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# Analysis of the impact on ecosystem and environment of marine reclamation--A case study in Jiaozhou Bay

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## Abstract

Reclamation is the important utilization manner of ocean for mankind. Yet because reclamation changes natural bank shape in short term and small scale, so it can strongly disturb the whole natural system and bring a new misbalance, which affect the stability, diversity and sustainability of the seashore. In order to avoid and lighten the influence of reclamation, we should analyze and diagnose the possible effects, which can do some theory preparations for settling this problem. As a case study in Jiaozhou Bay, this paper selects 9 indicators to base the indicator system. The frame principle of the indicator system includes scientific, synthetical, viable, representative, hierarchical, systematic and data available. Basing the influencing aspects, this article uses the method of analytic hierarchy process (AHP), qualitative and quantitative method to calculate the indicators. By using the judging matrix, hierarchy sorting and indicators, the paper calculates the effect degree of reclamation to environment and ecosystem is comparatively high, and its growth is an increasing process in Jiaozhou Bay. From this point, with the reclamation scale is increasing, the effect degree of reclamation to environment and ecosystem is more and more serious.

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*Keywords:* Reclamation of marine, ecosystem and environment, impact, Jiaozhou Bay;

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## 1. Introduction

Reclamation of marine is the important utilization manner of ocean for mankind and it is also the important means to produce goods and to provide living space for human. Coastal areas are often densely populated areas, which lead to great pressure. In china, costal areas are the areas, which have the highest

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development speed in economy, society and urbanization. And with the extension of non- agricultural land use and shortage of cultivated land, the extension from land to sea has become one of the most important manners to buffer the conflict of human and land resources.

Because of high intensity of exploitation and fragility character, coastland becomes one of the most gravely disturbed ecosystems, and which can block further social and economic development of coastland. And as the reclamation changes natural bank shape in short term and small scale [1], it can strongly disturb the whole natural system and bring a new misbalance, which affect the stability, diversity and sustainability of the seashore.

In order to avoid and lighten the influence of reclamation, we should analyze and diagnose the possible effects, which can do some theory preparations for settling the problem.

## **2. Relevant Theories and Methods**

Land use change largely reflects the integrate influences of human activities and ecological conditions, so land use change influences the ecosystem services from extremely complex aspects, and even a kind of change of land use can lead to many kinds of changes of ecosystem services. In order to maintain the habitat and balance the biological/ecological process, human take full use of land resources and then enjoy the ecosystem services directly or indirectly. In the mean while, the ecosystem services are changed in the sequence of land use activity, such as changing habitat, structure, material and energy circling [2].

Land use change is the most important factor, which can influence the ecosystem services. Reclamation of marine is one of the types of land use change. From the perspective of ecosystem services, reclamation of marine brings to the ecosystem and environment a series of negative effects, which can be manifested in the following areas:

### *2.1. To the habitat function*

According to the researches [3], when the impervious surface coverage (i.e. the percentage or ratio of cement surface or rigid surface in the entire land area) reaches to 10%, environmental degradation will generally occur. Reclamation often leads to high ratio of impervious surface coverage (>10%).

Reclamation usually leads to the decline of biological diversity, the decrease of natural wetlands, and the extinct of habitats for animals and plants. For migratory species, the living environment of marine plants and marine animals has been seriously affected. Particularly in the tidal estuary, there is no tide in existence, and from river estuaries to river ways, the grads from freshwater to seawater are no longer exist.

### *2.2. To the adjustment function*

Reclamation of marine can lead to many negative effects, such as the decreased space tide, disappeared beach, lost wave energy dissipation space, increased influx of disaster risks and filled up riverbed. And in the meanwhile, flow outside the channel slows down, seawater purification declines, frequency and intensity of alga bloom increase. Reclamation materials and pollutants generate during the reclamation activities and they can pollute the marine environment. In addition, the beach and barrier disappear, the impact of waves on coastal areas will be further increased, and the phenomenon of seawater intrusion will be increased in sequence [4]. Reclamation of marine, causing shoreline change, has also affected the deposition of modern sediments [5, 6].

