Pol. J. Environ. Stud. Vol. 33, No. X (2024), 1-12
DOI: *10.15244/pjoes/186646* ONLINE PUBLICATION DATE:

Original Research

Mechanisms for the Evolution of a Multiple Governance Model: Evidence from Water Pollution Control in the Erhai Lake Tourism Environment in China

Shu Fang, Bao Feng*

School of Economics, Guangxi University, Nanning City, Guangxi Province, China

Received: 16 January 2024
Accepted: 29 March 2024

Abstract

Starting from the perspective of multiple governance, we put the central government, the local governments, and tourism enterprises in the same analytical framework, regard local residents as the external supervisory force of the water pollution management process, construct a tripartite game model of water pollution management in the tourism environment of Erhai Lake in China by using the evolutionary game method, solve the model and discuss the equilibrium of the game, and further simulate and analyze the impacts of the relevant parameters on the game system by using MATLAB. It is found that: (1) the stronger the allocation of special funds for environmental protection, the more it can promote the positive governance of the local governments. However, at the same time, when the local governments are negatively governed, the value of the administrative penalty imposed by the central government on the local governments is too small to form a deterrent effect, and the pressure of the administrative penalty is too high to weaken the confidence of the local government, so the central government needs to be moderate in the administrative penalty imposed on the local officials. (2) The higher the proportion of local government environmental protection special funds allocated to tourism enterprises, the more they can promote the reduction of emissions by tourism enterprises, and their incentive to reduce emissions will be strengthened when the main business income of tourism enterprises increases due to the improvement of the tourism environment. (3) Local residents can influence the environmental behavior of the central government, the local governments, and tourism enterprises through the reputational feedback mechanism, which can promote the treatment of water pollution in the tourism environment. (4) The collection of environmental tax by the local government can motivate tourism enterprises to reduce emissions, but the environmental tax rate should be set at [0,3.5], and if it is too high, tourism enterprises will lose confidence in reducing emissions.

Keywords: Erhai Lake tourism environment, water pollution control, multiple governance, evolutionary game, numerical simulation

*e-mail: 1457302556@qq.com;
Tel.: +86-13657816902

Introduction

Tourism is currently one of the most active economic sectors in the world, and according to the World Travel and Tourism Council (WTTC), the global tourism industry will contribute 7.6% to the global GDP in 2022, creating 2.2 million new jobs. Many regions or cities promote tourism through the development of tourism resources in order to promote regional economic income growth and job creation. However, although tourism promotes the economic growth of destinations, tourism activities also cause negative impacts such as overconsumption of ecological resources and ecological environment pollution in destinations, among which water pollution in the tourism environment is one of the most serious problems. Tourism environmental water pollution events are not uncommon in the world, such as water pollution in Venice Canal tourist attractions in Italy and water pollution in Baikal Lake tourist attractions in Russia [1]. The development of tourism resources has caused serious and irreversible losses to the natural scenery of the world's scarce water resources. At the same time, the point that cannot be ignored is that the destruction of the environment in tourist destinations has seriously damaged the lives, health, and living standards of the residents of the destination, and in the subsequent environmental management process, filled with the conflict and complex game of the pluralistic rights and interests of the main body, and it may even lead to a major social event. Therefore, how to coordinate the relationship between tourism development and environmental pollution through effective water pollution management is a topic worthy of attention and in-depth investigation.

Over the past decade, China's Erhai Lake tourism industry has developed rapidly. From 2013 to 2023, Erhai Lake received an average of 1.986 million tourists annually, with tourism revenue growing from RMB 13.19 billion to RMB 36.91 billion. The development of Erhai Lake tourism is one of the key pillar industries driving GDP growth in Dali Prefecture, Yunnan, and Erhai Lake has become an important business card for China to advertise itself to tourists from around the world. In order to experience the scenery of Erhai Lake more closely, tourism enterprises have built hotels, lodges, and restaurants around the lake, but this has facilitated the discharge of pollutants from production and operation. While the number of Erhai Lake tourism receipts climbed year by year from 2013 to 2018, the number of months of exceedances of pollutants in the water increased. In July 2016, China's Central Ecological Environment Protection Inspection Group ("CEPIG") visited the Erhai Lake and found that the "blowout" of tourist catering and inns had led to a significant increase in the number of tourist visits to the Erhai Lake and a rise in the number of months of exceedances. Since January 2017, the local government of Yunnan Province has designated the core area for ecological protection in the Erhai Lake Basin, suspended the approval of catering and inns and other business establishments, carried out remediation and standardization of the existing catering and inn services, and launched a series of actions to control water pollution in the Erhai Lake Basin. The Erhai Lake Basin has successively carried out a series of actions to control water pollution.

The water pollution control of the Erhai Lake tourism environment is not only a technical problem of water pollution prevention, but also a dynamic evolution of the collective action of "tragedy of the commons" under the game of different interests and behaviors of multiple subjects. Firstly, the local government's preference for GDP performance may lead to the selective implementation of environmental protection policies and the willingness to shelter polluting enterprises, thus relaxing the regulation of tourism enterprises [2]. Secondly, in the case of the local government's laxity in regulation, the tourism enterprises will continue to develop the Erhai Lake in an unorganized manner and continue to discharge pollutants into the sea, resulting in further aggravation of water pollution in the Erhai Lake Basin. In this case, relying only on the power of the local government cannot achieve the best results in water pollution control in the Erhai Lake tourism environment. When it is difficult to achieve the goal of the conventional governance mechanism, which is based on the local government supervising the local enterprises, it will be supplemented by the central government's inspections. Some studies have shown that the central environmental protection inspection can reduce the pollution discharge of enterprises in the short term, but it is easy to cause the problem of "one size fits all" by the local government, which slows down the development of the local economy [3]. Finally, in the process of Erhai Lake governance, the local residents' demand for the environment is also an important driving force for governance, and the resistance of the local residents will become an external force to motivate the local government and polluting enterprises to reduce emissions.

As a matter of fact, it is an inevitable step in environmental governance to change from a government-led to a multiple governance model with government-led, enterprise-led, social organizations, and the public jointly participating in the environmental governance system. However, the realization of the multiple governance model requires certain policy conditions. For example, what is the range of penalties set by the CEPIG that can effectively promote the active implementation of environmental protection policies by local governments? Are financial means more conducive to promoting local governments to actively manage and enterprises to actively reduce emissions? The environmental tax rate set in what range is effective? All of these questions need to be examined. The Erhai Lake tourism environmental water pollution control in China is a successful case of the multiple governance model, and the Erhai Lake water pollution control is a dynamic process of realizing the multiple governance model in China. Therefore, this paper selects three representative subjects involved in the Erhai Lake governance process, namely the central government, local governments, and tourism enterprises, and the local residents of the Erhai Lake, as an external force influencing the subject's behavioral decision-making, and tries to analyze the mechanism of realizing this multiple governance model and find appropriate policy tools and institutional design to achieve the macro goal of environmental governance.

