International Journal of Innovation in Science and Mathematics
Volume 8, Issue 3, ISSN (Online): 2347–9051

The Northward Migration of Herring and Mackerel

Yilong Zhou [1] and Hui Xu [1*]
[1] Department of mathematics, school of science, yanbian university, Yanji 133002 P.R. China.
*Corresponding author email id: 920556141@qq.com

Date of publication (dd/mm/yyyy): 02/06/2020

***Abstract* – As global ocean temperatures rise, many sea creatures are migrating north to colder climes and disrupting the economies of fishing companies. This paper studied the variation of sea temperature in the north Atlantic and the distribution of herring and mackerel populations with sea temperature, and proposed a new business model for small fishing companies to reduce economic losses caused by ecological problems. Firstly, established seawater temperature point prediction model based on similarity divergence using the similarity analysis and prediction method, forecasted out the north Atlantic Ocean of seawater temperature distribution based on the model, pearson correlation coefficient is used to evaluate the forecast results. And the deviation correction is made to the forecast data. Based on the size and habits of herring and mackerel, and the swimming speed of the fish was calculated by building an elastomer model. Finally, we can obtain the living position of the two species in 50 years. Secondly, based on seawater temperature point prediction model, calculated in 50 years of arbitrary two adjacent years between the speed of temperature change, get the water temperature change speed threshold, determined the fish movement speed following water temperature, at the same time comparing similarity to ensure that data is reliable. The fishing scope is described in detail from the basic characteristics of fishing boats and port location. Based on the velocity threshold, the time required to migrate the population to a distance beyond the capture of a small fishery company in the best- and worst-case scenarios was predicted to be 4.7 and 2.1 years. In this paper, the mathematical analysis method is applied comprehensively, and the feasibility and effectiveness of the model are verified. Finally, extensive promotion suggestions are put forward.**

***Keywords* – Similarity Analysis and Prediction Method, Point-by-Point Prediction Model of Sea Water Temperature, Fish Elastomer Model, Benefit Function.**

I. Introduction

1.1. *Background*

1.1.1. *Overview of Sea Surface Temperature Over the North Atlantic*

As people burn fossil fuels, such as oil, coal, etc., or cutting down forests and burning it would produce large amounts of carbon dioxide, the greenhouse gas, these greenhouse gases to the high permeability of the visible light radiation from the sun, and the long wave radiation emitted on the earth are highly absorbent, can strongly absorb radiation in the infrared ground, causing the earth's temperature rises, the greenhouse effect. Rising sea temperatures caused by global warming. In terms of sea surface temperatures in the north Atlantic, the colder the sea is from the North Pole.

1.1.2. *Why Do Fish Migrate*

Both mackerel and herring are cold-water fish. Cold-water fish cold-water fish require lower water temperatures to live normally. High or low temperatures can cause loss of appetite, slow growth, or even stop feeding, and death. So the fish have to migrate to the right waters [1].

1.1.3. *Fisheries*

Fishing companies mainly catch mackerel and herring, so the location of mackerel and herring is the premise and key to fishing. Being able to predict the right fishing grounds can reduce the manpower and resources needed to find fish at sea.

1.2. *Problem Restatement*

Because of temperature changes, the movement of mackerel and herring can disrupt the way fishing companies operate.

1. Establish a mathematical model to determine the most likely location of the two species of fish in the next 50 years.
2. Based on the change rate of sea water temperature, the model can predict the best case, the worst case and determine the new position.

1.3. *The Basic Theory*

Randomness and uncertainty are the two characteristics of seawater motion law. Even with abundant observational data, it is impossible to accurately describe the law of ocean motion. Therefore, it is necessary to introduce the method of probability theory and mathematical statistics, and use the method of probability statistics to predict the change of sea water temperature in the future. This is the method of statistical prediction. Statistical prediction method is an important method to analyze and study the random change process of seawater temperature [2].