### *2.3. To the production function*

Large-scale reclamation projects cause the changes of topography and water in gulf, which can affect the fisheries resources directly. At the same time, the rapid development of industry, marine industry, aquaculture industry and the rapid increase of urban population, continue to generate a large number of pollutants discharged into the sea, and then seriously affect the regeneration capacity of fishery resources and marine aquaculture industry.

#### *2.4. To the information function*

Marine and coastal ecosystems have great tourism and entertainment value [7], reclamation of marine breaks the original ecological landscape, and which will have a great influence on tourism, entertainment and other industries, and the history and cultural value of coastal areas is also affected.

How to discuss the effects brought by reclamation of marine is a step by step process [4-16], which is developed by many scholars. At first, scholars barely discuss the effects from two aspects: hydrodynamics condition and marine erosion and deposition, including changes caused by tidal volume, the channel flow rate and bed deformation for a long period. With the marine environment causing for more concerns, many scholars have begun to discuss the impacts from the environmental view, including COD as an index factor, the change of COD concentration field and pollutant flux calculation, and even from water quality, marine species and community structure, reducing of the amount of tide water qualitative the environmental capacity, and so on. And more ecological scholars value, assess and predict the impact of the reclamation from the perspective of eco-economics. In all, researches have formed in the basic assessment framework, but not yet formed a system of evaluation indicator system.

Relying on the theory of ecosystem services and the impacts brought by land use change, this paper analyzes and diagnoses the possible effects, and then constitutes matrix, hierarchy sorting and indicators. Basing on the ecosystem services impacts brought by reclamation of marine, and with analyzing the impacts concretely, this paper chooses primary factors to build the assessment indicator system.

### **3. Impact of reclamation on the ecosystem and environment in Jiaozhou Bay**

#### *3.1. Introduction to the change of coastline and reclamation in Jiaozhou Bay*

Jiaozhou Bay is at the latitude of  $35^{\circ} 58' \sim 36^{\circ} 18'$ , the longitude of  $120^{\circ} 03' \sim 120^{\circ} 23'$ , which is a fan-shaped natural bay extending inland slightly between the Yellow Sea Southwest of Shandong Peninsula. Jiaozhou Bay is with an average depth of about 7m, the maximum water depth of 64m and the total area of  $388\text{km}^2$ . Jiaozhou Bay is often known as the "the mother Bay for Qingdao", and 7 districts and 5 county-level cities of Qingdao are built along the Bay. Jiaozhou Bay forms a cluster of industrial zone, thereby stimulates the economic, social and cultural development of various undertakings. From this point, Jiaozhou Bay may be called "the wealth of the Gulf for Qingdao."

According to historical documents and recent researches [17], in different periods, the maximum water area of Jiaozhou Bay are: an area of  $560\text{km}^2$  in 1928,  $535\text{km}^2$  in 1958,  $423\text{km}^2$  in 1977,  $390\text{km}^2$  in 1988,  $367\text{km}^2$  in 2001,  $362\text{km}^2$  in 2003. It is not difficult to see that, in 45 years Jiaozhou Bay reduced  $173\text{km}^2$ , reducing by nearly one-third. The sharp narrow of area is mostly because of the reclamation.

From the remote sensing images in 1980, 1995 and 2000 of Jiaozhou Bay, the changes of coastline and surrounding are very clear (see Fig. 1). By contrasting the remote sensing images, northwest of the town area is obviously extrapolated, the eastern coast appears a obvious manual work building extending to the sea, all of these is closely related to reclamation of marine. Yet because of the temporal difference in remote sensing images, it cannot calculate accurately the changes of coastline, but we still can compare with the changes from the original images.

