ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

A Study on Policy Simulation and Emulation for the Construction of Marine Ecological Civilization in Guangdong Province Based on System Dynamics

Kaijun Hu[1,a], Jianhua Xiao[1,b,*]

[1]College of Economics and Management, Wuyi University, Jiangmen, China
[a]kaijunhu@126.com, [b]jianhuaxiao1@126.com
**Corresponding author*

Abstract: *The construction of marine ecological civilization is an aspect that cannot be ignored in the development of the marine economy. It involves many issues such as social stability, economic development, technological progress, and environmental governance. During the "13th Five-Year Plan" period, Guangdong Province has made breakthrough progress in building a strong marine province by essentially establishing a demonstration area for strengthening the construction of marine ecological civilization. During the "14th Five-Year Plan" period, Guangdong Province still needs to vigorously promote the construction of marine ecological civilization. This article starts from the aspects of social population, economic development, technological progress, and environmental governance, and constructs a system dynamics model of Guangdong Province's marine ecological civilization. It simulates the construction of Guangdong Province's marine ecological civilization under six different policy scenarios in three categories. The results show that: (1) Maintaining the existing development policy will further improve the level of marine ecological civilization in Guangdong Province.(2) Under a single policy enhancement, the economic policy has the most significant overall promotion effect on the construction of ecological civilization in Guangdong Province, and the birth policy brings The promotion is very limited.(3) Under the combination of policies, although all policy impact factors have only been slightly improved, the synergy between different policies has greatly promoted the construction of marine ecological civilization, further verifying the important significance of development coordination.*

Keywords: *Marine ecological civilization construction, system dynamics, policy simulation*

1. Introduction

The 18th National Congress of the Communist Party of China pointed out that the construction of ecological civilization is an important part of the cause of socialism with Chinese characteristics. It is related to people's well-being and the future of the nation. The construction of marine ecological civilization is one of the key contents of the construction of a maritime power, and it is also a major part of the construction of ecological civilization[1].

Since the 21st century, with the rapid development of the world economy, land resources are scarce and the environment is constantly deteriorating, the ecosystem is teetering on the edge of imbalance. The ocean has become an important area for sustainable and rapid economic development due to its unique spatial and resource advantages, and it has also become a new track for major marine countries in the world[2]. At the time node where economic growth is slowing down, urbanization is continuously improving, and per capita resource ownership is continuously decreasing, it is an inevitable choice for China's economic and social future, especially for coastal provinces such as Guangdong, to base on the construction of marine ecological civilization, adhere to the integrated planning of land and sea, regional linkage, scientifically develop and use marine resources, and adhere to the red line of marine ecological protection.

During the "13th Five-Year Plan" period, the core position of Guangdong Province's marine economic competitiveness continued to consolidate, and the total volume of the marine economy continued to lead. In 2020, Guangdong Province's marine gross production value was 1.7245 trillion yuan, accounting for 15.6% of the region's total production value, and 21.6% of the national marine gross production value, ranking first in the country for 26 consecutive years. But at the same time, there are still a series of shortcomings in the marine development of Guangdong Province, such as weak awareness of land and

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

sea planning. Therefore, the research on the construction of marine ecological civilization in Guangdong Province has certain practical significance.

In recent years, domestic experts and scholars' research on marine ecological civilization mainly focuses on the following aspects: First, the construction index system of marine ecological civilization. Lin Jinlan and others[3] built the construction evaluation system of Beihai City's marine ecological civilization construction demonstration area from four levels of the blue economy system, resource guarantee system, ecological security system, and soft power support system. Feng Cuicui and others[4] constructed a performance evaluation index system for the construction of marine ecological civilization that includes 34 indicators of six subsystems: community, economy, governance, culture, resources, and ecology based on the natural-social-economic conforming ecosystem. The second is the research on the evaluation method of the construction of marine ecological civilization. Di Qianbin and others [5]sorted out existing research from five aspects: conceptual connotation, application neighborhood, evaluation index, demonstration area construction, practical experience, and used the importance index method to select evaluation indicators with greater importance to construct the evaluation index system of marine ecological civilization.

