Study on Monitoring the ecological environment by SAR model

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Abstract. Global environmental problems include environmental pollution and the destruction of ecological balance that transcend national boundaries. With the continuous development of human life, economy, trade, and technology, the intrusion into the environment has continued to deepen, causing extensive destruction of forests and other vegetation, large-scale killing of organisms, environmental pollution, and invasion of alien organisms. This has led to a sharp decline in biodiversity and a serious imbalance in the ecological environment. At the same time, the continuous improvement of information technology capabilities and the introduction of big data management and related detection models have brought new methods to the detection and governance of the global ecological environment. Based on the data related to the spread of Asian Hornet in the United States, this paper proposes a method and model for monitoring the number and distribution of new species based on the SAR model. Based on the spatial relationship and the distribution data of the Asian Hornet in the United States from May 2020 to October 2020, and taking into account environmental and climatic factors such as temperature, humidity, and air pressure, this paper conducts time series predictions to obtain the extent of the spread of the Hornet in the United States. The average RSME is 91.27, and a relatively ideal prediction result has been obtained, which proves that this model and method have a good effect on the control and management of alien species and the maintenance of ecological diversity.

1. Introduction
China’s 14th Five-Year Plan focuses on carbon emissions, combined with the conversion of farmland to forests and wildlife protection in recent years, reflecting China’s emphasis on and concern for the ecological environment. In fact, not only China is facing ecological and environmental problems, but global ecological and environmental problems are also prominent. Human activities are the main cause of environmental damage, including forests and wetlands; large-scale hunting of wild animals; and environmental pollution caused by industrialization. The invasion of alien species destroys the original ecology; soil, water and atmosphere are polluted and so on.

Invasion of alien species is a major threat to biodiversity because they can change the processes and functions of ecosystems and often lead to the reduction of endangered species (Wilcove et al., 1998; Dueñas et al., 2018). At the same time, new species also have a greater impact on the economic environment. In the United States, the annual economic loss of invasive species to agriculture, forestry
and public health is close to 120 billion U.S. dollars (Pimentel, Zuniga & Morrison, 2005). [1] Since November 2019, dead specimens of bumblebees were found in Washington State, and Asian bumblebees were introduced to the United States and spread further. It is reported that the invasion of the United States is likely to be caused by human trade. The DNA of the sample captured in Washington is related to a matrilinelineage in Chungcheonju, South Korea. [2]

The Asian hornet, belonging to the Vespa family Hymenoptera, is the largest known wasp species in the world, ranging in length from 38-50 mm. Compared with other wasps, the head is orange and bald (Lee 2010; Matsuura and Sakagami 1973). This type of wasp is native to India, Nepal, Sri Lanka, Vietnam, South Korea, Japan, Taiwan and China. Mainly distributed in dense woodlands and mountains, nests are also generally placed in existing caves, snake holes or rotting tree roots (Archer 1995). The population consists of queen bees, worker bees, and drones, each of which performs its duties (Archer 1995). There are usually 300 or more workers (up to 800-1000 workers) in each hive, and they usually move and forage in summer and autumn. [4]

As an alien species, the Asian Hornet has a greater impact on humans, some invertebrates, and the economy. The venom of the bumblebee not only causes pain in humans, it may cause allergic reactions, and in severe cases, it may damage related human tissues (Schmidt 2019). The venom of the bumblebee sprayed into human eyes can cause damage to the retinal function and so on. [3] This type of wasp is predatory and usually feeds on various terrestrial invertebrates, especially honeybees. [5] Bees are the main way of pollen transmission. Due to the death of a large number of bees, it will have a serious impact on effective pollination, and then affect the development of agriculture.

Based on the above analysis, how to identify and predict the Asian Hornet is particularly important. Claudia Nuñez-Penichet et al., Alberto J Alaniz et al., and avid A. Moo-Llanes et al. predicted the spread of bumblebees mainly based on the niche model, but this model is conservative. It is not saturated and belongs to a new species in the United States. Under the new environment, the environment and interspecies impacts will undergo new changes according to local conditions. If the environmental factors of Asian hornets in other regions are used to predict the hornet in the United States, There may be a certain deviation; at the same time, the niche model can only predict the presence of bumblebees in this area, and cannot measure the severity of the spread of this species in the area.

This paper is based on the Spatial Autoregressive Model (SAR) to predict the spread of Asian Hornet in the United States. The SAR model was proposed by cliff and ord in 1973. The core of this model is the spatial weight matrix, which analyzes the influence of geographical adjacent areas on the local area, the so-called spatial spillover effect. [6] This article is based on the spatial relationship of this model and the distribution data of Asian Hornet in the United States from May 2020 to October 2020. At the same time, taking into account the environmental and climate factors considered in the niche model, the time series prediction is carried out. The RSME evaluation standard evaluates the forecast results from May 2020 to October 2020. The average RSME is 91.27, and a relatively ideal forecast result has been achieved.

