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The Assessment Method About the Impact of Intensive Sea Use Project on Marine Ecological Environment

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ABSTRACT

As a more efficient and scientific way for sea use, the intensive sea use would also change and disturb the natural property of the sea to a certain extent, and even cause marine environmental pollution and ecological destruction. Therefore, it is very important to evaluate and minimize the impact of the intensive sea use project on marine ecological environment. In the present study, based on the abiotic and biotic factors of marine ecosystem, the evaluation index system about the impact of intensive sea use project on marine ecological environment was constructed. On this basis, combined with Chinese current marine ecological environmental monitoring and assessment, the evaluation standard and evaluation grade of each evaluation factor was determined. The model based on integrated assignment evaluation method was established, which may evaluate the impact of intensive sea use project on marine ecological environment, and thus determine the suitability of intensive sea use project using the variation of the marine ecological environment comprehensive index before and after the project construction of the intensive use sea (ΔI). The $\Delta I > 30\%$ indicates that the marine ecological environment is seriously affected; $15\% < \Delta I \leq 30\%$ indicates that the marine ecological environment is greatly affected; $5\% < \Delta I \leq 15\%$ indicates that the marine ecological environment is generally affected; and when $\Delta I \leq 5\%$, it indicates that the marine ecological environment is slightly affected or not affected. Therefore, these results are expected to offer appropriate technological support for deciding the scales and sites of the intensive marine engineering, and also provide service for scientific management of the intensive sea use.

INTRODUCTION

The intensive sea use is an intensive and economical way for sea use in accordance with uniform planning and deployment in a region. It is a new concept seeking the coordination and balance of marine development and protection and promoting the sustainable utilization of resources in coastal zone. However, it would also change and disturb the natural property of the sea to a certain extent, and even cause marine environmental pollution and ecological destruction. Therefore, in order to better use, protect and manage marine ecological environment and reduce the effect of intensive sea use project on marine ecological environment, it is necessary to scientifically evaluate the impact of intensive sea use project on marine ecological environment. At present, the studies about the impact of intensive sea use project on marine ecological environment are relatively few (wang et al. 2014). Most of these studies are about the impact of single reclamation project on marine communities or marine environment, and are mainly the qualitative and semi-quantitative assessment (Li 2010, Yu & Zhang 2011, Li et al. 2010, Alves 2007). The comprehensive assessment is less. The assessment methods in these studies mostly adopt the comparative analysis method, namely the relative evaluation, and only a few studies use the single factor evaluation method or the comprehensive index evaluation method of water quality (Khadija Zainal 2012, Feng et al 2014, Li 2014). This study aims to establish the evaluation index system and the evaluation methods about the impact of intensive sea use project on marine ecological environment, which can be used to objectively evaluate the impact of intensive sea use project on marine ecological environment. So it can provide technical support for the scientific management of intensive sea use project.

THE EVALUATION INDEX SYSTEM

The marine ecosystem is a multi-level and complex system and composed of abiotic and biotic factors. The impact of intensive sea use project on marine ecosystem is the harmful or beneficial effect on its abiotic factors and biotic factors. Therefore, the evaluation index system about the impact of intensive sea use project on marine ecosystem can be constructed from the two aspects of abiotic factors and

Table 1: The assessment index system about the impact of intensive sea use project on marine ecological environment.

Assessment objectives	Primary index	Secondary index	Tertiary index
The influence of intensive sea use on marine ecological environment	Marine biological community 0.680	Phytoplankton 0.167	Phytoplankton diversity index 0.475
			Phytoplankton density change 0.275
			Primary productivity 0.250
		Zooplankton0.167	Zooplankton diversity index 0.475
			Zooplankton density change 0.275
			Zooplankton biomass change 0.250
		Benthos 0.499	Benthos biomass change 0.250
			Benthos diversity index 0.475
			Benthos density change 0.275
		Fish 0.167	Fish eggs and larvae density 1.000
	Marine environment 0.320	Seawater Environment 0.279	Inorganic nitrogen 0.255
			Active phosphate 0.255
			Oil 0.163
			Suspended solids 0.072
			COD 0.255
		Depositional Environment 0.167	Organic carbon 0.500
			Sulfide 0.500
		Hydrodynamics 0.183	The flow rate change of high tide 0.209
			The flow rate change of low tide 0.209
			The reduction rate of tidal volume 0.583
		Biological quality 0.371	Pb 0.200
			Cd 0.200
			Hg 0.200
			As 0.200
			oil 0.200

