Research on the comprehensive benefits and driving forces of various typical types of marine development in Jiangsu Province

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Abstract. The comprehensive benefit assessment of marine development type is an important basis for marine development according to local conditions. It is of great significance to realize the rationality of marine development and promote the sustainable development of the ocean. This paper calculates the economic net benefit, ecosystem service function loss value, fishery resource loss value and ecological profit and loss value of four main types of marine development projects in Jiangsu Province. The evaluation, correlation and driving force analysis of the comprehensive benefit value per unit area of marine development type are carried out. It is found that the sequence of economic net benefit and comprehensive benefit value is the same, from the highest to the lowest, they are port industry, offshore wind power, sewage dumping and aquaculture. After deducting the economic benefit value, the comprehensive benefit value is in the order of offshore wind power, aquaculture, port industry, sewage dumping, and the evaluation value is very close. Economic net benefit, ecosystem service function loss value and comprehensive benefit value have the most significant correlation. Through principal component analysis, it is found that economic net benefit is the key driving factor.

1. Introduction
With the rapid development of social economy, the demand for marine development is becoming increasingly fierce. To accurately grasp the comprehensive benefits of marine development has gradually become the focus of marine development [1]. Ocean development not only expands the space of human activities and promotes social and economic progress, but also brings serious natural and environmental problems. The research on the types of marine development at home and abroad pays more attention to the comprehensive benefits of reclamation and land development, especially the social and economic benefits [2], while the research on the social, economic, resource and environmental benefits included in the calculation of the comprehensive benefits of marine development is less. Although some studies estimate and analyze the profit and loss of social and economic resources, they either ignore the accounting of ecosystem service function value, or do not include the value of ecological profit and loss into the calculation of comprehensive benefit value. For
example, Liu Q and Min X (2013) comprehensively considered the impact of reclamation on social economy and ecological environment, and evaluated the comprehensive benefit of reclamation project [3], but it was not included in the ecological profit and loss. Li JM et al., (2017) evaluated the environmental cost of reclamation [4], which only highlighted the compensation of ecosystem service function, not comprehensive.

The development and management of coastal areas requires a rigorous assessment to determine whether each type of marine development is sustainable over time [5]. Tian HY et al., (2017) proposed a coastal development index to assess the change of coastal development sustainability over time [6]. A variety of comprehensive evaluation methods can also be used to evaluate the suitability of coastal development for future sustainable development [7]. In the future, we should pay attention to the supporting role of marine development for social and economic development, and fully consider the ecological and environmental problems caused by improper selection of marine development types, as well as the restrictions and constraints on economic development. In order to avoid the rapid growth of marine economy, it is also accompanied by a series of problems, such as excessive development of resources, serious environmental pollution, and blind reclamation of land from the sea.

Different types of marine development have different constraints on development factors, which bring different social and economic benefits, loss of marine resources, cost of ecological environment, etc [8]. According to the actual situation of coastal areas, how to choose the type of marine development with high efficiency has become a problem to be solved. Based on the comprehensive consideration of economic net benefit, ecosystem service function loss value, fishery resource loss value and ecological profit and loss value, this paper calculates and analyzes the comprehensive benefit value of marine development type. Especially, the influence of economic net benefit on comprehensive benefit value is analyzed. Finally, principal component analysis is used to verify the calculation results of comprehensive benefit value.

2. Materials and methods

2.1. Data source

Jiangsu Province is located at 116°18'E~121°57'E and 30°45'N~35°20'N. The coastal area is about 3.5×10^4 km^2. Combined with the main marine industries and the actual situation of marine development in Jiangsu Province, the types of aquaculture development, offshore wind power development, sewage dumping development and port industrial development are finally selected (Table 1).

| Marine industry       | Marine development type       | Number | Marine development project                                      |
|-----------------------|-------------------------------|--------|----------------------------------------------------------------|
| Marine fishery industry | Aquaculture                  | A      | A coastal mariculture project                                   |
| Marine power industry  | Offshore wind power           | B      | A coastal 150MW wind power project                             |
| Marine transportation industry | Sewage dumping     | C      | Sewage discharge project of a coastal development zone           |
| Marine engineering construction industry | Port industry     | D      | A coastal power plant project                                   |