2. Process and method

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2.1. Normal analysis and analysis of variance

Since the one-way analysis of variance assumes that the sample obeys a certain normal distribution, this article needs to carry out a normal test on the collected climate and environmental data. The results are shown in the table below:
Table 1. Shapiro-Wilk W Normal Test.

| Factor | Elevation | Temperature | Humidity | Precipitation | Wind Speed | Atmospheric Pressure | Cloud Cover | Solar Radiation |
|--------|-----------|-------------|----------|---------------|------------|----------------------|-------------|----------------|
| W      | 0.972     | 0.945       | 0.894    | 0.936         | 0.953      | 0.904                | 0.962       | 0.987          |
| p      | 1.9e-8    | 1.1e-17     | 3.3e-42  | 6.4e-20       | 3.1e-15    | 2.4e-31              | 2.2e-12     | 2.0e-2         |

Through the above tests, this paper finds that climate and environmental data are similar to normal distributions. Significance level=0.05, although all p-values are less than 0.05, this article rejects H0. This article believes that the p-value is too small because the sample size is too large. Observing the value of W, it is found that the value of W is close to 1, so it can be considered that these data are approximately normally distributed.

On the basis of the above normal analysis, this article examines the influence of temperature, precipitation, humidity, wind speed and air pressure on the spread of Asian Hornet through analysis of variance. The test results are as follows:

Table 2. ANOVA Results.

| Factor | Elevation | Temperature | Humidity | Precipitation | Wind Speed | Atmospheric Pressure | Cloud Cover | Solar Radiation |
|--------|-----------|-------------|----------|---------------|------------|----------------------|-------------|----------------|
| W      | 1.526     | 144.667     | 3.464    | 83.441        | 7.646      | 12.093               | 0.628       | 0.649          |
| p      | 0.217     | 8.3e-33     | 0.063    | 9.8e-20       | 0.006      | 5.1e-4               | 0.428       | 0.421          |

Through the above test results, this article found that temperature, precipitation, humidity, wind speed and air pressure have a significant impact on the spread of the vespa.

2.2. SAR model analysis

The spatial autoregressive model (Spatial Autoregressive Model, SAR) mainly explores whether each variable has a diffusion phenomenon (spillover effect) in a certain area. The model expression is:

$$y = \rho W y + \beta X + \epsilon$$ (1)

In this article, $y$ represents the extent of the Asian Hornet's spread, the parameter $\rho$ reflects the influence of the spatial lag variable $Wy$ on the $y$ value, and the parameter $\beta$ reflects the influence of the $y$ value by the climate environment $X$. $\rho$ is the coefficient of the spatial weight matrix, $\beta$ is the coefficient of the extracted environmental variable, and $\epsilon$ is the error term.

Because the spread of the Asian Hornet is between 49.5 kilometers and 110 kilometers. [7] Therefore, this paper sets $k$ to 50km, and the spatial weight matrix is:

$$W_{ij}(d) = \begin{cases} 0 & \text{dis}(i,j) \leq 50 \\ 1 & \text{dis}(i,j) > 50 \end{cases}$$ (2)

And normalize the weight matrix according to the following formula to get the final weight matrix.

$$W_{ij} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}}, \ i, j = 1, 2, \ldots, n$$ (3)

Based on the distribution data of the Asian Hornet in the United States from May 2020 to October 2020, this paper obtains data on characteristic factors such as temperature, precipitation, humidity, wind speed, and air pressure according to its latitude and longitude. Since the average number of worker bees is 300 [4], and considering the accuracy of the bumblebee report, the dependent variable is defined as:

$$y = \text{positive number} \times 300 + \text{unverified number} \times 30$$ (4)

Among them, "positive number" is the number of reports that accurately identified the hornet; "unverified number" is the number of reports that did not accurately identify the hornet.
If the predicted value of $y$ in a certain area is greater than 300, it is considered that there is a nest of Asian hornet in this area. Due to the hibernation habit of the Asian Hornet, in order to effectively train the model parameters, this paper uses the data from May 2020 to October 2020 to train the model parameters $\rho$, $\beta$, and $\epsilon$.