The current research on marine ecological civilization mainly shows the following characteristics: (1) Existing research mainly evaluates the current construction status of marine ecological civilization by constructing an index system, and there is almost no research on the construction of marine ecological civilization from a systematic perspective. (2) Related research using the evaluation system can only analyze past data and cannot focus on subsequent development. (3) In the policy research on the construction of marine ecological civilization, there is relatively little quantitative research on the actual effects of different policies.

This article attempts to use the research method of system dynamics, based on the current situation of the construction of marine ecological civilization in Guangdong Province, starting from key elements such as society, economy, and ecology, and constructing the system dynamics model of the construction of marine ecological civilization in Guangdong Province under different policy intensities, through comparing the effects of single policies and combined policies, provide a basis for decision-making for the construction of marine ecological civilization in Guangdong Province[6-8]

2. System Dynamics Model for Marine Ecological Civilization Construction in Guangdong Province

2.1. System Boundaries

This study constructs a simulation model for the construction of the marine ecological civilization in Guangdong Province based on the research method of system dynamics. Based on current policies, the intensity of a single policy or a combination of policies is increased to analyze the dynamic changes in the level of marine ecological civilization construction in Guangdong Province under different scenarios. The spatial boundary of the simulation model is defined as Guangdong Province, and the time boundary is defined as 2006-2035, with the initial year being 2006, and a time step of one year.

2.2. Assumptions

In order to construct a current, accurate, and scientific system dynamics model, this paper combines the main goals of ecological civilization construction in the "14th Five-Year Plan (2021-2025) for National Economic and Social Development and 2035 Long-term Goals Outline" of the People's Republic of China. Based on theories of sustainable development, ecological economics, public policy, etc., and adhering to the guiding ideology of land-sea integration and regional linkage in the construction of the marine ecological civilization in Guangdong Province, a simulation model of the marine ecological civilization construction is built from the three criteria layers of economy, ecology, and society. The economic layer is represented by the Gross Domestic Product (GDP) and the Gross Ocean Product (GOP); the ecological layer is represented by energy consumption per unit of GOP and industrial waste gas emissions per unit of total value of marine industrial production; the social layer is represented by the number of people employed in marine-related jobs. Due to limitations such as data acquisition, this study proposes the following assumptions to highlight the research object and modeling purpose:

(1)The effectiveness of marine ecological civilization construction in Guangdong Province is measured by relevant indicators from the three criteria layers of economy, ecology, and society.

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

(2)The peel-off method can be used based on national economic industry data, with the ratio of GDP and GOP as the peel-off coefficient for calculating the contribution of some marine economic activities, such as marine industrial waste gas emissions, marine production energy consumption, etc.

(3)The main pollution sources are from industrial production, ignoring pollution from primary and tertiary industries during simulation.

(4)The economy and society operate smoothly, with no significant fluctuations.

2.3. Data Sources

The data required in the model mainly comes from the "China Marine Statistical Yearbook" and the "Guangdong Province Statistical Yearbook" for the years 2007-2017. Due to the absence of data on the number of marine-related employees in 2017, the smoothing prediction method is used to supplement it. For data with very large fluctuations in individual years, smoothing is done using data on both sides to ensure that the model runs smoothly and effectively.

2.4. Data Sources

According to the previous analysis and in combination with the actual situation, this study divides the system dynamics model of marine ecological civilization construction in Guangdong Province into four subsystems: economy, ecology, society, and policy, with the main indicators as shown in Table 1.

Table 1 Structure Index System of Marine Ecological Civilization Construction System in Guangdong Province

Marine Ecological Civilization Construction System	Economic Subsystem	Gross Domestic Production, Gross Ocean Production
	Ecological Subsystem	Marine Production Energy Consumption, Energy Consumption per Unit Gross Ocean Production, Marine Industrial Waste Gas Emissions, Industrial Waste Gas Emissions per Unit Marine Industrial Gross Production Value, Production Energy Consumption
	Social Subsystem	Total Population, Number of Employed, Number of Marine-Related Employees
	Policy Subsystem	Fertility Policy, Marine Economic Policy, Environmental Governance Policy, Science and Technology Policy

In the economic subsystem, the growth or decline caused by production activities determines people's quality of life, the efficiency of energy use, the pollution status of the environment, and impacts the ecological and social subsystems.

