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The impact of climate change on the sustainable use of marine living resources

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ABSTRACT

In order to assess the impact of climate change on the sustainable use of marine living resources, according to the projection value of the sustainable use of marine living resources, the Eviews6.0 software was used to estimate the nuclear density, and the dynamic characteristics of the sustainable use of marine living resources were obtained. In order to obtain the optimal allocation of the sustainable utilization of marine living resources and make the marine industry obtain the maximum net income, the set of climate factors affecting the sustainable utilization of marine living resources is established, and the AHP method is applied to establish the hierarchical structure model to realize the evaluation of the sustainable development of marine living resources. In the validation phase, one benchmark scenario and three simulation scenarios were set up for analysis. The simulation scenarios were temperature, precipitation, humidity and climate conditions. The results show that the climate factors of temperature and precipitation have little influence on the sustainable development of marine biological resources, while humidity has a certain influence on the sustainable development of marine biological resources. Through the comprehensive comparison of marine living resources consumption and economic development, it is concluded that marine living resources consumption has a great impact on social and economic development.

Keywords: Climate change; Marine biological resources; Sustainable use; Projection pursuit technology; Distribution density

1. Introduction

The sustainable development of marine living resources is a complex social and economic system, which involves many factors such as society, marine economy, marine resources and environment. Understanding the current situation of the sustainable utilization of marine living resources, finding out the problems in the process of the utilization of marine living resources, and exploring the optional path to realize the sustainable utilization of marine living resources are conducive to optimizing the management of marine living resources and promoting the sustainable development of marine economy [1]. The sustainable development of the ocean is how to coordinate the relationship between the subsystems and the factors in the system, and realize the continuous evolution of the whole system. The previous research work mostly focused on the unilateral research of marine environment, marine resources and marine economy, and mostly policy research on marine development measures, and the comprehensive and quantitative research results were less [2]. Moreover, climate change is not taken into account, and the results of the study on the sustainable utilization of marine living resources are relatively one-sided. However, changes in marine ecology caused by climate change are mainly reflected in the acidification of seawater caused by precipitation, the increase of ocean temperature, the change of dissolved oxygen (O_2), the change of ocean currents, and the change of humidity. Such changes have a serious impact on marine living resources, for example, ocean acidification prevents the formation of coral reefs and the formation of calcareous shells such as plankton. Rising seawater temperature increases the rate of coral degradation, changes the migration and living habits of fish and affects fishery resources, and inhibits the growth and

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photosynthesis of algae under certain changes, thus affecting the survival of algae-eating fish. Therefore, in order to promote the sustainable utilization of marine living resources, it is necessary to further study the related issues [3].

Stepanenko and Gritsay [4] study the sustainable utilization of groundwater in North China Plain under the influence of climate change. Based on the calibration of Mike SHE model, three atmospheric circulation models representing humid, normal and arid climate conditions under A1B carbon dioxide emission scenario are considered, and three climate change scenarios are set for simulation. The results show that the changes of groundwater level, groundwater recharge and aquifer reserves are positively correlated with the degree of dryness and wetness of climate. Compared with the current situation, the groundwater level increased by 0.156–0.295 m/a and 0.007–0.090 m/a, respectively in the humid and normal climate scenarios, and decreased by 0.106–0.345 m/a in the arid climate scenario; The recovery rate of aquifer reserves is 6.86 km^3/a and 0.84 km^3/a under wet and normal climate scenarios, respectively, while it decreases by 6.58 km^3/a under dry climate scenarios; The groundwater recharge increases by 53.1% and 8.5%, respectively under the humid and normal climate scenarios, and decreases by 69.2% under the arid climate scenarios. Therefore, the sustainable utilization of groundwater is a key issue in the social development of North China Plain. Only the comprehensive effect of all aspects of society can guarantee the sustainable utilization of groundwater in North China Plain. Dong et al. [5] analyze the impact of climate change on the sustainable development of China's marine economy. In order to assess the impact of climate change and the implementation of emission reduction policies on China's marine economy, this paper constructs a social and economic accounting matrix of China's marine economy, and constructs a computable general equilibrium model of China's marine economy based on this data, and combines this model with the climate change impact model. Thus, the transformation from the impact of climate change on the natural system to the impact on the economic system is realized. Six climate change scenarios with and without greenhouse gas emission reduction policies are designed. The simulation analysis of each scenario shows that the impact of implementing emission reduction policy on coastal GDP is 0.19% and 0.12% lower than that of not implementing emission reduction policy, respectively; Under the three scenarios of sea level rise superimposed with astronomical tide and storm surge, the impact of implementing emission reduction policy on marine economy is 1.67%, 0.72% and 0.37% lower than that of not implementing emission reduction policy, respectively.