Similarity analysis and prediction [3] is to use the law of sample evolution in the early stage to select similar cases from historical samples according to a certain similarity metric. After certain processing, the change trend of similar cases in the later stage can be used as the prediction of the current sample later stage. In this paper, a point-to-point prediction model of sea water temperature based on similar degrees of separation is established by means of regression analysis and similarity analysis. Is the

$$T_d = \sum_{m=1}^{M} \{ [hh_{md} + E(m)] \times \frac{cc(M+1-m)}{\sum_{m=1}^{M} cc(m)} \} \tag{1}$$

II. Model Establishment and Solution

In order to predict the distribution position of shoals in 50 years, the temperature of the surrounding sea should be predicted first, and then the migration position of shoals should be analyzed according to the swimming characteristics of shoals.

2.1. *Temperature Prediction*

Due to the water temperature changes enough to cause the population to migrate. In order to determine the most likely location of the two fish in the next 50 years, the prediction of sea temperature in the next 50 years should be based on the relevant principles and methods of statistical prediction. In this paper, a point-by-point prediction model of sea water temperature based on similar divergence is established by using the method of similarity analysis and prediction, and Pearson correlation coefficient is used to evaluate the prediction results, thus a deviation correction method of forecast data is designed. Finally, the feasibility and validity of the model are proved.

2.1.1. *Similarity Analysis and Prediction*

The method of similarity analysis and prediction is to use the law of sample evolution in the early stage, according to a certain similarity metric, the similar cases are selected from the historical samples. After some processing, the change trend of the similar cases in the later period can be used as the prediction of the current sample later period. In this paper, based on the seawater temperature in the current selected time range, *n* different similar samples are selected from the historical data set of the north Atlantic sea area in the same time period, and the temperature data in the later period of similar samples are taken as the forecast data. The weight coefficient Bj is introduced to represent the weight coefficient of the j sample, whose value is between 0 and 1. The higher the similarity between samples is, the larger the weight coefficient is. The quality of forecast results is often related to similar criteria.

a. *Premise of Similar Prediction*

The temperature characteristics of sea water are studied deeply. Based on the SST data set provided by the National Oceanic and Atmospheric Administration, the characteristics and similarities of sea water temperature are analyzed, which showed that there are years with similar trend and sea water temperature in the historical data of sea water temperature, so similar prediction can be made.

b. *Similarity Criterion*

As the key of similarity prediction, similarity criterion plays an important role in prediction results. Therefore, this paper focuses on analyzing the common similarity criterion-haiming distance, similarity quantity and similarity divergence.

1. *Haiming Distance*

If H_{ij} is used to represent the hamming distance between two different samples, the expression is:

$$H_{ij} = \sum_{k=1}^{m} \left| x_{ik} - x_{jk} \right| \quad (2)$$

2. *Similarity Quantity*

Assuming that Rij is used to represent the similarity between two samples, the expression is:

$$R_{ij} = 1 - \frac{\sum_{k=1}^{m} \left| (x_{ik} - \bar{x}_i) - (x_{jk} - \bar{x}_j) \right|}{\sum_{k=1}^{m} \left(|x_{ik} - \bar{x}_i| + |x_{jk} - \bar{x}_j| \right)} \quad (3)$$

In the expression, iand j represent two different samples, x represents the specific value of the sample factor, m represents the number of factors contained in the sample, and k represents the serial number. The range of Rij is [0, 1], When it is 1, the two samples are most similar, the larger the Rij, the better, and Rij is often greater than 0.

3. *Similarity Divergence*

Similar divergence can reflect the difference between the "shape" and "value" of the sample. For example,H is used to represent a sample set,$H = (H_1, H_2 \ldots H_m)$, H represents the i sample in the sample set, $H_i = (h_{i1}, h_{i2} \ldots h_{id})$, h_{ik} represents the k value in the i sample, then the expression of similar divergence between the two samples is:

$$C_{ij} = \frac{S_{ij} + D_{ij}}{2} \tag{4}$$

$$S_{ij} = \frac{1}{M}\sum_{k=1}^{M}\left|h_{ij} - e_{ij}\right| \tag{5}$$

$$D_{ij} = \frac{1}{M}\sum_{k=1}^{M}\left|h_{ij}\right| \tag{6}$$

$$h_{ij} = h_{ik} - h_{jk} \tag{7}$$

$$e_{ij} = \frac{1}{M}\sum_{k=1}^{M} h_{ij} \tag{8}$$

c. *Performance Test of Similarity Criterion*

In order to compare the advantages and disadvantages of the three similarity criteria, four samples are given by taking Table3.1 as an example. Four samples in Table 3.1(each sample has five factors, with the mean values of 3, 4, 4 and 2.8, respectively) and the sample curve in Fig. 3.1 can be seen. Sample 1 is more similar to sample 2, and sample 3 is more similar to sample 4. According to the calculation, the hamming distance between sample 1 and samples 2, 3 and 4 is H12 = 5, H13 = 7, and H14 = 5, respectively. Ignoring the difference in form, which is obviously not true, however, the haiming distance between sample 3 and sample 1, 2 and 4 did not reveal the difference in shape. It can be seen that the haiming distance has no obvious effect on the shape difference of samples. The similarity quantity method also fails to calculate the similar curve accurately. According to the comparison between the curve display in the Fig. 3.1 and the actual calculation, the similarity divergence method can accurately reflect the comprehensive similarity of “shape” and “value” between two samples, which is an ideal similarity comparison method.

Compared the performance of the three criteria through simple sample data analysis, the results show that the similarity dispersion method is better in similarity selection. It is verified that the similarity divergence method has better judging ability of shape and value, and can be applied to the similar prediction of seawater temperature. It provides a criterion for the design of the forecast method.

Table 3.1. Sample number.

Sample number *i*	X_{i1}	X_{i2}	X_{i3}	X_{i4}	X_{i5}	$\overline{X_i}$	H_{1i}	C_{1i}	R_{1i}	H_{3i}	C_{3i}	R_{3i}
1	1	2	3	4	5	3	-	-	-	7	1.4	0.7
2	2	3	4	6	5	4	5	0.6	0.8	6	1.0	0.7
3	3	5	4	4	4	4	7	1.3	0.7	-	-	-
4	2	3	3	3	3	3	5	1.0	0.8	6	0.7	0.7