In the ecological subsystem, the consumption of energy constrains the production and life of the region, environmental pollution also affects people's quality of life, the treatment of environmental pollution will increase the proportion of pollution treatment funds in total social investment, thereby affecting economic development, therefore the ecological subsystem affects the economic subsystem and social subsystem.

In the social subsystem, people's production and living activities generate economic value, resource consumption, and environmental pollution, affecting the economic and ecological subsystems.

The policy subsystem influences the direction of economic, social, and ecological development through the regulation of policies. The mechanisms of different policies are as follows:

(1) Fertility policy directly affects the population growth rate, thereby affecting other elements such as the number of employed;

(2) Marine economic policy directly affects the number of marine-related employees and the growth rate of GOP, thereby affecting elements such as GOP;

(3) Environmental governance policy affects the status of environmental pollution by influencing industrial waste gas emissions;

(4) Science and technology policy affects fixed asset investment, by improving the proportion used for production technology advancement and energy utilization efficiency in fixed asset investment, further affecting energy consumption per unit GDP. The interaction between the systems is shown in Figure 1.

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

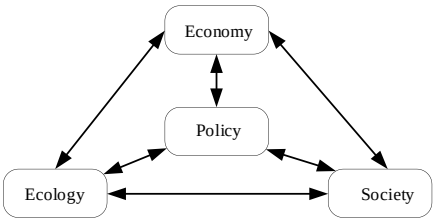

Figure 1: Diagram of the Relationship between the Subsystems of Marine Ecological Civilization Construction

Through the construction of the structure index system of the marine ecological civilization construction system and the analysis of the causal relationship of the subsystems, according to the principle of system dynamics, a system model of marine ecological civilization construction in Guangdong Province is constructed, and the system flow stock diagram is shown in Figure 2.

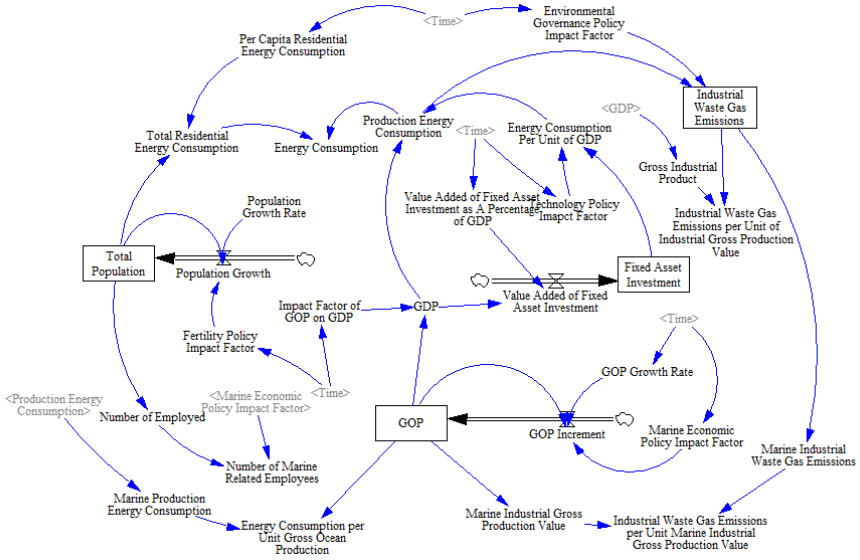

Figure 2: Stock-Flow Diagram of the Marine Ecological Civilization Construction System

Based on the principle of interrelationship and action among the variables in the system, the calculation equations among the variables and the related parameter values are established by combining practical experience and mathematical analysis methods, and the representative equations are shown in Table 2.