Based on the above research results, this paper studies the impact of climate change on the sustainable utilization of marine biological resources from the perspective of climate change factors.

2. Experiment

2.1. Distribution density of sustainable use of marine living resources

According to the projection value of the sustainable utilization of marine biological resources, the Eviews 6.0 software is used to estimate the nuclear density, and the window width is 0.8 h 0.9 SN to depict the nuclear density distribution of the sustainable utilization of marine biological resources from 2016 to 2020 [6]. In order to analyze more intuitively, select 3 nodes that can explain the change trend of sustainable utilization level. In 2016, 2018 and 2020, the distribution density of sustainable utilization of marine biological resources is presented, as shown in Fig. 1.

According to Fig. 1, the dynamic change process of the sustainable utilization level of marine living resources mainly presents the following characteristics:

- From the perspective of stage distribution, the sustainable utilization level of marine biological resources presents a relatively obvious skewed distribution. In 2016, it was basically unimodal. In 2018, it began to show a bimodal state. In 2020, the bimodal state will increase. This shows that in 2016–2020, the sustainable utilization of marine living resources in different regions presents a dynamic change process in which the polarization is not obvious in the initial stage, intensified in the middle stage, and further intensified in the later stage (more and more low, less and less high).
- From the overall distribution, the density curve showed a trend of gradually moving to the right, and the projection value of the sustainable utilization level corresponding to the peak gradually increased, indicating that the sustainable utilization level of marine biological resources increased year by year.
- From the perspective of peak fluctuation, the first peak corresponding to the peak rises and the second peak corresponding to the peak rises rapidly from 2016 to 2020, indicating that the areas with low utilization level of marine biological resources increase, and the progress speed of the areas with high utilization level is faster than that of the areas with low utilization level; From 2018 to 2020, the corresponding peaks of the first peak

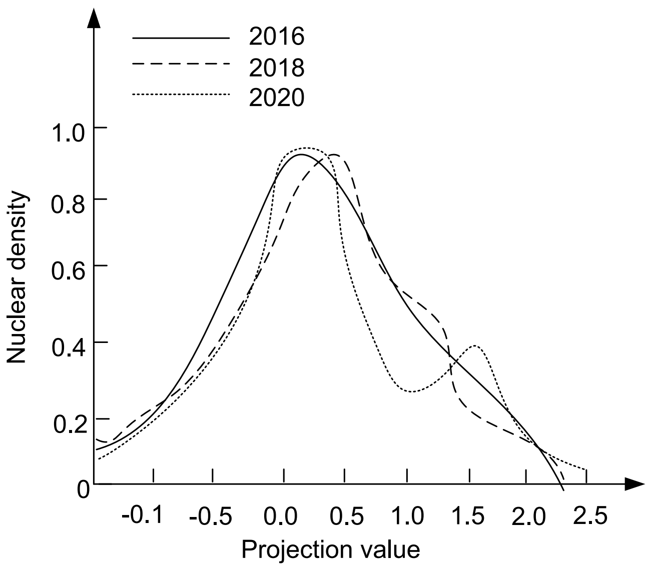

Fig. 1. Distribution density of sustainable use of marine biological resources.

and the second peak show a downward trend, indicating that the areas with low utilization level gradually increase, while the areas with high utilization level decrease; In 2018, the tail of the right peak shifted more to the right, indicating that the polarization of sustainable utilization level of marine living resources is more obvious, and the progress speed of high utilization level areas is much faster than that of low and medium utilization level areas.

2.2. Sustainable development model of marine living resources

In order to obtain the optimal allocation of the sustainable utilization of marine living resources and maximize the net income of the marine industry, a model for the sustainable development of marine living resources is established, and its modeling process is shown in Fig. 2.

Establishing a set of climate factors affecting the sustainable use of marine living resources:

$$S_y = \left\{h(j,k), d(j,k), e(j,k)\right\} \tag{1}$$

Among them, $h(j,k)$ represents the annual average precipitation; $d(j,k)$ represents the annual average evaporation; $e(j,k)$ represents the spatial distribution pattern of climatic elements.