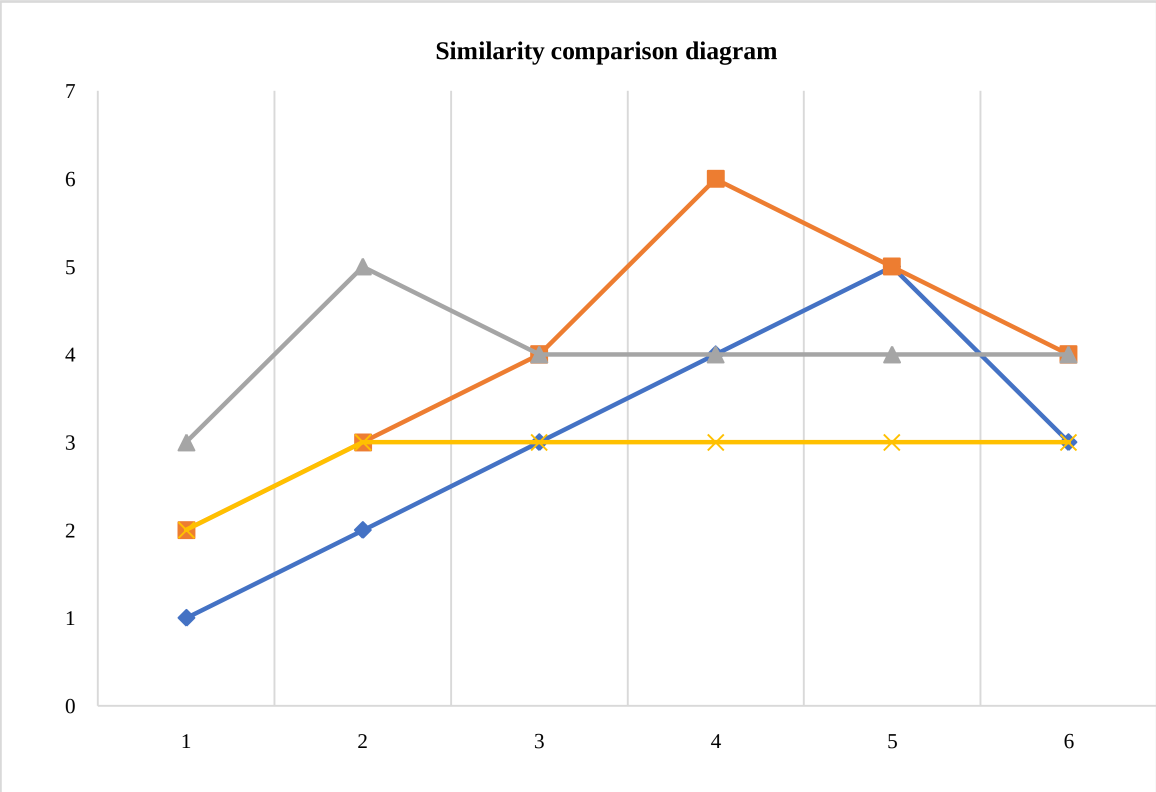


Fig. 3.1. Similarity comparison diagram.

2.1.2. *Point-by-Point Prediction Model of Seawater Temperature*

The basic idea of the design of the point-by-point seawater temperature prediction method is as follows: According to the forecast year and specific forecast quantity, the temperature samples with a certain length of time in the early period of each grid point forecast quantity are selected as the forecast factor, and the samples with the same length of time in the historical years are compared. Through the selection of similarity divergence, the samples HH, HH = (HH_1, HH_2…HH_i) = (hh_{i1}, hh_{i2}…hh_{id}) of similar arrangement of historical years are obtained and hh_{id} refers to the data on day d of the i year in the forecast period. At the same time, the similarity divergence set E(M) arranged by similarity between each year and the forecast year is obtained, and the similar divergence set CC(M) is taken as the weight to make the weighted average forecast of the set, and finally the temperature prediction expression (3-8) is obtained.

$$T_d = \sum_{m=1}^{M} \{[hh_{md} + E(m)] \times \frac{CC(M+1-m)}{\sum_{m=1}^{M} CC(m)}\} \tag{9}$$

In the expression, T_d represents the temperature forecast on day d of a grid point (0.25°×0.25°) in the prediction area, M represents the number of similar years, hh_{md} represents the temperature data on day d of the m similar year, since the smaller the similarity divergence is, the more similar it is, so $CC(M + 1 - m)$ means to choose the larger value as the weight of the year with high similarity. Temperatures at other points in the region will be predicted in the same way. In order to predict the seawater temperature 50 years from now, d is 18250, and then a similar year is selected point by point for prediction.

From the above prediction model, the temperature of sea water over 50 years can be obtained, as shown in the Fig. 3.2.

