

Analysis of Coastal Sea Reclamation Changes over Years and Sustainable Development Capacity of Liaoning Province

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Abstract: By collecting and collating related information of coastal sea enclosure and reclamation activities of Liaoning province, this article did trend study on changes of coastal sea enclosure and reclamation activities over years and environmental impact of Liaoning Province. The study showed that from 1990 to 2009, the area of sea enclosure and reclamation in Liaoning Province had increased year by year, natural shoreline diminished with the sea enclosure and reclamation activities year by year, total area of major bay decreased 18.4%. This article did the quantitative evaluation of six coastal cities' sustainable development level in Liaoning, result showed generally poor sustainable development capacity of Liaoning coastal areas and mean evaluation score of regional sustainability was 0.49, was non-sustainable development. Scores of Huludao City and Dalian City were greater than 0.6, on basic level of sustainable development; score of Yingkou was greater than 0.5 and less than 0.6, on low level of sustainable development; scores of Panjin, Dandong, Jinzhou were less than 0.5, belonged to the level of non-sustainable development basically.

1 RESEARCH BACKGROUND

Coastal zone is the area natural process very active, in terms of stability, the coastal zone is relatively vulnerable geographical unit (Wang Jin, 2005). As the socio-economic development, sea enclosure and reclamation activities impacted the coastal environment a lot, especially the damage to the mangroves, coral reefs, estuaries, wetlands and other ecosystems, according to the data of the Marine Environment Quality Bulletin, coastal reed, swamps, lagoons and other coastal wetlands lost by about 50% (Chen Jiyu and Chen Shenliang, 2002). In 1840 the area of Macau was just 2.78km², currently it had reached 23.5km², 8.5 times as the original, and had negative effect (Yang Chaoqun, 2000).

Research of Coastal Sustainable Development also had some progress in our research and implementation. Sheng Kerong et al., (2003) studied the capacity and controlling measures for sustainable development of Liaoning Province; Xiong Yongzhu (2007) constructed a set of coastal sustainable development evaluation model taking comprehensive coordination degree, sustainability and sustainable development as evaluation objectives, and did case study as Guangdong Province; Han Jiwu et al., (2007) studied coastal sustainable development evaluation

taking seven cities in China's coastal areas for example; Qiu Yunfeng *et al.* (2007) studied sustainable development of China's coastal province based on GIS. Such studies mainly raised the integrated management and development issues of the coastal zone, which was important but easily overlooked, to an understanding height, learning from foreign experience (Abul-Azm et al., 2003; Gladstone et al., 1999; Cave et al., 2003), pointed out some of the problems and proposed solutions for management and Sustainable Development of our coastal zone.

2 RESEARCH METHODS

This paper used "Pressure - State - Response" (PSR) model to build the coastal environment sustainable development evaluation index system in Liaoning province, and applied composite index method to quantitative zoning evaluate the sustainable development level of coastal six cities in Liaoning.

PSR model was established based on a causal relationship that human activities pressured the environment and would also change the number and status of the resources. Society responded to these changes by environment, economics and department

policies. These reactions formed a reverse circulation pressuring human activities. The PSR framework revealed a linear relationship between human activities and the environment, as shown in Figure 1.

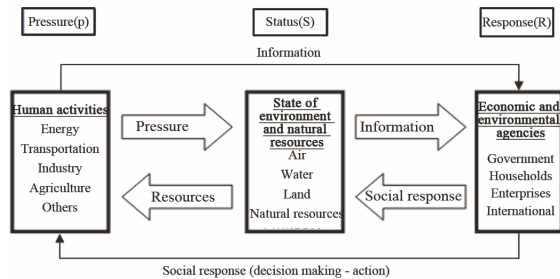


Figure 1: Pressure - state - response system and its indicator type.

3 OVERVIEW OF STUDY AREA

Liaoning Province is one of ocean provinces in China, across Huanghai and the Bohai. Coastal east began from the Yalu River, west ended at the coast demarcation point of Liaoning and Hebei. Its mainland coastline was 2 292.4 km, had 506 islands, reefs and lumps. There were 266 islands more than 500m², 10 rivers were more than 5 000 km², the island coastline was 627km, mudflat resources were 1973.33 km² (Zhang Yaoguang and Cui Lijun, 2001). Coastal prefecture-level cities are Huludao, Jinzhou, Panjin, Yingkou, Dalian and Dandong. Seas vast, coastline long, the huge potential of the oceans and marine resources and other advantages had become the carrier of Liaoning Province developing production space, ecological space and living space.

