THE CONTRIBUTION OF INTEGRATED COASTAL MANAGEMENT TO THE SUSTAINABLE DEVELOPMENT OF CHINA'S COASTAL AREA

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NATIONAL UNIVERISITY OF SINGAPORE, 2014

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously

YE GUANQIONG

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Table of Contents

SUMMARY

Integrated Coastal Management (ICM) is an international management paradigm for coastal governance to promote sustainable coastal development, and it has been initiated in over 100 nations around the world since 1992. In China, over 10 coastal cities have adopted the ICM framework to tackle the environmental and management challenges for nearly a decade. To study the effectiveness of this ICM approach in promoting sustainable development in China's coastal cities, and to further improve this approach, I developed three index frameworks to evaluate the performance of ICM in coastal cities of China with respect to the three aspects: coastal governance, ecological environment and social economic development. I then applied them to three case studies – Xiamen, Quanzhou and Dongying to assess the outcomes of ICM in contributing to the sustainable development of these coastal cities.

Based on the literature reviews of ICM indicators and the case studies in China's coastal cities, I built up an ICM governance index system with 12 indicators, an ecological index system with six indicators and a socio-economic index system with 13 indicators. Quantitative methods and variables were applied to get tangible ICM performance evaluation results. The principal component analysis (PCA) was employed as the weighting method to compose the final results.

In all the three coastal cities, results showed that their ICM performance had improved from 2004 to 2012, indicating that the ICM approach may have been effective in establishing coastal sustainable development. However, there remain some loopholes in coastal governance and the intricate environmental and coastal socio-economic issues in each city still need to be resolved to achieve better coastal sustainable development, for example, the poor implementation of an adaptive mechanism, a lack of external ICM funding, poor water quality, and intensive coastal resources exploitation. For management purposes, my study also identified and proposed a set of key performance indicators (KPIs) for each city to enhance efficiency in monitoring and measurement of ICM performance. The relationships between ICM governance, coastal environment changes and socio-economic development are also discussed using the driving force-pressure-state-impact-response (DPSIR) model.

List of tables

List of figures

List of abbreviations

AHP: Analytical Hierarchy Process

BAP: Budget Allocation Process

BOD: Biochemical Oxygen Demand

CBD: Convention on Biological Diversity

CCMP Comprehensive Conservation and Management Plan

CRC: Coastal Resources Center

CSD: Commission on Sustainable Development

COD: Chemical Oxygen Demand

COBSEA: Coordinating Body on the Seas of East Asia

CZMA: Coastal Zone Management Act

DEA: Data Envelopment Analysis

DO: Dissolved Oxygen

DPSIR: Driving force-pressure-state-impact-response

DSR: Driving force-state-response

EC: European Commission

EEA: European Environment Agency

EI: Ecological Index

EPA: Environmental Protection Agency

EU: European Union

FAO: Food and Agriculture Organization

GDP: Gross Domestic Product

GNP: Gross National Product

GEF: Global Environment Facility

GEO: Global Environment Outlook

GESAMP: Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

GI: Governance Index

ICM: Integrated Coastal Management

ICZM: Integrated Coastal Zone Management

IMO: International Maritime Organization

IOC: Intergovernmental Oceanographic Commission

IUCN: International Union for Conservation of Nature and Natural Resources

IPCC: Intergovernmental Panel on Climate Change

IPI: Integrated Performance Index

MMP-EAS: Partnerships in Environmental Management for the Seas of East Asia

NGO: Nongovernmental organization

NOAA: National Oceanic and Atmospheric Administration

NPC: National People's Congress

OECD: Organisation for Economic Co-operation and Development

OED: Operation Evaluation Department

PAGE: Pilot Analysis of Global Ecosystems

PCA: Principal Component Analysis

PEMSEA: Partnerships in Environmental Management for the Seas of East Asia

POC: Pew Ocean Commission

PSR: Pressure-State-Response

SDS-SEA: Sustainable Development Strategy for the Seas of East Asia

SER: State of the environment report

SI: Socio-economic Index

SOA : State of Ocean Administration

SPSS: Statistic Package for Social Science

UN: United Nations

UNCED: United Nations Conference on Environment and Development

UNCLOS: United Nations Convention on the Law of the Sea

UNDESA: United Nations Department of Economic and Social Affairs

UNDP: United Nations Development Programme

UNEP: United Nations Environment Programme

UNESCO: United Nations Educational, Scientific and Cultural Organization

US: The United States of America

USAID: United States Agency for International Development

WG-ID: Working Group on Indicators and Data (European Commission)

WRI: World Resources Institute

WSSD: World Summit on Sustainable Development

WWF: World Wildlife Fund

Chapter 1 Introduction

1.1 Background

The coastal zone supports rich marine biodiversity and at the same time is profoundly impacted by human activities. In terms of biodiversity, almost 80% of the total marine species are coastal or littoral (Ray, 1991). There exist diverse coastal ecosystems that include the estuaries, seagrass and algal beds, coral reefs, mangrove and tidal marsh, and globally, they all provide valuable ecosystem services that has been estimated to be worth $58,975/ha/year (Costanza et al., 1997). This translates to a 98% contribution to the overall value of marine ecosystems' services, despite that such ecosystems only account for 8.5% of the total marine area (Costanza et al., 1997). In terms of human population, the average coastal population density (defined as those living in a coastal area within 100km of nearest shoreline) was estimated to be nearly three times higher than the global population density (Nicholls & Small, 2002). Of the 17 mega cities in the world, 14 are located along the coast, and 40% of the world's major cities with population size of 1–10 million people live near coastlines (Tibbetts, 2002; Lee, 2013). Due to the intensive human pressure on coastal habitats and their resources, coupled with demographic trends indicating growing coastal populations, coastal areas face strong threats to its biodiversity (Gray, 1997). These threats include habitat loss, overexploitation, pollution, climate change, species introductions/invasions, watershed alteration and physical modification of coastlines (Gibbons et al., 2000).

China's coastal zone covers an area of 285,000km^2 (i.e. coastal area starts from the coastline, landward for 10km and seaward to a water depth of 15m), which includes 6500 offshore islands under its jurisdiction. The coastline stretches across 18,000km, which encompasses the temperate, subtropical and tropical zones, and mainly covers three large marine ecosystems (LMEs): the Yellow Sea, the East China Sea, and the South China Sea (Fig. 1-1). China's coastal areas are also extraordinary rich in marine biodiversity, comprising approximately 20,300 recorded marine species, making up almost 8.5% of the global marine flora and fauna (Huang, 2008). The vast and wealthy marine reserves have supported various coastal-related industries (e.g. shipping, fishing, oil explorations, and tourism), all of which contributing to nearly 10% of China's overall Gross Domestic Production (GDP) and have been growing at a rate of 15% per annum (State of Oceanic Administration, 2013). The mainland coast of China is divided into 11 administrative units (nine provinces, two municipalities, and 56 cities, Fig. 1-1), covering about 13.6% of its total area and supporting 46.3% of the total population (National Bureau of Statistics of China, 2013). In 2012, the GDP of these 11 coastal units contributed to 67% of the country's total GDP (National Bureau of Statistics of China, 2013). At the same time, most of these coastal cities are facing impacts due to rapid environmental and socio-economic development, and management challenges towards attaining sustainable development. It is therefore urgent to adopt sound management approaches to balance economic development with environmental sustainability.

Fig. 1-1 China's coast

1.2 Integrated Coastal Management (ICM)

1.2.1 ICM development

For nearly half a century, Integrated Coastal Management (ICM) has been a holistic approach for coastal governance to deal with multiple coastal environmental issues (Fig. 1-2), and widely recognized as an effective paradigm for promoting coastal sustainability (Cicin-sain & Knecht, 1998, Chua, 2006). This approach first adopted a set of principles and tools proposed in 1965 by the San Francisco Bay Conservation and Development Commission, whose concept was later generated and developed by the scientific community in the 1970s and 1980s. It became formally recognized at the Charleston Workshop in 1989 (Sorensen, 1993), and entered the international political sphere during the United Nations Conference on Environment and Development in 1992 (UNCED, 1992). Since then, it has been promoted as an effective and practical tool by several international organizations to achieve the goal of sustainable development (Cicin-sain & Knecht, 1998; Sorensen, 2002; AIDEnvironment, 2004). To effectively manage the coastal areas, the general ICM framework needs to be modified and incorporated into the local political, legal and institutional systems in order to manage the dynamic environment and to effectively tackle the various environmental impacts challenges. Over 100 coastal countries and regions have by now adopted the ICM approach for coastal governance (Sorensen, 2002), where many of these ICM efforts in coastal states globally have been supported and funded by multilateral banks (Tibbetts, 2002). These included the Inter-American Development Bank investment of $60 million during 1993–1996 in ICM programs in developing countries, the World Bank invested about $500 million for ICM efforts around the world from 1996–2004, and a number of Global Environment Facility (GEF) projects relied on ICM approaches to meet their objectives (Olsen & Tobey, 1997;

Olsen & Christie, 2000).

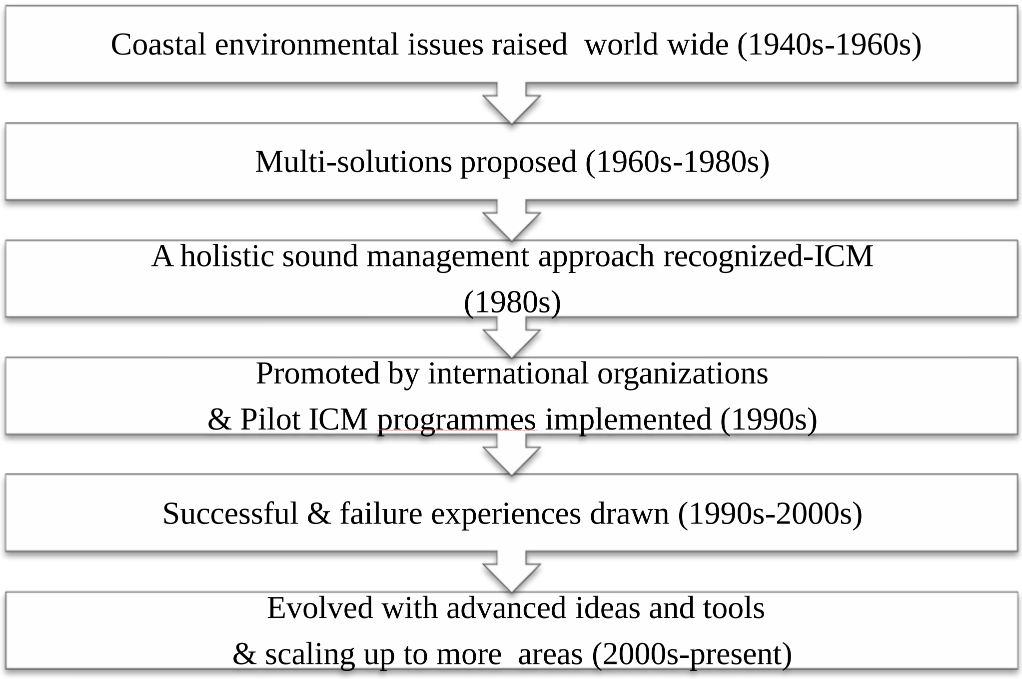

Fig. 1-2 Timeline of ICM development

1.2.2 Case studies of ICM successes and failure

Despite almost 700 ICM initiatives being recorded during the 1990s (Belfiore, 2003), only a few have been completed, sustained or considered successful. Some examples of successes were found in Tampa Bay Estuary of U.S.A (Lewis et al., 1999), Sri Lanka (Hettiarachchi & Samarawickrama, 2005), Batangas, Philippines (The Provincial Government of Batangas, 2008), and Xiamen, China (Ye et al., 2013). The success of the ICM implementation in these regions could be generalized to the following key principles or elements: sufficient financial resources, effective coordination mechanisms, well-implemented legislation, strong government commitments, powerful scientific database support, as well as successful public involvement and awareness. On the other hand, failed examples of ICM initiatives did not enter the implementation stage or continue to run a new cycle due to various reasons, such as the lack of external funds to carry out the projects (Pomeroy & Carlos, 1997; White & Salamanca, 2002), institutional disagreement (Archer, 1988; Imperial et al., 2000), and loopholes in legislation (Sharma, 1996).

1.2.3 ICM tools

Based on the case studies of both successes and failures of ICM initiatives, several advanced ideas and tools have since been introduced to improve the broad framework of ICM. An example is the application of the recently developed Ecosystem-based Management (EBM) in the marine realm (POC, 2003), which aims to sustain ecosystem structure and function. This could be considered as an expansion of current ICM approach, where it guides the management in an ecosystem context, rather than as a paradigm shift (McLeod et al., 2005; McLeod & Leslie 2009; Aswani et al., 2012). Other new tools such as the ICM indicators (Ehler, 2003; Olsen, 2003; UNESCO, 2003; Belfiore, 2005; Heileman, 2006; PEMSEA, 2011), Marine Protected Area Network (MPA Network) (Tongson, 2004; Aliño, 2010; Brock et al., 2012), and Marine Spatial Planning (MSP) (Douvere & Ehler, 2007; Ehler, 2008; Olsen et al., 2011) provide practical and effective ways to implement ICM in an ecosystem context for promoting coastal sustainability. ICM indicators are essential tools to measure the progress and effectiveness of past and presently implemented ICM programmes, as well as to forecast future trends. In this study, I have mainly used the ICM indicators to determine the contributions of ICM towards the sustainable development of China's coastal cities.

1.2.4 ICM initiatives in China

The ICM concept was first introduced to China in 1979 in an attempt to establish a coastal management law during the first investigation of coastal and tidal resources.

Although the intended law was not established, China began to develop ICM initiatives to tackle their coastal management problems, and their ICM development could be divided into three stages (Table. 1-1). Over the last three decades, the Chinese central government and many local governments have made substantial progress in different aspects to meet the goals of ICM, including legislation, institutional reform, scientific research, and international cooperation. However, a national ICM framework has not yet been established. In May 2013, China's central oceanic administration - the State Ocean Administration (SOA) - was restructured in a move to strengthen maritime law enforcement and marine resource protection. This was undertaken through the foundation of an integrated law enforcement agency: “China Coast Guard”, which unifies China’s Marine Surveillance of SOA, the coast guard forces of the Ministry of Public Security, the fisheries law enforcement command of the Ministry of Agriculture, and the maritime anti-smuggling authorities of the General Administration of Customs. This expanded administration will probably promote the setup of an ICM framework at the national level.

Table. 1-1 Key events, laws and projects during three stages of ICM development in China

Periods and goals	Key events, laws, projects
1979-early 1990s: **Introduction of ICM , coastal resource investigation, and growing awareness of coastal and marine protection**	1979: ICM concept was first adopted in establishment of a coastal management law, the law failed to be passed 1979-1986: the State Ocean Administration (SOA) conducted “Comprehensive Survey of China's Coastal Zones and Tideland Resources” 1980-1990:Initial development of MPA 1982: National People's Congress (NPC) enacted “Marine Environment Protection Law of the People's Republic of China” (Amended in 2000) 1986: NPC enacted “The Fishery Law of the People's Republic of China”(Amended twice in 2000 and 2004) 1988-1995: SOA conducted “General investigation of China's islands resources” 1992: NPC enacted “Law of the Peoples Republic of China on Territorial seas and adjacent zones” 1992: China joined Ramsar Convention
1990s-2000s: **Development of coastal policies, participation in**	1994: Become a member country of Coordinating Body on the Seas of East Asia (COBSEA), carried out several projects under COBSEA 1994: China participated in GEF/UNDP/IMO MMP-EAS’ “Action Plan for the Protection and Sustainable Development of the Marine

international organization and implementation of ICM projects	and Coastal Areas of the East Asian Seas Region" 1996: The State Council published "The 21st century China ocean agenda" 1996: the NPC Standing Committee ratified United Nations Convention on the Law of the Sea (UNCLOS) 1998: The State Council formulated "National Marine Affairs Development Plan" 1998: NPC enacted "Law of the Peoples Republic of China on the Exclusive Economic Zone and the Continental Shelf" 1994-1999: Xiamen local government joined GEF/UNDP/IMO MMP-EAS, Xiamen ICM pilot projects (First ICM project implemented at local level) 1997-2000: SOA joined UNDP Project of ICM capacity building of north part in South China Sea 1999: Be a country partner of PEMSEA, carried out several projects under PEMSEA 2001: NPC enacted "Sea Area Use Management Law of the People's Republic of China" 2002: NPC enacted "Law of the People's Republic of China on the Administration of the Use of Sea Areas" and " Marine resources development and protection law"
2000s-present : **Scaling up of ICM**	2002-2008: SOA joined the UNEP/GEF South China Sea project 2006-2014: China joined GEF/UNDP/UNOPS PEMSEA's project on

& calling for sustainable coastal development	ICM Scaling Up Programme 2006: ICM information system was incorporated into China's Eleventh Five-year Plan of Ocean Technology development; SOA conducted a project on Biodiversity Management in the Coastal Area of the China ́s South Sea 2007: The first provincial coastal plan established by Shandong provincial government: The coastal planning of Shandong province 2008: 10 coastal cities in China joined PEMSEA's project on Scaling up of ICM 2006-2013: SOA carried out more than 20 research projects on marine & coastal ecosystem restoration, marine protected areas and marine policy 2013: The foundation of China Coast Guard (for integrated law enforcement) by SOA

On the local level, the early ICM programme initiated in Xiamen was selected as a demonstration site under the Global Environmental Facility (GEF)/United Nations Development Program (UNDP)/ International Maritime Organization (IMO) Regional Program to adopt an ICM framework in 1994. The successful ICM experience in Xiamen has empowered the Chinese government to scale up the ICM programmes for China's coastal areas. To date, over 10 coastal cities in seven out of nine provinces have officially declared their adoption of the ICM framework to different degrees. Some other coastal cities, such as Shanghai, Tianjin, and Shenzhen are currently also trying to promote integrated management in coastal environmental issues (Shi et al., 2001; Lau, 2005). With the expansion of ICM efforts in China, there are several key questions that need to be addressed. For example, what is the current status of ICM implementation in these cities? Is ICM effective for these cities to promote sustainability?

1.3 Rationale for evaluation of ICM performance

It is well-known among numerous international organizations and scientists that it is crucial to develop measures that can assess the ICM's effectiveness in achieving coastal environment sustainability, as well as to assist governments or decision makers in updating their information on the progress of ICM programmes (GESAMP 1996; Olsen et al. 1997). An effective ICM evaluation not only reveals the progress, results, and impacts but also provides indications on why the project is or is not achieving the desired goals, and to pick up learning points for improvements in subsequent steps (Olsen, 2003). Furthermore, it is essential to adapt ICM interventions to changing conditions in a proactive way by systematically monitoring ICM progress and observing the environmental and socio-economic development over an extended period of time.

In the evolution of ICM regimes (Fig. 1-2), the methods and practices of ICM performance evaluation is the least developed phase that was started in the late 1990s (Cicin-Sain & Knecht, 1998). With a decade of research efforts, a number of indicator frameworks have been proposed for measuring ICM programmes, which could be categorized into three types: (1) to focus on ICM governance and assess the management progress of ICM initiatives, mostly within an ICM cycle (Burbridge, 1997; Olsen, 2003; Breton et al., 2006; Gallagher, 2010), (2) to measure the outcomes and/or impacts of ICM projects, with the main focus on environmental and social economic benefits towards sustainability (Kabuta & Laane, 2003; Linton & Warner, 2003; Bowen & Riley, 2003; Mcfadden & Priest, 2008; Tabet & Fanning, 2012), and (3) to measure the performance of ICM by integrating the management process and outcome indicators (Heileman, 2006; PEMSEA, 2011).

To effectively quantify the success of ICM initiatives in coastal regions, performance evaluation should account for both the management progress (governance) and outcomes (environmental and social economic benefits) and how it has promoted overall coastal sustainability. However, in practice, many ICM evaluation cases have only been concerned with one aspect of ICM performance (Lowery, et al., 1999), while only a few have integrated measures in their evaluation at national and local scales (NOAA, 2004; Marti, 2006; Schernewski et al., 2006; Heileman, 2006; The Provincial Government of Batangas, 2008). Presently, there is still no widely accepted methodology or common criterion for assessing ICM performance due to the complexity and heterogeneity of ICM programmes in various coastal regions (Billé, 2007; Gallagher, 2010). In addition, quantitative studies to assess the effectiveness or weakness of current ICM implementation are limited. The interdependencies of governance, socio-economic and coastal environmental dynamics have also not been studied intensively.

1.4 Overview of research

1.4.1 Research objectives

The main aim of my thesis is to evaluate the effectiveness of the ICM approach in China's coastal cities with respect to achieving the goal of environmental sustainability. To fulfill this aim, I first evaluated the performance of ICM from three aspects in coastal cities of China: (1) coastal governance, (2) ecological environment restoration, and (3) social economic development using specific ICM indicators. The specific objectives are:

a) To build a measurable model that includes a set of practical indicators and proper quantitative evaluation methods for measuring the performance of ICM in terms of its governance, ecological environment restoration, and socio-economic development.

b) To apply this model in assessing the progress and effectiveness of ICM in three coastal cities: Xiamen, Quanzhou, and Dongying in China, to identify general trends in the environmental and social economic conditions of the areas, and to promote adaptive management for ICM governance in response to changing conditions.

c) To use the outcomes of this model for comparison of ICM performance among the three cities and to generalize the most relevant factors associated with the effectiveness of ICM.

Case studies in Xiamen and Quanzhou have been published in “Journal of Environmental Planning and Management” (Ye et al, 2013) and “Ocean and Coastal Management” respectively (Ye et al., 2014).

1.4.2 Chapter organization

The framework of chapter organization in this dissertation is described in Fig. 1-3.

In Chapter 2 – “Materials and Methods”, I provide an overview of my research design and methodology on: (1) how I use the indicators to measure the ICM performance, (2) how I select these indicators, and (3) how I quantify and composite the indicators. I will also explain the rationale for the selection of study sites and briefly introduce them: Xiamen, Quanzhou, and Dongying.

In Chapter 3 – “The performance of ICM in coastal governance”, I first reviewed the indicators used in existing ICM governance evaluation, and later build an index system for the measurement of coastal governance adapted to China’s coastal cities. With this index, I applied it to evaluate the ICM governance of the three coastal cities and present the outcomes of their ICM performances. Finally, I provide a detailed analysis of the ICM performance in coastal governance in all three cities.

In Chapter 4 – "The performance of ICM in coastal ecological environment", I first reviewed the ICM indicators and its frameworks used in coastal environment evaluation, and later build an index system to measure coastal environment with respect to China's coastal cities. I applied the index system to evaluate the status (health) of coastal environment in three cases. Finally, I provide a detailed analysis of the ICM performance in coastal environment in all three case studies.

In Chapter 5 – "The performance of ICM in coastal socio-economic development", I firstly reviewed the indicators used in coastal socio-economic evaluation, and then build an index system to measure coastal socio-economic development under an ICM framework with respect to China's coastal cities. I applied the index system to evaluate the coastal socio-economic development in the three cases. Finally, I provide a detailed analysis of the ICM performance in coastal socio-economic development in the three case studies.

In Chapter 6 – "The overall performance of ICM in coastal sustainability", I synthesized all three index systems and analyzed the overall performance of ICM in all three coastal cities. The overall ICM performance of the three coastal cities was later compared to determine the similarities and differences, as well as to identify the key performance indicators for each city, and finally propose the common key factors that led to the success or failure of an ICM programme.

In Chapter 7 – "Summary", I conclude and discuss the major findings of my dissertation research and propose key suggestions for further improvements of the ICM approaches adopted in China's coastal cities.

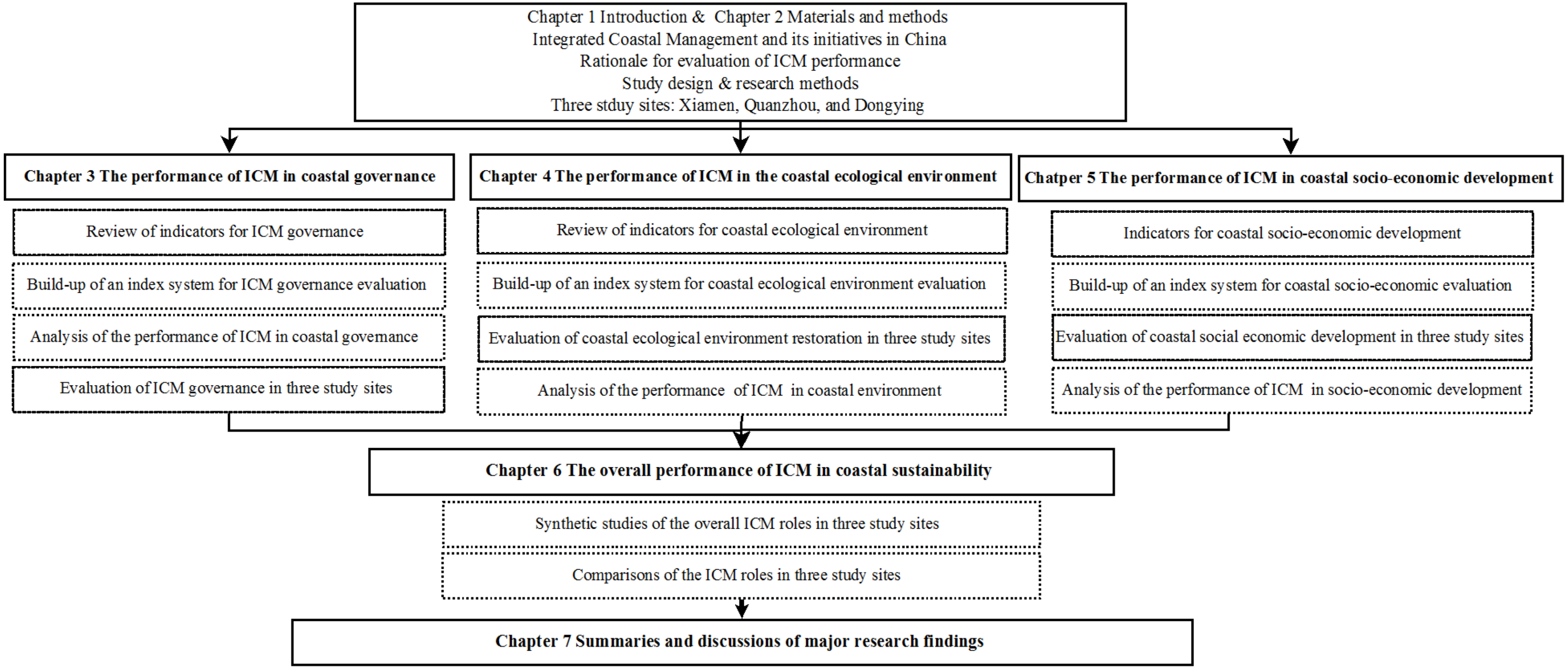

Fig. 1-3 The framework of chapter organization for the dissertation

Chapter 2 Materials and Methods

2.1 Research design

In this dissertation, I examine the ICM performance indicators in terms of coastal governance, coastal environment and socio-economic conditions, which has been demonstrated as effective tools that can be used to reflect the evolution of government institutions, changes in the state of coastal environments, and trends in socio-economic development. Of the 11 ICM sites in China, I pre-selected three sites (Xiamen, Quanzhou, and Dongying) to apply these indicators to evaluate their ICM performance based on the above mentioned three aspects. I then synthesize the outcomes based on these indicators and evaluate the effectiveness of overall ICM performance in coastal sustainability for China. Finally, I compared the three case studies to determine the similarities and differences of factors that lead to the success of ICM programme (Fig. 2-1).

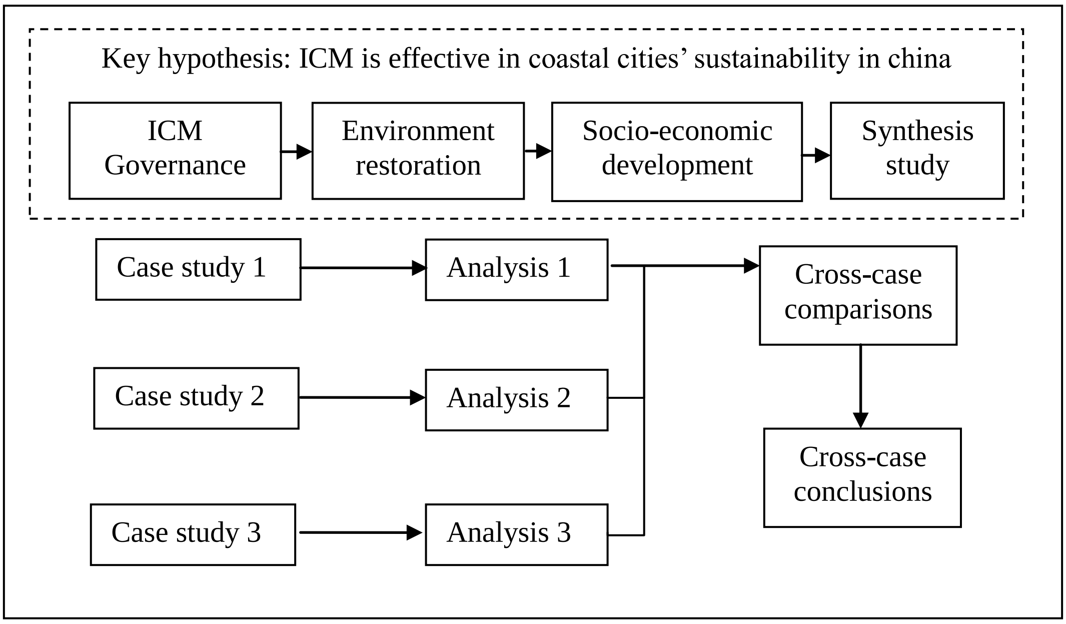

Fig. 2-1 An overview of my dissertation's research design

2.2 Selection of Indicators

The use of various indicators has proved effective in assessing the performance of ICM initiatives in relation to the typical goals and objectives (NOAA, 2004; Breton et al, 2006; Heileman, 2006; PEMSEA, 2010).

Three major categories of ICM indicators can be identified as follows:

(1) Indicators to evaluate the integration, legitimacy, quality, and adaptability of ICM governance evolution processes;

(2) Indicators to evaluate the outcomes and achievements of ICM programmes in the protection and restoration of the coastal ecosystems;

(3) Indicators to evaluate the outcomes and impacts of ICM programmes in terms of socio-economic benefits, such as improved life quality and coastal safety.

In this study, I use indicators that fall into these three categories to evaluate the effectiveness of ICM programmes in China's coastal cities. Through an extensive literature review of indicators used in coastal management and investigations of

China's coastal cities, the selection of specific performance indicators for measuring the ICM governance, coastal ecological environment and coastal socio-economic development in China's coastal cities will be presented in Chapters 3, 4 and 5 respectively.

The following general guiding principles are used to the development and selection of suitable indicators.

1. **Theoretically well defined**, indicators must be based on widely accepted scientific theory, and should be adequately defined and validated in literature.
2. **Interpretable and understandable**: Indicators should reflect properties of concern to stakeholders; understandable to a broad audience, many of whom will not have technical or statistical expertise.
3. **Readily measurable and comparable**, each indicator should be clearly defined with established measurement standards to be observed, documented and verified.
4. **Stable, independent and sensitive**, indicators should be well designed and remain broadly stable, independent and sensitive over time to facilitate a valid comparison of ICM performance over times and regions.
5. **Cost effective**: Indicators should be cost-effective based on the monitoring data that are acquirable.
6. **Reactive**, indicators should be able to measure the effects of ICM programmes so as to provide reliable feedbacks on the evaluation results.

2.3 Study sites

Of the 11 ICM sites in China, Xiamen represents the first site with an implemented ICM since 1994, and it is now running its third cycle of the ICM program. While there are 10 other parallel sites that have implemented ICM since 2005, they are now still in their initial stages. On the basis that Xiamen is the oldest implemented ICM in China, it was selected as one of the case studies for examination of its ICM progress in different stages. Amongst the 10 parallel ICM sites (Fig. 1-1 and Table. 2-1), two cities – Quanzhou and Dongying in different geographical and social settings, as well as having different coastal sustainable development concerns were selected as the other two case studies to demonstrate the effectiveness of ICM in China's coastal cities.