The model obtained after training is as follows:

$$y^{11} = 0.43Wy^{10} - 97.57x_{1}^{11} + 68.51x_{2}^{11} - 47.75x_{3}^{11} - 12.22x_{4}^{11} - 27.85x_{5}^{11} + 19.6042 \quad (5)$$

2.3. Result analysis

This article analyzes the spread of the Asian Hornet from two aspects.

1) First, from the geographical dimension, this article draws the forecast results for September, October, November, December 2020, and January and February 2021 into a heat map, as shown in the figure below:

![Heat map of predicted results](image)

**Figure 1.** Heat map of predicted results

According to the above heat map, it is found that the Asian Hornet is mainly distributed in northwestern Washington State, adjacent to Canada. At the same time, we can see that the center of the wasp gathering in Washington State is shifting from the northwestern United States like the central region. As of December 2020, it has been possible to discover that new gathering centers have emerged in parts of the central region.

2) Secondly, according to the value of the influencing factor $y$, this paper selects five major cities, including Point Roberts, Blaine, Custer, Rockport, and Chelan Falls, and observes the changes in the number of bumblebees in a certain area according to the changes in the $y$ value.
According to the above figure, it is observed that the y-values of the five cities exhibit seasonal fluctuations, and their fluctuation trends are basically the same, that is, there is an upward trend in May, June, July, September, and October, and a downward trend in other months. At the same time, comparing the data of January and February of 2021 with the data of January and February of 2020, the y value has slightly increased in the overall trend, reminding the government to strengthen its control over its proliferation. At the same time, the number of them is less than 300, which confirms the life habits of the bumblebee itself, that is, the main active seasons are in summer and autumn, and the winter is in hibernation, which also proves the accuracy of our model.

2.4. Model accuracy test
This article uses the report data from June to October 2020 as a test set to evaluate the model in this article. According to the evaluation standard RMSE, the RMSE error of the model's predicted y value is as follows:

![Figure 2. Changes in Y value of major cities.](image)

| Month | 5     | 6     | 7     | 8     | 9     | 10    |
|-------|-------|-------|-------|-------|-------|-------|
| RMSE  | 31.23 | 44.83 | 94.88 | 113.04| 100.9 | 162.75|

The average RMSE calculated in this paper is 91.27, which gives a more ideal result.

3. Conclusion
The United Nations Environment Program predicts that in the next two to three decades, a quarter of the biological species on the earth will be in desperate situation; by 2050, about half of the animals and plants will disappear from the earth. The invasion of new species poses a great challenge to the ecological environment and severely affects ecological diversity. Based on the data related to the spread of Asian hornet in the United States, this article predicts the number and distribution of new species. At the same time, a model method for effectively identifying Asian hornet is proposed. The proposal of this model provides a relatively accurate and convenient method for the monitoring of new species, and is also very beneficial to maintaining the balance of the ecological environment. However, there are still
shortcomings. The life cycle of bees, seasonal activities and other factors are not considered; due to limited effective data, the prediction model may not be able to reasonably fit the living environment of the Asian Hornet.

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References

[1] Nuñez-Penichet C, Osorio-Olvera L, Gonzalez VH, Cobos ME, Jiménez L, DeRaad DA, Alkishe A, Contreras-Díaz RG, Nava-Bolaños A, Utsumi K, Ashraf U, Adeboje A, Peterson AT, Soberon J. 2021. Geographic potential of the world’s largest hornet, Vespa mandarinia Smith (Hymenoptera: Vespidae), worldwide and particularly in North America. PeerJ 9:e10690 DOI 10.7717/peerj.10690.

[2] Erik D. Norderud 1, 2, Scott L. Powell 2 , Robert K. D. Peterson 2. Risk assessment for the establishment of the Asian giant hornet (Vespa mandarinia) in the Pacific Northwest, DOI: https://doi.org/10.1101/2021.02.01.429186.

[3] Koji Hiranoa Atsuhiro Tanikawab. Ocular Injury Caused by the Sprayed Venom of the Asian Giant Hornet (Vespa mandarinia). S. Karger AG, Basel. DOI: 10.1159/000508911O.

[4] Information on https://extension.psu.edu/european-hornet.

[5] United States Department of Agriculture Asian Giant Hornet Control Program in Washington State.2020.

[6] Jian Zhou, Jing Gao, Yangqianwen Zhou. Spatial Econometrics Model Setting Theory and Its New Development. China Journal of Economics, 2016, 3(2): 161-190.

[7] Gengping Zhu, Javier Gutierrez Illan, Chris Looney, and David W. Crowder. Assessing the ecological niche and invasion potential of the Asian giant hornet. Proceedings of the National Academy of Sciences, 117(40):24646–24648, October 2020. Publisher: National Academy of Sciences Section: Biological Sciences.