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How to reduce the impact of contaminated seafood on public health with the discharge of Fukushima nuclear wastewater

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As wastewater from the Fukushima nuclear disaster continues to drain into the sea, the supply system for healthy seafood is being seriously challenged. To protect public health, it is necessary to restructure the seafood supply mode. The seafood supply mode is divided into the original mode, land farming mode, and strengthen monitoring mode. To derive the applicable scope of the various modes of the seafood supply chain and to provide recommendations for the safety and sustainability of seafood supply chains for governments and enterprises, three differential game models are constructed in this study. Then, the equilibrium results obtained by the models are compared and analyzed. Based on the findings, the health impact of seafood pollution is relatively small, and the government tends to choose the original supply mode. As the health impact of seafood grows, governments tend to prefer land-based farming. The social benefit to the government is directly proportional to the monitoring cost of seafood. To protect public health, enterprises tend to choose the mode of strengthen monitoring if the proportion of unqualified seafood is low. In addition, if sea products show a high degree of adaptation to the land environment, they tend to choose land farming.

KEYWORDS

Fukushima nuclear wastewater, differential game, seafood supply, land farming, strengthen monitoring, social benefit

1. Introduction

1.1. Background and research significance

On 11 March 2011, a 9.0 magnitude earthquake struck the Tohoku region of Japan, marking one of the most powerful earthquakes in the country's history. It triggered a huge tsunami 10–15 m high, which hit the Fukushima Daiichi nuclear power plant and knocked out the plant's power system. With the power system down, the plant's cooling system failed to function properly, eventually triggering meltdowns at multiple nuclear reactors and the release of radioactive material. These radioactive substances pose a great threat to human health and the environment (Shuryak, 2021). After the Fukushima nuclear accident, the Fukushima Daiichi nuclear power plant generated a large amount of nuclear wastewater, including water used to cool and treat nuclear fuel and that collected through infiltration through reactors and groundwater. The disposal of these nuclear effluents has been a complex and controversial issue. The Japanese government has proposed a plan to treat nuclear wastewater through a treatment method called "decontamination." The process mainly involves treating the nuclear wastewater at a purification facility that removes most of the radionuclides, leaving only one type of nuclide called boric acid trichloride. The remaining nuclear wastewater will then be discharged into the ocean. This raises concerns about the possible effects of the discharge of nuclear wastewater on human health (Zhang et al., 2022).

Japan plans to release water from the Fukushima nuclear power plant into the ocean. While the Japanese government and organizations such as the International Atomic Energy Agency (IAEA) claim that treated wastewater is safe to put into the ocean, this decision has sparked significant concern. Some argue that such emissions could pose potential risks to marine ecosystems and human health. Even though wastewater from the Fukushima nuclear power plant has been treated, there are still traces of radioactive material. Therefore, some researchers think that such wastewater is polluted water (Yang et al., 2022). In this study, "wastewater" refers to "contaminated water," as designated by countries such as China, rather than "treated water," as claimed by Japan. Despite undergoing a series of purification treatments, the wastewater still contains radioactive materials such as tritium, strontium, and iodine. Hence, Japan's decision has raised considerable concern and doubt from the international community. If the Fukushima nuclear wastewater discharge is substantial, it will lead to the accumulation of radioactive substances in the ocean, which will inflict specific damage upon seafood. Specifically, high levels of radioactive substances in seafood will affect its quality and safety of seafood, affecting human health. For example, long-term consumption of seafood containing radioactive substances can cause cancer, affect people's reproductive system, increase the risk of cardiovascular disease, affect the immune system, and so on. It is especially harmful to children and pregnant women.

However, there are many benefits to eating seafood. First, seafood is rich in protein, vitamins, minerals, unsaturated fatty acids, and other nutrients, which are beneficial to the body (Koehn et al., 2022). Second, it reduces the risk of cardiovascular disease. The unsaturated fatty acids in seafood can lower cholesterol levels and reduce the risk of cardiovascular disease. Third, it strengthens immunity. Seafood is rich in vitamins and minerals, which can enhance immunity and improve the body's resistance (Lauritzen, 2021). Fourth, it promotes brain development. Docosahexaenoic Acid (DHA) in seafood is beneficial for brain development and function and helps increase intelligence. In terms of regional coverage of seafood consumption, the level of consumption is high in coastal areas and developed countries, and it is relatively low in inland areas and some developing countries. Traditional dietary habits also affect the level of seafood consumption in some regions, such as Japan, South Korea, and China, where consumption is high. In addition, with the growth of the global population and the improvement of the economic level, the demand for seafood is gradually increasing.

As the Fukushima nuclear wastewater continues to be discharged, seafood contamination needs to attract the attention of countries worldwide. Effective monitoring, control, and protection measures are required to ensure the safety and quality of seafood. To ensure a healthy seafood supply, governments and enterprises can take measures such as land seafood farming and strengthening seafood monitoring. Marine aquaculture on land has the characteristics of flexible geographical location, easy control of pests and diseases, and efficient production, but the cost of aquaculture is high. Although the cost of strengthening inspections is low, controlling seafood pollution is difficult. Therefore, the applicable scope of various seafood supply modes is an important issue in this study.

1.2. Literature review

As a major environmental crisis, Fukushima nuclear accident has had a huge impact on the environment. For example, some scholars believe that the accident will lead to increased environmental pollution caused by radionuclides, resulting in an increased external radiation dose rate (Taira et al., 2012). Kasar et al. (2021) discovered through research that radioactive elements in contaminated soil surrounding Fukushima exceeded the standard. Kitamura et al. (2017) believe that the Fukushima nuclear accident caused excessive radioactive cesium in the North Pacific Ocean. These studies highlight the substantial contamination stemming from the Fukushima nuclear accident.

Nuclear-contaminated water is potentially contaminated and should not be released into the ocean to safeguard global public health (Chang et al., 2022). Marine pollution will affect the seafood supply chain, a subject that many scholars have studied. For example, Loubet et al. (2022) studied the impact of marine plastics on the seafood supply chain. Mellett et al. (2021) studied the impact of packaging on the seafood supply chain environment. Tseng et al. (2021) analyzed the capacity of Vietnam's marine product processing cycle supply chain. Stentiford and Holt (2022) analyzed the global supply of aquaculture seafood. Chang and Kim (2020) tested the supply chain of the seafood industry by conducting a structural path analysis. As a kind of marine pollution, the ongoing discharge of the Fukushima nuclear wastewater into the sea will also have an impact on the seafood supply chain. However, since Fukushima nuclear wastewater has not been discharged into the sea, few studies have analyzed its impact on the seafood supply chain.

Some scholars have studied ways to reduce the effects of Fukushima wastewater. These can be divided into macro, micro, and combined macro-micro perspectives. For example, Yang et al. (2022) employed the graph mode with gray and unknown preferences to solve the challenges posed by Fukushima nuclear wastewater entering the sea. Meng et al. (2022) studied metal-free 2D/2D C3N5/GO nanosheets with customized energy level structures to treat radionuclear wastewater. Liu et al. (2021) used macro and micro simulation methods to analyze how Fukushima nuclear wastewater can be treated. The studies encompass algorithms, material science, and management analysis on the ways of reducing the impact of Fukushima wastewater.