Therefore, the three sites for case studies are Xiamen, Quanzhou and Dongying (Table. 2-2). Xiamen is an island coastal city. Quanzhou and Dongying are both bay cities. Xiamen and Quanzhou are neighbouring cities located in South China Sea Large marine ecosystems (LMEs), while Dongying is nearly 2000km north away from Quanzhou located in Yellow and Bohai Sea LMEs. Quanzhou has the largest land and sea area as well as the longest coastline, while Xiamen has the smallest land and sea area as well as the shortest coastline. However, Xiamen has the largest population density because of its rapid economic growth, while Dongying has the smallest population density. In the process of coastal urbanization, the three cities also have been facing different coastal environmental issues that will be discussed in detail in the following chapters.

Table. 2-1 Profile of 10 ICM parallel cities (ordered from north to south of China's coast) (Sources: State of Oceanic Administratoin)

ICM cities	Land area (km^2)	Sea area (km^2)	Coast -line (km)	Population (2010) ($*10^4$)	GDP (2010) (billion yuan)	Major coastal economic activities	Prioritized concerns
Pan jin	4071	1425	118	131	92.65	Oil industry and fisheries	Environmental monitoring, and conservation of key habitat
Le ting	1308	1808	98	50	23.33	Agriculture, industry, tourism and fisheries	Economic development and marine functional zoning
Dong ying	8053	4800	413	185	236.00	Oil industry and agriculture	Oil exploitation, coastal tourism, and aquaculture
Qing dao	10654	13800	862	764	566.60	Manufacturing industries, port and tourism	Coastal risk management, marine functional zoning
Liany u-nga ng	7446	6677	176	498	115.10	Port industry, agriculture and fisheries	Wastewater treatment, pollution control
Quan zhou	10866	11360	427	813	356.50	Industry and tourism	Industrial pollution control, coastal reclamation
Yang jiang	7813	12300	323	242	64.18	Tourism, fisheries and aquaculture.	Fishery resource protection, waste water treatment
Fang cheng gang	6181	40000	580	86.7	31.95	Port industry	Mariculture, coastal urbanization and port development
Hai kou	2305	830	131	205	59.05	Fisheries, agriculture, and tourism	Pollution control, coastal industry, and natural ecosystems protection
Wen chang	2403	4600	207	50.9	11.45	Fishery and aquaculture	Wastewater treatment, aquaculture activities, and coastal land reclamation

Table. 2-2 Profile of three selected coastal cities for case studies (State of Oceanic Administratoin, 2013)

	Xiamen - Island city	Quanzhou - Bay city	Dongying - Bay city
ICM implementation	1994-present	2005-present	2005-present
Climate	Subtropical	Subtropical	Temperate
Land area	1565 km^2	10,866 km^2	8053 km^2
Sea area	390 km^2	11,360 km^2	4800km^2
Coastline	234 km	427 km	413 km
Population density	2333ind/km^2 (2012)	761 ind/km^2 (2012)	262 ind/km^2 (2012)
Per capital GDP	76707 yuan (2012)	57291 yuan (2012)	144777 yuan (2012)
Gross Ocean Product	53.4 billion yuan (2012) (Fig. 2-2)	54.8 billion yuan (2012) (Fig. 2-3)	54.9 billion yuan (2012) (Fig. 2-4)
LMEs	South China Sea	South China Sea	Yellow & Bohai Sea
Coastal land use types	Ports, tourism, harbour industrial zones, ecological reserves	Harbour industrial zones, tourism, ports, fishing area, mangrove	Oil mining, ports, tourism, wetland, fishing area, agriculture
Coastal sustainability concerns	Coastal land reclamation, and tourism	Industrial pollution, and harbour development	Oil mining, coastal land reclamation, and aquaculture

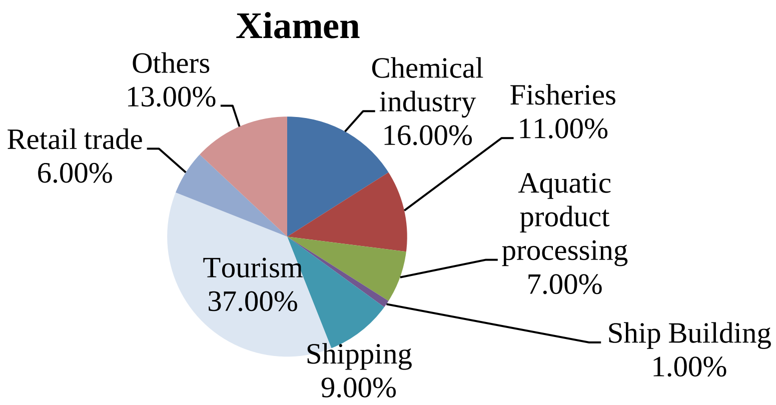

Fig. 2-2 Pie chart of gross ocean products in Xiamen, 2012 (Source: Xiamen Yearbook)

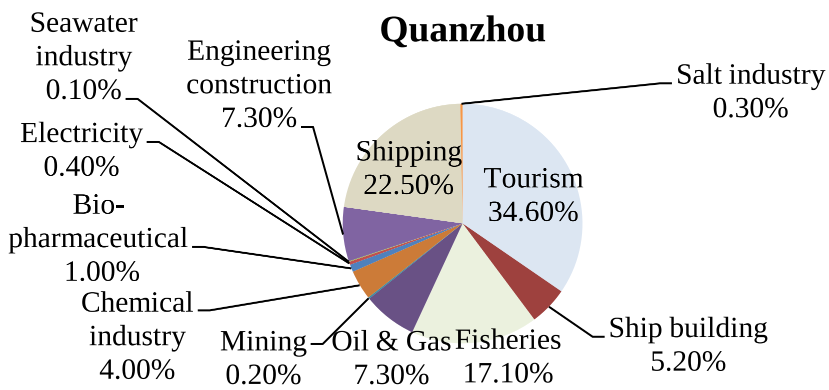

Fig. 2-3 Pie chart of gross ocean products in Quanzhou, 2012 (Source: Quanzhou Yearbook)

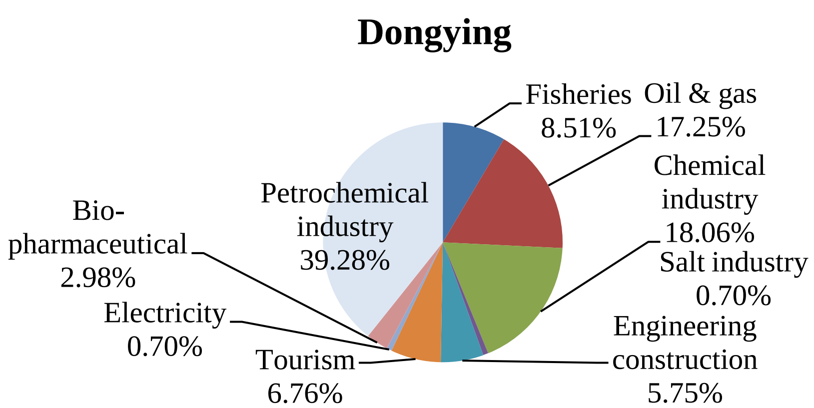

Fig. 2-4 Pie chart of gross ocean products in Dongying, 2012 (Source: Dongying Yearbook)

2.3.1 Xiamen

Xiamen (24°24'N ~ 24°55'N, 117°53'E ~ 118°25'E) is a tourist island city located in the southeastern coast of China, near the Taiwan Strait (Fig. 2-5). Its terrestrial boundary includes Xiamen Island and 4 other districts of Haicang, Jimei, Tongan, Xiangan, covering a total land area of 1565 km^2. Its territorial sea area boundary includes Dadeng Sea, Tongan Sea, Western sea area, Southern sea area, Eastern sea area and Jiulongjiang river estuary around the Xiamen Island with a coastline of 234 km, covering a total sea area of 390 km^2.

Xiamen has a monsoonal humid subtropical climate with an annual mean temperature of 20.4 ℃. It is the first Chinese city to adopt the ICM framework for coastal pollution control and sustainable environmental development. In 1994, Xiamen joined the GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas (MMP-EAS), and launched a series of ICM programmes. The initial purpose of establishing an ICM framework in Xiamen was to address coastal pollution issues (Chua et al, 1997). Early in 1995, after Xiamen became a demonstration ICM site, the Xiamen Marine Management and Coordination Committee was established as an inter-agency, multi-sector institution to provide policy advice, coordinate marine uses and review the entire program's progress (Fig. 2-6). Its legal framework had also been established (Fig. 2-7). After nearly 20 years, it is now running the third cycle of the ICM programme with the purpose of ecological rehabilitation and ecosystem-based management. The majority of current studies have been concentrated in Xiamen, which served as a demonstrate site (Chua & Chen, 1997; McCleave et al., 2003; Xue et al., 2004; Peng et al., 2006; Cao & Wong, 2007), while other ICM cities have been more or less neglected.

Fig. 2-5 Map of Xiamen municipality.

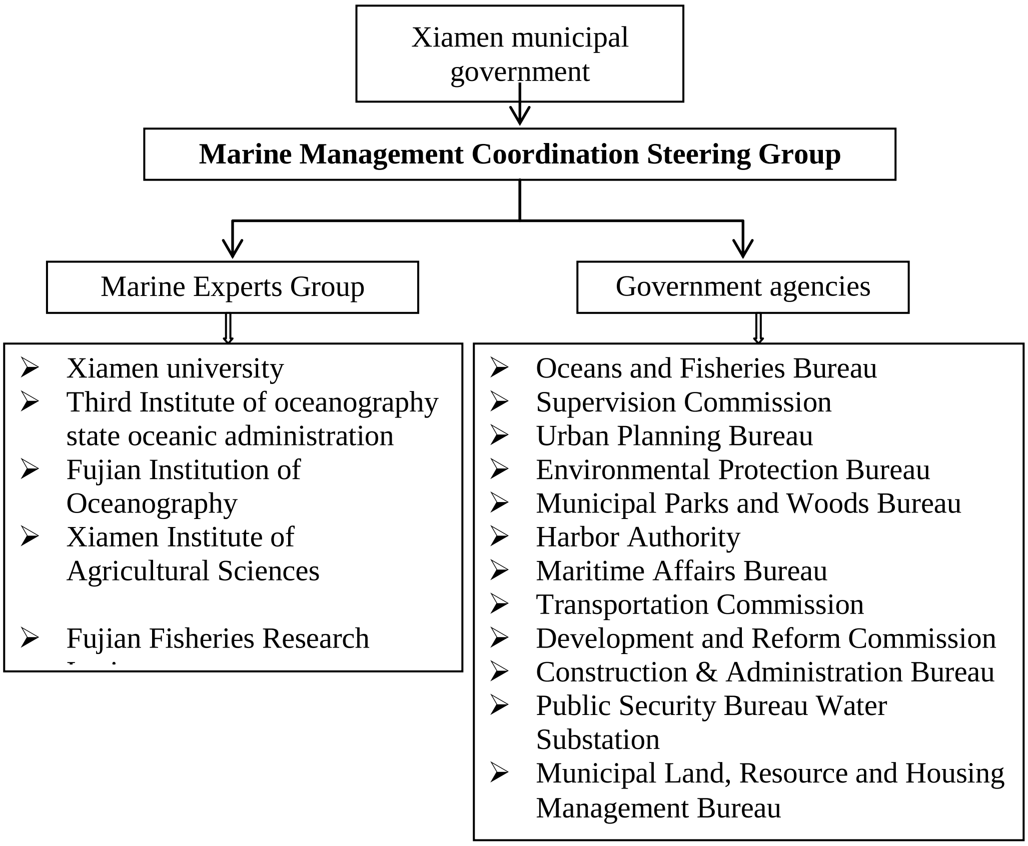

Fig. 2-6 Xiamen ICM Coordination Mechanism

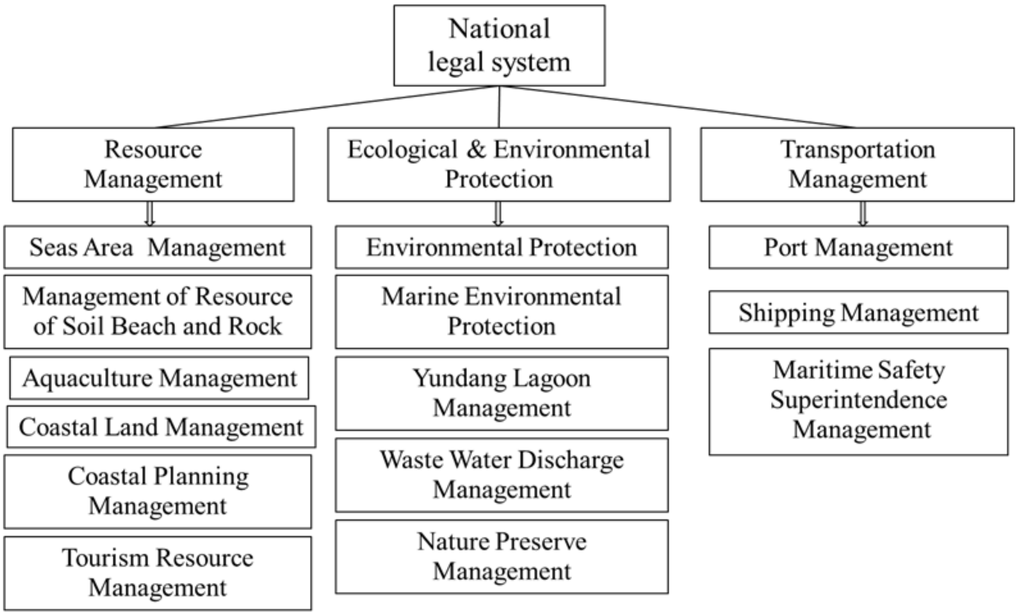

Fig. 2-7 Xiamen ICM legal framework

2.3.2 Quanzhou

Quanzhou ($24^{o}30'N \sim 25^{o}56'N$, $117^{o}25'E \sim 119^{o}05'E$) (Fig. 2-8) is an industrial bay city located in the southeastern coast of China, bordering Taiwan Strait to the east. Its terrestrial boundary includes Quanzhou downtown, 3 county-level cities of Jiangjiang, Shishi, Nanan, and 4 counties of Huian, Anxi, Yongchun, Dehua, covering a total land area of 8053 km^2. Its territorial sea area boundary stretches north to Meizhou Bay, and south to Weitou Bay, with a coastline of 413 km, covering a total sea area of 11360 km^2.

Quanzhou has a subtropical monsoon climate with an annual mean temperature of 19.8 ℃. It is one of the most developed cities in Fujian province, contributing the largest portion of GDP within the province. With rapid economic expansion and population growth since 1990s, it had faced severe coastal environmental problems, such as coastal water pollution and habitat loss. The pre existing environmental management framework could not solve the problems due to a lack of integrated planning, uncoordinated marine resource development, weak capacity for pollution control and treatment, inadequate legal system for regulation enforcement, and a lack of sufficient database for management. Therefore, the municipal government joined the GEF/UNDP/UNOPS-PEMSEA's ICM Scaling Up Programme in 2005, acting as an ICM parallel site to implement an ICM programme and to promote sustainable development.

After designated as one of the parallel ICM cities, the municipal government of Quanzhou started to reform the institutional mechanism of coastal management. Priority concerns included industrial pollution, marine reclamation and port construction, over exploitation of marine resources, illegal sand mining, and red-tides.

To coordinate marine uses and facilitate the working efficiency, an ICM steering committee was formally established at the municipal level. They are ocean development and management steering committee, offshore wastewater integrated treatment steering committee and coastal resource and environment protection steering committee, forming the main coordination body of the ICM framework in Quanzhou (Fig. 2-9). Quanzhou municipality itself has no legislative power, its ICM legal framework therefore is under the national and provincial legislation (Fig. 2-10).

Fig. 2-8 Map of Quanzhou municipality

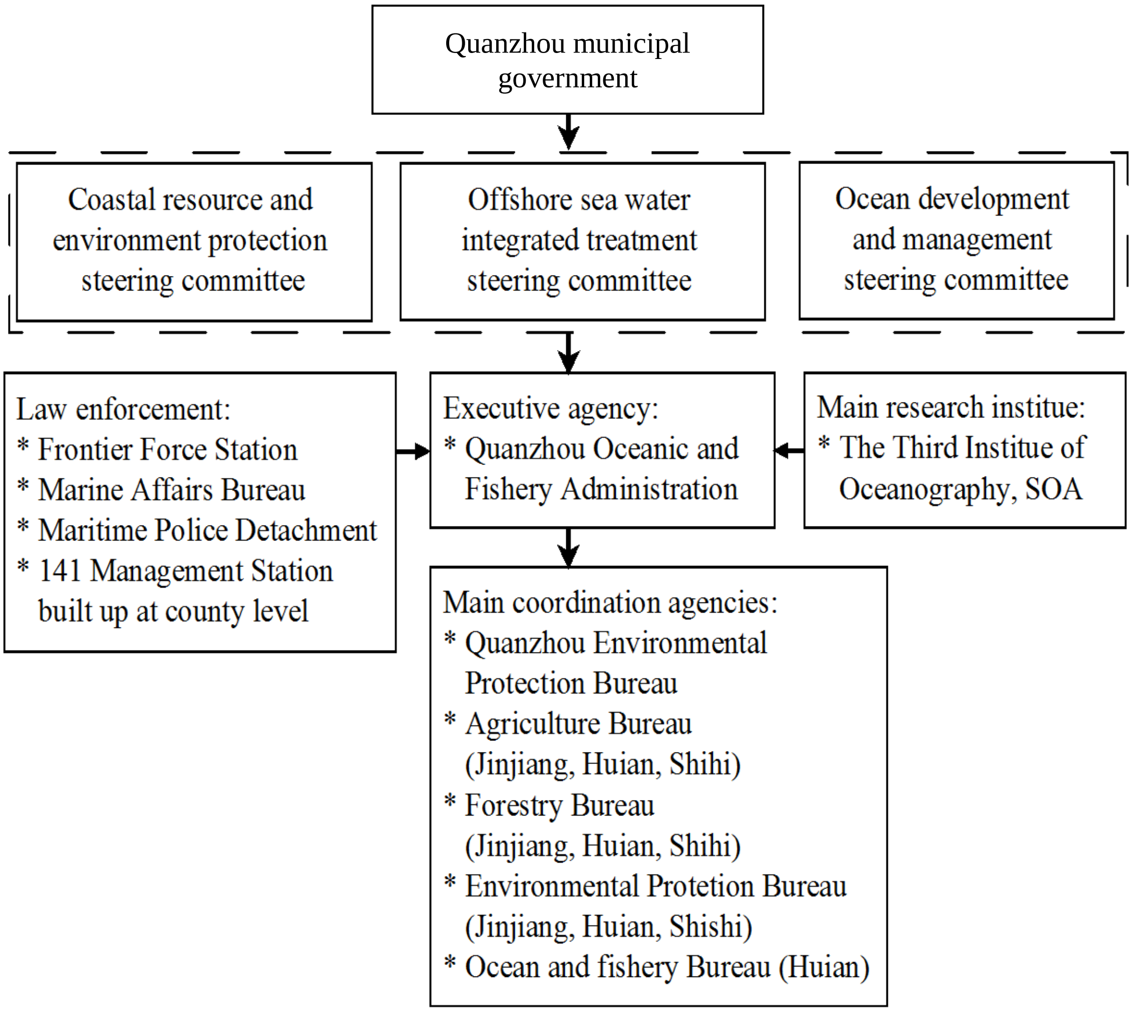

Fig. 2-9 The ICM coordination mechanism in Quanzhou

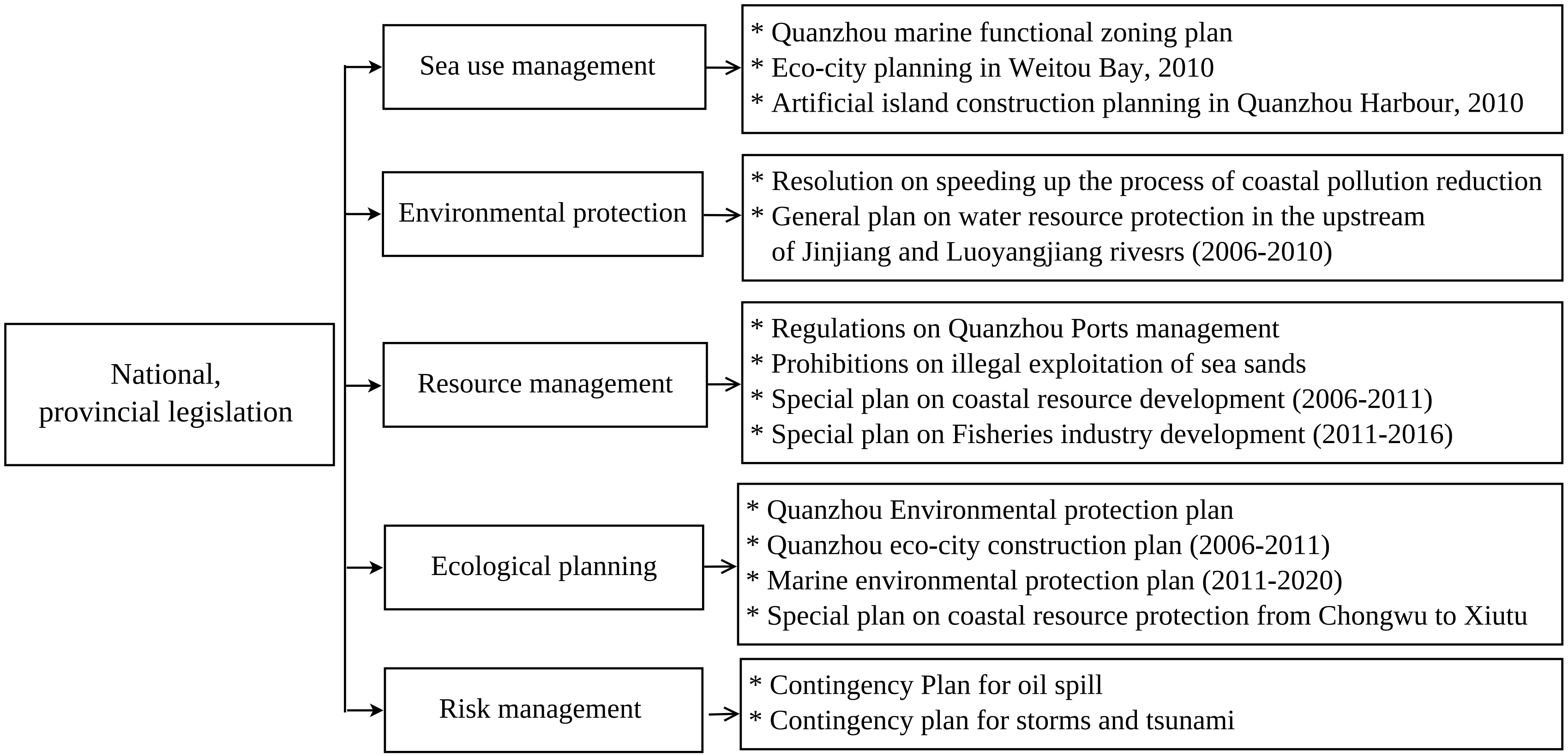

Fig. 2-10 Quanzhou ICM legal framework

2.3.3 Dongying

Dongying (36°58'N ~ 38°08' N, 118°50'E ~ 119°15'E) is also a bay city located in the Yellow River Delta of northeast China (Fig. 2-11). Its terrestrial boundary includes 2 districts of Dongying and Hekou and 3 county-level cities of Guangrao, Kenli, Lijin, covering a total land area of 8053 km^2. Its territorial sea area boundary includes part of Bohai Sea, and stretches north to south with a coastline of 413 km, covering a total sea area of 4800 km^2.

Dongying has a temperate monsoon-influenced climate with an annual mean temperature of 12.8 ℃. It has much colder weather than Xiamen and Quanzhou. Main income source of the city is from the oil exploitation industry. Other major coastal uses include pelagic fishery, aquaculture, salt production, sea port and tourism. These activities have caused a lot of conflicts in the use of the coastal area and many environmental issues such as oil spill risks, marine pollution and coastal and biodiversity loss. The municipal government also joined the PEMSEA's ICM Scaling Up Programme in 2005, acting as an ICM parallel site to launch a series of ICM projects to address these issues. Dongying had not built up its ICM coordination mechanism (Fig. 2-12) until 2009 and its ICM legal framework is also under the national and provincial legislation (Fig. 2-13).

Fig. 2-11 Map of Dongying municipality.

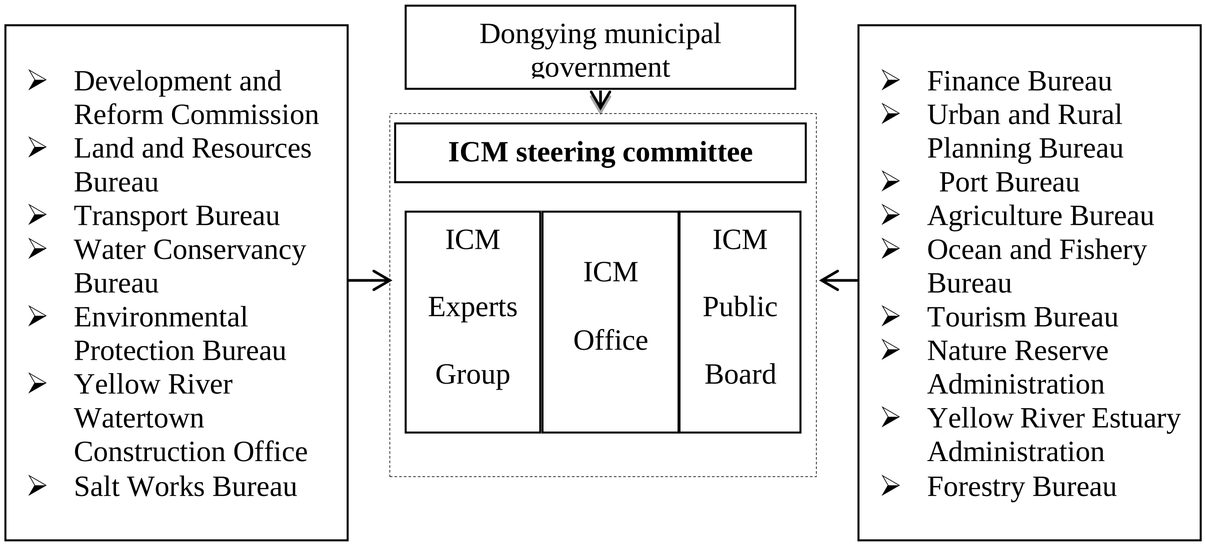

Fig. 2-12 Dongying ICM coordination mechanism

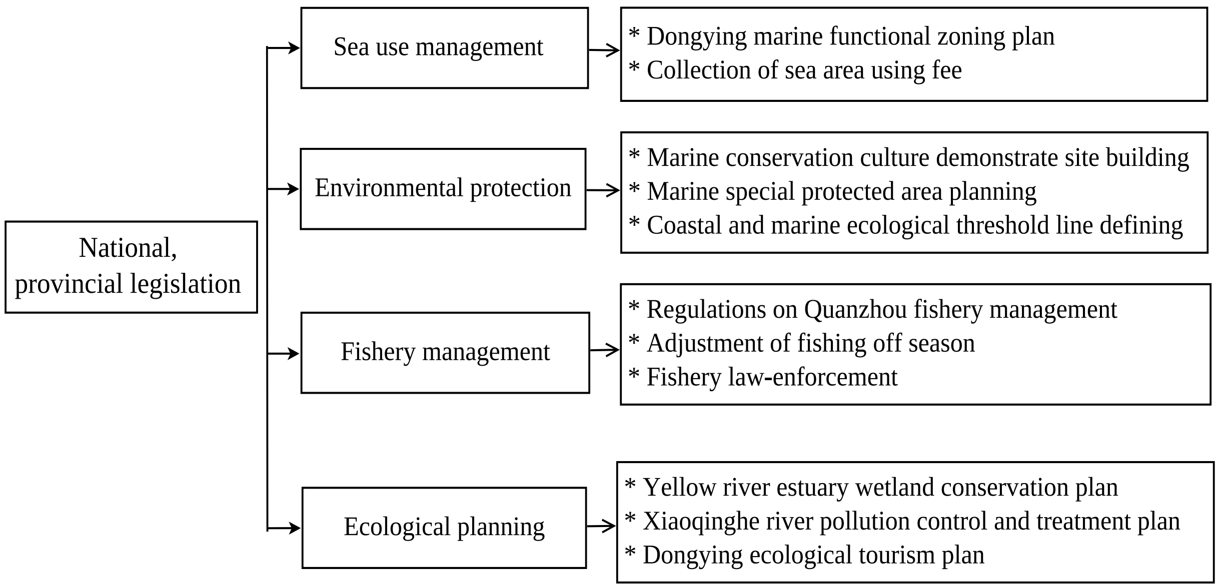

Fig. 2-13 Dongying ICM legal framework

2.4 Data collection and analysis

2.4.1 Time scale

Given that the ICM programmes were initiated in Quanzhou and Dongying in 2005, the year 2004 was chosen as a reference year. The evaluation period of ICM performance was from year 2004 to year 2012, a total of 9 years. To maintain consistency in the evaluation periods among the three case studies for cross-case analysis, the ICM performance in Xiamen was also evaluated from 2004 to 2012.

2.4.2 Data collection

I went to the three study sites – Xiamen, Quanzhou and Dongying for data collection during six field trips between 2011 and 2013. I spent about one to two months for each field trip. All the qualitative data and quantitative data were collected from three main sources: (1) government documents, (2) scientific and technical literatures, (3) face to face interviews among coastal management officers, key informants and stakeholders (See in appendix 1 & 2). More detailed information for the scientific data sources will be presented in Chapters 3, 4 and 5.

2.4.3 Data analysis

Data quantification: Governance data were quantified using a scoring system that is described in Chapter 3. Coastal environment and socio-economic data were quantified using available quantitative data presented in Chapters 4 and 5.

Weighting method: Among different weighting methods for indicator composition, commonly used methods include equal weighting, expert weighting, principal components analysis (PCA), budget allocation process (BAP), analytical hierarchy process (AHP) and data envelopment analysis (DEA) (Nardo et al., 2005;

Sharpes & Andrew, 2013). I chose the PCA for this study for the following reasons:

(1) It is a weighting method that is appropriate for this study, while others such as BAP and DEA could not be applied due to the data requirements (Jolliffe, 2005; Sharpes & Andrew, 2013).

(2) It is a statistical weighting method determined by each indicator itself, providing more objective weights for the indicators than some other methods, such as expert weighting and AHP (Nardo et al., 2005).

(3) It is a factor analysis, grouping together individual indicators to form a composite indicator that could capture as much as possible of the information common to individual indicators.

(4) It could eliminate the possibility of overlapping information in basic indicators to extract key information, accounting for the highest possible variation in the indicator set using the smallest possible number of factors.

The statistical processes are described as follows.

(1) Assume there are n indicators, p years to be evaluated.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \quad (2\text{-}1)$$

(2) Data standardization.

The normalization formula for each indicator is equation 2-2, so that all the indicators have similar dispersion across disciplines and over years.

$$Zx_{ij} = \frac{x_{ij} - \overline{x_j}}{\sqrt{Var(x_j)}} \quad (2\text{-}2)$$

(3) Calculation of correlation matrices.

r_{ij} (I, j=1, 2, ..., p) is the correlation coefficient of x_i and x_j, $r_{ij}=r_{ji},$ the equation is:

$$r_{ij} = \frac{1}{n-1}\sum_{k=1}^{n} Zx_{ki} Zx_{kj}, i, j = 1,2,..., p$$ (2-3)

New metrics for r_{ij}:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{np} \end{bmatrix}$$ (2-4)

(4) Calculation of the characteristics of R value and eigenvector.

Solve this characteristic equation $|\lambda I - R| = 0$, $\lambda_1 \geq \lambda_2 \geq \cdots, \geq \lambda_p \geq 0$, solve the eigenvector $e_i (i = 1,2,\cdots, p)$ of λ_i while $\|e_i\| = 1$.

(5) Calculation of contribution rate for each indicator as the weight.

Contribution rate of principal component j:

$$u_j = \frac{\lambda_i}{\sum_{k=1}^{p} \lambda_k} \quad (i = 1,2,\cdots, p), (j = 1,2,\cdots m)$$ (2-5)

Accumulative contribution rates of m principal components:

$$c_m = \frac{\sum_{k=1}^{i} \lambda_k}{\sum_{k=1}^{p} \lambda_k} \quad (i = 1,2,\cdots, p)$$ (2-6)

The calculation processes could be completed by SPSS16.0. The accumulative contribution rate of each indicator x_i could be considered as its weight.