Table 2: Main Equations and Parameters of the System Model for Marine Ecological Civilization Construction

No.	Variables	Equation	Unit
1	Total Population	*INTEG* (Population Increase, 9442.07)	Ten thousand people
2	Population Increase	Population Growth Rate × *DELAY 1* (Total Population, 1) × Fertility Policy Impact Factor	Ten thousand people
3	GOP	*INTEG*(GOP Increase, 4113.9)	Billion yuan
4	GDP	GOP × Impact Factor of GOP on GDP	Billion yuan
5	Energy Consumption per Unit of GDP	0.*8487*×*EXP*(-2.689e-05×Fixed Asset Investment × Science Technology Policy Impact Factor)	Tons of standard coal/billion yuan

In these equations:

(1) "INTEG" is a function that calculates the integral of the quantity over time.

(2) "DELAY 1" is a function that delays the input by a certain period, in this case, one time unit.

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

(3) "EXP" is the exponential function.

(4) The "Impact Factor" represents the degree of influence of one variable on another.

3. Model Verification and Scenario Design

3.1. Model Validation

Once the model is constructed, it needs to be validated to ensure that the constructed model matches the real system and can accurately reflect the features and rules of the real system. This study uses the historical validation method, comparing the data obtained from model simulation with historical data to test its fit. According to the focus of the model, four variables: total population, number of marine-related employees, GDP, and production energy consumption were chosen for historical testing. The simulation period was 2006-2017, and the historical values, simulated values, and their relative errors are shown in Table 3.

Table 3 Model Historical Test Comparison Result

Year	Total Population (Ten thousand people)			Year	Number of People Involved in Sea Employment (Ten thousand people)		
	Historical Values	Simulation Value	Relative Error (%)		Historical Values	Simulation Value	Relative Error (%)
2006	9442.07	9442.07	0.00%	2006	709.7	721.36	1.64%
2007	9659.52	9587.48	-0.75%	2007	755.5	735.49	-2.65%
2008	9893.48	9732.89	-1.62%	2008	771.6	749.61	-2.85%
2009	10130.19	9880.53	-2.46%	2009	784.1	763.95	-2.57%
2010	10440.94	10030.42	-3.93%	2010	803.4	778.51	-3.10%
2011	10505	10182.58	-3.07%	2011	820.4	793.29	-3.30%
2012	10594	10337.05	-2.43%	2012	831.6	808.3	-2.80%
2013	10644	10493.86	-1.41%	2013	842.6	823.53	-2.26%
2014	10724	10653.05	-0.66%	2014	852	838.99	-1.53%
2015	10849	10814.66	-0.32%	2015	860.3	854.69	-0.65%
2016	10999	10978.71	-0.18%	2016	868.5	870.62	0.24%
2017	11169	11145.26	-0.21%	2017	899.5	886.8	-1.41%
Year	GDP (Billion yuan)			Year	Production Energy Consumption (Tons of standard coal/billion yuan)		
	Historical Values	Simulation Value	Relative Error (%)		Historical Values	Simulation Value	Relative Error (%)
2006	25961.24	25958.71	-0.01%	2006	16831.29	16701.93	-0.77%
2007	31742.61	31728.87	-0.04%	2007	18642.42	18916.92	1.47%
2008	36704.16	36700.14	-0.01%	2008	19912.81	20304.85	1.97%
2009	39464.69	39498.45	0.09%	2009	20988.23	19912.05	-5.13%
2010	45944.62	45971.32	0.06%	2010	21602.17	20994.29	-2.81%
2011	53072.79	53031.85	-0.08%	2011	22368.55	23689.09	5.90%
2012	57007.74	57048.6	0.07%	2012	23169.44	23676.4	2.19%
2013	62503.41	62511.4	0.01%	2013	23944.36	23789.86	-0.65%
2014	68173.03	68134.89	-0.06%	2014	24589.53	24301.9	-1.17%
2015	74732.44	74671.73	-0.08%	2015	24937.8	24698.94	-0.96%
2016	82163.22	82237.69	0.09%	2016	25873.19	25843.84	-0.11%
2017	91648.73	91656.06	0.01%	2017	26650.41	26913.82	0.99%

