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Marine Ecological Governance Under New Media Environment: Tripartite Evolutionary Game and Simulation Analysis

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Based on the general reality that new media with massive information and strong interactivity play an increasingly prominent role in marine ecological governance, this study introduces the coastal public participation mechanism under the new media environment. Furthermore, based on the assumption of limited rationality, an evolutionary game model among local governments, marine enterprises, and the coastal public is constructed to explore the changes in game strategies among the three participating subjects over time. Then, we used MATLAB to simulate and analyze the evolutionary stabilization strategies under different parameters by combining our research data on governments at all levels, marine enterprises, and the coastal public in 14 cities in coastal areas of China. The study shows that: 1) an objective and a fair new media environment exert a positive guiding effect on marine ecological governance, whereas a false and distorted one will lead to chaos in marine ecological governance. 2) Considering the high accuracy of new media reports, the higher the sensitivity of the local governments and marine enterprises to media reports, the more inclined they are toward strong regulation and active governance. 3) The local governments can effectively restrain the marine hazard behavior of the marine enterprises by increasing penalties and environmental protection taxes, and it is equally important to guide marine enterprises to fully utilize high and new technology in the marine industry for improving economic benefits and reducing governance costs. 4) Coastal public participation can effectively compensate for the local governments' regulatory loopholes and can reduce the cost of government regulation. Therefore, for ensuring objective reports of new media by establishing reward and punishment mechanisms and regularly selecting excellent new media, using new media to enhance the level of marine publicity and education to encourage the coastal public to widely and fully participate in marine ecological governance is an effective means.

Keywords: new media environment, marine ecological governance, evolutionary game, numerical simulation, coastal public participation, accuracy of new media reports

INTRODUCTION

The overexploitation of marine resources, severe pollution of the marine environment, and increasing frequency of marine disasters have highlighted the crisis of sustainable development in coastal areas, which has gradually become a global focus. In recent years, the research on marine ecology by global scholars has been roughly classified into four aspects. First, the analysis of marine environmental regulation strategies based on evolutionary game theory, which mainly focuses on four levels—the environmental regulation strategy between governments (Wei, 2020), the environmental behavior of governments and enterprises (Du et al., 2021), the environmental behavior of governments and individual stakeholders (Ding et al., 2021), and the game of multiple interests of various subjects related to the process of environmental regulation (Wan et al., 2021; Xu et al., 2021). Second, from the perspective of marine pollution sources, scholars have proposed that the main factors of marine pollution include land-based pollution (Li et al., 2017), ship oil spill pollution (Cross, 1992), oil exploration (Xie et al., 2014), and marine accidents (Bailly du Bois et al., 2012). These sources of pollution compromise seawater quality, destroy marine biodiversity, and disrupt the normal operation of the marine ecosystem. Third, from the perspective of the impact of marine economic and social development on marine ecology, researchers suggested that although activities for marine development promote marine economic growth, they seriously alter the sustainability of marine ecosystems (Mcnelis and Schweitzer, 2001). The relationship between the two is more of an N-shaped relationship than a simple linear relationship (Wang et al., 2014). In addition, Wang et al. (2020) and Wu et al. (2020) pointed out that the coordinated development of marine ecology and economy is inseparable from the improvement of the levels of marine scientific and technological innovation. Finally, the fourth aspect involves the solution to marine ecological problems from the perspective of marine management mechanisms. Some scholars believe that the root of the increasingly severe marine ecological situation lies in the lack of coordination between marine management systems (Wang and Song, 2017), and put forward a collaborative governance mechanism with the government as the core and the participation of enterprises, the public, social organizations, and other subjects (O'hara, 1988; Castilla, 2000; Cicin-Sain and Belfiore, 2005). Moreover, it includes cross-boundary protection mechanisms between governments (Guerreiro et al., 2010) and the overall governance theory (Tissot et al., 2009) to reduce the cost and improve the efficiency of government supervision. In summary, scholars have made a detailed analysis of marine ecological problems from various viewpoints and provided suggestions for governance. Thus, scholars agree that marine ecological governance requires the joint participation of multiple subjects.

First, the government plays an important regulatory role in the process of marine ecological governance. However, government regulation does not always exhibit self-discipline and effectivity due to the existence of objective problems, such as opportunism (King and Lenox, 2000), the vague division of labor, and the duplication of functions (Khalid, 2016). Since enterprise development is crucial to the country's economic growth (Abbas et al., 2019c), it is easy for local governments (LGs) to deregulate marine enterprises (MEs) in order to maintain local economic growth (Cao et al., 2019; Liu and Lin, 2019; Yu et al., 2019), leading to further deterioration of marine ecology. With the increasing global attention on ecological issues, perfecting government regulation mechanisms and improving the level of regulation are urgent aspects. On the one hand, the regulatory mechanism of the government should be improved; moreover, the effect of marine ecological governance should be incorporated into the performance assessment system of the government (Gerhardinger et al., 2011). Another important aspect is strengthening communication and cooperation among all relevant government agencies at varying levels to enhance the exchange of information and benefits (Backer et al., 2010; Carollo and Reed, 2010). Doing so can effectively avoid the situation of each government or institution acting independently (Gerhardinger et al., 2006). On the other hand, the government should also recognize the important role of the public (Wan et al., 2021) and new media (Potts et al., 2016) in the regulation of marine ecology. Public participation can compensate for the lack of government regulation and become an important factor that influences the environmental behavior of enterprises (Kostka and Mol, 2013). Moreover, new media can provide the government with effective information channels, reduce the cost of government supervision, and reduce asymmetry in information (Aerts and Cormier, 2009).

Second, as the main body of governance, the public can supplement the unity of the government in marine ecological governance (Abe et al., 2016). For example, Busenberg (2007), Kathuria (2007), Dasgupta et al. (2001), and Trucco (2016) confirmed the role of the public in improving the effect of ecological governance through studies on public participation in the process of environmental policy-making. As such, public participation in ecological governance cannot only reduce governance costs but also enhance the awareness of the public about environmental protection (Dasgupta et al., 2001; Driessen et al., 2012), which is a cheap and effective strategy. To improve public participation, it is necessary to establish an ecological governance system with clear rights and responsibilities, rich paths, and smooth channels (Peschard, 2007).

With the progress of information technology, media forms are constantly changing, new media has rapidly replaced traditional media to become the mainstream of information transmission (Tur and Homsi, 2017), and the guidance and scope of social public opinion have greatly changed. Different from the one-way and fixed nature of traditional media, new media have the characteristics of instantaneousness, openness, interactivity and niche, which in turn make the information exchange between societies more convenient (Abbas et al., 2019a) and better promote the universality and enthusiasm of public participation in governance (Yang and Su, 2020). In turn, new media has fostered a better understanding among the public regarding the effects of marine ecological governance, thereby effectively improving social supervision and exerting a great impact on marine ecological governance. New media reports

can form a more effective external regulatory force for enterprises (Borochin and Cu, 2018) and improve the management decisions of enterprises by affecting their reputation (Liu and McConnell, 2013), thus enhancing their sense of social responsibility (Li et al., 2019), and reducing the probability of behavior which adverse to the public (Li et al., 2017), which can increase the public's willingness to purchase the products or services from socially responsible companies (Awan and Raza, 2012) and enhances their sustainable performance (Abbas et al., 2019b). When the ecological destruction behavior of enterprises is exposed, they will pay high violation costs in exchange for the loss of their reputation (Core et al., 2008). One can easily see that enterprises have not only faced the direct supervision of the LGs but have also been constrained by the external public opinion of new media. In other words, new media and the government have formed a dual supervision over enterprises. At the same time, great changes due to the rise of new media have occurred for LGs in terms of the information dissemination pattern and environment, which has led to great challenges for government public relations. When faced with the report of their dereliction of duty, controlling the spread of relevant scandals will be difficult for LGs, and a loss of credibility will occur among governments. Research has indicated that new media can judge the situation and identify disadvantages in the supervision of social and ecological events, which is an important supplement to administrative means. However, distorted reports from new media will cause adverse ecological problems to be ignored or even exacerbated by inciting public opinion and diverting public attention (Pennycook et al., 2020; Kapantai et al., 2021). This aspect will cause great harm to the process of social development. Therefore, the government should ensure the accuracy of reports and strengthen the qualification evaluation and real-time supervision of authoritative new media platforms before encouraging them to participate in governance (Wang and Guo, 2020).

Scholars point out that the government should adapt to the characteristics of the new media era in a timely manner in the process of promoting the transformation of marine ecological governance from the sole governance of governments to multiple co-governance. Although it utilizes new media and the public to participate in governance, the government should also attach importance to the objectivity and authenticity of new media reports. Therefore, this study considers the public participation mechanism under new media environment, constructs a three-party evolutionary game model among LGs, marine enterprises and coastal public (CP), analyzes the evolutionary stabilization strategies of each party and the influence of parameter changes on strategy choice, and then combines our research data on governments at all levels, MEs and CP in 14 coastal cities in China, and conducts numerical simulations using MATLAB 2020b. MATLAB 2020b was used to conduct numerical simulations to verify the results of our theoretical analysis. This study addresses the following questions: What role can the CP play in marine ecological governance under the new media environment? How can the change in the accuracy of new media coverage affect the strategic choices of various parties? How should government departments promote the active participation of all parties in marine ecological governance? In summary, the research in this study mainly follows three key points. The first point involves bringing the CP into the research framework of marine ecological governance and fully considering the role of the CP in the supervision of marine ecological governance to promote the practicality of research results. Second, based on the general reality that the role of new media in marine ecological governance is becoming increasingly prominent, this study constructs a three-party evolutionary game model that involves the LGs, MEs, and CP and discusses the influence of the accuracy of new media coverage on the equilibrium point between pure strategy and the mixed strategies of the three parties. Third, through the derivation and solution of the game model in the context of changes in various parameters, the study accurately describes the dynamic impact law of various parameters on marine ecological governance. These parameters include the influence of new media reports on the LGs and MEs, the punishment of the LGs, the supervision cost of the LGs, the participation cost of the CP, and the participation income of the CP.

This study first introduces the background of marine ecological governance, then makes assumptions and constructs the evolutionary game model in the model assumptions and construction. In the model analysis of each game subject, the stability of each party's strategy is analyzed, and in the stability analysis of the evolutionarily stable strategy (ESS), the stability of the strategy combination is analyzed according to Lyapunov's stability theory. In simulation analysis, we combined our research data with numerical simulations using MATLAB 2020b to analyze the effects of different parameter changes on the evolutionary stable strategy combinations, and finally, we give our results and suggestions and explain some research limitations of this study. From the abstract, introduction, and method to the results and discussion of this study, we draw on some excellent references to improve our study (Awan and Raza, 2012; Abbas et al., 2019a; Abbas et al., 2019b; Golinska-Dawson and Spychała, 2019).

