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Spatiotemporal distribution analysis of Vespa Mandarinia based on GM model

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Abstract. As a natural enemy of the European honeybee, the Chinese great steller's wasp can have a serious impact on local bee populations, so they are considered an agricultural pest. After the emergence of these pests, countries must decide how to prioritize their limited resources for follow-up investigations. In this paper, a model was established to predict the emergence of wild silkworm, which could be used to provide strong support for pest management. when predicting how pests spread over time, we built a GM model to predict the spread of Vespa mandarinia from the spatial and temporal distribution. When predicting the geographic location of Vespa mandarinia, we set up a two-dimensional GM model using longitude and latitude as two variables to predict the longitude and latitude of the next Vespa mandarinia. At the same time, when predicting the occurrence time of Vespa mandarinia, we formed a sequence of the annual 12-month report times of previous years, and still used GM model for data processing and prediction.

1. Introduction

Since Vespa mandarinia's colony was discovered on Vancouver Island in British Columbia, Canada, in September 2019, there have been a number of sightings of the pest in the neighboring state of Washington, including a few correct sightings and a multitude of false sightings.

The life cycle of Vespa mandarinia is similar to that of many other wasps. The queen bee lives for about a year. The young queens are born in the fall, mate shortly after, and then go into hibernation. The queen bees set out in the following spring to build nests and lay their eggs. At the end of the autumn season, the old queen bee dies.

Vespa mandarinia is the largest species of hornet in the world. They are the predators of European honeybees. A small number of Vespa mandarinia can destroy an entire European honeybee community in a short time [1]. Also, they are voracious predators of other insects that are considered agricultural pests. The presence of Vespa mandarinia causes a lot of anxiety because of the serious impact it could have on local bee populations [2]. The state of Washington has set up a helpline and a website for people to report sightings of the wasps.

2. The Grey Model (GM)

In this section, we propose the longitude and latitude model (i. e. the Grey Model based on longitude and latitude) and the Time prediction model (i. e. the Grey Model based on the detection time. We combined the latitude and longitude and the detection time of the 14 Positive ID [3] (as a data measure) to predict how the Vespa mandarinia will spread over time. In determining the spread of Asian Vespa mandarinia over time, we considered only the longitude and latitude and the detection time of the discovered Asian giant hornet and the nest-building habits of new queens (i.e., nests within a radius of 30KM). So once a new Asian giant hornet nest is found, we can use this model to predict its spread [4]. This method has a high accuracy.

2.1. GM model introduction

We have sequences**:**

$$x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(\mathrm{n}) \tag{1}$$

1. Accumulated Generating Operation **(**AGO**)**

$$x^{(1)}(1) = x^{(0)}(1), x^{(1)}(2) = x^{(1)}(1) + x^{(0)}(2), \ldots, x^{(1)}(n) = x^{(1)}(n-1) + x^{(0)}(n) \tag{2}$$

that is

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1,2,\ldots,n \tag{3}$$

The series of production means

$$\mathrm{z}^{(1)}(k) = \alpha x^{(1)}(k) + (1-\alpha)x^{(1)}(k-1), k = 2,3,\ldots,n \tag{4}$$

$0 \le \alpha \le 1$**.** Usually, we set $\alpha = 0.5$**.**

The differential equation based on GM is established:

$$x^{(0)}(k) + az^{(1)}(k) = b, k = 2,3,\ldots,n \tag{5}$$

The corresponding GM (1,1) albino differential equation is

$$\frac{dx^{(1)}}{dt} + ax^{(1)}(t) = b \tag{6}$$

Transform Equation (5) into:

$$-az^{(1)}(k) + b = x^{(0)}(k), k = 2,3,\ldots,n \tag{7}$$

where a and b are model parameters to be determined.
Equation (7) is expressed as:

$$\begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \dots & \dots \\ -z^{(1)}(n) & 1 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \dots \\ x^{(0)}(n) \end{bmatrix} \tag{8}$$

$$X\beta = Y \tag{9}$$

$$\text{And } X = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \dots & \dots \\ -z^{(1)}(n) & 1 \end{bmatrix}, \beta = \begin{bmatrix} a \\ b \end{bmatrix}, \ Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \dots \\ x^{(0)}(n) \end{bmatrix} \tag{10}$$