2.2. Comprehensive benefit value of marine development type

The comprehensive benefit value is equal to the total benefit minus the total cost, and the total benefit includes the economic benefit and the ecological benefit. The total cost includes economic cost and ecological cost. Economic cost refers to the total cost of marine development projects. Ecological cost refers to the ecological damage caused by marine development projects, including the loss of wetland ecosystem service function, the loss of biological resources and the loss of environmental capacity. Split the ecological profit and loss value, put the gains in the ecological benefits, and put the losses in
the ecological costs. Therefore, the calculation method of comprehensive benefit value of marine development type is as follows:

$$B_i = \frac{P_i - C_i - V_i - F_i \pm E_i}{S_i}$$

In the formula, $B_i$ is the comprehensive benefit value per unit area, unit: 10000 yuan/hm². $P_i$ is the total income of the project predicted during the operation period, unit: 10000 yuan. $C_i$ is the total cost of the project, unit: 10000 yuan. $V_i$ is the loss value of wetland ecosystem service function. $F_i$ is the loss value of fishery resources. $S_i$ is the area occupied by the type of marine development, unit: hm². $E_i$ is the ecological profit and loss value.

2.2.1. Economic net benefit value of marine development type. The net economic benefit of the type of marine development is equal to the total economic benefit minus the total economic cost. The total economic income is the annual income after the project reaches the designed production capacity multiplied by the use sea period. The total cost of marine development project includes engineering cost, operation cost and resource occupation cost. In order to consider the comparability of different projects, the economic net income per unit area within the development period is selected as the evaluation index, unit: 10000 yuan/year.

2.2.2. Loss value of service function of coastal wetland ecosystem. The different types of marine development have different impact on the service function of wetland ecosystem. According to the existing research results [9], the ecological damage coefficients of different types of marine development are finally determined. The loss value of wetland ecosystem services caused by marine development projects is calculated as follows:

$$V = \frac{v_i \sum S_j d_j}{S}$$

In the formula, $V$ is the loss value of service function of wetland ecosystem per unit area every year. $v_i$ is the ecological service value per unit area of the development bank section every year, unit: 10000 yuan/hm²·a. $S_j$ is the area of development type $j$, unit: hm². $S$ is the total development area. $d_j$ is the damage coefficient of development type $j$ to wetland ecological service function. $n$ is the number of types of marine development included in the project.

2.2.3. Loss value of fishery resources. Marine development projects may destroy the habitat conditions of marine organisms, occupy the aquaculture area, and cause the loss of intertidal organisms and benthos. Therefore, the loss of fishery resources caused by marine development projects is selected as the evaluation value of fishery resources loss. The formula is as follows:

$$f_i = \frac{F_i}{S}$$

In the formula, $f_i$ is the annual assessment value of fishery resources loss per unit area, unit: 10000 yuan/hm²·a. $F_i$ is the loss value of fishery resources caused every year. $S$ is the total area of marine development, unit: hm².

2.2.4. Ecological profit and loss value. For the type of marine development that produces ecological benefits, the positive benefit value of pollutant emission reduction shall be taken as the assessment value after the cost of pollutant emission is converted. For example, the type of offshore wind power development takes the economic benefit value generated by the carbon emission index exchanged by the standard coal with annual power generation savings as the evaluation value. For the type of marine development that causes ecological loss, the cost of eliminating the negative ecological impact is taken as the assessment value. Such as aquaculture, port industry, etc, in the process of development and operation, pollutants will be discharged into the sea, resulting in different degrees of ecological
pollution. Therefore, the restoration cost method is generally used to evaluate the virtual treatment cost paid by the annual emission of the treatment project.

For the development type of sewage dumping, the fee charged for the treatment of the same qualified sewage will be taken as the evaluation value. Based on the source intensity of water pollutants during the operation period of the sewage treatment plant, the total virtual treatment cost can be obtained by adjusting the pollution charge with 17% of the compensation degree of environmental pollution as the adjustment coefficient [10]. The type of offshore wind power development uses wind energy to generate electricity, which will not pollute the marine environment, and has the benefits of coal saving, power generation and emission reduction.

The representative projects of port industrial development type mainly affect the marine environment through the thermal drainage of power plant. Different kinds of aquatic organisms have limited adaptability to the rapid change of sea water temperature. In this paper, the method of restoration cost is used to calculate the ecological value damage caused by warm drainage. For the sea area with a temperature of more than 4°C, the specific method is to reduce the cost of reducing the temperature of the warming sea area to the temperature when it is not polluted, so as to conservatively evaluate the ecological pollution damage value of the warming sea area. The cooling path is balanced by the heat generated by coal combustion. For part of the sea areas where the continuous temperature drainage may cause the water temperature in the sea area to rise by more than 4°C, the temperature drainage volume obtained through the monitoring of the drainage outlet and the average temperature of the drainage higher than the normal sea water. Using the method of production factor price to estimate the part of the heat contained in the continuous temperature drainage that may cause the water temperature in the sea area to rise more than 4°C. The calculation formula of the damage value of warm drainage is as follows:

\[ V = V_1 + V_2 = cpV_1\Delta t_1 \frac{p}{q} + cpV_2\Delta t_2 k \frac{P}{q} \]