However, with the ongoing discharge of Fukushima nuclear wastewater into the sea, seafood will continue to be contaminated with radioactive materials. This will cause a healthy seafood supply chain to be challenged at any time. However, the studies mentioned above do not provide a clear picture of the continuing public health effects of contaminated seafood. To make up for the shortcomings of these studies, this study analyzes how public health can be protected, from the healthy seafood supply chain perspective. In this study, the supply mode of seafood is divided into three modes: original mode, land farming mode, and strengthen monitoring mode. The balance effect of different seafood supply modes is compared and analyzed. Finally, the applicable scope of various seafood supply modes is obtained. The study provides a theoretical basis for more effective management and supply of healthy seafood.

2. Methodology

2.1. Problem description, hypothesis, and variable definition

2.1.1. Problem description

The release of Fukushima wastewater into the sea could have a huge impact on human health. The Fukushima nuclear wastewater contains radioactive substances, which may enter the human food chain through seafood and fish in the ocean; this may result in the ingestion of a large number of radioactive substances, potentially harming human health (Ueda et al., 2021). The original seafood supply chain mode is struggling to meet the requirements. To protect people's health, the seafood supply chain needs to be reconsidered. Specific seafood supply chains include the following:

(1) The original seafood supply mode. It consists of four steps. The first is fishing and farming. Fishing and farming comprise the first link in the seafood supply chain. Fishing refers to the fishing of various kinds of fish, shellfish, shrimp, and other seafood in the sea, while aquaculture refers to the artificial cultivation of various kinds of seafood in the land or sea. The second is transportation and processing. After seafood is caught or farmed, it needs to be transported and processed. Transportation includes sea and land transportation, while processing includes sorting, cleaning, hulling, scaling, and gutting. The third is wholesale and retail. After processing, seafood usually undergoes wholesale distribution through wholesalers or distributors and eventually flows to various retail markets for consumers to buy. The fourth is restaurants and hotels. Apart from the retail market, seafood is also supplied to various catering and hospitality industries, such as seafood restaurants, hotel buffets, etc. The entire seafood supply chain involves many links and participants, so effective management and coordination are needed to ensure seafood quality and safety.

(2) Land seafood farming. This mainly refers to the artificial cultivation of various kinds of seafood on land, including fish, shrimp, crabs, shellfish, and so on. Some Canadian salmon farms follow this mode. It reduces external environmental effects on salmon, including global warming, the depletion of non-renewable resources, and acidification (Ayer and Tyedmers, 2009). Compared with the traditional method of sea farming, land farming has the following advantages: first, the geographical location is flexible. In other words, land farming is not restricted to the marine environment and can be conducted anywhere. The second advantage is environmental control. Factors such as water quality, oxygen content, and temperature can be controlled to create a more suitable environment for seafood growth. The third advantage is disease control. The spread and prevention of diseases can be more easily controlled. The fourth advantage is efficient production. Production efficiency and product quality can be improved by controlling environmental and disease conditions. There are several common land seafood farming methods. The first method is pond farming. Pond farming is conducted through the construction of ponds for aquaculture and is suitable for fish, shrimp, crabs, and other seafood. The second method is aquarium farming. Aquarium farming is conducted through the establishment of aquariums for cultivation and is suitable for all kinds of fish and shellfish. The third method is freshwater aquaculture. Freshwater aquaculture is conducted through aquaculture in freshwater environments and is suitable for seafood such as abalone, fish, and shrimp. The fourth method is simulated mariculture. Simulated mariculture involves simulation of the seawater environment for aquaculture and is suitable for all kinds of shellfish, seaweed, and other marine products.

(3) Strengthen seafood monitoring mode. Strengthening seafood monitoring is an important measure to ensure people's food safety. Since 2009, food monitoring and surveillance have been developing rapidly in China. At present, China has a well-functioning monitoring system (Wu and Chen, 2018). The specific measures that must be undertaken to strengthen seafood monitoring include the following. First, a scientific monitoring system must be established. Specifically, a seafood monitoring network, including the monitoring of seawater, marine ecology, and seafood, must be established. Second, the supervision of seafood production and management links must be strengthened. Specifically, the supervision and management of seafood production enterprises must be strengthened to ensure that the production process complies with relevant standards and regulations. Third, the monitoring and testing of seafood quality must be strengthened. More and more countries conduct seafood import and export (Chang, 2022). This requires the establishment of seafood testing centers to test imported and domestic seafood to ensure product quality standards. Fourth, the monitoring technology and means must be improved. Advanced monitoring technology and means must be constantly introduced to improve the accuracy and comprehensiveness of seafood monitoring. Fifth, information disclosure and early warning mechanisms must be improved. This includes the timely release of seafood monitoring results and food safety warning information, strengthening publicity and educating consumers, and raising public awareness of food safety.

The relationship between the three seafood supply modes is shown in Figure 1.

2.1.2. Hypothesis

(1) The government and enterprises have a variety of conditions for seafood aquaculture on land.

Seafood farming on land requires several conditions. The first is water conditions. Adequate clean water and water quality

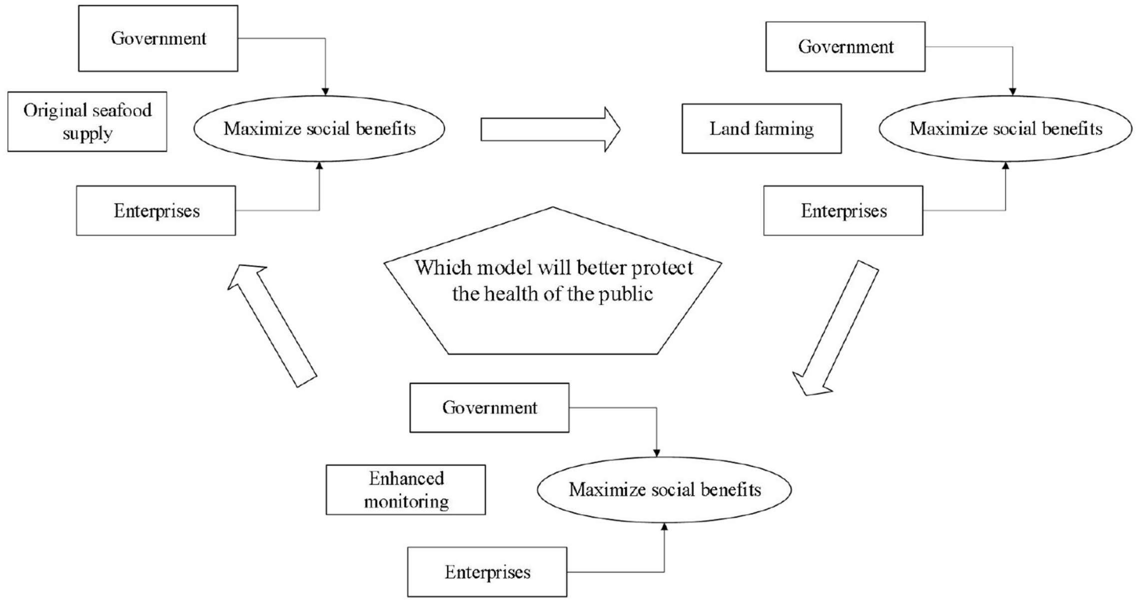

FIGURE 1
Relationship between the three seafood supply modes.

