The propagation of sustainable fishery by Arctic shipping route stakeholders

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Abstract:

This research addresses the question of how to better disseminate the concept of sustainable fishery along the Arctic shipping route. The fishery trade network of Arctic is constructed and the complex network theory is applied to conduct the analysis. We further simulate the network by introducing three factors, namely, national will, knowledge absorption capacity and initial propagation node and applying the SIR (susceptible–infective-removed) model. It is found that, in order to disseminate the sustainable fishery concept in the Arctic shipping route, there is a need for countries to increase their national will, increase their capacity to absorb knowledge, and give full play to the role of high-node countries. This paper theoretically suggests three countries of Norway, Denmark, and China to act as initiators of the network and proposes possible measures that countries can take to cooperate on sustainable fisheries development. Our findings offer a useful reference on international arctic fishery cooperation.

Keywords: Arctic; Sustainable fishery; Complex network; SIR propagation model

1. Introduction

The Arctic Ocean is a vital part of the global climate system. The movement of the atmosphere, oceans, and sea ice in the Arctic directly or indirectly affect the global scale of atmospheric circulation, ocean circulation, and climate variability. It is one of the drivers of global climate change [1-2]. As a result, the Arctic, including the Arctic Ocean, is one of the most sensitive regions to global climate change. Under the background of global warming, the climate and environment around the Arctic region have changed more significantly than those in other regions. The Arctic sea ice has experienced a significant and rapid decline in the past few decades [2] and the entire Arctic Ocean ecosystem has changed in many ways [3]; for example, the increase in air temperature and light has promoted the growth of phytoplankton, and the fishery resources also moved northward. On the one hand, the increase of fishery resources in the Arctic region has brought great economic benefits to those involved; however, excessive commercialization is bound to cause damage to the region's environment. Therefore, the development and utilization of fishery resources in the Arctic region have attracted significant attention [4-5].

The marine fishery industry is an important part of the marine economy as it provides 40% of the protein for two-thirds of the world's population [6]. However, the sustainable fishery is being threatened by the problems of marine plastic waste and overfishing. According to the *State of World Fisheries and Aquaculture* published by the FAO (Food and Agriculture Organization of the United Nations) in 2018, of the fishery resource stocks assessed, 59.9% are fully exploited, and 33.1% are exploited at a biologically unsustainable level [7]. Many sea areas in the Arctic are some of the world's most famous fishing grounds, with abundant fishery resources, and most of the coastal countries (e.g., Norway, Russia, and America) are also important fishery countries in the world. FAO statistics found in 2017 that the average catch in the Arctic region (18 fishing zone, 21 fishing zone, 27 fishing zone, 61 fishing zone, and 67 fishing zone) was 34.38 million tons in 2011-2017, accounting for the average global annual proportion of about 38% [8].

Sustainable fisheries include environmental, social and economic aspects [9]. The quality of Marine fishery resources, the degree of exploitation and utilization, the input and output to the environment will affect the sustainable fishery. To spread the concept of sustainable fisheries among countries means that countries respond to the call to make environmental, social and economic changes in the field of fisheries [10]. The sustainable fishery is of great value to the food security and marine economic development of Arctic countries. However, the melting of the Arctic sea ice makes it possible for the high-frequency navigation of the Arctic shipping routes, which increases the risk of pollution in the sea area and intensifies the unreasonable commercial exploitation of fishery resources, thus threatening the sustainable fishery of the Arctic area [11]. Therefore, under the background of Arctic navigation, it has become a realistic and urgent topic to explore sustainable fishery cooperation among Arctic stakeholders.

Some international conventions, multilateral agreements and relevant organizations have organized and managed fisheries on the Arctic's high seas for a long time. At the global level, such conventions include the *United Nations Convention on the Law of the Sea* and the *United Nations Agreement on Fish Stocks* [12-13]. There are also bilateral or multilateral fishery cooperation agreements include the *Treaty on the Conservation and Management of Salmon in the Pacific Ocean* signed by the United States and Canada in 1985, the *Agreement on Common Fishery Relations* signed by the United States and the Soviet Union in 1988, and the *Agreement on Common Fishery Relations* signed by Denmark, Norway and Russia in 1992 [14]. The fishery operation areas around the Arctic include the Northeast Atlantic Ocean, Northwest Atlantic Ocean, Northeast Pacific Ocean, and Northwest Pacific Ocean, in which some Arctic shipping countries are covered. Different types of fisheries management organizations and fisheries management committees have been established for each operation area, such as the Northwest Atlantic Fisheries Organization, North Atlantic Salmon Conservation Organization, Atlantic Tuna Fish Management Committee, Western and Central Pacific Fisheries Commission, and others [15].

Besides, countries have met to agree on sustainable fisheries management. For example, on 16 July 2015, the five Arctic coastal countries (Canada, the United States, Russia, Norway, and Denmark) signed the *Declaration on the Prevention of Irregular High Seas Fishing in the Core Area of the Arctic Ocean*. Between 1 and 3 December 2015, the five Arctic Ocean coastal countries, China, Japan, the Republic of Korea, Iceland and the European Union held the first round of dialogue in Washington on the establishment of an agreement on the management of fisheries in the high seas of the Arctic Ocean. At the 2016 meeting, there was a consensus to collaborate on fisheries research, despite disagreements over the timing of exploratory and commercial fishing, decision making and the legal binding power of fisheries agreements. The above-mentioned countries held another meeting in Iceland from March 15 to 18, 2017. They reached agreement on most issues and promised to summarize the results of the consultations soon. On 3 October 2018, those countries concluded the Agreement in Ilulissat, Greenland [16]. After discussions at several meetings from 2015 to 2018, cooperation on Arctic fisheries management has finally been tentatively reached. Accordingly, it can be seen that fishery cooperation in the Arctic region is feasible and underway, but how to better cooperate still needs to be considered. Therefore, the following research question is raised: How can the sustainable fishery concept be more effectively promoted among Arctic stakeholders?