Literature Review

The development of tourism based on natural scenery must be based on the primary principle of maintaining a high-quality ecological environment [4]. However, some studies have shown that the development of tourism has obviously caused the increasing deterioration of the ecological environment of tourist destinations [5-7], which not only affects the beautiful natural scenery and directly reduces the willingness of tourists to visit [8], but also destroys the living environment of the local residents and triggers their dissatisfaction [9]. With water resource development as the main focus of tourism, the water environment is more likely to be affected by tourism activities [10-12]. There are various factors of water pollution caused by tourism development, among which pollutant discharge from the accommodation and catering industries is an important cause of water pollution in tourism destinations [13]. Ning and He [14] found that tourism accommodation and catering have the highest concentration of water pollution, and both increasing the number of tourists and infrastructure construction will increase the nutrients in the water and lead to a decline in water quality. With the development of the economy, the number of tourists in China has been increasing year by year, making it necessary to control the pollutant discharge of tourism enterprises and strengthen the treatment of water pollution in the tourism environment.

From the existing literature, the issue of water pollution control in the tourism environment has attracted the attention of scholars. From the perspective of water pollution control technology, Zhao et al. [15] used a model of the water environment in a tourism area to simulate the dynamic process of water quality change caused by tourism activities due to season and tourist density and emphasized that the scale and intensity of tourism activities can be effectively controlled according to the response saturation threshold of the water environment. Wu et al. [16] believe that it is necessary to control the growth rate of tourism within a reasonable range to alleviate water pollution in the tourism environment. Larsen et al. [17] estimate the diffusion and influence range of pollutants in hotels around attractions by tracking pollutants in the water, find that water pollution in the tourism environment is the accumulation of many kinds of pollutants, and think that it is necessary to supervise the investment in hotels around scenic spots. From the perspective of the water pollution governance model, Zhuang et al. [18] found through field research that water pollution governance in tourist destinations presents a top-down model, and there is information opacity in the government, which leads to less than ideal results in water pollution governance. There is a need to improve the capacity and cooperation of local and regional governments and other stakeholders in order to reduce the gap with the governance objectives [19]. Water pollution management in the tourism environment is an action that involves the participation of multiple stakeholders, including the central government, the local governments, tourism enterprises, and local residents, mobilizing the ecological protection motivation of the participants through a series of institutional rules, which is also in line with China's new model of ecological and environmental management with multiple governance [20].

Evolutionary game theory is more and more widely used to reveal the game relationship between multiple stakeholders in ecological environment governance [21-23]. As the regulator of the environment, local governments can prompt enterprises to reduce emissions by means of environmental subsidies and environmental taxes [24, 25]. However, it is difficult to achieve the desired results of environmental governance by relying only on the participation of local governments and enterprises. On the one hand, there will be the possibility of ineffective regulation by local governments, and the political promotion of local officials is based on GDP performance as the main indicator [26]. When tourism becomes a major source of GDP revenue generation, local governments will have the willingness to shelter polluting enterprises in their jurisdictions [27]. On the other hand, both the improvement of production technology and the construction of wastewater treatment facilities increase the operating costs of enterprises. In the case of lax oversight by local governments, companies, as rational entities pursuing profit maximization, find it challenging to have the motivation for emission reduction. Some scholars have found that strengthening the gaming power of the central government can effectively reduce the efficiency loss brought about by the self-interested behavior of local governments; at the same time, the public's concern for environmental protection will also drive the environmental protection behaviors of enterprises, and public participation can make up for the shortcomings of the market mechanism in the government intervention [28-30].

Using exiting literature, this paper decides to adopt the evolutionary game method for research for two reasons. Firstly, the evolutionary game model has dynamic characteristics. The Nash equilibrium reached by each subject in the game system at the beginning is not the Pareto optimal result, but gradually optimizes strategic choices to obtain benefits in the process of continuous imitation, learning, and improvement, which is in line with the complexity and dynamics of Erhai Lake water pollution control. Secondly, the evolutionary game model has the assumption of an incomplete rational man, which is in line with the information asymmetry that exists between the central government, local government, and tourism industry operators, and there may be concealment or collusion in the game of each subject pursuing its own interest maximization, making it difficult to achieve the ideal Pareto optimal state of water pollution management. At present, there is a lack of literature studying water pollution management from the perspective of multiple governances and analyzing the mechanisms of its role. The marginal contribution of this paper is to study the multi-body interest game in water pollution management in the Erhai Lake tourism environment from the perspective of multiple governance, which provides a theoretical basis for the multiple governance model. At the same time, this paper adopts numerical simulation technology to explore the realization path of the multiple governance model, analyzes the role of different policy tools on water pollution management, reveals the impact factors of different policy tools on the water pollution management of the tourism environment in the Erhai Lake in China, and provides a realistic and effective policy basis for water pollution management.

Research Model

Problem Description and Theoretical Analysis

China's central government is the maker of environmental policy, and the central government allocates special funds for environmental protection each year to encourage local governments to carry out watershed management. At the same time, the central government sends environmental protection inspection teams to supervise the environmental management of local governments in Erhai Lake, and the central government will impose administrative penalties such as interviews, demotion of leaders of the relevant responsible departments for failing to meet the water quality standards, or withdrawal of the special funds for environmental protection as a financial penalty.

According to the Environmental Protection Tax Law of the People's Republic of China promulgated in 2018, local governments are required to collect environmental taxes from tourism operating enterprises. At the same time, local governments can adopt the means of subsidy incentives to prompt tourism enterprises to take emission reduction measures. The local governments can decide on their own the proportion of the central environmental protection special funds allocated to enterprises for emission reduction subsidies. If the tourism enterprises reduce emissions in accordance with the requirements of the local government, they can obtain subsidies from the local government, and if they don't reduce emissions, they can't obtain subsidies for emission reductions.

Local residents can defend their rights through network exposure, complaints, and reports and indirectly participate in water pollution control actions. When tourism enterprises do not reduce emissions and are found by local residents, they can expose their pollution behavior through the network or to the local government to complain or report. The active governance of local governments will put pressure on the tourism enterprises to suspend their business, but the local governments may also not act. At this point, local residents can further report to the local environmental protection inspection team, which will strictly monitor the accountability and punishment of enterprises and the local governments.

To summarize, in the tripartite game model, the set of strategies that tourism enterprises can choose is {reducing emission; not reducing emission}. The set of strategies that the local governments can choose is {positive governance; negative governance}. When they choose the positive governance strategy, they strictly follow the central government's environmental protection policy to carry out governance actions, and when they choose the negative governance strategy, they may have sheltering behavior. The central government can choose a strict regulation strategy to comprehensively judge whether the local government has whitewashed behavior and to hold it accountable and punish it, or it can choose a lax regulation strategy to let the local government's negative governance behavior go, and the central government's strategy set is {strict supervising; lax supervising}.