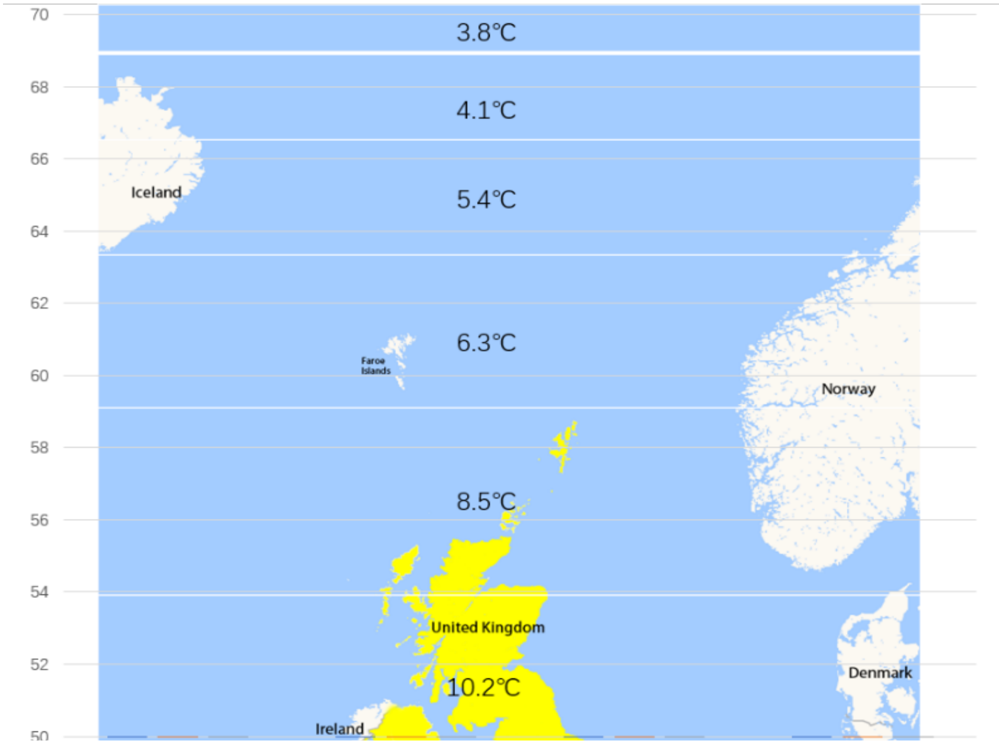


Fig. 3.2. Rough temperature distribution of sea water over 50 years.

2.1.3. *Assessment and Deviation Correction of Forecast Data*

After the forecast results are obtained, Pearson correlation coefficient r is used to evaluate and test the results. The calculation formula is shown in formula 3-9:

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2 \sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \tag{10}$$

In the expression, X_i represents the actual temperature on day i, X represents the average value of the actual temperature, Y_i represents the forecast temperature on day i, and Y represents the average value of the forecast temperature.

According to the deviation mean $e_{ij}(y)$ between the historical years and the forecast year data in the current selected time period, that is, the deviation value between the average temperature of the selected time period of the forecast year and the average temperature of the same time period of the historical year. Before the weighted forecast, the deviation valuee$_{ij}$ (y of the data of each historical year should be removed for deviation correction. The new deviation sequence E(i) can be obtained by arranging e_{ij} (y from large to small in accordance with the similarity. E(i) represents the deviation of the iyear, corresponding to HH_i. According to the magnitude of similarity divergence, the weighted set of historical data of similar years is averaged to obtain the forecast data, and thus the temperature prediction formula can be obtained, namely formula (3-10)

$$T = \sum_{m=1}^{5}\left\{[hh_m + E(m)] \cdot \frac{CC(6-m)}{\sum_{m=1}^{5} CC(m)}\right\} \tag{11}$$

After the above assessment and deviation correction, the temperature of sea water over the past 50 years can be obtained, as shown in the Fig. 3.3.

