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Research on Honeycomb Location and Dissemination Based on Cluster Analysis and Multivariable Probability Prediction

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Abstract: Asian giant hornets are extremely toxic and have an aggressive impact on local bee species. If the spread of Asian giant hornet is not predicted as early as possible and appropriate countermeasures are made, it will cause immeasurable losses. We predict the spread of the Asian giant hornet. Considering that the farthest movement axis of the Asian giant hornet is 5 km, it can be set as the constraint condition to achieve hierarchical clustering of the sighting positions. Therefore, based on the assumption that the Asian giant hornets in the same nest are grouped into a cluster, a yearly time-step probabilistic prediction model is built to estimate the possible nest coordinates.

1. Introduction

When the Asian giant hornet first appeared in North America in 2019, it caused a huge shock in society. The number of Asian giant hornet peaks in September and October every year. Asian giant hornets' nests are usually located in abandoned rodent burrows in the forest, related to pine roots, and no more than 3 to 6 feet above the ground. Due to the potential serious impact of Asian bumblebees on local bee populations and residents, a multitude of public sighting reports have been provided by people through the helplines and a website created by the State of Washington.

2. A Hierarchical Clustering Model

Cluster analysis refers to the analysis process of dividing a collection of things into multiple classes composed of similar objects based on similarity. Common ones are K-Means (K-means clustering), DBSCAN (density-based spatial clustering), Hierarchical Clustering and so on. In this problem, we can use the idea of cluster analysis to use the existing location information of the Asian giant hornet sightings to figure out the possible location of its hive. [1]

Considering that the number of hives is unknown and the number of witnessed and confirmed Asian giant hornet cases is small, we prefer to use Hierarchical Clustering to avoid the above problems.

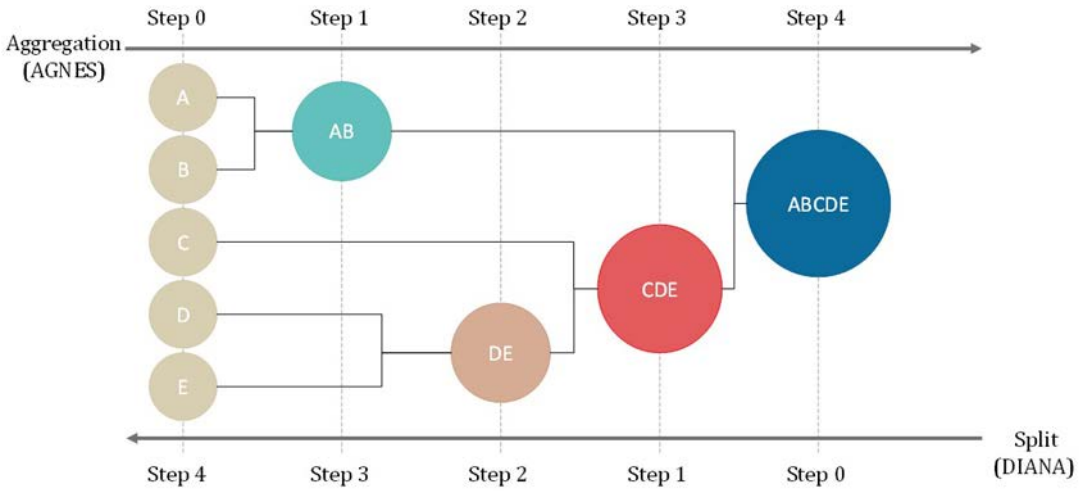

Figure 1: Aggregation and split hierarchical clustering graph of data objects |A, B, C, D, E|

The core of Hierarchical Clustering is to set a condition and classify step by step in a certain order, so that the final classification result can meet the target condition. According to its classification order, Hierarchical Clustering can be divided into aggregation method and split method. The two are equivalent to each other, only the difference in classification efficiency exists. The principle of Hierarchical Clustering is shown in Figure 1.

In order to accurately predict the spread of the Asian Giant Hornets in the future, it is a good way to find key information from their life history. According to the background, we know that the Asian Giant Hornets have one generation a year. It means that we can use a discrete time model to calculate the number and location of existing hives and calculate the number of new hives in the future.

Therefore, the factors that affect the distribution of Asian giant hornet queen and the survival of the early hornet are the main factors that affect the spread. The model mainly includes the following three parts:

(1) Factors affecting the distribution of female bees

Spatial distribution probability

Spatial distribution probability is a description of the possibilities that the fertilized Asian giant hornet queen in a certain area can successfully migrate to other areas, reflecting the uneven distribution of hive in space caused by terrain factors and distance factors. The essence of the formula is Radial Basis Function, denoted as:

$$P_{ij} = e^{-\frac{|d_{ij}-\mu|}{\mu}} \cdot T_j$$

Among them, i is the matrix unit of the existing honeycomb, and j is the target unit. It is the distance from i to j. According to the data, the farthest flight radius of the female Asian Hornet is 30 km. The average flight distance μ of the female bee is 28 km from the literature [2].

