules for the Implementation of Laws on Water Prevention and Curation of the People's Republic of China*	12 Jul. 1989
9. *Regulations of the People's Republic of China Concerning Pollution Damage to the Marine Environment by Coastal Construction Projects*	25 May 1990
10. *Regulations of the People's Republic of China Concerning the Prevention and Damage to the Marine Environment by Land-based Pollutant*	25 May 1990
11. *The Interim Regulations Concerning Management and Use of State Seawaters*	31 May 1993

Scope of Objectives — The *Marine Environmental Protection Law of the People's Republic of China,* as provided for in Item 2 of Article 2, applies to any ship, platform, aircraft, submarine, enterprises and individuals undertaking navigation, exploration, exploitation, production, scientific research and other activities within the territorial waters of China.

In addition, the law stipulates that individuals performing those activities have the responsibility to protect the marine environment of China. They have the obligation to supervise and report any behavior and/or source of pollution adversely affecting the country's marine environment.

Management Approaches to Protect Marine Environment — Laws and regulations, such as the *Environmental Protection Law* and the *Marine Environmental Protection Law* of the People's Republic of China, which embody the basic principle of environmental protection that puts primary importance on prevention and mitigation, have adopted the following approaches for marine protection and management:

- Environmental quality standards;
- Key protection areas of marine environment;
- EIA (Environmental Impact Assessment);
- System of three-concurrency (i.e., development projects and their facilities for pollution prevention and mitigation must be simultaneously designed, constructed, and put into production);
- System of application, registration, and licensing of pollutant discharge;
- Pollutant discharge fee;
- System of pollution control deadline;
- Compulsory emergency measures;
- Monitoring, surveillance, and inspection;
- Marine pollution reporting; and
- Administrative penalty.

Legal Liabilities:

- Administrative liabilities;
- Civil liabilities;
- Criminal liabilities; and
- Disciplinary sanctions.

Procedures for the Enforcement and Judicature of Marine Environmental Laws — The effective implementation of laws (specifically environmental laws) needs a set of well-defined and systematic procedures.

Without implementing rules and guidelines, government authorities and agencies will only find it difficult to implement laws in their areas of jurisdiction, as loopholes may arise. In addition, the presence of such guidelines will ensure that the concerned administrative department performs its functions efficiently and guide the conduct of its personnel in performing their duties relating to marine protection.

There are two sets of procedures in implementing the country's marine environmental laws:

- A set of unified supervision and management procedures have been stipulated in the Interim Regulations Concerning the Management and Use of State Seawaters. However, the general procedures on marine environmental management have not been formulated.
- Judicial procedures concerning enforcement of marine environmental laws and adjudication.

Institutional Arrangements for Marine Environmental Management — As stipulated in Article 5 of the *Marine Environmental Protection Law of the People's Republic of China*, the Environmental Protection Administration under the State Council is in charge of marine environmental protection for the whole country.

The SOA is responsible for "comprehensive marine management," organizing scientific

investigation, monitoring, surveillance and research on marine environment. It is also in charge of protecting the marine waters against damages caused by oil exploration and exploitation, as well as waste dumping at sea.

In the People's Republic of China, the Harbor Superintendency Administration, the State Fisheries Management Bureau, the Fishery Harbor Superintendency and the Environmental Protection Department of the Armed Forces are all responsible for the supervision and surveillance of port, fishing and navigational activities, including pollutant discharges from civilian ships, ports, fishing boats and military vessels.

The Environmental Protection Departments of the coastal provinces, autonomous regions and municipalities directly under the central government are responsible for coordinating, overseeing and monitoring marine environmental protection activities in their respective administrative areas. They are also in charge of protection against damage from coastal engineering projects and land-based pollutants.

The State Environmental Protection Administration assumes general responsibility for protecting the environment as a whole. The concerned departments of the State Council also share responsiblities and interact with the provincial and local government units and other sectors.

Local Marine Environmental Regulations *(Fujian Province and Xiamen Municipality)*

Purpose of Local Legislation — The Local People's Representative Congress and Its Standing Committee enact local marine environmental legislations by initially conducting a public hearing and considering the indigenous practices. Such legislations are applicable only to the local administrative districts.

The purposes of these legislations are: (1) to define national marine regulations in relation to local application; and (2) to formulate specific regulations or local measures to safeguard the local marine environment.

Legal Bases — The legal bases for the local legislative body to adopt local regulations on marine protection are:

- The rights and power of the Fujian Province and Xiamen Municipality People's Representative Congress and Its Standing Committee to enact laws are embodied in the *Constitution* and authorized by the National People's Representative Congress;
- Item 2 of Article 47 in the Marine Environmental Protection Law authorizes the Standing Committee of the People's Representative Congress and the People's Government of the coastal provinces, autonomous regions and municipalities directly under the central government to, in accordance with this law, adopt specific measures with due consideration of the actual local conditions;
- Articles 6 and 7 of the *Law for the Prevention and Mitigation of Water Pollution* and Article 38 of the *Detailed Rules and Regulations for the Implementation of the Law for the Prevention and Mitigation of Water Pollution* authorize the Local People's Government to formulate supplementary standards concerning the local aquatic environment; adopt regulations on local pollutant discharge which could be stricter than the national regulations; and report to the State Environmental Protection Administration for record keeping; and
- Article 35 of the *Regulations of the People's Republic of China Concerning the Prevention of Pollution Damage to the Marine Environment by Land-based Pollutants* and Article 32 of the *Regulations of the People's Republic of China Concerning the Prevention of Pollution Damage to Marine Environment from Coastal Construction Project* authorize the People's Government of the coastal provinces to formulate specific measures with due

consideration to the actual conditions of its administrative region.

Legislative Guidelines for Marine Environmental Protection of Fujian Province and Xiamen Municipality — There are several local marine environmental regulations enacted from 1986 to 1994, which are being implemented in Fujian Province and Xiamen Municipality *(see Table 6.2)*

The *Regulations for the Environmental Protection of the Xiamen Municipality* (herein referred to as *Regulations*) laid the groundwork for environmental legislations of the Xiamen Municipal Government. However, the concomitant regulations and management procedures have yet to be formulated.

Major Contents of the Marine Environmental Legislations of Xiamen Municipality — In relation to national legislations on marine environment, the marine laws and regulations of the Xiamen Municipality contain the following basic characteristics:

- Basic principles of marine environmental legislation are further defined;
- Distinctions on the functions and responsibilities of the various marine environmental protection organizations are made clear;
- Establishment of the system for water resource protection;
- Protection of the coastal environment; and
- Protection of the Yuan Dang Lake environment.

Approaches to Marine Environmental Management in Xiamen — Marine environmental management in Xiamen involves the following approaches:

- Local environmental quality standards (*Functional Zonation and Waste Discharge Standards of the Xiamen Municipality*);
- Environmental Impact Assessment (EIA) on the development and exploitation of water resources and construction in development zones (Articles 11 and 19 in the *Regulations*);
- A system of three-concurrency for construction projects (Article 21 in the *Regulations*);
- A system of review and approval for EIA of construction projects (Article 18 in the *Regulations*);
- A system of application, registration and licensing for pollutant discharge (Article 34 in the *Regulations*);
- Imposition of pollutant discharge fees (Article 33 in the *Regulations*);
- A schedule for pollution control deadline for projects which damage the environment by way of mitigation, correction, shut-down, suspension, transfer of business line and moving of project site (Articles 14, 15, 21, 43, and 44 in the *Regulations*);
- A system of limiting working time or pollutant discharge time and unit

Table 6.2. Marine environmental regulations in Fujian Province and Xiamen Municipality

Title	Date of promulgation
1. *Interim Provisions Concerning Resources Protection and Management of Sand, Stone and Soil*	1986
2. *Provisions Concerning Management of Storm Shelter at Shapowei Fishing Port by Xiamen Municipal Government*	1989
3. *Measures Concerning the Management of Yuan Dang Lake in Xiamen City*	1992
4. *Functional Zonation and Standards of Waste Discharge of Xiamen City*	1994
5. *Regulations for Environmental Protection of Xiamen City*	1994

quantity which produce severe environmental pollution and other public hazards (Article 36 in the *Regulations*);
- Environmental supervision and monitoring (Articles 6 and 35 in the *Regulations*);
- Accident reporting and emergency response (Article 37 in the *Regulations*); and
- Administrative punishments by means of penalty, deadline for improvement, correction or business suspension by order and other means (Articles 38-45 in the *Regulations*).

Supervisory Mechanisms for Marine Management Measures — For the purpose of supervising the conduct of marine management, several mechanisms have been adopted as follows:
- Responsibility system for overall environmental protection targets;
- Quantitative control system of comprehensive environmental improvements (Item 1 of Article 3 in the *Regulations*);
- Integration of environmental protection plan into the national economic and social development plans;
- Inclusion of expenditures for preventing and mitigating pollution into the government budgets (Item 2 of Article 3 in the *Regulations*); and
- Requirement for entities causing environmental pollution and other public hazards to include the environmental protection issues and problems into their management agenda and technical reform plan (Article 24 in the *Regulations*).

Comparisons of the National Legislation with the Local Legislation of Xiamen Municipality — Though national and local legislations for marine environment share the same objective (i.e., protection and management of the marine environment), some differences arise as to their scope and application.

Nevertheless, these differences only serve as points of comparison and not as hindrances to the overall objective because they actually complement each other.

Basically, national legislations on marine environmental protection are general or comprehensive in scope and serve as the basic legal framework for local legislations.

The local legislations, on the other hand, are specific in scope and application, such that legislations passed by the lawmaking body of Xiamen Municipality are effective only within its jurisdiction or as specified. For example, to protect the Yuan Dang Lake from pollution, specific regulations have been adopted to address such problems in the said area.

However, the institutional arrangements, measures of management, liabilities as determined by national legislations and those provided for by Xiamen's local lawmaking body are more or less the same.

It is worth noting that Xiamen's local legislations pay attention to the supervision of marine management measures by setting responsibility targets and environmental protection plans for government institutions down to the pollution-producing entities.

Legislations that define the rights and responsibilities of national agencies and local government units in terms of marine protection and management will strengthen the mechanisms for the implementation and supervision of environmental measures.

In Xiamen Municipality, there are local legislations that limit the quantity of waste discharges of pollution-producing entities within a certain timeframe.

The ICM Targets and the Existing Laws and Regulations

Integrated Coastal Management — ICM as promoted under Agenda 21 of the United Nations Conference on Environment and Development (UNCED), is a viable mechanism to address coastal issues including marine pollution from a multi-user perspective.

The Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas (MPP-EAS), has identified Xiamen as one of its three demonstration sites for the mitigation of marine pollution arising from economic development by using the ICM framework.

Currently, Xiamen's coastal zones have been experiencing development problems that basically involve conflicts among various sectoral activities like agriculture, fisheries, navigation and coastal urban development, etc.

The ICM framework can be effective given the following elements:

- Pollution management in the coastal zones requires the coordination among various institutions and agencies with mandates on fishery administration, fishing port, harbor supervision, maritime safety, environmental protection, land management, etc.
- Coastal pollution management also calls for coordinated and complementary regulations covering various sectors, such as the *Law of Water, Law of Land Management, Law of Mineral Resources, Law of Fishery, Law of Marine Environmental Protection and Law of Environmental Protection.*

Under the ICM framework, such issues being faced by Xiamen could be addressed by developing a comprehensive coordination and management mechanism for the prevention and mitigation of pollution in its coastal areas.

Existing Problems Concerning Marine Environmental Protection — In view of the need to use an integrated approach to coastal management, the coastal zone should be taken as a continuum and treated as an ecosystem.

In Xiamen, present laws and regulations on marine environment apply separately to sectors with individual concerns and interests. Thus, each sector addresses problems of pollution, which can spread across sectors and boundaries, arising within their specific areas.

An integrative mechanism is, therefore, needed to unify individual sectoral efforts in addressing pollution problems that have cut across sectors and boundaries.

In addition, the enactment of new local laws and regulations should take into account this situation and also attempt to integrate efforts of various government agencies working on marine environment protection and management. On the other hand, old laws that are not responsive to this predicament need to be reviewed and improved.

At present, no mechanism for ICM has been established. Under the environmental protection laws of China, the State Environmental Protection Administration of the State Council is tasked with national environmental management as a whole. The SOA, Harbor Superintendency, Fishery and Fishing Port Superintendency, and Military Environmental Protection are responsible for the management of their own sectors.

Although the functions and responsibilities on environmental protection of different departments are adequately defined, they are not effective in dealing with cross-sectoral management problems, thus leaving them unresolved. Another factor is that local environmental departments are authorized by law to perform the coordination function but this has not been fully executed due to lack of either specific coordination procedures or mechanisms. For this reason, an integrated management mechanism is needed.

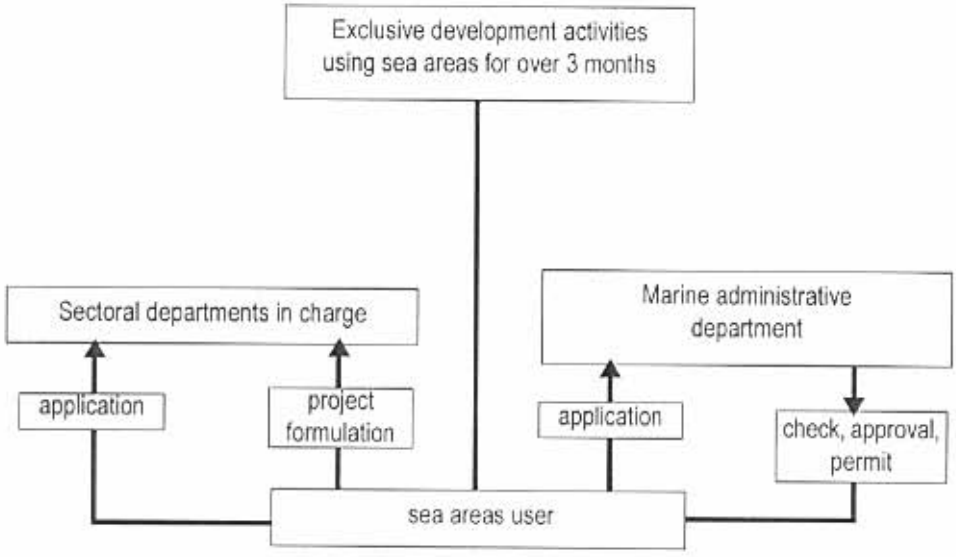
Previous experiences have shown that resource management when integrated with environmental protection is effective in achieving sustainable development. China, for instance, has not established such integrated approach. However, a similar mechanism is contained in the *Interim Regulations Concerning Management of the Use of State Seawaters* but is only applicable to the use of the sea. As provided for by the said law, the marine administrative department will

exercise, aside from coordination, overall supervision and management concerning use registration, issuance of use permit and use fee systems in the marine area; while other departments are responsible for the initial review and approval. Under this setup, the marine administrative department will ensure that management targets conform to overall societal interest rather than to departmental interest should use conflicts arise. Ideally, such mechanism should be more integrative than coordinative. However, this is not easy to achieve as there are rules to follow per department, as well as local and national laws to conform with, otherwise legal problems or impediments may arise.

As a concrete example, department rules (e.g., the *Interim Regulations*) have no power to prevail over other sectoral laws and regulations. The State Council or the Standing Committee of the National People's Congress has the power to modify the law or legal guideline in question.

Thus, it is necessary for an integrative mechanism to delineate the functions and responsibilities of various agencies which

Figure 6.1. Chart on institutional arrangements for a unified supervision and management of Xiamen coastal waters



(1) preliminary approval of project by sectoral department in-charge to secure sectoral benefit;
(2) final check, approval, and issuance of permit by marine administrative department to ensure that legal requirements are met;
(3) participation in management by sectoral departments in-charge and marine administrative department, embodying sectoral integration of marine management; and
(4) no direct coordination among sectoral departments and marine administrative departments concerned to assure efficient management and utilization of sea areas.

Source: *Interim Regulations Concerning Management and Use of State Seawaters*

have specific mandates on marine environment protection and management. It also has to take into account the need for a multi-sectoral and collaborative effort to marine pollution control and management.

Other problems that impede marine protection and management are due to legal issues. One problem is that procedures for the effective enforcement of laws by concerned agencies have not been formulated.

Also, existing regulations have not adequately defined pollution accidents by ships. Prevention and mitigation measures remain saddled by this inadequacy when faced by other types of accidents not defined in a specific regulation.

In case of pollution accidents, such as large-scale nearshore oil spill or spill of dangerous chemical goods arising from ship collision; grounding or fire where neither pollution-combating facilities onboard nor emergency measures can contain the rapid spread of the damage; the issue of compensation, persons to be held liable, and claimants in the oil pollution accidents have remain undefined. Coastal areas, such as Xiamen, need legislations that resolve these issues on pollution accidents for their own interest and benefit.

Another problem is that penalties or liabilities contained in the regulations on public hazards are hardly implemented due to vague judicial requirements and procedures. In disputes concerning civil damage compensations from public hazards, it is very difficult to prove the specific causal effect of pollution and corresponding damage. Therefore, in order to protect the rights and interests of the aggrieved, the law should specifically provide that in such disputes or cases, the complainant is only obliged to show a proof of damage. As for the cause of the damage, it should be up to the accused polluters to prove otherwise.

Chapter 7:

Environmental Management Status in Xiamen Coastal Waters

Marine Management System

At present, the management of marine resources and environment is done through the traditional sectoral approach at different levels.

Institutions Involved with Marine Management — Institutions and agencies for marine environmental management are established by the State in accordance with the rights and responsibilities to uphold the national interest as defined by the *Constitution.*

Several departments or agencies from the central government together with concerned units of the municipal government form the Xiamen marine management system *(see Figures 7.1* and *7.2).* The Xiamen municipal government units are described as follows:

- The Commission of the Sea/Frontier Defense of Xiamen Municipality is the coordinating body for the comprehensive management of marine frontier affairs.
- A branch of the Office of Ports Affairs was set up in 1980 in the Xiamen Municipal Government. It is responsible for the management and operation of the seaport and airport in Xiamen. Its functions include the organization, coordination, supervision and arbitration of various units defined by the *Provisional Management Regulations of Local Ports* issued by the State Council.
- The Xiamen Customs is the field agency of the State General Customs. Its function, as defined by the *Customs Law of the People's Republic of China,* is to execute the rights and

Figure 7.1. Departments, agencies and units involved in managing the coastal waters of Xiamen Municipality

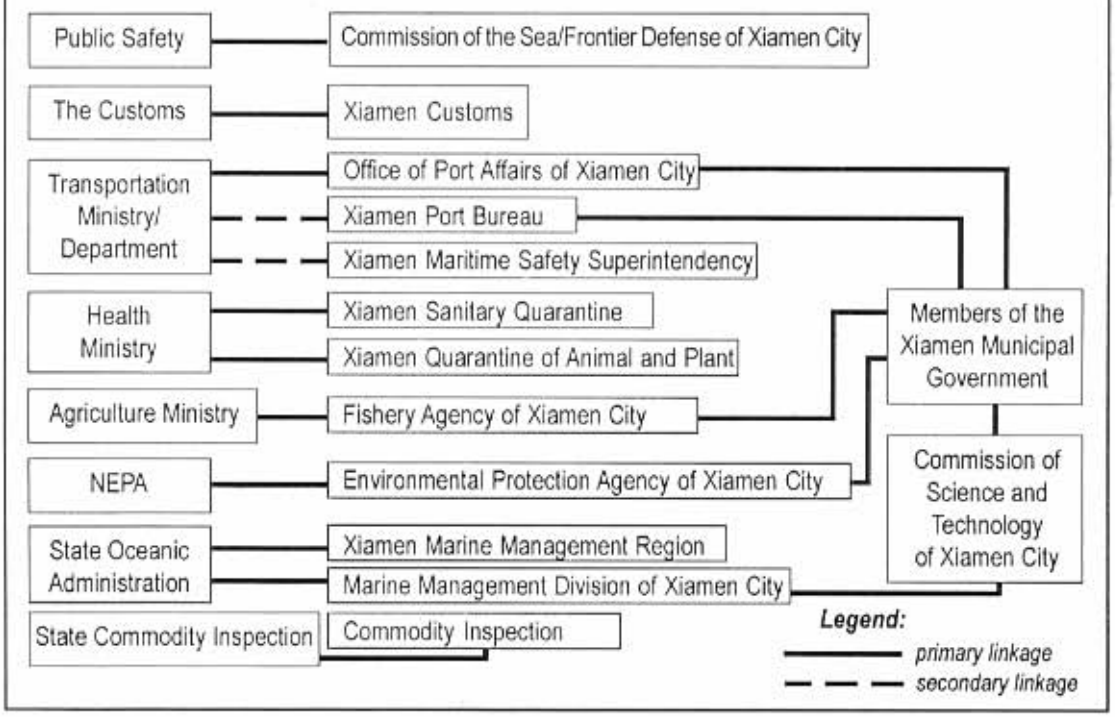


Figure 7.2. Functions and jurisdictions of Xiamen government units and their legal bases