In the formula, \( V \) is the total value of ecological damage assessment of warm drainage. \( V_1 \) is the assessment value of ecological damage in the water area with temperature rise exceeding 4°C. \( V_2 \) is the ecological damage assessment value of the water area to be heated. \( c \) is the specific heat capacity of water body, recorded as \( 1 \times 10^3 \text{cal/kg}^\circ\text{C} \). \( \rho \) is the average density of sea water in the project area, which is recorded as \( 0.9 \times 10^3 \text{kg/m}^3 \). \( V_1 \) is the total volume of warming water area, unit: \( \text{m}^3 \). \( \Delta t_1 \) is the average temperature rise of this part of water, unit: \( ^\circ\text{C} \). \( p \) is the unit price of coal, which is 0.44 yuan/kg according to the price of industrial coal. \( q \) is the calorific value of coal, and the calorific value of industrial coal is roughly recorded as \( 7 \times 10^6 \text{cal/kg} \). \( V_2 \) is the volume of internal temperature drainage per unit time, unit: \( \text{m}^3/\text{s} \). \( \Delta t_2 \) is the evaluation temperature of the water outlet exceeding the natural water temperature, unit: \( ^\circ\text{C} \). \( t \) is the drainage time, unit: \( \text{s} \). \( k \) is the proportion coefficient, and the ratio of the heat content in the heating area over 4°C to the total heat content in the heating area, the unit is percentage, and the item is taken as 1.5%.

3. Results

It is found that the industry near the port is the highest, reaching 161.3501 million yuan/hm²·a. Secondly, offshore wind power, sewage dumping and aquaculture were 1.62 million yuan/hm²·a, 523400 yuan/hm²·a and 201400 yuan/hm²·a, respectively.

By calculating the economic net benefit value per unit area of the representative projects of each type of marine development, it is found that the order of economic net benefit value is the same as that of comprehensive benefit value. The port industry is the highest, with 161.42 million yuan/hm²·a, while the other three types of marine development are relatively low, including 1.62 million yuan/hm²·a for offshore wind power, 523400 yuan/hm²·a for sewage dumping projects, and 201400 yuan/hm²·a for aquaculture (Table 2).

The loss value of ecosystem service function per unit area of the representative projects of each marine development type is similar. It is found that the loss value of port industry is the largest, which is -33600 yuan/hm²·a, followed by -23500 yuan/hm²·a for aquaculture and -20000 yuan/hm²·a for
sewage dumping, while the loss value of offshore wind power is the smallest, which is \(-14400\) yuan/hm\(^2\)·a. The loss value of fishery resources per unit area of the representative projects of each type of marine development has little difference. It is found that the loss value of sewage dumping is the largest, which is \(-58300\) yuan/hm\(^2\)·a, followed by \(-44000\) yuan/hm\(^2\)·a of offshore wind power, and \(-21000\) yuan/hm\(^2\)·a of aquaculture, while the loss value of port industry is the smallest, which is \(-13800\) yuan/hm\(^2\)·a. Among the ecological profit and loss value per unit area of representative projects of various types of marine development, offshore wind power is the highest, reaching \(392800\) yuan/hm\(^2\)·a, and sewage dumping is \(3800\) yuan/hm\(^2\)·a, all of which belong to benefit value. However, the loss values of port industry and aquaculture were \(-22600\) yuan/hm\(^2\)·a and \(-900\) yuan/hm\(^2\)·a, respectively (Figure 1).

Table 2. Economic net benefit and comprehensive benefit value per unit area of each marine development type.

| Marine development type | Aquaculture | Offshore wind power | Sewage dumping | Number |
|-------------------------|-------------|---------------------|----------------|--------|
| Economic net benefit    | 20.14       | 162                 | 52.34          | 16142  |
| Comprehensive benefit value | 15.60     | 195.44              | 44.88          | 16135.01 |

Figure 1. Comparison of ecosystem service function loss value, fishery resource loss value and ecological profit and loss value.

Figure 2. Percentage accumulation histogram of comprehensive benefit value of marine development type.

Figure 3. Comprehensive benefit value minus economic net benefit.

Figure 4. Histogram of percentage accumulation after deducting economic net benefit from comprehensive benefit value.

The composition proportion of the comprehensive benefit value is analyzed by drawing the percentage accumulation histogram of the comprehensive benefit value of the marine development type (Figure 2). It is found that the proportion of economic net benefit value is the largest in all types of marine development. In addition, the ecological profit and loss value of offshore wind power, and
the loss value of fishery resources in sewage dumping also account for an obvious proportion in the comprehensive benefit value.

