Problem Chosen	2020 MCM/ICM Summary Sheet	Team Control Number
A		2015018

The 0ptimal Fishing Strategy of Marine Fishery under the Background of Global Warming

Summery

Do you find it increasingly difficult to fish by the lake? It's not because of the moral constraints in Leister' s Enlightenment from Fishing, but the global warming. Can you believe it's because the migration of fish caused by global warming? This is not an alarmist talk, but what is happening in Scotland. Now, Scottish herring and mackerel are migrating slowly.

As a consultant of a Scottish North Atlantic fishery management consortium, our team specifically studied the migration of herring and mackerel in the North Atlantic Ocean, and proposed corresponding countermeasures for fishery companies.

We establish a **differential autoregressive moving average model** based on time series, and forecasts the water temperature changes of each area in the next 50 years based on data past 30 years. And we determine the likely locations by matching the optimal temperature. The results show that the location is 30-50 degrees north latitude and 30-50 degrees west longitude.

We set up a **benefit evaluation model of fishery company**, calculating profits of fishery company with considering temperature, migration distance, market impact and other factors on fishing income. The results show that: **(1)** the worst case is that when the distance between fish groups reaches 362 nautical miles, the income of each fishing boat is 3972 pounds; **(2)** the best case is that when the distance between fish groups reaches 589 nautical miles, the income of each fishing boat is 6293 pounds; **(3)** when the distance between fish groups reaches 973 nautical miles, the fishing boat will get nothing at sea, and the elapsed time is 19 years. The sensitivity analysis shows that: **(1)** the higher the temperature is, the higher the income will first increase, then decrease; **(2)** the longer the migration time is, the smaller the income will be; **(3)** the distance increases, the income will first decrease, then increase, then decrease.

We established the **optimization model** and calculated the income of fishery enterprises under three strategies: **(1)** fishing by small fishing vessel; **(2)** transferring part of the company's assets; **(3)** product transformation like building the production line of canned fish. The results show that compared with the previous best case, the three strategies increase the income by 385, 556 and 987, respectively. When part of the fish groups migrate to other countries' waters, we add the limitation of the model to the transfer of the company's asset location on the basis of maximizing the profits of the fishery companies.

For the article for the magazine, we highlighted the significant impact of climate change on marine fisheries, and cited a large number of data, enough to make fishermen readers realize the seriousness of the situation. At the end of the paper, a detailed solution is given, and fishermen are called to work together for the **sustainable development of marine fishery**.

Keywords: differential autoregressive moving average model based on time series; benefit evaluation model of fishery company; optimization model; sustainable development of marine fishery

Contents

1. INTRODUCTION

1.1 Restatement of the problem

Climate change has become the focus of international research on environmental issues. With the in-depth study of climate change at home and abroad, it is found that its impact on fisheries is more and more clear. With global warming and rising sea temperatures, Scottish herring and mackerel have also been affected by the temperature, starting to move from their habitats near Scotland to habitable areas.

As a consultant of a Scottish North Atlantic fishery management consortium, in order to better understand the migration of Scottish herring and mackerel from their habitats near Scotland and safeguard the interests of fishery companies, we mainly focus on the following four issues:

- Predict the most likely locations for herring and mackerel in the next 50 years.
- Forecast the best and worst profit situation of small-scale fishery companies, and predict how long the company will go out to sea to catch nothing.
- Should these fishery companies change their business model?
- When part of the fishery is moved to the territorial waters of another country, analyze the impact of the proposal.
- Prepare an article for the magazine that will help fishermen understand the severity of the problem and propose solutions that will improve their future business prospects.

1.2 Previous research

At present, there are a large number of literature on the impact of sea temperature rise on fisheries, as well as the operation measures and management methods of fishery companies. Five climate change assessment reports [1, 2] issued by the Intergovernmental Panel on climate change (IPCC) have analyzed in detail the impact of marine climate change on marine fisheries. These data are very important for us to analyze how mackerel and herring are affected by environmental factors.

The time series model established by Wuhao et al [18], can predict the future data better based on the time series data, which has a great inspiration for us to predict the water temperature of each region in the next 50 years.

Gu, E. et al.[11] Established a dynamic model of the interaction of fishery resource reserves, catch and market price, and analyzed the maximum benefit of fishery. This provides a starting point for us to create more complex models.

Shi, R. et al, [6] designed the optimal fishing strategy and put forward the replacement of boat to go out to sea fishing, which provided guidance for our optimization model.

Liu, H. and Zhu, Y. [4] analyzed the Countermeasures of marine fishery under the background of climate change by using the conference data released by IPCC. They proposed that the layout of fishery production could be adjusted, the dominant aquatic product industry belt could be established, and the ability of fishery to adapt to climate change could be enhanced. This article serves as a guide when we come up with solutions for fisheries that can improve our future business prospects.

1.3 Our work and some explanations to the problem

- ### What is the purpose of a Scottish North Atlantic fishery management consortium

With the climate change, marine fisheries have been severely affected, and many marine organisms have begun to migrate to more suitable sea areas. The Scottish North Atlantic fishery management consortium wants to know about the migration of mackerel and herring from their habitats near Scotland, so its objectives include:

- **Protect the interests of Fisheries:** In the next 50 years, the vast majority of marine organisms will migrate, so the interests of marine fisheries are likely to be threatened. Herring and mackerel are the fish with large import and export volume. Taking herring and mackerel as an example, this paper forecasts the most likely place for herring and mackerel in the next 50 years, and makes a decision for fishery companies whether to fish, so as to ensure the interests of fishery in the context of climate change.

- **To make fishermen aware of the seriousness of the problem and provide them with countermeasures:** A Scottish North Atlantic fishery management consortium hopes to make fishery companies aware of the current situation of fish migration through data and analysis, and hope that fishery companies can take relevant measures in time to cope with the marine climate change and ensure the sustainable development of marine fisheries.

- ### What are the most likely locations for two species of fish

With the aggravation of greenhouse effect, global warming, the rise of sea water temperature has become one of the most significant changes in the marine environment. According to the water temperature of mackerel and herring in their historical activity range, we determined the most suitable water temperature range for mackerel and herring to survive. Thus, the most likely location can be determined according to the water temperature of each sea area. Of course, there are many other factors such as oxygen content, pollution, etc., but we take water temperature as the main evaluation basis, and other factors play an auxiliary reference role.