At the same time, environmental factors can be set to:

$$Z' = \left\{Z_1 + Z_2 + Z_g\right\} \tag{2}$$

Among them, Z_1 represents environmental conditions; Z_2 represents the self-purification ability of the ocean; Z_g represents the autonomy ability of marine biological resources. According to Eq. (3), the utility coefficient of a certain marine biological resource can be obtained:

$$W = \left(M + Z_g\right) \times \left(N + Z_g\right) \tag{3}$$

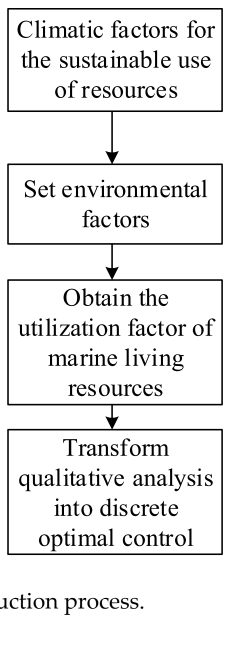

Fig. 2. Model construction process.

Assume that the utility function of generation *a* is $U(a)$, where U represents environmental factors. Although contemporary people are users of resources, the interests of future generations must be considered when deciding how to use marine biological resources, because contemporary people cannot predict the utility function of future generations, and can only look at the utility of future generations from the perspective of contemporary people. function. Under normal circumstances, the way to deal with this problem is to assume that each generation has the same utility function [7].

Sustainable development is the goal of economic and social development pursued by mankind, and the sustainable development of the marine industry is a part of sustainable economic development and has a close relationship with the whole [8]. The sustainable development of economy and society is a long-term process. For each generation, it is necessary not only to consider how many resources to use, but also to further consider the allocation of resources, how much is used for consumption, how much is used for investment, how much is used for pollution control and improvement of the environment, so as to ensure the sustainable development of resources. It is decided from the historical development process that the interests of future generations cannot be sacrificed solely for the interests of the present people [9].

Transform these qualitative analyses into discrete optimal control problems, namely:

$$\begin{aligned} \mu^2(x,y) &= \sum_{s=-a}^{a}\sum_{t=-b}^{b} \cdot \frac{1}{(2a+1)(2b+1)} \\ &= \left\{\left[g(x+a,y+b) - w(x+a,y+b)\right]\right. \\ &= \left.\bar{g}(x,y) - \overline{w(x,y)}\right\}^2 \end{aligned} \tag{4}$$

Among them, $\mu^2(x,y)$ represents the social discount rate; b represents the capital depreciation rate. The objective function expresses the constraints of maximizing human long-term utility. The dynamic optimization process is to make contemporary people not only proceed from their own interests, but also consider the use of future generations. The model is a nonlinear dynamic system, which is stable under certain assumptions [10]. From an intuitive point of view, it shows that human beings are gradually adjusting their own behavior and changing the way of using resources to gradually achieve sustainable goals, thereby gradually reaching the equilibrium point of the system.

2.3. Evaluation methods for the sustainable development of marine living resources

For the assessment of the sustainable development indicator system, the analytic hierarchy process is currently mostly used. At the same time, the sustainable development indicator system structure of marine biological resources also has obvious levels [11]. When using the analytic hierarchy process to evaluate marine biological resources, this article can be roughly divided into the following steps. Fig. 3 shows the evaluation process of the sustainable development of marine biological resources:

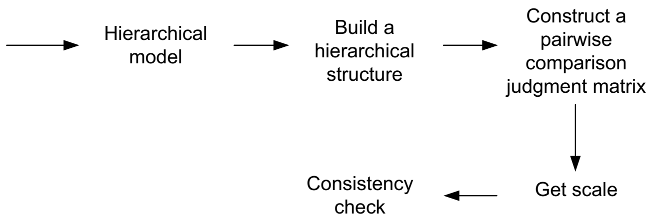

Fig. 3. Evaluation process of the sustainable development of marine biological resources.