The least squares solution is:

$$\hat{\beta} = (a,b)^T = (X^T X)^{-1} X^T Y \tag{11}$$

Solve the differential equation (6) to obtain the discrete solution of GM (1,1) model:

$$\hat{x}^{(1)}(k) = [x^{(0)}(1) - \frac{b}{a}]e^{-\alpha(k-1)} + \frac{b}{a}, k = 2,3,\dots,n \tag{12}$$

Restore to the original series, and the prediction model is:

$$\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1), k = 2,3,4,\dots,n \tag{13}$$

Substitute Equation (12) into Equation (13):

$$\hat{x}^{(0)}(k) = [x^{(0)}(1) - \frac{b}{a}]e^{-a(k-1)}(1 - e^{a}), k = 2,3,4,\dots,n \tag{14}$$

2.2. The latitude and longitude modele

2.2.1. Calculation. In 2021MCMProblemC_DataSet,we can find information on 14 sightings :Detection date, latitude and longitude which are the key messages for our models [5]. After processing this information into the longitude and latitude model and time prediction model respectively, the program compilation, the model results can be obtained.

Table 1. The information on the 14 Positive ID.

N	Global ID	Detection date	Latitude	Longitude
1	{0FAC3767-EAC4-477A-B5F0-24AF8A40BD09}	2020/9/30	48.979497	-122.581335
2	{124B9BFA-7F7B-4B8E-8A56-42E067F0F72E}	2019/9/19	49.149394	-123.943134
3	{7F3B6DB6-2ED4-4415-8DC2-3F03EC88F353}	2019/9/30	48.993892	-122.702242
4	{5EAD3364-2CA7-4A39-9A53-7F9DCF5D2041}	2019/10/30	48.971949	-122.700941
5	{F1864CC3-508C-4E60-9098-B158AB413B03}	2019/11/13	49.025831	-122.810653
6	{5AC8034E-5B46-4294-85F0-5B13117EBEFE}	2019/12/8	48.980994	-122.688503
7	{1C6D0EAB-F68D-411D-974E-1233618854CC}	2020/5/15	49.060215	-122.641648
8	{AD56E8D0-CC43-45B5-B042-94D1712322B9}	2020/5/27	48.955587	-122.661037
9	{FC6E894B-F6DF-4FDC-853A-D7372D253988}	2020/6/7	48.777534	-122.418612
10	{A717D86F-23E9-4C8C-9F12-198A71113E93}	2020/8/17	48.927519	-122.745016
11	{2138197A-F5CF-4308-93E2-62EA6F84D098}	2020/9/21	48.984269	-122.574809
12	{AA461F47-1B2B-4EA1-8154-ECF70B55A334}	2020/9/28	48.98422	-122.574726
13	{DEF5D82B-E326-41A5-9B6C-D46DCD86950C}	2020/9/29	48.984172	-122.57472
14	{BEAC832C-0783-414A-9354-C297F38570AD}	2020/10/1	48.983375	-122.582465

2.2.2. Calculation

[1.0001846975704398, 0.9963896808168174, 1.003958833135838, 0.9985672042968533, 0.9992991469768324, 1.0057953114234925, 0.9955839801418511, 1.0013565576460153, 0.9988414647976067, 1.0000974285219792, 0.9999208302817028, 0.9999837294381541, 0.9999990200925931]

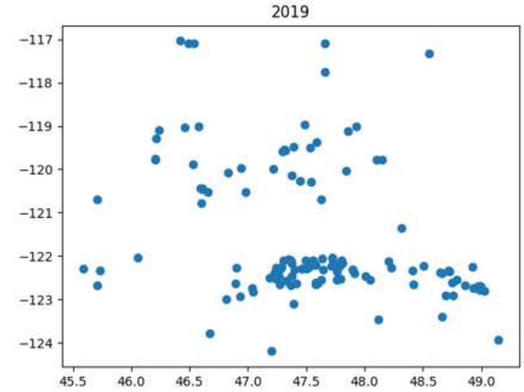
The relative error:

[0.0.00075013 0.00295042 0.00090886 0.00061297 0.00140106 0.00429797 0.0002248 0.00104358 0.00020393 0.0001943 0.00036121 0.00046522 0.00055393]