DEPARTMENTS	LEGAL BASES	FUNCTIONS	ADMINISTRATIVE JURISDICTION
Commission of the Sea/Frontier Defense of Xiamen	Regulations Concerning Frontier Inspection	Eight functions including securing Xiamen's water rights, preventing smuggling and drug trafficking	
Xiamen Customs	Customs Law	Customs sovereign within its range, supervising passengers, goods and waste, entry/exit in the State; levy duty	Xiamen Quanzhou Zhangzhou Longyan
Office of Ports Affairs	Interim Provisions for Management of Local Port	Eight functions such as organizing, coordination, supervision, arbitration of port units involved	
Xiamen Maritime Safety Superintendency	Maritime Traffic Safety Law, Maritime Commerce Law	Maritime safety supervision, rescue, pollution prevention, management of ship waste discharge	Weitou Cape, Jinjiang to Gongkou, Zhao'an
Xiamen Commodity Inspection	Law of Import and Export of Commodity	Inspection and supervision of import and export commodity	
Xiamen Sanitary Quarantine	Sanitary Quarantine Law of Frontier	Quarantine affairs on persons, goods, vehicles; certificate issuance	
Xiamen Quarantine of Animal and Plant	Quarantine Law of Animal and Plant	Quarantine on animal, plant and package, survey of epidemic situation	
Xiamen Marine Management Region	Marine Environmental Protection Law, Regulations on Waste Dumping at Sea	Marine surveillance, survey, waste dumping at sea, scientific research	Shachen, Fuding to Gongkou, Zhao'an
Xiamen Marine Management Division	Written Reply by Xiamen City Government on Its Responsibilities	Coordination of units involved and comprehensive management of the coastal waters	
Xiamen Port Bureau	Development and Management Plan for Xiamen Port		
Xiamen EPA	Environmental Protection Law, Marine Environment Protection Law, Regulations of Environmental Protection of Xiamen	Unified management of marine environmental protection organization and coordination of marine environmental protection by units involved, prevention of pollution damage to sea by coastal engineering and land-based sources	
Xiamen Fishery Agency/Fishery Superintendency	Fishery Law, Marine Environmental Protection Law	Management of fishery, mariculture at sea and tidal flat, fishery jetty development, waste discharge from fishing boat	

responsibilities of the State to collect customs duties. Its jurisdiction goes beyond Xiamen to cover the municipalities of Quanzhou, Zhangzhou and the Longyan prefecture.

- The Xiamen Frontier Inspection is under the Public Security System of the Central Government. Its function under the *Regulations Concerning Frontier Inspection* issued by the State Council is to supervise the entry and exit of passengers and inspect their passport or certificate, baggage and transportation vehicles.
- The Xiamen Maritime Safety Superintendency of Fujian Province, which was set up in 1987, is the agency of the Transportation Department of Fujian Province. Under the *Maritime Traffic Safety Law of the People's Republic of China* and the *Maritime Commerce Law of the People's Republic of China*, it is responsible for the maritime safety superintendency and management, including the prevention of pollution by ship, search and rescue at sea, issuance of certificates for ships entering and exiting the port, joint inspection of import and export ships on international navigation routes and maritime disaster response within its jurisdiction which covers Weitou Cape, Jingjiang, Gongkou and Zhao'an.
- The Xiamen Sanitary Quarantine is an agency of the Ministry of Health. Its function, as defined by the *Sanitary Quarantine Law of the Frontier of the People's Republic of China,* is to implement quarantine on animals and plants including the containers and vehicles used within the area that covers Xiamen, Zhangzhou, Quanzhou, Longyan and part of the Sanming region.
- The Xiamen Commercial Commodity Inspection, which was set up in 1951, is the agency of the Commercial Commodity Inspection of the State. Its function under the *Law of Import and Export Commodity Inspection of the People's Republic of China* is to carry out inspection and superintendency of import and export commodities, as well as issuance of certificates.
- The Xiamen Marine Management Region, which was set up in 1985, is an agency of the State Oceanic Administration. Its function under *The Marine Environmental Protection Law of the People's Republic of China* is to carry out marine surveillance, investigation, scientific research and supervision of ocean dumping within an area covering Shachen, Fuding in the north of Gongkou and Zhao'an in the south.
- The Marine Management Division of Xiamen Municipality, which was set up in 1991, is under the Xiamen Municipal Government but attached to the Commission of Science and Technology. Its function is to coordinate the various marine management sectors for the comprehensive management of the coastal waters.
- The Port Bureau of Xiamen Municipality has the main responsibility in undertaking the development and management of ports and jetties, as well as the management of cargo transportation by ship.
- The Environmental Protection Agency of Xiamen Municipality, which was set up in 1976, is a branch of the Xiamen Municipal Government. Its function under *The Environmental Protection Law of the People's Republic of China*,

The Marine Environmental Protection Law of the People's Republic of China, and the *Regulations of Environmental Protection of Xiamen Municipality* is to carry out unified surveillance and management of the Xiamen area including its coastal waters. It is responsible for organizing the coordination, surveillance and inspection of the coastal waters of Xiamen Municipality. It is also in charge of preventing damage to the coastal marine environment arising from coastal engineering projects and land-based pollution. It is supervised and guided by the National Environmental Protection Agency (NEPA) and the EPA of Fujian Province.

- The Fishery Agency of Xiamen Municipality is a branch of the Xiamen Municipal Government. Its main function under *The Fishery Law of the People's Republic of China* and *The Marine Environmental Protection Law of the People's Republic of China* is to take charge of fishery activities within the jurisdiction of the Xiamen Municipality. It is also responsible for the management and surveillance of aquaculture in coastal waters and beaches, and the surveillance and management of waste discharges from fishing jetties and fishing boats.
- The function of the Navy at Xiamen Municipality, as defined by *The Marine Environmental Protection Law of the People's Republic of China,* is to provide marine environmental protection to military ships and ports.

Environmental Management Mechanisms for Xiamen Coastal Waters

The protection and management of Xiamen's coastal waters is the responsibility of the Municipal Government. To make the waters viable and environmentally-sound is definitely not an easy task to undertake for the Municipal Government. It needs the concerted effort of all parties concerned. In doing so, the municipal government takes into consideration the conditions in Xiamen and the recommendations and technical advice from agencies involved in environmental protection and marine management.

For its part, the municipal government through the exercise of its legislative power, provides the legal bases and instruments in carrying this task. Relevant laws and regulations, provisions, resolutions, orders or instructions are enforced or implemented by relevant agencies or sectors mandated for environmental protection, marine management, fishery, port, maritime surveillance, planning and civil affairs, among others.

However, in the process of performing their tasks and functions, two major problems arose: first, protection and management of the marine environment is usually carried on a sectoral or individual basis due to lack of an integrated mechanism; and second, marine environmental laws are not adequately and strictly enforced.

In general, while marine problems cut across sectors, existing implementing machineries are basically sectoral and individualized. Concerned agencies function only in accordance with their mandates and limited by their administrative jurisdictions. While several agencies have certain jurisdiction and responsibilities over coastal waters, these have never been fully defined, hence coordination has been problematic.

The lack of a mechanism to manage and coordinate sectoral and institutional efforts, more often than not, hampers the overall task of protecting and managing Xiamen's coastal waters. On the other hand, an existing mechanism is saddled by lack of a well-defined institutional arrangement in carrying out integrative and coordinative functions.

The second problem, weak enforcement of environmental laws, is not a special case for

Xiamen alone. Nevertheless, strict and adequate enforcement of marine laws is most desired. There could be enough legal bases by which government agencies could implement marine protection measures. But with weak enforcement of laws, establishments or business activities that make use of the coastal waters cannot be compelled to integrate pollution control measures in their operations. It is also the reason why existing pollution-control facilities by these establishments are not activated.

The utilization of marine resources contributes a lot in the socioeconomic development of Xiamen. However, pollution-control measures that have been incorporated into economic development plans are not fully implemented because of the absence of a well-defined management mechanism, weak enforcement of environmental laws, and also most importantly, because of financial constraint.

In order to achieve sustainable development of the coastal areas, it is necessary to shift to another management approach: integrated coastal management (ICM). The ICM approach provides the necessary framework, including options and measures with respect to environmental management, in dealing with cross-sectoral coordination and integration.

The ICM approach facilitates the pooling of available scientific information for the assessment of various coastal management issues from a multi-user and multi-sectoral perspective. There is no doubt that various agencies, including research and academic institutions, with certain responsibilities over the coastal waters have valuable information on marine environment. Given an integrated approach, it is possible to use these data to re-examine the issues facing the coastal areas. Issues such as resource-use conflicts and pollution can be addressed by generating more realistic strategies and options. Such re-examination will lead to identification of data gaps to which research should be focused to improve existing management actions.

Furthermore, ICM approach can provide some guidelines in which various sectors can be integrated and coordinated in the process of implementing the necessary mitigating measures adopted.

The data generated by the various agencies and institutions in Xiamen will form the substance of the awareness and education campaigns on the rational use of coastal resources. Such public awareness campaigns may take the form of quiz show, beautification and cleanliness contest, media exposure, community involvement (e.g., fisherfolk, coastal residents, etc., reporting pollution incidents to authorities), and the like. Since public awareness activities are limited to government and academic sectors, it is necessary to widen the scope of environmental awareness campaigns to reach the members of the general public. They also have the responsibility to minimize the impacts of their activities in exercising their right to use and enjoy the coastal waters.

Legal Framework and Mechanisms for Environmental Management

As cited in Chapter 6, the legal framework and system for coastal environmental management in Xiamen has been established. However, there are loopholes in terms of technical standards and legal procedures. The lack of technical capability and inadequate knowledge on environmental laws and issues, by authorities and personnel from concerned agencies, add to the problem of weak enforcement.

Moreover, most of the existing marine environmental laws and regulations were formulated during the period of centralized planning. But with the present market-oriented economic planning, such laws and regulations are rendered insignificant and limited considering the existing conditions.

Despite such problems, the environmental quality of Xiamen's marine waters has steadily improved since the 1980s when these rather ineffective laws and regulations were passed and implemented.

Basically, Xiamen's legal framework and system of marine prevention and management are based on the following principles and mechanisms:

- prevention first;
- polluter pays;
- developers are bound to protect the environment; and
- strengthening supervision and management.