In this research, the complex network theory is applied to construct the Arctic sustainable fishery network and the SIR (susceptible–infective-removed) model is used to carry out simulations on the influencing factors. This paper makes the following contributions: 1) It enriches the literature on knowledge dissemination related to fishery sustainable cooperation with countries along the Arctic shipping routes. 2) It proposes three countries that can act as initiators of the concept of sustainable fisheries and explains the reasons behind the current slow development of sustainable fishery cooperation. 3) Possible measures are proposed for better cooperation over the sustainable fishery initiatives. For example, countries can strengthen scientific and technological innovation to improve the utilization rate of domestic fishery resources and can reduce costs by combining blockchain technology, artificial intelligence, and modern monitoring systems so as to better adopt sustainable fishery concept.

The rest of this paper is organized as follows: in the next section, we review the literature related to the sustainable fishery of Arctic shipping line and outline the factors that slow the dissemination of the sustainable fishery concept. In section three, we explain the propagation model of sustainable fishery cooperation based on the complex network theory in detail. In section four, the analysis and results of the model simulation are provided, and in section five, a discussion on how to improve the dissemination effect of sustainable fishery concept in the

Arctic shipping line is made based on the simulation results. Finally, we summarize the conclusion and limitations of this paper and propose future research directions.

2. Literature review

The Arctic route is a sea route shortcut connecting Europe, North America, and East Asia. The northeast and northwest routes circle the North Pole in a semicircle, known as the "Middle East at the end of the world" [17]. The Arctic is currently undergoing the most dramatic changes on earth, and the world is watching to see what positive and negative effects this change will bring. Although the Arctic issue is a fairly important research topic, the study of Arctic fisheries and sustainable fishery still needs to be developed [18].

There are some literatures on the sustainable fishery along Arctic routes, and the research methods on the sustainable development of marine fishery resources in other regions can also provide some research insights. As an important issue of marine exploitation, the sustainable utilization of marine fishery resources has attracted the attention of scholars since the early twentieth century. Scholars generally believe that sustainable fishery should include three aspects, namely, the sustainability of resources and environment, society, and the economy [19]. Management of Arctic environments and the exploitation of marine resources in these areas are challenged with balancing sustainable and long-term viability of natural resources, preventing overexploitation, degradation, and pollution of marine environments, and maintaining the economic, social, and cultural wellbeing of Arctic communities [20]. The quality and degree of exploitation and utilization of marine fishery resources usually reflect the sustainable of fisheries in terms of resources and the *environment*. The *economic sustainability* is measured in terms of inputs to and outputs from the resource environment, that is, the proportion of catches. The *sustainable utilization of the society* is measured by the degree to which the needs of the society can be met while ensuring sustainable practices [21].

Scholars have applied both quantitative and qualitative approaches to sustainable fisheries. *Quantitative* analysis evaluates the sustainable utilization of fishery resources, and the research method constructs the sustainable utilization evaluation index system. Principal component analysis [22], analytic hierarchy process [23] and the theory of ecological footprint index model [24] are used to measure and analyze the sustainable utilization of fishery resources. The *qualitative* analysis is usually discussed with the SWOT model [25].

Scholars have listed some solutions on how to carry out the sustainable utilization of fishery resources. For example, we can use Fishery Improvement Projects (FIPs) which are forms of private governance using seafood supply chains to reduce environmental impacts of fishing in some of the most challenged fisheries [26]. Also, the ecological-economic coupling optimization model shows that an ecosystem-based fisheries management will be able to offer society options for the solution of common conflicts between different resource uses, and adding equity considerations to the traditional trade-off between the economy and ecology will greatly enhance credibility concerning a further footstep towards healthy fish stocks and sustainable fisheries in the world’s oceans [27]. Carbon sequestration fisheries can absorb carbon dioxide from the water through fishery production activities, and promote income generation while protecting the environment [28-29]. Combating IUU (illegal, unreported, unregulated) fishing can also be used to address the practical challenges of fisheries management [30]. In the above literature, it is found that scholars' research focuses on the use of indicators to evaluate the sustainable fisheries itself, while few scholars use indicators to establish models for the study of sustainable fisheries among different countries.

Aiming at the dissemination of knowledge and ideas, scholars mostly use the infectious disease model for research. For example, Yang et al. (2019) [31] used the infectious disease model to study the spread of tacit knowledge in enterprises; and Xue et al. (2016) [32] used the same model to study the transmission of knowledge within the community. It has also been applied at country level [33]. Therefore, we employ the transmission model to carry out the dissemination research of sustainable fishery.

Among network transmission models, the SI model, the SIS model, and the SIR model are the most widely used [34]. In the SI and the SIS models, each node is only in one of two states – S (sensitive) and I (infected). There is no transmission but it can easily and actively spread to neighbor nodes. The SIR model introduces the R state (recovery) nodes that have been propagated but are no longer propagated to other nodes. In the reality of the dissemination of the concept of sustainable fishery, some nodal countries, even if they understand the concept of sustainable fisheries, choose not to spread it because of increased interests. For the discussion of the fishery propagation, the SIR model is more in line with the actual situation of sustainable fishery trade; thus we adopt it in this paper.

In conclusion, there is a lack of research on sustainable fisheries in the Arctic. Few papers use quantitative methods; and only limited articles have focused on the spread of sustainability in the Arctic. Meanwhile, the method of the complex network and the communication model is rarely used to explore the communication of sustainable concepts. Therefore, this paper takes the countries along the Arctic as a whole region, and studies the dissemination of sustainable fisheries concept based on the method of complex network and the infectious disease model.