Note: The numbers in the table are the weight of each index

biotic factors. Abiotic factors mainly reflect the quality status of marine biological habitat, namely marine environment, including sea water quality, sediment quality, biological quality and marine hydrodynamics. Biotic factors mainly reflect the response of sea creatures to the environmental change, namely marine biological community, including phytoplankton, zooplankton, benthos, fish eggs and larvae. The index system is given in Table 1.

THE EVALUATION METHOD

The determination of index weight: In actual evaluation, different indexes are of different importance to the evaluation results. Combined with the development key and the eco-environment characteristics in Caofeidian and its adjacent waters, each index is given corresponding weight in order to reflect its importance in the evaluation. In this paper, the method of analytic hierarchy process (AHP) is used to determine the weight of evaluation index. Taking the impact of intensive sea use project on marine ecological environment as the goal layer, first of all, the AHP method is used to construct the index judgment matrix of criterion level in order to determine the index weight of criterion layer and its consistency is tested (Liu 2010). After the index weight of criteria layer is determined, the three round of expert investigation about the index of factor layer (each of not less than 15 people) is performed. Using the Delphy method, the credibility of the expert investigation is analysed and the index weight of factor layer is determined. Then using the same method as the factors layer, the weight of index layer is determined. The weights about the impact of intensive sea use project on marine ecological environment are given in Table 1. The weight of each index only is the recommended value. When applied in other sea areas, according to the specific circumstances, the weight can be determined or adjusted by the expert evaluation method and the AHP method.

Evaluation criteria: There is no uniform academic evaluation standard about the impact of intensive sea use project on marine ecological environment. According to the national related laws and regulations, environmental background value, historical data and previous research results, the standard value of evaluation index about the impact of intensive sea use project in Caofeidian area on marine ecological environment is determined: (1) the evaluation standard of marine biological communities indexes: the biological marine communities indexes include phytoplankton, zooplankton, benthos and fish biology. The specific indexes include the biological density, biodiversity, biomass, pri-

mary productivity, etc. According to the structure and function characteristics of marine biological community, the assessment standards of biological density, biomass, eggs and larvae density indexes are determined by "Guidelines for Nearshore Marine Ecosystem Health Evaluation (HY/T087-2005) (State Oceanic Administration of China 2005). The evaluation standard of biodiversity index is determined by the reference of domestic and foreign scholars on the relationship of diversity and pollution (Cai 2002, Cai 2004, Van Dolah 1999). The evaluation standard of primary productivity is determined by the primary productivity standard in "the biological resources of habitat environment investigation and research" of 1997 National Marine Survey Project (Jin & Zhao 2005). (2) The evaluation standard of marine environmental indexes: the evaluation standards of seawater environment, sedimentary environment and biological quality indexes are determined by "Marine water quality standard (GB3097-1997)" (Ministry of Environmental Protection of China 1997), "Marine sediment quality (GB18668-2002)" (Administration of Quality Supervision of China 2002) and "Marine biological quality standard (GB18421-2001)" (Administration of Quality Supervision of China 2001) respectively. Referencing to relevant research, the line about the serious impact of intensive sea use project on marine ecological environment is divided by the grade II standard or above. The evaluation standard of hydrodynamic indexes are determined by "The technical guidelines for reclamation planning environmental impact assessment (GB/T29726-2013)" (Administration of Quality Supervision of China 2013). The standard threshold of each evaluation index is given in Table 2. The A, B, C, D and E in Table 2 are the base line values of the assessment standards, which can be given according to the actual situation of the evaluation sea area. In this study, the A, B, C, D and E values adopt the recommended values in "Guidelines for nearshore marine ecosystem health evaluation (HY/T087-2005)" (State Oceanic Administration of China 2005).