MODEL ASSUMPTIONS AND CONSTRUCTION

The logical relationship between the subjects of the three-party evolutionary game of marine ecological governance under the new media environment constructed in this study is shown in **Figure 1**.

Model Assumptions

To analyze the evolutionarily stable strategy of all parties and the relationship between various elements, the game model is constructed and the following assumptions are made:

Assumption 1. The MEs denote Player 1, the CP is Player 2, and the LGs represent Player 3. The three parties are limited rational participants, and the strategy selection is stable in the optimal strategy with the changes over time.

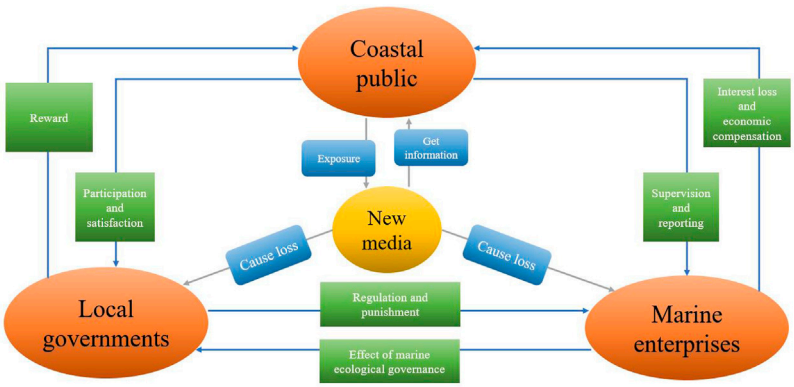

FIGURE 1 | Diagram of the logical relationships in the tripartite evolutionary game model.

Assumption 2. Due to the fluidity of water, the pollution of land-based rivers has become the major contributor to the pollution of the seas (Chen et al., 2021). Therefore, the scope of the MEs includes not only coastal enterprises but also inland river basin enterprises involved in land-based pollution discharge. MEs are not only the destroyer but also the administrator of marine ecology. MEs, as absolutely rational economic men, are driven by the pursuit of the maximization of economic benefits; therefore, MEs typically continue to expand production, ignore the discharge of pollutants into the sea, and reduce the cost of pollution control. However, as one of the subjects of marine ecology governance and under external incentives and supervision, MEs can effectively reduce pollutant emissions, realize the intensive utilization of marine resources, win social reputation and bring higher profits (Mubeen et al., 2021). These actions can be achieved by improving production technology, implementing lean management, changing production modes, and optimizing business processes. In view of this notion, the strategic space of the MEs can be classified into positive and negative governance. The proportions of positive and negative governance are denoted as x and $1-x$, respectively, where $x \in [0,1]$.

CP refers to social groups and individuals affected by the goal of marine ecological governance. On the one hand, the CP has always been in a passive position as a direct victim of marine pollution, with a weak awareness of participation in governance and a significant free-riding behavior. On the other hand, given the improvement in the CP's awareness of marine environmental protection and the enrichment of external incentive measures in some areas, a certain level of enthusiasm for participating in marine ecological governance has been effectively stimulated among the CP. The main forms of the participation of the CP are not limited to resisting MEs through supervision, reporting, and public prosecution but also include participating in the formulation and implementation of government policies and promoting publicity and education on environmental protection. Therefore, the strategy selection of the CP can be classified into "participation" and "nonparticipation," having the following respective proportions: y and $1-y$, where $y \in [0,1]$.

The strategy of LGs can be classified into "strong regulation" and "weak regulation." Regardless of the strategy, LGs will finally bear the governance cost of marine ecology to avoid superior accountability and protect territorial ecological, economic, and social interests. Under the "strong regulation" strategy, LGs actively respond to CP reports, thereby regulating and controlling the violations of the MEs; the proportion of "strong regulation" is denoted by z. Under the "weak regulation" strategy, LGs ignore marine ecological problems to achieve the purpose of economic development or political performance assessment, indulge in harmful behavior of enterprises, or opt to relax the regulation on MEs due to the high regulation cost. The proportion of choosing "weak regulation" is $1-z$, where $z \in [0,1]$.

Assumption 3. The income of the MEs under normal operations is R, whereas long-term additional income due to "active governance" is R', including social income from the improvements in corporate reputation, production efficiency due to the improvement in green technology, and profit from the improvement of product quality. The cost of "active governance" is C_E, which includes the costs of improving enterprise production technology and pollution control (proportion: $C_E > R'$). When selecting negative governance, the cost of being discovered by LGs is F, which includes LG fines and additional environmental taxes; F denotes the income of the LGs.

Assumption 4. When MEs opt for "active governance," marine ecology is improved, and the benefit obtained by the government is G_1. These benefits include ecological benefits, such as clean marine ecology, which ensures the sustainable supply of marine resources; economic benefits, such as additional local investments due to improvement in the marine ecology; and social benefits, such as the relative stability of local society. The benefit of the CP is denoted as P_1, which includes ecological benefits, such as healthy marine ecosystems that reduce the incidence rate of diseases; economic benefits, such as the development of coastal ecotourism that provides more jobs; and social benefits, such as house prices that match the ecological level and convenient supporting service facilities. On the contrary, if MEs opt for

TABLE 1 | Model parameters and definitions.

Player	Parameter	Description
Marine enterprises	R	Basic income of the MEs in normal operation
	R'	Long-term benefits increased by the MEs' active governance
	C_E	Cost of the MEs' active governance
	D_1	Losses to MEs caused by new media reports
Coastal public	P_1	Benefits to the CP when marine ecology is good
	P_2	Benefits lost by the CP when the marine ecology is poor
	C_P	Cost of the CP's participation in marine ecological governance
	P'	Spiritual benefits from successful CP supervision of the MEs
	A	Rewards given by the government after the CP reported successfully
	M	Economic compensation to the CP by MEs
Local governments	F	The fine paid by MEs after destroying marine ecology is also the income of the LGs
	G_1	The benefits obtained by the LGs when the marine ecology is good
	G_2	LGs will lose profits when the marine ecology is poor
	C_G	Costs paid by the LGs after accepting CP reports
	C_G'	The governance cost invested by the LGs after the MEs damage the marine ecology
	D_2	Losses to the LGs caused by new media reports

negative governance, then the LGs and CP will lose the abovementioned benefits, which are represented as G_2 and P_2, respectively.

Assumption 5. The cost of the CP participation in marine ecological governance is C_P, which includes information and economic costs. In particular, information cost refers to the cost of obtaining information on marine ecological governance, whereas economic cost refers to the funds paid by the CP to participate in marine ecological governance, including petition and prosecution costs. When LGs select strong regulation, then they will respond to the CP report. If the MEs commit violations, then the CP report will bring additional spiritual benefits to the CP, which is recorded as P', and obtain economic compensation from the MEs, which is denoted as M.

Assumption 6. If LGs select the "strong regulation" strategy, their cost after accepting public reports is C_G, which includes the supervision cost of the MEs. If the violations of the MEs are verified, then the reporting CP will be rewarded by LGs, and the reward amount is denoted as A. After MEs damage the marine ecosystem, the cost of governance invested by the LGs is denoted as C_G'.

Assumption 7. The report of new media will lead to certain losses for MEs, such as the loss of corporate social reputation, economic compensation to the CP, decline in share price, loss of customers, and other business losses. Indeed, the report will also lead to certain losses for LGs, including the decline of government credibility and the accountability of high-level governments, which are recorded as D_1 and D_2, respectively.

Assumption 8. If LGs select the "weak regulation" strategy, the CP cannot get the LGs' response to the reporting behavior of MEs, and the probability of independent exposure to new media will increase to put pressure on LGs and MEs. However, the reports of new media are not always true and reliable, such as deliberately falsifying facts to discredit a competitor or expressing with subjective intention, which will lead to the miscommunication of reported events and to misunderstandings of the outside world. We assume that the probability of correct media exposure is α, and the probability of false reporting is $(1-\alpha)$. **Table 1** presents the description of each parameter of the model.

Model Construction

According to the abovementioned assumptions, the evolutionary game payment matrix among MEs, CP, and LGs is constructed, as shown in **Table 2**.

MODEL ANALYSIS OF EACH GAME SUBJECT

According to the evolutionary game matrix, the expected and average returns of the MEs, CP, and LGs are calculated, following which the replication dynamic equation of each subject is constructed.

Analysis of Strategic Stability of the Marine Enterprises

Based on the payment matrix in **Table 2**, the expected returns corresponding to different strategy choices are calculated, and the replication dynamic equation of the MEs evolutionary game is constructed.

The expected return for active governance is U_E^1:

$$U_E^1 = yz(R + R' - C_E) + y(1-z)[R + R' - C_E - (1-\alpha)D_1] + (1-y)z(R + R' - C_E) + (1-y)(1-z)(R + R' - C_E).$$

The expected return of the MEs opting for negative governance is U_E^2:

TABLE 2 | Game payment matrix of the three parties.

		Coastal public	Local governments	
			Strong regulation (z)	Weak regulation (1−z)
Marine enterprises	Active governance (x)	participation (y)	$R + R' - C_E$, $P_1 - C_P$ and $G_1 - C_G$	$R + R' - C_E - (1-\alpha)D_1$, $(1-\alpha)(M + P') + P_1 - C_P$, and $G_1 - (1-\alpha)D_2$
		Non participation (1−y)	$R + R' - C_E$, P_1, and G_1	$R + R' - C_E$, P_1, and G_1
	Negative governance (1−x)	participation (y)	$R - F - M$, $A + P' + M - P_2 - C_P$, and $F - G_2 - C_G - C_G^{'} - A$	$R - \alpha D_1$, $\alpha(P' + M) - P_2 - C_P$, and $-G_2 - \alpha D_2 - C_G^{'}$
		Non participation (1−y)	R, $-P_2$ and $-G_2 - C_G^{'}$	R, $-P_2$, and $-G_2 - C_G^{'}$

$$U_E^2 = yz(R - F - M) + y(1-z)(R - \alpha D_1) + (1-y)zR + (1-y)(1-z)R.$$

The average expected return of the decision-making behavior of the MEs is $\overline{U_E}$:

$$\overline{U_E} = xU_E^1 + (1-x)U_E^2.$$

According to the evolutionary game theory, the replication dynamic equation for MEs for selecting active governance is as follows:

$$F(x) = \frac{dx}{dt} = x\left(U_E^1 - \overline{U_E}\right) = x(1-x)\left[R' - C_E + yz(F+M) + y(1-z)(2\alpha - 1)D_1\right].$$

Find the first-order partial derivative of $F(x)$ with respect to x as follows:

$$\frac{dF(x)}{dx} = (1-2x)\left[R' - C_E + yz(F+M) + y(1-z)(2\alpha-1)D_1\right].$$

Make $U(y) = [R' - C_E + yz(F+M) + y(1-z)(2\alpha-1)D_1]$. From $U(y) = 0$, $y_0 = \frac{C_E - R'}{z(F+M) + (1-z)(2\alpha-1)D_1}$; when $y = y_0$, $\frac{dF(x)}{dx} \equiv 0$; when $y \neq y_0$, we need to discuss α. If $0 < y_0 < 1$, then $\alpha > \frac{1}{2} - \frac{z(F+M)}{2(1-z)D_1}$.