These laws and regulations specifically require EIA, emission permit, waste treatment center, control of pollution at source, assessment of improvement on urban environment and responsibility system for environmental targets.

In particular, effluent standards serve as mechanisms to regulate pollutant discharges from land-based sources. Such standards were promulgated by the government of Fujian Province in 1989. Recently, the regulation on waste discharges has been applied to more than 1,000 new construction projects. For the marine environment as a whole, the Central Government has formulated the National Seawater Quality Standard which is the basis for the local implementation of water quality standards. However, such regulations remain to be enforced.

Mechanisms for Environmental Management of Construction Projects

An important strategy for environmental management is to control the pollution impacts of new construction projects. For this purpose, the law requires EIA for project development and operation.

EIA for Review and Approval of Construction Project Applications — The Environmental Protection Agency (EPA) reviews the construction project based on its EIA and design of environmental protection facilities before approval is given. The procedure is illustrated in *Figure 7.3.*

Procedures for Consideration and Approval of the EIA Report on Construction Projects — *The Environmental Protection Law of the People's Republic of China* stipulates that construction operators must apply with the Department of Environmental Protection for review and approval of its project. Large-, medium- or small-scale projects, which may cause pollution, must prepare an EIA report; while other small projects must fill in an EIA form.

The details of the *System of EIA Report for Construction Projects* used in China are as follows:

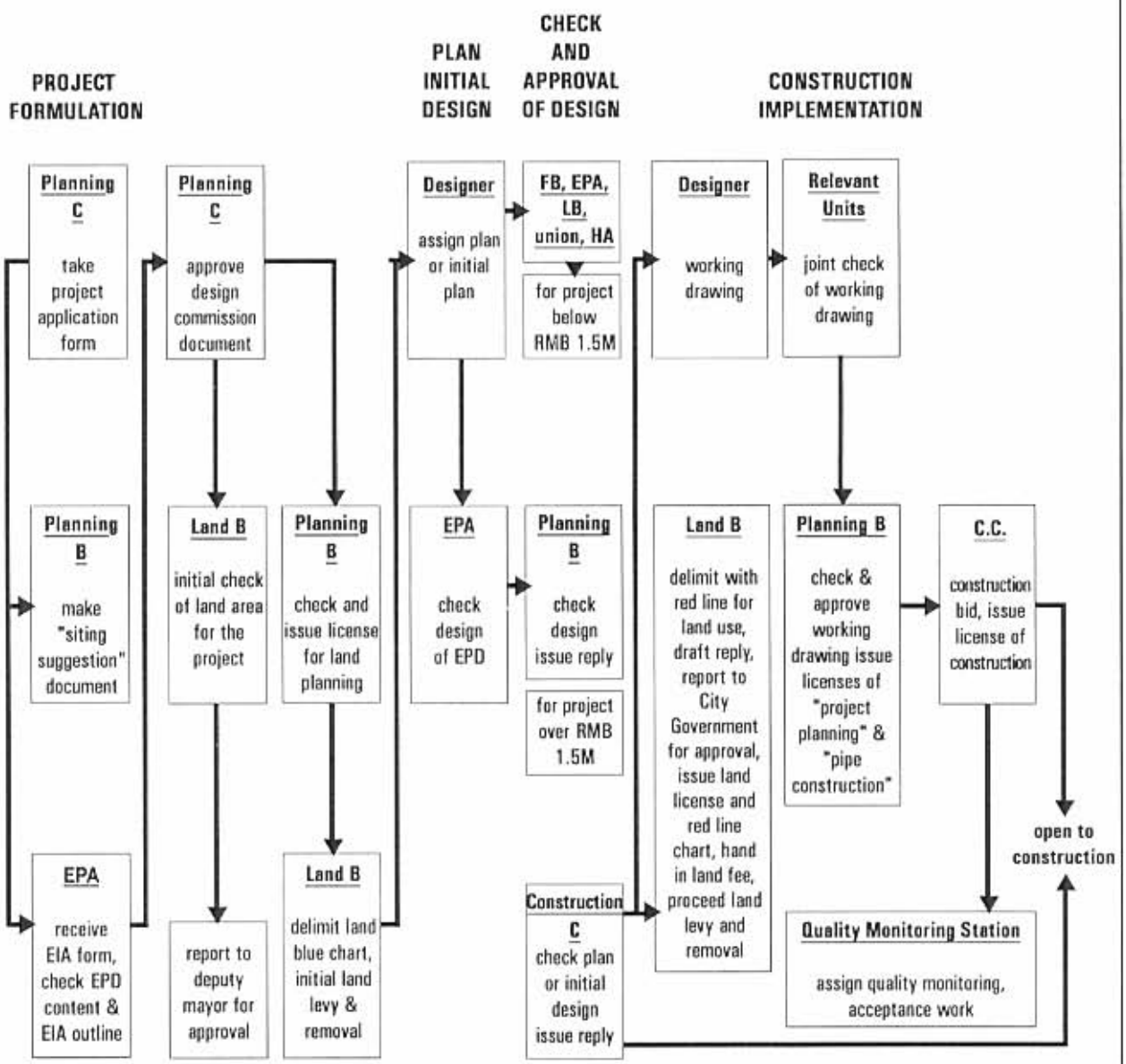
- The feasibility study of the construction project must contain a chapter(s) on environmental protection;
- A construction project shall report to the EPA and fill in an EIA form, with its map of location; and
- Large-, medium-, or small-scale projects with serious pollution potential shall prepare an EIA report in accordance with prescribed procedures *(see Figure 7.4).*

Management Problems

Several problems arose in protecting and managing Xiamen's coastal waters:

- The environmental laws and regulations on coastal waters usually lack operational rules and mechanisms;
- The responsibilities of concerned agencies and government units are not clearly defined. These agencies have their own functions and administrative jurisdictions to follow before anything else. Others, with no guidelines of their own to follow, usually lack direction. The lack of a mechanism for coordination results into confusion and overlapping of functions in terms of carrying out marine protection and management activities;
- Inadequate financial resources affect implementation and expectations;

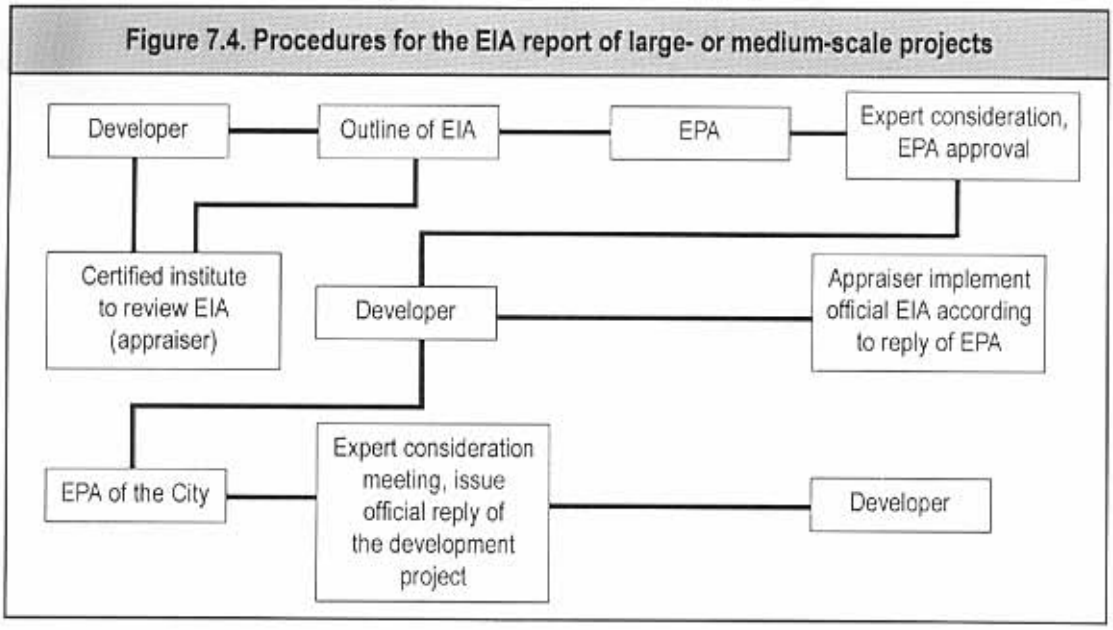
Figure 7.3. Flow chart for the evaluation and approval of construction projects



Legend:

Planning C = *Planning Commission*
Planning B = *Planning Bureau*
EPA = *Environmental Protection Agency*
EIA = *Environmental Impact Assessment*
M = *million*
Construction C/C.C. = *Construction Commission*
Land B = *Land Bureau*
EPD = *Environmental Protection Device*
FB = *Fire Brigade*
LB = *Labor Bureau*
HA = *Health Agency*
RMB = *Ren Min Bi (China currency)*

Figure 7.4. Procedures for the EIA report of large- or medium-scale projects



- Agencies involved lack the technical expertise, skills, knowledge and orientation;
- Outdated management methods due to limited use of computers and the lack of information exchange among concerned agencies hamper the enforcement of laws;
- Lack of economic incentives and inability of authorities to catch the violators who would rather pay fines than operate their waste treatment facilities;
- Marine planning lags behind land-use planning. Although individual plans exist for port development, shoreline, fishery, marine environmental protection and tourism, there is no integrated use plan for shoreline and the coastal waters. Other plans have no sound scientific basis;
- Infrastructures for pollutant source control remain inadequate. There is no efficient sewerage and drainage system. Existing waste water treatment facilities cannot cope with the increase in waste water discharges; and
- There is no emergency response system for pollution accidents. Existing response system is reactive rather than proactive.

Management Capacity, Marine Education and Scientific Study

The management structure and its functional capacity are weakened and fragmented due to the constraints of the abovementioned problems.

There are a number of cases to illustrate this predicament. For one, the Port Bureau is developing its environmental monitoring station while the Maritime Surveillance and Fishery Bureau has no specific role yet in marine environmental protection. Moreover, EPA has a comparatively strong force for land-based environmental protection, but it is weak on marine environmental protection. The Xiamen Marine Management Region has more capability than the Marine Management Division of Xiamen Municipality.

While the capability of government agencies and other institutions for marine environmental management has been waning due to so many constraints—there is, ironically, abundant supply of scientific knowledge on the marine environment due to the adequate number of academic and scientific institutions in Xiamen. Some academic institutions worth mentioning are the Xiamen University, Xiamen Fishery College, Jimei Navigation College, Lujiang College, Xiamen Fishery School, Xiamen

Ninth Middle School and Xiamen Technical School.