Indicators aggregation: The numerical results of indicators for governance evaluation, environmental restoration evaluation and socio-economic evaluation were aggregated by the following equation:

$$I_m = \sum_{i=1}^{n} P_i W_i$$ (2-7)

In Eq. (2-7), n represents the number of indicators, P_i is the standardized score of each indicator, W_i is the weight of each indicator calculated based on the principal component contribution rate.

All of these processes were completed by SPSS 16.0.

Chapter 3 The performance of ICM in coastal governance

3.1 Introduction

The word "governance" is used in various contexts with diverse definitions (Commission on Global Governance, 1995; Nye & Donahue, 2000; Bevir, 2012). At a general level, it refers to all processes of governing by a government, market, or network over a group of people or territory through all forms of rules and social coordination to manage their common affairs. To put it simply, governance is an art of steering societies and organizations, requiring one “actor” to make decisions over a variety of issues in a group which are expected be obeyed.

In ocean and coastal governance, since for most countries the ocean and coastal zones are public, good governance could be defined as the institutions and processes by public authorities to manage human behavior and activities in the coastal area through international, national and local laws, policies and programmes, as well as through traditional customs and culture. Integrated coastal management (ICM) itself is a governance tool used to manage human activities within a defined coastal and ocean zone. What distinguishes ICM from general coastal and ocean governance is the ability to create a “governance” system capable of managing the multiple uses of the coastal zone in an integrated way compared with “sectoral management” (Chua & Chen, 1997, 2006). It requires the cooperation and coordination of multiple “actors”, including government agencies at different level of authority and from different sectors including non-government organizations (NGOs), local communities, and other stakeholders from relevant industries such as fisheries and tourism, in order to achieve the goals of sustainable use, development and protection of coastal and ocean areas and resources (Ehler, 2003). The key word in ICM governance is “integration”, and there are mainly 3 dimensions of integration in an ICM process (Cicin-Sain & Knecht, 1998). (1) *Spatial integration*. Integration of land and ocean areas in an administrative area as the land-based activities and the ocean activities interact and are strongly influenced by each other. When nations border enclosed or semi-enclosed seas, trans-boundary integration is needed if there are disputes by two or more neighbouring countries over issues such as fishing or trans-boundary pollution. (2) *Intersectoral integration*. Integration among different sectors involves both “horizontal” and “vertical” integration among different terrestrial, coastal and marine sectors at different levels of authority, that is essential for addressing conflicts among government agencies. (3) *Science–management integration*. Integration among the different disciplines related to coastal and ocean management issues, such as the natural sciences, the social sciences and engineering. The key factors thought to be important in ICM governance are an appropriate legal authority, appropriate institutional arrangements, and effective legal instruments, adequate human, technical and financial resources.

In this chapter, I will discuss the use of ICM governance indicators for tracking the ICM governance progress, construct an ICM governance index system for China’s coastal cities, and apply it to case studies to analyze the performance of ICM in coastal governance.

3.2 Literature review

ICM governance indicators are designed to evaluate the quality and process of coastal governance aimed at mitigating anthropogenic pressures on the coastal and marine environment. The governance quality and process could be shown by the extent to which an institutional response is addressing an issue and achieving the intended goals of an ICM cycle (Fig. 3-1).

Fig. 3-1 The ICM Development and Implementation Cycle (Chua, 2006).

Several ICM governance indicator systems to monitor the progress of ICM at the global, regional and programme levels have been proposed (e.g. Olsen et al, 1999; World Bank, 1999; Ehler, 2003; Pomeroy et al., 2004; NOAA, 2004; Breton et al., 2006; Heileman, 2006; UNDP, 2008; Diedrich & Navinés, 2010; PEMSEA, 2011; Tabet & Fanning, 2012). However, most of the indicators are descriptive indicators. Few quantification methods have been proposed to get a more tangible evaluation results.

To further discuss the specific governance indicators used in ICM, I selected 5 specific index systems that are developed at different scales (from local to regional scale) by different intentional or national organizations. The Intergovernmental Oceanographic Commission (IOC) proposed a governance index system that could be used at the national or local scale (Heileman, 2006). The European Union (EU)'s index system were widely-applied at regional and national level (Breton et al., 2006). The National Oceanic and Atmospheric Administration (NOAA) in the United States developed an index system for its national ICM programmes (NOAA, 2004). PEMSEA's index system has been applied by many local governments in East Asia (PEMSEA, 2011). And International Union For Conservation Of Nature (IUCN) developed the indicators for marine protected areas (Pomeroy et al., 2004).

The framework/approaches used to develop these ICM governance indicators could be categorized into two groups. One is goal-oriented and the other is process-oriented. The goal-oriented framework is designed based on the ICM objectives, such as ensuring effective management framework, ensuring adequate legal instruments, and enhancing public participation. The specific indicators are selected to report the actual performance of these objectives. The process-oriented framework is constructed based on the entire processes of ICM implementation.

3.2.1 Goal-oriented framework

(1) IOC's ICM governance indicators (Table. 3-1)

To assist coastal managers in making ICM programmes more efficient as well as to promote experience sharing amongst coastal scientists and experts, the International Oceanographic Commission (IOC) published a handbook for measuring the progress and outcomes of ICM in 2006 (Heileman, 2006). For ICM governance indicators, the researchers pinpointed four main goals and 15 detailed objectives for the selection of 15 key governance indicators to measure governance performance. The four main goals cover the four key aspects in ICM governance, which are legal and institutional framework, management and implementation, public participation and financing mechanism. The 15 specific indicators are described clearly based on specific objectives and could be easily used at different levels of practical case studies. However, no quantification methods are provided, and many of the indicators are difficult to evaluate subjectively and quantitatively, such as G2 - Adequacy of legislation enabling ICM' and G3 - Procedures for plans, programmes and projects affecting coastal zones.

Table. 3-1 Governance goals, objectives, and 15 key indicators defined by IOC (Heileman, 2006)

Goals	Objectives	Indicators
Ensuring adequate institutional, policy and legal arrangements	Ensuring the coordination and coherence of administrative actors and policies	G1 Existence and functioning of a representative coordinating mechanism for ICM
	Supporting integrated managements through adequate legislation and regulations	G2 Existence and adequacy of legislation enabling ICM
	Assessing the environmental impacts of policies, plans, programmes and projects	G3 Procedures for plans, programmes and projects affecting coastal zones
	Resolving conflicts over coastal space and resources	G4 Existence and functioning of a conflict resolution mechanism
Ensuring adequate management process and implementation	Managing the coastline through integrated plans	G5 Existence, status and coverage of ICM plans
	Implementing and enforcing ICM plans and actions	G6 Active management in areas covered by ICM plans
	Routinely monitoring, evaluating and adjusting of ICM efforts	G7 Routine monitoring, evaluation and adjustment of ICM initiatives
	Supporting ICM through sustained administrative structures	G8 Sustained availability and allocation of human, technical and financial resources for ICM
Enhancing information, knowledge, awareness and participation	Ensuring the management decisions are better informed by science	G9 Existence, dissemination and application of ICM-related scientific research and information
	Ensuring sustained support from engaged stakeholders	G10 Level of stakeholder participation in, and satisfaction with, ICM decision-making processes
	Ensuring NGO and community involvement	G11 Existence and activity level of NGOs and community-based organizations supportive of ICM

	Ensuring adequate levels or higher education and professional preparation for ICM	G12 Incorporation of ICM into educational and training curricula and formation of ICM cadres
Mainstreaming ICM into sustainable development: economic instrument mainstreaming	Enabling and supporting ICM through technology, including environmentally-friendly technology	G13 Use of technology, including environmentally friendly technology, to enable and support ICM
	Incorporating economic instruments into coastal management policies	G14 Use of economic instruments in support to ICM
	Mainstreaming coastal and ocean management into sustainable development	G15 Incorporation of ICM into sustainable development strategy

(2) IUCN's MPA governance indicators (Table. 3-2)

To promote evaluation of the effectiveness of MPAs, IUCN published a guidebook on methodologies of the use of performance indicators in 2004 (Pomeroy et al., 2004). In the context of marine protected areas, the researchers proposed 16 indicators based on five key governance goals for MPA. In this index system, it focuses more on the stakeholders' involvement and conflict-solving among different stakeholders relevant to the MPA.

(3) NOAA's governance performance indicators for Coastal Zone Management Act (CZMA) (Table. 3-3)

NOAA had started to develop performance indicators based on existing practices of the USA's Coastal Zone Management Act since 1997 (Hershman et al., 1999). It formulated performance indicators in 2004 to measure the effectiveness of coastal management programmes in addressing the goals of the CZMA. The framework of the indicators is based on the seven focus areas of the CZMA, namely, coastal habitats, coastal hazards, coastal water quality, public access, coastal community development, coastal-dependent uses and government coordination and decision-making. Sixteen indicators under government coordination and decision-making are developed for assessing the ICM governance performance of the coastal management programmes. Compared to other governance indicators, these indicators can be measured quantitatively. But they only focus on the number of the approved projects, permits, meetings, financial assistance, participants and researches, more or less disregarding their implementing processes and effects.

Table. 3-2 Five governance goals and the 16 indicators for MPA (Pomeroy et al., 2004, 2005)

Goals	**Indicators**
1. Effective management structures and strategies maintained	G1—Level of resource conflict G2—Existence of a decision-making and management body G3—Existence and adoption of a management plan G4—Local understanding of MPA rules and regulations
2. Effective legal structures and strategies for management maintained	G5—Existence and adequacy of enabling legislation G6—Availability and allocation of MPA administrative resources G7—Existence and application of scientific research/input G8—Existence and activity level of community organization(s)
3. Effective stakeholder participation and representation ensured	G9—Degree of interaction between managers and stakeholders G10—Proportion of stakeholders trained in sustainable use G11—Level of training provided to stakeholders in participation
4. Management plan compliance by resource users enhanced	G12—Level of stakeholders participation and satisfaction in management process and activities G13—Level of stakeholder involvement in surveillance, monitoring, and enforcement
5. Resource use conflicts managed and reduced	G14—Clearly defined enforcement procedures G15—Enforcement coverage G16—Degree of information dissemination to encourage stakeholder compliance

Table. 3-3 Performance indicators related to governance based on Coastal Zone Management Act of USA Section 303 objectives (NOAA, 2004)

Government Coordination and Decision-Making
G1 Approved Coastal Management Programs
G2 Approved Coastal Nonpoint Source Pollution Control Programs
G3 Approved National Estuarine Research Reserves
G4 Approved Coastal Nonpoint Source Pollution Control Programs
G5 Approved Coastal and Estuarine Land Conservation plans
G6 Permits issued Projects
G7 Projects reviewed for federal consistency
G8 Financial assistance to local governments
G9 Technical assistance to local governments Closure
G10 Partnerships with local governments, agencies, and other institutions
G11 Publications developed/distributed
G12 Participants in workshops
G13 Public awareness
G14 Public meetings held or persons attending
G15 Participation in stewardship programs
G16 Research undertaken or supported

3.2.2 Process-oriented framework

(1) EU's ICM indicators (Table. 3-4)

After nearly a decade of ICM implementation in European countries, the European Integrated Coastal Zone Managemet (ICZM) Expert Group set up a comprehensive set of indicators (Breton et al., 2006), which are process-based, and the evaluation is thus strictly limited to the process. Thirty-two indicators have been selected based on the four key phases of ICM implementation, namely, planning and management, putting forward a framework, implementation and enforcement of plans, adaptive management. This framework explicitly lists out the key indicator for each action taking place to measure the ICM governance performance. However, some of the indicators overlap, such as Action 31: 'Monitoring' and Action 32: 'Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources'. In addition, most of the indicators are descriptive and difficult to measure quantitatively.

(2) PEMSEA’s ICM governance indicators (Table. 3-5)

PEMSEA initiated a project on the State of the Coast (SOC) reporting system for local government in the East Asia Seas region in 2011(PEMSEA, 2011). To provide guidelines to the local government in order to facilitate the project, PEMSEA published a guidebook on how to build up an ICM index system for measuringthe state of the coastal ICM towards achieving the goals of ICM. The organization framework of governance indicators focuses on 6 categories, namely policy, strategies and plans, intuitional agreements, legislation, public awareness, capacity development and financing mechanism. Although PEMSEA states that the framework is process-oriented, it also takes full consideration of ICM objectives when developing the specific indicators. Fourteen indicators are proposed, which could be applied at the local level. However, most of the indicators are also descriptive and are difficult to be measured quantitatively.

Table. 3-4 Indicators for measuring the progress in implementation of ICM in EU developed by European ICZM expert group (Breton et al., 2006)

Phase	Action	Indicators
Planning and management are taking place in the coastal zone	1	Decisions about planning and managing the coast are governed by general legal instruments.
	2	Sectoral stakeholders meet on an ad hoc basis to discuss specific coastal and marine issues.
	3	There are spatial development plans which include the coastal zone but do not treat it as a distinct and separate entity.
	4	Aspects of the coastal zone, including marine areas, are regularly monitored.
	5	Planning on the coast includes the statutory protection of natural areas.
A framework exists for taking ICZM forward	6	Existing instruments are being adapted and combined to deal with coastal planning and management issues.
	7	Adequate funding is usually available for undertaking actions on the coast.
	8	A stocktake of the coast (identifying who does what, where and how) has been carried out.
	9	There is a formal mechanism whereby stakeholders meet regularly to discuss a range of coastal and marine issues.
	10	Ad hoc actions on the coast are being carried out that include recognizable elements of ICZM.
Most aspects of an ICZM approach to planning and managing the coast are in place and functioning reasonably well	11	A sustainable development strategy which includes specific references to coasts and seas is in place.
	12	Guidelines have been produced by national, regional or local governments which advise planning authorities on appropriate uses of the coastal zone.
	13	All relevant parties concerned in the ICZM decision-making process have been identified and are involved.
	14	A report on the State of the Coast has been written with the intention of repeating the exercise every five or ten years.
	15	There is a statutory integrated coastal zone management plan.
	16	Strategic Environmental Assessments are used commonly to examine policies, strategies and plans for the coastal zone.

	17	A non-statutory coastal zone management strategy has been drawn up and an action plan is being implemented.
	18	There are open channels of communication between those responsible for the coast at all levels of government.
	19	Each administrative level has at least one member of staff whose sole responsibility is ICZM.
	20	Statutory development plans span the interface between land and sea.
	21	Spatial planning of sea areas is required by law.
	22	A number of properly staffed and properly funded partnerships of coastal and marine stakeholders have been set up.
	23	Coastal and estuary partnerships are consulted routinely about proposals to do with the coastal zone.
	24	Adequate mechanisms are in place to allow coastal communities to take a participative role in ICZM decisions.
An efficient, adaptive and integrative process is embedded at all levels of governance and is delivering greater sustainable use of the coast	25	There is strong, constant and effective political support for the ICZM process.
	26	There is routine (rather than occasional) cooperation across coastal and marine boundaries.
	27	A comprehensive set of coastal and marine indicators is being used to assess progress towards a more sustainable situation.
	28	A long-term financial commitment is in place for the implementation of ICZM.
	29	End users have access to as much information of sufficient quality as they need to make timely, coherent and well-crafted decisions.
	30	Mechanisms for reviewing and evaluating progress in implementing ICZM are embedded in governance.
	31	Monitoring
	32	Monitoring shows a demonstrable trend towards a more sustainable use of coastal and marine resources

Table. 3-5 Governance indicators developed by PEMSEA (PEMSEA, 2011)

Category	**Indicator**
Policy, strategies and plans	G1 Coastal profile/Environmental risk assessment
	G2 Coastal strategy and action plans
	G3 Local government development plan, including coastal and marine areas
Institutional arrangements	G4 Coordinating mechanism
	G5 Participation of stakeholders in the coordinating mechanism
Legislation	G6 ICM enabling legislation
	G7 Administration and monitoring of compliance to legislation
	G8 Environmental cases filed/resolved
Information and public awareness	G9 Public education and awareness
	G10 Stakeholder participation and mobilization
Capacity development	G11 Availability/accessibility
	G12 Human resource capacity
Financing mechanisms	G13 Budget for ICM
	G14 Sustainable financing mechanisms

3.2.3 Summary

(1) The ICM governance index systems discussed in this section serve different purposes. The pros and cons of each index system have been briefly discussed.

(2) Most of the indicators are descriptive indicators and no quantification methods were proposed. Difficulties remain with respect to deriving tangible results of ICM governance performance.

(3) For these index systems developed from different approaches and applied at different scales, it could be seen that almost all the indicator systems (developed by either goal-oriented or process-oriented frameworks) focus on the same areas that are key elements to ensuring the success of completing an ICM cycle.

(4) These common areas could be categorized into 5 factors, namely 1) a sound ICM mechanism in terms of a cooperation management system and a legal system, 2) an operational planning, 3) implementing and monitoring process, 4) a strong capacity building mechanism, 5) an effective public participation framework and a sustainable financing system.

3.3 Construction of ICM governance index system and quantification methods

3.3.1 Governance index system

To evaluate ICM performance in the coastal governance of China's coastal cities, I mainly adopted the PEMSEA's process-oriented approach with the consideration of ICM objectives. I generalized 5 main sub-elements that are key components for an ICM cycle adapted to China's coastal cities' ICM governance. The 5 sub-elements are ICM mechanism, planning, implementing and monitoring, capacity building, public involvement, and financing. In the light of these 5 sub-elements, I selected twelve specific indicators among all the indicators that could be found in the literature (NOAA, 2004; Pomeroy et al., 2004; Breton et al., 2006; Heileman, 2006; PEMSEA, 2011) based on discussions with local ICM experts and coastal governors (Table 3-6).

Table. 3-6 ICM Governance Performance Measurement Indicators

Main elements	Sub-elements	Indicators
Governance	ICM Mechanism	(G1) General ICM strategy
		(G2) Coordination mechanism
		(G3) Law enforcement mechanism
	Planning, implementation, and monitoring	(G4) Policy, strategies and action plans
		(G5) Implementation and monitoring of ICM initiatives
	Capacity Building	(G6) Scientific and technical support
		(G7) Staff capacity building
		(G8) Infrastructure and facilities allocation
	Public involvement	(G9) Stakeholders' involvement
		(G10) Publicity of government information
	Financing	(G11) Local government budget allocation for ICM
		(G12) External funding

3.3.2 Description of indicators

The rationale and evaluation criteria of each selected indicator are listed below.

ICM Mechanism

Building functional ICM mechanisms is the foundation for running an ICM cycle. Adequate planning, institutional and legal arrangements are the main factors for the development of the mechanisms. Three specific indicators (G1 – G3) are developed to assess the ICM mechanism.

G1 General ICM strategy

A general ICM strategy is a framework for overall integrated planning and management of ICM, providing key coastal strategies for coastal management. It serves as a platform for intuitional reforms and facilitates incorporating the interests and policies of the various regulatory and user agencies (PEMSEA, 2011).

The indicator assesses the scope, coverage and objectives of an overall ICM plan or strategy.

G2 Coordination mechanism

A functional coordinating framework is a primary component for implementation of ICM programmes. Its main body should consist of the related government agencies, nongovernment entities, science sectors and other stakeholders (Chua & Chen, 1997). An effective coordination improves the management efficiency by harmonizing overlapped responsibilities of the line agencies and stakeholders (PEMSEA, 2011).

This indicator measures the existence and performance of a multisectoral coordinating mechanism that overseas, guides and coordinates the development and implementation of the coastal strategies and action plans.

G3 Law enforcement mechanism

A strong integrated coastal law enforcement mechanism is key to the effectiveness of ICM implementation. Without an appropriately defined and actionable enforcement mechanism, the coastal laws, actions, and regulations serve no purposes. An integrated law enforcement mechanism could avoid overlapping powers and responsibilities to improve the efficiency of laws and to save the cost of enforcement (Chua. 1997).

This indicator evaluates the presence, capacity and function of an integrated enforcement mechanism for carrying out coastal laws and regulations.

Planning, implementation, and monitoring

Planning, implementation and monitoring are the three key steps in the ICM management process (Chua, 2006). The indicators pinpointed here for assessment are G4 and G5.

(G4) Policy, strategies and action plans

The existence, adequacy and effectiveness of policy, strategies and action plans is essential for implementing ICM (Olsen, 2003), such as, the enactment of ICM tools (e.g. coastal and sea use zoning plans), environmental monitoring and enforcement activities.

This indicator measures the presence and adequacy of policy, strategies and plans enabling the implementation of ICM interventions.

(5) Implementation and monitoring of ICM initiatives

The quality and efficiency of ICM implementation determines whether the ICM goals could be achieved (Chua, 2006). Routinely monitoring the ICM implementation is for evaluating and adjusting ICM initiatives so as to improve the quality and efficiency of the implementation.

This indicator measures the level of implementation of ICM projects and actions as well as the existence and adequacy of an operational monitoring system for initiatives.

Capacity Building

Capacity development is an indispensable component for achieving the goals of ICM through ICM implementation (PEMSEA, 2011). In particular, capacity building mainly consists of three parts: seeking scientific and technical supports, equipping local personal with sufficient technical and management skills, installing basic and advanced infrastructure and facilities. Hence, three proper indicators are selected: G6 – G8.

(G6) Scientific and technical support

The active involvement of local and international experts who can provide scientific and technical support is crucial to the success of an ICM programme. Local capacity can be greatly enhanced by the availability of experts with ample ICM experiences and knowledge from research institutes, universities and international organizations (Chua & Chen, 1997; Heileman, 2006).

This indicator evaluates the availability and accessibility of scientific and technical resources provided by experts who can impart their expertise in coastal management.

(G7) Staff capacity building

The local personnel’s skills and knowledge on ICM is fundamental for effective implementation of ICM programmes (PEMSEA, 2011). Building staff capacity to plan and manage their own ICM projects is important for sustaining the ICM programmes in a long run.

This indicator evaluates the staff capacity in terms of skilled human resources.

(G8) Infrastructure and facilities allocation

Basic and advanced infrastructure and facilities are needed to implement the ICM projects and to fulfill the ICM objectives. For example, an ICM office or building for routine management, a coastal water monitoring system for water quality real-time checking, and a computer-based decision support system for decision makings.

This indicator evaluates the availability and maintenance of infrastructure and facilities in ICM implementation.

Public involvement

Public involvement/public participation is a core principle of ICM (Chua & Chen, 1997). It is critical for long-term implementing and monitoring of ICM programmes. The level of public involvement in the decision making process in the coastal issues can be improved by the active participation of stakeholders and publicity through government information. Hence, the focus can be on the assessment of stakeholders' involvement (G9) and availability of government information (G10).

(G9) Stakeholders' involvement

An effective stakeholders' involvement is key to the success of community-based ICM programmes (Cicin-Sain and Knecht, 1998). In government-oriented ICM programmes, the active involvement of stakeholders from different areas is also an important factor to facilitate the ICM implementation.

This indicator evaluates the number of involved multi-stakeholders who are contributors to sustainability of coastal zones, and the level of involvement as well.

(G10) Publicity of government information

Easy access to government information can promote public awareness of coastal management and protection. Information usually includes the current threats, scope, uses and benefits of local ecosystems, as well as action plans and activities that ameliorate these threats while increasing the benefits.

This indicator mainly measures the scope and the extent of the publicity of government information on ICM.

Financing

Financing mechanisms are required for the sustainable implementation of ICM activities (such as management interventions and maintaining environmental improvement structure) (Lowry et al., 1999). Sustainable financing options thus include the allocation of internal funds from a regular government budget, and co financing from the private sectors for external funds. Hence, the aim here is to assess the availability of sustainable financing in terms of two indicators – G11 and G12.

(G11) Local government budget allocation for ICM

Sufficient internal funds allocated from the government budget are essential for the routine management of ICM progremmes. A lack of internal funds is a major factor leading to the failure of ICM (Lowry et al., 1999).

This indicator measures the funds allocated for ICM programmmes from the local government regular budget.

(G12) External funding

Seeking external funds sources through using the market-based instruments or seeking supports from the private sector and non-government organizations is an effective way to sustain the financing mechanism for ICM (Chua, 2006).

This indicator assesses the amount of external funds from non-government sponsors such as international organizations, private companies and other resources.

3.4 Quantification methods

Governance indicators (G1-G12) were scored as 0, 0.25, 0.5, 0.75 and 1 (Table. 3-7) based on the reviews of government documents and interviews with scientists and administrators who were main initiators and participants involved in the ICM programme in each city.

Data I used in evaluation of the ICM governance performance included the following 3 types.

1) Coastal policy statements, strategies, programs, and legislation both at national and local level.
2) Databases available online on the internet and in hard copy on coastal management programs provided by local agencies as well as other publicly available technical reports.
3) Reviews and evaluations of program and projects performance by officers from local governments and experts from universities and research institutes.

The involved key scientists and administrators for the discussions on the governance performance evaluation in each site are listed as follows.

Xiamen: five scientists from the Third Institute of Oceanography and Xiamen University, two experts from Fujian Ocean Institute, two administrators from Xiamen Oceanic and Fishery Administration and two administrators from Yundang Lagoon Administrative Office.

Quanzhou: four scientists from the Third Institute of Oceanography and Xiamen University, four administrators from Quanzhou Oceanic and Fishery Administration, and two administrators from Quanzhou Mangrove Reserve.

Dongying: Two scientists from First Institute of Oceanography and Ocean University of China, four administrators from Dongying Oceanic and Fishery Administration, two administrators from Yellow River Estuary Wetland Nature Reserve.

Table. 3-7 Scoring criterion for governance performance

Score	**Criterion**
0	the indicator was not identified, present, or recognized
0.25	the indicator was present, but the performance is weak
0.5	the indicator was present, and the performance is fair
0.75	the indicator was present, and the performance is good
1	the indicator was present, and the performance is excellent

3.5 Evaluation results

3.5.1 Xiamen

The detailed evaluation results and final scores of Xiamen's governance indicators in each year are listed in Table. 3-8 and Table. 3-9. G2, G8, G11 and G12 showed no variance within the 9 evaluation years and were therefore eliminated from the Z score transformation and PCA analysis. The standardized score, weight and the evaluation results of the rest of the 8 governance indicators are presented in Table. 3-10. The final evaluation results of Governance Index (GI) appear in Fig. 3-2. The variations of all the governance indicators with evaluation scores (before standardization) in 2004 and 2012 are shown in Fig. 3-3. It would not be necessary to use the standardized scores (which were used for EI and SI in Chapters 4 and 5) for governance indicators to show performance change as the evaluation scores are already in the same dimension from 0-1, and the evaluation scores reveal the changes more intuitively by their definitions in Table. 3-7.

The results showed that Xiamen's GI increased steadily from 2004 to 2012 (Fig. 3-2 Variation of the Xiamen Governance Index (GI) from 2004 to 2012

Table. 3-8 Detailed evaluation results of Xiamen ICM governance (2004-2012)

Indicators	Performance evaluation (2004 – 2012)
(G1) *General ICM strategy*	2004-2007, early in 2001, the general ICM plan for the second cycle has been formulated, the performance was fair
	2008-2012, the general ICM plan for the third cycle formulated in 2007, scaling up to the four other districts out of the Xiamen island, but no adaptive management mentioned in the plan, the performance was good
(G2) Coordination mechanism	2004-2012, the ICM coordination mechanism chaired by the vice mayor was established in 1995, the performance was good
(G3) *Law enforcement mechanism*	2004-2006, China Marine Surveillance Xiamen Team was established for integrated law enforcement in Xiamen coast in 2003, the performance was fair
	2007-2012, Its capacity has been increased greatly both in staff capacity and facilities, the performance was good
(G4) *Policy, strategies and action plans*	2004-2007, thirteen ICM relevant policies and regulations formulated, the performance was good
	2008-2012, fourteen ICM policies and regulations, the performance was excellent

(G5) Implementation and monitoring of ICM initiatives	2004-2007, more than hundreds projects on pollution treatment, ecosystem restoration implemented, the performance was good
	2008-2012, Routine monitoring, evaluation and adjustment of ICM initiatives established, the performance was excellent
(G6) Scientific and technical support	2004, five research institutes involved in ICM for steering, the performance was good
	2005-2006, World ocean week had held every year since 2005, serving as a platform for promoting sustainable development of the oceans. Coastal and Ocean Management Institute established in 2005 for ICM studies, further facilitate the research on ICM, the performance was excellent
(G7) Staff capacity building	2004-2005, more than 10 ICM experts were involved in the management of its ICM programmes, the performance was good
	2006-2012, the staff capacity was further strengthened by routine ICM training every year, the performance was excellent
(G8) Infrastructure and facilities allocation	2004-2012, the facilities and infrastructure were sufficient for ICM programmes, the performance was good
(G9) Stakeholders' involvement	2004-2008, less than 1000 stakeholders involved in decision making process every year, the performance was

	fair 2009-2012, more than 1000 stakeholders involved, the performance was good
(G10) *Publicity of government information*	2004-2007, only part of the information was publicized on official websites, the performance was weak 2008-2012, annual report of government plans, policies, decisions, and other information were publicized on official websites, the performance was good
(G11) *Local government budget allocation*	2004-2012, budget for ICM was nearly 2 million per year, the performance was good
(G12) *External funding*	2004-2012, no external funding supported

Table. 3-9 Evaluation scores of Xiamen's governance indicators (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
G1	0.5	0.5	0.5	0.5	0.75	0.75	0.75	0.75	0.75
G2	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
G3	0.5	0.5	0.5	0.75	0.75	0.75	0.75	0.75	0.75
G4	0.75	0.75	0.75	0.75	1	1	1	1	1
G5	0.75	0.75	0.75	0.75	1	1	1	1	1
G6	0.75	0.75	1	1	1	1	1	1	1
G7	0.75	0.75	1	1	1	1	1	1	1
G8	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
G9	0.5	0.5	0.5	0.5	0.75	0.75	0.75	0.75	0.75
G10	0.25	0.25	0.25	0.25	0.75	0.75	0.75	0.75	0.75
G11	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
G12	0	0	0	0	0	0	0	0	0

Table. 3-10 The EI results, standardized value, contribution rate (contrib. rate) and weight of Xiamen's governance indicators (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
G1	-1.05	-1.05	-1.05	-1.05	0.84	0.84	0.84	0.84	0.84	0.77	0.13
G3	-1.33	-1.33	-1.33	0.67	0.67	0.67	0.67	0.67	0.67	0.76	0.13
G4	-1.05	-1.05	-1.05	-1.05	0.84	0.84	0.84	0.84	0.84	0.77	0.13
G5	-1.05	-1.05	-1.05	-1.05	0.84	0.84	0.84	0.84	0.84	0.77	0.13
G6	-1.76	-1.76	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.73	0.12
G7	-1.76	-1.76	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.73	0.12
G9	-1.05	-1.05	-1.05	-1.05	0.84	0.84	0.84	0.84	0.84	0.77	0.13
G10	-1.05	-1.05	-1.05	-1.05	0.84	0.84	0.84	0.84	0.84	0.77	0.13
GI	-1.26	-1.26	-0.72	-0.47	0.74	0.74	0.74	0.74	0.74	NA	1.00

Xiamen

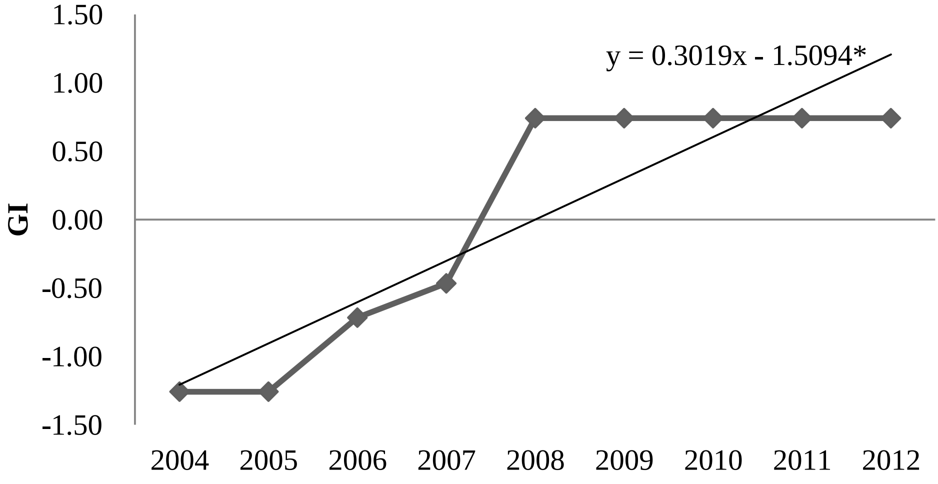

Fig. 3-2 Variation of the Xiamen Governance Index (GI) from 2004 to 2012

*: The annual growth rate of the index is calculated by the least-squares growth rate (OECD, 2005). The same equation is used for the rest of the indexes below.