3. Methods

3.1 Determination of Arctic stakeholders

According to previous studies [35-36], the main players of the Arctic shipping route are determined as eight countries in the Arctic Circle, comprising Canada, Finland, Denmark, Norway, Sweden, Iceland, Russia and the United States, and five countries in the Asian region comprising China, South Korea, Japan, India, Singapore. Meanwhile, Germany, Britain, France, Spain, the Netherlands, Poland and Italy account for seven countries in the European region. There are 20 countries in total as shown in Table 1:

Table 1
List of Arctic stakeholders**.**

Region	Countries

Inside the Arctic Circle	Canada, Finland, Denmark, Norway, Sweden, Iceland, Russia, America
In the Asian region	China, South Korea, Japan, India and Singapore
The European region	Germany, Britain, France, Spain, the Netherlands, Poland, Italy

3.2 Construction of sustainable fishery trade network in Arctic shipping countries.

Let us take the countries shown in Table 1 as the nodes of the network. There are various kinds of economic and trade cooperative relations among these countries, and the economic dependence and the close degree of trade links between countries vary with the amount of trade. The greater the volume of trade, the stronger the economic ties between countries, and vice versa. From the United Nations Conference on Trade and Development fisheries bilateral trade data (http://unctad.org/en/Pages/statistics.as-px) of relevant countries in the Arctic route in 2019, we set the country's imports and exports as more than US$10 million to the country's economic and trade cooperation between the two countries as the standard. If the fisheries bilateral trade is more than $10 million, we assume there are trade ties between the two countries, so the adjacency matrix of the corresponding item assignment is 1 and 0 otherwise. The UCINET software was used to draw the network map of fishery economic and trade cooperation between relevant countries of Arctic shipping routes, as shown in Figure 1:

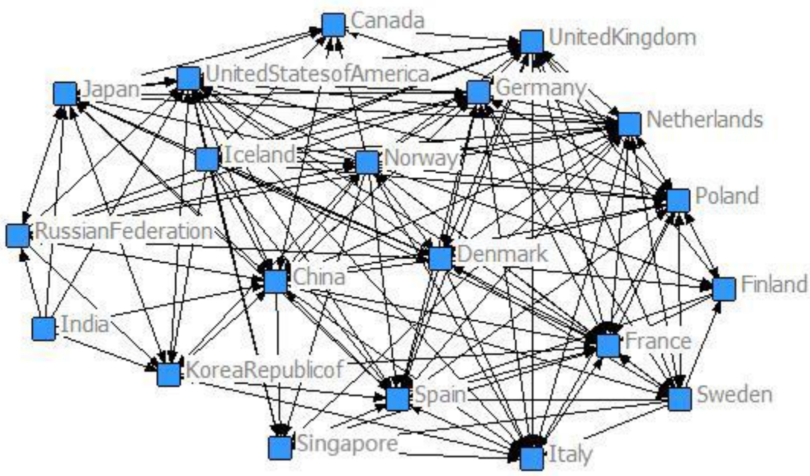


Fig.1. Map of fishery economic and trade cooperation network of Arctic stakeholders.

The 20 Arctic route countries are arranged in alphabetical order, so that the degree of each node country is calculated respectively as (4,15,14,4,7,11,14,5,4,5,6,13,17,9,3,9,11,10,10,12), and the average degree is 9.15.

3.3 Propagation model analysis of sustainable fishery cooperation in the Arctic shipping line

3.3.1 The classical model

In the classical SIR model, units can be divided into three categories according to their different states: susceptible countries S, infected countries I, and immune countries R. Susceptible countries S refers to the node countries to be informed in the spread of sustainable fisheries concept; Infected countries I is the disseminator of the concept of sustainable fishery; and Immune countries R are those who have the idea of sustainable fisheries but no longer spread such knowledge. The *infection* rate λ is the probability that a nodal country chooses to believe and implement the concept of sustainability after being exposed to it. The *immunity* rate μ is the probability that an infected country turns into an immune country who accepts the sustainable fisheries concept but do not further spread it. In each given situation, each country is in one of the three states, where $i_k(t)$, $s_k(t)$ and $r_k(t)$, respectively, represent the proportion of the three types of countries with degree k at time t in the population, and the normalization condition is satisfied [37-38]:

$$i_k(t) + s_k(t) + r_k(t) = 1 \tag{1}$$

Table 2 provides the detailed descriptions of the main variables in this article.

Table 2.
The meaning of main symbols.

Variable	Description
λ	The probability that a nodal country chooses to believe and implement the concept of sustainability after being exposed to it
μ	The probability that an infected country turns into an immune country
$i_k(t)$	The proportion of susceptible countries
$s_k(t)$	The proportion of infected countries
$r_k(t)$	The proportion of infected countries become immune
$\Theta[i_k(t)]$	The probability that a node with point degree k at time t touches the propagation node
W	The will of the country
M	The absorption capacity
ε	The disturbance term.
$k\ (l)$	The degree of node I that represent the number of neighbours owned
$\varphi(t)$	The auxiliary function

We further apply Mean-field theory in this research which is one of the popular analysis methods for SIR, SI and SIS epidemic models [39].The classical mean-field approximation is mainly applied to homogeneous networks, and there exist a finite critical value, which is the inverse of the average degree <k>. The mean-field theory can solve the epidemic threshold on networks, with the considerations of complex conditions. It can also be used to analyze the dynamics on spatial networks [40]. Based on the mean-field theory, the nonlinear differential equations of $i_k(t)$, $s_k(t)$ and $r_k(t)$ evolution with time t can be obtained as follows [37-38]:

$$\begin{cases} \frac{di_k(t)}{dt} = \lambda s_i(t)k\Theta - \mu i_k(t) \\ \frac{ds_k(t)}{dt} = -\lambda s_i(t)k\Theta \\ \frac{dr_k(t)}{dt} = \mu i_k(t) \end{cases} . \quad (2)$$

If $\Theta[i_k(t)]$ represents the probability that a node with point degree k at time t touches the propagation node, then：

$$\Theta[i_k(t)] = \frac{\sum_{k'} k' p(k') i_{k'}(t)}{<k>} \quad (3)$$

$<k>=\sum_k kp(k)$ is the average degree of nodes in the network.

3.3.2 Improved SIR model

In the classic SIR model, the transition probability λ and the transition probability μ are fixed values. However, for the spread of the concept of sustainable fisheries of Arctic area, many factors affect the transition probability, which cannot be simply represented by a fixed value. Therefore, in this paper, the classical SIR model is improved according to the characteristics of the dissemination of the sustainable fisheries concept.