For marine scientific studies, there are the Third Institute of Oceanography of the State Oceanic Administration, Fujian Institute of Oceanography, Center of Environmental Science Study of Xiamen University, Institute of Subtropical Oceanography of Xiamen University, Fujian Fishery Institute, and the Institute of Environmental Protection Science Study of Xiamen Municipality. Also, there exist the Fishery Bureau of Xiamen Municipality and the Xiamen Central Station of Hydrology under the State Oceanic Administration.

There are research and educational institutions that belong to different administrative line agencies. Joint investigations and studies on marine development and exploitation for the Xiamen Municipality have been carried out. However, the results have not been fully used because of the lack of mechanisms for coordination and information sharing.

The presence of these training and academic institutions will enable professionals and personnel involved and/or required in marine protection and management to upgrade their skills and knowledge.

From the academic circle, the Xiamen Association of Environmental Protection Science (XAEPS) has already made many significant recommendations on environmental protection and management.

Chapter 8:

Conclusions and Recommendations

Conclusions

Xiamen, which is situated at the subtropical zone, boasts of scenic spots and provides excellent conditions for port development. It has sufficient land and coastal water areas and resources.

Within a period of 40 years, Xiamen's economy underwent dramatic growth. The 1980s proved to be the turning point for its economy with the creation of special economic zones (SEZ). For a while, construction and development were concentrated in the Xiamen Island proper before the Xinglin District followed. Since the late 1980s, Xinglin, Jimei and Haicang have been experiencing rapid development while Tong'an County has lagged behind. This pattern implies that exploitation and utilization of coastal lands and waters are concentrated in limited areas.

Further development in Xiamen Municipality will definitely be impinged by natural factors, such as scarce freshwater supply, natural hazards (e.g., typhoon, storm surge, drought) and coastal erosion.

Conflicts in coastal land use exist among port construction, mariculture, reclamation, tourism and marine environmental protection, particularly in the West Harbor. In the said harbor, the resource-use conflicts between mariculture and port development; and between marine environmental protection and coastal wastewater discharge are serious and require urgent solutions.

Xiamen's economic boon has been accompanied by a population boom. Nevertheless, its economy has been strong enough to maintain the improvements in the socioeconomic conditions of its people.

The increase in human activities by sheer increase in population and the unrelenting economic activities have brought about a significant increase in wastewater and solid waste discharges, gaseous emissions and other pollutants.

For the next ten years, economic growth will largely occur on lands surrounding the West Harbor. Thus, there could be serious pollution problems if no adequate pollution control and management measures are in place. Wastewater treatment infrastructures are insufficient. It is now a question of whether they could keep pace with the increasing rate of waste discharge. With this situation, the future environmental quality of the West Harbor is a subject for concern.

In general, the environmental quality of Xiamen's coastal waters is good, falling within Class II of the National Seawater Standards. However, all is not well with its water bodies. Maluan Bay, for instance, is seriously polluted in its water column and sediments. It is affected by wastewater discharge from industry and agriculture, domestic effluents, wastes from mariculture and poor hydrodynamic condition. The sea areas around Baozhuyu Island are also seriously polluted while the rest of West Harbor waters show signs of organic pollution.

The best environmental quality appears at the estuary, the Outer Harbor and Tong'an Bay. In general, the marine environmental quality is low from the outer to the inner waters and from east to west. The Yuan Dang Lake, after having recovered from a polluted condition, has shown signs of pollution recurrence.

Organic pollution is a major problem in the Xiamen coastal waters. Inorganic nitrogen concentration has also increased. Bacterial pollution is rather serious except in the Tong'an Bay where the number of fecal coliform in water exceeds the control level of the seawater standard.

The nutrient concentrations in water column fall within the range of medium to eutropic. The inorganic nitrogen concentration is relatively high; while reactive phosphate concentration is comparatively low. In the past, several red tide outbreaks occurred in some coastal waters of Xiamen where eutrophication was believed to be the cause.

The slow paced construction of facilities for pollution control and prevention at Dongdu Port cannot possibly cope with its increasing trade and development activities.

The ability to respond in cases of pollution accidents is questionable. A system of preparedness and response for oil spill and dangerous chemical spill has not been installed. Hence, in case of an accident, the Xiamen Port may suffer extensive damage.

Xiamen has a wide array of marine species supported by medium to high primary productivity. However, species diversity is distinctly different at various sea areas, showing a general increasing trend from inner to outer bay. Most marine species in the Xiamen coastal waters fall within the categories of eury-therms or eury-warm water species. Their habitats in the Xiamen coastal waters include infraneritic, intertidal and community types.

For the past 40 years, the coastal ecosystems of Xiamen have significantly changed. For example, the quantity of some phytoplankton that are sensitive to environmental change has greatly decreased. Moreover, only few marine species could be found in the seriously polluted Maluan Bay and the sea areas around Baozhuyu Island. Red tide events have occurred several times in the West Harbor and Tong'an Bay. Also, the habitat and community structure in Yuan Dang Lake have significantly changed because of pollution. The lake's environment has likewise recovered as a result of comprehensive mitigation efforts supported by huge funding. Despite this improvement, there are signs that pollution may recur in the lake.

Aside from pollution, other activities less noticeable are unregulated sand quarrying and large-scale real estate developments that have adversely affected the shorelines. The once-perfect beaches and shorelines are now badly eroded. Erosion is serious in the north, east and southeast coastlines of Xiamen Island.

There is abundant information on Xiamen's coastal waters but this is poorly managed and underutilized for the benefit of marine protection and management. Furthermore, existing data have some constraints and limitations. For example, most of the data collected on Xiamen coastal waters concern the West Harbor and the estuary only. Studies on Tong'an Bay, Outer Harbor and Eastern Channel are scarce.

The pollution-source studies remain inadequate. In effect, the type and quantity of land-based and sea-based pollutants are not fully understood. Only one study on land-based pollution source was undertaken in 1989 and covered the West Harbor only. However, its results have to be verified and updated since many changes have already taken place.

There is a dearth of information on sea-based pollution sources. This is further complicated by the lack of a systematic study on atmospheric inputs of pollutants in coastal waters and urban runoffs during storms.

Some important marine pollution problems and issues, which impinge on marine protection and management, have not been explored, such as:

- Increase in the number of motor vehicles which have some impacts on marine pollution;
- Marine environmental impacts of automobile exhausts, mariculture, port development, shipping and other means of transportation;
- Response measures to possible oil and chemical spills;
- Contributions and impacts of sand and pollutants carried by the Jiuliongjiang River on navigation and environmental quality of the West Harbor;
- The social and economic impacts of the developments in West Harbor and other coastal waters to Xiamen in general; and

- Complete, systematic and long-term monitoring data on marine ecological changes.

The abovementioned problems and absence of scientific findings and studies could be the reasons why a decision-making system necessary for environmental emergency management has not been developed.

A mechanism to integrate data accumulated by different agencies, sectors and institutions to facilitate information exchange is needed. Clearly, the lack of such mechanism slows down the process of implementing environmental measures.

It is interesting to note that there are many institutions and agencies involved in marine environmental protection and management wherein basic legislative frameworks, implementing mechanisms and management systems play vital roles.

The improvement in marine environmental quality can be attributed to environmental planning, comprehensive pollution mitigation and environmental education and awareness campaign. The government, particularly the local unit, has been doing its part. Besides providing the legal framework, the Xiamen Government has been spending an average 0.8 percent (a little higher than the average national environmental expenditure) of its gross domestic product (GDP) for environmental protection.

Generally, in the course of analyzing the ramifications of marine environmental protection and management in the Xiamen Municipality in relation to the Xiamen Demonstration Site, the significant problems and issues are contained in the following findings:

a. In terms of institutional arrangements, there are twelve government organizations or entities involved in marine management. They fall under different line departments and agencies of the Central Government, the Provincial Government of Fujian and the Municipal Government of Xiamen. However, they perform individual functions and undertake measures in accordance with their organizational mandates and administrative jurisdictions. At present, there is no mechanism to coordinate and resolve cross-agency functions and management issues.
b. There are conflicts in the use of coastal waters, especially in the West Harbor.
c. Environmental protection has been included in the national socioeconomic plan. Also, land and marine environmental planning have been undertaken. However, due to lack of a master plan for the development of shorelines and coastal waters, sectoral conflicts in marine development have not been resolved, thus uncoordinated development of projects take place. Concomitantly, the requirements and mechanisms for integrated coastal management are lacking.
d. The legal framework for overall environmental protection and management exists. However, some general rules and measures for implementation still need to be reviewed in terms of their responsiveness. For marine protection and management at the local level, the legal framework needs to be strengthened. While there may be relatively enough legal measures, however, their enforcement remains weak.
e. For environmental protection, financial support is insufficient for it comes mainly from the government budget.
f. The development of environmental protection facilities is slow and often fails to achieve the environmental protection objectives and targets.
h. Public awareness on marine environmental protection is still low due to limited information campaign. This is also attributed to the low

compliance on marine laws and regulations. In addition, the lack of awareness makes citizens or sectors consider the coastal area a convenient place for waste disposal without due regard to its adverse effects. Also, due to lack of knowledge on the rational use of marine resources, marine economic activities are treated as hard indicators for development and therefore marine protection is only secondary.

i. The pollutants discharged from Jinmen Islands and carried by the Jiulongjiang River could produce harmful impacts on the coastal waters of the XDS and these may be difficult to control.

Recommendations

To protect the marine environment of the Xiamen coastal waters, it is imperative to implement sustainable development strategies and action plans for integrated coastal management and marine environmental protection.

Following are some recommendations to attain the above objective:

1. Develop a clearly-defined system of environmental laws and technical standards that manifest strong, practical and operational features within the framework of the State Constitution and by-laws. Make full use of the legislative rights and powers given by the State to pass legislations that reflect the specific conditions of Xiamen.
2. Strengthen the enforcement of marine environmental laws and regulations.
3. Formulate and develop scientific and rational zonation, protection, development and use plans for shorelines and coastal waters. These plans should be integrated into the overall socioeconomic development plan and mandated by an appropriate legislative measure.
4. Formulate and implement an integrated coastal management plan.
5. Create an environmental funding mechanism to ensure sustainable financial support for marine protection.
6. Carry out massive public awareness and educational activities on ICM and marine environmental protection.
7. Develop and implement a comprehensive inspection system on waste discharges. At the same time, establish a preparedness and response system for oil spill and dangerous chemicals spill.
8. Construct facilities for pollution prevention and mitigation. Control land- and sea-based pollution sources and waste discharge.
9. Develop and improve an environmental information system, including a data bank, a monitoring and surveillance system, and a geographic information system (GIS).
10. Undertake technical skills training and capacity building activities on ICM; recruit highly-qualified personnel, improve technical facilities; and strengthen marine environmental management capability;
11. Strengthen the environmental protection sector and integrate it into the comprehensive coastal management system. Encourage and promote the use of "clean" production technology, the reduction of waste production quantity and recycling.
12. Maximize the presence of marine science and technological institutions to improve the knowledge on marine ecosystem and raise the level of scientific services and expertise.
13. Establish a marine ecological monitoring station on a long-term basis to track changes in marine environmental quality and to provide scientific basis for decision-making.