Premises and Payoff Matrix of the Evolutionary Game Model

In the Erhai Lake governance tripartite game model, there are three types of game subjects: the central government, the local governments, and tourism enterprises. Based on the theoretical analysis in the previous section, the following four basic premises are made:

Premise 1: All participants are of bounded rationality. The strategy set for the central government includes "strict supervising" and "lax supervising". The strategy set for the local governments includes "positive governing" and "negative governing". The strategy set for tourism enterprises includes "reducing emissions" and "not reducing emissions". This paper categorizes "strict supervising", "positive governing", and "reducing emissions" as positive strategies. On the other hand, "lax supervising", "negative governing", and "not reducing emissions" are considered negative strategies. The proportions of choosing positive strategies among the central government, the local governments, and the tourism enterprises are respectively x, y, and z ($0 \leq x,y,z \leq 1$). Hence, the proportion of people choosing negative strategies is respectively 1-x, 1-y, and 1-z. In addition, assuming the initial payoffs of the three-party game subjects are R_1, R_2, and R_3.

Premise 2: In the three-party game system of Erhai Lake governance, assume that the central government's vigor of supervision is α ($0 \leq \alpha \leq 1$). When the central government supervises strictly, $\alpha=1$, the cost of supervision at this point is C_1; when the central government is lax in supervision, the cost of supervision is $\alpha \times C_1$. Assuming that the local government's governance effort is β, when the local government is positive governing, $\beta = 1$, the cost of action of positive governing at this time is C_2; when the local government is negative governing, the cost of action is $\beta \times C_2$. C_3 indicates the cost of abatement to tourism enterprises. The special funds granted by the central government to local governments for ecological environment protection are V. λ indicates the proportion of local government environmental protection special funds allocated to subsidize emission reductions by tourism enterprises. When the negative governance of the local government is detected by the central government, the central government will withdraw the funds earmarked for environmental protection, and at the same time, the local government officials may be subject to administrative penalties such as political depreciation, assuming that the value of the penalty is P.

Premise 3: Local governments levie environmental tax on tourism enterprises in accordance with the water pollutant equivalent discharged by the taxpayers as stipulated in the Environmental Protection Tax Law of the People's Republic of China multiplied by the corresponding tax rate, assuming that the environmental tax rate is t, the water pollutant equivalent discharged by the tourism enterprises when they reduce emissions is H_1, and the water pollutant equivalent discharged by the enterprises when they do not reduce emissions is H_2 ($H_1<H_2$). When tourism enterprises reduce emissions, local environmental quality improves, and the local government gains from it as B. When tourism enterprises do not reduce emissions, local environmental pollution makes the local government bear the environmental loss of L. θ ($0 \leq \theta < 1$) denotes the coefficient of influence of the local environmental gain on the national environmental gain. The main business income of tourism enterprises is affected by the quality of the local environment, with S_1 denoting the main business income of tourism operators when they reduce their emissions and S_2 denoting their main business income when they do not reduce their emissions.

Premise 4: When the tourism enterprises do not reduce emissions and are exposed, complained or reported by local residents on the Internet, the reputation of the tourism enterprises is damaged, assuming that the loss of corporate reputation is M_3; for the local government, the local residents evaluate the government's pollution control work, and the local government's negative governance will lose credibility, while the positive governance will enhance credibility, assuming that the value of the local government's credibility gain or loss is M_2; for the central government, the central government's lax regulatory attitude will make the local residents dissatisfied, the government's credibility loss, the central government's strict supervision will enhance its image in the eyes of local residents, establish the authority of the central government, and then enhance the credibility, assuming that the central government's credibility gain or loss value is M_1. Combined with the actual situation, the central government represents China's environmental protection enforcement authority, so it is considered that the central government's credibility gain or loss value M_1 is greater than its accountability cost C_1, i.e., $M_1>C_1$.

According to the parameter settings in the premises above, the payoff matrix of the game model is determined as shown in Table 1.

Game Equilibrium Analysis

This paper uses the replicator dynamics method for game analysis. According to the payoff matrix in Table 1, the replicator dynamics equations for the tripartite game of Erhai Lake water pollution control are listed as follows:

$$\begin{cases} F(x)=\dfrac{dx}{dt}=x(1-x)[(\alpha-1)C_1+2M_1] \\ G(y)=\dfrac{dy}{dt}=y(1-y)\{2M_2+(1-z\lambda)V+(1-\beta)[t(zH_1+(1-z)H_2-C_2]+[x+(1-x)\alpha]P\} \\ H(z)=\dfrac{dz}{dt}=z(1-z)\{M_3-C_3+S_1-S_2+t(H_2-H_1)[y+(1-y)\beta]+\lambda yV\} \end{cases} \tag{1}$$

With $\frac{dx}{dt}=0$, $\frac{dy}{dt}=0$, and $\frac{dz}{dt}=0$ in equation group (1), the local equilibrium points of the game system are $E_1(0,0,0)$, $E_2(1,0,0)$, $E_3(0,1,0)$, $E_4(0,0,1)$, $E_5(0,1,1)$, $E_6(1,0,1)$, $E_7(1,1,0)$, $E_8(1,1,1)$, and $E_9(x^*,y^*,z^*)$, where (x^*,y^*,z^*) is the solution of equation group (2).

$$\begin{cases} (\alpha-1)C_1+2M_1=0 \\ 2M_2+(1-z\lambda)V+(1-\beta)[t(zH_1+(1-z)H_2-C_2]+[x+(1-x)\alpha]P=0 \\ M_3-C_3+S_1-S_2+t(H_2-H_1)[y+(1-y)\beta]+\lambda yV_3=0 \end{cases} \tag{2}$$

Since the stable solution in a multi-population evolutionary game must be a strict Nash equilibrium solution [31], this paper focuses on the equilibrium points. According to the method proposed by Friedman [32], the local stability of the equilibrium point can be determined by the characteristics of the system Jacobian matrix. The Jacobian matrix of the game system is in the form of:

Table 1. Payoff matrix of the tripartite game model.

Game participant			Tourism enterprises	
		The local governments	Reducing emission	Not reducing emissions
The central government	Strict supervising	Positive governing	$R_1 - C_1 - V + \theta B + M_1$, $R_2 - C_2 + B + tH_1 + (1-\lambda)V + M_2$, $R_3 - C_3 - tH_1 + \lambda V + S_1$	$R_1 - C_1 - V + \theta B + M_1$, $R_2 - C_2 - L + tH_2 + V + M_2$, $R_3 - tH_2 - M_3 + S_2$
		Negative governing	$R_1 - C_1 + \theta B + M_1$, $R_2 + B + \beta tH_1 - \beta C_2 - P - M_2$, $R_3 - C_3 - \beta tH_1 + S_1$	$R_1 - C_1 - \theta L + M_1$, $R_2 - \beta C_2 + \beta tH_2 - P - L - M_2$, $R_3 - \beta tH_2 + S_2 - M_3$
	Lax supervising	Positive governing	$R_1 - \alpha C_1 + \theta B - V - M_1$, $R_2 - C_2 + tH_1 + B + (1-\lambda)V + M_2$, $R_3 - C_3 - tH_1 + \lambda V + S_1$	$R_1 - \alpha C_1 - \theta L - V - M_1$, $R_2 - C_2 - L + tH_2 + V + M_2$, $R_3 - tH_2 - M_3 + S_2$
		Negative governing	$R_1 - \alpha C_1 + \theta B - M_1$, $R_2 - \beta C_2 + B - \alpha P + \beta tH_1 - M_2$, $R_3 - C_3 + S_1 - \beta tH_1$	$R_1 - \alpha C_1 - \theta L - M_1$, $R_2 - \beta C_2 - \alpha P - L + \beta tH_2 - M_2$, $R_3 - \beta tH_2 - M_3 + S_2$

$$J = \begin{bmatrix} \partial F / \partial x & \partial F / \partial y & \partial F / \partial z \\ \partial G / \partial x & \partial G / \partial y & \partial G / \partial z \\ \partial H / \partial x & \partial H / \partial y & \partial H / \partial z \end{bmatrix} \tag{3}$$