The evaluation method and grade: In this study, the comprehensive assignment evaluation method is used to evaluate the impact of intensive sea use project on the marine ecological environment. First of all, each assessment index is assigned according to the evaluation standard in Table 2. If the evaluation index value is in the slight grade, it is assigned 100. If the evaluation index value is in the greater grade, it is assigned 70. If the evaluation index value is in the serious grade, it is assigned 40. Then the marine biological community index (I_B) and the marine environmental index (I_E) are calculated respectively.

$$I_B = \sum_{i=1}^{n} W_i \times E_i \quad ...(1)$$

$$I_E = \sum_{i=1}^{n} W_i \times E_i \quad ...(2)$$

In the formula, W_i is the weight of evaluation index, E_i is the score value of evaluation index, and n is the number of evaluation index. The $I_B \geq 75$ indicates good health of marine biological community; the $55 \leq I_B 75$ indicates that the marine biological community is lightly disturbed; the $I_E <$ 55 indicates that the marine biological community is seriously disturbed. The $I_E \geq 75$ indicates good health of marine environment; the $55 \leq I_E < 75$ indicates that the marine environment is light pollution; and the $I_E < 55$ indicates that the marine community is moderate and over pollution.

According to equations (1) and (2), the comprehensive evaluation index of marine environment and the comprehensive evaluation index of marine biological community are calculated respectively. According to equation (3), the comprehensive index of marine ecological environment is calculated as below.

$$I = 0.68 \times I_B + 0.32 \times I_E \quad ...(3)$$

In the formula, I is the comprehensive index of marine ecological environment. The $I \geq 75$ indicates that marine ecological environment quality is good; the $55 \leq I < 75$ indicates that marine ecological environment quality is general; and the $I < 55$ indicates that marine ecological environment quality is bad. The impact of intensive sea use project on marine ecological environment (ΔI) can be measured by the variation of the comprehensive index of marine ecological environment (I) in order to determine the suitability of intensive sea use project. The calculation method of ΔI is as follows:

$$\Delta I = \frac{|I_2 - I_1|}{I_1} \times 100\% \quad ...(4)$$

In the formula, ΔI is the variation value of the comprehensive index of marine ecological environment before and after the implementation of intensive sea use project. I_2 is the comprehensive index of marine ecological environment after the implementation of intensive sea use project. I_1 is the comprehensive index of marine ecological environment before the implementation of intensive sea use project. When $\Delta I > 30\%$, it indicates that the marine ecological environment is seriously affected; $5\% < \Delta I > 30\%$ indicates that the marine ecological environment is greatly affected; and $5\% < \Delta I \leq 15\%$ indicates that the marine ecological environment is generally affected; and $\Delta I \leq 5\%$ indicates that the marine ecological environment is slightly affected or not affected.

Table 2: The evaluation standard about the impact of intensive sea use project in Caofeidian area on the marine ecological environment.