Annex 1:

List of Dominant Marine Species in Xiamen Coastal Waters

BACILLARIOPHYTA

Actinoptychus annalatus (Wallich)
A. splendens (Shadbolt)
A. undulatus (Bailey)
Amphiprora alata Kutzing
Amphora costata W. Smith
A. ovalis Kutzing
Asterionella japonica Cleve
Bacillaria paradoxa Gmelin
Bacteriastrum comosum Pavillard
B. hyalinum Lauder
B. varians Lauder
Bellerochea malleus (Brightwell)
Biddulpa aurita (Lyngbye)
B. granulata Roper
B. longicruis Greville
B. mobiliensis Bsiley
B. otusa Kutzing
B. pulchella Gray
B. regia (Schultze)
B. rhombus (Ehrenberg)
B. sinensis (Ehrenberg)
Chaetoceros abnormis Pr-Laur
C. affinis Lauder
C. affinis var. *willei* Hustedt
C. borealis Bailey
C. castracanii Karaten
C. coarctatus Lauder
C. compressus Lauder
C. curvisetus Cleve
C. debilis Cleve
C. decipiens Cleve
C. densum Cleve
C. denticulatus Lauder
C. denticulatus f. angusta Hustedt
C. didymus Ehrenberg
C. distans Cleve
C. diversus Cleve
C. eibenii Grunow
C. pelagicus Cleve
C. pseudocurvisetus Margin
C. siamense Ostenfeld
C. socialis Lauder
C. subsecundus (Grunow)
C. subtilis Cleve
C. tortissimus Gran
C. weissflogii Schutt
Corethron hystrix Hensen
Coscinodiscus argus Ehrenberg
C. bipartitus Rattray
C. centralis Ehrenberg
C. excentricus Ehrenberg
C. gigas Ehrenberg
C. jonesianus
C. lineatus Ehrenberg
C. oculus iridis Ehrenberg
C. subtilis Ehrenberg
C. wailesii Ocan et Angst
Cyclotella cemta (Ehrenberg)
Dactyliosolen mediterraneus Perag
Diploneis bombus Ehrenberg
D. Simthii (Brebisson)
Ditylum brightwellii (West)
D. sol Orunow
Eucampia comute (Cleve)
E. zoodiacus Ehrenberg
Gyrosigma halticum Ehrenberg
Hemialus auckil Grunow
H. membranaceus Cleve
H. sinensis Greville
Leptocylindrus danicus Cleve
Licmophora abbreviate Agardh
Melosira moniliformis (Muller)
M. sulcata (Ehrenberg)
Nitzschia closterium (Ehrenberg)
N. delicatisima Cleve
N. longissima (Breb)
N. lorenziana Grunow
N. pungens Grunow
N. sigma (Kutzing)
Planktoniella sol (Wallich)
Pleurosigma fomosum W. Smith
P. normanii Ralfs
P. pelagicum Pergallo
Rhizosolenia alata f. gracillima Cleve
R. bergonii Peragallo
R. calcat-avis M. Schultze
R. castracanei Peragallo
R. imbricanta Brightwell
R. robusta Norman
R. setigera Brightwell
R. stolterfothi Peragallo
R. styliformis Brightwell
R. styliformis va. latissima Brightwell
Skeletonema costatum (Greville)
Streptotheca thamesis Shrubsole

Thalassionema nitzschioides Grunow
Thalassiosira condensata (Cleve)
T. rotula Meunier
T. subtilis (Ostenfeld)
Thaissiothrix frauenfeldii Grunow
Triceratium favus Ehrenberg

PYRROPHYTA
Ceratium breve (Ost. Schmidt)
C. deflexum (Kofoid)
C. furca (Ehrenberg)
C. fusus (Ehrenberg)
C. macroceros (Ehrenberg)
C. gibberum Gourret
C. kofoidii Jorgensen
C. inflatum (Kofoid)
C. pulchellum B. Schroder
C. tripos (O.F. Culler)
C. trichoeeos (Ehr) Kofoid
Dinophysis caudata Saville-Kent
Noetiluca seintillans (Macartney)
Peridinum conicum (Gran)
P. depressum Bailey
P. latissum Kofoid
P. oceanicum Vanhoffen
P. stenii Jorgensen
Pyrosystis fusiformis Murray
Pychrophacus horoligicum var. *steinii* Schiller

CYANOPHYTA
Trichodeamium erythaeum Ehrenberg

CHLOROPHYTA
Pediastrum biradiatum Meyen

CRYSOPHYTA
Distephanus speculum

ZOO/PHYTOPLANKTON

HYDROMEDUSAE
Dipurena ophiogaster
Dipurena spp.
Podocoryne minuta
Turriropsis lata
Bougainvillia britannica
Ramust xiamenensis
Obelia spp.
Laodicea indica
Eucheilota macrogana
Clytia folleatum
C. hemisphaericum
Blackfordia mahattensis
Phialucium carolinae

Eirene menoni
E. ceylonensis
E. kambara
Eutima levuka/Eutima sp.
Aequorea conica
Tiaricodon coeruleus
Proboscidactyla ornata
Aglaura hemistoma
Liriope tetraphyll
Aegimura grimaldi

SIPHONOPHORA
Physophora hydrostatica
Dipyes chamissonis
Lensia subtiloides
Muggiaea atlantica

SYPHOMEDUSAE
Syphomedusae larva

CTENOPHORA
Pleubrachia globosa
Beroe cucumis

THALICEA
Doliolidae

CHAETOGNATHA
Sagitta enflata
S. pulchra
S. ferox
S. bedoti
S. nagae
S. neglecta
S. delicula

PTEROPODA
Cresis acicula

CALADOCEA
Penilia avirostris
Evadane tergestina

OSTRACODA
Euconchoecia aculeata
Cypridina debtata
Microconchoecia curta

COPEPODA
Calanus sinicus
Canthocalanus pauper
Undinula vulgaris
Eucalanus crassus
E. subcrassus

Paracalanus parvus
P. aculeatus
P. crassirostris
Bestiola amoyensis
Acrocalacus gibber
Euchaeta consinna
Temora turbinata
Centropages tenuiremis
Schmackeria poplesia
S. dubia
Candacia discaudata
Calanopia thompsoni
C. elliptica
Labidocera bipinnata
L. euchaeta
L. pavo
Pontellopsis tenuicauda
Acartia pacifica
A. spinicauda
A. clausi
A. erythraea
Acartiella sinensis
Tortanus forcipatus
T. derjugini
T. dextrilobataus
Oithona similis
O. nana
O. simplex
O. rigida
O. brevicornis
O. decipiens
O. attenuata
Corycaeus affinis
C. andrewoi
C. lubbocki
Microsetella norvegica
M. rosea
Euterpina acutifrons
Monstrilla grandis
Clytemnastra scutellata
Halicyclops aequoreus
Kelleria purpurocincta

AMPHIPODA
Lestrigonus macropthalmus
Tullbergella cuspidata
Hyperioides sibaginis
Caprellidae
Gammaridea

MYSIDACEA
Acanthomysis laticauda
A. crassispinosa
Gastrosacus kojimaensis
G. hibii
G. formosensis
Mysidacea latva

EUPHAUSIACEA
Pseudeuphausia sinica

DECAPODA
Lucifer hanseni
L. faxonii
L. intermedus
Acetes japonicus
Leptochela grellis

LARVAL PLANKTON
Polychaeta larva
Cirriped naupliua
Macrura larva
Brachyura zoea
Brachyura megalopa
Pocellana zoea *Stomatepoda* larva
Cephalopoda larva
Fish eggs
Fish larva

INFRANERITIC BENTHOS

SONGIA
Siphoonochalina truncata lindgren

COELENTERATA
Cavetnularia hahereri
Moroff
Pteroeides chinensis Harteaub
Cerianthus
Edwardsis

PLATYHELMINTHES
Planecera

NEMERTINEA
Nemertinea spp.

POLYCHAETA
Haploscoloplos spp.
Cösswrella cimopha Hantman
Aonides
Polydo tentaculata Blake et Kudenov
Scolelepsis sp.
Prionospio malmgreni Claparede
Prionospio pinnata Ehlers
Laonice cirrata Sars
Poecilochaetus tropicus Okuda
P. paratropicus Gallardo

Chaetozone spp.
Tharyx marioni Saint-Joseph
Tharyx spp.
Dasybranchetus spp.
Notomastus latericeu Sars
Notomastus abrans Day
Notomastus spp.
Heteromatus filiformis Clarapede
Rashgua spp.
Parheteromastides spp.
Barantolle spp.
Neomediomastus spp.
Mediomastus xaliformiensis Hartman
Capitomastus spp.
Praxillella gracilis Sars
Asychix spp.
Ophelina acuminata Oersted
Scalibregma imflatum Rathke
Hyboscalex spp.
Genetyllis spp.
Harmothoe imbricata Linnaeus
Harmothoe spp.
Telolepidasthenia spp.
Pholoe spp.
Bhawania spp.
Leocrates spp.
Synelmis albinis Lagerhans
Sigambra hanaokai Kitamori
Syllis spp.
Neanthes donghaiensis Wu
Neanthes spp.
Nectoneanthes multignatha Wu et Sun
Leonates persoca Wesenberg-Lund
Dendronereis pinnaticirris Grube
Glycera subenes Grube
Glycera rouxi Audouin et M. Edwards
Glycera chirori Izuka
Glycera onomichiensis Lauka
Glycera alba Muller
Glycera tesselata Grube
Glycera spp.
Nephtys polybranchia Southern
Nephtys capenist Day
Nephtys tuleareusis Fanvel
Nephtys spp.
Aglaophamus dibranchis Grube
Aglaophamus lyrochaeta Tauvel
Inermonephtys gallardi Fauchald
Linopherus spp.
Eurythoe parvecarucukata Horst
Onuphis fukianensis Eschakov et Wu
Diopatra chiliensis Quatrefages
Marphysastragulum Grube
Eunice indica Kinberg
Eunphysaaculeata Wesenberg-Lund
Lumbrineris cruzensis Hartman
Lumbrineris nagae Gallardo
Lumbrineris shiinoi Gallardo
Lumbrineris tetraura Schmarda
Lumbrineris latreilli Audouin et M. Edwards
Lumbrineris spp.
Paranico spp.
Drilinereis filum Clarapede
Schistomeringos spp.
Sternaspis scutata Reiner
Owenia fusiformis Delle Chiaje
Lygdamis giardi Mcintosh
Pectinaria papillosa Caullery
Ampharete spp.
Isolda pulchella Muller
Samytha besslei Bill
Melinna spp.
Pista cristata Muller
Pista brevibranchis Caullery
Pista spp.
Liomia medusa Savigny
Anaeana trilobta Sars
Streblosoma spp.
Terebellides stroemi Sars

EUCHUROIDES
Listrolobus brevirostris Chen et Yeh

SIPUNCULOIDEA
Sipunculus nudus Linnaeus
Phascolosoma spp.