The historical test results show that, apart from the relative errors of simulated values of production energy consumption in 2009 and 2011 being more than 5%, the errors in the remaining years are all less than 5%. On the whole, the relative errors between the simulated values and historical values of the chosen variables are generally within 5%. For those few years where the relative error exceeds 5%, the error does not exceed 10%. Therefore, it can be concluded that the system dynamics model of marine ecological civilization construction in Guangdong Province, which was established in the previous sections, is quite reasonable, and can accurately reflect the real situation of the ecological civilization construction system in Guangdong Province.

3.2. Simulation Scenario Design

Guided by the thought and strategic orientation of the "Fourteenth Five-Year Plan", and combining the reality of marine ecological civilization construction in Guangdong Province, this study has selected

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

four representative policies, namely fertility, economy, environment, and technology, to study their dynamic impact on marine ecological civilization construction. The reasons for choosing are as follows:

(1) Under the regulation of the family planning policy, the aging of the population has become increasingly prominent since the 21st century. In 2016, after the full liberalization of the two-child policy, the natural population growth rate has slightly increased, but it is still necessary to optimize the fertility policy to promote long-term balanced population development. Therefore, studying the fertility policy for the construction of marine ecological civilization has a certain value.

(2) China adheres to the core position of innovation in our country's modernization construction, regards self-reliance in science and technology as the strategic support for national development, and also promotes the greening of production methods and reduces the energy consumption of unit GDP. Therefore, studying the impact of science and technology policies on the construction of marine ecological civilization is of certain significance.

(3) In 2020, Guangdong Province accelerated the construction of the "one core, one belt, one area" regional development pattern, strived to build a modern coastal economic belt, inject new vitality into the high-quality development of the marine economy, and cultivated new kinetic energy, so studying marine economic policies is crucial.

(4) Environmental governance policies directly act on all areas of ecological civilization construction. Quantitative analysis of environmental governance policies can better solve prominent environmental problems.

To study the impact of various policies on the construction of marine ecological civilization, this study divides the simulation scenarios into four categories. The first category is the benchmark scenario, which is to keep the current policy unchanged and continue the existing development trend. The second category is a single policy scenario, that is, to increase the strength of each of the four policies. The third category is the combination policy scenario, that is, the strength of the four policies is increased slightly at the same time. The reason for choosing a slight increase is that the implementation of policies cannot be separated from the consumption of a large amount of resources. Although the enhancement of all policy forces can greatly improve the level of marine ecological civilization construction, it is obviously not realistic to maintain the same growth rate as the second type of simulation scenario, so we chose to increase the policy strength slightly at the same time. In summary, this study has set up three categories, a total of six simulation scenarios.

Table 4 Simulation Scenarios and Parameter Settings

Scenario Categor	Policy Model	Parameter Setting			
		Fertility Policy Impact Factor	Marine Economic Policy Impact Factor	Science and Technology Policy Impact Factor	Environmental Governance Policy Impact Factor
Benchmark scenario	Current Policy	1	1	1	1
Single Policy Scenario	Fertility Leadership	1.5	1	1	1
	Economic Leadership	1	1.5	1	1
	Technology Leadership	1	1	1.5	1
	Environmental Leadership	1	1	1	1.5
Portfolio Policy Scenarios	Overall Enhancement	1.1	1.1	1.1	1.1

In the model setting, this study sets the value of each policy impact factor in the benchmark state to 1, which means to maintain the current policy strength. In the single policy mode, the impact factors of each policy are adjusted to 1.5, that is, the policy strength is increased. In the combination policy mode, all policy impact factor values are adjusted to 1.1, that is, efforts are made in all policy areas at the same time. The specific scenario categories and parameter settings are shown in Table 4.

