ISSN 2616-5872 Vol.3, Issue 1: 33-37, DOI: 10.25236/AJEE.2021.030107

Assessment of Fish Migration Routes in Scotland

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Abstract: *With the rapid rise of global ocean temperature, the living environment of mackerel and herring has changed and it forced them to move north. This phenomenon has seriously affected the future development of local small-scale fishery companies. In order to deal with this potential crisis, the paper build a Fish Temperature Spatial Migration model. In order to predict the migration routes of the two kinds of fish, we use the method of Stepwise Regression Prediction to predict the sea temperature changes in Scotland over the next 50 years. In addition, we use the method of Kriging Interpolation to establish a three-dimensional model of fish group and ocean temperature on the plane coordinate, and get the range of herring migration to 62-70N, 11.5-15W, and mackerel migration to 64-75N, and 12-16W in the next 50 years. All in all, the trend of fish migration to the north is realized.*

Keywords: *Kriging interpolation, stepwise regression analysis, migration routes, fishing years*

1. Introduction

With the rapid development of urbanization and industrialization, global warming has aroused people's deep concern. Oceans have a close relationship with climate change [1]. So in the context of global warming, such signals can also be found in the oceans. According to the study, the ocean surface temperature has experienced a rapid increase in the past 40 years, increasing by 0.11 ℃ about every 10 years [3].Although the warming trend of the ocean is slower than that of the land, the distribution of Marine species in the ocean shows a higher pole shift rate than terrestrial species because there are fewer physical barriers in the ocean [2].

The north Atlantic is no exception. According to the literature, sea surface temperatures in the north Atlantic have also changed a lot over the past 40 years. It is also clear that this will not stop for the next 50 years. The optimum temperature for herring is 4.6 °and the optimum temperature for mackerel is 7 °, which may lead to the migration of herring and mackerel, which play an important role in the fishing income of Scotland [3] [4].

2. 2d Extraction of Fishery Area

Since the migration route of the shoal exists in a two-dimensional plane, the location of shoal migration year by year in the next 50 years is coordinated [5].

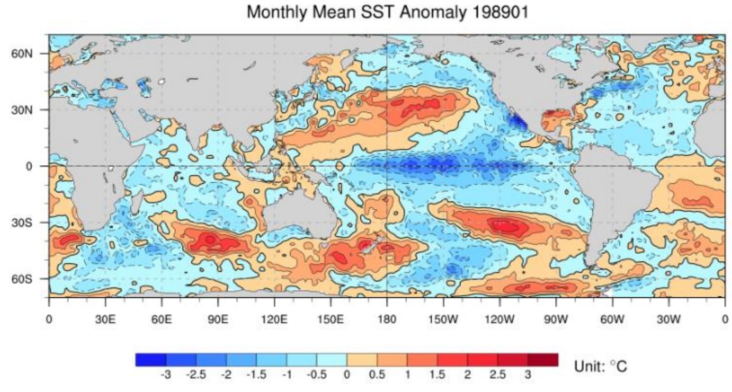

Figure 1: Sample global sea surface temperature in January 1989

The image was divided into 1000*10000 regions and the SST in the Scottish fishery area was extracted month by month and year by year. A 25 by 25 matrix is generated to represent this region evenly

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over a range of 51 to 63N and 4 to 16W.Due to the slow change of global temperature rise in a uniform month every year [3], in order to make the result change more obvious, the temperature was evenly divided into 300 equal parts within the temperature range of 14 grids (-3.5℃~3.5℃) to represent the temperature.

3. Prediction of SST in the Next 50 years

After the above cutting and numerical acquisition, 16 sample points were uniformly extracted from each matrix to generate a 4*4 matrix representing the temperature in a year and a month. Considering the complexity of data over 30 years and 12 months, we simplified the model. Considering that the production of herring and mackerel is mainly in the fishing season, the autumn fishing season in the UK is around October to December [2], and the range of the movement of fish in consecutive months adjacent to each other can be ignored, we made a one-by-one prediction of the sample points in November over the past 30 years.

Since the predicted year is larger than the existing data year, in order to reduce the trend error caused by the sharp change point of world temperature in the first 30 years, the gradual regression prediction is:

Let y be the dependent variable, x1, x2, …, xm is all the independent variables yi, xi1, xi2, …, xim (i=1, 2, …, n) are n sets of samples extracted independently. Let the significance level of the independent variables selected into the model be α_1, and the significance level of the excluded model be α_2, $0 < \alpha_1 \le \alpha_2 < 1$

(1) Calculate the dispersion matrix S

$$S = S_{m\times m} = \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1m} & s_{1y} \\ s_{21} & s_{22} & \cdots & s_{2m} & s_{2y} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ s_{m1} & s_{m2} & \cdots & s_{mm} & s_{my} \end{pmatrix} \tag{1}$$

(2) Gradually screen the independent variables

Step 1 screening:

Calculate the contribution of each variable:

$$V_j^{(1)} = \frac{s_{jy}^2}{s_{jj}} \tag{2}$$

Taking the maximum

$$V_{k_1}^{(1)} = \max_{1\le j\le m} V_j^{(1)} \tag{3}$$

Statistical test was conducted on whether the effect of x_{k_1} was significant:

$$F = \frac{V_{k_1}^{(1)}}{S_E^{(1)} \big/ (n-1-1)} \tag{4}$$

$$S_E^{(1)} = S_T - V_{k_1}^{(1)} \tag{5}$$

If $F \le F_{\alpha_1}(1, n-1-1)$, then all independent variables are independent of y, so the regression equation cannot be established;