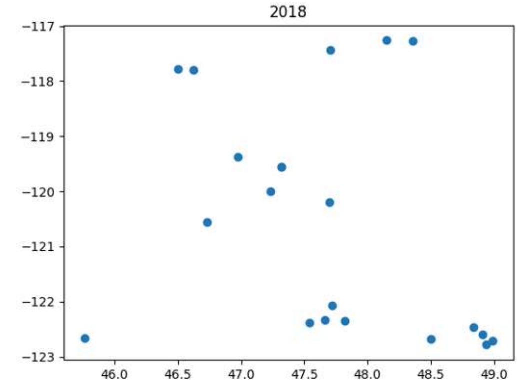
Prediction accuracy: 78.57142857142857%

[-0.0007483400646133287, 0.003699565947420713, -0.0038689084018048714, 0.001522237511707658, 0.0007903603900010214, -0.005705222194527737, 0.004505194455806216, -0.001266865994612898, 0.0012480015742982742, -7.8496561728425e-06, 0.00016873277205819992, 0.00010583924757057162, 9.054995773960517e-05]

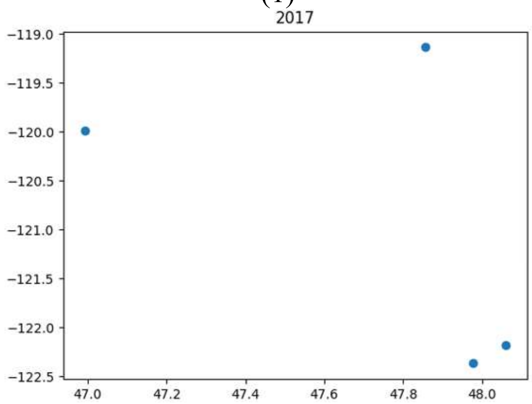
2.2.3. Longitude and latitude distribution visualization



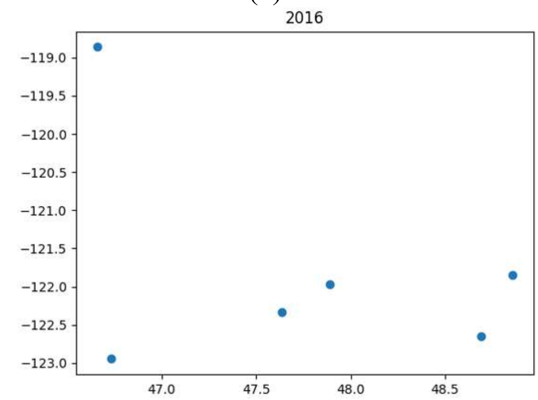
(1)



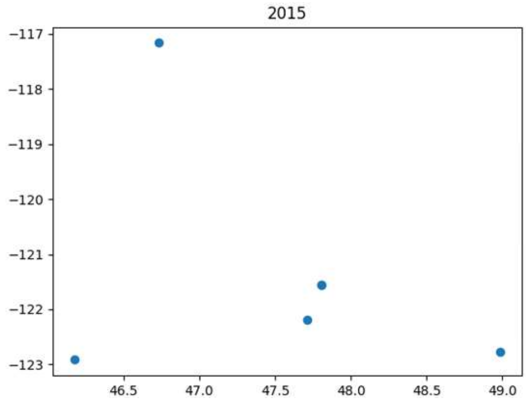
(2)



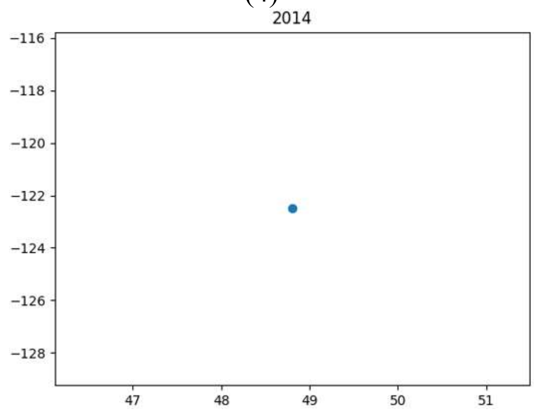
(3)



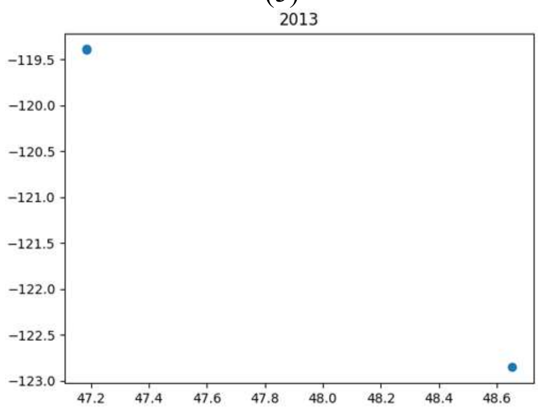
(4)