- ### What is the worst case and the best case

Because a Scottish North Atlantic fishery management consortium is mainly for the benefit of small fishing companies. So we judge the situation by how much small fishing companies benefit from fishing at sea. The best situation is when the profit is the biggest, and the worst situation is when the profit is the lowest or even the loss.

- **When will fish populations be too far away for small fishing companies**

As time goes on, the water temperature is also rising. After herring and mackerel are moved, it means that the distance of fishing boats to sea changes, and the company's profits are inevitably affected. After a period of time, when the fishing boat sailed to the location where herring and mackerel moved to fish and returned, its net profit was 0, that is, when the fishing company got nothing.

- **What are economically attractive strategies**

These strategies can cope with the changes of marine environment and protect the interests of fishery companies. They include:

  - **Transfer the asset position of small fishery companies:** after transferring the asset, the fishing boat can sail closer, which can reduce the cost of fuel consumption and thus make more profits
  - **Use a certain proportion of small fishing boats:** Although small fishing boats have small fishing capacity, their fuel consumption is small, and they are more suitable for going out to sea, which can reduce costs and increase profits.
  - **Product transformation:** Update the equipment, set up the production line of canned fish to increase the profit of the products.

- **About the article for magazines**

This paper needs to quote a large number of data to explain the impact of global warming on the marine climate, so that fishermen can understand the seriousness of the problem, and put forward corresponding solutions for their future business reference. Of course, the article needs interesting narration and novel title to attract readers' attention.

2. ASSUMPTIONS AND JUSTIfiCATIONS

- **It is assumed that there is no interaction between herring and mackerel during migration.** So we take herring and mackerel as a whole to study their migration
- **It is assumed that these two kinds of fish existed in other sea areas before migration.** Because the number of fish in other sea areas is not large, we treat it as a constant when we build the model.
- **The decrease of herring and mackerel during migration is ignored.** Herring and mackerel in the process of migration may have some individuals out of the population or a small number of deaths, we will ignore it.

- **Assume that these two kinds of fish account for the vast majority of the fish caught by the company.** Because we want to study the migration of herring and mackerel, we will treat all the fish as herring and mackerel.
- **It is assumed that the number of fish in different seasons does not fluctuate much.**
- **Assuming that the business volume will not be affected due to relocation, the market price in each region is basically the same.**

3. Symbols and Definitions

Table1. Symbols and their meanings

Variable	Meaning
$X(t)$	**Number of fish in original habitat**
$Y(t)$	**Number of fish in the migration area**
w_1	**Profits of each fishing boat at one time**
ADR	**Average daily income of enterprises**
$\cos t$	**Amount used by the enterprise to purchase small and large ships**
s	**Distance of ocean fishing vessel**

4. DIFFERENTIAL AUTOREGRESSIVE MOVING AVERAGE MODEL BASED ON TIME SERIES

4.1 Model preparation and data preprocessing

In order to assess the impact of climate change on the environment and ecology of the global marine region and analyze the adaptation of the marine region to climate change, AR5 creatively divides the global ocean (excluding the polar sea area) into seven regions based on the structure and function of the global marine ecosystem and the characteristics of Oceanography, which are high latitude spring algal bloom system (area 1), equatorial rise The system (area 2), semi closed sea (area 3), nearshore and offshore system (area 4), upwelling ecosystem (area 5), subtropical vortex (area 6) and deep sea (area 7) are seven sub regions [1].

Because IPCC is based on the climate conditions to divide the marine area, so this paper uses IPCC to divide the marine area is very suitable. However, this paper only analyzes the migration of Scottish herring and mackerel from their current habitats near Scotland, so this paper only intercepts the possible areas that Scottish herring and mackerel may pass through for analysis, as shown in Figure 1.

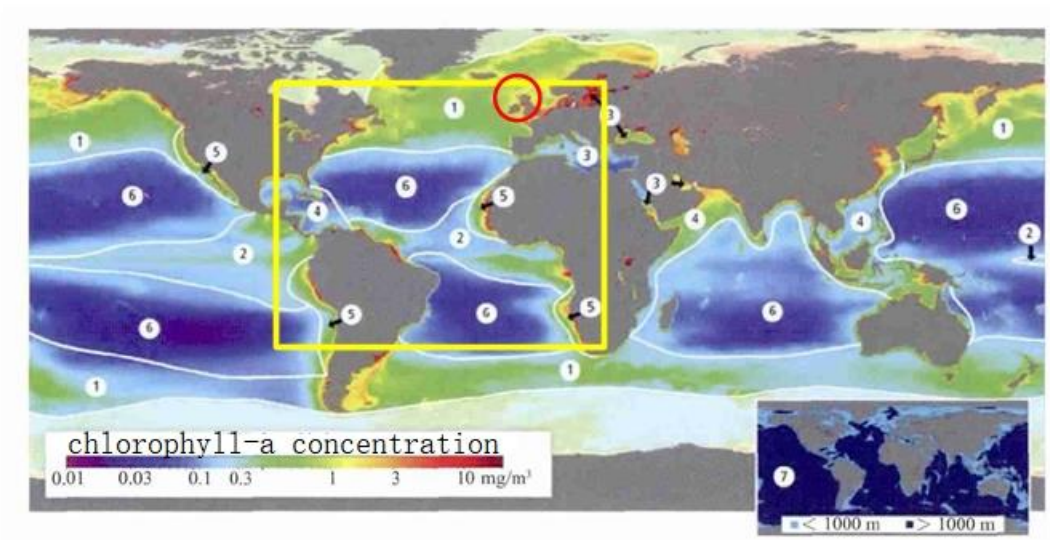

FIGURE 1. Division map of marine area[1]

It can be seen from Figure 1 that the migration destinations of herring and mackerel may be eight areas in the figure, i.e. area 1, area 2, area 3, area 4, northern Africa area 5, southern Africa area 5, northern Atlantic area 6 and southern Atlantic area 6.