Conclusion 1. When the probability of the authenticity of new media reports is high and if the CP tends to opt for the "participation" strategy, then the probability of the MEs selecting "active governance" will approach 1. On the contrary, if the CP tends to select the "non-participation" strategy, then the probability of the MEs opt for the negative governance strategy will approach 0.

Proof: If $y = y_0$, then $U(y) = 0$, because $U(y)$ is an increasing function of y, which indicates that the points on the x-axis are in a stable state, i.e., the strategy selection of the MEs remains the same over time. If $y \neq y_0$, then x = 1 and x = 0 are the possible ESSs of F(x). According to the stability theory of the replication dynamic equation, if $\frac{dF(x)}{dx} < 0$, then this point is the ESS (Friedman, 1991), and $\frac{dF(x)}{dx} = (1-2x)[R' - C_E + yz(F+M) + y(1-z)(2\alpha-1)D_1]$.

(1) If $0 < y_0 < y < 1$, then $U(y) > 0$, $\frac{dF(x)}{dx}|_{x=1} < 0$, and $\frac{dF(x)}{dx}|_{x=0} > 0$; therefore, $x^* = 1$ is the ESS.
(2) If $0 < y < y_0 < 1$, then $U(y) < 0$, $\frac{dF(x)}{dx}|_{x=1} > 0$, and $\frac{dF(x)}{dx}|_{x=0} < 0$; therefore, $x^* = 0$ is the ESS.

The abovementioned conclusions can be expressed in three-dimensional coordinates, and the dynamic evolution trend of the behaviors of the MEs can be obtained, as shown in **Figure 2**.

Conclusion 1 indicates that media reports speak using facts in a fair and objective new media environment. At this time, the choice of strategy of the MEs is closely related to the behavior of the CP. When the probability of the CP's participation in marine ecological governance increases, MEs tend to govern actively. When MEs select the "active governance" strategy, they undertake a series of marine eco-friendly behaviors. Even if they are monitored by LGs or exposed by new media at this time, their positive behaviors related to marine ecological governance do not cause serious consequences; as such, the actual reputation and operation losses are small. In contrast, if the CP does not participate in marine ecological governance and tolerate the actions of the MEs, then MEs will be increasingly inclined to choose the negative governance strategy, which is inconducive to the maintenance of public interests in marine ecology.

Figure 2 indicates that volume V_1 on the left side of y_0 represents the probability that MEs choose negative governance, whereas V_2 on the right side of y_0 represents the probability that MEs select active governance. From the calculation, we derived the following equations:

$$V_1 = \int\int \frac{C_E - R'}{z(F+M) + (1-z)(2\alpha-1)D_1} dxdz = \frac{C_E - R'}{F + M - (2\alpha-1)D_1} ln \frac{F+M}{(2\alpha-1)D_1},$$

$$V_2 = 1 - \int\int \frac{C_E - R'}{z(F+M) + (1-z)(2\alpha-1)D_1} dxdz = \frac{C_E - R'}{F + M - (2\alpha-1)D_1} ln \frac{F+M}{(2\alpha-1)D_1}.$$

Conclusion 2. When the other parameters remain unchanged, the probability of the MEs selecting the active governance strategy will increase with the increase in long-term additional income R'

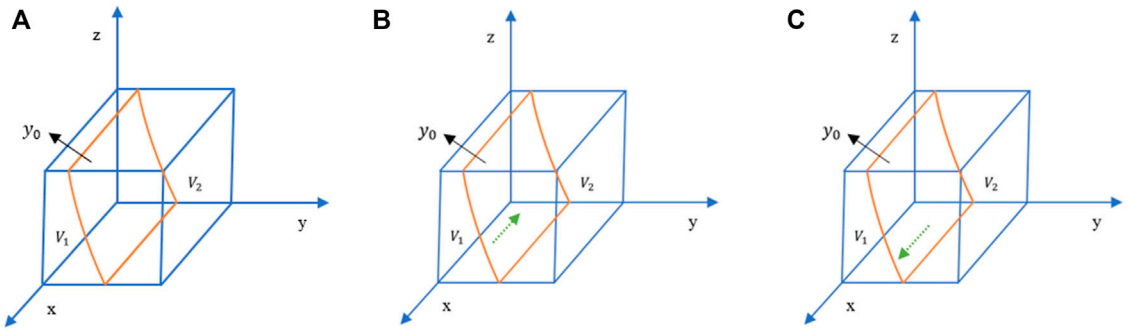

FIGURE 2 | Dynamic evolution trend of the behaviors of the Marine enterprises. **(A)** $y = y_0$. **(B)** $y < y_0$. **(C)** $y > y_0$.

after active governance, the punishment F of the LGs, economic compensation M to the CP, and loss D_1 due to new media exposure. Alternatively, this probability decreases with the increase in marine ecological cost C_E.

Proof: Find the first-order partial derivative of each element for V_2, then $\frac{\partial V_2}{\partial R'} > 0$, $\frac{\partial V_2}{\partial F} > 0$, $\frac{\partial V_2}{\partial M} > 0$, $\frac{\partial V_2}{\partial D_1} > 0$, and $\frac{\partial V_2}{\partial C_E} < 0$. Therefore, if R', F, D_1, and M gradually increase or if C_E gradually decreases, then the volume of V_2 increases, i.e., the probability of the MEs selecting the active governance strategy increases.

Conclusion 2 shows that in a fair and objective new media environment, MEs can win a good social reputation and gain great long-term benefits by undertaking social responsibilities and actively governing marine ecology. Moreover, the chance of attracting more MEs to participate in marine ecological governance increases. In addition, improvement of the punishment of the LGs and the influence of new media reports on MEs can also induce MEs to choose the "active governance" strategy. Indeed, the economic compensation to the CP due to the non-governance of the MEs is also an alternative punishment for the MEs.

Analysis of the Coastal Public's Strategic Stability

Based on the payment matrix in **Table 2**, we calculated the expected returns corresponding to different strategy choices of the CP; then, the replication dynamic equation of the public evolutionary game is constructed.

The expected benefits of the CP selecting participation in marine ecological governance are given as U_P^1:

$$\begin{aligned} U_P^1 = {} & xz(P_1 - C_P) + x(1-z)\left[(1-\alpha)(P'+M) + P_1 - C_P\right] \\ & + (1-x)z(A + P' + M - P_2 - C_P) \\ & + (1-x)(1-z)\left[\alpha(P'+M) - P_2 - C_P\right]. \end{aligned}$$

The expected return of the CP choosing "nonparticipation" in marine ecological governance is given as U_P^2:

$$\begin{aligned} U_P^2 = {} & xzP_1 + x(1-z)P_1 + (1-x)z(-P_2) \\ & + (1-x)(1-z)(-P_2). \end{aligned}$$

The average expected return of the decision-making behavior of the CP is given as $\overline{U_P}$:

$$\overline{U_P} = yU_P^1 + (1-y)U_P^2.$$

According to the evolutionary game theory, the replication dynamic equation of the CP's "participation" strategy is derived as follows:

$$\begin{aligned} F(y) = \frac{dy}{dt} &= y\left(U_P^1 - \overline{U_P}\right) \\ &= y(1-y)\{\alpha(P'+M) - C_P - x(2\alpha-1)(P'+M) + z[A \\ &\quad + (1-\alpha)(P'+M)] - xz[A + 2(1-\alpha)(P'+M)]\}. \end{aligned}$$

Make $M(x) = \alpha(P'+M) - C_P - x(2\alpha-1)(P'+M) + z[A + (1-\alpha)(P'+M)] - xz[A + 2(1-\alpha)(P'+M)]$.

From $M(x) = 0$, $x_0 = \frac{z[A+(1-\alpha)(P'+M)]+\alpha(P'+M)-C_P}{(2\alpha-1)(P'+M)+zA+2z(1-\alpha)(P'+M)}$, if $x = x_0$, $\frac{dF(y)}{dy} \equiv 0$; if $x_0 \neq x_0$, we need to discuss α.

Conclusion 3. When media reports are more credible and if MEs tend to select the active governance strategy, the probability of the CP choosing the "nonparticipation" strategy will approach 1. On the contrary, if MEs tend to opt for the "negative governance" strategy, then the probability of the CP selecting the participation strategy will be close to 1.

Proof: If $\alpha > \frac{(1-2z)(P'+M)-zA}{2(1-z)(P'+M)}$, $\frac{dM(x)}{dx} < 0$, then M(x) is a monotonically decreasing function of x; if $x = x_0$, then $M(x) = 0$. All levels are ESS, i.e., regardless of the probability of the MEs opting for positive or negative governance, the strategy of the CP will remain the same over time. If $x \neq x_0$, then $y = 1$ and $y = 0$ are $F(y)$ ESS, and $\frac{dF(y)}{dy} = (1-2y)\{\alpha(P'+M) - C_P - x(2\alpha-1)(P'+M) + z[A + (1-\alpha)(P'+M)] - xz[A + 2(1-\alpha)(P'+M)]\}$.

(1) If $0 < x_0 < x < 1$, then $M(x) < 0$, $\frac{dF(y)}{dy}|_{y=1} > 0$, and $\frac{dF(y)}{dy}|_{y=0} < 0$; therefore, $y^* = 0$ is the ESS.
(2) If $0 < x < x_0 < 1$, then $M(x) > 0$, $\frac{dF(y)}{dy}|_{y=1} < 0$, and $\frac{dF(y)}{dy}|_{y=0} > 0$; therefore, $y^* = 1$ is the ESS.