are essential to meet the needs of aquaculture. The second is land conditions. A specific area of land with flat terrain and fertile soil is required. The third is climatic conditions. Suitable climate conditions, encompassing factors such as temperature, humidity, and light have important effects on farming. The fourth is technical conditions. Professional and technical personnel with expertise in breeding technology and disease prevention and treatment are needed for management and operation. The fifth is market conditions. Stable market demand and sales channels are required to ensure the sales of aquaculture products. The sixth is legal conditions. Seafood farming must comply with relevant laws and regulations, including those concerning environmental protection, safety, and other requirements. Strengthening seafood monitoring can ensure people's food safety and promote the healthy development of the seafood industry. Some countries and companies do not meet the requirements for seafood farming on land, which creates the need to build seafood supply chains through other modes. For the sake of convenience, this study assumes that the government and enterprises have various conditions for land seafood farming and can carry out this type of farming.

(2) The public is concerned that seafood containing radioactive substances will affect their health

The public is often concerned about the effects of radioactive seafood on their health (Miyagawa et al., 2021). This is because nuclear radiation can adversely affect the human body, such as cell damage, genetic mutations, immune system damage, and so on. Exposure to high doses of nuclear radiation particles can cause acute radiation sickness, which can have symptoms such as nausea, vomiting, headache, diarrhea, and poisoning and, in severe cases, even lead to death. In addition, long-term exposure to low-dose nuclear radiation particles may also increase the risk of certain chronic diseases, such as cancer and cardiovascular disease. Therefore, public concern about radiation after seafood is exposed to it is highly legitimate.

(3) Seafood monitoring technology is quite mature.

The technology for monitoring radioactive particles is relatively mature, and there are several ways to monitor radioactive materials in ecosystems (Ota and Koarashi, 2021). The first is radionuclide measurement techniques. Radionuclides in seafood samples are measured to determine whether they are contaminated by nuclear radiation. The second is food radiation dose measurement technology. By analyzing the types and contents of radionuclides in seafood samples, combined with food intake and other factors, the radiation dose to the human body is calculated. The third is radioisotope analysis techniques. Radioactive isotopes in seafood samples are analyzed to determine whether they are contaminated by nuclear radiation. The fourth is laser-induced fluorescence technology. Protein samples of seafood are tested for radiation contamination by laser-induced fluorescence. The above techniques have been verified in practical application and have been widely used to monitor radioactive substances in seafood.

2.1.3. Variable definition

When constructing the differential game model in this study, many parameters and variables were designed. These parameters and variables are defined in Table 1.

TABLE 1 The main definition of variables and parameters in this article.

Variables and parameters	Specific meaning
$Y = \{A, L, M\}$	Three seafood supply modes (original mode, land farming, and enhanced monitoring)
Independent variable	
$S_{Y1}(t)$	The quantity of seafood supplied by the government under mode Y
$S_{Y2}(t)$	The quantity of seafood supplied by enterprises under mode Y
$x_{Y1}(t)$	The reputation of the government under the seafood supply mode Y
$x_{Y2}(t)$	Business goodwill under the seafood supply mode Y
Parameter	
ρ	The discount rate that occurs over time, $0 \leq \rho \leq 1$
δ	Decay of reputation, $\delta > 0$
a_{S1}	Revenue from the government's supply of a unit quantity of seafood, $a_{S1} > 0$
a_{S2}	Income from the supply of seafood per unit quantity, $a_{S2} > 0$
c_{s1}	The cost to the government of supplying per unit quantity of seafood, $c_{s1} > 0$
c_{s2}	The cost of supplying seafood per unit quantity, $c_{s2} > 0$
h_{s1}	Public health effects per unit quantity of contaminated seafood, $h_{s1} > 0$
p_L	Financial support from the government for land seafood farming, $p_L > 0$
l	The positive impact of reputation per unit quantity, $l > 0$
b_s	Increased reputation for supplying seafood, $b_s > 0$
b_{A1}	Eating contaminated seafood has led to public discontent with the government, $b_{A1} > 0$
b_{A2}	Eating contaminated seafood has led to public discontent with companies, $b_{A2} > 0$
c_{M1}	Monitor the unit cost of seafood, $c_{M1} > 0$
c_{d2}	Deaths caused by marine products not adapted to the environment, $c_{d2} > 0$
b_{M1}	Poor monitoring has led to public discontent with the government, $b_{M1} > 0$
b_{M2}	Poor monitoring has led to public dissatisfaction with companies, $b_{M2} > 0$
q_M	Percentage of substandard seafood, $q_M > 0$
Function	
$J_{Y1}(t)$	The social welfare function of the government under the seafood supply mode Y
$J_{Y2}(t)$	The social welfare function of enterprises under seafood supply mode Y
$V_{Y1}(t)$	The social benefits of the government under the seafood supply mode Y
$V_{Y2}(t)$	The social benefits of enterprises under the seafood supply mode Y

2.2. Differential game of three seafood supply modes

The differential game aims to optimize independence and conflicts among players, leading to the determination of evolving strategies for each player over time and the achievement of the Nash equilibrium. At present, it is mainly applied in the fields of advertising decisions (Viscolani and Zaccour, 2009), logistics management (Bai et al., 2022), supply chain (Zhu et al., 2021), and so on. With the spread of the Fukushima nuclear wastewater, seafood safety is changing. Seafood safety is also constantly changing due to the degree of supply chain optimization by governments and companies. To describe this change more clearly, this study analyzes the seafood supply mode selection by using the differential game.

In the context of differential games, the strategies adopted by governments and firms are time-dependent functions. The actions taken by one participant are influenced by the strategies adopted by other participants. This leads to a continuous evolutionary process of participants looking for the best strategy. This dynamic interaction can be described in terms of differential equations that capture the rate of change in the relationship between variables, usually with respect to time or space variables (Arnone et al., 2022). In the specific context of this study, both the seafood supply and the decisions of governments and businesses are constantly changing. Therefore, the application of the differential game theory has strong relevance and applicability. In the context of the continuous discharge of Fukushima nuclear wastewater, the differential game effectively captures the conflict and cooperation between the government and enterprises in the optimization process of the seafood supply chain.

Under the original seafood supply mode, the social welfare functions of the government and enterprises are as follows:

$$J_{A1} = \int_0^{\infty} \left[a_{S1} S_{A1}(t) - \frac{c_{S1}}{2} S_{A1}^2(t) - h_{S1} S_{A1}(t) + l x_{A1}(t)\right] e^{-\rho t} dt \quad (1)$$

$$J_{A2} = \int_0^{\infty} \left[a_{S2} S_{A2}(t) - \frac{c_{S2}}{2} S_{A2}^2(t) + l x_{A2}(t)\right] e^{-\rho t} dt \quad (2)$$

In the above formula, $a_{S1}S_{A1}(t)$ represents the revenue that the government gets from supplying seafood under the original supply mode. $\frac{c_{S1}}{2} S_{A1}^2(t)$ represents the cost of seafood supplied by the government under the original supply mode. $h_{S1}S_{A1}(t)$ represents the cost of contaminated seafood to public health under the original supply mode. $lx_{A1}(t)$ represents the influence of government reputation on social benefits under the original supply mode. $a_{S2}S_{A2}(t)$ represents the income obtained by enterprises supplying seafood under the original supply mode. $\frac{c_{S2}}{2} S_{A2}^2(t)$ represents the cost of seafood supply under the original supply mode. $lx_{A2}(t)$ represents the positive impact of business goodwill on social benefits under the original supply mode.