In order to better model the time series of ocean temperature change trend, we first need to process the existing ocean temperature change data[2]. First, according to GPS satellite map

[1] Picture is from reference [1].

positioning, we determine the longitude and latitude range of the above eight sea areas, randomly select five points in each sea area, and then calculate the average water temperature of five points in each area through the observation data set of fishery statistics for the International Council for the Exploration of the Sea (ICES), so as to represent the water temperature of the sea area in the current year, so as to calculate The water temperature change data of each sea area in the first 30 years are shown as follows:

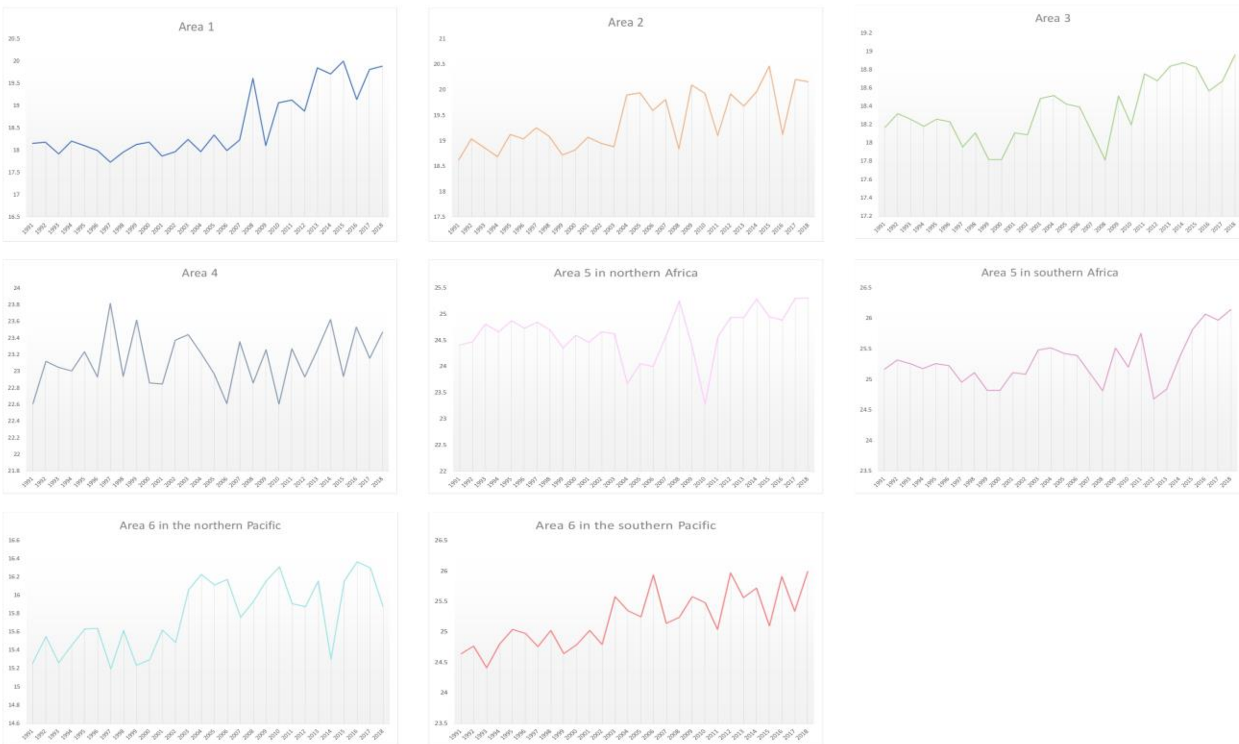

FIGURE 2. Water temperature changes in the first 30 years of eight sea areas

4.2 Model building

From Figure 2, we can see that the change of ocean temperature has certain periodicity, taking 2-3 years as a cycle, so we can judge that the change trend of ocean temperature has seasonal fluctuation. We make a time series model with time splitting for the ocean temperature of these eight regions.

Considering that the ocean temperature change sequence is a time significant sequence, that is, dynamic data, and we often build a mathematical model through curve fitting and parameter estimation according to the time series data obtained from systematic observation, that is, to build a time series. Time series are also used in meteorological forecast, hydrological forecast, ecological balance and oceanography. Because the time series can be divided into four categories: long-term trend, seasonal, cyclical and random.

[2] Ocean temperature data from ICES. Data download can visit http://www.ices.dk/marine-data/guidelines-and-policy/pages/ices-data-policy.aspx

Time series analysis is not to explain the behavior of the observed time series through other variables, but to build a model which can reflect the past behavior of the time series through the characteristics of the data itself, so as to help us predict the future behavior.

In this paper, a differential autoregressive moving average model is established to predict the sea water temperature changes in the next 50 years based on the data of water temperature changes in the past 30 years.

The difference autoregressive moving average model is tested for stationarity after obtaining the observation value sequence, and then tested by difference operation, and then tested by white noise test and fitting with ARMA model, finally the prediction results are obtained. The model flow chart is as follows:

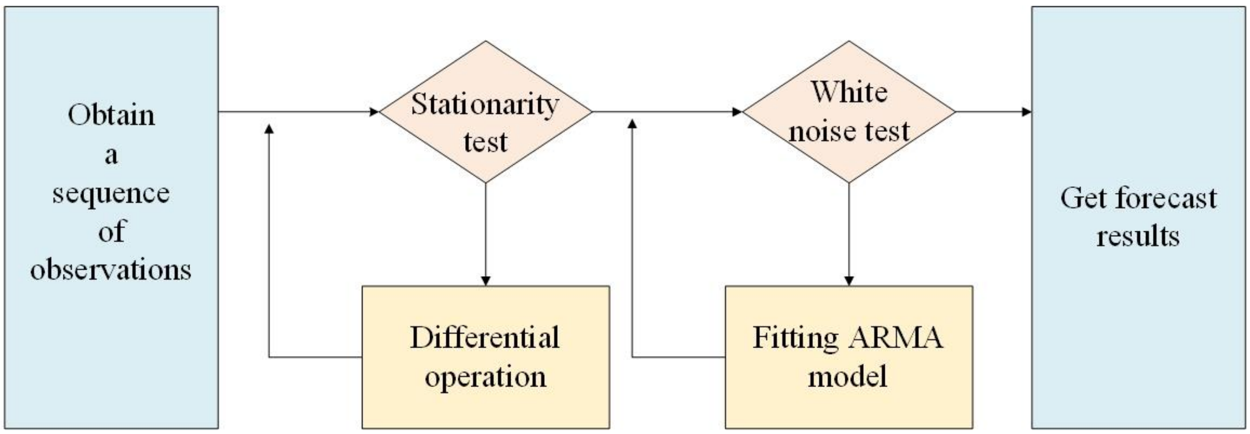

Figure 3. Model structure diagram

The expression of ARIMA (p , q , d) model is:

$$\phi(B)k^d\tilde{X}_t = \theta(B)a_t$$

While,

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$$
$$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$$

$$k = 1 - B$$

Where: $\{\tilde{X}_t\}(t = 1, 2, 3, \cdots)$ is a time series; $\{a_t\}$ is a normal white noise process with a mean value of 0 and a variance of σ_a^2; $\phi_i = (i = 1, 2, \cdots, p)$ and $\theta_j (j = 1, 2, \cdots, q)$ is the coefficient to be estimated of the model; B is a backward difference operator.