In recent years, Liaoning Province increased the input into the marine industry continuously, and the ocean economic had developed lastingly and rapidly, sea enclosure and reclamation activities also showed development trend of fast, large area and wide range. But in the process of seeking growth of ocean economic, blind development and excessive use were serious, causing serious environmental pollution in coastal waters, deteriorating state of resources and environment.

4 CHANGES OF SEA ENCLOSURE AND RECLAMATION OVER YEARS AND ITS ENVIRONMENTAL IMPACT OF LIAONING PROVINCE

4.1 Changes of Sea Enclosure and Reclamation over Years

In this paper, we used remote sensing images of 1990, 2000, 2005, 2008, 2009, combining with field reconnaissance as well as data collecting in places, got data of sea enclosure and reclamation over years of Liaoning Province, and the results were shown in Table 1.

Table 1: Statistics of regional sea enclosure and reclamation situation over years of Liaoning Province (Unit: km²).

Year Region	1990	2000	2005	2008	2009
Huludao	32.81	59.59	64.61	74.31	92.08
Jinzhou	86.43	178.9	193.49	201.63	213.82
Panjin	78.99	137.85	142.5	162.85	168.41
Yingkou	272.14	274.01	285.56	293.89	312.13
Dalian	428.73	669.75	740.27	824.69	884.47
Dandong	118.46	123.04	126.21	131.85	131.85
Total	1017.56	1443.14	1552.64	1689.22	1802.7

4.2 Sea Enclosure and Reclamation Occupying Continental Natural Shoreline

Due to the development and utilization of the coast, natural shoreline changed into artificial shoreline continuously in mainland coastline. In accordance with the method determining natural shoreline in the technical regulations of coastline resurvey, extracted natural shoreline from remote sensing images over years, and the results were shown in Table 2.

Table 2: Change statistics of mainland natural shoreline over years of Liaoning Province (KM).

Year Region	1990	2000	2005	2008	2009
Huludao	177.04	152.13	137.42	128.66	127.04
Jinzhou	26.81	20.18	19.88	18.43	18.43
Panjin	76.76	52.37	51.35	45.86	45.86
Yingkou	50.44	49.53	45.17	41.41	37.19
Dalian	579.40	536.69	488.02	442.73	437.48
Dandong	12.55	12.35	10.21	10.21	10.21
Total	923.00	823.24	752.05	687.30	676.20

4.3 Sea Enclosure and Reclamation Occupying Bays

In this paper, we selected Jinzhou Bay, Taiping Bay, Fuzhou Bay, Hulushan Bay, Dongjiakou Bay, Pulandian Bay, Jinzhou Bay, Yingchengzi Bay, Dalian Bay, Dayao Bay, Xiaoyao Bay, Changjiangao, qingduizi Bay, 13 bays in total as evaluation objects in bay log (Zhang Zongshu, 2002) of Liaoning province. Taking outside boundary of sea enclosure and reclamation in 1990 as coastline, analyzed the bay area and sea enclosure and reclamation type in bays, the results were shown in Table 3.

Table 3: Situation of sea enclosure and reclamation occupying bays over years of Liaoning Province (km²).

	1990	2000	2005	2008	2009
Area of bays	1367.31	1271.74	1214.72	1170.82	1115.6
Area of sea enclosure and reclamation	0	95.59	152.09	195.77	234.39

5 CAPACITY FOR SUSTAINABLE DEVELOPMENT OF LIAONING PROVINCE COAST

Coastal area of six cities in Liaoning Province as the research objectives, according to evaluation objectives and situation of information acquisition, based on P-S-R model framework and analytic hierarchy to establish evaluation index system of coast area sustainable development capacity, including three subsystems: pressure, state and response, four levels: objective layer, criteria layer, elements layer and indicator layer. The data to calculate the pressure indicator, status indicators, response index were coastal six cities' socio-economic statistic data at the end of 2006. Using GIS spatial overlay and statistical analysis to calculate the various space utilization ratio involved, based primarily on the using status quo of sea, distribution situation of water quality, space distribution of sea and land resources in Liaoning Province. Table 4 was shown below.