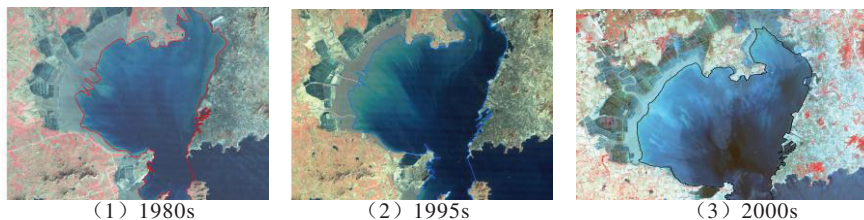


Fig. 1. The change of coastline and surrounding in Jiaozhou Bay in 1980、1995 and 2000

Researches also show that in Jiaozhou Bay the total area of wetlands decreased obviously from 1988 to 2005[18]. Since 1988, the east of Jiaozhou Bay (the four downtown districts in Qingdao) is largely occupied by artificial buildings. And in 1997, as the construction of Jiaozhou Bay Expressway, the whole beach almost entirely disappeared. The southwest side of Jiaozhou Bay (Huangdao) is a large proportion of artificial reclamation area, and the land is fully connected to Huangdao in 2005.

The resulting effect is that the tidal volume of Jiaozhou Bay continues to decline, and the self-purification capacity is reduced, while water pollution is increasing in every year. Experts [17] points out that, if the reclamation is allowed to continue, and which leads to the reduce of sea area, in the near future, Qingdao Port will become a dead port because of sediment deposition, and the economic advantages of Qingdao will the no longer exist. To some extent, pollution can be controlled, but the ecological and environmental impact of reclamation cannot be restored. Therefore, it is of great practical significance to evaluate on the impact of the reclamation in Jiaozhou Bay.

### 3.2. Indicator system

By integrating the effects and data available, and with the principles of scientific, synthetical, viable, representative, systematic and systematic, and then by using the method of analytic hierarchy process (AHP), qualitative and quantitative method, this paper selects 9 indicators to base the indicator system.

Table 1 Indicator system of reclamation impacts on ecosystem and environment

A Target Layer	B Effect Layer	C Analysis Layer	D Concrete Indicators Layer	Explanation of Indicators	
A Impact assessment of reclamation	B1 Ecological impacts	C1 Impact on habitat function	D1 Number of species	Mainly referring to intertidal species	
		C2 Impact on the fishery industry	D2 Representative species of fish		
		C3 Impact on the hydrodynamic conditions	D3 Water Area		
	B2 Environmental impacts	C4 Impact on the marine erosion and deposition conditions	C4 Impact on the marine erosion and deposition conditions	D4 Coastline length	Referring to the intertidal zone as the main reference area
			C5 Impact on environmental quality	D5 Tidal volume	
			D6 Water exchange capacity		
			D7 Inorganic N content	Referring to Section representation of tidal flux	
			D8 Inorganic P content		
			D9 COD content		

### 3.3. Explanation of the selection of indicators

- The impact on habitat: Reclamation of marine causes the destruction of wetlands and biodiversity damage of marine, “number of species” is chosen to reflect the effect of habitat function.
- The impact on fishery resources : In the coastal areas, fishery is the most important industry. Reclamation will inevitably have a significant impact on the fishery, so “representative species of fish” is selected to measure the impact on species, which is also an important character of the production function.
- The impact on dynamic condition of the water: Hydrodynamics is relatively important to the environmental quality of coastal water, while the changes of sea hydrodynamic condition are closely related to coastline shape. The basic indicators include the changes of “water area” in different depths and “coastline length” of coastline. Reclamation can effect the changes of shape inevitably, resulting to the hydrodynamic changes in the environment, and so “water area” and “coastline length” are chosen to characterize this effect, in which the change of inter-tidal area is the most representatively. Just know a highest and lowest water level within the tidal cycle, the inter-tidal area of the region can be calculated according to the terrain data [11].
- The impact on marine erosion and deposition conditions: Reclamation will influence the formation of marine erosion. “tidal water” and “water exchange capacity” can reflect the influence, and tidal water in which needs to be calculated. Harbour tide level is an important parameter, which reflects the exchange of in-water and off-water. The reduction of tidal volume and water exchange capacity will directly affect sea level, flow rate, the gulf migration and diffusion of pollutants. Tidal volume is calculated as follows:

$$Q = (S_1 + S_2 / 2) \cdot \Delta H \tag{1}$$

The formula for the tidal volume is Q, S<sub>1</sub> for the sea area, S<sub>2</sub> for the beach area, ΔH for the tidal range. It means that the tidal water and tidal water area are directly related. With the increase of reclamation, the reduction of tidal water area will be corresponding to the reduction in tidal volume and flow velocity [8].

- Impact on environmental quality: Reclamation will affect the marine environment capacity, it needs to examine “inorganic N content”, “inorganic P content” and “COD content” to reflect this influence.

### 3.4. Impact analysis

By using the small expert decision system “Mathpro” and the method of “AHP”(“The analytic hierarchy process”), and with the ecological and environmental data available, this paper constructs the impact assessment matrix of reclamation in Jiaozhou Bay as follows:

Table 2 B-C judging matrix and hierarchy sorting

	B1	B2	W	Sorts
C1		0.500	0.250	1
C2	0.500		0.250	1
C3	0.500	0.333	0.167	3
C4	0.500	0.333	0.167	3
C5		0.333	0.167	3

Table 3 C-D judging matrix and hierarchy sorting

C1	C2	C3	C4	C5	W	Sorts
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	0.250	0.250	0.167	0.167	0.167		
D1	1					0.250	1
D2		1				0.250	1
D3			0.500			0.084	4
D4			0.500			0.084	4
D5				0.667		0.111	3
D6				0.333		0.056	6
D7					0.333	0.056	6
D8					0.333	0.056	6
D9					0.333	0.056	6

Basing the data available, the indicators are collected in the category of three times and nine sorts in 1970s-2000s. In order to reflect the impact effect, the annual change rates are standardized by polarized standardization of the formula, and then can eliminate the range of different indicators and units of different dimension. The positive indicators:

$$x_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}}; \quad (2)$$

The reverse indicator:

$$x_{ij} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}} \quad (3)$$

After the process of standardization, the maximum value of the various elements is 1, the minimum value is 0, and the rest of the values are between 0 and 1.

Summing the product of the standardized values and their weights, the ecological and environmental impact degree can be attained. The degree from 1970 to 1990s is 0.446, and the degree from 1990 to 2000s is 0.557. So the conclusion can be attained that the later (from 1990 to 2000s) impact of reclamation is higher than the earlier one (from 1970 to 1990s). Contrasting with the trend of the extent of reclamation, the impact on environment and ecosystem also presents a gradually increasing trend.

Among them, the habitat function and the production function are the two, which are the most severe infected in all the functions. Reclamation changes the natural attributes of Jiaozhou Bay coastal environment, making coastal habitat and the biological resources severely damaged, and the number of species and representatives declines sharply. In addition, as the main tide area, reduced tidal volume is the direct result of the reduction of Jiaozhou Bay area, and then affects the transport of pollutants, the circulation of sea water level, velocity, and hydrodynamic condition [12]. So the reduced tidal volume weakens the physical self-purification ability, which greatly reduces the regulatory function of the Gulf.

### 3.5. Suggestion

For the Jiaozhou Bay area, the ecological and environmental impact caused by the reclamation has been clearly shown out and it has become an irreversible situation to some extent. Therefore, it is a need to put this issue on the strategic height, which is about how to effectively take use of marine space resources, how to minimize the cost of the ecosystem and environment, and how to scientifically plan and control the reclamation of marine.

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