4.3 Results and analysis

Based on the sea water temperature data of the previous 30 years, we predict the water temperature of each sea area in the next 50 years. The results are as follows:

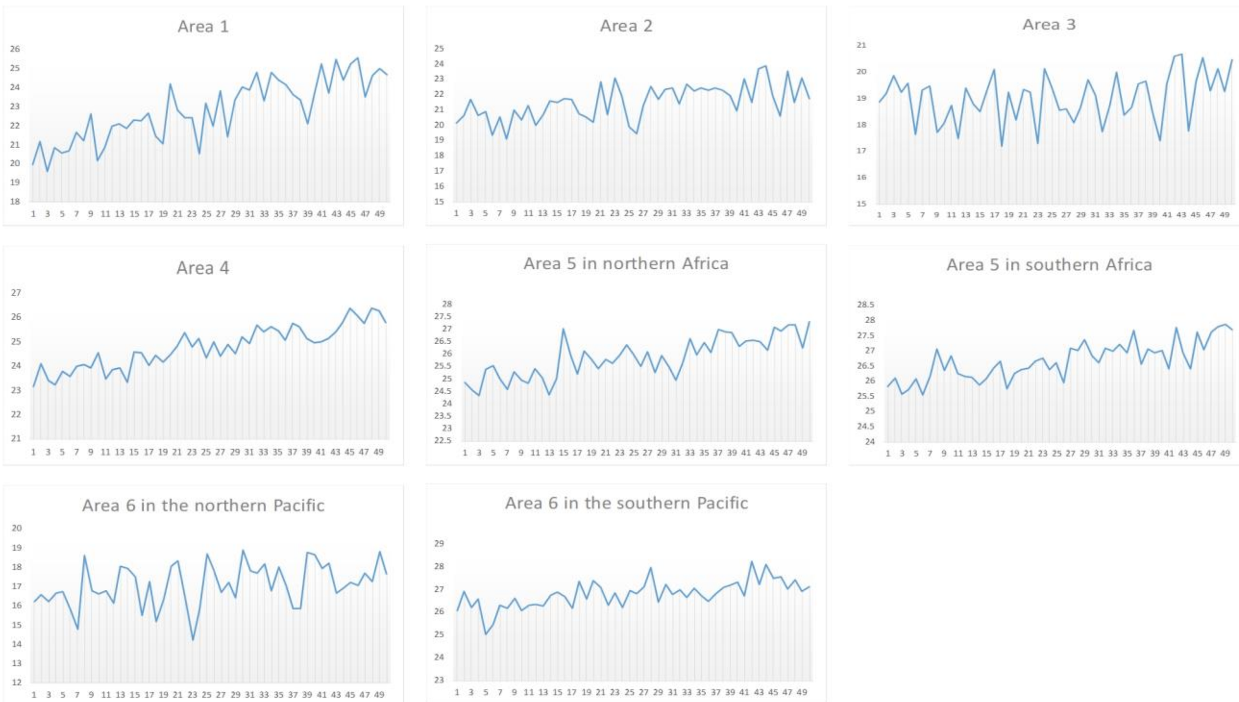

Figure 4. Water temperature of each sea area in the next 50 years and migration path of herring and mackerel

We checked the historical data of the activities of mackerel and mackerel in the Pacific Ocean. We found that mackerel and herring often live in the water temperature of 15-17 ℃, but the quality of their habitats is not only related to the temperature, but also to many other situations. We can't judge the most likely location of mackerel and herring in the next 50 years only based on the temperature trend.

So we checked the relevant literature. According to the literature climate change and global oceans: Interpretation of impact, adaptation and vulnerability assessment [16], these areas are not only changing the water temperature, but also many other environmental factors:

Under the background of climate change, the increase of organic carbon stimulates the level of microbial oxygen consumption in some sea areas of region 1, 2 and 5, which results in the most obvious decrease of dissolved oxygen concentration in these areas.

Region 1 (the location of North Atlantic Fisheries in Scotland) has a significant response to ocean warming. Among them, the biggest change is the phenological characteristics, geographical distribution and abundance of plankton and the change of fish population in the sea area since the end of 1970s, especially the migration speed of fish and zooplankton in this sub area is the fastest. That is to say, herring and mackerel are one of the most obvious migration populations.

During the period from 1950 to 2009, the equatorial upwelling system in region 2 (equatorial upwelling system), especially in Africa and South America, has warmed, and the surface temperature of the equatorial upwelling system in the Pacific Ocean and the Atlantic Ocean has risen [2].

With the global warming, marine ecosystem, biological population and fishery have significant uncertainty for the risk caused by upwelling change. For the effects of ocean warming and acidification Because of the characteristics of high CO2 concentration and low pH value of upwelling water, region 5 (upwelling ecosystem on the eastern boundary of the ocean) and region 2 (upwelling system on the equator) are also potentially vulnerable; moreover, due to the decrease of oxygen content and aragonite saturation, the risk of nearshore ecosystem and fishery in region 5 (upwelling ecosystem on the eastern boundary of the ocean) will be increased.[7]

There have been significant warming phenomena in area 4 (most of the nearshore and offshore systems) and area 3 (semi closed sea) since 1950 and 1982, respectively. Among them, the warming of the Mediterranean results in the invasion of tropical species from the Atlantic Ocean and the Indian Ocean, while the warming of some sea areas also increases the risk of sea stratification, hinders the exchange of sea air, and forms the low oxygen area, especially in area 3 (Baltic Sea and Black Sea).

Among them, there is a significant warming in the coastal area of region 4 (Mexico), and the pollution in some areas also has an impact on the expansion of low oxygen areas, which may affect the ecosystem and Fisheries in these areas. In 1998-2010, the concentration of chlorophyll in area 6 (the subtropical vortex sea area of the North Atlantic) decreased by 11% [17], which was higher than its internal seasonal and interannual variability.