Table 4: Sustainable development evaluation index system of Liaoning Province.

Target layer	Criteria layer	Elements layer	Index layer	
level of coastal sustainable development	pressure subsystem	level of socio-economic	Year-end population density	
			GDP per unit area	
			Investment in fixed assets per unit area	
			Per unit output value of marine fishery	
			Per unit output value of mariculture industry	
		Level of resource utilization	Utilization rate of land space	
			Number of domestic tourists per unit shoreline	
			Artificial rate of shoreline	
			Utilization rate of sea space	
			Net deadweight of shipping tools per unit sea area	
			Direct environmental pressure	Emissions of industrial waste water per unit area
				Emissions of domestic sewage per unit area
	Emissions of industrial solid waste per unit area			
	State subsystem	resource utilization	Proportion of available land space	
			Proportion of available shoal space	
			Proportion of available sea space	
			Proportion of natural shoreline	
		Ecological environment	Proportion of clean water	
			Proportion of water worse than grade IV	
			Red Tide Frequency	
			Nekton density	
			Benthos density	
			Response subsystem	management policies
	Sewage discharge rate reaching standard			
	Proportion of protected marine areas			
	Relevant inputs	Employment number of ocean management per unit area		
		Funding for ocean management per unit area		
Pollution control investment per unit area				
Other humanities response	Proportion of employed population above the high school education			
	Proportion of higher education population			

Table 5: Evaluation results list of six coastal cities' sustainable development in Liaoning.

	City of Dandong	City of Dalian	City of Panjin	City of Yingkou	City of Huludao	City of Jinzhou
ressure system	0.16	0.12	0.17	0.15	0.20	0.11
State system	0.05	0.07	0.04	0.06	0.09	0.06
Response system	0.13	0.48	0.18	0.37	0.40	0.09
Sustainability score	0.35	0.68	0.38	0.58	0.69	0.27

Using composite index method, based on the weight above to evaluate the sustainable development capacity of the coastal six cities in Liaoning Province comprehensively, the evaluation results were shown in Table 5.

Reference on the research results related to sustainable evaluation of Zhang Zongshu (2002), Wu Dun et al., (2005) composite index classification of sustainable development of Liaoning Province's coast were in Table 6 below.

Table 6: Grading standard of composite index.

Classification	Index value	Grading standard
i	0.8<I<1	strong sustainable development
ii	0.6<I<0.8	basic sustainable development
iii	0.5<I<0.6	weak sustainable development
iv	I<0.5	non-sustainable development

On the score of each index, land area of Jinzhou City was small, high density population, had the maximum pressure on coastal, and the lowest score of 0.11; whether waters or land resources were abundant in Huludao City, it had smaller population density, lower economic development level, the minimum pressure on coastal ecological environment, the score of 0.20.

6 CONCLUSION

(1) Environmental Impact of the Coastal Zone Development Activities in Liaoning Province. In 1990-2009, sea enclosure and reclamation area increased year by year in Liaoning Province, the accumulated area was 1797.13 km² in 2009, especially in 2008 and 2009, it increased 108km². Natural shoreline declined with sea enclosure and reclamation activities year by year in Liaoning Province, from 1990 to 2009, natural shoreline decreased 246.8km, in which sea enclosure farming occupied the most, in sea reclamation activities, urban construction occupied the most. Since 1990, the main bay area reduced from 1367km² to 1116km²,

decreased by 18.4%.

(2) Capacity for Sustainable Development of Liaoning Province Coast Zone. Synthesized scores of main system indicators, getting the evaluation results of coastal six cities' sustainable development capacity in Liaoning Province: with the descending order Huludao 0.69, Dalian 0.68, Yingkou 0.58, Panjin 0.38, Dandong 0.35, Jinzhou 0.27. Overall, Liaoning had poor sustainable development capacity in coastal areas and mean evaluation score of regional sustainability was 0.49, was non-sustainable development. Scores of Huludao City and Dalian City were greater than 0.6, on basic level of sustainable development; score of Yingkou was greater than 0.5 and less than 0.6, on low level of sustainable development; scores of Panjin, Dandong, Jinzhou were less than 0.5, belonged to the level of non-sustainable development basically.

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