As a kind of knowledge transmission, the factors that influence the dissemination of knowledge play a certain role in the dissemination of the concept of sustainable fisheries. Knowledge is spread in the network knowledge community. A network knowledge community is a group that gathers due to the common interest of some people in a certain topic and the demand for knowledge acquisition and communication and forms a close interactive relationship through the activities of creating and sharing relevant knowledge in a network environment [41]. The members of the network knowledge community are almost unaffected by the geographical location, ethnic difference, and other real-life factors, and there are only limited objective obstacles to the knowledge exchange among the members, which gives the exploration and creation of knowledge great potential, opportunity, and possibility.

The trade network of Arctic shipping countries can be regarded as a network knowledge community, so the diffusion factor of knowledge within the organization is applicable to individual countries. Scholars who studied the influence factors of knowledge dissemination found that organizational climate factors lead to knowledge dissemination activity, tools, and techniques, knowledge-sharing attitude, subjective norm [42], cost and benefit balance, and knowledge recipient's structured relationship [43], and prestige, mutual benefit, common language, social communication and trust [44]. In this paper, based on the actual situation of sustainable fisheries on Arctic routes, and by summarizing and simplifying the above influencing factors, the influencing factors can be divided into two aspects: (i) the internal influence; that is, the influence of country factors, and (ii) the external influence; that is, the influence of inter-country network [45].

3.3.2.1 Influence of country factors. In this paper, α is used to describe the influence of internal factors – that is, *country* factors. Each country's acceptance of knowledge is influenced by its willingness to learn and accept the sustainable fishery concept and its ability to absorb knowledge [46]. It is assumed that the relationship between the two is linear, so

$$\alpha = a_0 + a_1 W + a_2 M + \varepsilon (0 < \alpha < 1) \quad (4)$$

Where W refers to the will of the country, M refers to the absorption capacity, and ε is the disturbance term.

Whether a country is willing to accept the concept of sustainable fisheries is measured by accepting the resources and capabilities of the sustainable concept and the national will. In the formula, M represents the absorption capacity, and M is measured by the resource utilization rate [47] in the simulation. The tolerance of a country for the dissemination of knowledge affects the efficiency of the dissemination. In turn, the acceptance of the dissemination of the sustainable concept of fisheries by the countries of the Arctic route is influenced by the country’s ability to coordinate the economy, society and resources. The state's acceptance of the concept of sustainable fisheries is somewhat limited by the utilization rate of its fishery resources. Therefore, it is reasonable to use resource utilization to measure resources and capabilities.

In the formula, W represents the will of the country, and W is measured by the degree of national attention [48] in the simulation. This article has a certain basis for measuring the degree of national attention: according to the *UN Food and Agriculture Organization's 2030 Agenda for Sustainable Development*, the proportion of sustainable fishing fisheries in GDP varies from region to region. This partly reflects the degree to which each country attaches great importance to the concept of sustainable fisheries. Some countries believe its development is very important and take the concept seriously, while other countries believe that sustainable fisheries consume high resources due to the extra cost and the income is relatively small, so they do not take the concept of sustainable fishery seriously [49]. It can be seen from this that it is reasonable to use the degree of national attention to measure the impact of national will on the spread of sustainable fisheries. The degree of national attention is a value between 0 and 1, which is reflected in whether a country has incorporated the concept of sustainable fisheries into its national strategy or whether it has been fixed in the form of laws. The more times it appears in laws and relevant national policies, the greater the weight and the stronger the national will ‘W’ is. Taking China as an example, in the *Report to the 18th National Congress of the Communist Party of China* and *the Report to the 19th National Congress of the Communist Party of China*, China has successively put forward the concept of "sustainable development", and the State Council has issued 16 administrative regulations. These include the opinions of the State Council on promoting the sustainable and healthy development of marine fishery, and 21 administrative rules and regulations of the State Council [50]. Since 2017, the country has extended the period of closed season fishing; from 1 January 2016, the Yangtze River fishing ban period was adjusted to expand the scope and period of the fishing ban [51]. It can be seen that China attaches great importance to the concept of sustainability and assigns a high value to its weight.

In the subsequent simulation, this paper summarizes the terms of sustainable fisheries from the legal and strategic levels of various countries, and assigns values ranked from large to small, with the higher the number, the higher the value. This is on the basis of the empirical analysis of the influence of other scholars on enterprise knowledge transmission [46], since the enterprise is part of the national knowledge transfer subsystem, thus we assume the mechanism of transfer between countries follow the same pattern. Moreover, some scholars have also used the SIR model to discuss the knowledge transmission at the national level [52].Accordingly to literature, if $a_1 = 0.152, a_2 = 0.141$, when $a_0 = 0$, it is the standard SIR Model without considering W, M, or disturbance term. However, this paper studies the improved model, so $a_0 = 0.1$ [48]. It can be expressed as:

$$\alpha = 0.1 + 0.152W + 0.141M + \varepsilon \tag{5}$$

3.3.2.2 Trade network factors. Governance network structure also has a certain influence on fishery management [53-54]. According to the complex network theory, node degree is an indicator that reflects the influence and activity of nodes in the network. The higher the degree value is, the more neighbors there are. In the Arctic route trade network, it shows the frequent foreign trade of the node countries, which is more conducive to influencing others and to the spread of trade [55]. Let k (I) be the degree of node I and represent the number of neighbors owned. Under the influence of inter-country network factors, the more the neighbors of each country are infected, the more the susceptible nodes are affected and the more likely they are to be infected. Therefore, the infection rate can be defined as:

$$\lambda' = [1\text{-}(1\text{-}\alpha)^{k(i)}]\lambda \tag{6}$$

Therefore, the improved differential equation is:

$$\begin{cases} \frac{di_k(t)}{dt} = \left[1\text{-}(1\text{-}\alpha)^{k(i)}\right] * \lambda s_k(t) k\Theta \text{-} \mu i_k(t) \\ \frac{ds_k}{dt} = \text{-}p[1\text{-}(1\text{-}\alpha)^{k(i)}] * \lambda s_k(t) k\Theta \\ \frac{dr_k}{dt} = \mu i_k(t) \end{cases} \tag{7}$$