Xiamen

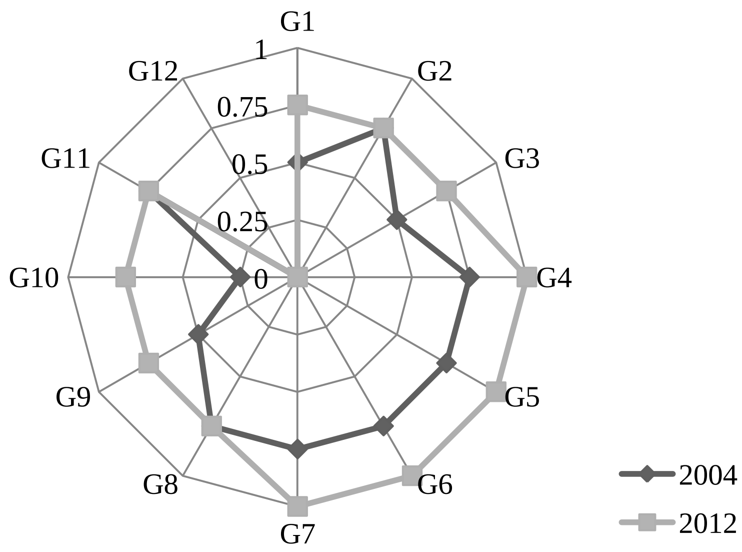

Fig. 3-3 Variation of Xiamen governance indicators in 2004 and 2012

3.5.2 Quanzhou

The detailed evaluation results and final scores of Quanzhou's governance indicators in each year are listed in Table. 3-11 and3-12. G12 showed no variance during 2004 - 2012 and was eliminated from the Z score transformation and PCA analysis. The standardized score, weight and the evaluation results of the other 11 governance indicators are presented in Table. 3-13 Table. 3-9. The final evaluation results of Governance Index (GI) are illustrated in Fig. 3-4. The variation of all the governance indicators with evaluation scores (before standardization) in 2004 and 2012 is shown in Fig. 3-5.

The results showed that Quanzhou's GI increased steadily from 2004 to 2012 (Fig. 3-4). The scores of G1, G2, G3, G5, G6, G7, and G8 had higher increments than the other 4 indicators. G12 showed no variances during 2004-2012 with its constant score 0 (Fig. 3-5 and Table. 3-12).

Table. 3-11 Detailed evaluation results of Quanzhou ICM governance (2004-2012)

Indicators	**Performance evaluation (2004 – 2012)**
(G1) General ICM strategy	2004-2008, no general ICM plan 2009-2011, an ICM plan formulated, the overall performance was fair 2012, the ICM plan updated with new plans and actions, the performance was good
(G2) Coordination mechanism	2004-2005,there was a marine development and management team, but the performance was poor 2006-2010, three ICM steering committees set up, the performance was fair 2011-2012, the cooperation between land and ocean authorities was strengthened, the performance was good
(G3) Law enforcement mechanism	2004-2005, few agencies involved in law enforcement, the performance was poor 2006-2008, an integrated team of marine and fishery law enforcement established, the performance was fair 2009-2012, an integrated law enforcement mechanism formulated, the performance was good
(G4) Policy, strategies and action plans	2004-2005, only one major project on coastal pollution treatment, the performance was poor 2006-2012,Quanzhou Marine Function Zoning was enforced, several integrated regulations and projects were launched as well,

	the performance was fair
(G5) Implementation and monitoring of ICM initiatives	2004-2005, only coastal pollution treatment projects were implemented, the performance was poor 2006, more than 300 projects on pollution treatment implemented, the performance was fair 2007-2012, several projects on mangrove restoration, fishery conservation, and coastal ecosystem restoration were implemented, the monitoring work was enhanced, the performance was good
(G6) Scientific and technical support	2004-2005, the scientific and technical support was weak, the performance was poor 2006-2009, several research institutes and universities involved to provide scientific support, national and international communication of ICM experiences, the performance was fair 2010-2012, a research workstation established, the performance was enhanced to be good
(G7) Staff capacity building	2004, no staff be aware of ICM 2005-2008, few administrators took ICM training courses, the performance was weak 2009-2010, most of the administrators started to know ICM, the performance was fair 2011-2012, more ICM training courses provided for the administrators, the performance was good
(G8) Infrastructure	2004-2005, the performance was weak

and facilities allocation	2006-2008, advanced laboratories were setup, more monitoring sites were installed, and a decision making system was setup, the performance was fair 2009-2012, an ICM center with an entire set of facilities was setup, the performance was good
(G9) Stakeholders' involvement	2004-2005, very few stakeholders involved in decision making process, the performance was weak 2006-2012, stakeholder involvement was enhanced by the hearing system, the performance was fair
(G10) Publicity of government information	2004-2007, only part of the information was publicized on official websites, the performance was weak 2008-2012, government plans, policies, decisions, and other information were publicized on official websites, the performance was fair
(G11) Local government budget allocation for ICM	2004, budget for coastal management was low, the performance was weak 2005, budget for ICM increased, the performance was fair 2006-2012, the financial mechanism for ICM was setup, the sea area use revenue has been invested into coastal management, more than 1 billion was allocated for ICM each year, the performance was good
(G12) External funding	2004-2012, no external funding supported

Table. 3-12 Evaluation scores of Quanzhou's governance indicators (2004-2012)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
G1	0	0	0	0	0	0.5	0.5	0.5	0.75
G2	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.75	0.75
G3	0.25	0.25	0.5	0.5	0.5	0.75	0.75	0.75	0.75
G4	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5
G5	0.25	0.25	0.5	0.75	0.75	0.75	0.75	0.75	0.75
G6	0.25	0.25	0.5	0.5	0.5	0. 5	0.75	0.75	0.75
G7	0	0.25	0.25	0.25	0.25	0.5	0.5	0.75	0.75
G8	0.25	0.25	0.5	0.5	0.5	0.75	0.75	0.75	0.75
G9	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5	0.5
G10	0.25	0.25	0.25	0.25	0.5	0.5	0.5	0.5	0.5
G11	0.25	0.5	0.75	0.75	0.75	0.75	0.75	0.75	0.75
G12	0	0	0	0	0	0	0	0	0

Table. 3-13 The EI results, standardized value, contribution rate (contrib. rate) and weight of Quanzhou's governance indicators (2004-2012)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Contrib . rate**	**Wi**
G1	-0.82	-0.82	-0.82	-0.82	-0.82	0.82	0.82	0.82	1.63	0.66	0.09
G2	-1.41	-1.41	0.00	0.00	0.00	0.00	0.00	1.41	1.41	0.70	0.10
G3	-1.47	-1.47	-0.27	-0.27	-0.27	0.93	0.93	0.93	0.93	0.75	0.10
G4	-1.76	-1.76	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.63	0.09
G5	-1.64	-1.64	-0.50	0.63	0.63	0.63	0.63	0.63	0.63	0.67	0.09
G6	-0.84	-0.84	0.11	0.11	0.11	-1.79	1.05	1.05	1.05	0.43	0.06
G7	-1.53	-0.55	-0.55	-0.55	-0.55	0.44	0.44	1.42	1.42	0.70	0.10
G8	-1.47	-1.47	-0.27	-0.27	-0.27	0.93	0.93	0.93	0.93	0.75	0.10
G9	-1.76	-1.76	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.63	0.09
G10	-1.05	-1.05	-1.05	-1.05	0.84	0.84	0.84	0.84	0.84	0.65	0.09
G11	-2.36	-0.94	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.60	0.08
GI	-1.48	-1.26	-0.19	-0.09	0.09	0.47	0.64	0.87	0.95	NA	1.00

Quanzhou

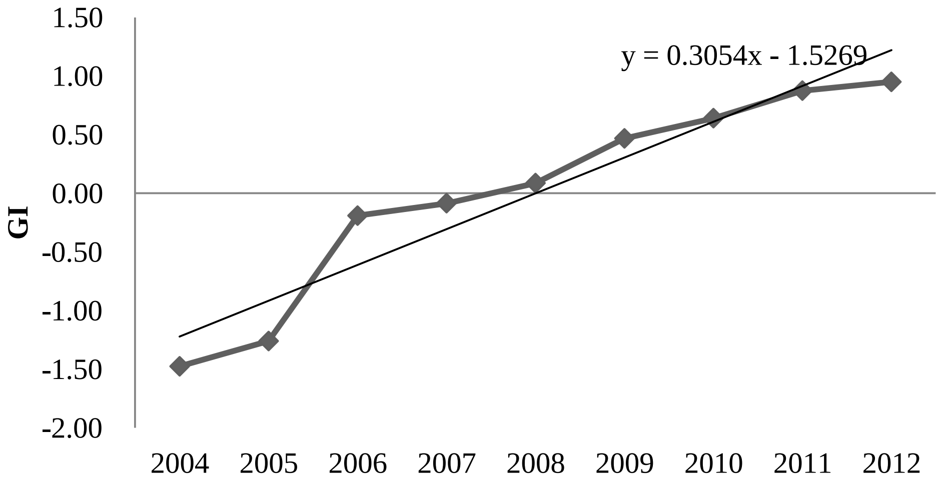

Fig. 3-4 Variation of the Quanzhou Governance Index (GI) from 2004 to 2012

Quanzhou

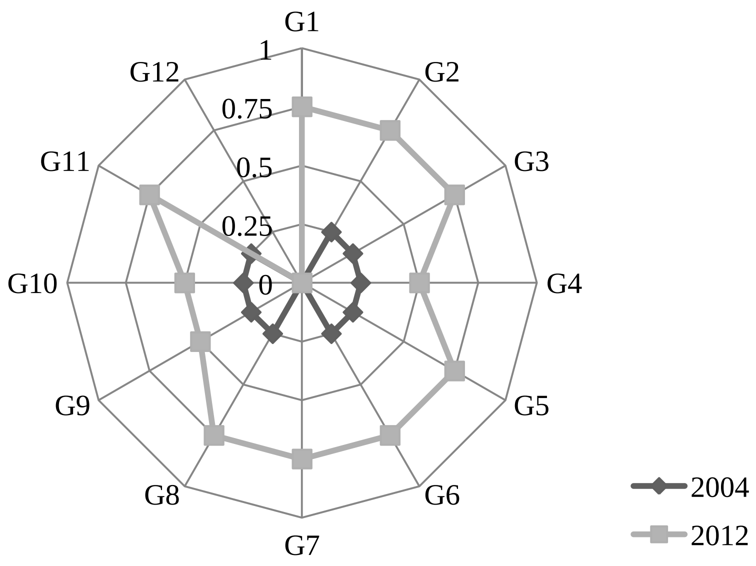

Fig. 3-5 Variation of Quanzhou governance indicators in 2004 and 2012

3.5.3 Dongying

The detailed evaluation results and final scores of Quanzhou's governance indicators for each year are listed in Table. 3-14 and Table. 3-15. G12 also showed no variance during 2004 - 2012and was eliminated from the Z score transformation and PCA analysis. The standardized score, weight and the evaluation results of the rest of 11 governance indicators are listed in Table. 3-16. The final evaluation results of GI are illustrated in Fig. 3-6. The variations of all the governance indicators with evaluation scores in 2004 and 2012 are shown in Fig. 3-7.

The results showed that Dongying's GI also increased steadily from 2004 to 2012 with a slightly higher annual growth rate of 32.18%. GI stopped increasing from 2011 to 2012. The scores of all the indicators except G12 had increased from 2004 to 2012. The scores of G5, G6, G7, and G8 had higher increments than the other 7 indicators. G12 also showed no variances during 2004-2012 with its constant score of "0" (Fig. 3-5 and Table. 3-12).

Table. 3-14 Detailed evaluation results of Dongying ICM governance (2004-2012)

Indicators	**Performance evaluation (2004 – 2012)**
(G1) General ICM strategy	2004-2009, no general ICM plan 2009-2011, the ICM plan formulated with new plans and actions, the performance was good
(G2) Coordination mechanism	2004-2008, no ICM coordination mechanism 2009-2012, an ICM coordination mechanism set up, the performance was fair
(G3) Law enforcement	2004-2009, few agencies involved in law enforcement, the performance was poor

mechanism	2010-2012, an integrated team of marine and fishery law enforcement established, the performance was fair
(G4) Policy, strategies and action plans	2004-2006, only two policy of coastal environment management, the performance was poor 2007-2012, four more plans formulated, a marine function zoning plan was enforced, the performance was fair
(G5) Implementation and monitoring of ICM initiatives	2004-2006, only coastal pollution treatment projects were implemented, the performance was poor 2007-2009, more projects on wetland ecosystem restoration and fishery management implemented, the performance was fair 2010-2012, an integrated coastal environment monitoring system established, the performance was good
(G6) Scientific and technical support	2004-2006, the scientific and technical support was weak, the performance was poor 2007-2009, two research institutes involved to provide scientific support, the performance was fair 2010-2012, more collaborations with research instates and international organizations, the performance was enhanced to be good
(G7) Staff capacity building	2004, no staff be aware of ICM 2005-2006, few administrators took ICM training courses, the performance was weak 2007-2009, most of the administrators started to know ICM, the performance was fair 2010-2012, more ICM experts joined, the performance was good
(G8)	2004, the facilities were inadequate, the performance was weak

Infrastructure and facilities allocation	2005-2008, more monitoring sites were installed, the performance was fair 2009-2012, an ICM office was setup with basic infrastructures, the performance was good
(G9) Stakeholders' involvement	2004-2009, very few stakeholders involved in decision making process, the performance was weak 2010-2012, stakeholder involvement was enhanced by the hearing system, the performance was fair
(G10) Publicity of government information	2004-2007, only part of the information was publicized on official websites, the performance was weak 2008-2012, government plans, policies, decisions, and other information were publicized on official websites by law <Regulation of the People's Republic of China on the Disclosure of Government Information>, the performance was fair
(G11) Local government budget allocation for ICM	2004-2005, budget for coastal management was low, the performance was weak 2006-2008, budget for ICM increased, the performance was fair 2009-2012, the financial mechanism for ICM was setup, the sea area use revenue has been invested into coastal management, more than half billion was allocated for ICM each year, the performance was good
(G12) External funding	2004-2012, no external funding supported

Table. 3-15 Evaluation scores of Dongying's governance indicators (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
G1	0	0	0	0	0	0.5	0.5	0.5	0.5
G2	0	0	0	0	0	0.25	0.25	0.25	0.25
G3	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.5
G4	0.25	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5
G5	0.25	0.25	0.25	0.5	0.5	0.5	0.5	0.75	0.75
G6	0.25	0.25	0.25	0.5	0.5	0.5	0.5	0.75	0.75
G7	0	0.25	0.25	0.5	0.5	0.5	0.75	0.75	0.75
G8	0.25	0.5	0.5	0.5	0.5	0.75	0.75	0.75	0.75
G9	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.5	0.5
G10	0.25	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5
G11	0.25	0.25	0.5	0.5	0.5	0.75	0.75	0.75	0.75
G12	0	0	0	0.5	0	0	0	0	0

Table. 3-16 The EI results, standardized value, contribution rate (contrib. rate) and weight of Dongying's governance indicators (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
G1	-0.84	-0.84	-0.84	-0.84	-0.84	1.05	1.05	1.05	1.05	0.75	0.10
G2	-0.84	-0.84	-0.84	-0.84	-0.84	1.05	1.05	1.05	1.05	0.75	0.10
G3	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	1.33	1.33	1.33	0.72	0.09
G4	-1.33	-1.33	-1.33	0.67	0.67	0.67	0.67	0.67	0.67	0.63	0.08
G5	-1.14	-1.14	-1.14	0.14	0.14	0.14	0.14	1.42	1.42	0.73	0.09
G6	-1.14	-1.14	-1.14	0.14	0.14	0.14	0.14	1.42	1.42	0.73	0.09
G7	-1.79	-0.84	-0.84	0.11	0.11	0.11	1.05	1.05	1.05	0.76	0.10
G8	-1.89	-0.47	-0.47	-0.47	-0.47	0.94	0.94	0.94	0.94	0.74	0.09
G9	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	1.33	1.33	1.33	0.72	0.09
G10	-1.33	-1.33	-1.33	0.67	0.67	0.67	0.67	0.67	0.67	0.63	0.08
G11	-1.47	-1.47	-0.27	-0.27	-0.27	0.93	0.93	0.93	0.93	0.75	0.09
GI	-1.19	-0.97	-0.85	-0.21	-0.21	0.40	0.85	1.09	1.09	NA	1.00

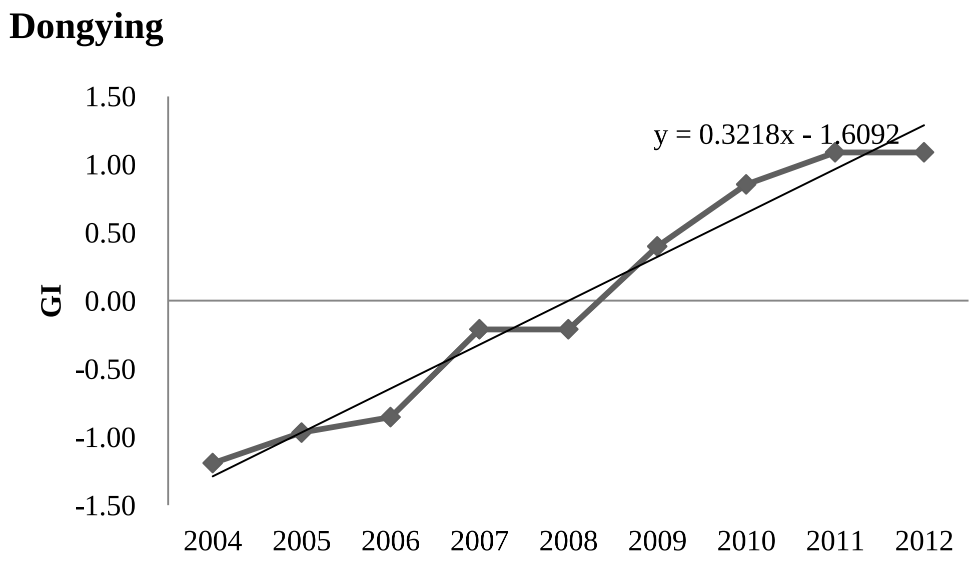

Fig. 3-6 Variation of the Dongying Governance Index (GI) from 2004 to 2012

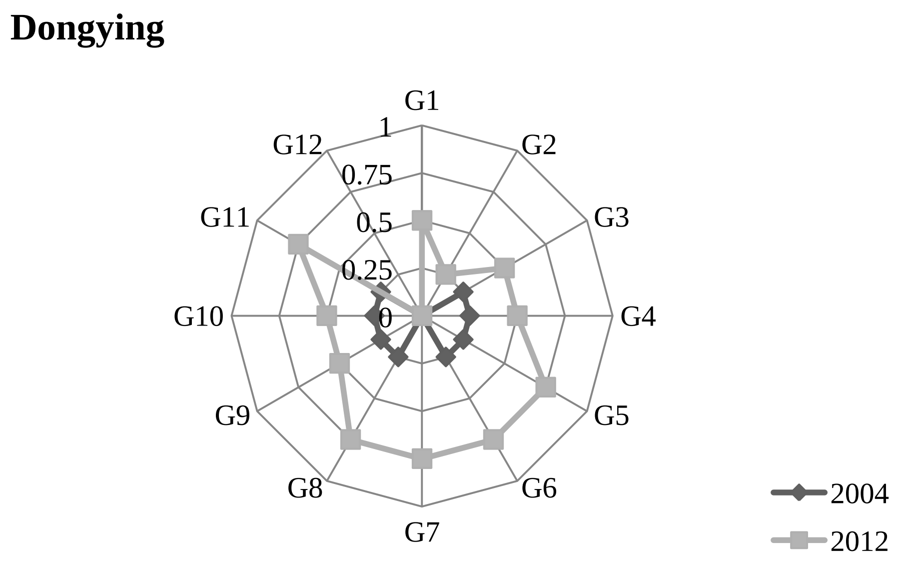

Fig. 3-7 Variation of Dongying governance indicators in 2004 and 2012

3.6 Discussion

3.6.1 Xiamen

The performance of GI in Xiamen improved during 2004 - 2012 with an annual growth rate of 30.54% (Fig. 3-2). Indeed, Xiamen's GI only increased from 2004 to 2008, and had stopped increasing since 2008. The performance of all indicators did not improve during this later stage of the evaluation period. It was because of this that most of the indicators' score already achieved a "good" or "excellent" level, making it difficult for further improvement. The maintenance of the performance at the "good" or "excellent" level in the following 4 years (2009-2012) could prove that the government had performed well in ICM governance. The growth rate from 2007 to 2008 was the fastest, during which the local government started to run the third cycle of ICM, thus the governance capacity was further strengthened.

In 2004, as Xiamen had already entered the second cycle of ICM, the performance score of two thirds of the indicators reached the "fair" or "good" level, indicating that the adoption of the ICM framework in Xiamen had improved the coastal governance. In the following 4 years (2005-2008), the performance of 8 governance indicators had improved, including two indicators of ICM mechanism (G1 and G3), and two indicators of public involvement (G9 and G10). In 2008, two indicators of ICM planning, implementation and monitoring (G4 and G5) and two indicators of capacity building (G6 and G7) reached the "excellent" level (Table. 3-9), showing that the government had made great efforts with ICM implementation and capacity building. The other seven indicators except G12 all reached the "good" level. As external funds from other economic sources other than the government were invested in ICM programmmes during 2004 - 2012, the performance score of the G12 – External Funding was zero. It is suggested that the government should try to seek other economic sources to improve the financing mechanism.

3.6.2 Quanzhou

The performance of GI in Quanzhou improved significantly from 2004 to 2012 with an average annual growth rate of 30.54% (Fig. 3-4). It showed that the GI increased sharply from 2004 to 2006, and tended to increase much slower afterwards. It therefore seemed that the improvement of governance performance from a "fair" level to a "good" or "excellent" level were more difficult than the improvement from a "weak" level to a "fair" level, which may require input of continual efforts to improve the performance.

The performance of governance indicators all improved except G12 - External Funding (Fig. 3-5), seeing that external funds had not been invested in ICM in Quanzhou as well. The performance scores of 8 indicators including law enforcement mechanism, implementation and monitoring, scientific and technical support all reached the "good" level in 2012, while other 3 indicators, namely G4 - Policy, Strategies and Action Plans, G9 - Stakeholder Involvement and G10 Publicity of Government Information were still at the "fair" level (Fig. 3-5). The results suggested that the local government of Quanzhou should focus more on the legal system building and policy formulation as well as the public participation system building in the whole process of ICM preparation, planning, implementation, monitoring and adjustment. Stakeholder involvement was often the key factor determining the success of ICM in many cases of other countries (Archer, 1988; Ernoul, 2010; Imperial et al., 2000). In China, because of its top down administrative approach, the performance of this factor has been often weak and was not always "the key" to the success (Liu et al., 2012). It however cannot be neglected as it is one of the key principles of ICM (Cicin-Sain et al., 1998).

3.6.3 Dongying

The performance of GI in Dongying also improved significantly during 2004 - 2012 with an annual growth rate of 32.18% (Fig. 3-6). It increased steadily from 2004 to 2011 and stopped increasing from 2011 to 2012. The results also proved that Dongying government succeeded to adopt the ICM framework to improve its coastal governance.

The performance of all governance indicators except G12 had improved from 2004 to 2012. After 8 years' implementation of ICM, G5 - Implementation and Monitoring of ICM Initiatives, G6 - Scientific and Technical Support, G7 - Staff Capacity Building and G8 - Infrastructure and Facilities Allocation had reached the "good" level, while G2 – ICM Mechanism was still in the "weak" level (Fig. 3-7). This suggested that Dongying government put a lot of efforts on projects implementation and capacity building. The government should input more endeavors to improve its ICM mechanism and to seek external funds to sustain the financing system.

3.7 Conclusions

The results showed that the performance of ICM governance in all three sites had improved during 2004-2012, which proved the success in adoption an ICM framework. The local government played a key role for the implementation of the ICM programmes, which is a major difference comparing with other coastal states (Chua, 2006; Xue et al, 2006). All of the three ICM sites had made great input on ICM governance capacity building and projects implementation. As Xiamen had a longer time in implementation of ICM, its governance performance in 2012 was better than the other two sites. However, it seems that a lack of external funds was a common issue in all three case studies. Indeed, a lack of external funds from private companies or non-government organizations, is also an issue for the whole country (Liu, et al., 2012). Seeking ICM funds from other economic sectors would be a target for China's coastal cities to sustain the financing system from a long-term perspective (Chua, 2006). The comparisons of the three sites as well as with other ICM sites will be discussed in Chapter 6.

Chapter 4 The performance of ICM in the coastal ecological environment

4.1 Introduction

Management of coastal and ocean ecosystems usually requires long-term efforts and needs to be put within a broader management scheme. A number of case studies have demonstrated that ICM is an effective framework for coastal environment protection and restoration (Chou, 1998; Tagliania et al., 2003; Lenzia et al., 2003; Suman et al., 2005; Mart ńez-Paz 2013l; Ye et al., 2013). Indeed, maintenance of coastal ecological environment health and sustainability is one of the basic goals of ICM (Cicin-Sain & Knecht, 1998; Chua, 2006). It is maintaining or restoring the structure and function of coastal ecosystems over time in the presence of external stress (Costanza, et al., 1992). Through the implementation of ICM, a variety of engineering projects on environmental protection and restoration would be more effective, such as land-based pollution treatment and control, coastal water cleanup, ecological restoration of critical coastal ecosystems (e.g. lagoons, mangroves, coral reefs, and wetlands), and marine protected area design. Sound ICM governance could ensure the success of the projects so as to achieve the goal of environment health and sustainability. In order to measure the outcomes and impacts of ICM interventions to the coastal ecological environment, the use of proper ecological indicators would be an effective tool to show the status and changes of coastal environment (Kerhner et al., 2011; Halpern et al., 2012).

In this chapter, I will mainly discuss the use of coastal ecological indicators for tracking the status of the coastal environment, to construct a coastal ecological index system for China's coastal cities, and apply it to the three case studies to analyze the performance of ICM in the health of the coastal environment.

4.2 Literature review

4.2.1 Coastal ecological indicators

Coastal ecological indicators are designed to represent the state and trends of the coastal environmental components, such as water flow, nutrient concentration, sediment quality, plankton/nekton/benthos diversity and sometimes ecological integrity at a system level. They are a useful tool to reveal and track the performance of environmental projects and policies in achieving environmental goals, so as to assist decision makers to identify priorities, and to formulate policy options (OECD, 1993; Heileman, 2006).

A large number of ecological indicators exists for coastal environment assessment due to the extreme complexity of coastal ecosystems. The indicators range from single species index (e.g. Warwick & Clarke, 1994; Borja et al., 2000; Chase et al., 2000) to a system-level measure of coastal ecosystem structure and function (e.g. Gibson et al., 2005; Nicholls et al., 2008; Hu & Zhang, 2012). The different composition of ecological indicators could serve different purposes for coastal ecosystem assessment (e.g. coastal vulnerability assessment, Nicholls et al., 2008; coastal safety/risk assessment, Hu & Zhang, 2012; coastal ecosystem health assessment, Xu et al., 2004; coastal sustainability assessment, Gibson et al., 2005. Figure 4-1) However, no well-established frameworks and indicators could precisely reveal and predict the changes of coastal environments.

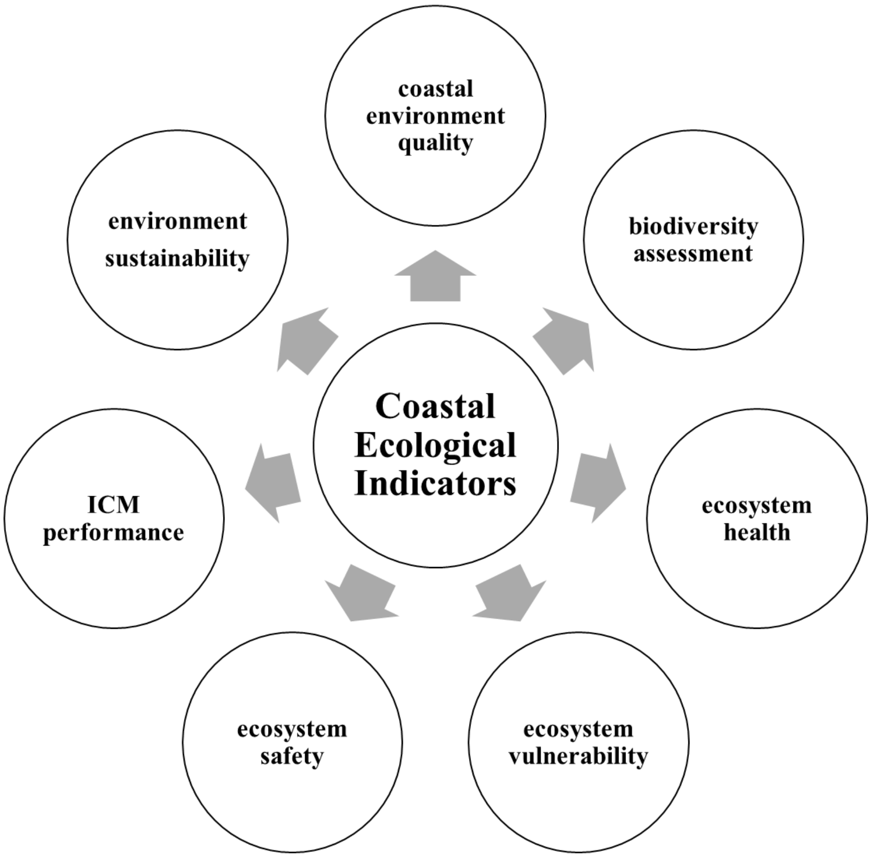

Figure 4-1 Coastal ecological indicators serves for multiple assessments with different purposes.

4.2.2 Coastal ecological indicators in ICM evaluation

In the context of an ICM evaluation, a comprehensive index at the system-level must be developed, allowing for an integrated assessment of the outputs and impacts of ICM programmes on coastal environment (Olsen, 2003). Many research works have been conducted at the global, regional, national and local (project and program based) scales in the use and development of ecological indicators that contribute to integrated coastal management programs (OECD, 1993; DiSano, 2002; Millennium Ecosystem Assessment, 2005). Some widely-applied indicator systems developed at the international level have facilitated the progress on the use of the indicators in ICM performance evaluation. For example, the Commission on Sustainable Development

(CSD) first developed 3 indicators within 2 sub-themes for Oceans and Coasts under Agenda 21 to assess sustainable development (DiSano, 2002; UNDESA, 2007). UNEP also developed a set of environmental indicators for oceans and coasts in the Global Environment Outlook Report (GEO-3, GEO-4 and GEO-5). The Organisation for Economic Co-operation and Development (OECD) proposed the OECD core set of environmental performance indicators and key environmental indicators for coasts and oceans (OECD, 1993, 2008). The International Oceanographic Commission (IOC) established the Global Ocean Observing System (GOOS) and developed an index system with 5 major monitoring themes for observing and modeling marine variables to support global ocean services (http://gosic.org/goos). The World Resources Institute (WRI) conducted the Pilot Analysis of Global Coastal Ecosystems (PAGE) and compiled 35 coastal ecological indicators within 6 categories for synthesis of information from global, regional, and national assessments (Burke et al., 2001). Among the above mentioned index systems, almost all of them cover two categories of the coastal environment – water quality and biodiversity, which are the two basic indices to represent the status of the coastal environment (Table. 4-1). However, the specific indicators selected under these two categories vary significantly, also suggesting that there are no widely-recognized indicators for coastal environment assessment.

Table. 4-1 Summary of indicators for state of the coastal environment

	Water quality	**Biodiversity**
CSD	Algae concentration, total pollution	-
OECD	BOD, DO, N, P	Threatened or extinct species
GOOS	Surface temperature, current	Phytoplankton
IOC, PAGE	Eutrophication, oil spill, solid waste	Species richness, threatened species, habitat degradation
GEO	Pollution	

Meanwhile, the coastal ecological indicators specifically designed for ICM measurement also have been developed. Unlike ICM governance indicators, not all ICM evaluations have systematically listed out all the ecological indicators in their index systems. For example, the EU's ICM index system incorporated the ecological indicators into ICM progress (Breton et al., 2006), PEMSEA's SOC report system integrated the ecological indicators into the sustainability aspects, and NOAA's ICM index system has three ecological indicators (namely water quality, endangered species, invasive species) under the "contextual indicators" category. However, to measure the overall performance of ICM, ecological indicators are important components to show the changes of the coastal environment that will indicate the performance of ICM in the conservation of coastal ecosystems. It might be better to measure the coastal environment systematically through the construction of a set of ecological indicators. IUCN's performance index system for MPA (2004) and IOC's ICM performance index system (2006) include a core set of ecological indicators for measuring the effectiveness of MPA and ICM respectively (Pomeroy et al., 2004, 2005; Heileman, 2006). Both of the frameworks are goal-oriented.