Where the core part of the mathematical judgment is

$$F_{11} = \frac{\partial F(x)}{\partial x} = (1-2x)[(\alpha-1)C_1 + 2M_1] \tag{4}$$

$$F_{22} = \frac{\partial G(y)}{\partial y} = (1-2y)\{2M_2 + (1-z\lambda)V + (1-\beta)[t(zH_1 + (1-z)H_2 - C_2] + [x + (1-x)\alpha]P\} \tag{5}$$

$$F_{33} = \frac{\partial H(z)}{\partial z} = (1-2z)\{M_3 - C_3 + S_1 - S_2 + t(H_2 - H_1)[y + (1-y)\beta] + \lambda yV\} \tag{6}$$

The local stability of equilibrium points in the multi-party game system can be determined using Lyapunov's criterion. By applying this method, the local stability of E_1~ E_8 can be analyzed, resulting in Propositions 1 to 5.

Proposition 1. Regardless of parameter values, E_1 (0,0,0), E_3 (0,1,0), E4 (0,0,1), and E_5 (0,1,1) are either saddle or unstable points; their stability is all unstable.

Proof of Proposition 1. Substituting (0,0,0) into equation group (3), the Jacobian matrix of E_1 is obtained as:

$$J = \begin{bmatrix} 2M_1 + (\alpha-1)C_1 & 0 & 0 \\ 0 & V + 2M_2 + \alpha P + (1-\beta)(tH_2 - C_2) & 0 \\ 0 & 0 & M_3 - C_3 + S_1 - S_2 + \beta t(H_2 - H_1) \end{bmatrix} \tag{7}$$

From the conditions for the determination of Lyapunov's criterion for Evolutionarily Stable Strategy (ESS), this equilibrium point is an ESS when and only when the values on the diagonal of the Jacobian matrix are all negative. The conditions for the unstable point are when, and only when, the values on the diagonal of the Jacobian matrix are all positive, and the rest of the cases are saddle points. By definition, $2M_1+(\alpha-1)C_1>0$, $V+2M_2+\alpha P+(1-\beta)(tH_2-C_2)$ is unable to determine positive or negative, and $M_3-C_3+S_1-S_2+\beta t(H_2-H_1)$ is also unable to determine positive or negative. According to Lyapunov's criterion, regardless of whether $V+2M_2+\alpha P+(1-\beta)(tH_2-C_2)$, $M_3-C_3+S_1-S_2+\beta t(H_2-H_1)$ is positive or negative, E_1 (0,0,0) can only be a saddle or unstable point. Similarly, E_3 (0,1,0), E_4 (0,0,1), and E_5 (0,1,1) are all either saddle or unstable points.

Proposition 2. When conditions $(1-\alpha)C_1-2M_1<0$, $V+2M_2+P+(1-\beta)(tH_2-C_2)<0$ and $M_3-C_3+S_1-S_2+\beta t(H_2-H_1)<0$ are met simultaneously, E_2 (1,0,0) becomes the ESS for the game system. When $(1-\alpha)C_1-2M_1<0$, $2M_2+(1-\lambda)V+P+(1-\beta)(tH_1-C_2)<0$, and $C_3-M_3+S_2-S_1+\beta t(H_1-H_2)$ <0 are met simultaneously, E_6 (1,0,1) becomes the ESS for the game system. When $(1-\alpha)C_1-2M_1<0$, $(1-\beta)(C_2-tH_2)-2M_2-V-P<0$, and $M_3-C_3+S_1-S_2+t(H_2-H_1)$ $+\lambda V<0$ are met simultaneously, E_7 (1,1,0) becomes the ESS for the game system.

Proof of Proposition 2. Substituting (1,0,0) into equation group (3), the Jacobian matrix of E_2 is obtained as:

$$J=\begin{bmatrix}(1-\alpha)C_1-2M_1 & 0 & 0\\ 0 & V+2M_2+\alpha P+(1-\beta)(tH_2-C_2) & 0\\ 0 & 0 & M_3-C_3+S_1-S_2+\beta t(H_2-H_1)\end{bmatrix} \tag{8}$$

By Premises 1-4, $(1-\alpha)C_1-2M_1<0$ clearly holds. The condition for $V+2M_2+P+(1-\beta)(tH_2-C_2)<0$ to hold is $(1-\beta)C_2>V+2M_2+P+(1-\beta)tH_2$. Thus, the cost of negative governance to local governments is greater than the sum of the environmental taxes collected from tourism enterprises, the loss of local government's credibility, the funds earmarked for environmental protection allocated by the central government, and the administrative penalties imposed by the central government for negative governance. The condition for $M_3-C_3+S_1-S_2+\beta t(H_2-H_1)<0$ to hold is that the sum of the abatement cost of the tourism enterprises, the main business income after the abatement, and the environmental tax paid without the abatement is greater than the sum of the corporate reputation lost without the abatement, the main business income without the abatement, and the environmental tax paid after the abatement. At this point, the game system converges to the evolutionary stable strategy of {strict supervising; negative governing; not reducing emission}. Similarly, it can be proved that when $(1-\alpha)C_1-2M_1<0$, $2M_2+(1-\lambda)V+P+(1-\beta)(tH_1-C_2)<0$, and $C_3-M_3+S_2-S_1+\beta t(H_1-H_2)<0$ are met simultaneously, E_6 becomes the ESS for the game system. And when $(1-\alpha)C_1-2M_1<0$, $(1-\beta)(C_2-tH_2)-2M_2-V-P<0$, and $M_3-C_3+S_1-S_2+t(H_2-H_1)+\lambda V<0$ are met simultaneously, E_7 becomes the ESS for the game system.

Proposition 3. When $(1-\alpha)C_1-2M_1<0$, $(1-\beta)(C_2-tH_1)-2M_2-(1-\lambda)V-P<0$, *and* $C_3-M_3+S_2-S_1+t(H_1-H_2)-\lambda V<0$ are met simultaneously, E_8 (1,1,1) becomes the ESS for the game system. The three-party game system converges to the Pareto optimal state.