According to the aforementioned analysis, the dynamic evolution trend of the CP's behavior can be obtained by

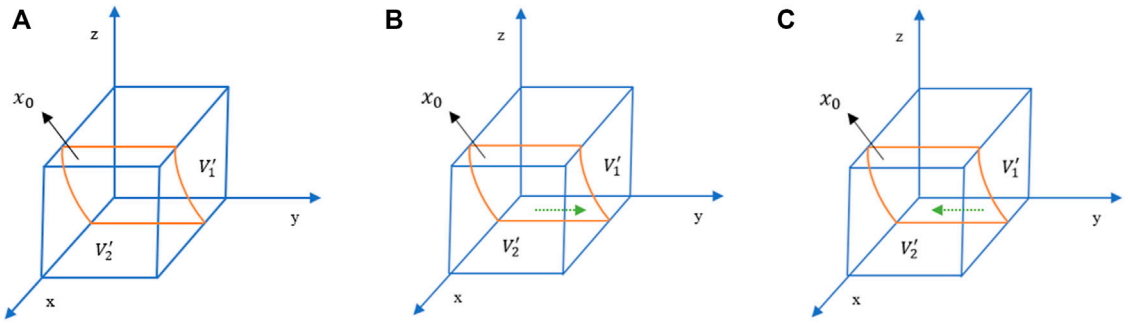

FIGURE 3 | Dynamic evolution trend of the behavior of the CP. **(A)** $x - x_0$. **(B)** $x < x_0$. **(C)** $x > x_0$.

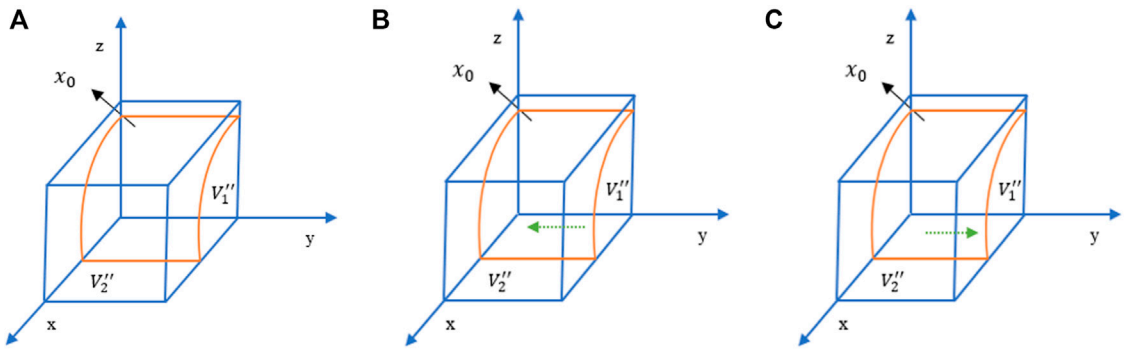

FIGURE 4 | Dynamic evolution trend of the behavior of the CP. **(A)** $x = x_0$. **(B)** $x < x_0$. **(C)** $x > x_0$.

expressing the aforementioned conclusions as three-dimensional coordinates, as shown in **Figure 3**.

Conclusion 3 demonstrates that the probability of the CP to participate in governance is influenced by the choice of strategy of the MEs in a fair and objective new media environment. If MEs display a series of marine pollution behaviors to maximize their interests, such as expanding the production scale, ignoring the extensive use of marine resources, directly discharging pollutants into the sea, and reducing the cost of marine governance, and these behaviors have caused severe losses to the public interests in marine ecology. To safeguard their interests, MEs will pay a huge price regardless of whether or not the public opts to report or expose them through new media. On the contrary, if MEs pay attention to marine ecological governance, then doing so will help the CP to obtain a healthy marine ecological environment, additional sea-related jobs, and convenient supporting facilities and services; moreover, the probability of the CP to select supervision, reporting, and litigation will decrease.

Conclusion 4. If the probability of fair and objective reporting by new media is low and if MEs tend to govern actively, then the probability of the CP participation will approach 1. On the contrary, if MEs tend to opt for negative governance, then the probability of the CP's participation will approach 0.

Proof: If $\alpha < \frac{(1-2z)(P'+M)-zA}{2(1-z)(P'+M)}$, $\frac{dM(x)}{dx} > 0$, then $M(x)$ is a monotonically increasing function of x; if $x = x_0$, then $M(x) = 0$; all levels are the ESS. In other words, regardless of the probability of the MEs opting for positive or negative governance, the strategy of the CP will remain the same over time. If $x \neq x_0$, then $y = 1$ and $y = 0$ are the $F(y)$ ESS, and $\frac{dF(y)}{dy} = (1-2y)\{\alpha(P'+M) - C_P - x(2\alpha-1)(P'+M) + z[A + (1-\alpha)(P'+M)] - xz[A + 2(1-\alpha)(P'+M)\}$.

(1) If $0 < x_0 < x < 1$, then $M(x) > 0$, $\frac{dF(y)}{dy}_{|y=1} < 0$, and $\frac{dF(y)}{dy}_{|y=0} > 0$; therefore, $y^* = 1$ is the ESS.
(2) If $0 < x < x_0 < 1$, then $M(x) < 0$, $\frac{dF(y)}{dy}_{|y=1} > 0$, and $\frac{dF(y)}{dy}_{|y=0} < 0$; therefore, $y^* = 0$ is the ESS.

Figure 4 expresses the abovementioned conclusions as three-dimensional coordinates, and the dynamic evolution trend of the behavior of the CP can be obtained.

Conclusion 4 illustrates that reports are biased and even turn black and white upside down in a false and distorted new media environment. At this point, the CP's strategy selection is completely opposite to that of Conclusion 3. Even if the probability of the MEs selecting the "active governance" strategy increases at this time, the probability of the CP reporting will not be reduced. The reason for this finding is that the positive governance behavior of the MEs is reported by

unscrupulous and distorted new media, which maliciously fabricate facts and deliberately tarnish the image of related MEs. Even if MEs do not cause actual damage to marine ecology, the CP who lacks certain independent thinking and discrimination abilities will also tend to report due to their sense of environmental responsibility or to safeguard their interests. Thus, the trust between CP and MEs is undermined, and the stable development of the coastal economy and society is endangered.

Analysis of the Strategic Stability of the Local Governments

Referring to the payment matrix in **Table 2**, the study calculated the expected returns corresponding to the different strategy choices of the LGs; the replication dynamic equation of the evolutionary game of the LGs was then constructed.

The expected return of the LGs selecting strong regulation marine ecology is given as U_G^1:

$$U_G^1 = xy(G_1 - C_G) + x(1-y)G_1 + (1-x)y\left(F - G_2 - C_G - A - C_G^{'}\right) + (1-x)(1-y)\left(-G_2 - C_G^{'}\right).$$

The expected return of the LGs choosing the weak regulation marine ecology is given as U_G^2:

$$U_G^2 = xy[G_1 - (1-\alpha)D_2] + x(1-y)G_1 + (1-x)y\left(-G_2 - \alpha D_2 - C_G^{'}\right) + (1-x)(1-y)\left(-G_2 - C_G^{'}\right).$$

The average expected return of the decision-making behavior of the LGs is given as $\overline{U_G}$:

$$\overline{U_G} = zU_G^1 + (1-z)U_G^2.$$

According to the evolutionary game theory, the replication dynamic equation of the LGs selecting the strong supervision strategy is as follows:

$$F(z) = \frac{dz}{dt} = z\left(U_G^1 - \overline{U_G}\right) = z(1-z)y\{x[A - F + (1-2\alpha)D_2] + (F - C_G - A + \alpha D_2)\}.$$

Find the first-order partial derivative of $F(z)$ with respect to z:

$$\frac{dF(z)}{dz} = (1-2z)y\{x[A - F + (1-2\alpha)D_2] + F - C_G - A + \alpha D_2\}.$$

Make $K(x) = x[A - F + (1-2\alpha)D_2] + F - C_G - A + \alpha D_2$.

When $K(x) = 0$, $x_0 = \frac{C_G + A - F - \alpha D_2}{A - F + (1-2\alpha)D_2}$; when $x = x_0, \frac{dF(z)}{dz} \equiv 0$; when $x \neq x_0$, we need to discuss α, as $x_0 \in [0,1]$, $\alpha > \max\{\frac{D_2 + A - F}{2D_2}, \frac{C_G + A - F}{D_2}, \frac{D_2 - C_G}{D_2}\}$.

Conclusion 5. When the probability of fair and objective reporting by new media is high and if MEs actively govern marine ecology, then the probability of the LGs selecting weak regulation will be close to 1. On the contrary, if MEs negatively govern marine ecology, then the probability of the LGs opting for strong regulation is close to 1.

Proof: If $\frac{dK(x)}{dx} = 0$, then $\alpha = \frac{D_2 + A - F}{2D_2}$. From $\frac{d^2(K(x))}{dxd\alpha} = -2D_2 < 0$, if $\alpha > \frac{D_2 + A - F}{2D_2}$, $\frac{d(K(x))}{dx} < 0$, then K(x) is the subtraction function relative to x. If $x = x_0$, then $K(x) = 0$; all levels are the ESS, i.e., regardless of the probability of the MEs selecting positive or negative governance, the strategy of the LGs will remain the same over time. If $x \neq x_0$, then $z = 1$ and $z = 0$ are the $F(z)$ ESS, and $\frac{dF(z)}{dz} = (1-2z)y\{x[A - F + (1-2\alpha)D_2] + (F - C_G - A + \alpha D_2)\}$.

(1) If $0 < x_0 < x < 1$, then $K(x) < 0$, $\frac{dK(x)}{dx}|_{z=1} > 0$, and $\frac{dK(x)}{dx}|_{z=0} < 0$; therefore, $z^* = 0$ is the ESS.
(2) If $0 < x < x_0 < 1$, then $K(x) > 0$, $\frac{dK(x)}{dx}|_{z=1} < 0$, and $\frac{dK(x)}{dx}|_{z=0} > 0$; therefore, $z^* = 1$ is the ESS.

Figure 5 expresses the abovementioned conclusion using three-dimensional coordinates and presents the dynamic evolution trend of the behavior of the LGs.