2.3.1. Establish a hierarchical structure model

To apply the AHP method to analyze problems in the field of economics, society and scientific management, must first organize and hierarchize the problems, and construct a structural model with clear levels. Under this structural model, complex problems are decomposed into components that people call elements [12]. These elements are divided into several groups according to their attributes, forming different levels. The elements of the same level are used as guidelines to dominate certain elements of the next level, and at the same time, it is dominated by the elements of the previous level. These levels can be divided into three types:

- The highest level: There is only one element in this level. Generally, it is the predetermined goal or ideal result of analyzing the problem, so it is also called the target level.
- Intermediate level: This level includes the intermediate links involved in achieving the goal. It can be composed of several levels, including the criteria and sub-criteria that need to be considered, so it is also called the criterion level.
- The bottom layer: It represents various measures, decision-making plans, etc. that can be selected to achieve the goal. Therefore, it is also called the measure layer or the plan layer.

The dominance relationship between the above levels is not necessarily complete, that is, there can be such an element that does not dominate all the elements of the next level, but only dominates some of the elements. The hierarchical structure formed by this top–down domination relationship is called the hierarchical structure.

The number of levels in the hierarchical structure is related to the complexity of the problem and the level of detail to be analyzed, and there is generally no limit. Generally, there should be no more than 9 elements dominated by each element in each level. This is because too many dominated elements will make pairwise comparison and judgment difficult [13]. A good hierarchical structure is extremely important to solve the problem. Therefore, the hierarchical structure must be established on the basis of a comprehensive and in-depth understanding of the problems faced by decision makers, and clarify the interrelationships between various elements to ensure the establishment of a reasonable level structure.

For the evaluation of sustainable development of marine living resources, according to the membership relationship between the evaluation index system determined above, each factor can be divided into four levels from top to bottom: The highest level, namely the target level (A), is the goal of achieving sustainable development of the ocean; The middle layer is divided into two layers. The planning layer includes 4 indicators, namely, social development indicators (B_1), marine economic indicators (B_2), marine resources and environmental indicators (B_3), and intellectual support indicators (B_4); The criterion level includes 23 indicators, which are represented by C_1, C_2, …, C_{23}, respectively, and the fourth level is the lowest level, which represents the country, region and city being evaluated.

2.3.2. Constructing a pairwise comparison judgment matrix

After the hierarchical structure model is established, the affiliation of the elements between the upper and lower levels is determined. Assuming that the element B of the previous level is the criterion, and the element of the next level dominated are C_1, C_2, …, C_{23}, the purpose of constructing the pairwise comparison judgment matrix is to give corresponding weights according to their relative importance to criterion B When C_1, C_2, …, C_{23}, the importance of criterion B can be directly expressed quantitatively (such as how much value is added, resource consumption, etc.), their corresponding weights can be directly determined. However, for most economic and social issues, especially the more complex issues, the weights of elements are not easy to obtain directly. At this time, it is necessary to derive their weights through appropriate methods [14]. The method of deriving weights used in the AHP method is the method of pairwise comparison.

In this step, the decision-maker has to answer the question repeatedly: For criterion B, which of the two elements C_1 and C_2 is more important, how important is it, and assign a value to the degree of importance on a scale of 1–9. Table 1 lists the meanings of scales 1–9.

For criterion B, each compared element constitutes a pairwise comparison judgment matrix:

$$\varpi_{ij} = \sum_{i,j=1}^{n} S_{ij} + e_{ij} \tag{5}$$

Among them, S_{ij} represents the proportional scale of the element.

Obviously, the judgment matrix has the following properties:

$$\begin{cases} S_{ij} \geq 0 & i = 1,2,...n;\ j = 1,2,...,m \\ e_{ij} < 0 & i = 1,2,...n;\ j = 1,2,...,m \\ \varpi_{ij} = 1 \end{cases} \tag{6}$$

Since the judgment matrix is a reciprocal matrix, according to its properties, for a judgment matrix containing T elements, only $t(t-1)/2$ elements of the upper (or lower) triangle need to be given. In other words, only need to make $t(t-1)/2$ judgments.

In special cases, the elements of the judgment matrix are transitive, that is, satisfy the formula:

Table 1
The meaning of 1–9 scale

Scale 1	Specific meaning.
1	Two elements have the same importance.
3	Of the two elements, the former is slightly more important than the latter.
5	Of the two elements, the former is obviously more important than the latter.
7	Of the two elements, the former is more important than the latter.
9	Of the two elements, the former is extremely important than the latter.
2, 4	Intermediate value of adjacent judgment.
6, 8	The ratio of importance between the two elements is 1.

$$\frac{\left(k-N_g\right)\times N\left(q-1\right)}{2N_t}=M_q \tag{7}$$

According to Eq. (7), if the importance ratio scale between C_1 and B is C_2, then the importance ratio scale between C_2 and C_3 is 3. If the importance scale between C_1 and C_3 is 5, then the relationship between the two satisfies Eq. (7). However, under normal circumstances, the judgment matrix is not required to satisfy the above-mentioned transitivity. Therefore, when Eq. (7) holds for all elements, the judgment matrix can also be regarded as a consistency matrix.