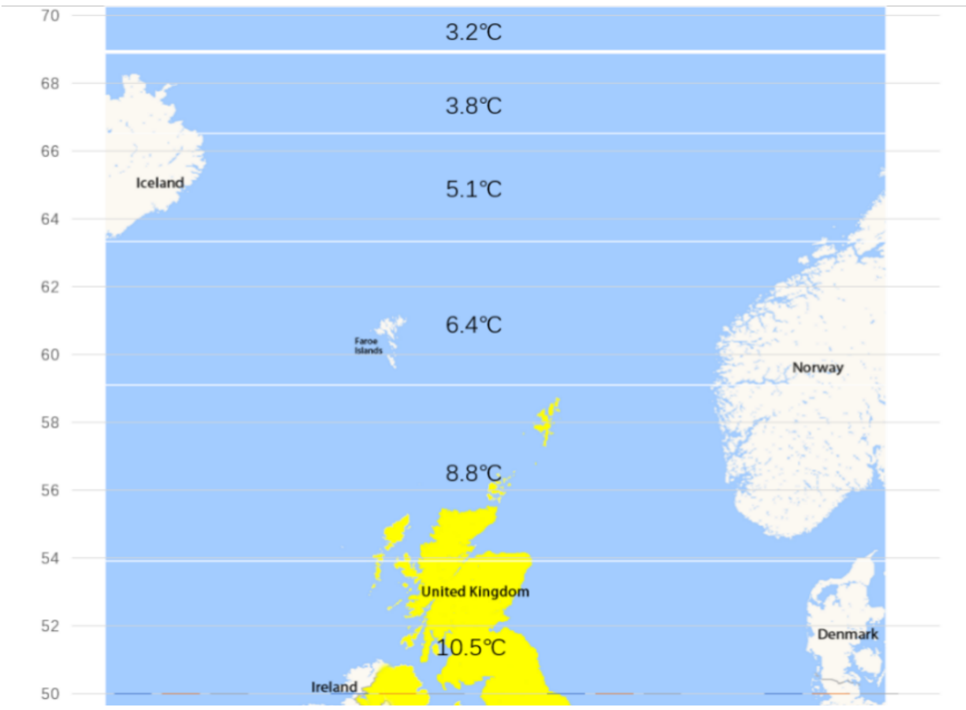


Fig. 3.3. Temperature distribution of sea water over 50 years.

2.2. *Characteristics of Herring and Mackerel*

The swimming speed and habits of fish determine the overall migration direction and speed of fish population. Herring and mackerel are quite different in habits, so they are studied respectively here.

2.2.1. *Basic Features*

The main characteristics of herring and mackerel are shown in Table 3.2.

Table 3.2. Basic features.

	Length	Tail fin	Migration distance	Food
Herring	20-40cm	Wedge	Short	Plankton, Tiddler
Mackerel	20-40cm	Spindle	Far	Plankton, Tiddler

According to the Table 3.2, it can be seen that herring and mackerel have similar body shape and different tail fins, as shown in the Fig. 3.3; All of them are social migratory fish, but the migratory distance of herring is short. At the same time, their food is similar, so the difference in migration direction and speed between herring and mackerel is mainly determined by the shape of the tail fin and migration distance [4].

(a) Herring (b) Mackerel

Fig. 3.3. The appearance of the fish.

2.2.2. *Fish Swimming Model*

In order to accurately analyze the swimming speed of the two kinds of fish [5], the elastic body model of the fish is established based on the swimming mechanism of the fish. The fish body is simplified into the shape shown in Fig3.4, with a total length of L. The fish body is divided into two parts: fish head and fish tail. L1 section of the fish head controls the swimming direction, while L2 section of the fish tail generates the swimming energy of the fish [6].

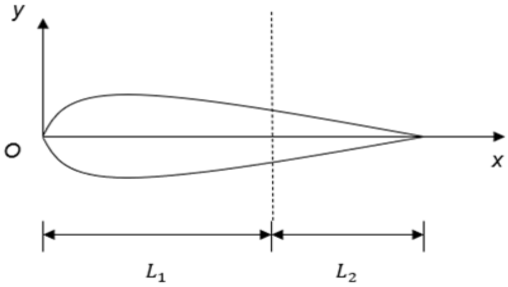
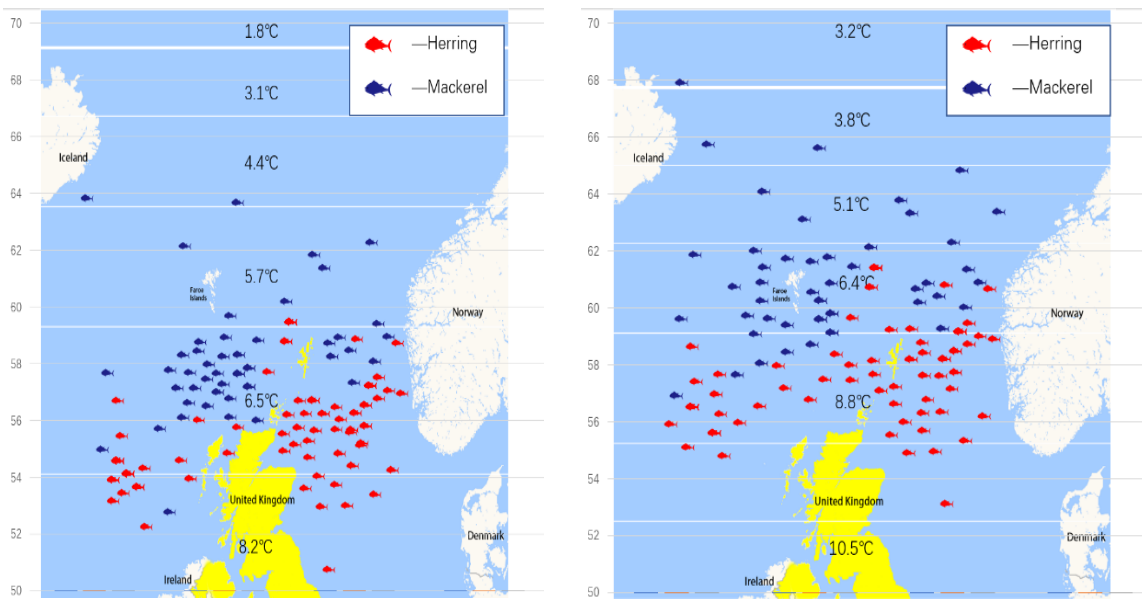