Conclusion 5 demonstrates that media reports follow facts in a fair and objective new media environment. At this time, the strategy choice of the MEs will influence the strategic stability of the LGs. If MEs select active governance, then CP and LGs will gain more ecological, economic, and social benefits; in particular, LGs will increase their trust in MEs. Even if LGs opt for the weak regulation strategy, the outside world will default that LGs have done their best in marine ecological governance (Du et al., 2022). To reduce unnecessary financial expenditure, LGs prefer to select the weak regulation strategy. Conversely, if MEs choose negative governance to pursue short-term economic interests and damage the interests of the LGs and CP, then the probability of the CP reporting will increase; in addition, LGs will increase their response to public reporting and actively investigate and punish illegal MEs.

In **Figure 5**, volume $V_1^{''}$ in the area behind the x_0 represents the probability of the LGs to select strong regulation, whereas the volume $V_2^{''}$ of the area in front of the x_0 represents the probability of choosing weak regulation. We derived the following equations:

$$V_1^{''} = \int\int \frac{C_G + A - F - \alpha D_2}{A - F + (1-2\alpha)D_2} dydz = \frac{C_G + A - F - \alpha D_2}{A - F + (1-2\alpha)D_2},$$

$$V_2^{''} = 1 - \int\int \frac{C_G + A - F - \alpha D_2}{A - F + (1-2\alpha)D_2} dydz = 1 - \frac{C_G + A - F - \alpha D_2}{A - F + (1-2\alpha)D_2}.$$

Conclusion 6. when other parameters remain unchanged, the probability of the LGs selecting strong regulation will increase with the increase of penalty F for MEs and loss D_2 after new media exposure, and will decrease with the increase in supervision cost C_G of the LGs and reward A to the CP.

Proof: Find the first-order partial derivative of each element for $V_1^{''}$, $\frac{\partial V_1^{''}}{\partial F} > 0$、 $\frac{\partial V_1^{''}}{\partial D_2} > 0$、 $\frac{\partial V_1^{''}}{\partial C_G} < 0$, $\frac{\partial V_1^{''}}{\partial A} < 0$; therefore, if F and D_2 gradually increase or if C_G and A gradually decrease, then the volume of $V_1^{''}$ increases, that is, the probability of the LGs selecting strong regulation increases.

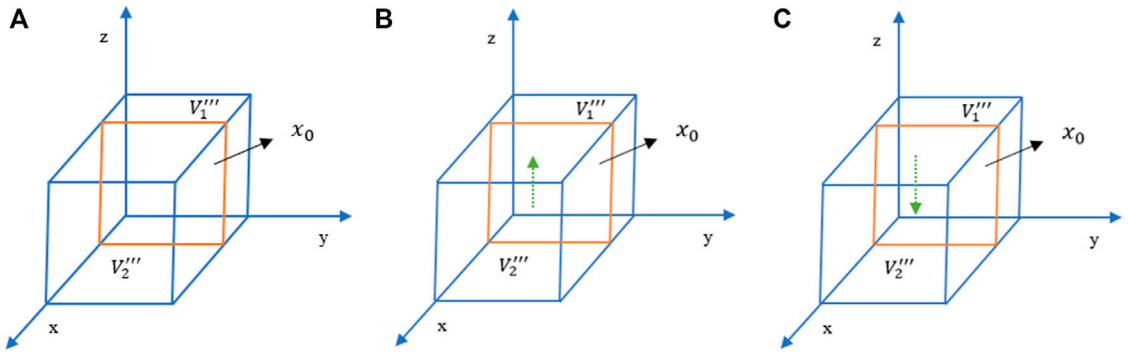

FIGURE 5 | Dynamic evolution trend of the behavior of the LGs. **(A)** $x - x_0$. **(B)** $x < x_0$. **(C)** $x > x_0$.

TABLE 3 | ESS and eigenvalues of the dynamic system.

	Eigenvalue		
	λ_1	λ_2	λ_3
(0, 0, 0)	$R' - C_E$	$\alpha(P' + M) - C_P$	0
(1, 0, 0)	$-R' + C_E$	$-C_P + (1 - \alpha)(P' + M)$	0
(0, 1, 0)	$R' - C_E + (2\alpha - 1)D_1$	$-\alpha(P' + M) + C_P$	$F - C_G - A + \alpha D_2$
(0, 0, 1)	$R' - C_E$	$A - C_P + P' + M$	0
(1, 1, 0)	$-R' + C_E - (2\alpha - 1)D_1$	$C_P - (1 - \alpha)(P' + M)$	$(1 - \alpha)D_2 - C_G$
(1, 0, 1)	$-R' + C_E$	$-C_P$	0
(0, 1, 1)	$R' - C_E + F + M$	$C_P - A - P' - M$	$-F + C_G + A - \alpha D_2$
(1, 1, 1)	$-R' + C_E - F - M$	C_P	$C_G - (1 - \alpha)D_2$

Conclusion 6 illustrates that the media has a broad mass base in a fair and objective new media environment because the levels of authenticity and credibility of its reports are high. Therefore, the LGs will suffer high losses due to the exposure to weak regulation by new media, which can stimulate LGs to strictly perform their duties. Second, the greater the penalty amount set by LGs is, the more profitable the LGs are, and the more encouraged are the strong regulatory behavior of the LGs. However, the implementation of the strong regulation strategy by LGs will be restricted by the high supervision cost of the MEs. Finally, the increase in the rewards of the LGs to the CP will encourage more CP to participate in the governance of marine ecology, which will win the space of weak regulation for LGs.

Stability Analysis of the ESS in the Tripartite Evolutionary Game

The previous discussion only analyzes the strategy evolution process of each game player and the influence of changes in parameter from the perspective of a single game player. However, as the constraints on the behavior of MEs, which damages marine ecology, it requires the joint participation of the LGs, CP and new media, this study will continue to conduct overall research on the three parties. From $F(x) = F(y) = F(z) = 0$, the ESS of the system can be obtained. In the three-party evolutionary game, we only need to discuss the following ESSs: $E_1(0, 0, 0)$, E_2 (1,0,0), $E_3(0, 1, 0)$, E_4 (0,0,1), $E_5(1, 1, 0)$, E_6 (1,0,1), $E_7(0, 1, 1)$, and E_8 (1,1,1) (Bjornerstedt and Weibull, 1994). According to Lyapunov stability theory, the asymptotic stability of a system at the equilibrium point can be determined using the eigenvalue of the Jacobian matrix. When the eigenvalue is less than 0, the equilibrium point is the ESS. Thus, we can obtain the eigenvalue expression of the corresponding Jacobian matrix by replacing the abovementioned eight points into the Jacobian matrix, respectively (**Table 3**).

In particular, we only need to discuss $E_3(0, 1, 0)$, $E_5(1, 1, 0)$, and $E_7(0, 1, 1)$ because $\lambda_3 = 0$, $R' - C_E < 0$ for $E_1(0, 0, 0)$, E_2 (1,0,0), E_4 (0,0,1) and E_6 (1,0,1); $\lambda_2 = C_P > 0$ for E_8 (1,1,1). The stability conditions of the equilibrium point of $E_3(0, 1, 0)$, $E_5(1, 1, 0)$, and $E_7(0, 1, 1)$ evolutionary game are shown in **Table 4**:

Conclusion 7. If $R' - C_E + (2\alpha - 1)D_1 < 0$, then $-\alpha(P' + M) + C_P < 0$ and $F - C_G - A + \alpha D_2 < 0$, $\frac{C_P}{P'+M} < \alpha < \min\{\frac{1}{2} + \frac{C_E - R'}{2D_1}, \frac{C_G + A - F}{D_2}\}$; thus, the ESS is $E_3(0, 1, 0)$.

Proof: According to the Lyapunov stability theory, if the eigenvalue of the Jacobian matrix is negative, then the equilibrium point is the ESS.

Conclusion 7 indicates that the contents of media reports frequently distort facts and display severe subjective orientation in a false and distorted new media environment, which easily leads to an errant understanding of the behavior of the MEs by the outside world. If the cost of the CP's participation is low, if the benefit of participation is high, and if all sanctions of the LGs on illegal MEs and the impact of media exposure on LGs and MEs are small, then the evolution of strategy combination will gradually stabilize in $E_3(0, 1, 0)$ (negative governance, participation, and weak regulation). At this point, owing to the lack of interest incentive and media binding force, performing their regulatory responsibilities is inconducive to LGs. As a result, the marine destruction behaviors of the MEs cannot be effectively restrained, which will damage the public interests and lead to dissatisfaction among the CP. The probability of the CP reporting will then increase; however, the efficiency of the response of the LGs to reporting is low, which virtually increases the probability of the CP to seek help from new media. Fully restoring marine damage events is difficult due to the serious subjective tendency of new media reports. This notion results in the lack of a clear

TABLE 4 | Stability conditions of equilibrium points in the evolutionary game.

ESS	Stability condition
(0, 1, 0)	$R' - C_E + (2\alpha - 1)D_1 < 0$; $-\alpha(P' + M) + C_P < 0$; $F - C_G - A + \alpha D_2 < 0$
(1, 1, 0)	$-R' + C_E - (2\alpha - 1)D_1 < 0$; $C_P - (1 - \alpha)(P' + M) < 0$; $(1 - \alpha)D_2 - C_G < 0$
(0, 1, 1)	$R' - C_E + F + M < 0$; $C_P - A - P' - M < 0$; $-F + C_G + A - \alpha D_2 < 0$

pressure effect on MEs and LGs, which is inconducive for forcing MEs and LGs to perform their governance responsibilities, and it ultimately increases the risk to marine ecological security and harm to the CP. Therefore, to avoid the occurrence of such a stable strategy combination (i.e., negative governance, participation, and weak supervision), the LGs must increase the punishment and tax intensity after the destruction of marine ecology to increase the cost of the illegal destruction of the MEs. However, it is also necessary to establish a fair and objective new media environment.

Conclusion 8. If $-R' + C_E - (2\alpha - 1)D_1 < 0$, then $C_P - (1 - \alpha)(P' + M) < 0$, $(1 - \alpha)D_2 - C_G < 0$, and $\max\{\frac{1}{2} + \frac{C_E - R'}{2D_1}, 1 - \frac{C_G}{D_2}\} < \alpha < 1 - \frac{C_P}{P' + M}$; thus, the ESS is $E_5(1, 1, 0)$.

Proof: The proof is similar to that for Conclusion 7.