After subtracting the economic net benefit from the comprehensive benefit per unit area of the representative projects of each marine development type (Figure 3), it is found that the value of offshore wind power is the highest and belongs to the positive benefit, reaching 334400 yuan/hm²·a. However, the other three types of marine development are all negative and close to each other. The value of aquaculture is -45400 yuan/hm²·a, port industry is -69900 yuan/hm²·a, sewage dumping is -74600 yuan/hm²·a.

By drawing the percentage accumulation histogram (Figure 4) of the comprehensive benefit value minus the economic net benefit of the marine development type, the composition proportion is further analyzed. It was found that the loss of ecosystem services and fishery resources accounted for a significant proportion. The ecological profit and loss value of offshore wind power is relatively obvious. The loss value of fishery resources and ecosystem service function in the sewage dumping is obvious. The loss value of ecosystem service function and the value of ecological profit and loss in port industry are obvious.

Based on the correlation analysis of the comprehensive benefit value and the index value of each component, it is found that the economic net benefit value, the ecosystem service function loss value and the comprehensive benefit value are highly correlated, which are 1.000**, -0.882 respectively. In particular, the correlation of economic net benefits is the most significant (Table 3).

**Table 3. Correlation coefficient between comprehensive benefit value and each component index.**

| Correlation coefficient | Economic net benefit | Loss value of ecosystem service function | Loss value of fishery resources | Ecological profit and loss value | Comprehensive benefit value |
|-------------------------|---------------------|----------------------------------------|-------------------------------|---------------------------------|-----------------------------|
| Economic net benefit    | 1                   | -0.883                                 | 0.662                         | -0.379                          | 1.000**                     |
| Loss value of ecosystem service function | 1                   | -0.760                                 | 0.739                         | -0.882                          |
| Loss value of fishery resources | 1                   | -0.356                                 | 0.662                         |                                  |
| Ecological profit and loss value | 1                   | -0.377                                 |                               |                                  |
| Comprehensive benefit value | 1                   |                                        |                               |                                  |

Note: **. At 0.01 level (double tail), the correlation is significant.

In the indicators of comprehensive benefit value, the greater the variation degree of a certain indicator value, indicating that the more information it provides, the greater the role it plays in the comprehensive benefit value, and the greater the weight value should be. It was found that the cumulative variance contribution rate of economic net benefit and ecosystem service function loss reached 91.30%, and the initial variance contribution rate was 73.24% and 18.06% respectively (Table 4). It shows that these two variables basically cover variable information, especially the net marine economic benefits can be used as the main component to measure the comprehensive benefits of various types of marine development.

**Table 4. Eigenvalue, contribution rate and cumulative contribution rate of principal components.**

| Evaluation factor                  | Initial characteristic value | Extract the sum of load squares |
|------------------------------------|-------------------------------|---------------------------------|
|                                    | Total | Variance percentage | Cumulative% | Total | Variance percentage | Cumulative % |
| Economic net benefit               | 2.93  | 73.24 | 73.24 | 2.93  | 73.24 | 73.24 |
| Loss value of ecosystem service function | 0.72  | 18.06 | 91.30 | 0.72  | 18.06 | 91.30 |
| Loss value of fishery resources    | 0.35  | 8.70  | 100.00 | 0.35  | 8.70  | 100.00 |
| Ecological profit and loss value   | 1.623E-16 | 4.056E-15 | 100.00 | 1.623E-16 | 4.056E-15 | 100.00 |
4. Discussion

In this study, the comprehensive benefits of four typical types of marine development, including aquaculture, offshore wind power, sewage dumping and port industry, are taken as the research objects. Take the representative projects of each type of marine development as the case of comprehensive benefit evaluation and analysis. When choosing the type of marine development, we should compare the social, economic and environmental benefits of each type of marine development according to the local actual situation. At the same time, we should also compare and calculate the ecological and environmental losses caused by different types of sea use, rather than just look at the size of comprehensive benefits. We should choose the type of marine development that will not damage the local ecological environment, or even be conducive to the development of ecological environment and promote the local social and economic development [11]. The most important thing is not to neglect the accounting of ecosystem service function value [12,13]. According to the research results of ecosystem service function value [14,15,16], and based on the research method of ecological service value evaluation proposed by Xu Min [17], this study evaluates the ecological service value of coastal wetland in Jiangsu Province by sections, and concludes that the average ecological service value of Jiangsu beach is 40000 yuan/hm² per year.