- Area 1: the water temperature rises and the dissolved oxygen content drops, which is not suitable for herring and mackerel to survive. They will move away quickly, which is unlikely to occur;
- Area 2: the water temperature is obviously increased, and the dissolved oxygen content is decreased, which is not suitable for herring and mackerel to survive, and they are unlikely to occur;
- Area 3: the invasion of species is serious, there are many low oxygen areas, which are not suitable for the survival of mackerel and herring, and the possibility of their occurrence is very small;
- Area 4: water temperature rises significantly, local waters are polluted, not suitable for herring and mackerel to survive, and they are less likely to occur;
- Area 5: the water temperature rises obviously, with potential vulnerability, which is not suitable for herring and mackerel to survive, and they are less likely to occur;

- Area 6: Coral turns white and water temperature rises, but the range of change is the slowest. It belongs to the water temperature suitable for mackerel and herring, which are more likely to occur.

According to the distribution of mackerel and herring in the North Pacific Ocean of England, as the water temperature in their original habitat (area 1) rises, they must move south. According to the data we predict for the next 50 years, it is found that herring and mackerel are most likely to occur in the middle of region 6, namely the high latitude spring algal bloom system region in the northern Pacific Ocean. The migration sites of mackerel and mackerel are described by latitude and longitude, i.e. 30-50 degrees north latitude and 30-50 degrees west longitude (the central area of the North Pacific Ocean). Figure 4 shows the migration direction and most likely location of mackerel and mackerel.

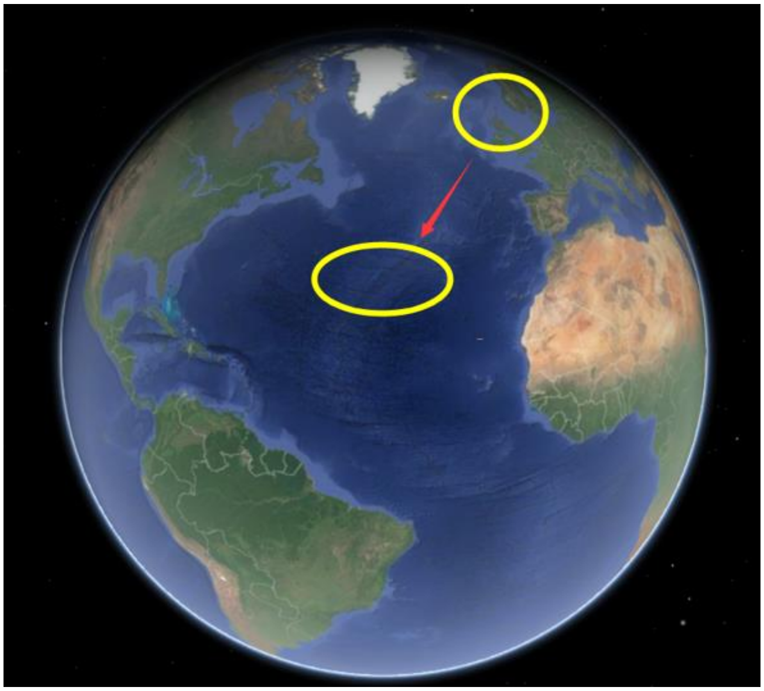

Figure 5. **Schematic diagram of migration track and location**

5. Benefit Evaluation Model of Small Fishery Company

5.1 Model building

For any sea area, the change of fish population is affected by three factors: natural growth, population migration and human capture, which can be expressed as follows:

$$X(t) = R_1 + R_2 + R_3 + \alpha_0$$

It represents the number of fish in any place at time, R_1, R_2, R_3, α_0 which respectively represents the natural growth of fish, the net increase of population migration, the number of human catches, and the number of fish.

1. When $R_2 > 0$, it means that the number of fish moving in and out of this sea area is greater than that of moving out;

2. When $R_2 < 0$, it was said that the number of fish moving out was greater than the number of fish moving in;

3. When $R_2 = 0$, it was said that the number of mackerel and herring moving in and out of the sea area was the same.

Considering only natural growth, **the natural increment of fish** can be obtained from logistic equation:

$$R_1 = \int_{t_0}^{t} v_1 \times X(t) \times (1 - \frac{X(t)}{k}) dt$$

Among them, k is environmental capacity, v_1 is the natural growth rate. The environmental temperature mainly affects the population number by affecting the **birth rate**[3] and **mortality** of the population:

$$v_1 = (r_1 - r_2) \times \alpha_1$$

Among them r_1, r_2, α_1 are birth rate, death rate and temperature influencing factors. For fish of different populations, if the temperature may only inhibit their birth or stimulate their death for a certain population, then:

$$\alpha_1 = (1 - \left|\frac{t}{t-T}\right|)$$

When temperature has a negative effect on birth and death:

$$\alpha_1 = (1 - \left|\frac{t}{t-T}\right|)^2$$

When the loss of fish number caused by migration is not included, the migration amount of fish group can be obtained by logistic model, which is as follows:

[3] Mackerel and herring mortality data from NOAA Fisheries. Data download can visit https://search.noaa.gov/search?utf8=%E2%9C%93&affiliate=www.fisheries.noaa.gov&sort_by=&query=birth+rate&commit=Search

$$R_2 = \int_{t_0}^{t} \alpha_2 \times (Y(t) - X(t))dt$$

Where α_2 is the migration diffusion coefficient.

When the migration diffusion coefficient is positive, it means that the fish population in this area has an overall migration trend in this period; when it is negative, it means the migration trend. Considering that the migration diffusion coefficient is related to the distance between the two places and the natural growth rate, that is, the farther the distance is, the smaller the migration diffusion coefficient is; the larger the natural growth rate is, the larger the migration diffusion coefficient is. It can be concluded that:

$$\alpha_2 = \pm\alpha_3 \times \frac{\ln(1+v_1)}{dist}$$

Where α_3 is the migration coefficient.

Profit per vessel at sea:

$$w_1 = p \times \alpha_3 \times X(t) - dist \times c - \frac{dist}{v_2} \times n \times \alpha_4$$

Among them, p is the average price of mackerel and herring, α_3 is the capture coefficient, $dist$ is the distance to sea of the vessel, c is the average oil cost per nautical mile of the vessel, v_2 is the average daily speed of the vessel, $\frac{dist}{v_2} \times \alpha_4$ represents the days to sea, n is other costs, including the daily wages of the crew, the daily consumption cost of goods storage or use, etc.

To sum up, the basis for judging the profitability of small-scale fishery companies is:

- When w reaches the maximum value, it is the best case;
- When w reaches the minimum value, it is the worst case;
- When w is equal to 0, there is no gain for the company's fishing at sea.