Define $\varphi(t)$ as the auxiliary function:

$$\varphi(t) = \int_0^t \Theta\,[i_k(t)]dt = \int_0^t \frac{\sum_{k'} k' p(k') i_{k'}(t)}{\sum_{k'} k' p(k')} dt = \frac{\sum_{k'} \mu^{-1} k' p(k') r_{k'}(t)}{\sum_{k'} k' p(k')} . \tag{8}$$

So:

$$\frac{d\varphi(t)}{dt} = d\,\frac{\sum_{k'} \mu^{-1} k' p(k') r_{k'}(t)}{\sum_{k'} k' p(k')} / dt = \frac{\sum_{k'} k' p(k') i_{k'}(t)}{\sum_{k'} k' p(k')} = \frac{\sum_{k'} k' p(k')(1 - s_k(t) - r_k(t))}{\sum_{k'} k' p(k')} = 1 - \frac{\sum_{k'} k' p(k') s_{k'}(t)}{\sum_{k'} k' p(k')} - \mu\varphi(t) \tag{9}$$

According to the initial conditions:

$$s_k(t) = \exp\{[1\text{-}(1\text{-}a)^{k(i)}]\lambda k \varphi(t)\} . \tag{10}$$

Substituting equation (10) into equation (9), we get

$$\frac{d\varphi(t)}{dt} = 1 - \frac{\sum_{k'} k' p(k') \exp\{[1-(1-a)^{k(i)}]\,\lambda\, k\varphi(t)\}}{\sum_{k'} k' p(k')} - \mu\varphi(t) . \tag{11}$$

If we set this equal to 0, we get

$$\varphi(t) = \mu^{-1}(1 - \frac{\sum_{k'} k' p(k') \exp\{[1-(1-a)^{k(i)}]\,\lambda\, k\varphi(t)\}}{\sum_{k'} k' p(k')} = f(\varphi) . \tag{12}$$

There is a zero solution to the above equation. In addition, the necessary condition for the existence of non-zero solutions is

$$\frac{df(\varphi)}{d\varphi}\Big|_{\varphi=0} \geq 1 . \tag{13}$$

Therefore, the propagation threshold is

$$\lambda = \frac{<k>\mu}{<k^2>[1-(1-a)^{k(i)}]} = \frac{<k>\mu}{<k^2>[1-\left(1-(a_0+a_1W+a_2M+\varepsilon)\right)^{k(i)}]} \quad . \tag{14}$$

3.3.3 Analysis of model calculation results

According to the calculation results of the model, we can make a preliminary judgment:

The propagation threshold is proportional to the recovery rate. That is, the higher the recovery rate is, the higher the transmission threshold is, and the worse the transmission effect is. This conclusion can be explained according to the propagation principle of the SIR model. The recovery rate is the probability of transitioning from state I to state R. The R state is a relatively closed node in the network. Although it accepts transmission from its neighbors, it is reluctant to spread to other countries. When the recovery rate is high, it means that more nodes will switch from being infected to being removed and the behavior of interrupting transmission will significantly reduce the transmission effect.

The communication threshold is inversely proportional to the degree of initial communication nodes, the willingness of the country, and the ability to absorb knowledge. With other conditions unchanged, the higher the willingness of a country in the Arctic shipping route to implement sustainable fishing; the lower the transmission threshold, and the faster the spread of the idea of sustainable fishing in the Arctic shipping route. Similarly, the node degree of initial propagation means that the more neighbor nodes of countries act as initiators of ideas, the lower the propagation threshold will be; which is more conducive to propagation. The higher the ability of a country to absorb knowledge, the lower the threshold of transmission, and the more conducive it is to transmission.

The results of model calculation can only judge whether the above factors have a positive or negative influence on the propagation effect, and the influence degree will be explored in the next section through simulation.

4. Simulation and results

Based on the above model, we analyzed the influence of various factors on the network through MATLAB simulation. The simulation process is shown in Figure 2. Because the purpose of our paper is to investigate the influence of different factors on the propagation effect, the setting of the initial value in the simulation mainly considers the value range of factors and the obvious degree of the results, which will not substantially change our research results. According to the actual situation and data experiment, the variable value is set uniformly in the simulation process. We selected the 19th node which was close to the average node degree and defined it as the initially infected node. We then set the simulation time as t=100, and the initial values are λ=0.7, μ=0.08, W=0.1, M=0.1, respectively.

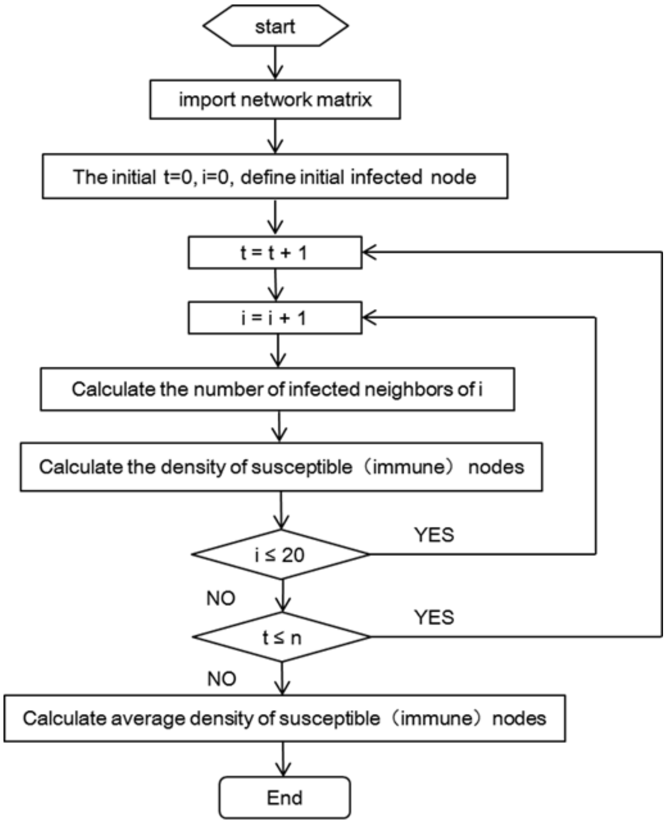
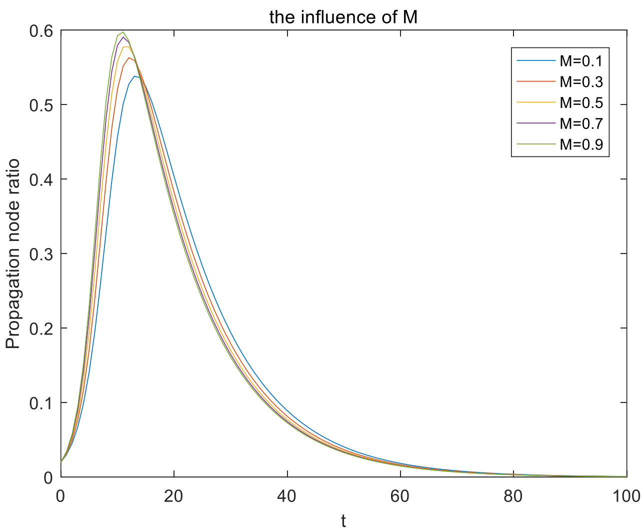