When calculating the single-level ranking weights, consistency checks are also required [15]. As mentioned earlier, in the construction of the judgment matrix, the judgment is not required to be transitive and consistent, that is, Eq. (7) is not required to be established. This is determined by the complexity of objective things and the diversity of human understanding. However, since the judgment matrix is the basis for calculating the ranking weight vector, it is required that the judgment matrix has the general consistency [16]. It is against common sense that "A is extremely important than B, B is extremely important than C, and C is extremely important than party A". And the above-mentioned method of ranking vector is an approximation algorithm. When the deviation of the judgment matrix is too large, the reliability of this approximate estimation is questionable. Therefore, the consistency of judgment matrix needs to be tested, and the steps are as follows:

- The consistency index was calculated:

$$T=\frac{G_{\max}+G_{\min}}{2} \tag{8}$$

Among them, $G_{\max}$ represents the maximum degree of consistency; $G_{\min}$ represents the minimum degree of consistency.

- Find out the corresponding average random consistency index, which is an integer from 1 to 9, corresponding to 0.00, 0.13, 0.24, 0.39, 0.87, 1.25, 1.67, 1.69 and 1.80, respectively. The average random consistency index shows a gradual increase trend.
- Calculate the consistency ratio:

$$p_w=\sum_{i=1}^{N}q_r r_i \,/\, \sum_{i=1}^{N}q_i \tag{9}$$

When $p_w < 0$, the consistency of the judgment matrix is considered acceptable, otherwise the values of the elements of the judgment matrix need to be adjusted.

2.4. Projection pursuit technology

The key to the projection pursuit model is to optimize the projection objective function. The use of traditional function optimization methods usually requires the function to be continuous and derivable, and the amount of calculation is large, which will increase the application difficulty of the model to a certain extent. The projection pursuit technology takes the agent's perception of the surrounding environment as the starting point, and designs new operators to realize the agent's behavior and achieve the goal of optimizing the objective function [17]. The establishment of a projection pursuit evaluation model can more objectively evaluate the sustainable utilization of marine biological resources: First, the information contained in the model is not easy to lose, and the drawbacks of artificial empowerment can be avoided to the greatest extent; Secondly, the use of MGA to find the optimal solution of the objective function has a much faster convergence rate than traditional algorithms, which can improve the accuracy of the calculation results; Finally, the MGA used in the PP model does not need to assign the index weights in advance, and in turn, the index weights can be determined according to the projection results.

Projection pursuit is a new mathematical statistical method for dealing with complex problems with multiple factors. It has unique features in the analysis and processing of high-dimensional, non-linear, and non-normal data, and has been applied to the evaluation of many system fields [18]. The basic idea is to project high-dimensional data to low dimensional subspace through some combination, then set constraints, optimize the projection index function, finally solve the projection value that can reflect the original high-dimensional data structure, and analyze the structural characteristics of the original data. The specific modeling process is shown in Fig. 4.

Analyzing Fig. 4, assume that the m-th index of the n-th sample of the evaluation object is $g(n,m)$, where n = 1, 2, ..., N, m – 1, 2, …, M, N is the number of samples, M is the number of indicators, and $x = (x_1, x_2, …, x_k)$ is the k-dimensional

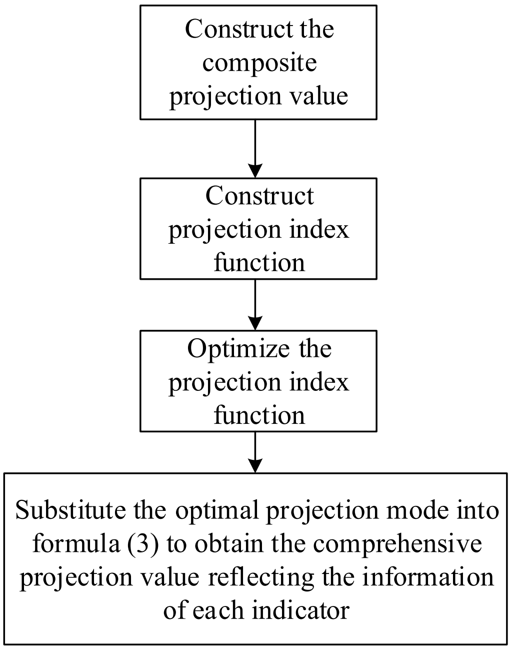

Fig. 4. Modeling process of projection pursuit technology.

unit projection vector, then the comprehensive projection value of the n-th sample is:

$$a_n = \sum_{n=1}^{i} v_n v_x \tag{10}$$

Among them, v_n represents the global convergence coefficient; v_x represents a single projection index.