4. Model Verification and Scenario Design

4.1. Simulation Results

Using the Vensim PLE software to simulate the three categories and six policies established earlier,

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

we can determine the effects of Guangdong Province's marine ecological civilization construction in 2025 and 2035 under different policies. The specific results are shown in Table 5, and the related figures are shown in Figures 3.

Table 5: Status of Marine Ecological Civilization Construction in Guangdong Province under Different Policy Strengths

Levels	Variables	Time	Current Policy	Fertility Leadership	Economic Leadership	Technology Leadership	Environmental Leadership	Overall Enhancement
Social	Total population (Ten thousand people)	2025	12571.9	12716.8	12571.9	12571.9	12571.9	12600.8
		2035	14614.6	15553.4	14614.6	14614.6	14614.6	14798.7
	Number of people Involved in Sea Employment (Ten thousand people)	2025	1025.37	1039.45	1194.08	1025.37	1025.37	1062.05
		2035	1223.79	1314.98	1702.58	1223.79	1223.79	1339.22
Economy	GOP (Billion yuan)	2025	32822	32822	34671	32822	32822	33185.1
		2035	63220.3	63220.3	82952	63220.3	63220.3	66779.1
	GDP (Billion yuan)	2025	137852	137852	145618	137852	137852	139377
		2035	189661	189661	248856	189661	189661	200337
Ecology	Marine Production Energy Consumption (Tons of standard coal)	2025	3787.39	3787.39	3961.24	2955.21	3787.39	3636.41
		2035	1742.82	1742.82	1903.84	576.809	1742.82	1420.72
	Energy Consumption per Unit of GOP (Tons of standard coal/billion yuan)	2025	0.115	0.115	0.114	0.09	0.115	0.11
		2035	0.028	0.028	0.023	0.028	0.028	0.021
	Marine Industrial Waste Gas Emissions (Billion cubic meters)	2025	3439.69	3439.69	3619.17	2580.55	2728.76	3124.06
		2035	1328.87	1328.87	1495.1	125.07	729.1	862.98
	Industrial Waste Gas Emissions per Unit Marine Industrial Gross Production Value (Billion cubic meters/billion yuan)	2025	0.26	0.26	0.25	0.19	0.2	0.23
		2035	0.052	0.052	0.045	0.0049	0.029	0.032

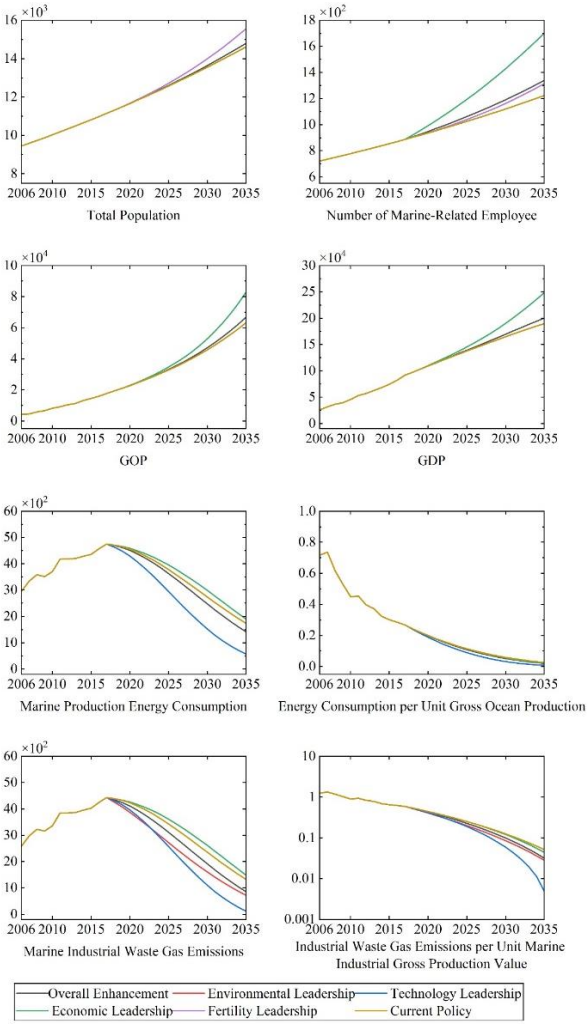

Figure 3: Simulation results diagram

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

4.2. Simulation Result Analysis

The simulation results show that comprehensive promotion of social, economic, ecological, and birth control policies have varying effects on population, employment, GOP, GDP, and ecological factors such as energy consumption and industrial waste gas emissions.