The reason for the negative value of the comprehensive benefit of the type of marine development may be that it only considers the relevant cost and benefit in the early stage of construction, while each type of marine development needs huge investment in the early stage, and the initial benefit is small. With the continuous improvement of the development, the income also increases rapidly. Therefore, when evaluating similar types of marine development, it is suggested to use the discounted future cash flow method for a more objective and fair evaluation. There are several aspects that need to be improved in the follow-up study. First, the total cost of general marine development projects includes the preliminary survey cost, demolition compensation cost, fishery resource compensation cost, sea area or land use fund, etc. the loss value or compensation cost of ecosystem service function should be included in the comprehensive benefit evaluation. Secondly, the financial evaluation and the national economic evaluation should be carried out for the marine development activities [18]. The social benefits generated by the types of marine development, such as providing jobs, improving happiness index and other social indicators, should be included in the comprehensive benefit assessment, which can better reflect the people-oriented development concept. Third, the choice of the type of marine development will have an impact on marine living resources, and fishery resources are only a small part of it. Therefore, we can't generalize the loss value of fishery resources, but calculate the loss value of marine biological resources.

Through the calculation, it is found that the comprehensive benefit values of the four types of marine development are all positive, indicating that the impact on marine ecological environment is positively correlated, which can promote the optimization and coordination of marine economy and marine environment. After deducting the net economic benefits, only the comprehensive benefits of offshore wind power are positive, while the comprehensive benefits of the other three types of marine development are negative, indicating that the impact on the marine ecological environment is negatively correlated. The Sewage dumping is close to the impact of port industry on the marine ecological environment, and the aquaculture also causes damage to the marine ecological environment, but the damage is less than the former. In order to make clear the important effect of the economic net benefit of the type of marine development on the comprehensive benefit objectively, the percentage accumulation histogram is drawn, the percentage composition of the comprehensive benefit value and the percentage composition of the comprehensive benefit value after deducting the economic net benefit value are compared and analyzed. It is found that the net benefit of marine economy has a significant impact on the value of comprehensive benefit. Through the correlation analysis and principal component analysis, it is also found that the correlation between marine economic net benefit and comprehensive benefit value is the highest. The economic net benefit is the main component of the comprehensive benefit value.
At present, the selection of evaluation indexes, the determination of index weight and safety threshold, the selection of evaluation methods need to be explored and demonstrated. It is widely used to establish indicator system by relying on model framework, but there is a big shortage in a large number of studies, that is, there is no unified and perfect evaluation indicator system. Therefore, to establish a unified standard evaluation index system, to strengthen the evaluation of the reliability and accuracy of the model, and to control the quality control in the evaluation process are the major focus and development direction of the research on the application of the index model framework in the future.

5. Conclusions
First, it is found that the order of the comprehensive benefit value of each type of marine development is the same as that of the economic net benefit value. From high to the bottom, the comprehensive benefit values are port industry, offshore wind power, sewage dumping and aquaculture. It is found that the economic net benefit of port industrial development type is very high, which is the key reason for the highest comprehensive benefit value. But its ecosystem service function loss value and ecological loss value are also the largest. The economic benefit value of offshore wind power development type is next to that of port industry, and it has the highest ecological benefit value and the smallest loss value of ecosystem service function, which is the main reason why the comprehensive benefit value ranks the second. The economic net benefit of sewage dumping is more than twice that of aquaculture, and the other three indicators are very close, which is the main reason why the comprehensive benefit value exceeds that of aquaculture. The economic benefit value of the aquaculture type is the lowest, which results in the lowest comprehensive benefit value.

Second, the order of the comprehensive benefit value after deducting the economic benefit value is offshore wind power, aquaculture, port industry and sewage dumping. And the latter three types of marine development are negative comprehensive benefit values, and very close. This fully shows that the net benefit of marine economy has a significant impact on the comprehensive benefit value, especially on the type of port industrial development.

Third, it is found that the economic net benefit value, ecosystem service function loss value and comprehensive benefit value are significantly correlated. Based on the principal component analysis, it is found that the contribution rate of economic net benefit as a principal component reaches 73.24%, which is the key factor of the comprehensive benefit value.

Fourth, scientific evaluation of the comprehensive benefit value of various types of marine development can provide important decision-making basis for the choice of types of marine development in coastal areas, and is of great significance to promote the rational development of coastal areas. In the future research, it is necessary to further analyze the components of the comprehensive benefit value of the type of marine development. It is necessary to include social and economic benefits, resource loss and ecological environment cost into the analysis and selection process of marine development type, accurately calculate the loss value of biological resources caused, and improve the connotation of comprehensive benefit value.

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