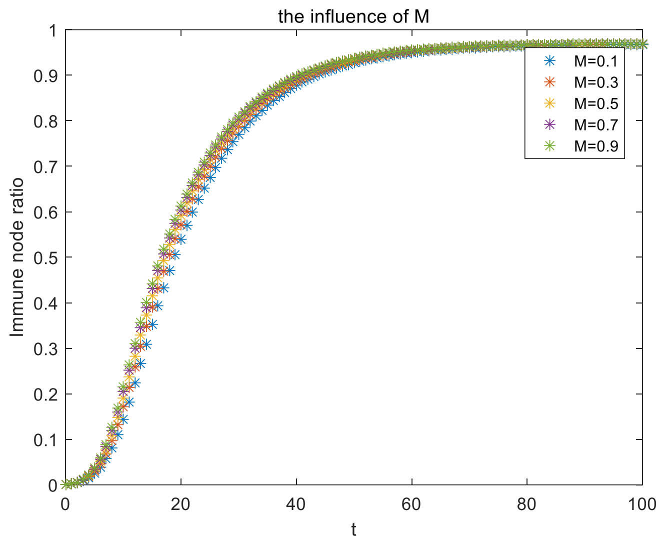
Fig.2. Model simulation flow chart.

4.1 The effect of absorption capacity M

If the average degree is 9.15, we select the 19th node as the initial propagation node. In the previous section, we assumed that resource utilization was used to measure resources and capabilities [47]. The value of resource utilization ranged from 0 to 1, so M=0.1. M = 0.3; M = 0.5; M = 0.7; M=0.9, and the influence of absorption capacity M on the transmission process was observed, as shown in Figure 3:



a)



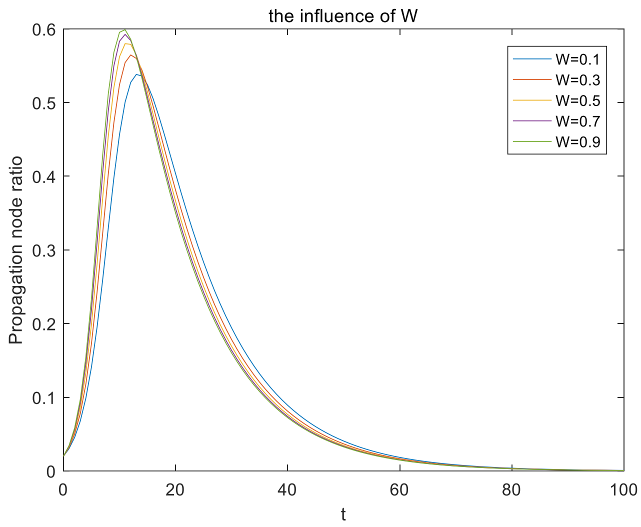
b)

Fig.3. The influence of absorption capacity M on the propagation node a) and immune nodes b).

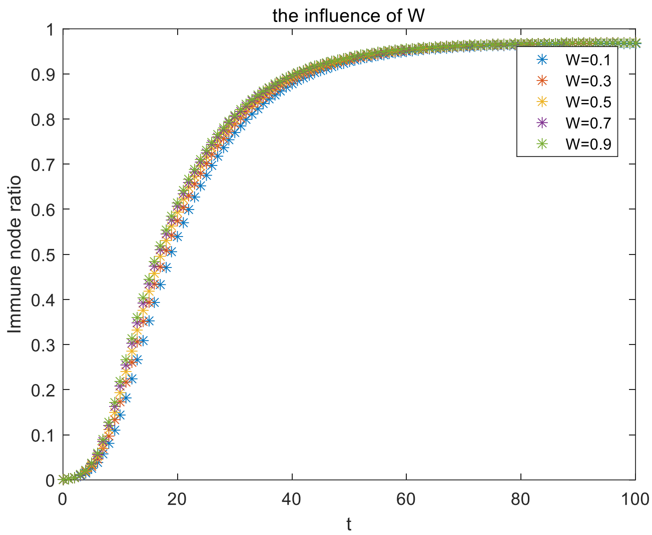
The figure above shows the changing status of the propagation node and of the immune node. Resource utilization is used to measure the impact of national knowledge absorption capacity on dissemination. The results show that the stronger the absorptive capacity is, the higher the probability is that the node will change from susceptible node to transmission node, the faster the node will rise, and the more beneficial it will be to the spread of sustainable concept. The knowledge absorptive capacity has a positive effect on the spread of the sustainable fishery concept, and the higher the value of M, the faster the propagation effect is.