5.2 Example analysis

According to the survey of relevant data [13~15], the growth rate of mackerel and herring is about 0.256-0.381 per year. For the convenience of calculation, we take the growth rate as 0.3per year. The average price of herring in recent years is 382 pounds per ton, and that of mackerel in recent years is 1018 pounds per ton[4]. Therefore, the average price of herring and mackerel is 700 pounds per ton. Ships can catch 15 tons of fish every time they go out to sea. We assume that the

[4] The price of herring and mackerel per ton. Data download can visit https://www.gov.scot/

total number of herring and mackerel in this area is 300000 tons. The annual catch is 0.35 of the population. The ship consumes 10 liters of oil at 100 nautical miles. An average liter of oil is £ 0.7.[5]

After calculation, we get the final result:

(1) **The worst case** is that when the distance between fish groups reaches 362 nautical miles, the income of each fishing boat is 3972 pounds;

(2) **The best case** is that when the distance between fish groups reaches 589 nautical miles, the income of each fishing boat is 6293 pounds;

(3) When the distance between fish groups reaches 973 nautical miles, the fishing boat will get nothing at sea, and the elapsed time is **19 years**.

Table2. Corresponding result table

Profit (£ / vessel)	Migration distance (nautical miles)	Time (year)
3972	362	5
6293	589	8
0	973	19

5.3 Sensitivity analysis

We analyzed the sensitivity of temperature, time and migration distance:

[5] The price of British diesel can be inquired in https://www.confused.com/on-the-road/petrol-prices

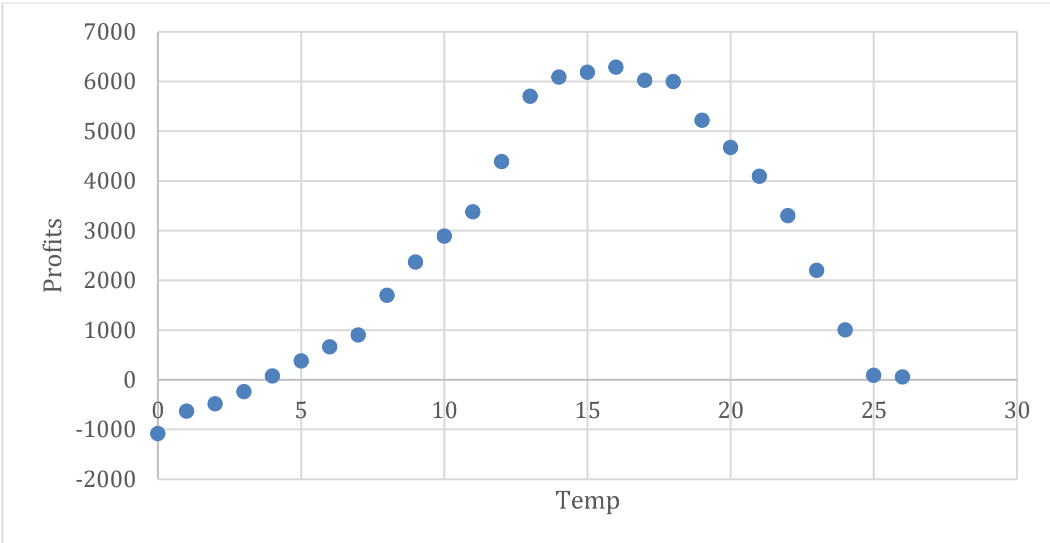

Figure 6. **Sensitivity analysis of migration distance factor**

Figure 5 shows the impact of sea temperature on corporate income. It can be seen from the figure that when the sea temperature is 16 ° C, the enterprise's income is the largest. When the sea temperature is lower than 16 ° C, and the lower the temperature is, the smaller the enterprise's income is, or even the loss may be; when the sea temperature is higher than 17 ° C, and the higher the temperature is, the smaller the enterprise's income is.

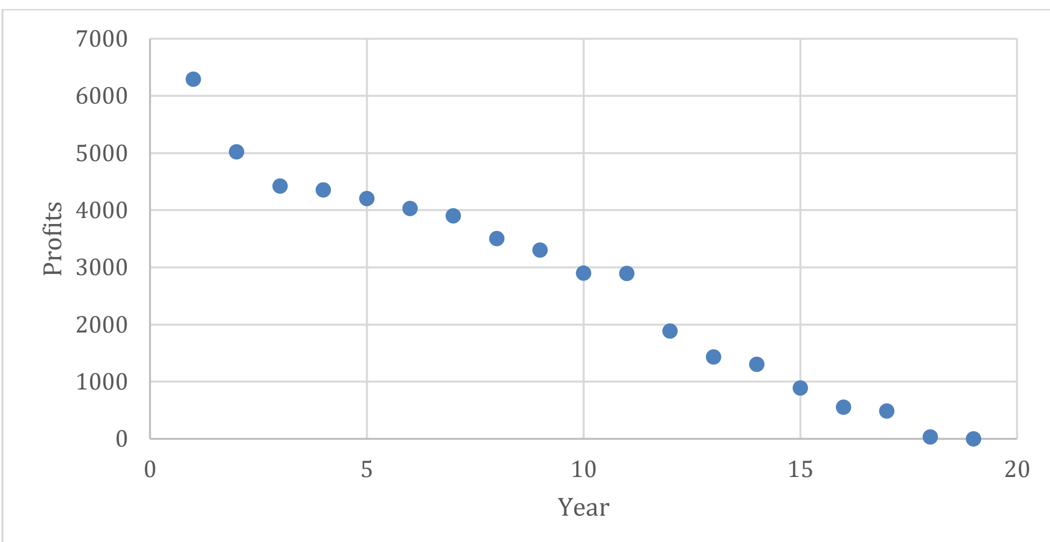

Figure 7. **Sensitivity analysis of time factor**

Figure 6 shows the impact of migration time factor on corporate earnings. According to the above analysis, the longer the migration time is, the smaller the enterprise income is. The higher the cost of going to sea. After 19 years, the fishing boats will get nothing out of the sea.