The change in government reputation and business goodwill can be expressed as follows:

$$\dot{x}_{A1}(t) = \left(b_S - b_{A1}\right) S_{A1}(t) - \delta x_{A1}(t) \quad (3)$$

$$\dot{x}_{A2}(t) = \left(b_S - b_{A2}\right) S_{A2}(t) - \delta x_{A2}(t) \quad (4)$$

In the above formula, $b_A S_{A1}(t)$ represents the discontent of the people caused by neglect. $b_{A2}S_{A2}(t)$ represents public discontent with seafood companies due to the neglect of contaminated seafood. $b_S x_{A1}(t)$ represents the increased reputation of the government's seafood provision. $b_S x_{A2}(t)$ represents the increased reputation of companies providing seafood. $\delta x_{A1}(t)$ represents the decline in the government's reputation. $\delta x_{A2}(t)$ represents the decay of corporate goodwill.

Under the land farming mode, the social welfare functions of the government and enterprises are as follows:

$$J_{L1} = \int_0^{\infty} \left[a_{S1} S_{L1}(t) - \frac{c_{S1}}{2} S_{L1}^2(t) - p_L + lx_{L1}(t)\right] e^{-\rho t} dt \tag{5}$$

$$J_{L2} = \int_0^{\infty} \left[a_{S2} S_{L2}(t) - \frac{(c_{S2}+c_{d2})}{2} S_{L2}^2(t) + p_L + lx_{L2}(t)\right] e^{-\rho t} dt \tag{6}$$

In the above formula, $a_{S1} S_{L1}(t)$ represents the revenue that the government gets from supplying seafood under the land farming mode. $\frac{c_{S1}}{2} S_{L1}^2(t)$ represents the cost of seafood supplied by the government under the land farming mode. p_L represents support for government policies. $lx_{L1}(t)$ represents the influence of government reputation on social benefits under the land farming mode. $a_{S2} S_{L2}(t)$ represents the income obtained by enterprises supplying seafood under the land farming mode. $\frac{(c_{S2}+c_{d2})}{2} S_{L2}^2(t)$ represents the cost of seafood supply under the land farming mode. $\frac{c_{d2}}{2} S_{L2}^2(t)$ represents the risk of death from environmental maladaptation. $lx_{L2}(t)$ represents the positive impact of business under the land farming mode.

The change in government reputation and business goodwill can be expressed as follows:

$$\dot{x}_{L1}(t) = b_S S_{L1}(t) - \delta x_{L1}(t) \tag{7}$$

$$\dot{x}_{L2}(t) = b_S S_{L2}(t) - \delta x_{L2}(t) \tag{8}$$

In the above formula, $b_S x_{L1}(t)$ represents the increased reputation of the government's seafood provision. $b_S x_{L2}(t)$ represents the increased reputation of companies providing seafood. $\delta x_{L1}(t)$ represents the decline in the government's reputation. $\delta x_{L2}(t)$ represents the decay of corporate goodwill.

Under the strengthen monitoring mode, the social welfare functions of the government and enterprises are as follows:

$$J_{M1} = \int_0^{\infty} \left[a_{S1} S_{M1}(t) - \frac{(c_{S1}+c_{M1})}{2} S_{M1}^2(t) + lx_{M1}(t)\right] e^{-\rho t} dt \tag{9}$$

$$J_{M2} = \int_0^{\infty} \left[a_{S2} S_{M2}(t)\left(1-q_M\right) - \frac{c_{S2}}{2} S_{M2}^2(t) + lx_{M2}(t)\right] e^{-\rho t} dt \tag{10}$$

In the above formula, $a_{S1} S_{M1}(t)$ represents the revenue that the government gets from supplying seafood under the strengthen monitoring mode. $\frac{(c_{S1}+c_{M1})}{2} S_{M1}^2(t)$ represents the cost of seafood supplied by the government under the strengthen monitoring mode. $\frac{c_{M1}}{2} S_{M1}^2(t)$ represents the cost of monitoring. $a_{S2} S_{M2}(t) q_M$ represents the proportion of seafood discarded due to disqualification. $\frac{c_{S2}}{2} S_{M2}^2(t)$ represents the cost of seafood supply under the strengthen monitoring mode. $lx_{M1}(t)$ represents the influence of government reputation on social benefits under the strengthen monitoring mode. $lx_{M2}(t)$ represents the positive impact of business under the strengthen monitoring mode.

The change in government reputation and business goodwill can be expressed as follows:

$$\dot{x}_{M1}(t) = \left(b_S - b_{M1}\right) S_{M1}(t) - \delta x_{M1}(t) \tag{11}$$

$$\dot{x}_{M2}(t) = \left(b_S - b_{M2}\right) S_{M2}(t) - \delta x_{M2}(t) \tag{12}$$

In the above formula, $b_S x_{M1}(t)$ represents the increased reputation of the government's seafood provision. $b_S x_{M2}(t)$ represents the increased reputation of companies providing seafood. $b_{M1} S_{M1}(t)$ represents the decrease in the government's reputation due to poor monitoring. $b_{M2} S_{M2}(t)$ represents the decrease in the reputation of businesses due to poor monitoring. $\delta x_{M1}(t)$ represents the decline in the government's reputation. $\delta x_{M2}(t)$ represents the decay of corporate goodwill.

3. Results

In the differential game, the choice of the seafood supply mode by the government and enterprises is affected not only by the control variables and parameters but also by changes over time. For improved calculation of the amount of control and social benefits, the HJB formula is adopted. The HJB formula is a partial differential equation, which is the core of optimal control.