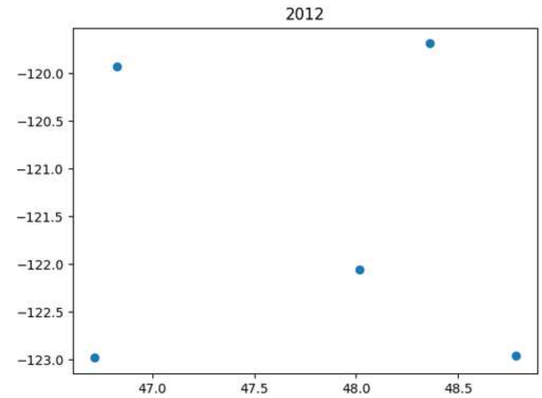
(5)



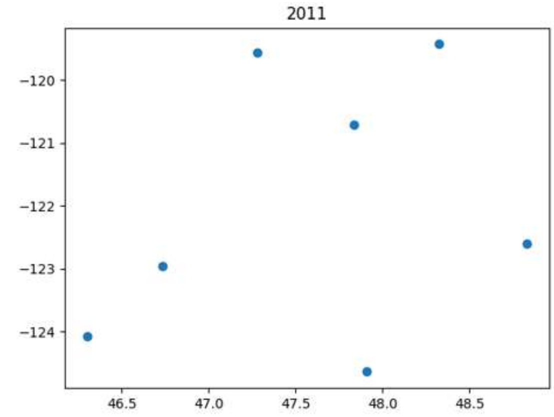
(6)



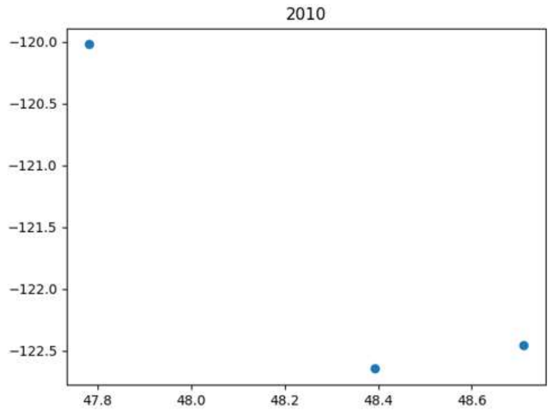
(7)



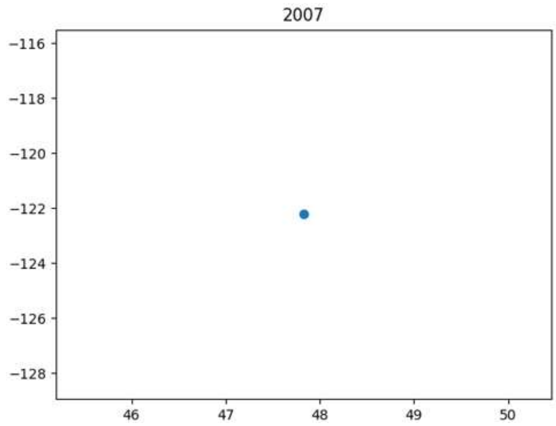
(8)



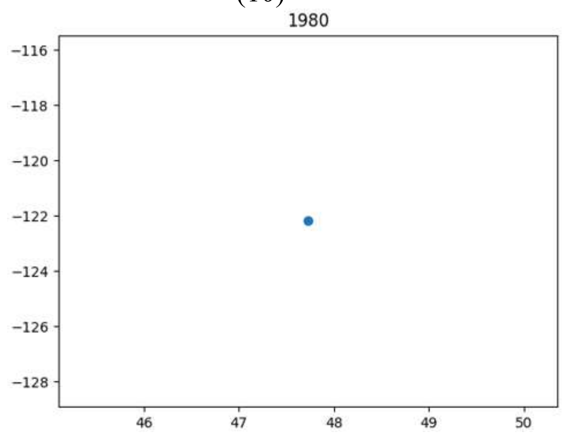
(9)