Index	Slight impact	Greater impact	Serious impact
Phytoplankton diversity index	> 3.0	1.0-3.0	≤ 1.0
Phytoplankton density change, ind/m^3	50%A-150%A	10%-50% or 150%200%	≤ 10% or > 200%
Primary productivity, mgC/m^2·d	≤ 200	200-300	> 300
Zooplankton diversity index	> 3.0	1.0-3.0	≤ 1.0
Zooplankton density change, ind/m^3	75%B-125%B	50%-75% or 125%-150%	≤ 50% or > 150%
Zooplankton biomass change, mg/m^3	75%C-125%C	50%-75% or 125%-150%	≤ 50% or >150%
Benthic biomass change, g/m^2	75%D-125%D	50%-75% or 125%-150%	≤ 50% or >150%
Benthic diversity index	> 3.0	1.0-3.0	≤ 1.0
Benthic density change, ind/m^3	75%E-125%E	50%-75% or 125%-150%	≤ 50% or > 150%
Fish eggs and larvae density, ind/m^3	> 50.0	5.0-50.0	≤ 5.0
Inorganic nitrogen, mg/L	≤ 0.2	0.2-0.3	> 0.3
Active phosphate, mg/L	≤ 0.015	0.015-0.03	> 0.03
Oil, mg/L	≤ 0.05	0.05-0.3	> 0.3
Suspended solids, mg/L	≤ 10.0	10.0-100.0	> 100.0
COD, mg/L	≤ 3.0	3.0-4.0	> 4.0
Organic carbon, %	≤ 2.0	2.0-3.0	> 3.0
Sulfide, mg/kg	≤ 300	300-500	> 500
The flow rate change of high tide, cm/s	< 5.0	5.0-10.0	≥ 10.0
The flow rate change of low tide, cm/s	< 5.0	5.0-10.0	≥ 10.0
The reduction rate of tidal volume, %	< 2.0	2.0-5.0	≥ 5.0
Pb, mg/kg	≤ 0.1	0.1-2.0	> 2.0
Cd, mg/kg	≤ 0.2	0.2-2.0	> 2.0
Hg, mg/kg	≤ 0.05	0.05-0.1	> 0.1
As, mg/kg	≤ 1.0	1.0-5.0	> 5.0
Oil, mg/kg	≤ 15	15-50	> 50

DISCUSSION

The impact assessment about the intensive sea use project on marine ecological environment is an important part of technology optimization with intensive sea use and is the foundation of intensive sea use management based on ecological system. In this study, based on multi-objective decision theory to build the impact assessment model of intensive sea use project on marine ecological environment, including the selection of evaluation index, the establishment of evaluation index system, the choice of empowering methods, quantitative evaluation and standardization, the comprehensive evaluation method and evaluation standards. The evaluation index system is clear and the evaluation results can comprehensively and objectively reflect different levels of subsystem characteristics and state change and the influence degree. The evaluation techniques and methods combine with the present situation of Chinese ocean ecological environment monitoring and assessment, and have stronger operability.

However, there are some questions in the assessment method of intensive sea use project on marine ecological environment. For example, there are more tertiary index in the index system, which makes higher requirement for data in the evaluation process. Therefore, In view of the different intensive sea use projects, how to more scientifically choose the representative and greater relevant indexes associated with the changes of ecological environment is the focus of future study. At the same time, the evaluation criteria, weight and evaluation grade of each index are the recommended value, which need to further improve in the future. In the impact assessment of the intensive sea use project on marine ecological environment, the choice of index, the determination of standard and the division of evaluation grade are very complex. In practice, for different marine ecological systems, the measurement methods and measurement standards are some different and need to be adjusted appropriately according to the specific situation. How to correctly evaluate the impact of intensive sea use project on marine ecological environment from different spatial and temporal scales is an important research content in the future.

CONCLUSION

In this paper, based on the complexity of marine ecological environment, the evaluation index system about the impact of intensive sea use project on marine ecological environment is constructed from two aspects of marine biological community and marine environment. The comprehensive evaluation method based on integrated assignment evaluation method is established for assessing the impact of intensive sea use project on marine ecological environment. According to the variation of the marine ecological environ-

ment comprehensive index (ΔI) before and after the project construction of the intensive use sea project, the impact of intensive sea use project on marine ecological environment is determined. When $\Delta I > 30\%$, it indicates that the marine ecological environment is seriously affected; when $15\% < \Delta I \leq 30\%$, it indicates that the marine ecological environment is greatly affected; when $5\% < \Delta I \leq 15\%$, it indicates that the marine ecological environment is generally affected; and when $\Delta I \leq 5\%$, it indicates that the marine ecological environment is slightly affected or not affected. The evaluation index system is clear. The evaluation method is simple and has stronger operability.

However, the characteristics of different intensive sea use engineering are different. In the application of this evaluation system, evaluation criteria and evaluation index may need to adjust appropriately. To establish a set of evaluation system about the impact of intensive sea use project on marine ecological environment from different spatial and temporal scales is an important research content in the future.

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