3.1. HJB formula

Under the original supply mode, the HJB equation of the social welfare function of the government and enterprises is as follows:

$$\begin{aligned}\rho V_{A1} = \max_{S_{A1}(t)} \Big\{ &\Big[a_{S1} S_{A1}(t) - \frac{c_{S1}}{2} S_{A1}^2(t) - h_{S1} S_{A1}(t) + lx_{A1}(t)\Big] \\ &+ \frac{\partial V_{A1}}{\partial x_{A1}} \Big[\left(b_S - b_{A1}\right) S_{A1}(t) - \delta x_{A1}(t)\Big]\Big\}\end{aligned} \tag{13}$$

$$\begin{aligned}\rho V_{A2} = \max_{S_{A2}(t)} \Big\{ &\Big[a_{S2} S_{A2}(t) - \frac{c_{S2}}{2} S_{A2}^2(t) + lx_{A2}(t)\Big] \\ &+ \frac{\partial V_{A2}}{\partial x_{A2}} \Big[\left(b_S - b_{A2}\right) S_{A2}(t) - \delta x_{A2}(t)\Big]\Big\}\end{aligned} \tag{14}$$

Under the land farming mode, the HJB equation of the social welfare function of the government and enterprises is as follows:

$$\begin{aligned}\rho V_{L1} = \max_{S_{L1}(t)} \Big\{ &\Big[a_{S1} S_{L1}(t) - \frac{c_{S1}}{2} S_{L1}^2(t) - p_L + lx_{L1}(t)\Big] \\ &+ \frac{\partial V_{L1}}{\partial x_{L1}} \Big[b_S S_{L1}(t) - \delta x_{L1}(t)\Big]\Big\}\end{aligned} \tag{15}$$

$$\begin{aligned}\rho V_{L2} = \max_{S_{L2}(t)} \Big\{ &\Big[a_{S2} S_{L2}(t) - \frac{(c_{S2}+c_{d2})}{2} S_{L2}^2(t) + p_L + lx_{L2}(t)\Big] \\ &+ \frac{\partial V_{L2}}{\partial x_{L2}} \Big[b_S S_{L2}(t) - \delta x_{L2}(t)\Big]\Big\}\end{aligned} \tag{16}$$

Under the strengthen monitoring mode, the HJB equation of the social welfare function of the government and enterprises is as follows:

$$\rho V_{M1} = \max_{S_{M1}(t)} \left\{ \left[a_{S1} S_{M1}(t) - \frac{(c_{S1}+c_{M1})}{2} S_{M1}^2(t) + l x_{M1}(t) \right] + \frac{\partial V_{M1}}{\partial x_{M1}} \left[(b_S - b_{M1}) S_{M1}(t) - \delta x_{M1}(t) \right] \right\} \tag{17}$$

$$\rho V_{M2} = \max_{S_{M2}(t)} \left\{ \left[a_{S2} S_{M2}(t)(1-q_M) - \frac{c_{S2}}{2} S_{M2}^2(t) + l x_{M2}(t) \right] + \frac{\partial V_{M2}}{\partial x_{M2}} \left[(b_S - b_{M2}) S_{M2}(t) - \delta x_{M2}(t) \right] \right\} \tag{18}$$

3.2. Equilibrium results

Proposition 1: Under the original supply mode, the seafood supply quantity and the social benefits of the government and enterprises, respectively, are as follows (the specific solving procedure is shown in Appendix 1):

$$S_{A1}^*(t) = \frac{1}{c_{S1}} \left(a_{S1} - h_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A1} \right) \tag{19}$$

$$S_{A2}^*(t) = \frac{1}{c_{S2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A2} \right) \tag{20}$$

$$\begin{aligned} V_{A1}^* = {} & \frac{l}{\rho+\delta} x_{A1} + \frac{1}{\rho} a_{S1} \frac{1}{c_{S1}} \left(a_{S1} - h_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A1} \right) \\ & - \left(a_{S1} - h_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A1} \right)^2 \frac{1}{\rho} \frac{1}{2} \left(\frac{1}{c_{S1}} \right) \\ & - \frac{1}{\rho} h_{S1} \frac{1}{c_{S1}} \left(a_{S1} - h_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A1} \right) \\ & + \frac{1}{\rho} \frac{l}{\rho+\delta} (b_S - b_{A1}) \\ & \frac{1}{c_{S1}} \left(a_{S1} - h_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A1} \right) \end{aligned} \tag{21}$$

$$\begin{aligned} V_{A2}^* = {} & \frac{l}{\rho+\delta} x_{A2} + \frac{1}{\rho} a_{S2} \frac{1}{c_{S2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A2} \right) \\ & - \frac{1}{\rho} \frac{1}{2} \frac{1}{c_{S2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A2} \right)^2 \\ & + \frac{1}{\rho} \frac{l}{\rho+\delta} (b_S - b_{A2}) \\ & \frac{1}{c_{S2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{A2} \right) \end{aligned} \tag{22}$$

Conclusion 1: Under the original seafood supply mode, the seafood supply of the government and enterprises is directly proportional to the income from the seafood supply and inversely proportional to the cost of the seafood supply. The amount of seafood supplied by the government and companies is inversely proportional to the level of public dissatisfaction caused by contaminated seafood.

Proposition 2: Under the land farming mode, the seafood supply quantity and the social benefits of the government and enterprises, respectively, are as follows (the specific solving procedure is shown in Appendix 2):

$$S_{L1}^*(t) = \frac{1}{c_{S1}} \left(a_{S1} + \frac{l}{\rho+\delta} b_S \right) > S_{A1}^*(t) \tag{23}$$

$$S_{L2}^*(t) = \frac{1}{c_{S2}+c_{d2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S \right) \tag{24}$$

$$\begin{aligned} V_{L1}^* = {} & \frac{l}{\rho+\delta} x_{L1} + \frac{1}{\rho} a_{S1} \frac{1}{c_{S1}} \left(a_{S1} + \frac{l}{\rho+\delta} b_S \right) \\ & - \frac{1}{2} \frac{1}{\rho} \frac{1}{c_{S1}} \left(a_{S1} + \frac{l}{\rho+\delta} b_S \right)^2 - \frac{1}{\rho} p_L \\ & + \frac{1}{\rho} \frac{l}{\rho+\delta} b_S \frac{1}{c_{S1}} \left(a_{S1} + \frac{l}{\rho+\delta} b_S \right) \end{aligned} \tag{25}$$

$$\begin{aligned} V_{L2}^* = {} & \frac{l}{\rho+\delta} x_{L2} + \frac{1}{\rho} a_{S2} \frac{1}{c_{S2}+c_{d2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S \right) \\ & - \frac{1}{2} \frac{1}{\rho} \frac{1}{c_{S2}+c_{d2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S \right)^2 + \frac{1}{\rho} p_L \\ & + \frac{1}{\rho} \frac{l}{\rho+\delta} b_S \frac{1}{c_{S2}+c_{d2}} \left(a_{S2} + \frac{l}{\rho+\delta} b_S \right) \end{aligned} \tag{26}$$

Conclusion 2: Under the land farming mode, the seafood supply of the government and enterprises is directly proportional to the income from the seafood supply and inversely proportional to the cost of the seafood supply. The death caused by the inadaptation of seafood to the environment is inversely proportional to the seafood supply by enterprises. The supply of marine products under the government's land farming mode is greater than that under the original mode.