Proof of Proposition 3. The Jacobian matrix of E_8 is:

$$J=\begin{bmatrix}(1-\alpha)C_1-2M_1 & 0 & 0\\ 0 & (1-\beta)(C_2-tH_1)-2M_2-(1-\lambda)V-P & 0\\ 0 & 0 & C_3-M_3+S_2-S_1+t(H_1-H_2)-\lambda V\end{bmatrix} \tag{9}$$

By Premises 1-4, $(1-\alpha)C_1-2M_1<0$ holds. The condition for $(1-\beta)(C_2-tH_1)-2M_2-(1-\lambda)V-P<0$ to hold is that the cost of negative governance to local governments is less than the sum of the environmental tax collected from tourism enterprises when they do not reduce emissions, the loss of credibility of local governments, the special funds allocated by the central government for environmental protection, and the administrative penalties imposed by the central government for negative governance. The condition for $C_3-M_3+S_2-S_1+t(H_1-H_2)-\lambda V<0$ to hold is that the sum of the abatement costs of tourism enterprises, their main business income after abatement, and the environmental taxes they would have paid if they had not abated their emissions is less than the sum of their lost corporate reputation if they had not abated their emissions, their main business income if they had not abated their emissions, and the environmental taxes they would have paid if they had abated their emissions. At this point, the game system converges to the stable strategy of {strict supervising; positive governing; reducing emission}, and the tripartite game system towards the Pareto optimal state.

Table 2 summarizes the local stability of equilibrium points in the game system, as inferred from the propositions above. E_1, E_3, E_4 and E_5 are either saddle or unstable points. If and only if specific conditions are met, E_2, E_6, E_7 and E_8 can become the ESS of the tripartite game system. Through the game equilibrium analysis, the ideal evolutionary stabilization strategy under the multiple governance model should be {strict supervising; positive governing; reducing emission}. However, how can this ideal evolutionary strategy be realized? How can the national macro-control system incentivize or urge the environmental protection governance entities to adopt active governance strategies? For this reason, we carried out the numerical simulation analysis using MATLAB.

Results and Discussion

This section uses MATLAB to numerically simulate the behavioral evolution of the participating subjects in the three-party game system. The number of iterations for the simulation is 1000.

Initial Value Setting of Simulation Parameters

According to the actual situation of Erhai Lake water environment management, the cost of environmental management by the local government C_2 is set at 13, the cost of supervision by the central government C_1 is 5, the cost of emission reduction by tourism enterprises C_3 is 2, and the central environmental protection special fund V is 6. The calculation of the tax t per hundred tons of pollution equivalent for water pollutants is 3.5, and the pollutant equivalent of Erhai Lake is about 150 tons. Based on this, it is assumed that the pollutant equivalent H_2 discharged by tourism enterprises without emission reduction is 160 tons, and the pollutant equivalent H_1 discharged by tourism enterprises with emission reduction is 130 tons. Referring to Chu et al. [33], we set the initial values of the main business income of tourism enterprises S_1 and S_2 as 10 and set the initial values of λ, α, and β as 0.5. In addition, referring to the valuation idea of Pan et al. [34] for government credibility and

Table 2. Equilibrium point analysis of the game system.

Equilibrium Point	(F_{11}, F_{22}, F_{33})	Det J	Tr J	Stability Judgement
$E_1(0,0,0)$	(+, +/-, +/-)	TBD[1]	- or +	Saddle or unstable point
$E_2(1,0,0)$	(-, +/-, +/-)	TBD	- or +	Saddle point or ESS
$E_3(0,1,0)$	(+, +/-, +/-)	TBD	- or +	Saddle or unstable point
$E_4(0,0,1)$	(+, +/-, +/-)	TBD	- or +	Saddle or unstable point
$E_5(0,1,1)$	(+, +/-, +/-)	TBD	- or +	Saddle or unstable point
$E_6(1,0,1)$	(-, +/-, +/-)	TBD	- or +	Saddle point or ESS
$E_7(1,1,0)$	(-, +/-, +/-)	TBD	- or +	Saddle point or ESS
$E_8(1,1,1)$	(-, +/-, +/-)	TBD	- or +	Saddle point or ESS

[1] "TBD" stands for "to be determined".

corporate reputation, it is assumed that M_1 is 6, M_2 is 6, and M_3 is 2. At the same time, it is assumed that the administrative penalty P imposed by the central government is 1 when the local government governs negatively. The above initial conditions simultaneously satisfy the parameter conditions in Proposition 3. Except for studying the effect of the initial proportion of positive strategy on the evolutionary path, the initial proportion of positive strategy of the game participants is set to 0.5.

The Influence of Initial Positive Strategies Proportion on Evolutionary Trajectories

The evolution paths of the game system under different initial strategy proportions are illustrated in Fig. 1, where the X, Y, and Z axes respectively represent the proportions of the central government choosing the "strict supervising" strategy, the local governments choosing the "positive governing" strategy, and the tourism enterprises choosing the "reducing emission" strategy. As can be seen from Fig. 1, regardless of the initial strategy ratio of each game subject, it will eventually evolve to the (1,1,1) point, forming countless evolutionary paths from all directions to the (1,1,1) point, i.e., the stable convergence to the Pareto optimal state of (strict supervising, positive governing, and reducing emission). This aligns with the analysis of Proposition 3, confirming the accuracy of the model derivation.

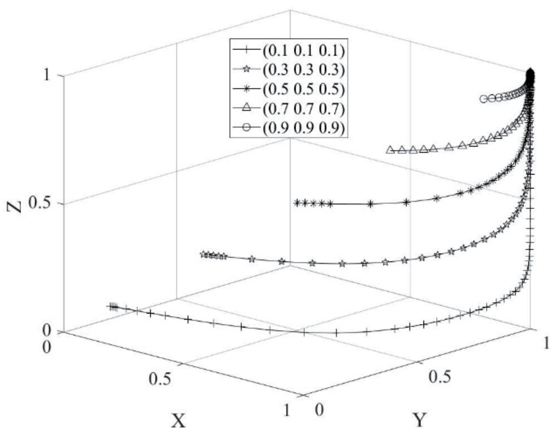

Fig. 1. The evolutionary trajectories with a variation in the initial proportion of positive strategy.

The Effects of V, λ, P, and t on Evolutionary Paths

As can be seen from Fig. 2a), when V is 0 or 1, the game system converges to the point (1,1,0), and with the increase of V, the speed of convergence becomes slower; while when V is 5, 8, and 12, the game system converges to the point (1,1,1), and with the increase of V, the speed of convergence becomes faster. To sum up, the V can promote the game system from convergence to the (1,1,0) point to convergence to the Pareto optimal state (1,1,1) point, and as the amount of funds continues to increase, the game system's convergence to the Pareto optimal state of speed will continue to become faster.