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If $F > F_{\alpha_1}(1, n-1-1)$, select x_{k1} into the model and convert S into for the $S^{(1)}_{m\times(m+1)}$ second step of screening;

$$S^{(1)}_{m\times(m+1)} = \begin{pmatrix} s^{(1)}_{11} & s^{(1)}_{12} & \cdots & s^{(1)}_{1m} & s^{(1)}_{1y} \\ s^{(1)}_{21} & s^{(1)}_{22} & \cdots & s^{(1)}_{2m} & s^{(1)}_{2y} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ s^{(1)}_{k_1 1} & s^{(1)}_{k_1 2} & \cdots & s^{(1)}_{k_1 m} & s^{(1)}_{k_1 y} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ s^{(1)}_{m1} & s^{(1)}_{m2} & \cdots & s^{(1)}_{mm} & s^{(1)}_{my} \end{pmatrix} \tag{6}$$

Among them

$$s^{(1)}_{ij} = \begin{cases} \dfrac{s_{k_1 i}}{s_{k_1 k_1}} \text{ when } i = k_1, \ j \neq k_1 \\ s_{ij} - \dfrac{s_{ik_1} s_{k_1 j}}{s_{k_1 k_1}} \text{ when } i \neq k_1, \ j \neq k_1 \\ \dfrac{1}{s_{k_1 k_1}} \text{ when } i = j = k_1 \\ -\dfrac{s_{ik_1}}{s_{k_1 k_1}} \text{ when } i \neq k_1, \ j = k_1 \end{cases} \tag{7}$$

Step 2 screening:

① Calculate the contribution of each variable according to

$$S^{(1)}_{m\times(m+1)}$$

Contributions of independent variables outside the model:

$$V^{(2)}_i = \frac{\left(s_{iy}\right)^2}{s_{ii}} \tag{8}$$

Contributions of independent variables in the model:

$$V^{(2)}_{k_1} = \frac{\left(s^{(1)}_{k_1 y}\right)^2}{s^{(1)}_{k_1 k_1}} \tag{9}$$

② Take the maximum contribution of the independent variable outside the model, i.e

$$V^{(2)}_{k_2} = \max_{All j \neq k_1} V^{(2)}_j \tag{10}$$

If $F \leq F_{\alpha_1}(1, n-2-1)$, the screening is completed. The regression equation established in the first step is the optimal regression equation.

If $F > F_{\alpha_1}(1, n-2-1)$, select to enter the model, change into $S^{(2)}_{m\times(m+1)}$ and perform the third step screening;

4. Temperature changes in the space region

The migration of shoals changes with the change of temperature in space, and the adaptive temperature range of herring is determined to be: 0-10℃, the optimal temperature is 4.6 ℃ and the adaptive temperature range of herring is: 5-20℃, the optimal temperature is 7℃. Therefore, we need to consider the variation distribution of control properties in the spatial position, and estimate the properties of the points to be interpolated by generating 16 sample points for the temperature of the whole sea area. By means of Kriging interpolation, we obtain the temperature graph of each point on the ocean surface in the next 50 years and present them in a three-dimensional graph. The x and y coordinates represent longitude and latitude respectively, and the z coordinates represent the temperature in specific coordinates. As shown in figure 2

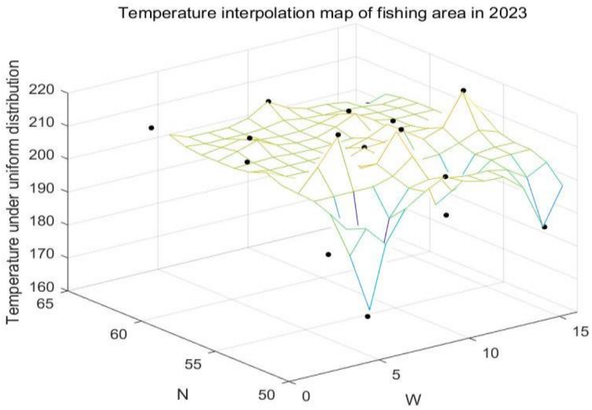

Figure 2: Kriging interpolation spatial distribution of temperature in 2023

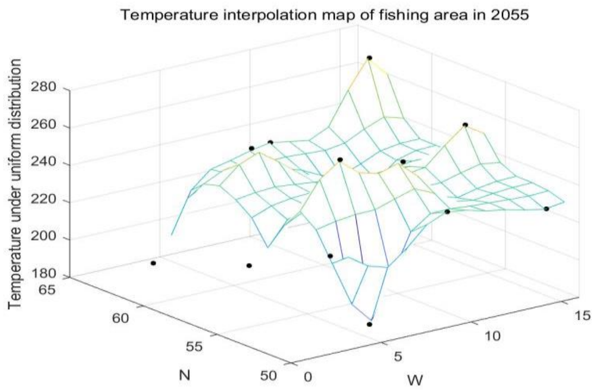

Figure 3: Kriging interpolation spatial distribution of temperature in 2035

5. Conclusions

Through the establishment of the fish-temperature spatial migration model, the temperature data in the next 50 years are obtained by using the method of gradual regression prediction. In addition, the paper also USES the kriging interpolation method to obtain the spatial three-dimensional model of fish-ocean temperature. The freshness of the fish is evaluated, the range of the company's catch is determined, and the maximum fishing life is determined by its intersection with the migration route. As a creative way, the main influencing factors of population density were analyzed by AHP algorithm. Eventually, the model is analyzed with full consideration of the issue of territorial sea by deducting the profit trend from the cost and further evaluating the operation mode.

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