Proposition 3: Under the strengthen monitoring mode, the seafood supply quantity and the social benefits of the government and enterprises, respectively, are as follows (the specific solving procedure is shown in Appendix 3):

$$S_{M1}^*(t) = \frac{1}{c_{S1}+c_{M1}} \left(a_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M1} \right) \tag{27}$$

$$S_{M2}^*(t) = \frac{1}{c_{S2}} \left(a_{S2} - a_{S2} q_M + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M2} \right) \tag{28}$$

$$\begin{aligned} V_{M1}^* = {} & \frac{l}{\rho+\delta} x_{M1} + \frac{1}{\rho} a_{S1} \frac{1}{c_{S1}+c_{M1}} \\ & \left(a_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M1} \right) \\ & - \left(a_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M1} \right)^2 \frac{1}{2} \frac{1}{\rho} \frac{1}{c_{S1}+c_{M1}} \\ & + \frac{1}{\rho} \frac{l}{\rho+\delta} (b_S - b_{M1}) \frac{1}{c_{S1}+c_{M1}} \\ & \left(a_{S1} + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M1} \right) \end{aligned} \tag{29}$$

$$\begin{aligned} V_{M2}^* = {} & \frac{l}{\rho+\delta} x_{M2} + \frac{1}{\rho} a_{S2} \frac{1}{c_{S2}} \\ & \left(a_{S2} - a_{S2} q_M + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M2} \right) (1 - q_M) \\ & - \frac{1}{\rho} \left(a_{S2} - a_{S2} q_M + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M2} \right)^2 \frac{1}{2} \frac{1}{c_{S2}} \\ & + \frac{1}{\rho} \frac{l}{\rho+\delta} (b_S - b_{M2}) \frac{1}{c_{S2}} \\ & \left(a_{S2} - a_{S2} q_M + \frac{l}{\rho+\delta} b_S - \frac{l}{\rho+\delta} b_{M2} \right) \end{aligned} \tag{30}$$

Conclusion 3: In the mode of strengthen seafood monitoring, the seafood supply of the government and enterprises is inversely proportional to the dissatisfaction of the public caused by unqualified seafood monitoring. The government seafood supply is inversely proportional to seafood monitoring costs. The quantity of seafood supplied by enterprises is inversely proportional to the unqualified proportion of seafood.

3.3. Numerical analysis

To describe the change in the social utility of the government and social organizations in further detail, numerical analysis is conducted in this study. The discounting rate ρ over time is 0.9. The reputation decay rate δ is 0.1. The income a_{s1} that the government receives from the seafood supply per unit quantity is 1.5. The income a_{s2} from the seafood supply per unit quantity is 2. The cost c_{s1} for each unit quantity of seafood supplied by the government is 1. The cost c_{s2} for a firm to supply a unit quantity of seafood is 1.5. The government's financial support p_L for land seafood farming is 5. The positive influence l brought by unit reputation is 1. The increase b_s in reputation for supplying seafood is 1.5. The public dissatisfaction b_{A1} with the government due to eating contaminated seafood is 2. The public dissatisfaction b_{A1} with enterprises due to eating contaminated seafood is 2. The unit cost r_W of monitored seafood is 1. The public dissatisfaction b_{M2} with the government caused by unqualified monitoring is 2. The public dissatisfaction b_{M2} with enterprises caused by unqualified monitoring is 1.5.

Therefore, the following can be calculated:

$$V_{A1}^{*} = 1.56 - 0.56h_{S1}^{2} \tag{31}$$

$$V_{L1}^{*} = 0.44 \tag{32}$$

The following graph (Figure 2) can also be produced:

Conclusion 4: The original seafood supply mode can obtain greater benefits when the public health impact of contaminated seafood per unit quantity is small. With the increasing public health impact of contaminated seafood per unit quantity, the land farming mode can achieve greater benefits.

The following can be calculated:

$$V_{L1}^{*} = 0.44 \tag{33}$$

$$V_{M1}^{*} = 1 - 1.11 \times \frac{1}{1+c_{M1}} + 0.56 \times \frac{1}{(1+c_{M1})^{2}} \tag{34}$$

The following graph (Figure 3) can also be produced:

Conclusion 5: With the increasing cost of seafood monitoring, the government's social benefits will also increase under the strengthen monitoring mode. However, it is growing more and more slowly.

The following can be calculated:

$$V_{A2}^{*} = 1.81 \tag{35}$$

$$V_{L2}^{*} = 1 + \frac{6.8}{1.5+c_{d2}} \tag{36}$$

The following graph (Figure 4) can also be produced:

Conclusion 6: When the death cost due to the inadaptation of seafood to the environment is low, the social benefits of enterprises in the land seafood farming mode are greater than those in the original seafood supply mode. However, with the increase in the death cost due to the inadaptation of seafood to the environment, the social benefits of enterprises in the land seafood farming mode are smaller than those in the original seafood supply mode.

The following can be calculated:

$$V_{A2}^{*} = 1.81 \tag{37}$$

$$V_{M2}^{*} = 1 + 1.48\left(1 - q_{M}\right)^{2} \tag{38}$$

The following graph (Figure 5) can also be produced:

Conclusion 7: When the proportion of unqualified seafood is low compared with the original seafood supply mode, strengthening monitoring can make enterprises gain more benefits. However, with the increase in the unqualified proportion of seafood, the original seafood supply mode can make enterprises acquire more benefits.

4. Discussion

The Fukushima nuclear wastewater is moving along the ocean current. This can cause seafood to be contaminated with radioactive substances. Countries can ensure seafood quality levels by implementing land-based seafood farming and strengthening monitoring. Marine aquaculture on land has the characteristics of flexible geographic location, easy control of pests and diseases, and efficient production, but the cost of aquaculture is high. Although the cost of strengthening monitoring is low, controlling seafood pollution is difficult. Therefore, the applicable scope of various seafood supply modes is an important issue in this study. The spread of Fukushima wastewater and the seafood supply are dynamic. To clearly delineate this dynamic change, the differential game is applied to the seafood supply field in this study to provide a reference to the government and enterprises supplying seafood.

In reality, salmon farming in Canada also needs to consider several factors, such as cost, efficiency, and environmental protection (Ayer and Tyedmers, 2009). Similarly, this study shows that aquaculture on land needs to consider multiple factors such as demand, cost, and technological benefits. First, the market demand must be assessed. Before selecting a breed, the market demand and price level of the breed product must be assessed. If both the market demand and price are high, then the yield of breeding is expected to be higher. Second, the cost must be estimated. The cost of infrastructure, feed, manpower, water, and electricity needed for breeding needs to be fully accounted for, and the payback period and possible risks and uncertainties must also be accounted for. Third, the benefits of different breeds must be compared. The market price of and demand for different breeding varieties are different, and the income is expected to be different. Different breeding varieties must be compared, and the most favorable and feasible ones must be selected. Fourth, advanced breeding technologies must be mastered. Mastering advanced breeding technologies can improve the production and quality of breeding, thereby increasing income. The technology and efficiency of breeding must be improved, while simultaneously

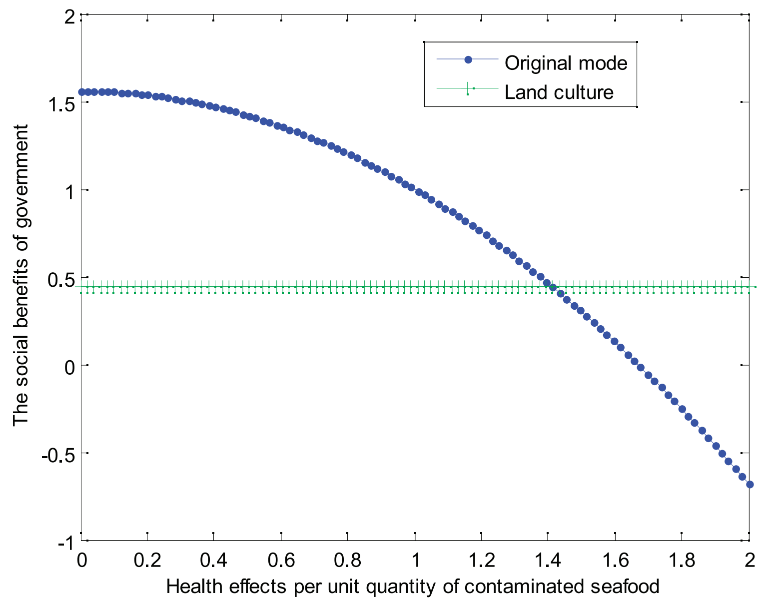

FIGURE 2
Impact of threats to health on the social benefits of the government.