- Construct the projection index function. First, the indicators are standardized, and the product of the standard deviation and the local density of the comprehensive projection values of each sample is used to construct the projection index function, namely:

$$Z_k = \sum_{n=1}^{i} \sum_{m=1}^{j} C_{nm} X_{nm} \tag{11}$$

- According to Eq. (11), the local density formula can be obtained as:

$$W_f\left(n,m\right) = \sum_{n=0}^{N} r \times R\left(Z_k + x_k\right) \tag{12}$$

Among them, r represents the local density window radius; $W_f(n,m)$ represents the unit step function. When $R \geq r$, the function value is 1, and when $R < r$, the function value is 0.

- Optimize the projection index function. Estimating the best projection direction of the evaluation index by maximizing the objective function is actually a high-dimensional nonlinear function optimization problem. Genetic algorithm (GA), accelerated genetic algorithm (AGA) and particle swarm optimization (PSO) are often used for optimization. These algorithms have the problem of premature convergence. In this paper, multi-agent genetic algorithm is used to optimize the objective function globally, in order to obtain a more reliable and effective optimal solution.
- Comprehensive evaluation. Substituting the best projection direction into Eq. (3), a comprehensive projection value that comprehensively reflects the information of each index is obtained, and the size of the projection value is used as the basis for evaluation.

3. Results and discussion

In order to analyze the impact of climate change on the sustainable use of marine biological resources, a climate change scenario design is carried out, and the sustainable use of marine biological resources under different scenarios is analyzed [19].

3.1. Overview of the study area

The study area belongs to a semi-humid and semi-arid climate, with cold and dry winters and springs, hot and rainy summers, uneven distribution of precipitation during the year, and large inter-annual variability. The annual average precipitation is 554 mm and the water surface evaporation is from 900 to 1,400 mm. Areas with the greatest water pressure. The natural groundwater volume is 22.74 billion m^3/a, the shallow and deep groundwater exploitation levels are 112% and 139%, respectively, and a total of 90 billion m^3 of shallow and deep groundwater has been over-exploited. The deep groundwater level continues to drop below sea level. It has reached 55% of the total area. Due to the long-term impact of natural and human factors, the reduction of forest coverage in the study area not only leads to low water conservation capacity, surface water and soil erosion, and reduction of groundwater volume, but also reduces air humidity and increases the frequency of droughts. On the other hand, in order to meet production and domestic water use for many years, a large amount of groundwater has been exploited in the study area, which has caused the groundwater level to drop drastically, forming the world's largest groundwater fall funnel area.

3.2. Scene setting

In order to assess the impact of climate change on marine living resources, this study sets up one baseline scenario and three simulation scenarios for analysis. The baseline scenario refers to the possible trend of the utilization of marine biological resources in 2030 when there is no climate change disaster impact and no climate change policy disturbance, providing a comparative reference for analyzing the disaster impact of climate change. The three simulation scenarios mainly consider the impact of temperature, precipitation, and humidity on marine biological resources.

3.3. Result analysis

After standardizing the original data, the analysis chart of the marine development trend is directly integrated