IUCN defined 5 biophysical attributes for an MPA that should be achieved through proper management. It then selected 10 indicators that are mostly related to the 5 goals for the performance assessment (Table. 4-2). The 10 indicators mainly cover the themes of species, community, habitat and water quality. IOC's framework of ecological indicators (Table. 4-3) relies heavily on the concept of marine ecosystem health. It formulated objectives based on the abilities of a healthy ecosystem to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience) (Costanza & McMichael, 1998; Boesch & Paul, 2001). It then identified three key elements contributing to ecosystem health - biological organization, vigour and quality for the selection of 9 indicators. Compared to the indicators for MPAs, the 9 indicators developed by IOC are for the measurement of ICM that could be applied over a larger regional scale.

Table. 4-2 MPA biophysical indicators (Pomeroy et al., 2004, 2005)

Goals	Indicators
	B1—Focal species abundance
1. Marine resources	B2—Focal species population structure
sustained or protected	B3—Habitat distribution and complexity
2. Biological diversity	B4—Composition and structure of the community
protected	B5—Recruitment success within the community
3. Individual species	B6—Food web integrity
protected	B7—Type, level, and return on fishing effort
4. Habitat protected	B8—Water quality
5. Degraded areas	B9—Area showing signs of recovery
restored	B10—Area under no or reduced human impact

Table. 4-3 Ecological goals, objectives and indicators developed by UNESCO (Heileman, 2006)

Goals	Objectives	Indicators
Organization: Conserve the ecosystem structure to maintain the biodiversity and natural resilience of the ecosystem	Maintaining biodiversity	E1 Biological diversity
	Maintaining species distribution	E2 Distribution of species
	Maintaining species abundance	E3 Abundance Biomass (key populations)
Vigour: Conserve the function of each component of the ecosystem so that its role in the food web and its contribution to overall productivity are maintained	Maintaining primary production and reproduction	E4 Production and reproduction
	Maintaining trophic interactions	E5 Trophic interactions
	Maintaining primary production and reproduction	E6 Mortality
Quality: Conserve geological, physical and chemical properties of the ecosystem so as to maintain the overall environmental quality.	Maintaining species health	E7 Species health
	Maintaining water and sediment quality	E8 Water quality
	Maintaining habitat quality	E9 Habitat quality

4.2.3 Summary

(1) There are still no commonly accepted frameworks or criteria for ecological coastal environment assessment due to the complexity of the coastal ecosystems.

(2) The different index systems had different objectives for assessment. Thus, the composition of the indicators varied significantly.

(3) The majority of the index systems focused on the common indicators that could measure the quality of water environment, coastal habitats, community health and species biodiversity.

(4) Many of the biological indicators were qualitative rather than quantitative due to the difficulties in quantitative measurements, such as species quality, trophic interaction, and species health.

(5) Selecting proper methods to quantify the indicators and to provide tangible evaluation results remains a big challenge for all the proposed ecological indicators,

4.3 Construction of ecological index system and quantification methods

4.3.1 Ecological index system

To construct a general ecological index system for evaluating the performance of ICM in the coastal environment of China's coastal cities, I also adopted the goal-oriented framework. Based on the literature reviews, I identified two basic goals in coastal environment protection/restoration that need to be achieved through ICM programmes for coastal cities. They are to maintain the quality and the biodiversity of coastal ecosystems so as to retain the health and sustainability of the coastal environment. Six specific indicators were selected based on the main components of coastal ecosystems (Table. 4-4).

Table. 4-4 Ecological index system for China's coastal cities

Main elements	Goals	Indicators
Coastal Environment	Quality: Conserve overall environmental quality	(E1) Coastal water quality (E2) Marine sediment quality (E3) Marine biological quality
	Biodiversity: Conserve the ecosystem structure and function to maintain the biodiversity and natural resilience of the ecosystem	(E4) Phytoplankton diversity (E5 Zooplankton diversity (E6) Benthos diversity

4.3.2 Description of indicators

The rationales and evaluation criteria of ecological indicators are described as follows.

Quality

Maintaining the quality of coastal environment means to manage physical, chemical and geological properties of the coastal ecosystem in terms of water quality, sediment quality, and biological quality. Thus, four indicators (E1 – E4) were selected.

(E1) Coastal water quality

Coastal water quality refers to the chemical, physical and biological characteristics of coastal water. It is a measure of the condition of coastal waters based on the water quality standards set for the specific water usage (e.g., fishing, aquaculture, tourism, etc.).

The evaluation criteria for coastal water quality in China’s coast are based on the “National Standard 3097–1997 Criteria of Seawater Quality” of the P.R.C (State Bureau of Environmental Protection, 2002; Table. 4-5).

Table. 4-5 The monitoring criteria of variables for coastal water quality in China’s coast (State Bureau of Environmental Protection, 2002)

Variables	Standards (level I, fishery, MPAs; level II, aquaculture; level III, industrial area, tourism; level IV, ports), mg/L			
	Level I	Level II	Level III	Level IV
pH	7.8－8.5		6.8－8.8	
DO (Dissolved Oxygen)	6	5	4	3
COD (chemical oxygen	2	3	4	5
Inorganic nitrogen ≤	0.20	0.30	0.40	0.50
Active phosphate ≤	0.015	0.030		0.045
Petroleum ≤		0.05	0.30	0.50
Cu ≤	0.005	0.010		0.050
Pb ≤	0.001	0.005	0.010	0.050
Zn ≤	0.020	0.050	0.10	0.50
Cr ≤	0.001	0.005		0.010
Hg ≤	0.00005		0.0002	0.0005
As ≤	0.020		0.030	0.050

(E2) Marine sediment quality

Marine sediment refers to any deposit of insoluble materials such as soil particles, marine organisms remaining and chemical precipitates that accumulate on the seabed. In this study, I focus on the sediment in coastal waters. Its quality is a measure of the complex nature of sediment, such as the concentrations of organic matter, chemical contaminants, heavy metals, etc.

The evaluation criteria for marine sediments in China's coast are based on the "National Standard *18668*－*2002* Criteria of Marine Sediment Quality" of the P.R.C (State Bureau of Environmental Protection, 2002; Table. 4-6).

Table. 4-6 The monitoring criteria of variables for marine sediment quality in China's coast (State Administration for Quality Supervision and Inspection and Quarantine, 2002)

Variables	Standards (level I, fishery, MPAs; level II industrial area, tourism; level III, ports), g		
	Level I	Level II	Level III
Organic matters ($\times10^{-2}$) ≤	2.0	3.0	4.0
Sulfide ($\times10^{-6}$) ≤	300.0	500.0	600.0
Petroleum ($\times10^{-6}$) ≤	500.0	1000.0	1500.0
Pb ($\times10^{-6}$) ≤	60.0	130.0	250.0
Cr ($\times10^{-6}$) ≤	0.50	1.50	5.00
As ($\times10^{-6}$) ≤	20.0	65.0	93.0
Cu ($\times10^{-6}$) ≤	35.0	100.0	200.0
Hg ($\times10^{-6}$) ≤	0.20	0.50	1.00
Zn ($\times10^{-6}$) ≤	150.0	350.0	600.0

(E3) Biological quality

Biological quality refers to the health of shellfish (bivalve). Shellfish have been proposed as good indicators of coastal environment as they accumulate heavy metal and petroleum from water much more easily than other organisms (Gold-Bouchot et al., 1995; de Mora, et al., 2004). The quality is a measure of the concentrations of heavy metals in the body of the shellfish.

The evaluation criteria for biological quality in China's coast are based on the "National Standard 18421－2001 Criteria of Marine Biological Quality" of the P.R.C (State Administration for Quality Supervision and Inspection and Quarantine, 2001; Table. 4-7).

Table. 4-7 The monitoring criteria of variables for marine shellfish quality in China's coast (State Administration for Quality Supervision and Inspection and Quarantine, 2001)

Indicators	Standards (level I, fishery, MPAs; level II industrial area, tourism; level III, ports) , mg/kg		
	Level I	Level II	Level III
DDT ($\times 10^{-6}$) ≤	0.01	0.10	0.50
Pb ($\times 10^{-6}$) ≤	0.1	2.0	6.0
Cd ($\times 10^{-6}$) ≤	0.2	2.0	5.0
As ($\times 10^{-6}$) ≤	1.0	5.0	8.0
Cu ($\times 10^{-6}$) ≤	10	25	50
Hg ($\times 10^{-6}$) ≤	0.05	0.10	0.30
Xn ($\times 10^{-6}$) ≤	20	50	100

Biodiversity

Maintaining and conserving the biodiversity of coastal ecosystems means to conserve the structure and function of a coastal ecosystem to maintain its biodiversity and natural resilience. The basic components of the marine biological community are really essential for sustaining ecosystem integrity, including phytoplankton, zooplankton, nekton, and benthos. Due to a lack of nekton monitoring data in China's coast, the indicator of nekton was not selected. Three indicators (E4-E6) have been selected under this goal. Unlike the quality indicators, no consolidated standards have been established for biodiversity measurements in China's coast as well as in other coastal countries.

The quantitative variables used for biodiversity evaluation of indicator E4 to E6 are basically the same, including species richness, evenness, Shannon-Wiener diversity index and the presence of endemic species (Dickman, 1968; Irigoien & Harris, 2004).

(E4) Phytoplankton diversity

Phytoplankton, also known as microalgae, are photoautotrophs containing chlorophyll that live and grow through photosynthesis. They are a part of the foundation in marine food webs food, offering food for a wide range of marine faunal groups. If phytoplankton grow out of control, they may form algal blooms, which may cause dramatic death of fishes (Shumway, 1990; Glibert et al., 2002).

(E5) Zooplankton diversity

Zooplankton are heterotrophic (or detritivorous) plankton, usually drifting in oceans. Zooplankton species composition and diversity reveal the environmental heterogeneity patterns (Attayde & Bozelli, 1998).

(E6) Benthos diversity

Benthos is the community of invertebrates living on, in, or near the seabed. Benthic communities are often used as indicators of coastal ecosystem health as many species are sensitive to pollution and sudden changes of the environment (Melhuus et al., 1970; Simboura & Zenetos, 2002).

4.4 Quantification methods

Theoretically, more than one variable can be used to quantify the selected indicators. For example, water quality could be measured by water temperate, pH, water transparency, chemical oxygen demand (COD), and dissolved oxygen (DO). However, the available data are often limited in practical cases. To choose the most appropriate quantified variables that could show the changes of the indicators, I complied all the available ecological data in each case and selected quantified variables (Table. 4-8) in light of the following 3 criteria.

(1) The variable can indicate the changes of the indicator.

(2) The variable can be quantified.

(3) The variable is monitored and available during the evaluation time scale that is from 2004 to 2012.

For diversity indicators (E4-E6), the quantitative variables selected for each case study are different due to the limited available monitoring data (Table. 4-8). For Xiamen and Quanzhou, I selected “species richness” for the 3 diversity indicators. For Dongying, I selected “Shannon-Wiener diversity index” as the quantitative variable. Both of the variables could partially indicate the species diversity (Gray, 2001; Irigoien & Harris, 2004).

All of these variables represent positive correlations with sustainability; the larger value of the variable indicates the better status of coastal environment.

Table. 4-8 Quantitative indicators selected for each ecological indicators and their data source

Indicators	Quantitative variables	Data source
E1	Proportion of sea areas up to the sea water standard of level II (%)	Municipal Oceanic and Fishery Administration
E2	Proportion of the monitored variables up to sediment quality of standard of level I (%)	
E3	Proportion of the monitored variables up to biological quality standard of level I (%)	
E4	Species richness (number of species) (ind) (Xiamen and Quanzhou)	Municipal Oceanic and Fishery Administration
	Shannon-Wiener diversity index (Dongying)	State Oceanic Administration
E5	Species richness (number of species) (ind) (Xiamen and Quanzhou)	Municipal Oceanic and Fishery Administration
	Shannon-Wiener diversity index (Dongying)	State Oceanic Administration
E6	Species richness (number of species) (ind) (Xiamen and Quanzhou)	
	Shannon-Wiener diversity index (Dongying)	State Oceanic Administration

4.5 Evaluation results

4.5.1 Xiamen

All the quantified data of ecological indicators of Xiamen are provided in Table. 4-9. E3 showed no variance during the evaluation period from 2004 to 2012, it was therefore eliminated during Z score transformation and PCA analysis. The final evaluation results of ecological indicators (EI) in Xiamen are presented in Table. 4-10 and Fig. 4-1. The variations of 5 ecological indicators (except E3) with standardized values in 2004 and 2012 are shown in Fig. 4 2.

The results showed that EI of Xiamen's coastal environment had increased from 2004 to 2012 with severe fluctuations in between (Fig. 4-1). Although the overall trend was up ward, there was a sharp decline from 2004 to 2008. Its average annual growth rate was 20.69%. The lowest EI value (-0.65) was in 2008, while the highest value (1.27) occurred in 2012. Indicator E3 - Biological Quality was uchanged during 2004-2012 with good performance (Table. 4-9). The variations of 5 ecological indicators in 2004 and 2012 (Fig. 4-2) showed that the standardized values of 4 ecological indicators (E2 - Sediment Quality, E4 - Phytoplankton Diversity, E5 - Zooplankton Diversity, and E6 - Benthos Diversity) increased from 2004 to 2012. E4 and E5 had higher increments than E2 and E6 from 2004 to 2012. Only the value of E1- Water Quality decreased.

Table. 4-9 Quantified indicators and actual vales of coastal ecological indicators (EI) in Xiamen (2004-2012)

Indicators	2004	2005	2006	2007	2008	2009	2010	2011	2012
E1	8.6	8.6	0	0	0	0	0	11.5	2.6
E2	67	11	56	78	67	67	78	100	100
E3	100	100	100	100	100	100	100	100	100
E4	89	87	84	102	76	79	123	141	227
E5	26	34	36	35	49	43	49	58	85
E6	45	56	54	44	34	47	63	78	60

Table. 4-10 The EI results, standardized score and contribution rate (contrib. rate), weight (Wi) of the indicators in Xiamen (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
E1	1.09	1.09	-0.74	-0.74	-0.74	-0.74	-0.74	1.70	-0.19	0.36	0.16
E2	-0.09	-2.20	-0.50	0.33	-0.09	-0.09	0.33	1.16	1.16	0.34	0.16
E4	-0.48	-0.52	-0.58	-0.21	-0.75	-0.68	0.23	0.60	2.38	0.50	0.23
E5	-1.15	-0.69	-0.58	-0.63	0.16	-0.18	0.16	0.68	2.22	0.43	0.20
E6	-0.66	0.20	0.04	-0.73	-1.51	-0.50	0.74	1.91	0.51	0.54	0.25
EI	-0.34	-0.37	-0.44	-0.43	-0.65	-0.45	0.20	1.21	1.27	NA	1.00

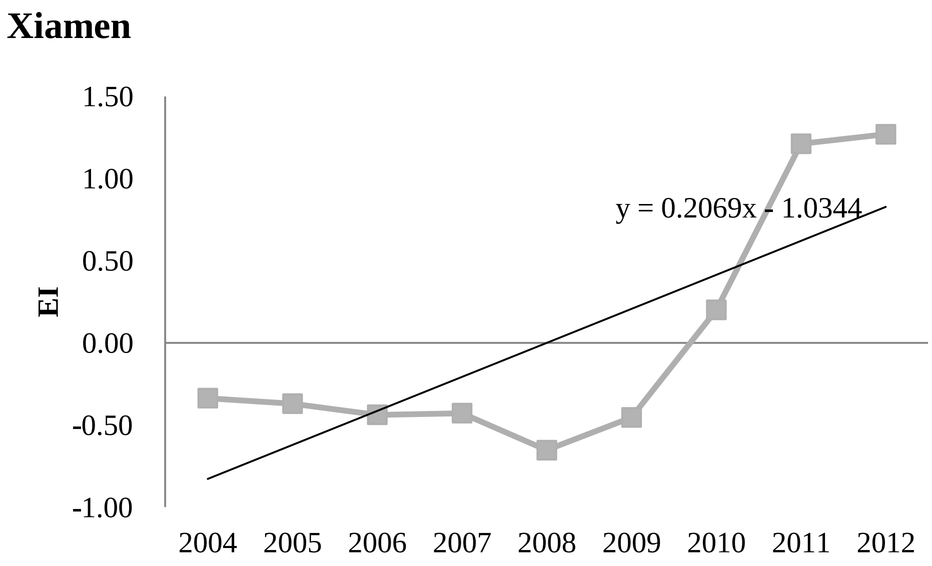

Fig. 4-1 Variation of the Xiamen Ecological Index (EI) from 2004 to 2012

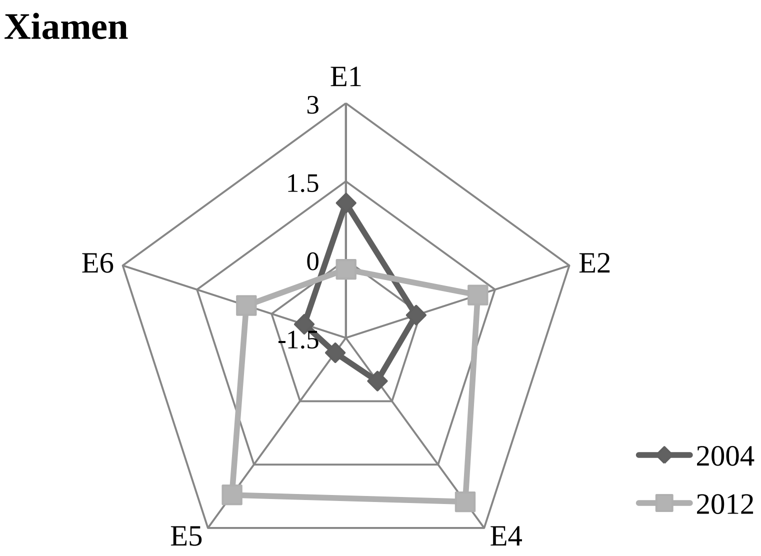

Fig. 4-2 Variation of Xiamen ecological indicators in 2004 and 2012

4.5.2 Quanzhou

All the quantified data of ecological indicators of Quanzhou are provided in Table. 4-11. E2 and E3 showed no variance during the evaluation period from 2004 to 2012 and were therefore eliminated during Z score transformation and PCA analysis. The final evaluation results of EI in Quanzhou are presented in Table. 4-12 and Fig. 4-3. The variations of 4 ecological indicators (except E2 and E3) with standardized values in 2004 and 2012 are shown in Fig. 4-4.

The results indicated that Quanzhou's EI had increased from 2004 to 2012 despite fluctuations (Fig. 4-3). The overall trend was upward with exceptions during 2009 – 2010 and 2011-2012, where the EI declined (Table. 4-12). Its average annual growth rate was 27.79%. The lowest EI value (-1.26) was in 2005, while the highest value (0.89) presented in 2011. Indicator E2 – Sediment Quality and E3 - Biological Quality was unchanged during 2004-2012 with good performance (Table. 4-11). The variations of 4 ecological indicators in 2004 and 2012 (Fig. 4-4) showed that the standardized values of 3 ecological indicators (E1 - Water Quality, E4 - Phytoplankton Diversity, and E5 - Zooplankton Diversity) increased from 2004 to 2012. The increments of the 3 indicators from 2004 to 2012 were more or less the same. Only the value of E6- Benthos Diversity decreased.

Table. 4-11 Quantified indicators and actual vales of coastal ecological indicators (EI) in Quanzhou (2004-2012)

Indicators	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
E1	40	50	50	55.6	70.8	75	75	77.8	79.5
E2	80	80	80	80	80	80	80	80	80
E3	80	80	80	80	80	80	80	80	80
E4	66	96	110	232	234	283	272	282	256
E5	133	114	130	193	246	195	225	280	237
E6	135	54	135	180	74	213	157	134	103

Table. 4-12 The EI results, standardized score and contribution rate (contrib. rate), weight (Wi) of the indicators in Quanzhou (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
E1	-1.60	-0.93	-0.93	-0.55	0.48	0.76	0.76	0.95	1.06	0.26	0.26
E4	-1.58	-1.23	-1.07	0.33	0.35	0.91	0.79	0.90	0.60	0.30	0.30
E5	-1.06	-1.39	-1.11	-0.03	0.88	0.00	0.52	1.46	0.73	0.25	0.25
E6	0.07	-1.56	0.07	0.97	-1.16	1.63	0.51	0.05	-0.58	0.19	0.19
EI	**-1.13**	**-1.26**	**-0.82**	**0.14**	**0.22**	**0.79**	**0.66**	**0.89**	**0.52**	NA	1.00

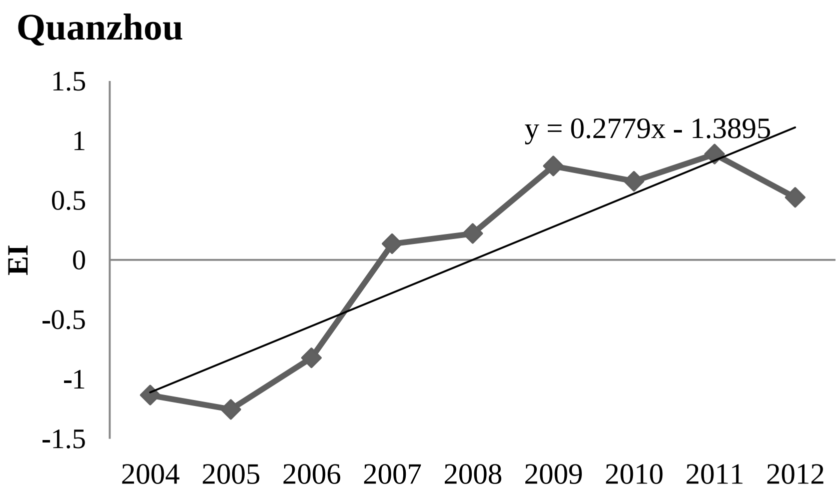

Fig. 4-3 Variation of the Quanzhou Ecological Index (EI) from 2004 to 2012

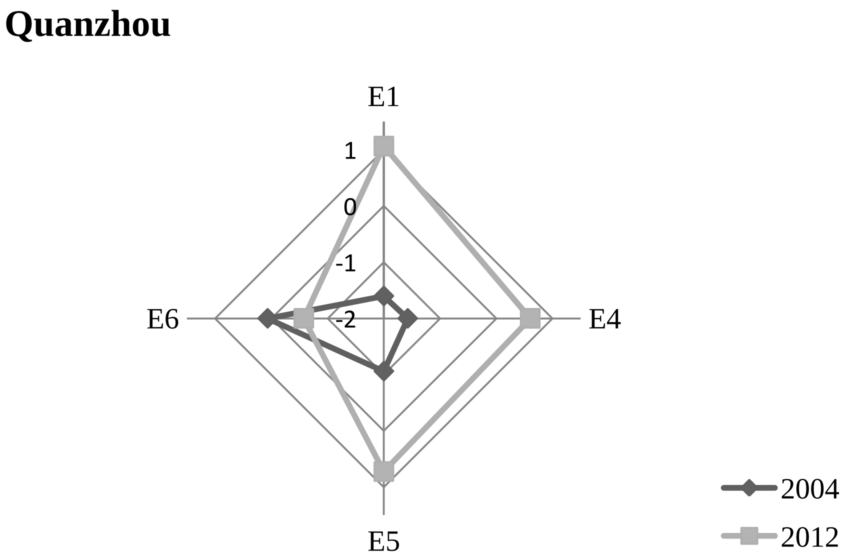

Fig. 4-4 Variation of Quanzhou ecological indicators in 2004 and 2012

4.5.3 Dongying

All the quantified data of ecological indicators of Dongying are provided in Table. 4-13. The monitoring data on coastal and marine biodiversity in Dongying were not available before 2007 due to a lack of monitoring from 2004 to 2006. Therefore, I only evaluated the trends of Dongying's coastal environment from 2007 to 2012. E3 showed no variance from 2007 to 2012, it was therefore eliminated during Z score transformation and PCA analysis. The final evaluation results of EI in Dongying are presented in Table. 4-14 and Fig. 4-5. The variations of 5 ecological indicators (except E3) with standardized values in 2004 and 2012 are in Fig. 4-6.

The results showed that Dongying's EI increased from 2007 to 2012 (Fig. 4-5). Its average annual growth rate is 39.53%. Although it also showed an overall increasing trend, a decline of EI occurred from 2010 to 2011. The lowest EI value (-1.41) was in 2007, while the highest value (0.81) presented in 2010. E3 - Biological Quality was invariable during 2004-2012 with good performance (Table. 4-13). The variations of 5 ecological indicators in 2007 and 2012 (Fig. 4-6) showed that the standardized values of all the 5 ecological indicators (E1 - Water Quality, E2 – Sediment Quality, E4 - Phytoplankton Diversity, E5 - Zooplankton Diversity, and E6 - Benthos Diversity) increased from 2007 to 2012. The increments of the 4 indicators from 2007 to 2012 were close to each other.

Although the biodiversity data were lacking from 2004 to 2006, the quality of the coastal environment could be evaluated based on the quality data, E1, E2 and E3. It could be seen that E2 and E3 showed no variation from 2004 to 2006 with good performance for both. The value of E1 – Water Quality (Proportion of sea areas with sea water standard of level II) had increased by 100% (Table. 4-13).

Table. 4-13 Quantified indicators and actual vales of coastal ecological indicators (EI) in Dongying (2004-2012)

Indicators	2004	2005	2006	2007	2008	2009	2010	2011	2012
E1	20	40	41	30	35	42	48	46	42
E2	78	78	78	78	100	100	100	100	100
E3	100	100	100	100	100	100	100	100	100
E4[1]	-	-	-	1.28	2.02	2.04	2.12	1.98	2.54
E5[1]	-	-	-	0.64	0.85	1.65	2.23	1.74	1.86
E6 [1]	-	-	-	2.35	1.73	1.87	2.15	1.95	3.04

1 The monitoring data of E4- Phytoplankton diversity, E5 -Zooplankton diversity, E6 Benthos Diversity before 2007 were not available.

Table. 4-14 The EI results, standardized score and contribution rate (contrib. rate), weight (Wi) of the indicators in Dongying (2007-2012)

	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
E1	-1.54	-0.81	0.22	1.10	0.81	0.22	0.58	0.21
E2	-2.04	0.41	0.41	0.41	0.41	0.41	0.51	0.19
E4	-1.77	0.05	0.17	0.29	-0.05	1.32	0.64	0.23
E5	-1.36	-1.02	0.10	1.23	0.43	0.63	0.64	0.24
E6	0.34	-1.00	-0.54	-0.09	-0.52	1.82	0.34	0.13
EI	-1.41	-0.45	0.12	0.66	0.27	0.81	NA	1.00

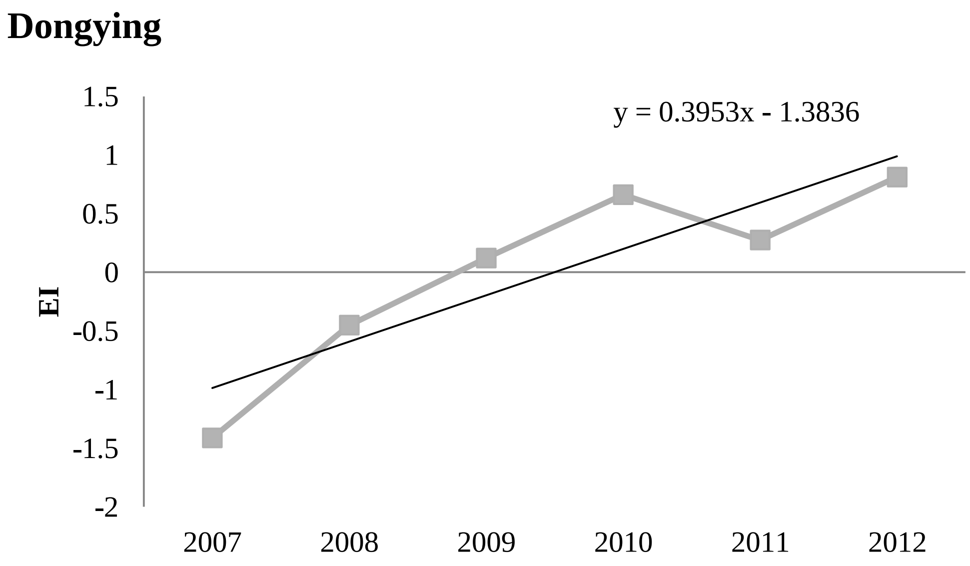

Fig. 4-5 Variation of the Dongying Ecological Index (EI) from 2007 to 2012

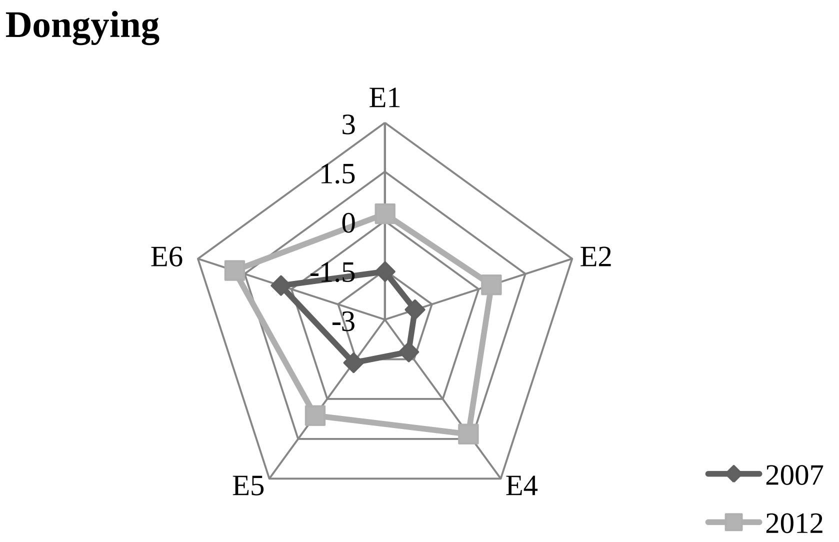

Fig. 4-6 Variation of Dongying ecological indicators in 2007 and 2012

4.6 Discussion

4.6.1 Xiamen

The performance of EI in Xiamen had improved greatly from 2004 to 2012 with an average annual growth rate of 44.83% (Fig. 4-1). Although the average growth rate was high, a sharp decline was seen from 2004 to 2008. It was mainly because of the declining water quality from 2004 to 2006 (Table. 4-9). During 2006 – 2010, the water quality of Xiamen coastal waters were severely polluted with almost all of the coastal waters declining to the third level (for industry and tourism areas) of China's national sea water standard. The major cause could be the discharge of a huge amount of reactive phosphate and inorganic nitrogen from domestic sewage (Xiamen Ocean and Fishery Bureau, 2010). Indicator E3 - Biological Quality had been of good performance during 2004-2012 (Table. 4-9). The performance of 4 indicators (E2 - Sediment Quality, E4 - Phytoplankton Diversity, E5 - Zooplankton Diversity, and E6 – Benthos Diversity) had improved, among which E4 and E5 were more significant than E2 and E6. It suggested that the biodiversity of Xiamen's coastal ecosystem had improved through ICM implementation. The performance of E1 - Water Quality decreased from 2004 to 2012 (Fig. 4-2), suggesting that the improvement of water quality remain a major challenge for Xiamen's ICM implementation.

4.6.2 Quanzhou

The performance of EI improved from 2004 to 2012 with an annualgrowth rate of 27.79% (Fig. 4-3). Although the general trend was upward, two declines existed during 2009-2010 and 2011-2012. It was mainly because of the declining performance of biodiversity index (E4-E6) as the species number of benthic fauna decreased from 2010 to 2009, and the species number of phytoplankton, zooplankton and benthos all decreased from 2012 to 2011 (Table. 4-12). Two quality indicators (E2 Sediment quality and E3 Biological quality) were invariable during 2004-2010 with very good status. The performance of three indicators (E1 - Water Quality, E4 - Phytoplankton Diversity, and E5 - Zooplankton Diversity) improved from 2004 to 2012, indicating that ICM programmes may play a positive role in water quality improvement and biodiversity conservation. The overall growth rate of E2 -Water quality was the highest among the 5 ecological indicators, suggesting that Quanzhou ICM projects on pollution reduction and control to improve the water quality were effective. However, the performance of E6 – benthos diversity declined, which meant that the benthic environment continued to deteriorate. Many case studies also showed that the restoration of benthic environment usually needed more time and effort than the upper layer water environment (Boris et al., 2010; Resh et al., 2013).