Conclusion 8 implies that the media reports are true and reliable in a fair and objective new media environment. At this time, the strategic choice of the MEs is only opposite to that in Conclusion 7. If MEs opt to destroy the sea and harm public interests, then the CP will choose to report or expose them through new media. As new media reports are more authentic and reliable, they will form a certain pressure on LGs. To maintain their image, LGs will tend to select strong regulation, actively accept the report of the CP, and investigate and punish illegal MEs. Moreover, MEs will choose to comply with and implement relevant laws and regulations to avoid the double blow of loss caused by new media exposure and the punishment of the LGs. To reduce unnecessary financial expenditure, if the probability of the MEs selecting the active governance strategy stabilizes at 1, then the probability of the LGs selecting the strong regulation strategy will gradually decrease and stabilize at 0. Finally, the strategic combination of the three will gradually evolve to $E_5(1, 1, 0)$ (active governance, participation, and weak regulation), which is the ideal state of the strategic combination of the three.

Conclusion 9. If $R' - C_E + F + M < 0$, then $C_P - A - P' - M < 0$, $-F + C_G + A - \alpha D_2 < 0$, and $\alpha > \frac{-F + A + C_G}{D_2}$; thus, the ESS is $E_7(0, 1, 1)$.

Proof: The proof is similar to that for Conclusion 7.

Conclusion 9 demonstrates that if the cost of the marine ecological governance of the MEs is greater than the sum of the punishment of the LGs in a fair and objective new media environment, then the long-term benefits of active governance, the economic compensation was given to the CP, as well as the benefits of the CP and LGs from participating in governance are greater than the cost; consequently, the evolution of the strategy combination of the three will gradually evolve to $E_7(0, 1, 1)$ (negative governance, participation, and strong regulation). At this time, government regulation and public participation cannot effectively restrict the violations of the MEs. The risk of marine ecological security will then increase, which is inconducive to safeguarding the public interest of environmental protection. Therefore, to avoid the emergence of a stable strategy combination (e.g., negative governance, participation, and strong regulation), the government must increase punishment and enhance the deterrence of the LGs, while simultaneously reducing the corporate governance costs and ensuring long-term governance benefits, which is equally important.

SIMULATION ANALYSIS

For the abovementioned ESS $E_5(1, 1, 0)$ (Conclusion 8), the following section uses numerical simulation analysis to determine the impact of parameter changes on the strategy choice of various subjects of marine ecological governance by successively adjusting the parameter values of the game model. To enable the parameter value to objectively reflect the participation of the CP in marine ecological governance in the new media environment, a research group was organized to conduct a questionnaire survey on marine ecological governance in 14 key coastal cities in China from August to December 2021 based on the suggestions of experts. Parameter value was assigned according to the statistical data obtained from the survey.

First, the survey involves Chinese LGs, MEs, and CP. The form of the questionnaire is semi-open, and the main contents of the questionnaire include the basic information of interviewees and the value of relevant parameters in the income matrix. In detail, 1) 550 questionnaires were distributed to LGs out of which 442 were completed (recovery rate: 80%); 2) 1,230 questionnaires were distributed to MEs out of which 1,085 were returned (recovery rate: 88%); and 3) 1,170 questionnaires were distributed to the CP out of which 1,000 were recovered (recovery rate: 85%). Some questionnaires were discarded because they contained a substantial quantity of missing data or had too many similar responses. Then, 397, 877, and 832 valid surveys were received, respectively. Several variables of the survey results are interval values; hence, this study adopts the average values. The specific survey values are as follows. 1) LGs: the average amount of punishment set for illegal MEs is 31,876 RMB each time, and the total annual amount of administrative penalties for the marine environment is approximately 1.011 billion RMB. The annual average number of reports received from the CP is 20,198, and the cost of supervision is approximately 19,876 RMB each time, which indicates that the total annual cost of supervision to MEs is 402 million RMB. 2) MEs: the total annual investment in marine ecological governance is approximately 1.123 billion RMB. Second, for data that were not investigated, the study was proposed based on stability conditions. (400 million RMB as a unit) ① LGs: $C_G = 1$, $F = 2.5$, and $D_2 = 5$; ② MEs: $C_E = 2.8$, $R' = 0.8$, and $D_1 = 6$; ③ CP:

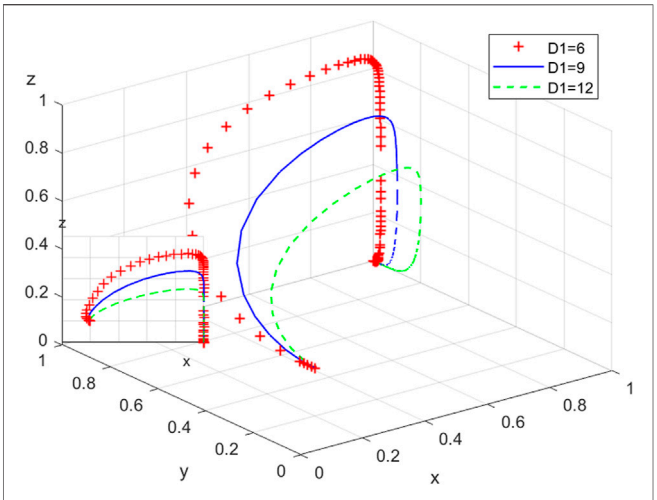

FIGURE 6 | Impact of the losses of the MEs due to new media exposure on the evolution track of the tripartite evolutionary game.

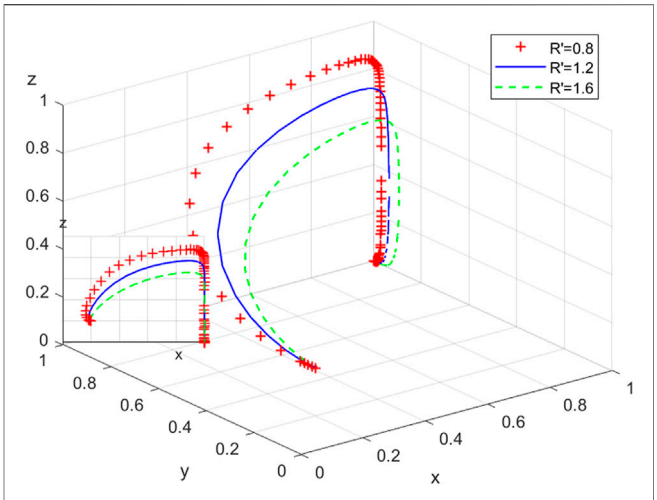

FIGURE 8 | Impact of long-term additional benefits on the evolution track of the tripartite game when MEs govern actively.

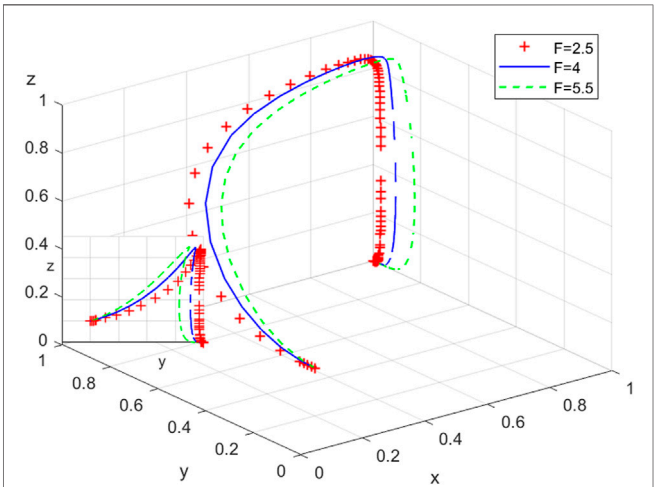

FIGURE 7 | Impact of the punishment of the LGs on MEs on the evolution track of the tripartite evolutionary game.

$A = 2$, $P' = 1$, $M = 2$, and $C_P = 0.2$; ④ if the accuracy of new media coverage is high, then $\alpha = 0.9$. However, if the accuracy of new media coverage is low, then $\alpha = 0.1$. Finally, the initial group proportion of the three subjects is set to 0.2.

To satisfy the conditions of Conclusion 8, we assume that $\alpha = 0.9$. The abovementioned parameters are assigned as array 1, and the numerical simulation is conducted using MATLAB 2020b.

First, to analyze the influence of D_1, F, and R' on the process and result of evolutionary game, D_1 is assigned the values of 6, 9, and 12, respectively. **Figure 6** provides the corresponding simulation results. Similarly, F is designated as 2.5, 4, and 5.5, respectively; **Figure 7** illustrates the corresponding simulation results. Last, R' is assigned the values of 0.8, 1.2, and 1.6, respectively, with the corresponding simulation results presented in **Figure 8**.

Figure 6 illustrates that the increase in the losses of the MEs due to new media exposure can improve the probability of the "active governance" of the MEs, while decreasing the probability of the "strong regulation" of the LGs. This finding implies that the greater the negative impact of new media exposure on MEs is, the higher is the violation cost they will take, which in turn will urge MEs to actively govern marine ecology. New media can share the regulatory pressure of the LGs, which wins the space of weak regulation for LGs.

Figure 7 highlights that when the probability of active governance of the MEs stabilizes before 1, with the increase in government punishment on MEs, then LGs are profitable and the probability of the "strong regulation" of the LGs increases. However, if the probability of "active governance" has stabilized at 1, then the probability of the "strong regulation" of the LGs decreases and tends to approach 0. To reduce the probability of high punishment by LGs, MEs who seek to maximize benefits will gradually tend to active governance of marine ecology. Thus, the greater the punishment is, the higher is the probability of active governance. At the same time, the benefits obtained by the CP are improved; the trust of the CP in MEs and LGs reaches a high level; and the probability of public reporting will also decline. After MEs choose active governance, the LGs will gradually select "weak regulation" for reducing the regulation cost.

As shown in **Figure 8**, the probability of selection of strong regulation by LGs decreases with the increase in the long-term benefits after the active governance of the MEs, which can effectively stimulate the active governance behavior of the MEs. This result indicates that when MEs win social reputation by safeguarding the marine public interests or obtain better corporate performance by improving the competitiveness of their products (Liu et al., 2021), which leads to a greater increase in their operating income, it is beneficial to strengthen their main responsibility and

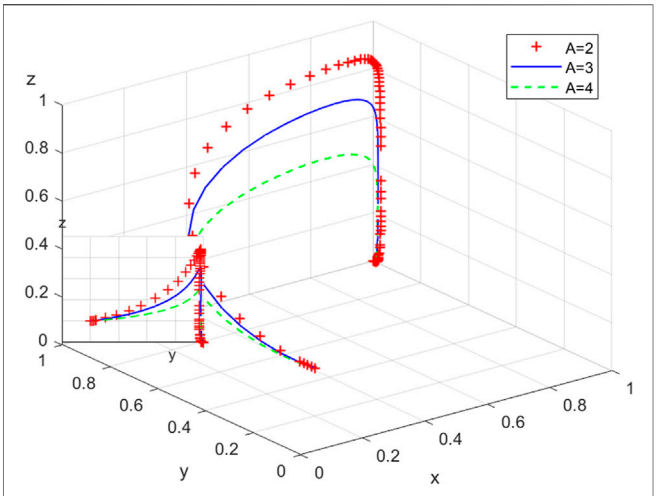

FIGURE 9 | Impact of the reward amount set by LGs for CP on the evolution track of the tripartite evolutionary game.