Fig. 3.4. The shape model of the fish.

Suppose the average density of the sea water in the north Atlantic is $p = 1.0 * 10^3 \mathrm{kg/m^3}$, and the moving viscosity coefficient is $v = 1.0 * 10^{-6} \mathrm{m^2/s}$. Herring and mackerel head shape is similar, so the elastic modulus of fish head L1 segment is the same, $E1 = 2.5 * 10^6 \mathrm{Pa}$, the main difference between the two types of fish is the length of the caudal fin and the elastic modulus.

The tail of herring is wedge-shaped. The normal fish model is selected. The length of tail is $L2 = 0.3l$, and the elastic modulus of L2 is $E2 = 2.5 * 10^6 \mathrm{Pa}$; the mackerel tail is short and spindle-shaped, so the short caudal fish model is selected. The length of the tail is $L2 = 0.24l$, and the elastic modulus is $E3 = 2.15 * 10^6 \mathrm{pa}$.

It can be calculated that the average speed of herring is $52.94 \mathrm{cm/s}$ and that of mackerel is $48.26\ \mathrm{cm/s}$. [7] Fig. 3.5 (a) shows the distribution of herring and mackerel at the current sea temperature. According to the predicted distribution of sea temperature 50 years from now, the distribution of the two kinds of fish 50 years from now is shown in the Fig. 3.5(b).



(a) Herring (b) Mackerel

Fig. 3.5. The appearance of the fish.

III. Conclusion

In this paper, the mathematical analysis method is applied comprehensively, and the feasibility and effectiveness of the model are verified. Finally, extensive promotion suggestions are put forward.

References

[1] Xue Liu. Adaptation of monthly temperature changes in the yellow sea to salmon farming [J]. Journal of ocean university of China (natural science edition), 2019, 49(03):36-46. (in Chinese with English abstract)
[2] Lili Xu. Effects of sea temperature and sea surface height in different water layers on tuna fisheries [J]. China water transport (second half month), 2008, 18 (12): 120-121+124.
[3] GuangqiangJi. Research and realization of seawater temperature similarity prediction method [D]. Harbin engineering university, 2018.
[4] Feng Xiong. Comparative experimental study on swimming ability of typical fish in songhua river basin [J]. Journal of three gorges university (natural science edition),2014,36(04):14-18.
[5] Dongwei Hao. Research on factors influencing the autonomous linear cruising speed of a bionic fish [J]. Journal of applied mathematics and mechanics, 2014, 35 (06): 674-683.
[6] Sunli Guo. GRNN based steady-state velocity modeling of robot fish [J]. Ordnance automation, 2010, 29(11): 82-84 + 96.
[7] Pin Wang. Discussion on the classification method of fish swimming speed [J]. Chinese academy of fisheries, 2010, 17(05): 1137-1146.

Author's Profile

First Author
Yilong Zhou, 1999, student study in the department of mathematics in Yanbian University (Yanji, China).
email id: 920556141@qq.com

Second Author
Hui Xu, (Corresponding author) Associate professor and master tutor of mathematics department, School of science, Yanbian University. Main research directions: mathematics education technology, mathematical modeling, intelligent algorithm (Yanji, China).