4.6.3 Dongying

The performance of EI improved from 2007 to 2012 with an annualgrowth rate of 39.53%. (Fig. 4-5). The performance of quality indicators (E1 – E3) during 2004 – 2006 showed that the water quality had improved and sediment and biological quality were with good status (Table. 4-13). The performance of E3 - Biological Quality had been also good during 2004-2012. The decline of EI from 2010 to 2011 was because of the overall declining performance of biodiversity indicators (E4 – E6). The performance of the 5 ecological indicators (E1 - Water Quality, E2 – Sediment Quality, E4 - Phytoplankton Diversity, E5 - Zooplankton Diversity, and E6 - Benthos Diversity) had all improved from 2007 to 2012, implying that the quality and biodiversity of Dongying’s coastal environment had been improved through the ICM programmes.

4.7 Conclusions

It can be seen that for the overall trends of the three coastal cities, EI all increased, which means coastal environment had improved through ICM implementation. Comparing these three ICM cities with two non-ICM cities (Tianjin and Zhoushan) (Fig. 4-7), it could be found that the two non-ICM cities were much more polluted. Indeed, the water quality of the two non-ICM cities had deteriorated since early 2000s without improvements (Tianjin Oceanic and Fishery Administration, 2003-2012; Zhoushan Oceanic and Fishery Administration, 2005-2012). It further proves that ICM has contributed to the improvement of the coastal environment in the three ICM cities.

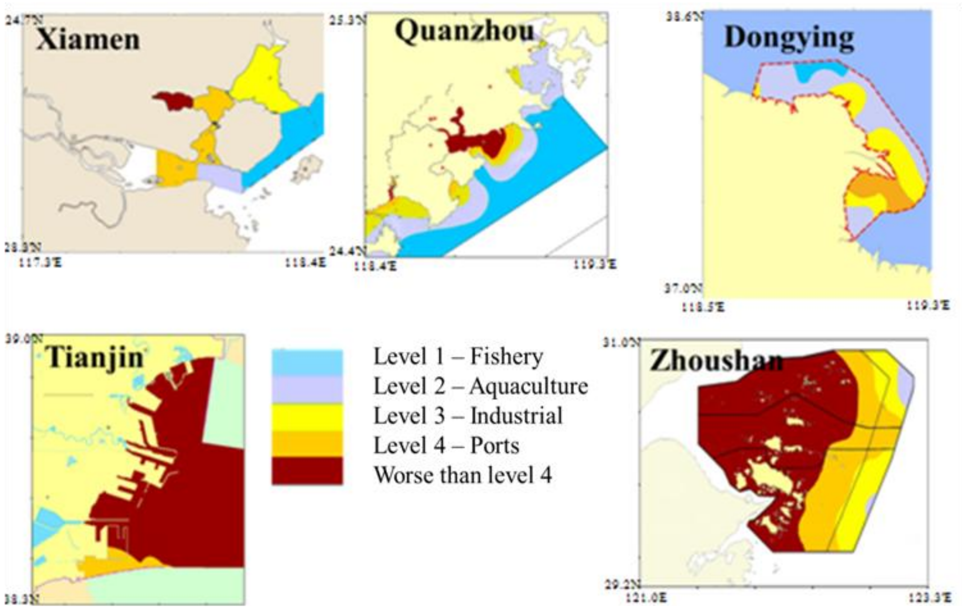

Fig. 4-7 Water quality in five coastal cities in China (2012)

(Source: Oceanic and Fishery Administration in Xiamen, Quanzhou, Dongying, Tianjin and Zhoushan)

However, challenges still remain for promoting coastal environmental health and sustainability in the three cities. For the specific indicators, the performance of E2 Biological Quality was good in all three cities and remained invariable during the evaluation time. It can be concluded that the biological quality of these coastal cities was good, but one of the possible reasons may be that the standards for biological quality were set too low to reveal differences or that the bivalve species chosen for monitoring was not sensitive to environmental changes (Gray, 2001; Boria and Dauer, 2008).

In contrast, the biodiversity index (either quantified by species richness or Shannon-Wiener diversity index) varied significantly over different years among the three cities. No general increasing or declining trends showed. Two possible reasons could be: firstly, sampling methods for plankton and benthos were not uniform year after year; secondly, the biodiversity in the three sites were severely impacted by the coastal activities such that the status was not stable. More discussion in the comparisons of the three sites will be presented in Chapter 6.

Chapter 5 The performance of ICM in coastal socio-economic development

5.1 Introduction

Coastal social and economic development relies on quality and use of the coastal environment. The loss of coastal resources and environmental degradation affects the development of socioeconomic development (Tumer, 2000). For example, fishery resources depletion directly influences the health of coastal societies and economies. Socioeconomic activities also exert pressures on coastal ecosystems. Thus, the socioeconomic and environmental aspects of the coastal area are irrevocably linked. As the ultimate goal of ICM is to achieve the sustainable development of coastal areas, socio-economic aspects must be taken into consideration in ICM implementation (Olsen, 2003; Heileman, 2006).

The use of socio-economic indicators can not only indicate the impacts of ICM in coastal socio-economic development but also provide a way to understand governance–nature–society interactions (OECD, 1993; Bowen & Riley, 2003). Unlike ICM governance indicators, they are indicators of socioeconomic circumstances that can influence ICM management but are usually not within direct control of ICM management agencies (Heileman, 2006).

In this chapter, I will discuss the use of socio-economic indicators for tracking the coastal socio-economic development, construct a socio-economic index system for China’s coastal cities, and apply it to the three case studies to analyze the performance of ICM in coastal economic development.

5.2 Literature review

Coastal socio-economic indicators mainly cover two fields – social and economic fields. Social indicators are designed to reflect people's objective living conditions in a defined geographic or cultural unit (Diener & Suh, 1997). Coastal social indicators cover a wide range of subject-matter fields, including demographic information, health, safety, education, and environment protection. The economic indicators in this study focus on the macroeconomic indicators that are based on the statistical data that characterize the performance, structure, behavior, and decision-making of an economy as a whole of a given country or region (Blanchard, 2000), such as Gross Domestic Product (GDP), Gross National Product (GNP), per capital income, employment, etc..

5.2.1 Socioeconomic indicators in environment assessment and ICM

Socioeconomic indicators are a useful tool to reveal the state of the human component in a coastal system (e.g. demographic data and economic data.) as well as an indispensable means in the development and implementation of ICM strategies and programmes (IOC, 2003). Unlike coastal governance and ecological indicators that require survey data or usually have no scientific data available for quantification, the majority of socioeconomic indictors already have available data that could be collected by government agencies (Heileman, 2006).

In the past two decades, a lot of efforts have been made to incorporate the socioeconomic indicators into the coastal environment monitoring and assessment for the purpose of promoting coastal sustainability. A number of international monitoring and assessment protocols have been designed with socioeconomic indicators, providing frameworks and methodologies for systematic reflection of social and economic aspects in the entire coastal ecosystem. For examples, the CSD's indicators under Agenda 21 (DiSano, 2002; UNDESA, 2007), UNEP's GEO-3, GEO-4 and GEO-5, OECD's core set of environmental indicators (OECD, 1993, 2008), IOC's GOOS indicators (http://gosic.org/goos), WRI's PAGE indicators(Burke et al., 2001), and the Millennium Ecosystem Assessment (MA) indicators (Millennium Ecosystem Assessment, 2005). The common sub-themes in these protocols are (a) coastal population, (b) coastal development, (c) coastal hazards, (d) fisheries, (e) tourism and recreation, (f) ports, and (g) health.

In ICM evaluation international protocols, the IOC proposed a more systematic and complete social and economic index system for the evaluation of the success of ICM progrmmes than the other organisations. This index system covers 4 broad dimensions of the socioeconomic aspects of ICM – economic, environmental, public health and safety, and social dimensions. These are collectively combined under the goal of sustainable development. Thirteen code indicators are proposed under different objectives. It provides a clear road map for developing indicators in social and economic dimensions related to ICM. However, this index alone could not reveal the interactions with the environment. Governance and environmental indicators need to be taken into account as well. I will discuss the interactions in Chapter 6.

Table. 5-1 Socioeconomic goals, objectives and indicators for ICM evaluation (Heileman, 2006)

Goals	Objectives	Code Indicators
A healthy and productive economy	Maximize economic development	G1 Total economic value G2 Direct investment
	Increase employment	G3 Total employment
	Foster economic diversification	G4 Sectoral diversification
A healthy and productive environment	Minimize habitat destruction and alteration from human pressures	G5 Human pressures on habitats
	Reduce the volume of introduction of all types of pollutants	G6 Pollutants and introductions
Public health and safety	Protect human life and public and private property	G7 Disease and illness G8 Weather and disaster
Social cohesion	Maintain equitable population dynamics	G9 Population dynamics G10 Marine dependency G11 Public access
Cultural integrity	Maintain cultural integrity	G12Traditional knowledge, innovations and practices/ cultural integrity G13 Protection of coastal heritage resources

5.2.2 Summary

(1) Coastal socioeconomic indicators cover a wide range of fields closely related to environmental and socio-economic characteristics of the coastal area.

(2) ICM socioeconomic indicators are designed not only to reflect the economic and social benefits offered by the coastal ecosystems but also to reveal the stresses to the ecosystems caused by human activities.

(3) These indicators are usually quantitative variables that are routinely measured by economic sectors. Thus, the challenges become how to collect and compile the existing data in a most useful way.

(4) Understanding the complexity of socioeconomic and environmental l linkages remains a challenge, requiring the proper integration of governance, environmental and socioeconomic indicators.

5.3 Construction of indicators

5.3.1 Socio-economic indicators

To better evaluate the success of ICM in China's coast, I assessed the performance of ICM in coastal economic development in China's coastal cities. I constructed the framework based on the literature and the experiences from local experts of social economic conditions in China's coastal cities. Three broad dimensions to the socioeconomic aspects of ICM have been identified for the selection of socioeconomic indicators. They are demographic and economic development, coastal resource utilization and public safety and protection. A total of 13 indicators were selected for ICM performance evaluation in coastal socio-economic development (Table. 5-2 Socio-economic).

Table. 5-2 Socio-economic index system for ICM effectiveness evaluation of China's coastal cities

Main elements	Sub-elements	Indicators
Social Economic Condition	Demographic and economic development	(S1) Population density
		(S2) Income
		(S3) Employment
		(S4) GDP
	Coastal resource utilization	(S5) Gross Ocean Product
		(S6) Fishery resources exploitation
		(S7) Ports development
		(S8) Tourism development
	Public safety and environmental protection	(S9) Marine and coastal hazards
		(S10) Sea level rise
		(S11) Sewage treatment
		(S12) Discharge of total pollutant into sea
		(S13) Environmental funding

5.3.2 Description of indicators

The rationale and quantitative variables of socio-economic indicators are described as follows.

Demographic and economic development

Basic indicators for providing relevant information from an economic perspective for ICM include the indicators measuring the population density (S1), income per person (S2), employment (S3) and Gross Domestic Product (GDP) (S4).

(S1) Population density

It has been estimated that both population growth rates and density in coastal areas are greater than the inland growth rates (Un-habitat, 2010). On the one hand, population growth propelled the coastal economy; on the other hand, high population densities impose a number of the environmental stressors on coastal systems. The quantitative variable used for measuring the trend of population growth is the population density of a given coastal region.

(S2) Income

Income is the total monetary value of all the types of earnings received in a given period for an individual or a household (Case & Fair, 2007). It measures the wealth of the population of a society.

The quantitative variables used for measuring the income in a coastal society could be the per capita income (PCI) which is the average income of the people in an economic unit. It could be a good indicator for the comparison of wealth between different coastal regions.

(S3) Employment

The employment status in a coastal society reflects people's living standards and the stability of their life. Productive employment is the foundation that provides households with goods and services.

It could be measured by the unemployment rate, which is the rate of unemployed individuals dividing by all individuals currently in the labor force.

(S4) GDP

GDP is commonly used to indicate the economic health of a region. For comparison purposes, per capital GDP is chosen as the quantitative variable, which is the GDP divided by the total population in a given coastal unit.

Coastal resource utilization

The sustainable use of coastal resources is the core objective for ICM. There are various types of coastal resources. Common coastal resources with high economic values include fisheries, ports and tourism resources.

(S5) Gross Ocean Product

Gross Ocean Product (GOP) is a monetary measure of the sum of all final goods and services related to coastal and marine resources in a coastal region. It is an indicator of the economic health of coastal resources utilization. The quantitative variable is the ratio of GOP to GDP, which is calculated as the GOP divide by GDP.

(S6) Fishery resources exploitation

Fish is a major economic resource in the coastal area, providing both proteins and livelihood to coastal societies Sustainable fishery is a challenging but an integral part of ICM. To measure the trends of fishery resources exploitation, marine fish production per year is chosen as the quantitative variable.

(S7) Ports development

The economy of the port region or even the whole country can benefit from the increased exports and industrial activities after port expansion and modernization. However, development of the port may also have negative influence on coastal ecosystems. Therefore, sustainable port development is a key issue in ICM. The quantitative variable selected for measuring the trends of port development is the port cargo through-put per year, which is the key indicator to measure the capacity of port handling.

(S8) Tourism development

Sustainable coastal tourism is also a key issue in ICM. Coastal tourism offers various types of recreational services such as sea, beach, rich coastal and marine biodiversity at the interface of land and ocean. The coastal tourism sector is increasingly important in its contribution to national economies and to the well-being of coastal communities (Markovic et al., 2011). The quantitative variable to measure the trends of coastal tourism development could be the number of coastal tourism population per year.

Public safety and environmental protection

Improvements of public safety in the face of marine and coastal hazards as well as strengthening environmental protection are two major objectives for ICM towards sustainability. Five indicators were selected under this category for the measurement, with S9 and S10 for public safety evaluation and S11 to S13 for environmental protection evaluation.

(S9) Marine and coastal hazards

Marine and coastal hazards include both natural and man-made disasters that take place in the sea or along the coastline. There is potential for coastal and marine disasters to have socioeconomic and environmental impacts.

The quantitative variable for measuring the damage caused by coastal hazards could be converted to the monetary value of total economic loss. Alternatively, if no data are available for economic loss estimates, the occurrence frequency in a certain period of the disasters could be used as a proxy for the measurement.

(S10) Sea level rise

The current rise of sea level is now significantly faster than the historical record, becoming a major threat to coastal safety. It happens in two ways (IPCC, 2007): sea water thermal expansion and land ice melting. Sea level rise can considerably influence coastal and ocean natural environments like beach stabilization and marine ecosystems, and human behaviour in coastal and island regions.

The quantitative variable chosen for measuring the sea level rise is the sea level change compared to the 30 year mean sea level.

(S11) Sewage treatment

Much of the pollution in many coastal areas is land-based. Sewage treatment is a process to remove pollutants from household and industrial wastewater by a combination of physical, chemical and biological approaches. It is an important indicator of pollution reduction and waste treatment.

The quantitative variable to measure it is the ratio of sewage disposal to sewage discharge. The bigger ratio represents a better coastal environment.

(S12) Discharge of total pollutants into the sea

The land-based pollutants discharged into the sea mainly include COD, inorganic nitrogen, reactive phosphate, oils, and heavy metals. The smaller the amount of total pollutant discharged into the coastal waters, the better the coastal environment would be.

The amount of the total pollutants discharged into the sea per year is chosen as the quantitative variable.

(S13) Environmental funding

Environmental funding is the investment of the funds in a broad area of environment management and protection. It could indicate the overall local capacity of environment management and protection

To measure it, the ratio of environmental investment to GDP is chosen as the variable to measure the government investment in environment protection.

5.4 Quantification methods

Given that most of the social and economic indicators already have quantitative variables that are routinely measured by economic sectors, I collected the data mainly from the published government reports and statistical books. Based on the available information and previous literature, I selected the quantitative variables for each social and economic indicator (Table. 5-3). For indicator S9 'Marine and coastal hazards', I selected different quantitative variables for each case study due to a lack of common available data for the three cities.

It needs to be noted that not all the quantitative variables chosen as the socio-economic indicators are positively correlated to sustainability. Four indicators S3, S9, S10 and S12, are negatively correlated to sustainability. The smaller values of these four indicators indicate a better socioeconomic condition. The rest of 9 indicators are supposed to have positive correlations with coastal sustainability of socioeconomic development.

Table. 5-3 Quantitative variables selected for socio-economic indicators and their data source

Indicators	Quantitative variables	Data source
S1	Population density(ind./km^2)	Municipal Year Book, municipal statistical bureau
S2	Per capita income(Yuan)	Municipal Year Book, municipal statistical bureau
S3	Unemployment rate (%)	Municipal Year Book, municipal statistical bureau
S4	Per Capita GDP (Yuan)	Municipal Year Book, municipal statistical bureau
S5	Ratio of Gross Ocean Production to GDP (%)	China Marine Statistical Book, State Oceanic Administration; municipal government reports
S6	Marine Fish Production(thousand tonnes)	Municipal Year Book, municipal statistical bureau
S7	Port Cargo Throughput (million tonnes)	Municipal Year Book, municipal statistical bureau
S8	Tourist population (million people)	Municipal Year Book, municipal statistical bureau
S9	Xiamen: Red tide (frequency of occurrence)	Xiamen Marine Environment Monitoring Center
	Quanzhou: Economic loss from marine hazards (10^8 Yuan)	China Marine Statistical Book, State Oceanic Administration
	Dongying: Ice disaster (Duration time)	Dongying Municipal Oceanic and Fisheries Administration
S10	Sea level change (mm)	China sea level communiqué, State Oceanic Administration
S11	Ratio of sewage disposal to sewage discharge (%)	Municipal Oceanic and Fisheries Administration
S12	Discharge of total pollutant into sea (* 10^4 tonnes)	Municipal Environmental Protection Bureau
S13	Ratio of Environmental investment to GDP (%)	Municipal Environmental Protection Bureau

5.5 Evaluation results

5.5.1 Xiamen

All the quantified data of socioeconomic indicators of Xiamen are provided in Table. 5-4. The standardized score and contribution rate of each indicator are presented in Table. 5-5. The final results of the Socio-economic Index (SI) of Xiamen (Fig. 5-1) and the variations of 13 social economic indicators with standardized values in 2004 and 2012 (Fig. 5-2) are presented.

The results showed that Xiamen SI increased steadily from 2004 to 2012. Its annual growth rate was 29.23% (Fig. 5-1). The lowest EI value (-1.21) was in 2004, while the highest value (1.32) in 2012. The variations of the ecological indicators (Fig. 5-2) showed that the standardized values of all indicators except S10 increased from 2004 to 2012. Seven indicators (S1, S2, S4, S6, S7, S8, and S9) had relative higher increments than the other 5 indicators from 2004 to 2012. S10 showed an overall declining trend from 2004 to 2012, together with great fluctuation among different years (Table. 5-5).

Table. 5-4 Quantified indicators and actual vales of coastal socioeconomic indicators (SI) in Xiamen (2004-2012)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
S1	1640.00	1735.00	1830.00	1932.00	2072.00	2097.00	2263.00	2294.00	2333.00
S2	14443.00	16402.00	18513.00	21503.00	23948.00	26130.00	29300.00	33565.00	37576.00
S3	4.10	3.80	3.70	3.50	4.10	4.00	3.30	3.20	3.50
S4	34407.60	36871.20	40756.90	46137.70	49408.30	52643.50	57867.20	70341.10	76707.60
S5	3.30	13.20	13.60	14.40	13.70	12.90	11.70	11.20	11.30
S6	291.00	323.00	348.00	302.00	333.00	329.00	341.00	377.00	400.00
S7	42.60	47.70	55.60	81.20	97.00	111.00	127.30	157.00	172.00
S8	16.20	17.10	18.60	20.60	21.90	25.30	30.30	35.20	41.20
S9	3.00	2.00	4.00	5.00	2.00	2.00	3.00	4.00	1.00
S10	67.00	32.00	68.00	48.00	54.00	65.00	55.00	65.00	111.00
S11	72.10	77.00	83.70	84.70	96.50	94.10	90.40	97.70	97.70
S12	18.90	27.40	40.30	36.00	15.20	15.30	10.20	24.40	13.50
S13	2.40	2.40	2.60	2.60	2.70	2.60	2.50	2.60	2.50

Table. 5-5 The SI results, standardized score and contribution rate (contrib. rate), weight (Wi) of the indicators in Xiamen (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
S1	-1.51	-1.14	-0.76	-0.36	0.20	0.30	0.96	1.08	1.23	0.61	0.10
S2	-1.30	-1.05	-0.78	-0.40	-0.08	0.20	0.60	1.15	1.66	0.60	0.10
S3	-1.16	-0.39	-0.11	0.50	-1.16	-0.92	1.18	1.56	0.50	0.34	0.08
S4	-1.19	-1.02	-0.75	-0.38	-0.16	0.07	0.43	1.29	1.72	0.59	0.10
S5	-2.53	0.41	0.52	0.76	0.55	0.32	0.32	-0.19	-0.16	0.30	0.05
S6	-1.38	-0.45	0.29	-1.06	-0.15	-0.27	0.08	1.14	1.81	0.52	0.09
S7	-1.20	-1.09	-0.92	-0.38	-0.04	0.25	0.60	1.23	1.55	0.59	0.10
S8	-1.03	-0.93	-0.75	-0.52	-0.37	0.02	0.59	1.16	1.85	0.56	0.10
S9	-0.39	0.29	-0.74	-0.94	0.29	0.29	-0.39	-0.74	2.34	0.27	0.03
S10	-0.44	2.24	-0.47	0.53	0.15	-0.36	0.10	-0.36	-1.41	-0.27	0.05
S11	-1.71	-1.19	-0.48	-0.37	0.88	0.63	0.23	1.01	1.01	0.62	0.10
S12	-0.05	-0.73	-1.21	-1.09	0.49	0.47	1.83	-0.54	0.83	0.28	0.04
S13	-1.42	-1.42	0.55	0.55	1.53	0.55	-0.44	0.55	-0.44	0.35	0.05
SI	**-1.21**	**-0.87**	**-0.44**	**-0.37**	**0.10**	**0.16**	**0.45**	**0.84**	**1.32**		1.00

Xiamen

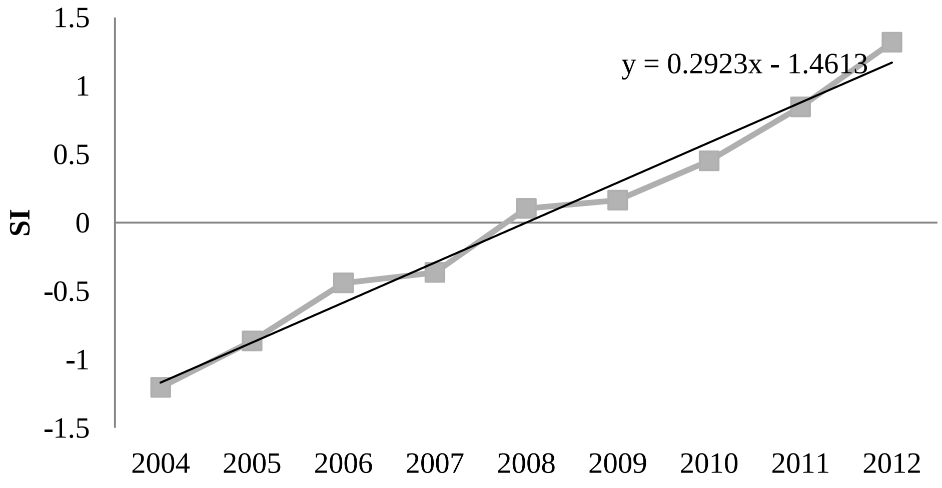

Fig. 5-1 Variation of the Xiamen Socioeconomic Index (SI) from 2004 to 2012

Xiamen

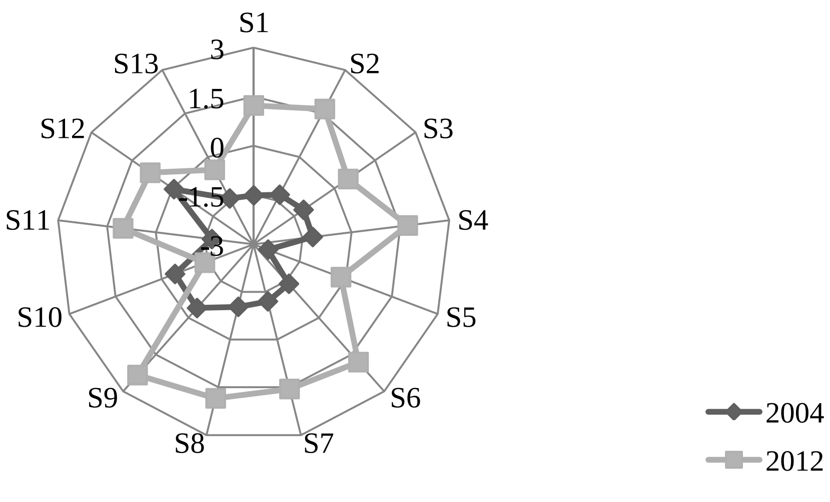

Fig. 5-2 Variation of Xiamen socio-economic indicators in 2004 and 2012

5.5.2 Quanzhou

All the quantified data of socioeconomic indicators of Quanzhou are provided in Table. 5-6. The standardized score and contribution rate of each indicator are presented in Table. 5-5. The final results of SI are shown in Fig. 5-3 and the variations of 13 social economic indicators with standardized values in 2004 and 2012 appear in Fig. 5-4.

The results showed that Quanzhou SI had increased from 2004 to 2012. Its annual growth rate was 21.39% (Fig. 5-3). The SI value in 2005 was lower than in 2006. The lowest EI value (-1.61) was in 2004, while the highest value (1.67) in 2012. The variations of all the 13 ecological indicators in 2004 and 2012 (Fig. 5-4) showed that the standardized values of 9 indicators (S1, S2, S4, S6, S7, S8, S11, S12, and S13) had increased from 2004 to 2012. Seven indicators (S1 S2 S4 S6 S8 S11 and S13) had higher increments than the other two. Only four indicators' standardized values (S3, S5, S9, and S10) declined from 2004 to 2012. S3 and S10 had higher decline than S5 and S9.

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Table. 5-6 Quantified indicators and actual vales of coastal socioeconomic indicators (SI) in Quanzhou (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
S1	695.70	701.30	707.70	712.30	716.90	723.40	748.20	755.60	763.00
S2	12699.00	14209.00	15972.00	18097.00	20420.00	22913.00	9296.00	28703.00	32283.00
S3	1.19	1.19	1.19	1.19	1.20	1.21	1.18	1.20	1.20
S4	18636.00	21427.00	24815.00	29601.00	34840.00	38368.00	43900.00	52245.00	57291.00
S5	19.50	19.69	19.23	19.04	18.33	18.95	18.36	17.64	19.46
S6	953.20	939.50	940.60	950.20	960.80	963.80	975.10	986.30	994.70
S7	30.94	40.46	51.35	62.15	72.24	76.66	84.55	933.00	103.71
S8	9.85	11.97	14.48	17.03	21.63	19.46	24.44	27.65	32.47
S9	1.69	13.88	5.13	0.46	0.90	0.12	4.47	2.73	2.37
S10	67.00	32.00	68.00	48.00	54.00	65.00	55.00	65.00	111.00
S11	40.70	70.00	76.80	83.00	85.01	85.20	80.30	82.60	86.89
S12	26.22	20.52	28.75	5.60	4.85	4.01	5.66	7.18	6.25
S13	1.95	1.97	1.98	2.03	2.05	2.06	2.10	2.38	2.68

Table. 5-7 The SI results, standardized score and contribution rate (contrib. rate), weight (Wi) of the indicators in Quanzhou (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
S1	-1.18	-0.96	-0.70	-0.51	-0.32	-0.06	0.94	1.24	1.54	0.51	0.09
S2	-1.27	-1.04	-0.78	-0.46	-0.11	0.26	0.60	1.13	1.67	0.55	0.10
S3	0.50	0.50	0.50	0.50	-0.63	-1.75	1.65	-0.63	-0.63	-0.35	0.06
S4	-1.26	-1.05	-0.80	-0.45	-0.06	0.20	0.61	1.22	1.60	0.56	0.10
S5	0.87	1.16	0.47	0.19	-0.86	0.06	-0.82	-1.89	0.81	-0.40	0.07
S6	-0.49	-1.19	-1.14	-0.64	-0.10	0.06	0.64	1.22	1.65	0.50	0.09
S7	-0.45	-0.42	-0.38	-0.34	-0.31	-0.29	-0.27	2.66	-0.20	0.33	0.06
S8	-1.35	-1.06	-0.73	-0.38	0.23	-0.06	0.61	1.04	1.69	0.54	0.10
S9	-0.34	-0.54	-0.49	0.26	-0.15	2.58	-0.48	-0.43	-0.41	0.20	0.04
S10	-0.44	2.24	-0.47	0.53	0.15	-0.36	0.10	-0.36	-1.41	-0.28	0.05
S11	-2.49	-0.46	0.01	0.43	0.57	0.59	0.25	0.41	0.70	0.47	0.08
S12	-1.26	-1.12	-1.30	0.53	0.88	1.43	0.51	0.03	0.29	0.48	0.09
S13	-0.76	-0.68	-0.63	-0.43	-0.34	-0.30	-0.14	1.02	2.26	0.42	0.08
SI	**-1.61**	**-1.52**	**-1.00**	**-0.42**	**0.21**	**0.61**	**0.47**	**1.59**	**1.67**		1.00

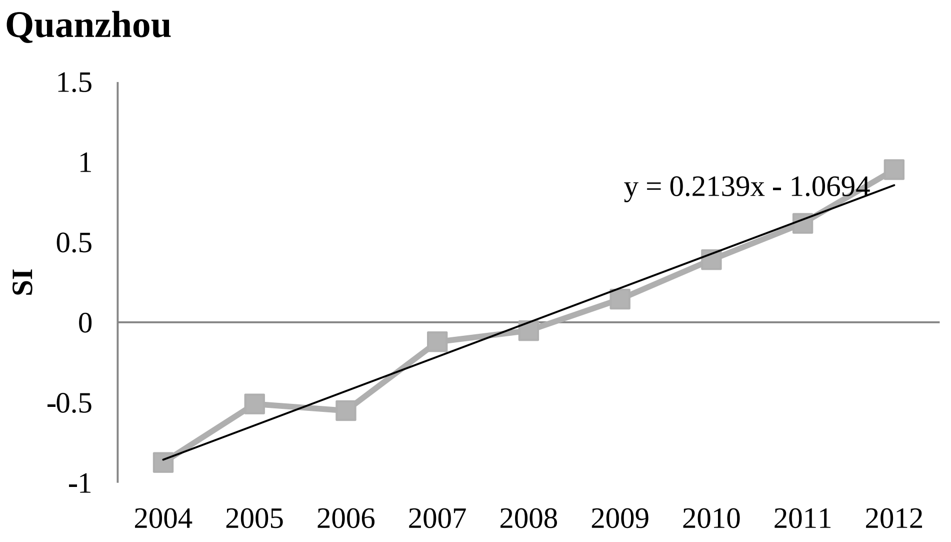

Fig. 5-3 Variation of the Quanzhou Socioeconomic Index (SI) from 2004 to 2012

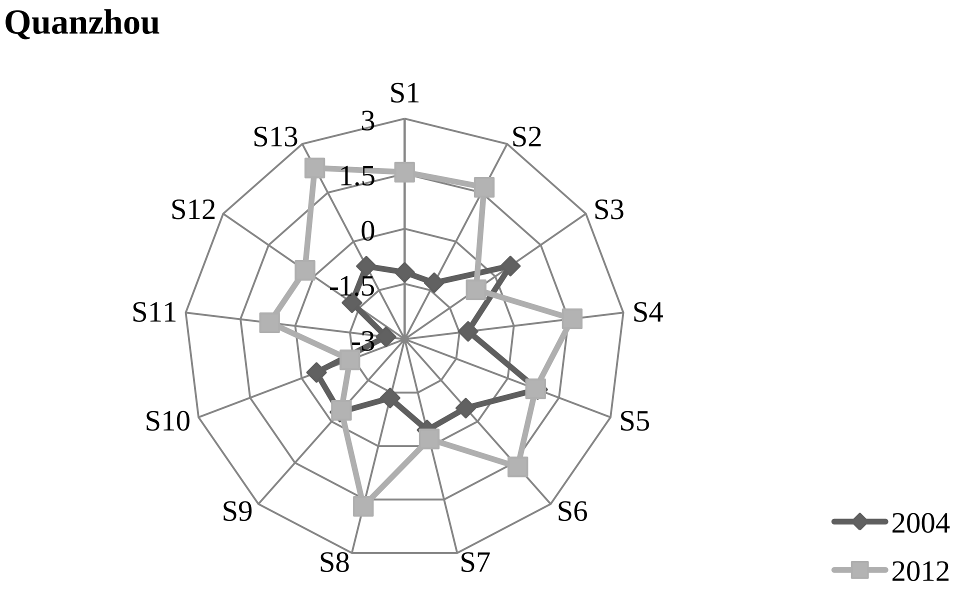

Fig. 5-4 Variation of Quanzhou socio-economic indicators in 2004 and 2012

5.5.3 Dongying

All the quantified data of socioeconomic indicators of Dongying are provided in Table. 5-8.The standardized score and contribution rate of each indicator appear in Table. 5-9. The final results of SI are presented in Fig. 5-5 and the variations of 13 social economic indicators with standardized values in 2004 and 2012 are shown in Fig. 5-6.