From Fig. 2b), when λ is 0.1, the game system converges to (1,1,0); and when λ is 0.3, 0.5, 0.7, and 0.9, the game system converges to (1,1,1), and with the increase of λ, the speed of convergence gradually becomes faster. In summary, the λ can promote the game system from convergence to the (1,1,0) point to convergence to the Pareto optimal state (1,1,1) point, and with the increasing proportion λ of environmental protection special funds allocated to the Pareto optimal state of the game system convergence, the speed will continue to become faster.

From Fig. 2c), when P is 0 or 2, the game system converges to the point (1,0,0), and the convergence becomes slower with the increase of P. When P is 6, 10, and 15, the game system converges to the point (1,1,1), but the convergence becomes slower with the increase of P gradually. In conclusion, P can promote the game system from converging to the (1,0,0) point to converging to the Pareto optimal state (1,1,1) point, but there exists a threshold value for this kind of

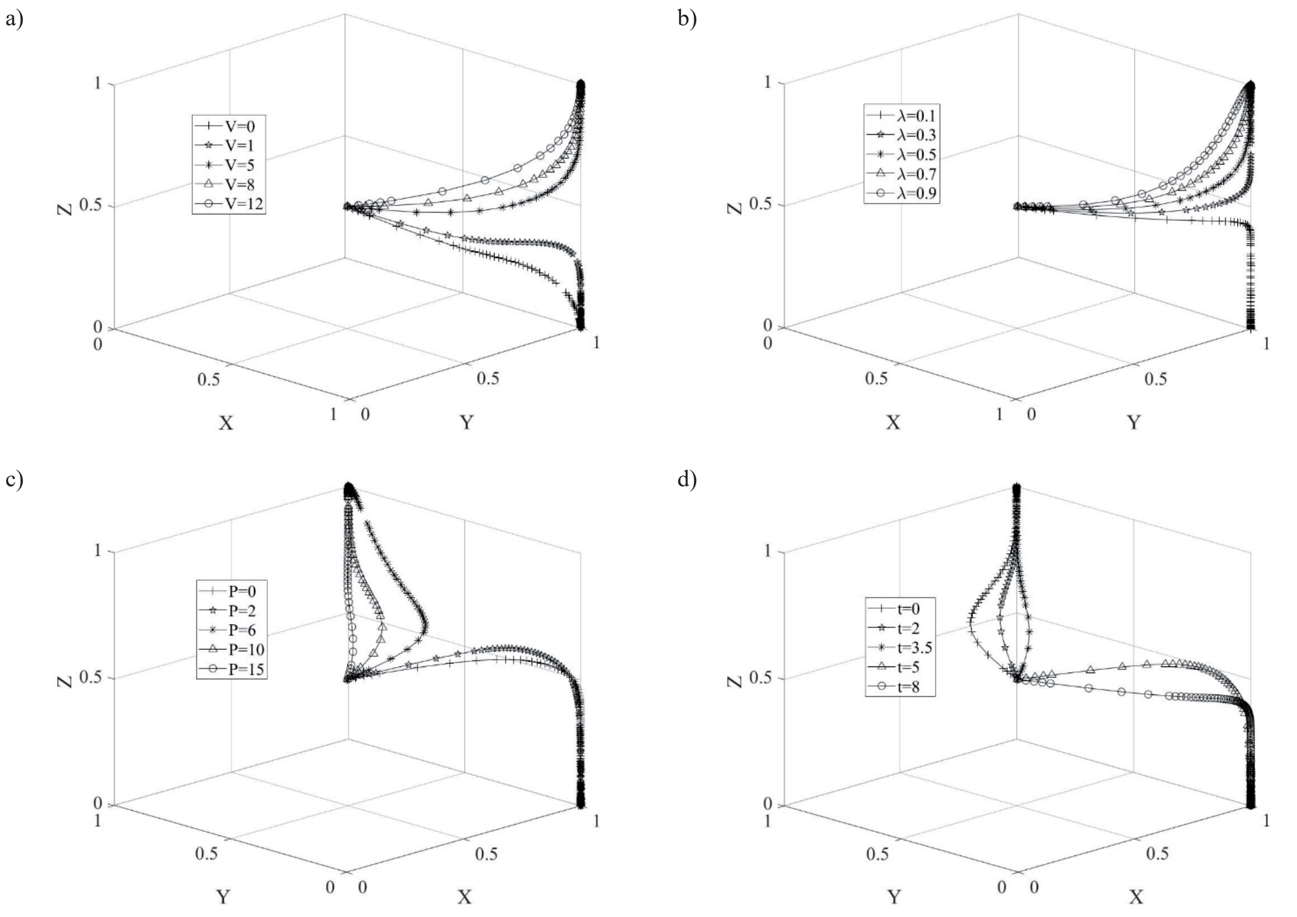

Fig. 2. The evolutionary trajectories with variations in different factors: a) V; b) λ; c) P; d) t.

promotional effect, and after exceeding this threshold value, with the increase of P, the convergence of the game system to the Pareto optimal state will be slowed down. Therefore, the central government needs to penalize the local agent's failure to meet the standard of environmental protection regulation on the one hand, and on the other hand, it also needs overly harsh penalties to combat the enthusiasm of local governments to implement the central environmental protection policy.

From Fig. 2d), when t is 0, 2, and 3.5, the game system converges to the point of (1,1,1), and with the increase of t, the speed of convergence gradually becomes slower; while when t is 5 and 8, the game system converges to the point of (1,0,0), and with the increase of t, the speed of convergence becomes faster. In summary, the t can make the game system from converging to the Pareto optimal state point of (1,1,1) to converging to the point of (1,0,0), and with the increasing of t, the game system will converge to the point of (1,0,0) and continue to become faster. It can be known that when the t is in the interval of [0,3.5], it is favorable for the game system to evolve towards the Pareto optimal state of (1,1,1), but when the t exceeds 3.5, the game system will converge to the point of (1,0,0).

The Effects of M_1, M_2, and M_3 on Evolutionary Paths

As can be seen from Fig. 3a), when the central government's credibility gain or loss M_1 is 6, 8, 10, 12, 14, the game system converges to the point (1,1,1), and with the increase of M_1, the speed of convergence gradually becomes faster. To sum up, as the M_1 increases, the game system will converge to the Pareto optimal state faster.

From Fig. 3b), when the local governments credibility gain or loss M_2 is 0 and 2, the game system converges to the point (1,0,0), and with the increase of M_2, the speed of convergence becomes slower gradually; while when the local governments credibility gain or loss M_2 is 5, 7, and 9, the game system converges to the point (1,1,1), but the speed of convergence gradually slows down with the increase of M_2. In summary, M_2 can promote the game system from converging to the (1,0,0) point to converging to the Pareto optimal state (1,1,1) point, but there is a threshold value of 5 for this kind of promotion effect, and after exceeding this threshold value, with the increase of M_2, the speed of the game system converging to the Pareto optimal state will slow down.