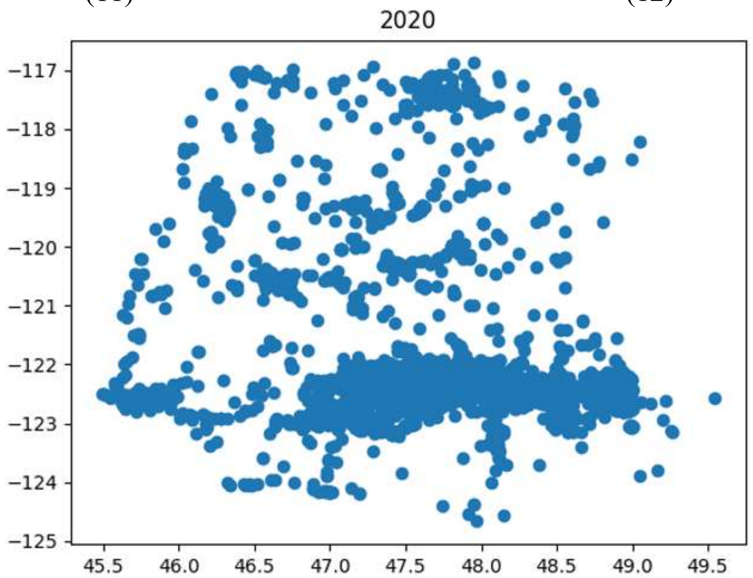
(10)



(11)



(12)



(13)

Figure 1. Longitude and latitude distribution visualization.

2.3. Time Prediction model

2.3.1. Calculation. Put the detectionDate in Table 1 into the GM model, after programming, can be solved.

2.4. Predicting the disappearance of the Asian giant hornet
In proving that the Asian giant hornet had disappeared [6], we assumed that the pest had disappeared when the number of reported sightings dropped to a low point. It was calculated that the pest disappeared from the state of Washington when it reached 10% of the minimum.

2.5. Text analysis
According to Notes about positive ID in the data set, extract keywords and conduct text analysis.

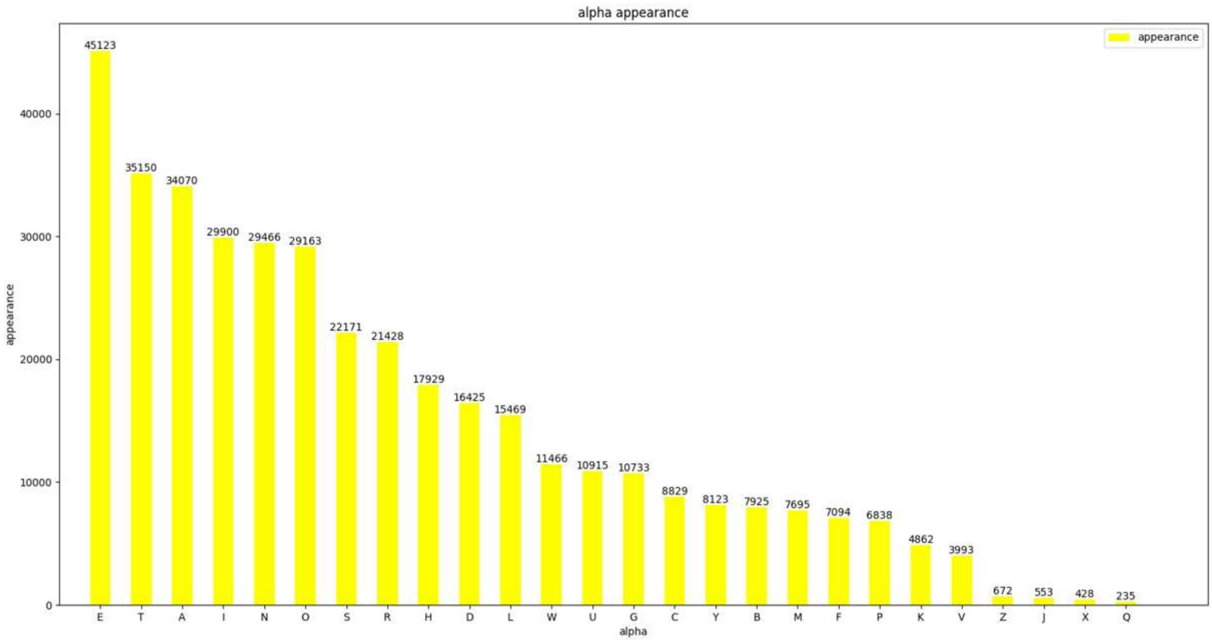


Figure 2. Alpha appearance.