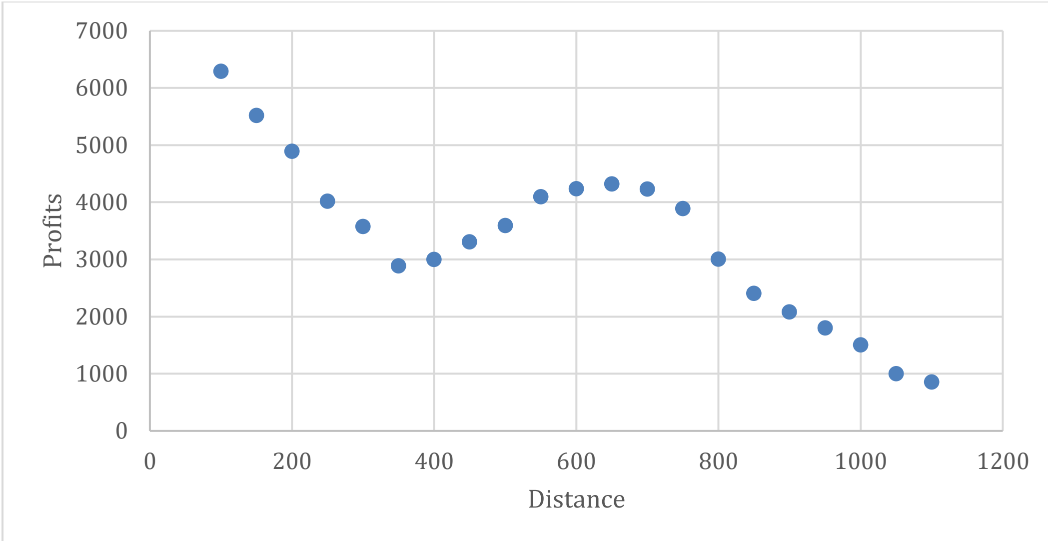

Figure 8. Sensitivity analysis of migration distance factor

Figure 7 shows the impact of migration distance factor on corporate income. With the increase of migration distance, the enterprise income first decreases and then increases. After reaching the maximum, it shows a downward trend.

6. OPTIMIZATION MODEL

6.1 Establishment of model

In order to judge whether these small-scale fishery companies should change their business model, we optimize the model and put forward three strategies. By calculating the actual income of each strategy and comparing it with the original income, we can decide whether these companies should adopt strategies or not. Three strategies are proposed as follows:

1. Transfer part of the fishery company's assets from the existing location of the Scottish port to a place closer to the migration of both kinds of fish;

2. A certain proportion of small fishing boats are used;

3. Update the equipment and set up the production line to produce canned fish.

We define the average daily income of small fishing companies as the sum of the average daily income of small boats and large boats, less human resources, less fuel consumption, less production line facilities, less moving expenses. Set the daily average income of the enterprise as ADR, the carrying capacity of the small boat and the big boat as w_1, w_2 respectively, the number of the small boat and the big boat as num_a, num_b respectively, the market price as mp, the additional output value as av, the cost per person as p, the number of the crew of the small boat and the big boat as n_a, n_b respectively, the price of fuel oil as p_o, the fuel consumption coefficient as fcc, the voyage distance as s, the power of the small boat and the big boat as n_a, n_b respectively. The income of small boat and large boat is E_a, E_b respectively, the time is t_a, t_b respectively, the cost of updating the equipment is C_e, the time used by the equipment is T_e, the enterprise is used to purchase small vessels, the amount of large vessels is $cost$, it is the fixed value, and the moving expense is E_m:

$$ADR = \frac{E_a}{T_a} - \frac{E_b}{T_b} - \frac{C_e}{T_e} - E_m$$

While,

$$E_a = (num_a \times w_a) \times (mp + av) - num_a \times p \times n_a - p_o \times fcc \times s \times P_a \times num_a$$
$$E_a = (num_b \times w_b) \times (mp + av) - num_b \times p \times n_b - p_o \times fcc \times s \times P_b \times num_b$$

6.2 Linear programming

According to the relevant data, the load of small ocean fishing boats is 1 million 200 thousand, the power is 300 kilowatts, the price is £ 329196.2, and the number of crew members is 8; the load of large ocean fishing boats is 4 million 800 thousand tons, the power is 1500 kilowatts, the price is £ 877856.5, the number of crew members is 20, the market price is £ 700 per million tons, the added value is £ 3500 per million tons, and the price of fuel oil is £ 543.2 per tons, the fuel consumption coefficient is 0.6642 tons per kilowatt.

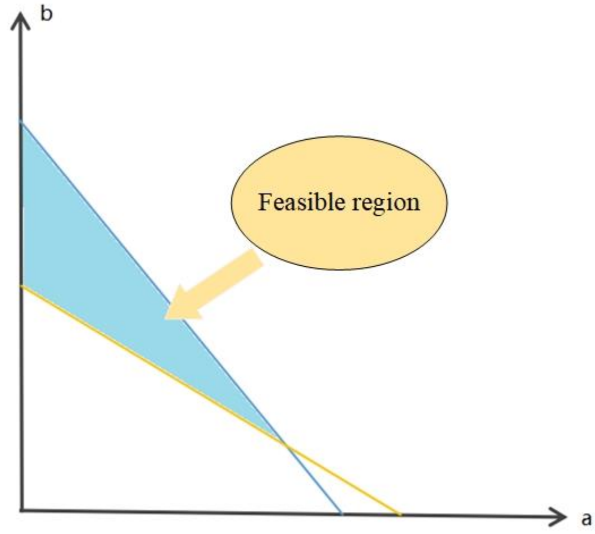

Figure 9. Linear programming diagram

Through calculation, we can get:

$$a = \frac{\cos t^2 - 2.7999\times10^9}{2.2461\times10^9 - 1.1877\times10^9 \times s \times \cos t - 6.3346\times10^9 \times s}$$

And for each small fishery company, the amount of money each small fishery company uses to purchase asthma and large ships is different. The number of large ocean going fishing vessels is:

$$b = \frac{\cos t - \dfrac{\cos t^2 - 2.7999\times10^9}{2.2461\times10^9 - 1.1877\times10^9 \times s \times \cos t - 6.3346\times10^9 \times s}}{877856.5}$$

The enterprise can get the highest daily average income. In addition, after industrial upgrading, the daily average income of fishing companies that can produce additional output value increases with time.

6.3 Results

By calculation, we get the following results：

(1) Replacing fishing with small boats will increase the income by 385 pounds per catch;

(2) Transfer part of the company's assets to the position will increase the income by 556 pounds per catch;

(3) Product transformation, construction of fish canning production line will increase the income by 987 pounds per catch.