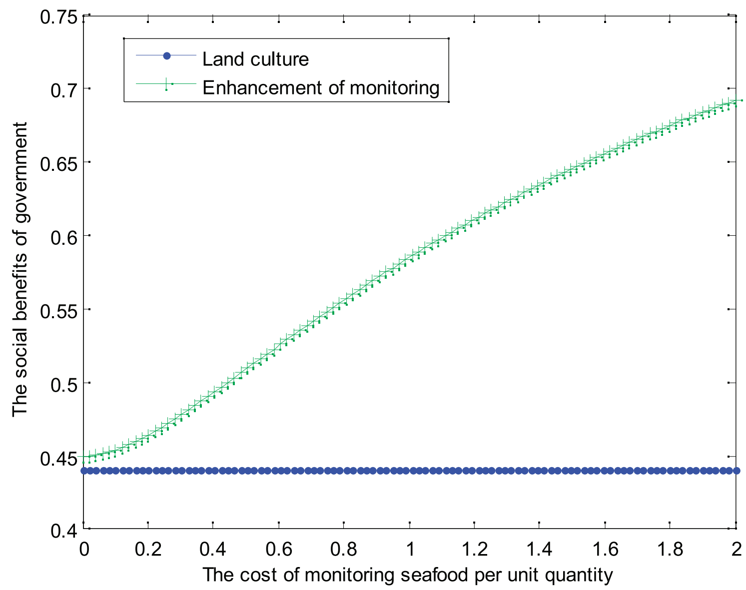

FIGURE 3
Impact of monitoring costs on the social benefits of the government.

reducing the cost. Fifth, a scientific management system must be established. The establishment of a scientific management system can improve the efficiency of breeding, avoid risks, and ensure the sustainable development of the breeding industry. Specific measures include the development of regulations and policies, ecological assessment, farming planning, water quality management, feed management, disease prevention and control, the development of farming operation guidelines, supervision and law enforcement, and communication and cooperation (Suplicy et al., 2015). In short, the market demand, breeding species, cost estimation, breeding technology, and management system must be considered to balance the costs and benefits of seafood farming on land to ensure long-term profitability and sustainable development of the aquaculture industry.

Poor seafood monitoring may pose health risks for people. If seafood contains radioactive substances, it will be harmful to

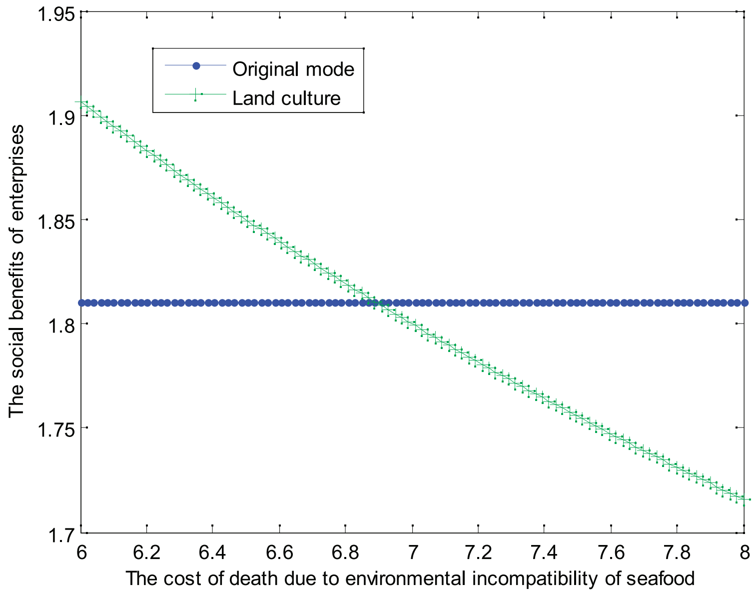

FIGURE 4
Impact of death cost of seafood on the social benefits of enterprises.

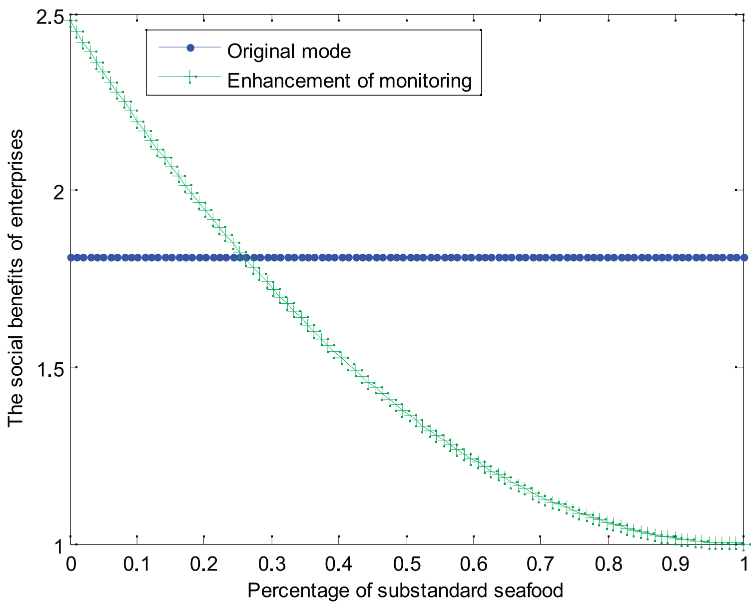

FIGURE 5
Impact of the percentage of substandard seafood on the social benefits of enterprises.

human health and result in food poisoning or chronic toxicity. This, in turn, will affect the sales and consumption of seafood, which may lead to price decline, market contraction, and even the loss of related enterprises. Furthermore, substandard seafood can also affect trade. This is because if substandard seafood is exported to other countries, it can cause trade disputes and even lead importing countries to ban seafood imports from exporting countries. If consumers find substandard seafood products, they will distrust related brands and companies, which can lead to the loss of consumers and damage the brand image. The consequences of unqualified seafood monitoring are extremely serious, and the nuclear safety of Fukushima nuclear wastewater must be correctly analyzed (Lam et al., 2022). Governments and companies monitor contaminated seafood through sampling, laboratory analysis, setting standards, establishing monitoring networks, conducting spot checks, and participating in international cooperation. These measures ensure seafood safety and quality to protect public health and maintain the sustainability of the food supply chain.