4.2 The influence of national will W

If the average degree is 9.15, we select the 19th node as the initial propagation node. In the previous section, we assumed that the degree of national attention [47] was used to measure the national will, and the value of national attention ranged from 0 to 1, so W=0.1; W = 0.3; W = 5; W = 0.7; W=0.9, and the influence of national will W on the transmission process was observed. As shown in Figure 4:



c)



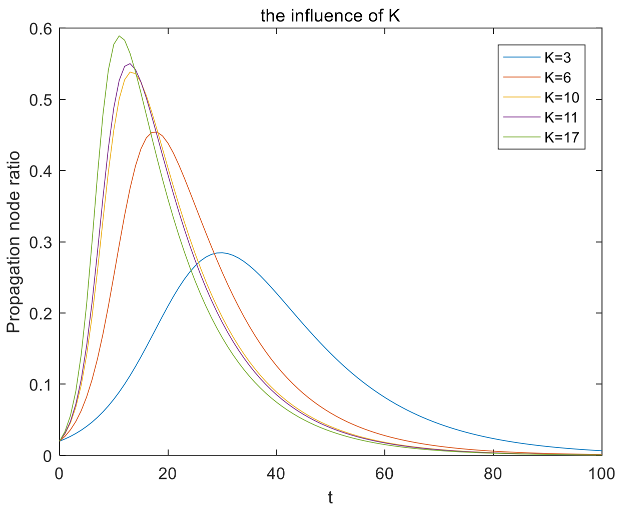
d)

Fig.4. The influence of national will W on the propagation node c) and immune nodes d).

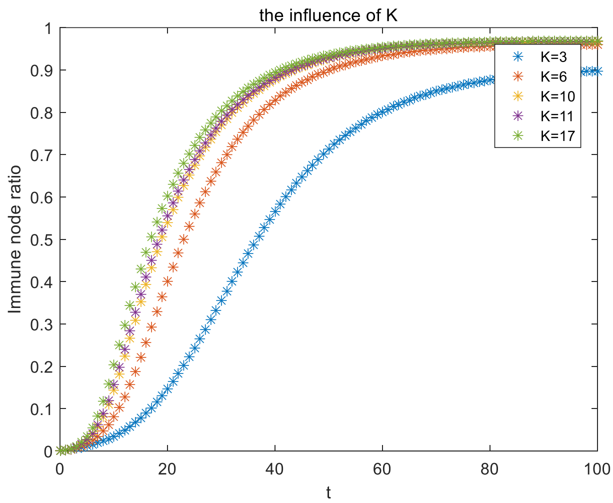
The figure above shows the changing status of the propagation node and the immune node. The influence of national will on communication is measured by the degree of national attention. The results show that the stronger the willingness of a country to implement sustainable fishery, the higher the probability that the node will be transformed from a susceptible node to a transmission node, and the faster the transmission node will rise, the more favorable it will be to the spread of the sustainable fishery concept. Thus, there is a positive effect of national willingness on the spread of sustainable fishery concept.

4.3 The influence of initial propagation node degree k on the propagation of the sustainable fisheries concept

With all other assignment assumptions held constant, we select the degree of some node countries for simulation. The degrees are (3, 6, 10, 11, 17), and i are (15, 11, 19, 17, 13). The influence of degree k of the initial propagation node on the propagation of the concept of sustainable fisheries is shown in Figure 5:



e)



f)

Fig.5. Effect of initial node k on propagation node e) and immune nodes f).

The figure above shows the changing status of the propagation node and the immune node. The higher the k value of the initial propagation node is, the earlier the density of the propagation node reaches the peak, and the better the propagation of the concept of sustainable fishery. The degree k of the initial propagation node has a positive effect on the propagation of the concept of sustainable fisheries and, from the simulation results, it can be seen that the degree k has a greater impact on development than the willingness and absorption capacity have. In addition, the influence of M and W do not significantly change the final results while the degree k has a significant influence on the results.

5. Discussion

Widespread acceptance of the idea of sustainable fisheries will take time. Whether under the influence of initial communication nodes, knowledge absorption capacity or national will, the peak time of transmission is relatively long and the speed of transmission is slow, indicating that the transmission of sustainable fisheries along Arctic shipping countries needs to be implemented in the long term rather than in a short time period, which suggests that existing fishery collaborations are essential to establish a foundation for future sustainable fishing practices and international collaboration.

According to the trend that the immunization node eventually approaches 1, it can be predicted that after a long period of time, most countries in the Arctic fishing route countries will accept the concept of sustainable fishing. Therefore, all countries and relevant organizations need to set a long-term strategic goal to cope with the future development needs of sustainable fishing. Countries could develop ecological fisheries to make the symbiosis between the fish and other organisms complementary and improve the benefits of breeding [2].

The idea of sustainable fishery in Arctic shipping route countries is feasible and has some practical bases. The first is the existence of an imperfect but diverse set of laws and regulations and the fact that, over time, countries have repeatedly met to agree on sustainable fisheries management. In addition, all countries have a shared culture of sustainable fisheries. Taoism, which was born in China, contains ecological thoughts. It advocates the moral feelings that "heaven and nature are precious" and establishes the moral code of "keeping to the road and walking" [56]. The main feature of Eco criticism in European and American countries is ecological holism, which emphasizes that the overall interests of the ecosystem are the highest value, and the maintenance and protection of the integrity, harmony, stability, balance and sustainability of the ecosystem are the fundamental measures against which to measure *all* things [57]. Therefore, the countries that belong to the Arctic shipping route have the consensus and basic conditions to develop sustainable fisheries. The current slow progress of sustainable fisheries may simply be due to the lack of a large organization that includes all countries of the Arctic shipping route to negotiate sustainable management of fisheries in the arctic region [58].