Table 3. **Profit of three strategies**

Measures	Profit (pounds per catch)
Replacing fishing with small boats	385 pounds
Transfer part of the company's assets to the position	556 pounds
Product transformation, construction of fish canning production line	987 pounds

6.4 Proposal restrictions

According to the International Convention on the law of the sea, if a foreign ship carries out any fishing activities in the coastal area, its adoption shall be deemed to damage the peace, good order or safety of the coastal state. Therefore, when some fish groups migrate to the sea areas of other countries, considering the Territorial Sea sovereignty of other countries, the fishery of the enterprise cannot be moved to the territorial sea of another country, that is to say, the migration scope of the enterprise is limited to a certain extent and can only be moved at home. When the fish migrate to other countries, the enterprise can not follow the migration direction of the fish to move the company, the moving cost in the proposal changes, the fishing range of the enterprise is limited, and the fishing quantity will be reduced. Therefore, the model in the enterprise income should limit the distance s, that is, when s < the distance between the current fishing range of the company and the sea area of other countries, we modify model 3 as follows:

$$a=\frac{\cos t^{2}-2.7999\times10^{9}+6.3346\times10^{9}\times a\times s}{2.2461\times10^{9}-1.1877\times10^{9}\times s\times\cos t}(s<MAX\_d)$$

$$\mathrm{b}=\frac{\cos t-\dfrac{\cos t^{2}-2.7999\times10^{9}+6.3346\times10^{9}\times a\times s}{2.2461\times10^{9}-1.1877\times10^{9}\times s\times\cos t}}{877856.5}(s<MAX\_d)$$

Where *Max_D* represents the maximum distance that the company can change under the legal restrictions.

7. AN ARTICLE FOR THE MAGAZINE

Fishery Industry, First Victim

In 1998, the First World Climate Conference held in Geneva, the first proposed "Climate Change" this concept. Following the release of five intergovernmental panel on Climate Change (IPCC) climate change assessment reports in 1990,1995,2001,2007 and 2013, and the signing of a series of climate change treaty agreements, the issue of global climate change has attracted the attention of the international community and become the focus of the global environment. Almost all parts of the world have experienced warming in recent decades. The report of the first working group of the 5th assessment of the IPCC shows that the increase of greenhouse gas concentration, the warming of air temperature, the melting of glaciers, the thermal expansion of sea water and the inflow of large amounts of glacial meltwater cause sea level rise, extreme weather, etc. , have a range of impacts on humans and natural ecosystems. Fishery is an industry based on all kinds of water environment, especially marine fishery. Its natural characteristics of water environment are directly affected by climate change, and the impact is significant. The impact of climate change on the State of marine fisheries can not be ignored.

Specific manifestations of the impact of climate change on marine fisheries:

According to the data of the global surface thermometer, the global climate shows a significant change with warming as the main feature, the current evidence from observations of global average temperature and sea temperature increases, widespread snow and ice melt, and global average sea level rise support this view. The oceans have absorbed and are absorbing 80% of the heat added to the climate system. This warming causes sea water to expand, helping to raise sea levels. Satellite data show that the rate increased between 1993 and 2006 to about 3.3 mm, with sea level rise estimated at 0.17 cm throughout the 20th century.

A. Sea level rise

Sea-level rise disrupts the ecosystems of the Delta, reduces the area of mariculture, reduces freshwater fish catches, damages coastal ecosystems such as mangroves to varying degrees or to a considerable extent, and exposes fisheries to the sea, the risk of damage from waves and storm surges increases. At the same time, rising sea levels have made extreme ocean disasters, such as tsunamis and storm surges, more likely to occur and cause more damage. There is evidence that the extent of storm surge damage is directly related to changes in sea level.

B. Coral bleaching

Coral bleaching is caused by rising ocean temperatures. Bleaching is a disaster for marine life, unable to provide shelter for colorful fish populations, which means the loss of marine rainforests, the destruction of biodiversity, and threats to marine ecosystems.

C. Increase in sea temperature

Tropical oceans are warming as a result of global warming. SST changes will affect the life cycle of fish such as growth, feeding, migration, spawning, death and the population changes, and ultimately affect the production and exploitation of fishery resources. When the water temperature rises 1 °C and 2 °C, the Yellow Sea area will reduce the yellow croaker production by 3% ~ 6%, the east China sea area by 5% ~ 12%, and the south China Sea area by 20%.

D. Increased acidity of sea water

Much of the CO2 is absorbed by the ocean, and the Ph of the ocean has dropped by 0.1 units. If the ocean becomes increasingly acidic, experts warn, it could damage the entire ocean ecosystem, slowing the growth and shrinking populations of corals, shellfish and marine organisms with calcium in their bones, the number of fish that feed on these sea creatures will also decrease or disappear.

We must be fully aware of the importance and severity of the impact of global climate change on fisheries. The impacts of global climate change on fisheries are profound and long-term. It is important to understand the impacts of climate change on fisheries and the vulnerability of fisheries, but it is even more important and necessary to respond accordingly.

To that end, we've come up with a solution for fisheries to deal with climate change:

1. The impacts of global climate change on marine organisms and marine ecosystems can not be ignored. It is necessary to understand the impacts of climate change on the development of marine fisheries.

2. The social response of fisheries to climate change also includes reforming existing development and lifestyles to make them greener and more frugal, minimizing anthropogenic interference with the natural world and mitigating the pace of climate change.

3. Climate change is causing the loss of large amounts of marine life, so overfishing should be avoided in order to rebuild declining marine populations.

4. Through strengthening the construction of fishery infrastructure and adjusting the layout of fishery production, the advantageous fishery industry zone will be established, and the ability of fishery to adapt to climate change will be enhanced.

So let us act together to save our first victims and achieve the sustainable development of marine fisheries in the context of climate change.

8. STRENGTHS AND WEAKNESSES

Strengths

- This paper makes a pre-analysis of the historical data of the ocean, in order to initially reveal the trend law of global ocean temperature change, and then model the time series, and predict the more reliable results.

- This paper takes into account the temperature, migration distance, market influence and other factors, and constructs a stock system of stocks that combine natural growth, natural migration and human fishing to interact with each other, and describes the mathematical expression of fish stocks.

- In view of the business strategy of enterprises, aiming at the maximum economic profit in a harvest cycle, this paper discusses the comprehensive decision-making model of combination of different, types of boats, relocation of enterprises.

- Industrial upgrading three coupling, and obtains a specific expression through linear planning, which can help enterprises with different investment funds, different sizes and different needs to make the most suitable decisions for them. It has theoretical guidance on actual production.

Weaknesses

- In model one, due to time, we only passed the sea temperature forecast for the first 30 years for each region in the next 50 years, without taking into account the impact of future regional economic development on the local sea temperature.

- When considering the cost of fishing, only labor costs and fuel consumption costs, not consideration of fishing vessel refurbishment, fishing nets and other equipment costs9. References.

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