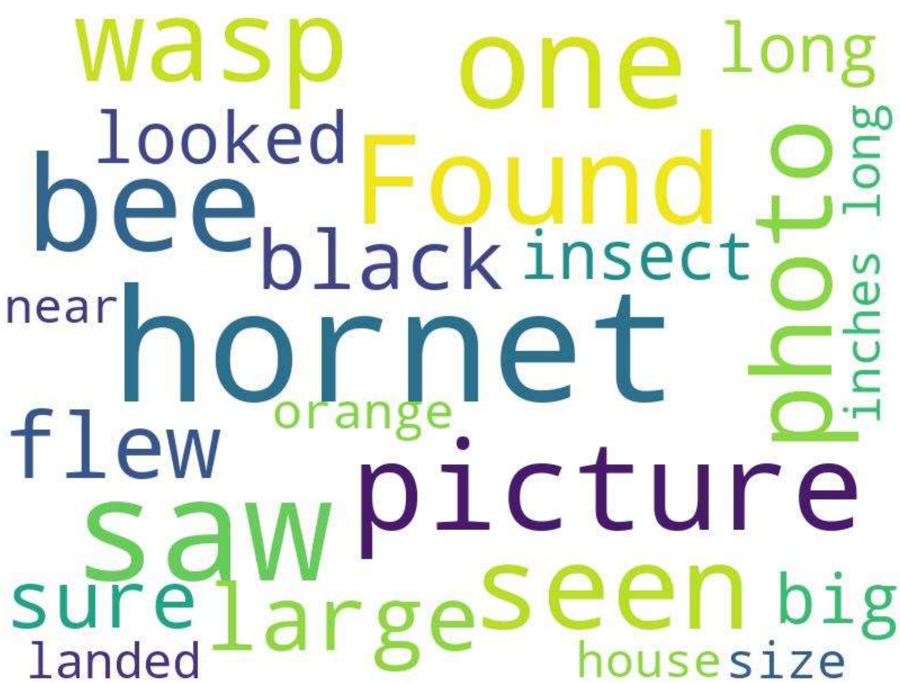


Figure 3. The key words.

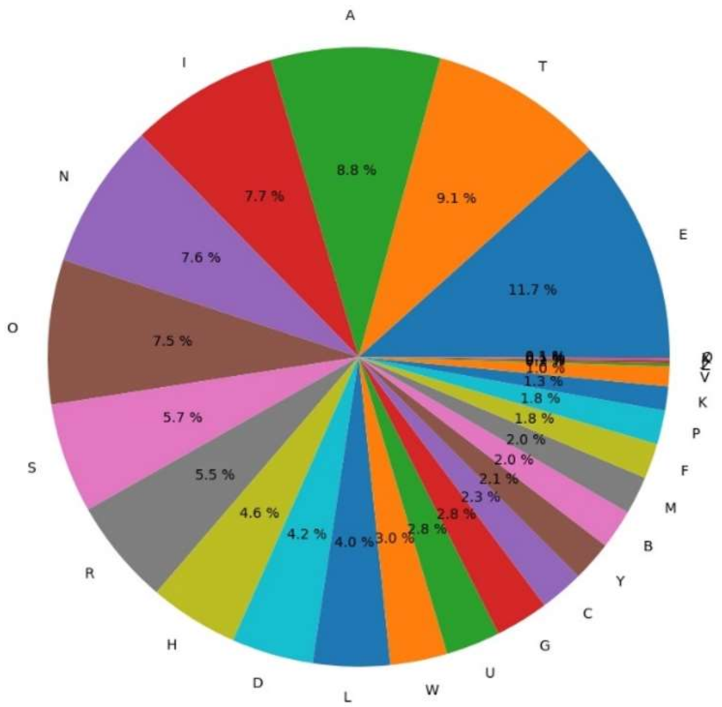


Figure 4. Alpha appearance.

2.6. Conclusion
To predict how Asian Vespa mandarinia spread, we developed two models: a latitude and longitude model and a time prediction model. The longitude and latitude model uses the known longitude and latitude of the 14 positiveID to predict the spread of the Asian Vespa mandarinia wind. The time prediction model is to sort the detectiondates of 14 POSITIVEID and form a sequence, more than the 12-month POSITIVEID report in 2020, and predict the spread of Asian Vespa mandarinia in 2021 and beyond.

The accuracy of the model is about 78.57%.

When the number of PositiveID becomes very low, or at that low point, it is predicted that Washington will have eliminated the pest.

Reference
[1] Lin Dakun, Huang Shiguo, Zhang Feiping, Liang Guanghong, Wu Songqing, Hu Xia, Wang Rong.Image recognition of Lepidoptera based on improved differential evolution algorithm [J]. Scientia Silvae Sinicae,2020,56(03):73-81.

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