4.2.1. Benchmark Scenario Analysis

Table 5 shows that under the current policy strength, by 2035, the total population of Guangdong Province will reach 14614.6 million, the number of people employed in marine-related jobs will be 1223.79 million, GDP will be 189661 billion yuan, GOP will be 63220.3 billion yuan, marine production energy consumption will be 1742.82 tons of standard coal, the unit GOP energy consumption will be 0.028 tons of standard coal/billion yuan, marine industrial waste gas emissions will be 1328.87 billion cubic meters, and unit marine industrial added value industrial waste gas emissions will be 0.052 billion cubic meters/billion yuan.

4.2.2. Single Policy Scenario Analysis

Under the guidance of the fertility policy, both the total population and the number of employees engaged in maritime activities in Guangdong province significantly increased. By 2035, compared to the baseline scenario, the total population increased by 6.42%, the number of employees involved in maritime activities increased by 7.45%, and energy consumption increased by 2.5%. Although the fertility policy promotes rapid population growth and replenishes the labor force to some extent, the sole emphasis on intensifying the fertility policy without increasing supporting infrastructure has also imposed a considerable burden on energy consumption and the environment.

Under the economic policy, both the GOP and GDP of Guangdong province have notably increased. The growth rate of the GOP continues to accelerate, while the GDP growth rate slightly lags behind. From the growth rates of both, it can be seen that the marine economy has become a new growth pole for the economic development of Guangdong province. Under the economic policy, the number of employees involved in maritime activities has risen significantly, surpassing the fertility-led policy by 29.5%, ranking first. Meanwhile, economic development has also led to an increase in energy consumption and industrial exhaust emissions, which are 5.55% and 12.94% higher than the baseline scenario, respectively. Notably, although under this policy the emission of industrial exhaust gases from the marine industry ranks first, the emission per unit of the total output value of the marine industry ranks fourth, a slight improvement from the baseline scenario. The reason may be that the economy has achieved high-quality development, and the production process has become greener and more environmentally friendly.

Under the guidance of the technology policy, the consumption of marine energy and the emission of industrial exhaust gases have significantly decreased, far below other policy modes, and are only 33.1% and 9.41% of the baseline scenario, respectively. Under the technology-led policy, the continuous innovation of production methods has reduced the need for traditional energy sources, reduced environmental pollution, and provided new ideas for the construction of an ecologically friendly and resource-saving society.

Under the environmental policy, the emission of industrial exhaust gases from the marine industry has decreased to a certain extent, being only 55% of the baseline scenario. Compared with technology-led policy, the environment-led policy held the advantage before 2023. However, from 2023 to 2035, the technology-led policy made a significant counter-surpass. Therefore, to control environmental pollution, we should start at the source. Environmental management policies can only solve urgent needs.

4.2.3. Combined Policy Scenario Analysis

From the simulation data and graphics, the comprehensive improvement model performs best in terms of energy consumption per unit of total marine production value. It ranks third in the emission of industrial exhaust gases from the marine industry and the emission of industrial exhaust gases per unit of added value in the marine industry, while it ranks second in other indicator data. Although only a slight influence was exerted on each policy, the combination of the four policies nevertheless demonstrates an extraordinary vitality.