From Fig. 3c), the game system converges to the point (1,1,0) when the M_3 of the corporate reputation

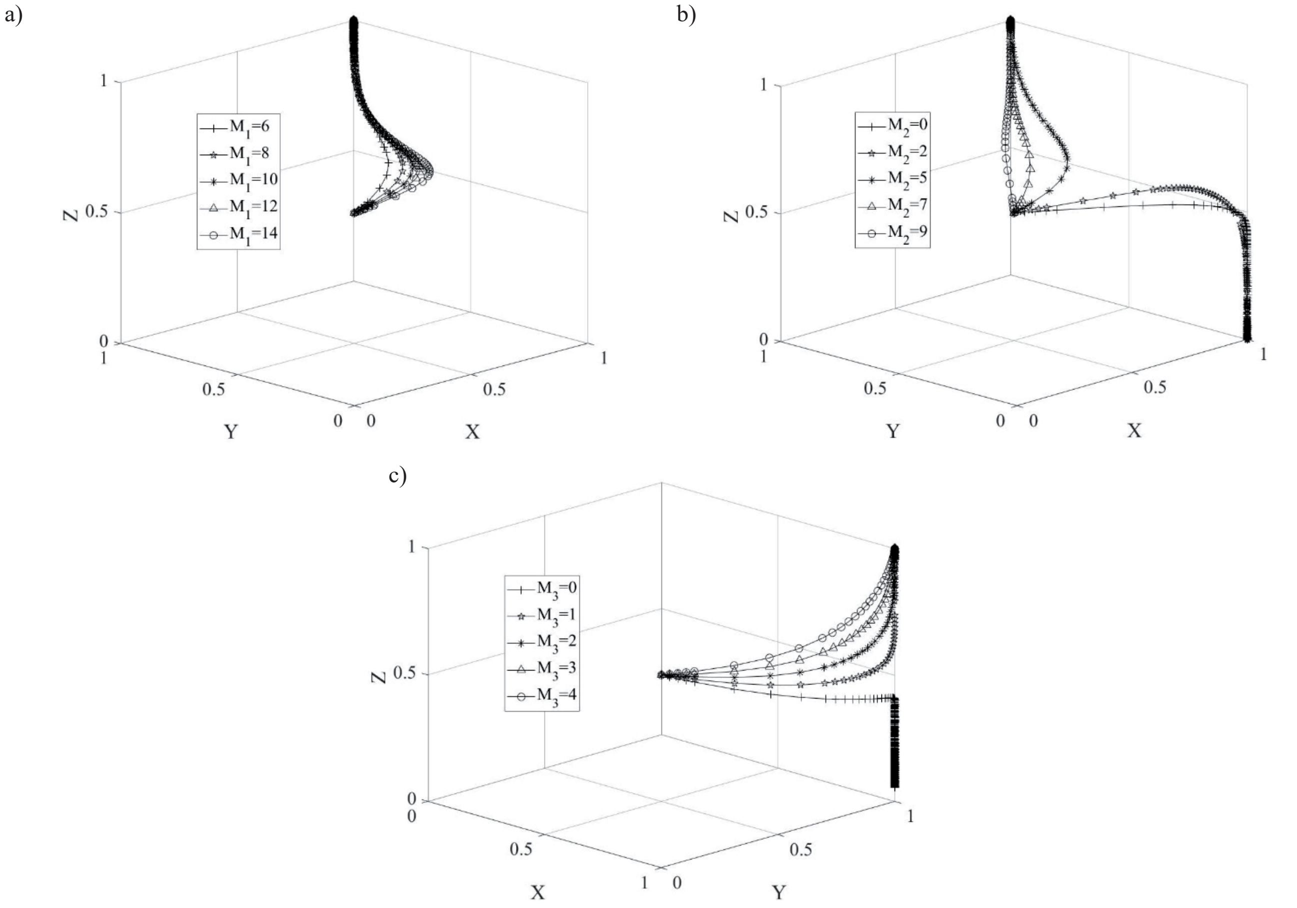

Fig. 3. The evolutionary trajectories with variation in government credibility gains or losses and corporate reputation: (a) M_1; (b) M_2; (c) M_3.

of tourism enterprises' loss is 0. The game system converges to the point (1,1,1) when the M_3 is 2, 3, 4, and 5, and the convergence speed becomes faster with the increase of M_3. Therefore, M_3 can promote the game system from converging to the (1,1,0) point to converging to the Pareto-optimal state (1,1,1) point, and as M_3 increases, the speed of convergence of the game system to the Pareto optimal state will become faster and faster.

Conclusions

Water pollution management in the tourism environment is a joint action of multiple stakeholders that need to consider the impacts of multiple factors on water pollution management, such as the government, tourism enterprises, and local residents, and explore the effective conditions for the behavior and decision-making of each subject. This paper adopts the method of evolutionary game, puts the central government, the local governments, and tourism enterprises in the same analytical framework, and constructs a three-party evolutionary game model of water pollution control in the Erhai Lake tourism environment. Meanwhile, local residents are regarded as the external supervisory force of the water pollution control process, and the influence of relevant parameters on the game system is analyzed. This paper derives the following conclusions:

(1) Water pollution control in the tourism environment still needs the financial support of the central government. In the case of the central government's financial resources, the greater the allocation of environmental protection special funds, the more it can promote the positive governance of the local governments. But at the same time, the central government needs to grasp the administrative supervision of the local governments. When the local governments negative governing, the central government of the local government's administrative penalty value is too small, which is not conducive to the formation of the deterrent effect, and too high administrative penalty pressure also weakens the confidence of the local governments. Therefore, the administrative penalties imposed by the central government on local officials need to be moderate.

(2) The higher the proportion of local government environmental protection special funds allocated to tourism enterprises, the more they can promote emission reduction by tourism enterprises, and their incentives

to reduce emissions will be strengthened when the main business income of tourism enterprises increases due to the improvement of the tourism environment.

(3) Local residents are able to influence the environmental behavior of the central government, the local governments, and tourism enterprises through a reputational feedback mechanism, which can promote the treatment of water pollution in the tourism environment.

(4) The collection of environmental tax by the local government can motivate tourism enterprises to reduce emissions, but the environmental tax rate should be set appropriately. The environmental tax rate in [0,3.5] is a more reasonable range; too high will make the tourism enterprises lose confidence in reducing emissions.

Acknowledgments

This research was supported by the Innovation Project of Guangxi Graduate Education (YCSW2023069).

Conflict of Interest

The authors declare no conflicts of interest.