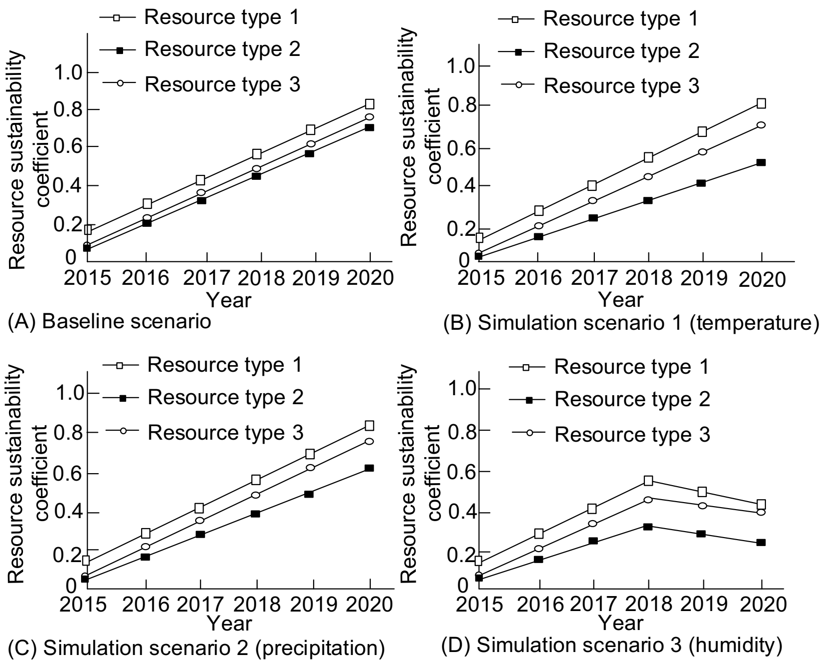

Fig. 5. The development trend of marine biological resources ((A) Baseline scenario, (B) Simulation scenario 1 (temperature), (C) Simulation scenario 2 (precipitation), (D) Simulation scenario 3 (humidity)).

and integrated. Take 2015–2020 as an example to analyze the development trend of marine biological resources, as shown in Fig. 5.

Analyzing Fig. 5, the following conclusions can be drawn:

- The sustainable development of marine biological resources under simulated scenario 1 (temperature): In general, the sustainable development trend of marine biological resources has been rising from 2015 to 2020. It can be seen from the figure that the sustainable development of marine living resources in 2019 has a significant improvement over 2018 and 2017. It can be seen that the climate factor of temperature has a smaller impact on the sustainable development of marine living resources.
- The sustainable development of marine biological resources under simulated scenario 2 (precipitation): The sustainable development of marine biological resources under this simulated scenario is similar to that of simulated scenario 1, and the sustainable development curve of marine biological resources is basically the same. It shows that precipitation also has a small impact on the sustainable development of marine biological resources.
- The sustainable development of marine biological resources under the simulation scenario 3 (humidity): It was initially in the growth stage, reached a peak in 2018, and then declined. It can be seen that humidity will have an impact on the sustainable development of marine biological resources. The change of ocean water level is related to the degree of dryness and wetness of the climate. Compared with the status quo scenario, the development of marine biological resources under humid and normal climate change scenarios will produce certain changes [20].

Marine resource issues do not occur in isolation, and the research must be linked to the development of society and marine economy. To this end, mainly analyze the following contents:

Resource-development comprehensive index L: reflects the relationship between resource consumption and social and marine economic development, that is, the social and marine economic development brought about by a certain resource consumption. The proportional relationship between the two is determined by Eq. (13):

$$L_f = \frac{L(x_i)\cdot L(x_j)}{\sqrt{L(x_i)\cdot L(x_i)}} \tag{13}$$

After standardizing the data, the calculation results are shown in Table 2.

The following conclusions can be drawn from Table 2.

- In general, the consumption of marine biological resources has a greater impact on social and economic development, and it is increasing year by year, reaching a peak in 2018, and then slowly decreasing.
- The impact of the consumption of marine biological resources on the society is basically declining year by year, but the rate of decline is relatively slow, indicating that my country's ocean opening is still in a resource-dependent state, and it needs to optimize the industrial structure and realize the transformation of economic growth mode.

4. Conclusion

Climate change has led to a decrease in precipitation, but human activities cannot be stopped. Therefore, it is necessary to increase the amount of groundwater extraction, which has an indirect impact on the exploitation and development of marine biological resources. Six possible climate change scenarios are designed with and without the implementation of greenhouse gas emission reduction policies. This article is to assess the impact of climate change on the sustainable use of marine living resources, calculate the nuclear density estimation results for the sustainable use of marine living resources, and at the same time obtain the dynamic change characteristics of the sustainable use of marine living resources. Use the AHP method to establish a hierarchical structure model to complete the evaluation of the sustainable development of marine biological resources. Through experimental research, it is concluded that the influence of temperature and precipitation climatic factors on the sustainable development of marine biological resources is relatively small, and humidity will have a certain impact on the sustainable development of marine biological resources.

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