Different parts of the world's oceans are affected differently. The impact of Fukushima's wastewater on the world's oceans is influenced by two factors. The first is ocean flows and hydrological conditions. Ocean flow and hydrological conditions determine the extent and speed of the diffusion of Fukushima nuclear wastewater after its release. The flow and circulation patterns in different ocean areas may cause the movement and distribution of Fukushima nuclear wastewater to differ. The second is distance and diffusion time. After the release of Fukushima nuclear wastewater, the time and distance it takes to spread to a particular ocean area will also affect its impact on the region. The concentration of the radioactive material may be reduced and diluted in an ocean located farther away from the Fukushima plant. Therefore, countries need to respond flexibly to the Fukushima nuclear wastewater incident (Xu and Zhang, 2021). In particular, they need to assess whether existing supply chain modes can be adopted on a case-by-case basis. If seafood is found in relatively clean waters, and pollution is strictly controlled during transportation, processing, and storage, then the old supply chain mode can continue. However, if there is a pollution problem, a safer and more reliable supply chain mode needs to be considered. For example, by establishing a green supply chain, pollution can be controlled at the source to ensure product safety and quality. In addition, as consumers have increased requirements for seafood quality and safety, companies must also continuously improve the traceability and transparency of the supply chain to enhance consumers' trust in their products. Therefore, governments and businesses can increase consumer trust in seafood products in the following ways. The first is through the establishment of a supply chain traceability system by enterprises. Enterprises can establish a supply chain traceability system to track and record the flow and conversion process of products in the supply chain. The second is through the setting of compliance and certification standards by the government. It can adhere to food safety and sustainability compliance standards and demonstrate compliance by obtaining certification where necessary. For example, fishermen or businesses can be certified by a certification body such as Marine Stewardship Council (MSC) to demonstrate that their seafood harvesting or farming practices and related management meet sustainability standards. The third is by ensuring transparent supply chain partnerships. This can include building close relationships with supply chain partners and requiring suppliers to provide transparent and trusted information. The fourth is through consumer education and communication between the government and enterprises. Accurate and easy-to-understand information on various topics, including product quality, sustainability, and procurement processes, can be provided to consumers through several channels.

Prolonged failure to manage the Fukushima nuclear disaster could lead to a range of potential long-term consequences, such as the spread of radioactive contamination, public health risks, destruction of ecosystems, damage to agriculture and fisheries, and economic impacts. Among these impacts, the public health risk is particularly prominent. This is mainly because of the potential risks to human health caused by nuclear radiation. Long-term exposure to radioactive materials may increase the risk of cancer, genetic damage, and other health problems. The risk is especially greater for certain populations that are more vulnerable to radiation, such as children and pregnant women (Etherington et al., 2014). To address these potential consequences, appropriate post-disaster management measures should be taken, including monitoring and assessing health risks and strengthening terrestrial seafood farming. For instance, let us consider strengthen surveillance; strengthening the monitoring of seafood quality can produce many effects. First, the health and safety of consumers must be protected. Seafood is an important part of people's daily diet, and strengthening the monitoring of seafood quality can help identify problems related to quality in time to ensure the health and safety of consumers. Second, the quality of seafood must be improved. Strengthening the monitoring of seafood quality can help identify problems related to the quality of products so that timely measures can be taken to promote enterprises to improve product quality. Third, the healthy development of the seafood industry must be promoted. Strengthening the monitoring of seafood quality can help establish a healthy market competition environment and promote the healthy development of the seafood industry. Fourth, marine environmental protection must be promoted. Strengthening the monitoring of seafood quality can help discover the problem of marine environmental pollution and promote the protection of the marine environment. Thus, as the cost of seafood monitoring continues to increase, so will the social benefits to the government under the strengthen monitoring mode.

An increase in land-based seafood deaths could have the following consequences. The first is the deterioration of the ecological environment. A large amount of wastewater and waste materials may be discharged in the process of seafood farming, which may cause pollution and damage to the surrounding ecological environment if not handled properly. The second is economic losses. An increase in the death of land-farmed seafood may lead to economic losses for farmers and also have a certain impact on related industrial chains, such as aquaculture equipment and feed suppliers. The third is food safety. Increased deaths from land-based farming of seafood may lead to quality problems in some farmed products, and consumption may have implications for human health. The fourth is social issues. An increase in land-based seafood deaths can cause mood swings among farmers and even cause social problems. Therefore, to avoid the problems associated with the increase in deaths due to seafood farming on land, the management and supervision of seafood farming must be strengthened, and scientific and reasonable farming methods must be adopted to ensure the health and quality of seafood. To reduce deaths in land seafood farming, governments and businesses can take the following steps. First, enterprises can optimize the breeding environment. They can ensure that the water quality, temperature, oxygen, and breeding media (such as soil or aquariums) of the breeding environment meet the conditions suitable for growth. Second, the government and enterprises can ensure disease prevention and control. This includes the implementation of effective disease prevention and control measures, such as regular health checks, isolation, immunization, and treatment. Third, enterprises can carry out feed management, including the provision of balanced and appropriate feed to meet the nutritional requirements of seafood. Fourth, the government should conduct water quality management. This includes regular testing and maintenance of the water quality to avoid excessive accumulation of hazardous substances and wastes. The government should utilize water treatment equipment, such as filtration systems, aeration units, etc., to maintain clean and stable water quality clean. Fifth, scientific research and experience sharing are necessary. Active participation in scientific research and experience sharing are necessary to explore the best farming practices and improvement methods. Collaboration with other farmers, experts, and research institutions is necessary to continuously learn and improve farming techniques. Collectively, these measures can help reduce deaths from seafood farming on land. However, there is no single solution to all farming situations, as each farm has its own specific environmental and management requirements. Therefore, individual and integrated management methods are crucial in practice.

5. Conclusion

This study hypothesized that seafood safety can be ensured through land farming and by strengthening surveillance. Considering that the Fukushima nuclear wastewater is constantly diffused and the decisions of the government and enterprises are constantly changing, this study constructed a differential game model under the original supply, land farming, and strengthen monitoring modes. The results showed that the health impact of seafood pollution is relatively small, and the government tends to choose the original supply mode. As the health impact of seafood grows, the government tend to prefer land-based farming. The social benefit to the government is directly proportional to the cost of monitoring seafood. To protect public health, enterprises tend to choose the strengthen monitoring mode if the proportion of unqualified seafood is low. Contrarily, if the sea products to the land environment have a high degree of adaptation, they tend to choose land farming.

This study's scope can be extended to include only the conditions for land seafood farming, public concerns about the health effects of contaminated seafood, and well-established monitoring technologies. Situations where land farming cannot meet the conditions, public awareness regarding the dangers of contaminated seafood is lacking, the monitoring technology is not mature, and so on can be considered, and relevant research can be carried out accordingly. In future research, some gaps in the present research can also be addressed. First, specific criteria must be established for determining the seafood supply model that must be adopted in different situations. Second, the findings of this study must be translated into practical policy recommendations for governments and seafood enterprises. Third, a sequence of actions must be established for governments and enterprises to conduct relevant research, rather than acting simultaneously.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

YB: model building, problem description, main paper writing, and result analysis. XY: graphic drawing and literature collection. LW: quality control and grammar modification. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1226534/full#supplementary-material

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