References

1. CECCHI T. Analysis of volatiles organic compounds in Venice lagoon water reveals COVID 19 lockdown impact on microplastics and mass tourism related pollutants. Science of the Total Environment, **783**, 146951, **2021**.
2. ZHANG Z., ZHU P. Empirical study on heterogeneous dynamic path of local expenditure under inter-temporal budget constraints. Economic Research Journal, **45**, 82, **2010**.
3. WANG H., FAN C., CHEN S. The impact of campaign-style enforcement on corporate environmental Action: Evidence from China's central environmental protection inspection. Journal of Cleaner Production, **290**, 125881, **2021**.
4. CAO S., YANG L. Study on comprehensive treatment of the water pollution of Qingjiang River Basin's tourism environment. Ecological Economics, **31**, 141, **2015**.
5. RICO A., MARTÍNEZ-BLANCO J., MONTLLEÓ M., RODRÍGUEZ G., TAVARES N., ARIAS A., OLIVER-SOLÀ J. Carbon footprint of tourism in Barcelona. Tourism Management, **70**, 491, **2019**.
6. GÜRSOY Ö., YÜĞRÜK AKDAĞ N. Evaluation of the environmental noise problems in holiday villages: a case study from Antalya, Turkey. Environmental Science and Pollution Research, **26**, 10972, **2019**.
7. FILIMONAU V., SANTA ROSA M., FRANCA L.S., CREUS A.C., RIBEIRO G.M., MOLNAROVA J., PIUMATTI R.G., VALSASINA L., SAFAEI A. Environmental and carbon footprint of tourist accommodation: A comparative study of popular hotel categories in Brazil and Peru. Journal of Cleaner Production, **328**, 129561, **2021**.
8. SU Y., HAMMOND J., VILLAMOR G.B., GRUMBINE R.E., XU J., HYDE K., PAGELLA T., SUJAKHU N.M., MA X. Tourism leads to wealth but increased vulnerability: a double-edged sword in Lijiang, South-West China. Water International, **41** (5), 682, **2016**.
9. HSU C.-H., LIN H.-H., JHANG S. Sustainable tourism development in protected areas of rivers and water sources: a case study of Jiuqu stream in China. Sustainability, **12** (13), 5262, **2020**.
10. SUN Q., LIU Z. Impact of tourism activities on water pollution in the West Lake Basin (Hangzhou, China). Open Geosciences, **12** (1), 1302, **2020**.
11. DOU W., WANG Z., FANG J., HAN T., PU T., ZHANG P. Coupling analysis of tourism activities and water environment: a case study of Yulong Snow Mountain-Lijiang basin. Journal of Glaciology and Geocryology, **43** (4), 1210, **2021**.
12. KURNIAWAN F., ADRIANTO L., BENGEN D.G., PRASETYO L.B. Hypothetical effects assessment of tourism on coastal water quality in the Marine Tourism Park of the Gili Matra Islands, Indonesia. Environment Development and Sustainability, **25** (8), 7959, **2023**.
13. YANG P., ZHAN Z., MING X., CHEN F., REN J., DENG S., HONG A. Hydrochemical variation of the karst groundwater impacted by the contaminant discharge from a tourism hotel. Journal of Lake Sciences, **31** (2), 416, **2019**.
14. NING B., HE Y. Tourism development and water pollution: Case study in Lijiang Ancient Town. China Population Resources and Environment, **17** (5), 123, **2007**.
15. ZHAO M.-F., XI J.-C., LIU S.-H. Simulating the saturation threshold of a water environment's response to tourist activities: A case study in the Liupan mountain eco-tourism area. Journal of Mountain Science, **11**, 156, **2014**.
16. WU X., WU F., HE Z., WANG R. Determining a reasonable speed for Xinjiang's tourism development in the '14th five-year plan'under the green concept: Analysis from the perspective of water environment regulation. Polish Journal of Environmental Studies, **31** (1), 899, **2022**.
17. LARSEN J., MAAR M., RASMUSSEN M.L., HANSEN L.B., HAMAD I.Y., STÆHR P.A.U. High-resolution hydrodynamics of coral reefs and tracing of pollutants from hotel areas along the west coast of Unguja Island, Zanzibar. Marine Pollution Bulletin, **191**, 114968, **2023**.
18. ZHUANG Z., YAN S., WEN W., YILIN Y. Study on the utilization and protection of water resources in the eco-tourism development of the Boluo Lake wetland nature reserve in Jilin Province. Desalination and Water Treatment, **169**, 114, **2019**.
19. NITIVATTANANON V., SRINONIL S. Enhancing coastal areas governance for sustainable tourism in the context of urbanization and climate change in eastern Thailand. Advances in Climate Change Research, **10** (1), 47, **2019**.
20. CHEN Y. On the logic of check and balance in China's environmental multi-governance. China Population Resources and Environment, **30** (6), 116, **2020**.
21. BAI M., CHEN M., ZHANG L., DUAN Y., ZHOU S. Research on Evolutionary Game Analysis of Spatial Cooperation for Social Governance of Basin Water Pollution. Water, **14** (16), 2564, **2022**.
22. TANG J., LI S. Research on multiple co-governance of agricultural non-point source pollution in China on the perspective of ENGOs and public participation. Plos One, **18** (2), e0280360, **2023**.
23. WEI G., LI G., SUN X. Evolutionary Game Analysis of the Regulatory Strategy of Third-Party Environmental

Pollution Management. Sustainability, **14** (22), 15449, **2022**.
24. CHEN W., HU Z.-H. Using evolutionary game theory to study governments and manufacturers' behavioral strategies under various carbon taxes and subsidies. Journal of Cleaner Production, **201**, 123, **2018**.
25. LIU G., YANG Z., ZHANG F., ZHANG N. Environmental tax reform and environmental investment: A quasi-natural experiment based on China's Environmental Protection Tax Law. Energy Economics, **109**, 106000, **2022**.
26. ZHOU L.-A. Governing China's local officials: An analysis of promotion tournament model. Economic Research Journal, **7** (36), 36, **2007**.
27. CHU Z., BIAN C., LIU C., ZHU J. Simulation of haze pollution, regulatory governance and public participation based on evolutionary game analysis. China Population Resources and Environment, **29** (7), 101, **2019**.
28. ZHOU B., DING H. How public attention drives corporate environmental protection: Effects and channels. Technological Forecasting and Social Change, **191**, 122486, **2023**.
29. CHU Z., BIAN C., YANG J. How can public participation improve environmental governance in China? A policy simulation approach with multi-player evolutionary game. Environmental Impact Assessment Review, **95**, 106782, **2022**.
30. ZHANG H., XU T., FENG C. Does public participation promote environmental efficiency? Evidence from a quasi-natural experiment of environmental information disclosure in China. Energy Economics, **108**, 105871, **2022**.
31. FRIEDMAN D. On Economic Applications of Evolutionary Game Theory. Journal of Evolutionary Economics, **8**, 15, **1998**.
32. SAMUELSON L., SWINKELS J.M. Evolutionary stability and lexicographic preferences. Games and Economic Behavior, **44** (2), 332, **2003**.
33. CHU Z., BIAN C., LIU C., ZHU J. Evolutionary game analysis on haze governance in Beijing-Tianjin-Hebei: based on a simulation tool for proposed environmental regulation policies. China Population Resources and Environment, **28** (12), 63, **2018**.
34. PAN F., LIU Y., WANG L. Game Analysis of the Evolution of Environmental Regulation with the Participation of Four Parties. Operations Research and Management Science, **31** (3), 63, **2022**.