The results indicated that Dongying SI had also increased steadily from 2004 to 2012 with an annualgrowth rate 21.65% (Fig. 5-3). The lowest EI value (-1.61) was in 2004, while the highest value (1.67) in 2012. The variations of all the 13 ecological indicators in 2004 and 2012 (Fig. 5-4) showed that the standardized values of 10 indicators (S1, S2, S4, S6, S7, S8, S9, S11, S12, and S13) had increased from 2004 to 2012. Seven indicators (S1 S2 S4 S6 S8 S11 and S13) had higher increments than the other three. Only two indicators' standardized values (S9 and S10) declined from 2004 to 2012.

Table. 5-8 Quantified indicators and actual vales of coastal socioeconomic indicators (SI) in Dongying (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
S1	225.71	227.81	229.46	251.28	253.04	254.68	256.89	258.40	261.59
S2	8484.00	9771.00	10949.50	12247.50	13073.50	14320.00	16111.50	18684.00	21221.00
S3	2.00	1.90	1.93	1.88	1.88	1.87	1.86	1.86	1.86
S4	49874.38	64607.38	79775.03	83300.02	102385.30	102914.60	115950.50	130725.80	144777.60
S5	4.40	7.80	5.00	4.50	10.40	7.70	15.04	18.50	18.30
S6	283.30	323.00	348.00	383.90	333.30	329.70	341.20	376.60	399.90
S7	0.49	0.57	0.54	0.66	1.13	1.16	4.62	6.12	8.31
S8	1.65	1.97	2.42	3.30	4.29	5.15	6.40	7.79	9.44
S9[1]	20.00	20.00	20.00	20.00	20.00	20.00	50.00	75.00	78.00
S10	47.00	26.00	55.00	53.00	54.00	53.00	64.00	79.00	110.00
S11	0.68	0.68	0.68	0.68	0.70	0.75	0.75	0.85	0.85
S12[2]	-	4.19	-	0.91	1.06	4.45	5.21	1.19	0.57
S13	1.30	1.30	1.62	3.00	2.20	1.70	1.35	1.92	1.98

1 No statistical data of marine hazard was recorded in Dongying before year 2010. As the major marine hazard is ice disaster, the duration time before 2010 was about 20 days in winter time for December to January. So the duration time from 2004 to 2010 was set as 20 days.
2 No data were found for S12 in 2004 & 2006 and for S13 in 2004. The value of S12 in 2004 and 2006 was set to be the average value of S12, which was 82326.

Table. 5-9 The SI results, standardized score and contribution rate (contrib. rate), weight (Wi) of the indicators in Dongying (2004-2012)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Contrib. rate	Wi
S1	-1.44	-1.29	-1.18	0.33	0.45	0.56	0.71	0.82	1.04	0.64	0.08
S2	-1.29	-0.98	-0.7	-0.39	-0.19	0.11	0.53	1.15	1.76	0.69	0.09
S3	-2.29	-0.17	-0.83	0.28	0.28	0.51	0.74	0.74	0.74	0.56	0.07
S4	-1.53	-1.06	-0.56	-0.45	0.17	0.19	0.61	1.09	1.55	0.69	0.09
S5	-0.97	-0.49	-0.86	-0.95	0.11	-0.38	0.45	1.57	1.53	0.61	0.08
S6	-1.77	-0.66	0.04	1.05	-0.37	-0.47	-0.15	0.84	1.5	0.63	0.08
S7	-0.72	-0.69	-0.7	-0.66	-0.5	-0.49	0.68	1.18	1.92	0.62	0.08
S8	-1.13	-1.01	-0.84	-0.52	-0.16	0.16	0.62	1.13	1.74	0.67	0.09
S9	0.66	0.66	0.66	0.66	0.66	0.66	-1.06	-1.44	-1.47	-0.58	0.08
S10	0.27	2.37	-0.11	-0.02	-0.07	-0.02	-0.42	-0.78	-1.22	-0.55	0.07
S11	-0.78	-0.78	-0.78	-0.78	-0.5	0.2	0.2	1.61	1.61	0.61	0.08
S12	-0.83	-0.83	0.67	0.67	0.4	-1.21	-0.91	0.22	1.8	0.47	0.06
S13	-0.95	-0.95	-0.36	2.16	0.7	-0.22	-0.86	0.19	0.29	0.34	0.04
SI	**-1.63**	**-1.3**	**-0.78**	**-0.13**	**-0.07**	**-0.14**	**0.54**	**1.46**	**2.04**		1.00

Dongying

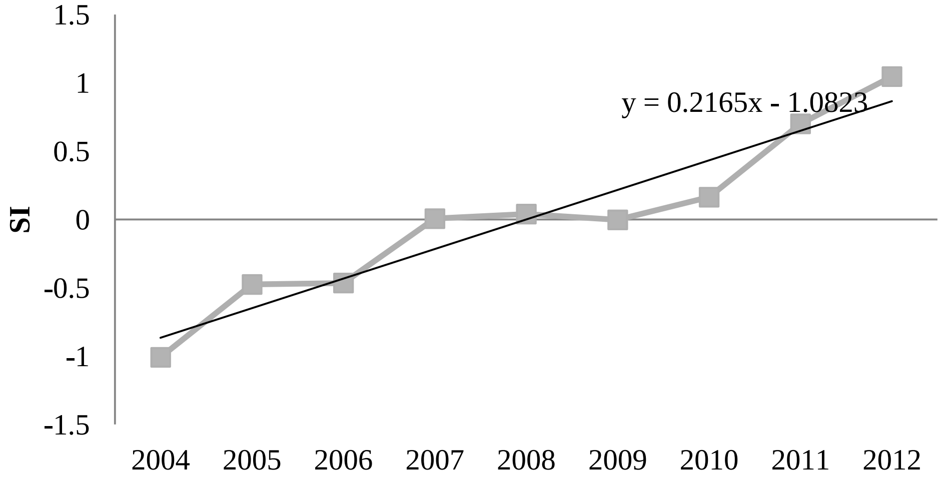

Fig. 5-5 Variation of the Dongying Socioeconomic Index (SI) from 2004 to 2012

Dongying

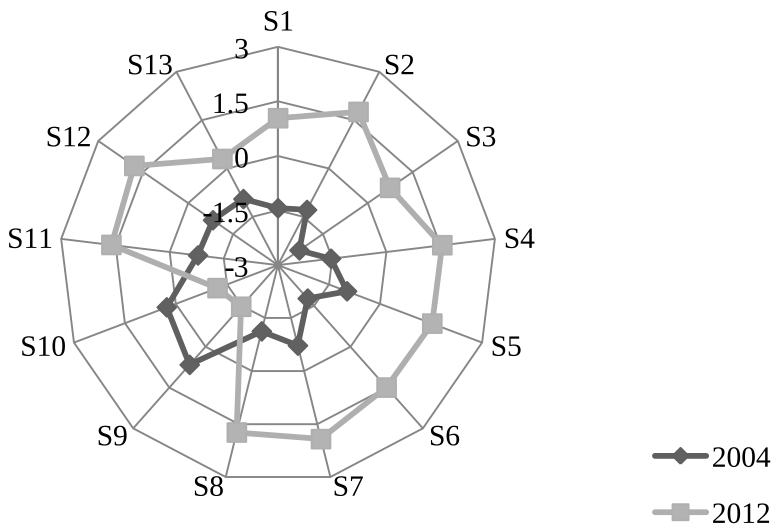

Fig. 5-6 Variation of Dongying socio-economic indicators in 2004 and 2012

5.6 Discussion

5.6.1 Xiamen

The performance of Quanzhou's SI improved steadily from 2004 to 2012 with an annual growth rate of 29.23% (Fig. 5-1), implying that the overall trend of Xiamen's coastal social and economic development had been sustainable during 2004 to 2012. Among all the indicators showing an increasing trend, S1 – Population Density, S2 – Income, S4 – GDP, S7 – Ports development and S8 - Tourism showed a steadily rising trend (Fig. 5-7), indicating that the population, living standards (income and general economic growth), ports and tourism in Xiamen might be in a sustainable development status during the evaluation period under its ICM framework. However, the population density which showed an increasing trend may already exceed the sustainable population capacity of Xiamen (Dai, 2011). For other indicators (S3, S5, S9, S11, S12, S13), although the overall trends were increasing, some fluctuations still existed, indicating the status might not be at a sustainable level yet.

Only the indicator E10 - Sea Level Rise showed a decreasing trend from 2004 to 2012 (Fig. 5-8), indicating that sea level rise might be a major potential challenge for Xiamen's coastal safety. Indeed, current sea level rise has already imposed various threats to coastal ecosystems, including flooding, coastal erosion, and ocean acidification (Nicholls et al., 1999; Hanebuth & Grootes, 2000; Nicholls & Cazenave, 2010). These could directly affect the social economic activities, such as tourism and fisheries. Thus, climate change and sea level rise could be a major challenge for coastal development in Xiamen. As it is a global issue, cooperative efforts among different regions are needed to address this issue through ICM programmes over the long-term.

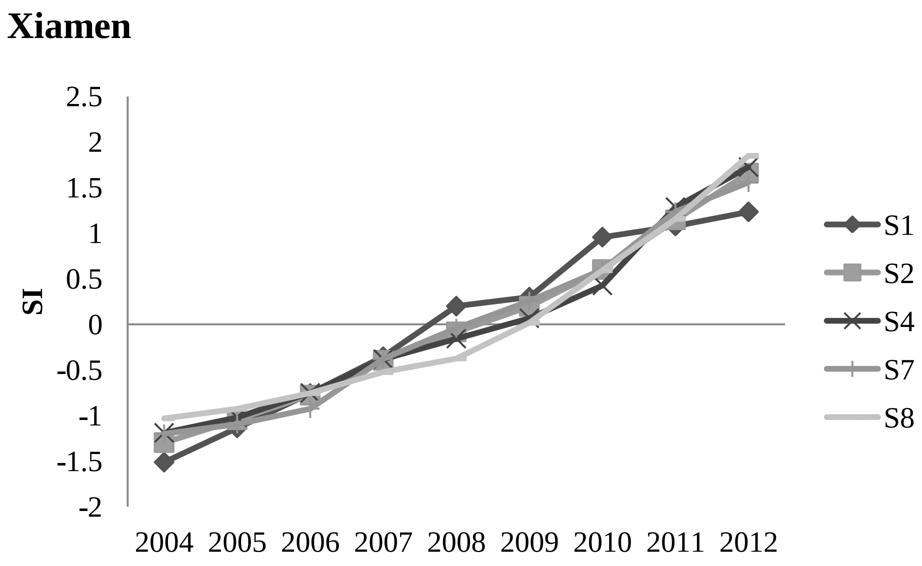

Fig. 5-7 Variation of Xiamen socio-economic indicators (S1, S2, S4, S7 and S8) 2004 – 2012

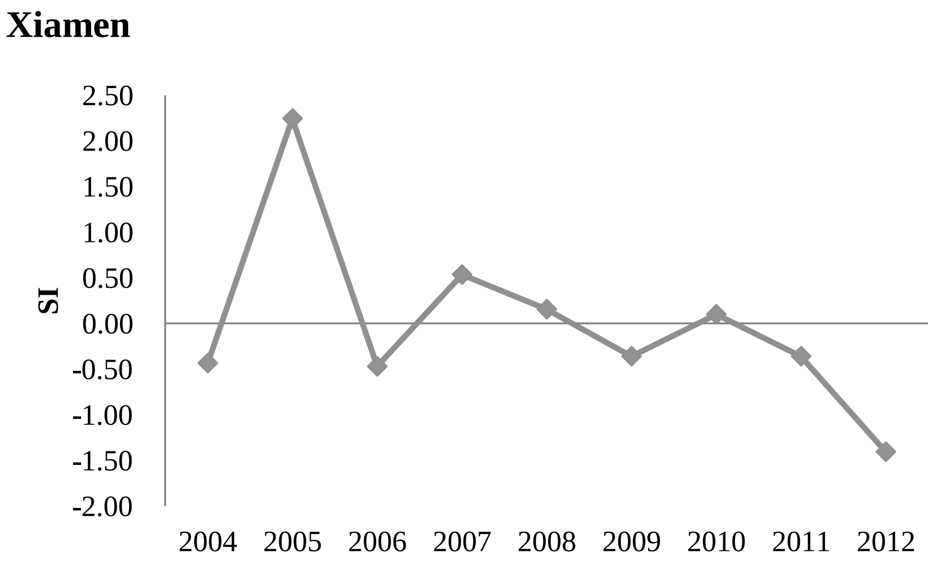

Fig. 5-8 Variation of Xiamen socio-economic indicators (S10) during 2004 - 2012

5.6.2 Quanzhou

The performance of Quanzhou's SI improved steadily from 2004 to 2012 with an annual growth rate of 21.39% (Fig. 5-3), also indicating an overall sustainable trend of coastal social and economic development from 2004 to 2012. S1 – Population Density, S2 - Income, S4 - GDP, and S13 –Environmental Funding presented a steadily increasing trend during the evaluation period (Fig. 5-9). It suggests that the socioeconomic aspects of population growth, income, GDP growth and government investment on environmental protection in Quanzhou had showed a sustainable developing trend during the 9 years.

Four indicators S3, S5, S9 and S10 did not show an overall upward trend, of which the standardized scores fluctuated in different years (Fig. 5-10). For S3 –Employment and S5 –Gross Ocean Products, although the standardized scores showed a declining trend, the actual values of each indicator did not decrease much (Table. 5-6), and the overall trend of the actual values tend to be stable. Given the fact that Quanzhou and Xiamen are neighbouring cities in Southern Fujian sea area, the values of S10 –Sea Level Rise are the same. Climate change and sea level rise would also be one of the challenges for Quanzhou. Besides, S9 – Marine and Coastal Hazards also fluctuated among different years. This was because the frequency and intensity of coastal and marine disasters varied in different years. In 2005, typhoons and storm surges hit 11 prefectures in Quanzhou, destroying 2,127 houses and 17,506 km^2 coastal aquaculture areas. The economic loss caused by the coastal hazards in this year was at peak, which was about 1.39 billion RMB. Therefore, marine and coastal hazards management would be another major challenge for ICM implementation in Quanzhou (Chua, 2006).

Quanzhou

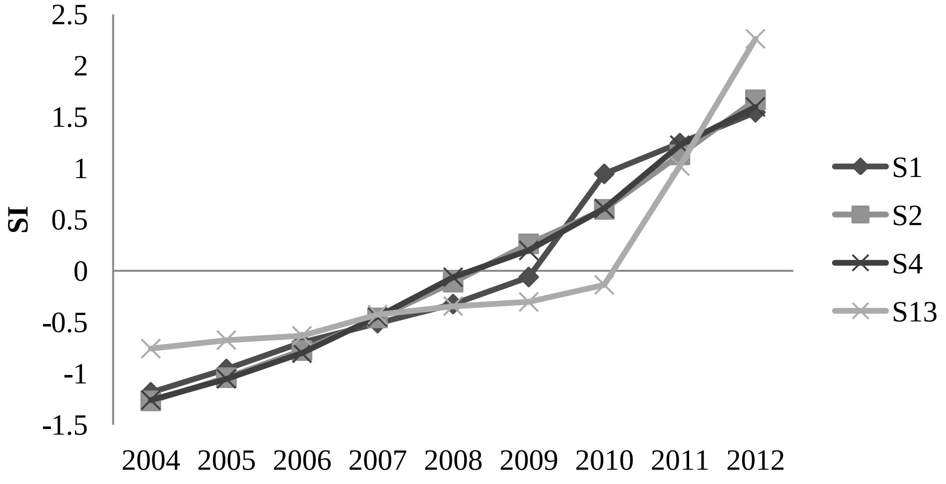

Fig. 5-9 Variation of Quanzhou socio-economic indicators (S1, S2, S4, S13) during 2004 – 2012

Quanzhou

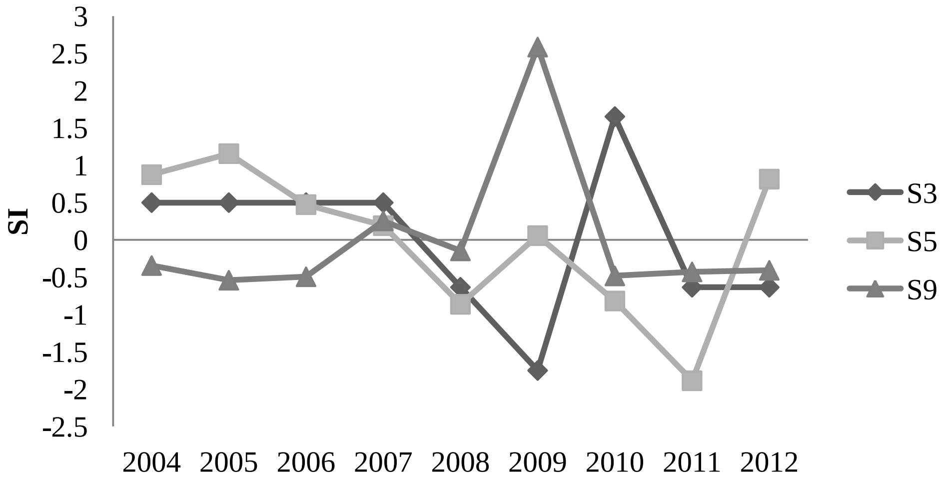

Fig. 5-10 Variation of Quanzhou socio-economic indicators (S3, S5 and S9) during 2004 - 2012

5.6.3 Dongying

The performance of Dongying's SI also improved steadily from 2004 to 2012 with an annualgrowth rate 21.65% (Fig. 5-5), implying an overall sustainable trend of coastal social and economic development from 2004 to 2012. Six indicators (S1 – Population Density, S2 - Income, S4 - GDP, S7 - Ports Development, S8 – Tourism, and S11 - Discharge of total pollutant into sea) showed a steadily rising trend from 2004 to 2012 (Fig. 5-11). This could demonstrate that the socioeconomic aspects of population growth, living standard, ports development, coastal tourism, pollution reduction in Dongying tended to be sustainable during the evaluation period after the adoption of ICM approaches. The performance of five indicators (S3, S5, S6, S12, S13) had also improved, but fluctuations existed between different years, implying that the status had not reached a sustainable level.

S9 – Coastal and Marine Hazard and S10 – Sea Level Rise showed an overall decreasing trend, indicating that the performance of coastal hazard management had not improved, and climate change and sea level rise are also a big challenges to Dongying's ICM implementation. The major coastal hazard in Dongying was ice disaster, which happened in Laizhou Bay every year during the winter time. In 2010, it caused an economic loss of more than 6.3 billion yuan (Sun et al., 2011). Therefore, managing and reducing the risks of the ice disasters had and will be a major issue for Dongying's coastal management.

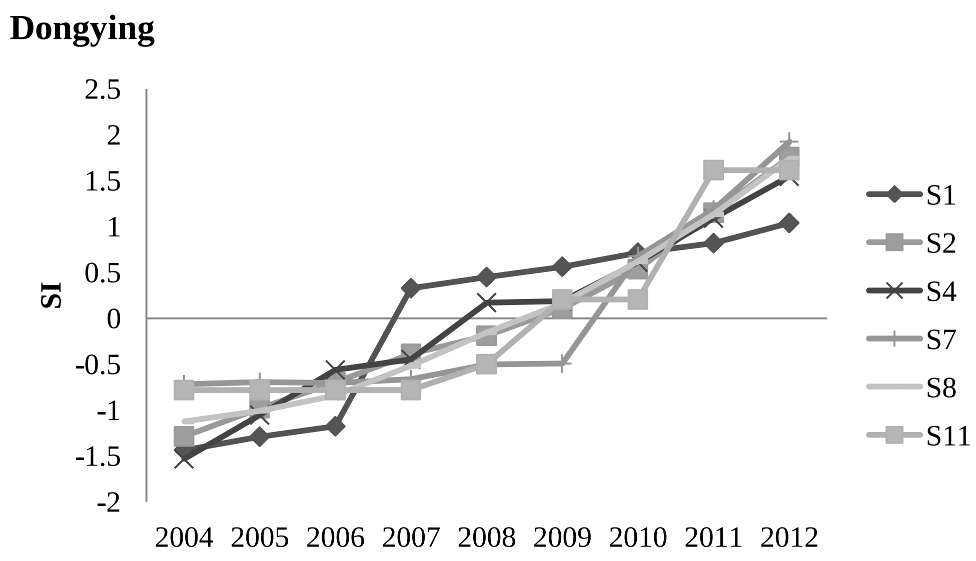

Fig. 5-11 Variation of Dongying socio-economic indicators (S1, S2, S4, S7, S8, and S11) during 2004 - 2012

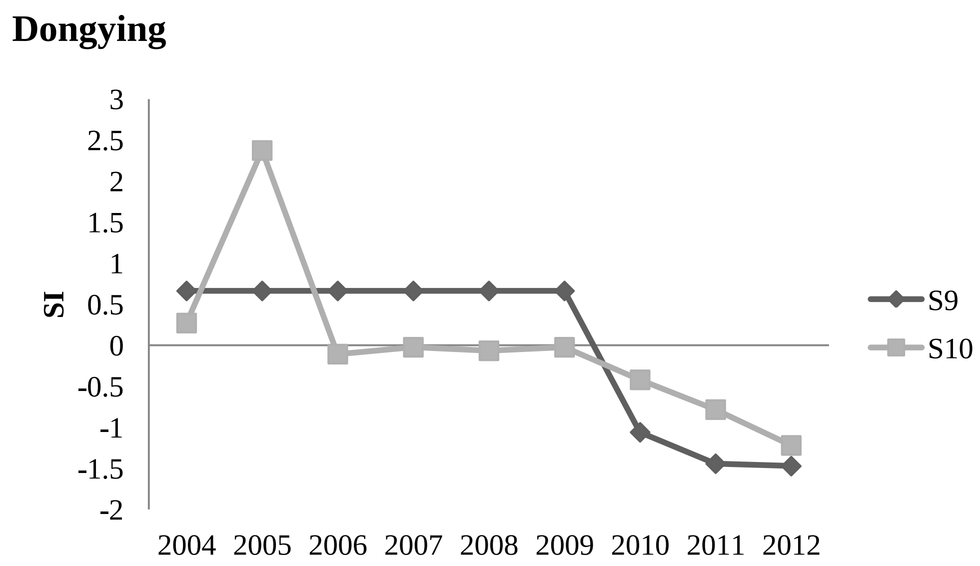

Fig. 5-12 Variation of Dongying socio-economic indicators (S9 and S10) during 2004 - 2012

5.7 Conclusions

The results showed that the overall trends of SI in all three cities were increasing, which proved that ICM could promote the sustainable socioeconomic development in these sites. It showed that not only the overall economy and the population grew, but also the living standard (income) and the public safety improved. Indeed, the rates of environmental funds input in these three cities (more than 2% of the GDP) are much higher than those non-ICM coastal cities, such as Tianjin, Zhoushan, as well as the average standard of China (about 1.5% in 2012) (Ministry of Environmental Protection, 2012). However, many challenges still remain for each site. The common challenges facing by the three cities are climate change and sea level rise, which is a global concern for all coastal nations. Management of marine and coastal disasters was and will be another challenge for the two sites Quanzhou and Dongying. Further discussion of the comparisons of the case studies will be presented in Chapter 6.

Chapter 6 The overall performance of ICM in coastal sustainability

6.1 The overall performance of ICM in coastal sustainability

6.1.1 Synthesized results of ICM performance evaluation

To synthesize the evaluation results of ICM governance, coastal environment and socioeconomic development, the integrated ICM performance index (IPI) was calculated for each site. It was set as the average value of Governance Index (GI), Ecological Index (EI) and Socio-economic Index (SI), where the weights of three indexes were considered evenly as 1/3. As Dongying's EI was not calculated for 2004 to 2007 due a lack of biodiversity monitoring data, the overall Integrated Performance Index (IPI) of Dongying during 2004 -2007 was calculated only by the average value of GI and SI.

The results (Fig. 6-1) showed that the IPI of Xiamen and Quanzhou had increased steadily during the 9 evaluation years with an annual growth rate of 34.3% and 26.6% respectively. Xiamen's IPI increased sharply from 2010 to 2011, and tended to be flat from 2011 to 2012. Dongying's IPI also showed an overall increasing trend with an annual growth rate of 25.4%. However, IPI declined from 2007 to 2008 due to the adding of EI from 2007 to 2008.

In general, it could be concluded that the ICM had played a positive role in the coastal development of the three ICM sites in China, promoting the sustainability in terms of governance, ecological environment and socioeconomic development.

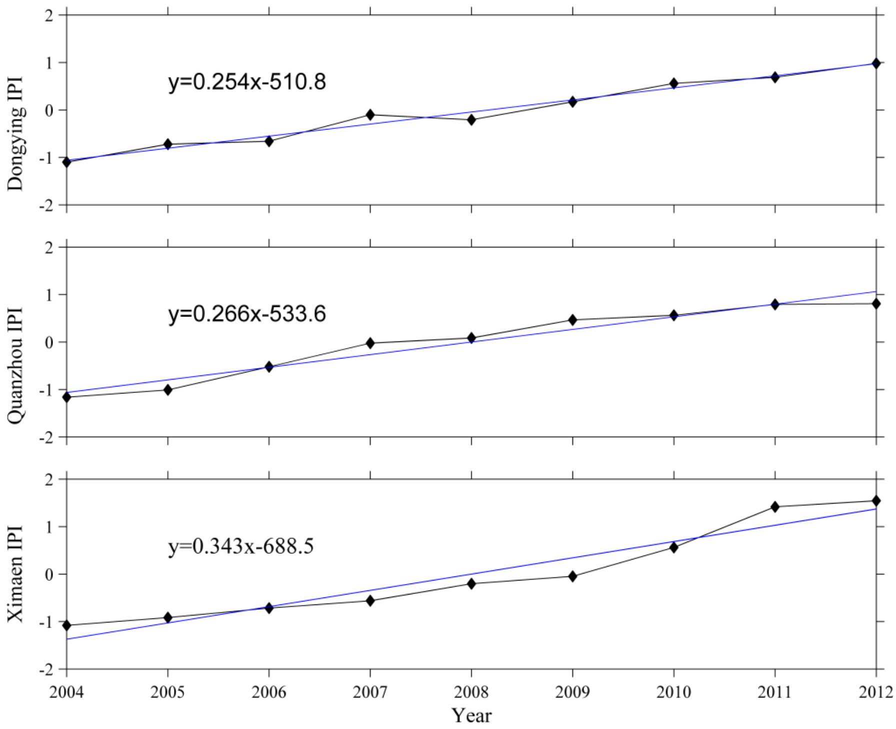

Fig. 6-1 Variation of the Integrated Performance Index (IPI) of Xiamen, Quanzhou and Dongying (2004 - 2012)

6.1.2 Comparison and discussion

To find the differences and similarities in ICM performance amongst the three sites and to further discuss the results of my studies, I compared the evaluation results of three case studies in terms of GI, EI and SI. The comparison of the annual growth rates was presented in Table. 6-1. To compare the current ICM performance of three sites, I compared their ICM performance in 2012 in terms of 10 sub-elements of GI, EI and SI. For E4 - E6 and S9, the results are shown in Table. 6-2. The detailed information of each indicator in 2012 of three sites are shown in Table. 6-3. The major achievements and remaining issues of ICM performance in three coastal cities are generalized in Table. 6-4.

GI: The overall ICM governance performance had improved in three ICM sites. The major achievements in their coastal governance included setup of an operational and effective ICM coordination mechanism, strong capacity building, adequate scientific support and sufficient internal funds. These achievements could also be considered as the key factors leading to the success of ICM implementation in China.

The comparison of the annual growth rates showed that all three sites had similar growth rate; Dongying and Quanzhou had slightly higher growth rate than Xiamen, showing that the improvement of Dongying and Quanzhou's ICM governance was better than Xiamen. This could be because the three cities were at different development stages of ICM. In 2004, Xiamen had entered the second ICM cycle, and its governance performance was already beyond the "fair" level, while Quanzhou and Dongying had not yet adopted an ICM framework. In 2012, Xiamen entered the third cycle of ICM, and its governance performance reached the "good" level, while Quanzhou and Dongying were still in the initial stage of ICM implementation, and their performance were just beyond the "fair" level (Table. 6-2). The results also indicated that the improvement of ICM governance performance from a "weak" or "poor" level to a "good" level were much easier than from a "fair" to a "good" or "excellent" level. Indeed, Xiamen finished its institutional reform from sectoral to integrated management in 2 years (Chua & Chen, 1997). Improvement of coastal governance was usually the most obvious achievement that could be assessed in its initial stage of implementation. Other ICM case studies in EU countries (Breton et al., 2006), Philippines (Chua, 2006), Canada (McCleave et al., 2003) and Japan (Kojima and Kinoshita, 2013) also proved that. However the major difference is that as China's ICM programmes are government-oriented, the time for ICM mechanism setup and operation was usually much shorter than in other coastal states. Moreover, unlike other coastal states where the public participation or community-based engagement was the key to the success of ICM (Pomeroy, 1995; Hegarty, 1997; Keamey, 2007), stakeholder involvement in the three cities' ICM programmes was usually quite weak due to the current top-down management scheme in China and was not receiving sufficient attention (Enserink & Koppenjan, 2007). Developing of appropriate approaches for managing participation and co-operation in China's ICM programmes would be a tough task for the local government.

In addition, the progress of ICM performance of all sites tended to be much slower during the later evaluation period (2010-2012). It might be the time to run a new cycle of ICM with a more adaptive framework in the next 6-7 years according to the experience in other regions (Sorensen, 2002; Chua, 2006).

The common issues for three ICM cities were lack of external funds and poor adaptive management. For many other developing countries, ICM funds were mainly from international donors, such as Asian Development Bank and Inter-American Development Bank (Lowery et al., 1999). For developed countries, such as US and some EU countries, a part of the ICM funds was from various environmental taxations (Ekins, 1999; Chua, 2006; Bagstad et al., 2007). In China, the ICM funds were mainly from the local government budget. Although the funds provided by the government were usually sufficient, funds from various economic sources would be necessary to sustain the ICM programmes from a long-term perspective (Chua, 2006). Routine evaluation and adjustment of ICM plans was a key step for ensuring the success of ICM to tackle the complex and changing problems in coastal areas (Cicin-Sain et al., 1998; Chua, 2006). An adaptive management system provided a means for enforcement (Loftin, 2014). In Australia, it was reported that 59% of organizations currently claimed that monitoring informs adaptive management (Jacobson et al., 2014). However, the performance of adaptive management in China's coastal cites remained poor due to a number of reasons, such as the lack of legal basis and no routine evaluation systems.

EI: The achievements in coastal environment of three study sites were quite different. For Xiamen, its coastal and marine biodiversity had improved significantly; for Quanzhou, its coastal water quality had improved dramatically; and for Dongying, both water quality and biodiversity improved, too.

The annual growth rates of EI in the three sites were smaller than the growth rates of GI, indicating that improvement of the coastal environment might be more difficult due to the complexity of coastal ecosystems. Quanzhou and Dongying's growth rate of EI was slightly higher than Xiamen's. Previous studies in Xiamen's coastal environment also showed that its water quality, sediment, and the benthic community had improved after ICM implementation (Xue et al., 2004). Other case studies in US (Lewis et al., 1999), Brazil (Tagliani et al., 2003), and Italy (Suman et al., 2005) also showed the positive role of ICM in coastal environmental protection and restoration.
However, it also showed that Xiamen's coastal water quality remained in a very poor status in 2012. More than 90% of its coastal waters were under the level II-fishing water standard (Table. 6-3). Excessive nutrient loading as a main cause of water pollution worldwide (Canfield, 2010; Cardinale, 2011) was also the leading cause of water quality decline in Xiamen. Xiamen had the biggest population density amongst the three cities and its total pollutants discharge into the sea per year was about two times that of Quanzhou and 20 times that of Dongying. Land-based pollution control and treatment would thus be a major challenge for Xiamen's ICM in a quite long period from now on. For the other two cities, the improvement of water quality was obvious, especially for Quanzhou. More than 80% of Quanzhou's coastal waters had reached the fishing water standard (Table. 6-3). The results suggested that the ICM project on land-based pollution control and treatment in Quanzhou was successful. Other studies

in Quanzhou Bay area also proved that (Chen et al, 2009; Zhou et al., 2011).