MOLLUSCA
Nucula (Lamaellihucula) *convexa* (Sowerby)
Saccella cuspidata (Gould)
Yoldia similis Kuroda at Habe
Barbatia bistrigata (Dunker)
Modiolus (Modiolus) *metcalfei* Hanley
Musculista senhausia (Benson)
M. japonia (Dunker)
Spiniplicatula muricata (Sowerby)
Lucinoma annulata (Reeve)
Lucinoma spp.
Leptaxinus spp.
Cyladicama cumingi (Hanley)
Galeomma spp.
Maoricardium setosum (Redfield)
Mactra spp.
Mactrimuls dolobrata (Reeve)
Angulus spp.
Moerella culter (Hanley)
M. iridescens (Benson)
Nitidotellina iridella (Martens)

N. minuta (Lischke)
Macoma (Pxammacoma) *candida* (Lamarck)
Pulvinus mican (Hanley)
Theora lata (Hinds)
Gari hosoyai Habe
Mytilopsis sallei (Reclus)
Corbicula fluminea (Muller)
Corbicula spp.
Liocancha spp.
Cyciosunetta concinna (Dunker)
Meretrix meretrix (Linnaeus)
Paphia (Paratapes) *undulata* (Born)
P. (Protapes) *gallus* (Gmelin)
Ruditapes Philippinarum (Adams et Reeve)
Anisocorbula lineata (Lynge)
A. cuneata (Hinds)
Potamocorbula ustulata (Reeve)
P. rubromuscul Zhuang et Cai
Periploma otohimaea Ozaki
Laternula (Exolaternula) *marilina* (Reeve)
Trigonotracia jinxingae Xu
Clithon oualaniensis (Lesson)
Turritella spp.
Architectonica perdix (Hinds)
Sermyla riqueti (Grateloup)
Cerithidea cingulata (Gmelin)
C. microptera (Keiner)
Batillaria zonalis (Bruguiere)
Clypoemorus spp.
Ochetoclava kochi (Philippi)
Cirsotrems perplexum (Pease)
Eulima maria (A. Adams)
Natica onca (Roding)
N. lineata (Roding)
Lunatica gilva (Philippi)
Polynices macrostoma Philippi
Volva birostris (Linnaeus)
Primovolva spp.
Murex trapa Roding
Pyrene bicincta (Gould)
P. bella (Reeve)
Cantharus cecillei (Philippi)
Nassarius succinctus (A. Adams)
N. variciferus
N. caelatus (A. Adams)
N. dealbatas (A. Adams)
N. thersites (Bruguiere)
N. siquinjorersis (A. Adams)
Reticunassa spp.
Zeuxis spp.
Oklivella spp.
Sydaphera spp.
Brachytoma flav dulus (Lamarck)
B. vexillium (Babe et Kosuge)
Clavatula pseudopriciplis (Yokoyama)
Lophiotoma leucotropis (A. Adams et Reeve)
Turricula javana (Linnaeus)
Turricula spp.
Diplomeriza duplicata (Linnaeus)
Tuiboniilla spp.
Retusa (C.) *boenesis* (A. Adams)
Eocylichna cylindrella (A. Adams)
Dentalium octangulatum Donovan
Episiphon kiaochowwanense Tchang et Tsi
Graptachme spp.

CRUSTACEA

Eocums hilgedorfi Marcusen
Corophium spp.
Cleantis panicauda (Benedict)
Idunella spp.
Eriopisella spp.
Orchestia spp.
Phofis spp.
Caprella scaura Templefon
Caprella spp.
Solenocera crassicornis (H. Milne-Edwards)
Solenocera spp.
Metapenaeus spp.
Parapenaeopsis tenellus (Bate)
P. hardwickii (Miers)
P. cultrirostris Alcock
Metapenacopsis barbatus (De Haan)
Leptochela gracilis Stimpson
L. pugnax De Man
Alpheus brevicristatus De Haan
A. distinguendus De Man
A. hoplocheles Contiere
Ogyrides orientalis (Stimpson)
Lysmata vitlata Stimpson
Exopalaemon carinicauda (Helthuis)
Palaemon gravieri (Yu)
Porcellanella picta (Stimpson)
Raphidopus ciliatus Stimpson
Diogenes avarus Heller
Diogenes spp.
Dardanus spp.
Nursia rhomboidalis (Miers)
Achaeus tuberculatus (Herbst)
Portunus sanguinolentus (Herbst)
P. trituberculatus (Miers)
P. gracilimanus (Stimpson)
P. haxtatoides (Fabricius)
Charybdis japonica (A. Milne-Edwards)
C. variegata (Fabricius)
Parapanope euagora De Man
Pilumnus spp.
Heteroplax nagasakiensis Sakai

Ser fukiensis Rathbun
Typhlocarcinus nudus Simpson
T. villosus Stimpson
Typhlocarcinops canaliculata Rathbun
Typhlocarcinops spp.
Hexapus anfractus Rathbun
Hexapus spp.
Xenophthalmus pinnotheroides White
Neoxenophthalmus obscurus (Henderson)
Tritodynamia haiannanensis Tai
Animaliforms lightana Rathbun
Macrophtalmus (Mareortis) *definitus* Adams et White
Uca (Deltuca) *arcuata* De Haan
Camptandrium sexdentatun Stimpson
Eriodheir leptognathus Rathbun
Helice spp.
Cloride decorata (Wood-Mason)
Harpiospuilla annandalei (Kemp)
Oratosquwilla spp.

ECHINODERMATA

Comathns japonicus (J. Muller)
Leptopentacta imbricata (Semper)
Protankyra bidentata (Woodward et Barrett)
Pernella lesueuri (Valenciennes)
Amphioplus laevis Lyman
Amphioplus lucidus Koehler
Amphiura pachybactra Murakami
Ophionereis dubia sinensis Duncan

CHORDATA

Cnemidocerpa chinensis Tokioka
Styela plicata (Linnaeus)
Botryllus tuberatus

FISHES

Coilia grayii Richardson
C. mystus (Linnaeus)
Arius sinensis Lacepede
Ambassis gymnocephalus (Lacepede)
Johnius amblycephalus (Bleeker)
J. belenserii (Cuvier et Valenciennes)
Collchthys lucidus (Richardson)
Callionymus virgis Jordan et Fowler
C. beniteguvi Jordan et Fowler
Triaenopogon barbatus (Gunther)
Oxyurichthys tentacularis (Cuvier et Valenciennes)
O. micrilepis (Bleeker)
O. papuensis (Cuvier et Valenciennes)
Parachaeurichthys polynema (Bleeker)
Trypauchen vagina (Bloch et Schneider)
Ctenotrypauchen chinensis Stenidachner
C. microcephalus (Bleeker)
Odontamblyopus rubicundus (Hamilton-Buchanan)
Trichurus muticus Gray
Polycaulus indicus (Linnaeus)
Solea ovata Richardson
Cyoglossus melampetalus (Richardson)
C. puncticeps (Richardson)
C. joyneri Gunther
C. semilaevis Gunther
C. abbreviatus (Gray)

INTERTIDAL BENTHOS

Enteromorpha prolifera
E. intestinalis
E. clathrata
Giffordia spp.
Rhizoclonium implexum
Pteroides chinensis
Haliplarella luciae
Cavernularia habareni
Nemertines
Chromoplana bella Bock
Planocera spp.
Phylo ornatus (Vennill)
Haploscoloplos kerguelensis (McIntosh)
Aedicina spp.
Laonice cirrata (Sars)
Malacocerocs indicus (Fauvei)
Paraprionospio pinnata (Enlers)
Prionospio malmgreni Clarapese
Pseudomalacoceros spp.
Polydora spp.
Cirriformia tentaculata Moontag
Magelina cincta Ehlers
Tharyx marioni Saint-Joseph
Peocilochaetus paratropicus Gallardo
P. serpens Allen Malmfnen
Heteromastus californiensis Hartman
Mediomastus spp.
Notomastus latericeus Sars
N. cf. berans Day
Euolymene annadaiei Southern
Asychis spp.
A. cf. ganeticus Fauvel
Praxillella tracilis Sars
Ophelina grandis Pillai
Sthenolepis japonia McIntosh
Parahalosysdna spp.
Halosydna spp.
Polynoella spp.
Polyodintes melannonoteus Grube
Leocrates chinensis Kinberg
Synelmis albini (Langerhans)