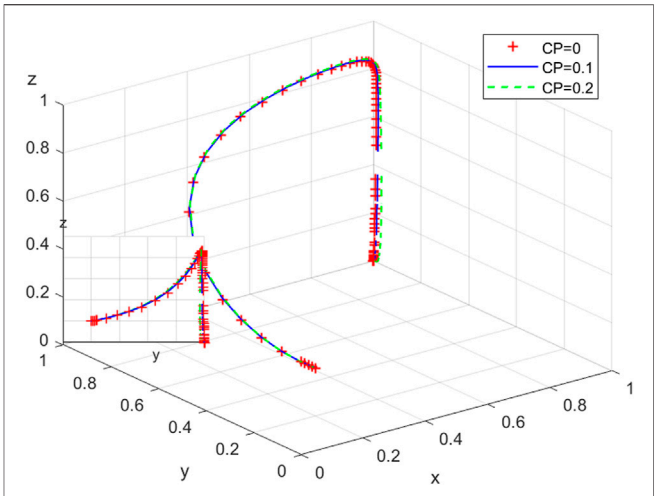

FIGURE 11 | Impact of the CP's participation cost on the evolution track of the tripartite evolutionary game.

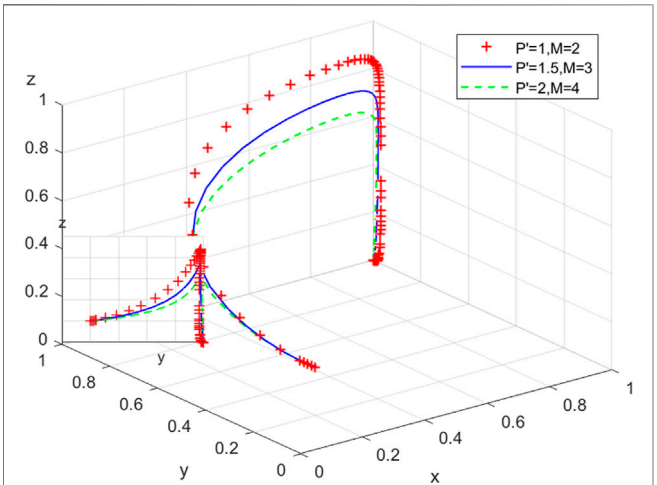

FIGURE 10 | Impact of the benefits obtained by CP after successfully supervising MEs on the evolution track of the tripartite evolutionary game.

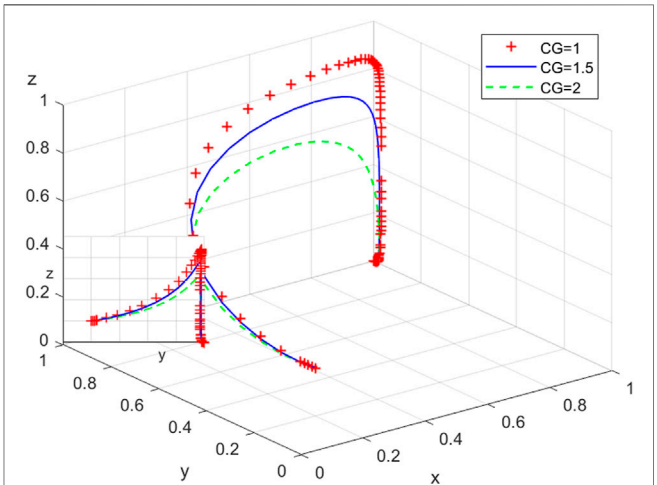

FIGURE 12 | Impact of the supervision cost of the LGs on MEs on the evolution track of the tripartite evolutionary game.

promote their transformation from negative to active governance. This notion is conducive to the protection of the interests of the CP, such that the trust of the LGs in MEs will increase, and the probability of the strong regulation of the LGs will decrease.

Next, this study denotes $A = 2, 3,$ and 4. **Figure 9** presents the simulation results as follows: $P' = 1,\ \mathrm{M} = 2,\ P' = 1.5, \mathrm{M} = 3,$ and $P' = 2, \mathrm{M} = 4$; the simulation results are shown in **Figure 10** ($C_P = 0,\ 0.1,$ and 0.2) and **Figure 11**.

Figure 9 indicates that with the increase of the reward amount set by LGs for the CP, the probability of the CP's participation in marine ecological governance will increase, whereas the probability of the LGs selecting strong regulation will decrease. In other words, LGs will influence the CP's choice of strategy; thus, LGs play a guiding role for the CP. When the reward amount is set at a high level, then the willingness of the CP to participate in governance is high for profit, such that they can supervise the behaviors of the MEs through new media, which wins the space of weak regulation for LGs. If the probability of the active governance of the MEs stabilizes at 1, then LGs will gradually eliminate regulation.

Figures 10, **11** imply that with the increase in the benefits obtained by the CP after successfully supervising MEs or the decrease of the CP's participation cost, there will be an increase in the probability of the CP's participation in marine ecological governance, whereas the probability of LGs selecting strong regulation will decrease. This result indicates that displaying a high sense of achievement or economic compensation after the successful supervision of the MEs by the CP is conducive to

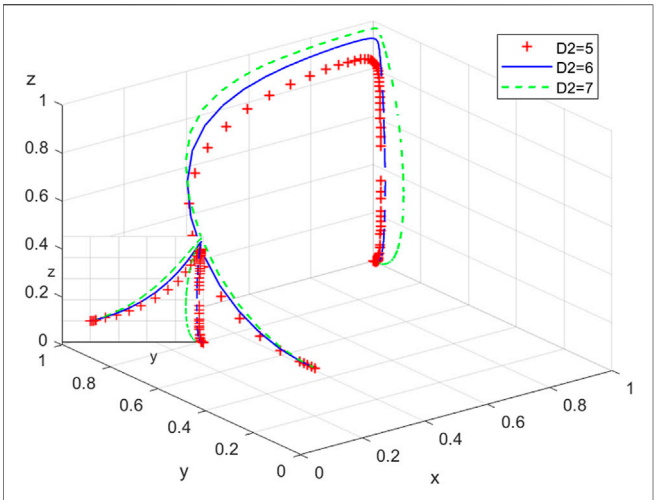

FIGURE 13 | Impact of the losses of LG by new media on the evolution track of the tripartite evolutionary game.

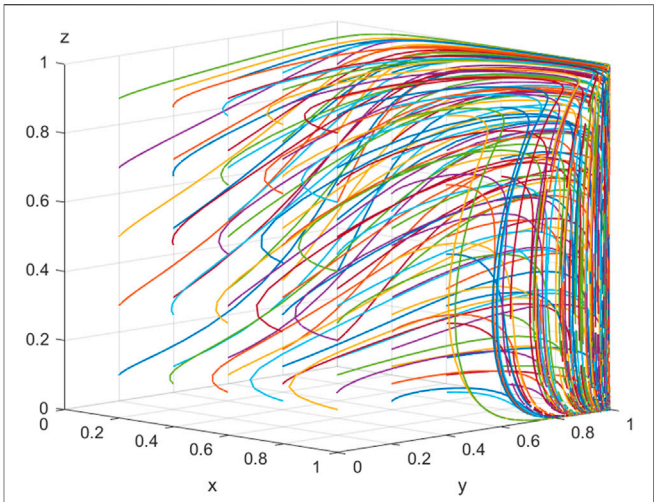

FIGURE 14 | Fifty evolution results of array 1.

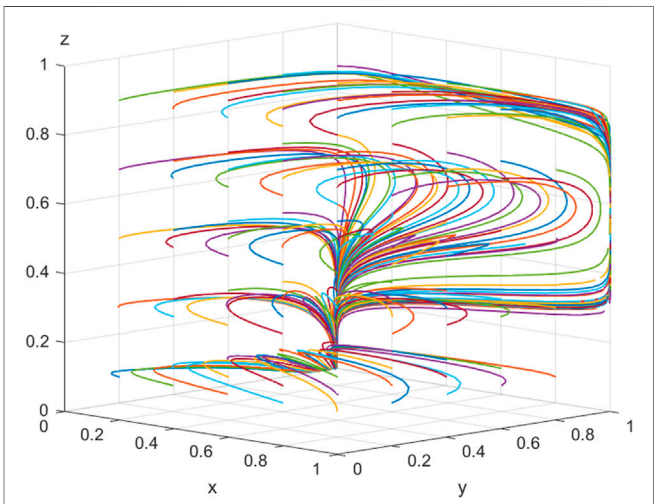

FIGURE 15 | Fifty evolution results of array 2.

enhancing the awareness of the CP in participating in marine ecological governance and stimulating their enthusiasm for supervising marine ecology. At the same time, the low information and economic costs of the CP's participation in marine ecological governance also promote the initiative and enthusiasm of the CP's participation to a great extent, which can effectively supplement the regulatory function of the LGs.

Finally, we assume that $C_G = 1, 1.5,$ and 2, and **Figure 12** depicts the corresponding simulation results. Similarly, we considered $D_2 = 5, 6,$ and 7, and the corresponding simulation results are shown in **Figure 13**.

Figure 12 indicates that with the increase in the cost of the supervision of the LGs on MEs, the probability of the LGs selecting the strong regulation strategy has decreased, whereas the probability of the CP's participation has increased. The reason is that LGs cannot afford high regulation costs due to limited resources, which results in a large number of MEs that lack efficient supervision. In addition, the lack of supervision by LGs will increase the illegal behavior of the MEs, promote the loss of the CP's interests, arouse the CP's dissatisfaction, and force the CP to report. However, in terms of the CP reports, the LGs intend to respond, but the cost of supervision is extremely high. This is consistent with the old adage: the spirit is willing, but the flesh is weak. As such, the CP will then further expose illegal MEs through new media; consequently, MEs will gradually govern marine ecology to safeguard their reputation and interests. When the probability of active governance stabilizes at 1, the LGs will gradually and completely divert from regulation.