The comparisons of overall coastal ecological environment in 2012 showed that Dongying had a relatively better coastal environment than Xiamen and Quanzhou. There are two possible reasons. Firstly the ICM programmes were effective for the improvement of coastal environment. Secondly the low population density and less intense coastal resource exploitation imposed less environmental pressures on its coastal waters. Although Xiamen's water quality was poor, its biodiversity index was relative higher than the other two cities in 2012 (Table. 6-2 and Table. 6-3). This implied that coastal and marine biodiversity conservation in Xiamen might be much better than the other two cities. It also suggested that nutrient loading did not directly affect the biodiversity in Xiamen's coastal waters. In fact, the mechanism of how species diversity is affected by nutrient uptake has not been fully studied (Huston, 1997; Hooper et al., 2005).

SI: Three cities all had rapid growth in population, GDP, coastal resources exploration as well as the environmental funds. The sewage treatment had also been enhanced dramatically.

It could be seen that Xiamen had a higher annual increase rate of SI than the other two cities (Table. 6-1), indicating that its improvement of coastal social and economic aspects was better than the other two cities. Looking at the rankings of SI in 2012 (Table. 6-2 and Table. 6-3), Xiamen also had the highest performance rating of SI. An earlier case study in Xiamen in 2004 also showed that the implementation of ICM program had led to an increase of over 40% in annual socioeconomic benefit from its coastal and marine sectors (Peng et al., 2006). Xiamen could be considered as the most developed city with the highest population density and per capita income amongst the three cities based on the aspect of demographic and economic development in 2012 (Table. 6-2 and Table. 6-3). It also had higher performance ratings in public safety and environmental protection. Quanzhou had experienced the most intensive coastal resources exploitation and its gross ocean products contributed nearly one fifth of the total GDP. Dongying had the highest per capital GDP due to its low population density with less intensive development of its coastal resources. Although Xiamen seemed to have the highest SI rating, its population might already exceed its sustainable carrying capacity. The population density in Xiamen Island was about 13000 ind/km^2 which was nearly two times that of Singapore (about 7000 ind/km^2) and Hongkong (6500 ind/km^2). Overpopulation could cause a number of environmental threats (*e.g.* overexploitation of coastal resources, over discharge of pollutants into sea, and intensification of coastal resources utilization) and impede the sustainable development (Irtem & Azbar, 2005; Sales, 2009).

The common issues in the three coastal cities' social and economic development were sea level rise and natural hazard management, which are actually two critical global issues (Domingues, et al, 2009; Hyndman & Hyndman, 2010). There was a rise in sea level of 11 cm in the three sites' coast in 2012, which had reached the highest sea level since 1980. The average rate of sea level rise in China was about 2.9 mm/year over the past 30 years (State of Oceanic Administration, 2012). Although the rate was lower than the average global rate and China was reported in its relatively low increase in flood risk (Nicholls et al., 1999), the sea level rise and climate change combined with natural disasters such as storms, typhoons and ice disasters in the populated China's coastal area could still be a big threat to coastal environment safety. Adaptive management would be a necessary solution for enhancing the coastal resilience to climate change and natural disasters (Tompkins & Adger, 2004; Pahl-Wostl, 2007).

Based on the three case studies, several suggestions for the ICM implementation in China's coastal cities would be: (1) building up an adaptive decision making support system based on the ICM performance indicators and seeking proper mechanisms to rise external funds, such as setting up of different types of environmental funds from private donations (Chua, 2006); (2) reinforcing the monitoring and research efforts on overall water quality and biodiversity in the coastal waters; (3) building up an integrated disaster reporting and responding system for risk management (O'Brien et al, 2006).

Table. 6-1 Comparisons of the annual growth rates of Xiamen, Quanzhou and Dongying's GI, EI, SI and IPI from 2004 to 2012

	Xiamen		**Quanzhou**		**Dongying**	
	Rank	Value	Rank	Value	Rank	Value
GI	3	30.19%	2	30.54%	1	32.18%
EI	1	20.69%	3	27.79%	2	39.53%
SI	1	29.23%	3	21.39%	2	21.65%
IPI	1	34.29%	2	26.57%	3	25.44%

Table. 6-2 Rankings of ICM evaluation results of Xiamen, Quanzhou and Dongying in 2012

	Xiamen	**Quanzhou**	**Dongying**
ICM Mechanism	1	1	3
Planning, implementation, and monitoring	1	2	2
Capacity Building	1	2	2
Public involvement	1	2	2
Financing	1	1	1
Overall performance of GI	**1 (good)**	**2 (fair)**	**3 (fair)**
Quality	3	2	1
Biodiversity	1	3	2
Overall performance of EI	**2**	**3**	**1**
Demographic and economic development	1	2	3
Coastal resource utilization	2	1	3
Public safety and environmental protection	1	3	2
Overall performance of SI	**1**	**2**	**3**

Table. 6-3 Values of governance, ecological and socio-economic indicators in 2012.

Indicators	Value of quantitative variables		
	Xiamen	Quanzhou	Dongying
(G1) General ICM strategy	0.75	0.75	0.5
(G2) Coordination mechanism	0.75	0.75	0.25
(G3) Law enforcement mechanism	0.75	0.75	0.5
(G4) Policy, strategies and action plans	1	0.5	0.5
(G5) Implementation and monitoring	1	0.75	0.75
(G6) Scientific and technical support	1	0.75	0.75
(G7) Staff capacity building	1	0.75	0.75
(G8) Infrastructure and facilities	0.75	0.75	0.75
(G9) Stakeholders' involvement	0.75	0.5	0.5
(G10) Publicity of government information	0.75	0.5	0.5
(G11) Local government budget	0.75	0.75	0.75
(G12) External funding	0	0	0
(E1) Coastal water quality	4.5	79.5	42
(E2) Marine sediment quality	100	80	100
(E3) Marine biological quality	100	80	100
(E4) Phytoplankton diversity[1]	2.5	2.3	2.54
(E5 Zooplankton diversity[1]	2.95	2.7	1.86
(E6) Benthos diversity[1]	3.42	2.1	3.04
(S1) Population density	2333	763	261.59
(S2) Income	37576	32283	21221
(S3) Employment	3.5	1.2	1.86
(S4) GDP	76707.6	57291	144777.6
(S5) Gross Ocean Product	11.3	19.46	18.3
(S6) Fishery resources exploitation	400	994.7	399.9
(S7) Ports development	172	103.71	8.31
(S8) Tourism development	41.2	32.47	9.44
(S9) Marine and coastal hazards[2]	0	2.37	0.35
(S10) Sea level rise	111	111	110
(S11) Sewage treatment	97.7	86.89	0.85
(S12) Discharge of total pollutant into sea	13.5	6.25	0.57
(S13) Environmental funding	2.5	2.68	1.98

1. The quantitative variable for three sties was unified to be Shannon-Wiener diversity index.
2. The quantitative variable was unified to be the economic loss from marine hazards (10^8 Yuan) for comparison.

Table. 6-4 Generalizations of major achievements, remaining issues for Xiamen, Quanzhou and Dongying towards the goals of ICM

Goals		**Xiamen**	**Quanzhou**	**Dongying**
Effective ICM governance	Major achievements	Strong legal basis, routine monitoring system	Adequate ICM coordinating mechanism, effective implementation and enforcement of ICM programmes, strong capacity building, sufficient internal funds	Formulation of the ICM mechanism, effective implementation and enforcement of ICM programmes, strong capacity building, sufficient internal funds
	Remaining issues	Lack of external funds, poor adaptive mechanism	Low-level public participation, lack of routine monitoring system, lack of external funds, poor adaptive mechanism	Weak ICM coordination mechanism, low-level public participation, poor adaptive mechanism, lack of routine monitoring system, lack of external funds
Health coastal environment	Major achievements	Sediment quality improved	Water quality improved	Benthic environment improved
	Remaining issues	Very Poor water quality	Poor benthic environment	Poor water quality
Social economic sustainability	Major achievements	Improvement of living standard, rapid development of coastal tourism, rising of environmental funds	Improvement of living standard, rising of environmental funds	Improvement of living standard, rapid development of rising of environmental funds
	Remaining issues	Rapid population increase, huge amount of land-based pollutants, sea level rise	Rapid population increase; intensive coastal resource utilization; poor natural hazard management , sea level rise	Poor natural hazard management, sea level rise

6.2 Key performance indicators

Not all the indicators are effective to reveal current performance gaps and provide indications of progress towards fulfilling the gaps. Careful identification of key performance indicators (KPIs) is critical for maintaining the functioning of ICM. KPI has been widely applied in projects evaluation and management (Chan & Chan, 2004; Parmenter, 2010). The identification of KPIs could be done by following the 3 criteria listed below.

1. The variation has higher contribution rate derived from PCA, which means the indicator shows high homogeneity and has more information to represent the overall trend of the index.
2. The contribution rate of the indicator defined by PCA is negative, the data shows high statistical heterogeneity, and is not sustainable
3. The performance of the indicator is relative weaker, which needs to be strengthened in the future.

In the case studies of Xiamen, Quanzhou and Dongying, eleven common KPIs, seven specific KPIs for Xiamen, seven specific KPIs for Quanzhou and six specific KPIs for Dongying were identified (Table. 6-5). For each site, the KPIs reduced 40% of the indicators (13 indicators for Xiamen and Quanzhou, 14 indicators for Dongying) but kept over 80% of the information of the three index systems. The KPIs therefore could be used to simplify the original indicator framework, and to enhance the efficiency of monitoring and measurement in ICM performance.

Table. 6-5 Identification of KPIs in Xiamen, Quanzhou and Dongying

	Weak performance	Higher weight	Negative contribution rate
Xiamen	G12, E1, S12	G1, G4, G5, G9, G10, E4, E5, E6, S1, S2, S4, S7, S8, S11	S10
Quanzhou	G12, G9, G10, S9	G2, G3, G7, G8, E1, E4, E5,S1, S2, S4, S8, S12	S3, S5, S10
Dongying	G12, G2, G9, G10, S13	G1, G2, G7, E1, E4, E5,S1, S2, S4, S6, S7, S8	S9, S10

Table. 6-6 KPIs for Xiamen, Quanzhou and Dongying

Common KPI (11)	Xiamen (7)	Quanzhou (7)	Dongying (6)
(G9) Stakeholders' involvement	(G1) General ICM strategy	(G2) Coordination mechanism	(G1) General ICM strategy
(G10) Publicity of government information	(G4) Policy, strategies and action plans	(G3) Law enforcement mechanism	(G2) Coordination mechanism
(G12) External funding	(G5) Implementation and monitoring of ICM initiatives	(G7) Staff capacity building	(G7) Staff capacity building
(E1) Coastal water quality	(E6) Benthos diversity	(G8) Infrastructure and facilities allocation	(S6) Fishery resources exploitation
(E4) Phytoplankton diversity	(S7) Ports development	(S3) Employment	(S7) Ports development
(E5 Zooplankton diversity	(S11) Sewage treatment	(S5) Gross Ocean Product	(S9) Marine and coastal hazards
(S1) Population density	(S12) Discharge of total pollutant into sea	(S12) Discharge of total pollutant into sea	
(S2) Income			
(S4) GDP			
(S8) Tourism development			
(S10) Sea level rise			

6.3 DPSIR analysis

The "Drive force – Pressure – Status – Impact - Response" (DPSIR) model is a useful tool to analyze the interdependencies between the institutional, governance, environmental, social and economic dimensions in the field of ICM (Bowen & Riley, 2003). It was initially developed by the OECD as an extended version of the Pressure – Status - Response (PSR) model (OECD, 1993). Within the DPSIR model, the "Drivers" and "Pressures" cause the changes of environmental "Status"; the "Impacts" result from environmental changes and socio-economic development, as well as the institutional "Responses" to these changes (Smeets et al., 1999; Bowen & Riley, 2003).

To further understand the effectiveness and challenges of ICM governance in environmental problem solving and sustainability promotion, I adopted the DPSIR model. I re-categorized the governance, ecological and socio-economic indicators into the four domains – D/P, S, I and R (Fig. 6-2). To obtain the final numerical results of D/P, S, I and R, indicators under the same domain were re-processed using the same methods for the GI, EI, and SI. The standardized score of each indicator would be the same, but the weight of each indicator would be different as the indicators were in different groupings when applying the DPSIR model. The results of DPSIR analysis of three case studies are presented in Fig. 6-3, Fig. 6-4, and Fig. 6-5.

The results showed that the indices of D/P, S, I, R of three cities all increased from 2004 to 2012 (Fig. 6-3, Fig. 6-4, and Fig. 6-5). In general, the Response index had the highest annual growth rate. It could be inferred that with a rapid increase of the Response index, the Impacts and State index increased with lower growth rates, demonstrating the effectiveness of the Responses. The status of the coastal environment had been improved and better social and environmental impacts had been perceived. For D/P index, Xiamen had the highest annual increase rate (26%) and Dongying had the lowest annual increase rate (18%), indicating that Xiamen had higher environmental pressures while Dongying had lower environmental pressures. In contrast, Dongying had higher increase rate of S Index (26%) and Xiamen had lower S Index increase rate (20%). It seemed that lower increase rate in D/P index resulted in higher growth rate of S (environment state) Index. It also indicated that the population increase, GDP growth, coastal utilization, wastewater emission, natural hazard and climate change imposed pressures on the coastal environment in the three cities (Hou et al. 2012; Döll et al, 2013).

To sum up, although the improved status of coastal environment and social/environmental impacts had proved the effectiveness of ICM governance to some extent, the increase of driving forces/ pressures from rapid economic development and intense coastal resources utilization as well as coastal natural hazards still called for continuous ICM efforts to improve the overall eco-efficiency in the future.

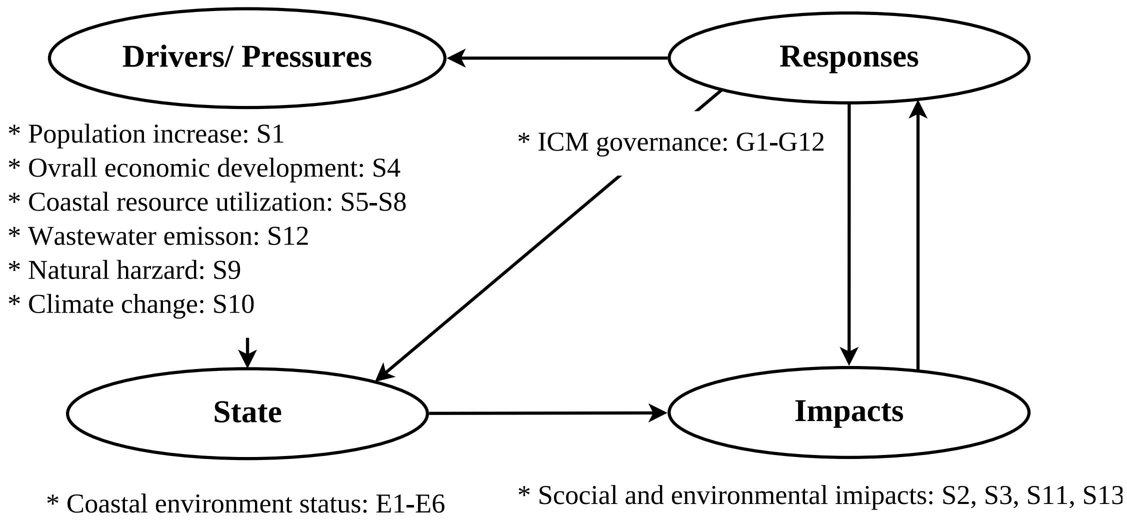

Fig. 6-2 DPSIR model for ICM performance analysis in China’s coastal cites

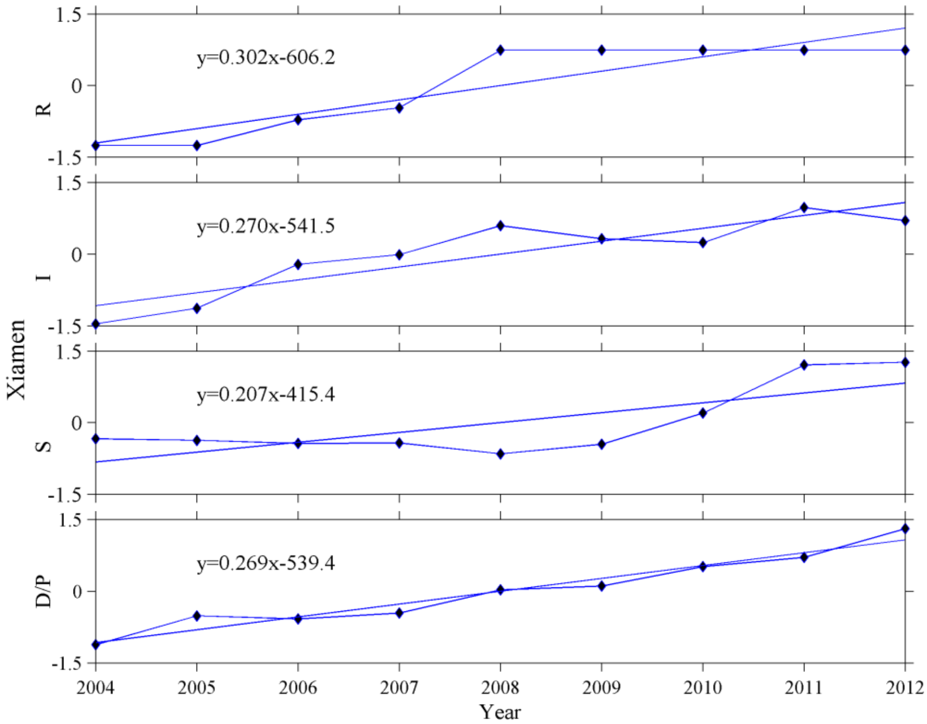

Fig.　6-3 Xiamen DPSIR analysis (2004-2012)

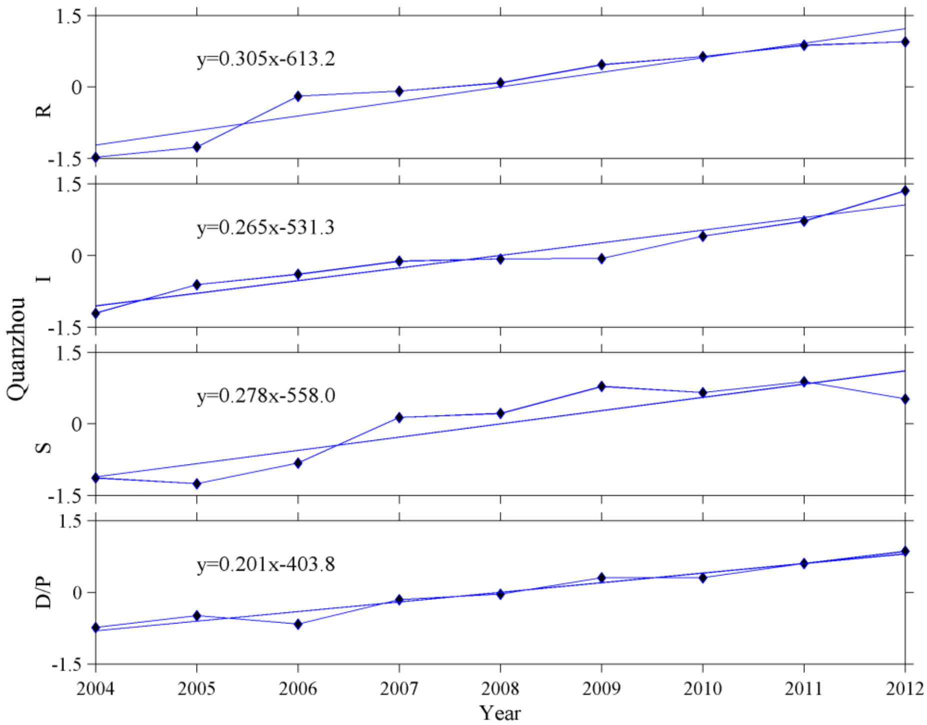

Fig.　6-4 Quanzhou DPSIR analysis (2004-2012)

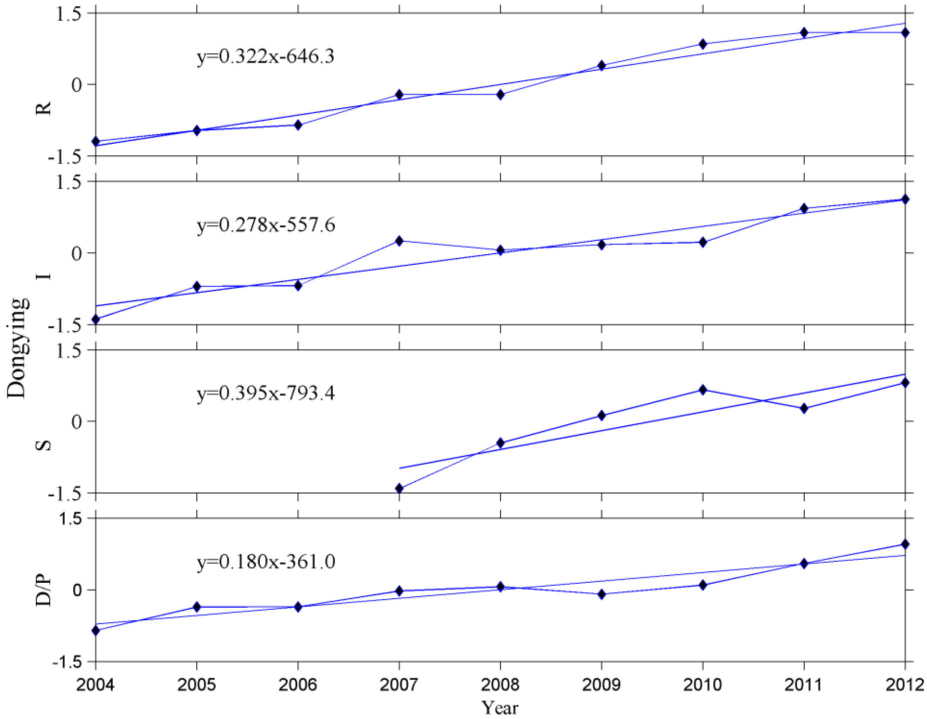

Fig. 6-5 Dongying DPSIR analysis (2004-2012)

Chapter 7 Conclusions

To my knowledge, this dissertation represents the first attempt to quantitatively and systematically evaluate ICM performance in terms of coastal governance, ecological environment and socio-economic aspects at a regional level by using ICM performance indicators.

My study has shown that the ICM approach can be an effective tool for the local government to promote the overall sustainability in coastal governance, ecological environment and socioeconomic development of China's coastal cities (Fig. 7-1). The results of Chapters 3–5 all indicate that the ICM performance in terms of the three aspects in coastal sustainability has improved in the three coastal cities. The improvements in coastal governance progress and socio-economic development are more apparent than the coastal ecological environment. The overall ICM performance annual growth rates of Xiamen, Quanzhou and Dongying are 34.3%, 26.6% and 25.4% respectively. ICM implementation in Xiamen has both the highest annual increase rate and the best performance rate in 2012, where a long-term implementation of ICM can be effective and yield better performance in coastal sustainability. The major challenges for ICM implementation towards the goal of sustainability are fairly similar in all three cities, suggesting that these major challenges may also apply for other China's coastal cities. An integral understanding of the effectiveness of ICM would be achieved if the case studies were scaled up not only to the ICM sites but also to non-ICM cities in China for comparisons.

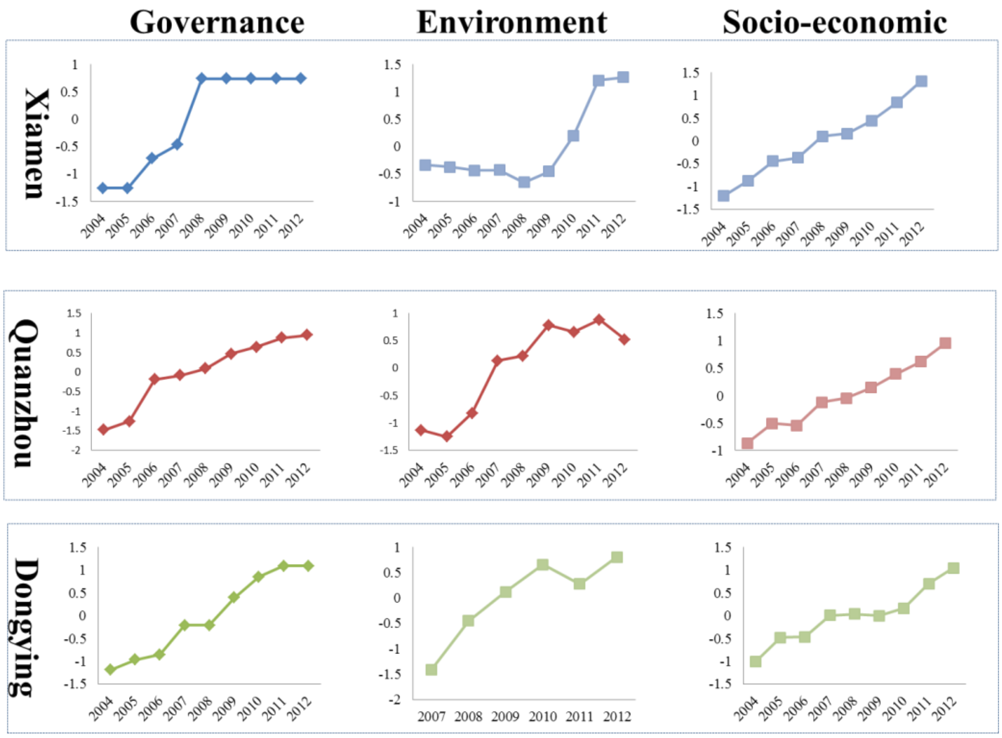

Fig. 7-1 Performance in governance, environment and socio-economic in the three ICM sites

The current proposed methodologies are effective and operational in assessing the progress of ICM performance. The use of integrated performance indicators and quantification methodologies could clearly reveal the trends of coastal governance progress, as well as the environmental and social-economic conditions of study sites. Based on the analyses of trends and specific performance indicators, the gaps in the progress of ICM towards coastal sustainability could also be identified, and this will depend on the selection of proper indicators that is key to producing reliable results. However, this is subjected to the quality of available data in coastal regions. In This study, the governance data were collected based on the integration of the existing documents and scientists and administers' perspectives, which might not be fully accurate due to a lack of annual reviewing data. The evaluation results would be closer to the truth if local governments could conduct an annual review of the governance performance in the light of the governance indicators. The environmental and socioeconomic data were collected from different research institutes and government agencies, which also might need to be verified by the third party to improve the quality of the data. In the future studies, verification of the data would be important to ensure the quality of the results.

With the development of ICM programmes, the routine evaluation of ICM performance would provide the necessary and accurate data on governance progress. Moreover, the advancement of environmental monitoring technologies would allow for more indicators to be made available for analysis, for example the marine spatial indicators that can monitor the changes of coastal and marine habitats. The inclusion of accurate and reliable data, and available indicators would definitely better represent the changing conditions related to ICM performance.

In addition, identifying Key Performance Indicators (KPIs) can be another effective approach to facilitate monitoring efficiency of ICM progress. The number of KPIs identified in Chapter 6 for all three cities only covered 60% of the total indicators, which kept over 80% of the overall information. The indicators with low performance or high heterogeneity are also included in the KPIs. The relationships between ICM governance, coastal environment changes and social economic development could be analyzed using the Drive force – Pressure – Status – Impact – Response (DPSIR) model. Results from the DPSIR analysis in Chapter 6 indicate that the lower anthropogenic driving forces and pressures seemed to result in better coastal environments. However, the correlations between the Drive force, Pressure, Status, Impact and Response could not be addressed due to a lack of long-term monitoring data. Along with the long-term monitoring on ICM performance in the future, more research efforts can focus on exploring the interdependence between the inputs of government interventions (Response), the outcomes of the coastal environment (Pressure and State), and the impacts of coastal development (Impacts), so as to build up a forecasting model to provide the decision makers with indications for sound adaptive management.

Overall, my study could contribute to the quantitative studies in ICM evaluation, as well as the current proposed index systems and methodologies could be applied to other coastal cities for ICM evaluation.

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Appendix 1 Questionnaires of ICM governance performance evaluation in Xiamen, Quanzhou & Dongying

Dear sir/madam:

We are conducting a research on ICM performance evaluation in Xiamen/Quanzhou/Dongying. To evaluate the governance performance from 2004-2012, we kindly invite you to score the governance performance in table 1. The scoring standards are presented in table 2 and the evaluation criteria are presented in table 3.

Thanks so much for your help!

Table 1 Evaluation results of Quanzhou ICM governance

Indicators	2004	2005	2006	2007	2008	2009	2010	2011	2012
(G1) General ICM strategy									
(G2) Coordination mechanism									
(G3) Law enforcement mechanism									
(G4) Policies, regulations and projects enabling ICM									
(G5) Implementation and monitoring of ICM initiatives									
(G6) Scientific and technical support									
(G7) Staff capacity building									

(G8) Infrastructure and facilities allocation									
(G9) Stakeholders involvement									
(G10) Publicity of government information									
(G11) Local government budget allocation for ICM									
(G12) External funding									

Table 2 Scoring system for ICM governance indicators

Score	**Criterion**
0	the indicator was not identified, present, or recognized
0.25	the indicator was present, but the performance is weak
0.5	the indicator was present, and the performance is fair
0.75	the indicator was present, and the performance is good
1	the indicator was present, and the performance is excellent

Table 3 Evaluation criteria for ICM governance indicators

	Evaluation criteria
(G1) General ICM strategy	scope, coverage and objectives of an overall ICM plan or strategy
(G2) Coordination mechanism	the existence and performance of a multisectoral coordinating mechanism

(G3) Law enforcement mechanism	the presence, capacity and function of an integrated enforcement mechanism
(G4) Policy, strategies and action plans	the presence and adequacy of policy, strategies and plans
(G5) Implementation and monitoring of ICM initiatives	the level of implementation and the existence and adequacy of an operational monitoring system
(G6) Scientific and technical support	the availability and accessibility of scientific and technical resources
(G7) Staff capacity building	the staff capacity in terms of skilled human resources
(G8) Infrastructure and facilities allocation	the availability and maintenance of infrastructure and facilities
(G9) Stakeholders' involvement	the number of involved multi-stakeholders
(G10) Publicity of government information	the scope and the extent of the publicity of government information on ICM
(G11) Local government budget allocation for ICM	the government funds allocated
(G12) External funds	the amount of external funds

Appendix 2 Name list of key scientists and administrators involved in ICM governance evaluation

Name	Affiliation	Involved cases
Chen Bin	The Third Institute of Oceanography, SOA	Xiamen
Du Jianguo	The Third Institute of Oceanography, SOA	Xiamen and Quanzhou
Zhou Qiulin	The Third Institute of Oceanography, SOA	Xiamen and Quanzhou
Chen Mingru	Xiamen University	Xiamen
Xiao Jiamei	Xiamen University	Xiamen
Xie Xiaoqing	Yundang Lagoon Administrative Office	Xiamen
Hu Dengjin	Fujian Ocean Institute	Xiamen
Huang Xianliang	Quanzhou Oceanic and Fishery Administration	Quanzhou
Wu Shouji	Quanzhou Oceanic and Fishery Administration	Quanzhou
Chen Zhiyuan	Quanzhou Oceanic and Fishery Administration	Quanzhou
Chen Ruohai	Quanzhou Mangrove Reserve	Quanzhou
Ji Jianfeng	Quanzhou Mangrove Reserve	Quanzhou
Zhang Zhaohui	The First Institute of Oceanography, SOA	Dongying
Zang Huiru	The First Institute of Oceanography, SOA	Dongying
Liu Pei	Dongying Oceanic and Fishery Administration	Dongying
Liu Jie	National Marine Data & Information Service	Dongying
Wen Quan	National Marine Data & Information Service	Dongying
Liu jing	Yellow River Estuary Wetland Nature Reserve	Dongying