Ceratonereis erythraeensis Fauvel
C. burmensis Monro
Leonnates persica Wesenberg-Lund
Neanthes donghaiensis Wu et Sun
Nectoneanthes multignatha Wu et Sun
N. oxypoda Marenzeller
Nereis heterocirrata Treadwell
Paraleonnates uschaikovi Chlebovitsch
Perinereis nuntia (Savigny)
Tambalagamia fauvel Pillai
Marphysa sanguinea Montagu
M. macinto shi Grossland
M. sinensis (Monro)
M. stragulum Grube
Glycera subaena Grube
Glycera spp.
Aglaophamus lyrochaeta Fauvel
Goniada spp.
Inermonephtys gallardi Fauchald
Nephtys polybranchis Southern
N. oligobranchia Southern
Diopatra chiliensis Quatrefages
Onuphis eremita Audouin et E. Edwards
Eunipysa aculeata Wesenberg-Lund
Schistimeringes japonia Annenekova
Lumbrineris heteropoda (Marenzeller)
L. meteorana Augener
L. nagae Gallardo
L. tetraura (Schmarda)
L. latreilli Audouin et M. Edwards
Drilonereis filum Clarapede
Sternaspis scutata Renier
Owenia fusiformis Delle Chiaje
Pectinaria papillosa Caullery
Isolda pulchella Muller
Mellinna aberrans Fauvel
Amaeana occidentalis (Hartman)
A. trilobata Savigny
Pista typha Grube
Terebellides stroemi Sars
Sabellidae spp.
Phascolosoma esculenta
Ph. spp.
Sinpunculus nudus
Nucula spp.
Didimacar tenebrica (Reeve)
Musculista senhousia (Benson)
Modiolus metcalfei (Harley)
Mactra (M.) *veneriformis* Reeve
Felaniella spp.
Angulus vestalioides (Yokoyams)
Merisca diaphana (Deshayes)
Cadella spp.
Moerella culter (Hanley)
M. iridescens (Benson)
Macoma (Psammacoma) candia (Lamarck)
Pulvinus micans (Hanley)
Abrina spp.
Theora lata (Hinds)
Atactodea striata (Gmelin)
Hiatula spp.
Sinonovacula constricta (Lamarck)
Solen grandis Dunker
Culetllus attenuatus Dunker
Dosinia (Phacosoma) japonia (Reeve)
Clausinella calophylla (Philippi)
Cyclina sinensis (Gmelin)
Ruditapes philippinarum (Adams et Reeve)
Chione isabellina (Philippi)
Glauconme chinensis Gray
Anisocorbula cuneata (Hinds)
Laternula (Exolaternula) marilina (Reeve)
Trigonothracia jinxingae Xu
Clithon sowerbianus (Recluz)
Assiminea brevicula Pfeiffer
Batillaria zonalis (Bruguiere)
Cerithisac cingulata (Gmelin)
C. microptera (Kiener)
C. sinensis (Philippi)
Clypemorus spp.
Balcis spp.
Eulima maria (A. Adams)
Neverita didyma (Roding)
N. lineata (Roding)
N. spadiceoides Liu
Eunaticina papilla (Gmelin)
Rapana bezoar (Linnaeus)
Rapana spp.
Chicoreus ramosus (Linnaeus)
Thais gradata (Jonas)
Cantharus cecilllei (Philippi)
Pyrene bella (Reeve)
Nassarius spp.
Reticunassa spp.
Zeuxis spp.
Alivella spp.
Allopea pyrgula
Akera constricta Kuroda
Onchidium verrculatim Cuvier
Bullacta exara (Philippi)
Retusa (C.) *boenesis* (A. Adams)
Tiberia ebarana (Yokoyama)
Dentalium spp.
Graptacme spp.
Porcellana spp.
Raphidopus ciliatus Stimpson
Ebalia malefactrix Kemp
Philyra caninata

P. olivacea Rathbun Bell
Charybdis spp.
Ser fukiensis Rathbun
Eucrate crenata de Haan
Typhlocarcinus nudus Stimpson
T. villosus Stimpson
Hexapus(Hexapus) *granuliferus* Campbell et Stephens
Xenophthalmus pinnotheroides White
Nepxenophthalmus ohscurus (Henderson)
Mictyris longicarpus Latreille
Ocypode stimpsoni-ortmann
U. (Deltuca) *arcuata* (de Haan)
U. D. dussumieri dussumieri H. Milne- Edwards
U. (Thalssura) *vocans cocans* (Linnaeus)
U. (Celuca) *lactea lactea* (de Haan)
U. spp.
Macrophthalmus (M.) *cilatum* de Haan
M. (Mareotis) *crato* de Haan
M. (Mareotis) *japonicus* de Haan
M. (Mareotis) *tomentosus* (Souleyet)
M. spp.
Camptandrium sexdentatum Stimpson
Cleistostoma dilatum de Haan
Ilyoplax deschampsi (Rathbun)
I. serrata Shen
I. tansuiensis Sakai
Scopimera globosa de Haan
Metapograpsus guadridentatus Stimpson
Hemigrapsus penicillatus (de Haan)
Nanosesarma (N.) *minitum* (de Man)
Helice spp.
H. sheni Sakai
H. wuana (Rathbun)
Metaplax spp.
M. elegans de Man
M. lonhipes Stiapson
M. sheni Gordon
M. takashii Sakai
Lingula unguis
L. shantugensis K. Hatai
Comantheria grandicalyx (P.H. Carpenter)
Leptopentacta imbricata
C. japonia (J. Muller)
Pentacta quasrangularis
P. anceps (Selenka)
Mensamaria intercedens (Lampent)
Protankyra bidentata (Woodward et Barrett)
Acaudina molpadioides (Semper)
Placophiothnic striclata
Amphioplus laevis lyman
A. depressus (Ljungman)
Hartemyeria chinensis
Styela plicata
Microscosmus sustralis
Plotosus aguillaris
Prionobuti koilomatodon
Synechosobius hasta
Scartetaris viridis
Boleophthalmnus pectininoskis
Tridentiser trigonocephalus
Syncnathus djarong
Acentrogobius carinus
Polycaulus unanoscopus
Omobranchus japonicus

Annex 2:

Seawater Quality Standards of the People's Republic of China

PARAMETER		Class I	Class II	Class III	Class IV
Floating materials		no oil film, bubble, other floatings on sea surface			no clear oil film bubble, plastics, other floatings on surface
Color, odor, smell		Sea water has no foreign, color, odor, smell			no clear foreign color, odor, smell
Suspended materials		man-made increase ≤ 10	man-made increase ≤ 30	man-made increase ≤100	man-made increase ≤150
Coliform (≤)		10,000	10,000	10,000	10,000
Fecal coliform		≤ 140 for culturing water used in shellfish for human consumption without cooking. ≤ 2,000 for water used for recreation.			
Pathogens (PFU/m³)		undetected for culturing water used in shellfish for human consumption without cooking. ≤ 25 for water used for recreation.			
Water temperature (°C)		no artificial excessive increase of 1°C than surrounding in summer, 2°C increase in other seasons.		no artificial increase of 4°C than surrounding.	
pH		7.8-8.5 and variation relative to normal range of the water in question less than 0.2 pH.		6.8-8.8 and variation relative to normal range of the water in question less than 0.2 pH.	
Dissolved oxygen		6	5	4	3
COD ≤		1	2	3	5
BOD_5 ≤		1	1	2	3
Inorganic nitrogen (in N) ≤		0.20	0.30	0.40	0.50
Non-ion nitrogen (in N) ≤		0.005	0.010	0.010	0.20
Reactive phosphate (in P) ≤		0.015	0.030	0.030	0.045
Mercury ≤		5×10^{-5}	2×10^{-4}	2×10^{-4}	5×10^{-4}
Cadmium ≤		0.001	0.005	0.010	0.010
Lead ≤		0.001	0.005	0.010	0.050
Cr^{6+} ≤		0.005	0.010	0.20	0.050
T-chromium ≤		0.05	0.10	0.20	0.50
Arsenic ≤		0.020	0.030	0.050	0.050
Copper ≤		0.005	0.010	0.050	0.050
Zinc ≤		0.020	0.050	0.10	0.50
Selenium ≤		0.010	0.020	0.020	0.050
Nickel ≤		0.005	0.010	0.020	0.050
Cyanide ≤		0.02	0.10	0.20	0.20
Sulfide (in S) ≤		0.02	0.05	0.10	0.25
Volatile phenole ≤		0.005	0.005	0.010	0.050
Petroleum oil ≤		0.05	0.10	0.30	0.50
666 ≤		0.001	0.002	0.003	0.005
DDT ≤		5×10^{-6}	1×10^{-4}	1×10^{-4}	1×10^{-4}
Malathion ≤		5×10^{-4}	0.001	0.001	0.005
Methyl parathion ≤		5×10^{-4}	0.001	0.001	0.005
Benzopyrene (a) ≤		2.5×10^{-6}	2.5×10^{-6}	2.5×10^{-6}	2.5×10^{-6}
Anion surfactant ≤		0.03	0.10	0.10	0.10
Radionuclide (Bq/l)	^{60}Co	0.03			
	^{90}Sr	4			
	^{106}Ru	0.02			
	^{134}Cs	0.6			
	^{137}Cs	0.7			

Note: Units in mg/l unless specified. All radionuclides should be maintained at "reasonably achievable level."

Annex 3:

Standards of Fishery Water Quality

No.	Parameter	Standards (mg/l)
1	Color, odor, smell	Fish, shrimp, shellfish, algae should not be stained with foreign color, odor and smell.
2	Floatings	No obvious oil film or bubble on water surface.
3	Suspended matter	Artificial increase should not exceed 10 and should produce harmful impacts on fish, shrimp, shellfish, algae after sinking on bottom.
4	pH	6.5-8.5 after for freshwater, 7.0-8.5 for seawater.
5	Dissolved oxygen	Exceed 5 for over 16 hours out of consequent 24 hours and not less than 3 for the remaining hours; not less than 4 for the remaining hours for water habitat of salmon at ice periods.
6	BOD_5 (20°C)	Not exceed 5, not exceed 3 at ice period.
7	Total coliform	Not exceed 5,000 ind/l (not exceed 500 ind/l for shellfish culture water).
8	Hg	≤ 0.0005
9	Cd	0.005
10	Pb	0.05
11	Cr	0.1
12	Cu	0.01
13	Zn	0.1
14	Ni	0.05
15	As	0.05
16	Cyanide	0.005
17	Sulfide	0.2
18	Fluoride	1
19	Non-ion nitrogen	0.02
20	K-nitrogen	0.05
21	Volatile phenole	0.005
22	Yellow phosphorus	0.001
23	Petroleum oil	0.05
24	Acrylon	0.5
25	Acrolein	0.02
26	666 (y)	0.02
27	DDT	0.001
28	Malathion	0.005
29	Penchlorosodium	0.01
30	Daphene	0.1
31	Metamidophos	1
32	Methylparathion	0.0005
33	Furantoin	0.01

Annex 4:

Assessment Standards of Sediment Environmental Quality

PARAMETER	Standards
Cu (ppm)	30
Pb (ppm)	25
Zn (ppm)	80
Cd (ppm)	0.5
T-Ha (ppm)	0.2
oil (ppm)	1,000
666 (ppb)	0.5
DDT (ppb)	0.02
Organic matter %	3.4
Sulfide (ppm)	30

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