5. Conclusion

This study, following a comprehensive analysis of the development of the marine economy and the

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

construction of marine ecological civilization in Guangdong Province, has combined related theoretical research on the construction of ecological civilization, and elucidated the feedback mechanisms among the main factors. With the help of the research method of system dynamics, a system dynamics model for the construction of marine ecological civilization in Guangdong Province has been constructed. According to the needs of social development progress, single policy and combination policy simulations have been set up, in order to observe the dynamic situation of the construction of marine ecological civilization in Guangdong Province under different policy intensities. The following conclusions have been reached after conducting a simulation analysis with the model:

(1) Under the current policy conditions, as long as all policies are implemented well, the overall level of marine ecological civilization construction in Guangdong Province can achieve the expected goals. The development advantage of the green ecological layer is significantly greater than the advantages of the economic development layer and the people's livelihood layer.

(2) Under the simulation of single policies, the fertility-led mode is relatively single, almost only having a significant effect on the growth of the total population, and its effect on the employment population related to the sea is not as good as the economic leading mode. In the economic-led mode, the number of people employed in marine-related jobs has a significant increase compared to other modes, and the simulated values of GDP and GOP rank in the first tier, while the performance of marine production energy consumption is at a moderate level, and the energy consumption per unit of GOP ranks second. Therefore, under the single policy scenario, the economic-led mode has the greatest promoting effect on the construction of marine ecological civilization, and there is an improvement in economic, social, and ecological aspects. Under the technology-led mode, the efficiency of energy utilization is optimal, and the production energy consumption and industrial exhaust gas emissions are significantly reduced, which is particularly prominent in terms of resource conservation and ecological protection. In the environment-led mode, in the short term, its pollution control capacity is outstanding, but over a longer period, its effect is not as good as the technology-led mode.

(3) The simulation results of the combination policy show that although some indicators perform excellently under the single policy mode, the effect of the combination policy is the best overall. Therefore, society, economy, and ecology must maintain coordinated development in order to promote the construction of marine ecological civilization at a faster pace.

In summary, while continuously developing the economy and society, efforts must be made to solve energy and ecological problems. We must strictly adhere to the upper limit of energy consumption, the bottom line of environmental quality, and the red line of ecological protection, and construct marine ecological civilization from multiple perspectives.

Acknowledgements

This research was supported by the Humanities and Social Sciences Research Planning Fund of the Ministry of Education, Project No. 21YJA630097; Hong Kong and Macao Joint Research and Development Fund of Wuyi University, Project No. 2021WGALH20.

References

[1] He Decheng. Evaluation Study of Development Level of Marine Ecological Civilization in China [D]. Liaoning Normal Universit, 2019

[2] Ma Jun. Study on Evaluation and Promotion Strategy of Marine Ecological Civilization Construction in Shandong Province [D]. University of Science and Technology of China, 2020

[3] Lin Jinlan, Lai Tinghe, Chen Yuan, et al. Preliminary analysis on evaluation indicators of national marine ecological civilization demonstration zone construction in Beihai [J]. Marine Environmental Science, 2018, 37(06): 871-878.

[4] Feng Cuicui, Ye Guangqiong, Zeng Jiangning, et al. Research of performance evaluation of marine ecological civilization construction in Zhejiang province [J]. Journal of Zhejiang University(Science Edition), 2021, 48(05): 584-591.

[5] Di Qianbin, Zhou Hui. Research on the interaction between population development and marine economy in China's coastal areas [J]. Marine Science Bulletin, 2019, 38(05): 499-507.

[6] Liu Kaidi, Yang Duogui, Wang Guanghui, et al. Policy Modeling and Simulation on Ecological Civilization Construction in China Based on System Dynamics [J]. Chinese Journal of Management Science, 2020, 28(08): 209-220.

ISSN 2706-6827 Vol. 5, Issue 7: 134-143, DOI: 10.25236/IJFS.2023.050722

[7] Chen Weidong, Gu Peiliang, Liu Bo. The Dynamic Simulation of a SD Model on Ocean Sustainable Development of China [J]. Mathematics in Practice and Theory, 2009, 39(21): 21-30.
[8] Tong Hefeng, Yang Yang, Wang Jingyi, et al. Modeling China's Green Economy 2050:Scenario Analysis Based on the System Dynamics Model [J]. China Soft Science, 2015, (06): 20-34.