Figure 13 indicates that with the increase in the negative effects of LGs exposure through new media, the probability of strong regulation will increase, whereas the probability of the CP participation in marine ecological governance will decrease. In other words, the higher the traffic is, the greater is the impact of new media, and the greater is the change in the behavior choice of the LGs and MEs. To avoid the deterioration of their credibility due to new media exposure, LGs will actively perform their responsibilities. To avoid the high-pressure punishment by the strong regulation of the LGs and great losses after media exposure, MEs will also opt to actively govern marine ecology. The CP will then be satisfied with the MEs and the LGs due to the improvement of their interests; as a result, their reporting behavior will decrease.

In the aforementioned discussion, the influencing factors of the tripartite evolutionary game are analyzed separately. To verify the analysis of the equilibrium and strategic stability of the evolutionary game system, arrays 1 and 2 are substituted into the model for simulation analysis. Among them, array 1 exceeds the parameter value, which meets the conditions of Conclusion 8. We set array 2 at the same time: $\alpha = 0.1, R' = 0.8, C_E = 2.8, D_1 = 2, D_2 = 1, C_P = 0.2, P' = 1,$ M $= 2,$ F $= 2.5, C_G = 1,$ and A $= 2$, which satisfies the conditions of Conclusion 7. Referring to Zou et al. (2022), the two groups of data are randomly combined using different initial strategies within the range of [0,1] and evolve 50 times with the change over time. The operation results of array 1 and array 2 are shown in **Figures 14**, **15**, respectively.

Figure 14 demonstrates that when array 1 satisfies the following: $R' - C_E + (2\alpha - 1)D_1 > 0$, $C_P - (1-\alpha)(P' + M) < 0$, and $(1-\alpha)D_2 - C_G < 0$, $E_5(1,1,0)$ exists in the evolutionary game system and the new media reports are fair and objective. Thus, the strategic stability combination of the MEs, CP, and LGs becomes the ideal combination (active governance, participation, weak regulation), which is consistent with Conclusion 8.

Finally, **Figure 15** suggests that only one ESS (negative governance, participation, strong regulation) exists when the new media reports distort the truth because array 2 satisfies the following: $R' - C_E + (2\alpha - 1)D_1 < 0$, $C_P - \alpha(P' + M) < 0$, and $F - C_G - A + \alpha D_2 < 0$, which is consistent with Conclusion 7. Therefore, first, it is important to create a positive new media environment. Second, strengthening their main responsibility is beneficial for MEs by ensuring their benefits after governing marine ecology, increasing the negative effects of new media exposure on MEs, and reducing the cost of marine ecological governance for MEs. Third, reducing the cost of participation in governance is beneficial for the CP, and improving its environmental awareness and participation benefits can effectively stimulate participation. Finally, the reduction in the supervision cost of LGs as well as the promotion of the influence of new media exposure on LGs is beneficial for LGs to give full play to the regulatory function.

CONCLUSION AND DISCUSSION

Based on the evolutionary game theory, this study focuses on the problem of marine ecological governance and constructs a three-party evolutionary game model composed of the MEs, CP, and LGs in a new media environment. Moreover, it intends to analyze and infer the stability of strategy selection, the stability of equilibrium strategy combination of the game system, and the mechanism of influence of various elements on the subjects. This study conducts an empirical analysis of the results of the evolutionary game through numerical simulation, particularly highlighting the impact of changes in relevant parameters on the dynamic evolution trajectory of the three parties in a fair and objective new media environment. These parameters include the sensitivity of the MEs and LGs to new media reports, the increased benefits of the MEs after active governance, the supervision cost of the LGs, and the intensity of punishment on MEs by LGs. The study draws the following conclusions.

(1) The authenticity of new media reports will exert an impact on the results of the tripartite evolutionary game. The fair and objective new media environment can not only serve as an effective means for the CP to safeguard their interests but also complement the governance functions of the LGs. The greater the influence of new media reports is, the more will the MEs tend to govern marine ecology in an active manner, which will increase the probability of strong regulation of the LGs. On the contrary, a false and distorted new media environment will lead to chaos in the marine ecological governance order.
(2) In a fair and objective new media environment, the punishment and environmental taxes for MEs, which are increased by LGs, or the increase in the benefits of the MEs after actively governing marine ecology will help to improve the probability of the MEs. Furthermore, improving the CP's awareness regarding environmental protection and social responsibility is required to effectively stimulate the CP's enthusiasm to participate in marine ecological governance. Similarly, reducing the cost of the CP's participation in marine ecological governance is important.
(3) Implementation of the strong regulation strategy by LGs will be restricted by the high supervision cost of the MEs. The high cost of regulation is inconducive to the exertion of the administrative guiding role of the LGs. Notably, however, the participation of the CP in marine ecological governance can compensate for the lack of the regulation function of the LGs to a certain extent, i.e., it can reduce the negative impact of marine ecology due to the lack of LG regulation.

At present, the global marine ecological degradation situation is serious, posing a serious threat to life on Earth (Cheng et al., 2021), therefore, it is important to join forces to govern marine ecology to achieve human sustainable development. Based on the abovementioned conclusions, this study proposes the following suggestions.

Creation of a Fair and Objective New Media Environment

First, considering the importance of cultivating the social responsibility of the new media platform, it is necessary to establish a reward and punishment system and regularly select excellent new media institutions and websites. In this manner, new media can be encouraged to strengthen their own construction, earnestly fulfill their obligation to disseminate information, and improve the accuracy and quality of their disclosure of marine ecological information. Second, since new media platforms with large traffic and high specifications can win more CP trust and exert a greater impact on MEs and LGs, LGs must focus on such new media platforms. This aspect is one means of ensuring their reporting quality and utilizing new media as a truly powerful assistant of the LGs in supervision. Therefore, LGs must severely punish or even ban new media platforms that blindly pursue traffic and hotspots regardless of facts. Third, creating a positive new media environment requires acceleration of the legal construction of new media, standardization of the behavior of network communication, elimination of false information and extreme speech according to law and regulations, and the cessation of unhealthy tendencies of using new media to incite CP opinion and disrupt the market.

Reduce the Regulation Cost of the Local Governments

The responsibilities and authorities of various government departments require clarification to avoid miscellaneous costs. Various measures need to be implemented—for example, establishing a cross-departmental and special marine ecological supervision and management organization, centralizing the management authority, conducting unified management, and constantly refining marine ecological supervision measures. The second pertains to strictly controlling the recruitment of personnel

and institutions. On the one hand, the team of government personnel should be optimized through high-standard recruitment, education and training, competition, and incentive. On the other hand, necessary measures need to be taken to abolish outdated institutions, streamline troops, and simplify administration, which could reduce administrative links and eliminate unnecessary administrative examination and approval aspects. Third, e-government should be promoted; modern information technologies, such as big data and cloud computing, should be fully utilized; and work procedures should be simplified to improve productivity and realize intensive operation in an active manner. In addition, the application of detection technology, satellite remote sensing, and telemetry technology in marine ecological regulation continued improvement in the pertinence and effectiveness of the marine ecological supervision of the CP; the timely and efficient discovery of the violations of MEs need to be fully promoted.

Increase in the Motivation of the Marine Enterprises to Actively Govern Marine Ecology

The study initially suggests establishing the idea of paying equal attention to both land and sea. To impose strict external constraints on MEs, high amounts of penalties, resource taxes, and environmental protection taxes need to be set. This will increase the cost of negative governance for MEs, which will have a deterrent effect on MEs and promote their governance of marine ecology. Second, a special fund for marine ecological protection should be established using the proceeds from fines and taxes collected from illegal MEs. The LGs can then provide financial support to the fund for marine ecological protection through equity participation. In return, the fund provides preferential loans to MEs actively engaged in marine ecological protection. In this manner, a new mechanism of compensating for corporate interests is constructed, which can reduce the costs incurred for the ME governance of marine ecology and enhance the willingness of the MEs to govern. Third, due to the protection of carbon emissions and long-term sustainable environment, more attention should be paid to the application of renewable energy (Abbasi et al., 2021a). Therefore, it is necessary to replace the traditional non-renewable energy as the goal (Abbasi et al., 2021b), to provide the necessary policy guidance and technical guidance to MEs, and to encourage them to increase investment in advanced marine technology. Thus, an intensive production mode with low levels of consumption and greater environmental protection can replace an extensive production mode with fundamentally high levels of energy and pollution and make renewable energy instead of traditional non-renewable energy, thereby promoting change in the income growth mode of the MEs to win long-term economic benefits and achieve social sustainability. Other studies have also shown that green manufacturing practices can help achieve social sustainability performance at the firm level (Awan, 2019).

Cultivation of the Coastal Public's Marine Awareness

To meet the different needs of various groups, establishing a targeted and multidimensional, integrated marine ecological education system is necessary. At the same time, promoting the popularization of marine knowledge and the development of marine awareness is important for the adoption of methods to strengthen the publicity of marine environmental protection, such as the use of new media. Second, improving the reward mechanism for CP complaints and reports on marine ecological problems and encouraging the CP to express their opinions and suggestions regarding the decision of the LGs related to marine ecological supervision, administrative licensing, and law enforcement are necessary aspects, given the importance of the CP's attention toward the ocean. Third, establishing a disclosure system for marine ecological information is crucial for reducing the information cost of the CP's participation in governance. Simultaneously, LGs should fulfill their public service functions, establish a special foundation for marine ecological governance to provide financial subsidies for the CP, and formulate tax reduction policies to provide adequate financial support for the CP participating in marine ecological governance. These measures can effectively reduce the economic cost of the CP.

It should be noted that since the outbreak of COVID-19, it has not only posed a serious threat to human health but also posed unprecedented challenges to economic development (Li et al., 2021), public health (Faruqui et al., 2021), social entrepreneurship (Ge et al., 2022), mental health (Zhou et al., 2021), and environmental governance (Lehmann et al., 2021). However, this study only focuses on the negative impact of public reporting on government and enterprises through new media, and does not consider the impact of COVID-19 on the marine ecological governance system. Therefore, in further research, it is a worthwhile topic to integrate the impact of COVID-19 into the dynamic evolutionary game of marine ecological governance in a more fine-grained way, which is also more relevant to the actual situation.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of the privacy and confidential nature of its respondents, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethics review and approval/written informed consent was not required as per local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

LG: conceptualization and writing—review and editing. AY: conceptualization, writing—original draft, methodology, and software. QY: writing—original draft and writing—reviewing, and editing.

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