Many factors influence the spread of sustainable fisheries. The effect of the initial communication node on communication is obvious. The influence of countries with many neighbors can promote the spread of sustainable concepts more effectively. In the Arctic shipping route fishery trade network, Norway, China and Denmark are the top three participants in terms of the number of nodes. Combined with the results of this study, these three countries should play leading roles. In addition, the three countries have their own characteristics, which will be more conducive to the spread of sustainable ideas. First, as two of the five Arctic countries, Norway and Denmark should be responsible for the initiative and initiation of sustainable fisheries network, and have been working actively on fisheries management in the Arctic. Some examples of such initiatives are *the Agreement on Cooperation in Fishery Affairs* signed between Norway and the Soviet Union in 1975, and the 1992 *Agreement on Common Fishery Relations* between Denmark, Norway and Russia. In

August of the same year, Denmark formulated a new policy on fisheries resource management in the core area of the Arctic Ocean [14]. As a result, Norway and Denmark are well-positioned to act as communicators and initiators of sustainable ideas. Second, as the largest developing country, China's economic size, huge market, and international status will be of great significance to the spread of the concept of sustainability. From 1950 to 2014, China's domestic marine fishery continued to decline, and sea farming was gradually adopted as a method to increase seafood production [59]. Thus, China can not only lead the world with its huge economic size and demographic dividend, but can also disseminate advanced sustainable fishery technologies. In order to better play its role in communication, China can make full use of its future status as the high seas fishery resource management agency and the Arctic Council in the core area of the Arctic Ocean, and promote the scientific research of various countries on Arctic-related issues through the Arctic Council. Therefore, this paper argues that among the Arctic shipping countries, Norway, Denmark and China should give full play to their roles as the leaders in the dissemination of the sustainable fishery concept.

Knowledge absorption capacity plays a positive role in communication; that is, the higher the knowledge absorption capacity is, the faster the transmission speed will be, and the earlier the peak of transmission will come. Therefore, scientific and technological innovation should be strengthened to improve the utilization rate of domestic fishery resources. At present, there are still many countries in the Arctic shipping route with only a 50% resource utilization rate, which will not be conducive to the wider sustainable development of fishery resources, and the resultant illegal fishing will cause great harm to the environment. Solving the problem of low resource utilization rate will improve the ability to accept ideas from the perspectives of the country, industry, enterprises and consumers. First, at the *national* level, sustainable fisheries can be taken as a national strategy, and policies can be introduced to encourage marine fishery to eliminate backward-operating methods. Further, the pace of innovation and transformation of fishing vessels can be accelerated to reform backward-operating methods. Second, at the *industrial* level, the advantages of the marine fishing industry should be explored, the added value of marine products should be increased, the industrial chain should be extended, and new economic growth points should be cultivated. Third, at the *enterprise* level, we should increase investment in scientific research, strengthen industry-university-research cooperation in fisheries, encourage researchers to conduct in-depth research on the nutritional value of various marine products, and conduct in-depth research on practical, efficient extraction and preservation technologies, such as deep-sea cage technology. Finally, at the *consumer* level, consumers' sustainable consumption practices will drive the transformation of corporate farming methods. New technologies such as blockchain can be applied to ensure an end-to-end transparent supply chain to eliminate illegal fishing [60]. Currently, there are some carbon sink fishery products, and consumers are willing to buy such green products at a premium price. Therefore, various measures would be taken to encourage consumers to buy green/sustainable products [19].

The spread speed of a sustainable fishery development concept is influenced by the nation will, which is limited by the acceptance cost and input of the sustainable fishery concept. Hartje et al. (2018) [61] evaluated small-scale fisheries in Cambodia and found that only livelihood activities supported by policy makers could contribute to sustainable fisheries management. Similarly, the extent to which Arctic shipping countries accept the idea of sustainable fisheries will vary depending on the costs. Taking Denmark as an example, the fishery output of Denmark is not high, but the fishery occupies a relatively important position in the development of its national economy, and the fishery development level is high. A policy such as a "no-take" (no commercial fishing) would be costly for Denmark, and it would hesitate to embrace the idea if only a few countries accepted it, which would make it difficult to achieve the desired sustainable goals [62]. On how to reduce costs so that countries can better accept sustainable fisheries, we propose this can be achieved through technological innovation, such as combining today's blockchain technology or using artificial intelligence and modern monitoring systems to monitor the ecological breeding behavior of fishery enterprises.

6. Conclusion

In this paper, a complex network approach, combined with an infectious disease model, is used to discuss the spread of the sustainable fisheries concept in Arctic shipping route stakeholders. There are certain differences in the cultural concept, economic development level, national quality, and sustainable fishery technology level of Arctic shipping countries. It is a long-term process for Arctic shipping countries to accept and practice the sustainable fishery development concept. The factors influencing transmission are influenced by the will of these countries for sustainable fisheries, the capacity for sustainable fisheries of fisheries, and the political and economic relationship structure of Arctic shipping route countries. The influence of the above factors was simulated by MATLAB.

According to the simulation results, the more a country is willing to define the concept of sustainable fishery development strategically, the more likely it is to accept and spread sustainable fisheries, and the more it can promote sustainable fishery development in the entire Arctic shipping route. A country's capacity to drive forward the sustainable fisheries directly influences the spread of the concept and the sustainable development of these countries' fishery technology research and development abilities. The more carbon sinks fisheries there are – that is, where green fisheries industry development level is higher – the greater the chance of these countries accepting and practicing of sustainable development and the greater the chance that the sustainable development of the Arctic route state fisheries can promote the Arctic route from overall sustainable fishery development. The structure of the Arctic shipping route fishery trade and economic network will also affect the spread of sustainable fisheries concepts; the higher the average degree, the faster the spread speed and the better the spread effect. From the simulation results, it can be seen that the structure of the trade and economic network has a greater impact on development than national will and ability to develop. This paper identifies three countries that can be the initiators of the concept of sustainable fisheries, and puts forward possible measures for countries to better carry out sustainable fisheries development cooperation, which will help expand the arctic sustainable practices. At the theoretical level, this paper also provides an idea for mechanism innovation to solve global ocean problems, that is, to give full play to the role of key countries, and at the same time, to encourage other countries to improve the willingness to protect Marine resources and the ability to effectively and efficiently use Marine resources. On the basis of the research in this paper, future scholars can further explore the mechanism to make countries more receptive to sustainable fisheries, and the research scope can be extended from the Arctic shipping routes to other regions.

Nevertheless, this research also has some limitations. First, although there are many fishery countries in the Arctic shipping routes, we only selected those that have established trading relations. Second, our discussion is based on a static network; however, the real network is changing dynamically at any time, so predicting the dynamic relationship according to the static network has certain limitations. Third, we explore three factors of the dissemination of sustainable fisheries, there are possibly other factors which worth exploring in the future.

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