(2) Factors affecting the survival probability of early hornets

a) Environmental suitability:

Environmental suitability is a description of whether a certain area is suitable for queen settlement and hive development, and is related to the environmental weight and distance of the surrounding matrix units of the area. The formula is as follows:

$$E_{jk} = \xi \sum_{k=1}^{k} e^{-\frac{d_{jk}^2}{2\sigma_e^2}} \cdot T_k$$

Where j is the target unit, k is the matrix unit within a certain range around the target unit; d_{jk} is the distance from j to k. According to the data, the farthest foraging radius of the Asian Hornet is 5 km, so $d_{jk} < 5$ km; σ_e is the average foraging radius, which is about 1 km. ξ is a normalized parameter to ensure that the sum of the environmental suitability of all k units to j units is 1 and conforms to the normal distribution. [3]

b) Population competition degree

The degree of population competition is a description of the impact of the settlement of the queen and colony development in a certain area by other nearby hives, and is related to the number and distance of hives around the area. Because the competition between populations is related to population density, it is also called the density-dependent effect in ecology. Its formula is as follows:

$$C_{jl} = \sum_{l=1}^{l} e^{-\frac{d_{n_n^2}}{2\sigma_c^2}}$$

Where j is the target unit and l is the matrix unit within a certain range around the target unit. d_{jl} is the distance from j to l. Since the farthest foraging radius of the Asian Hornet is 5 km, the critical condition for the overlap of the two swarm activity spaces is d_{jl} less than twice the furthest foraging radius, namely 10 km. Similarly σ_c is twice σ_e, namely 2 km.

c) Reproductive potential

Reproductive potential is a description of the number of female hornets that can be fertilized. It means the maximum number of bee colonies that a bee colony can derive in one year under the premise of perfection.

(3) Probability Model of Propagation Dynamics

Based on the above-analyzed influencing factors, a propagation dynamics model can be established, and the probability distribution of honeycombs in various regions can be constructed. Suppose that the set of all matrix units currently known to have a honeycomb is ***I***, and the set of all matrix units that can be propagated to is ***J***. Suppose there is a honeycomb in unit *i*, and the probability ***Z*** of its propagation to *j* area is

$$Z_{ij} = \frac{BE_i f(\text{ lat })}{1 + C_i} \cdot \frac{P_{ij} \cdot T_j}{\sum_{j=1}^{J} P_{ij} \cdot T_j}$$

It can be seen that the probability of all cells with honeycombs in set $\boldsymbol{I}$ propagating to cell j is:

$$Z_j = \sum_{i=1}^{I} Z_{ij}$$

Thus, the probability of a new honeycomb appearing at all points in the matrix is calculated. The threshold T can be obtained by:

$$\begin{cases} Z_j < T, \text{ without a nest} \\ Z_j \geqslant T, \text{ have a nest} \end{cases}$$

3. Model Solving

In the establishment of the model, we believe that as long as the distance between the two Asian giant hornets found exceeds 10 km, it means that the two Asian giant hornets do not belong to the same species, and the two Asian giant hornets found through cluster analysis The nesting distance of an Asian giant hornet is more than 30 km, indicating that there is no transmission relationship between the two Asian giant hornets. Figure 2 shows the geographical location of the Asian giant hornet and the different types obtained after hierarchical clustering. The geographical location of the colony nest.

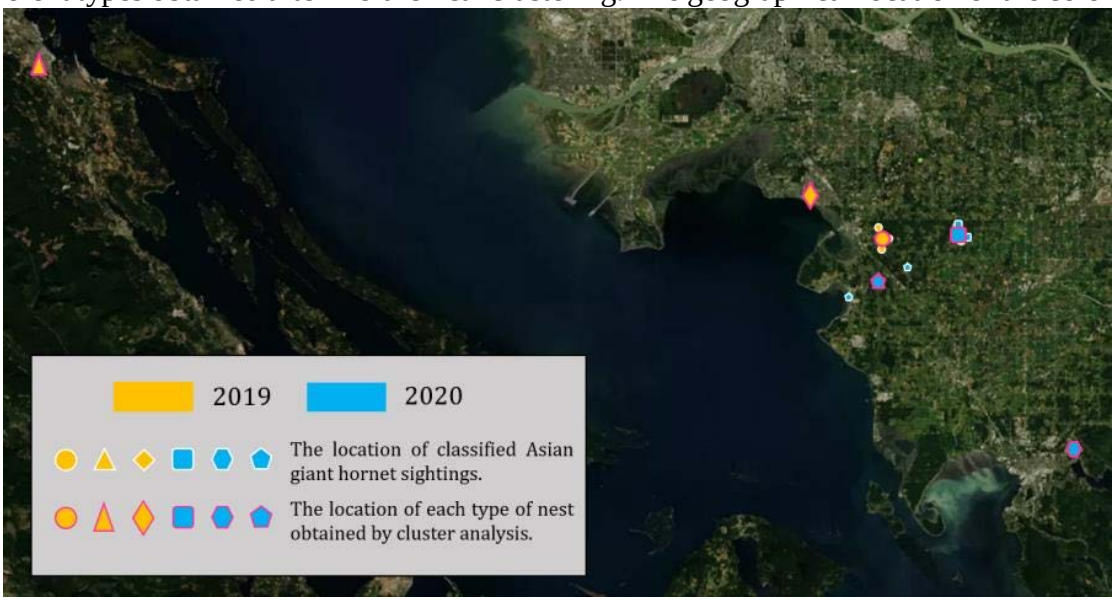

Figure 2: The sighting location of Asian giant hornet in 2019 and 2020 and the geographical location of each type of nest after clustering

4. Conclusion

By screening the geographic location of the Asian giant hornet and performing hierarchical cluster analysis on it, the geographic location information of each type of bee colony nest can be obtained, combined with factors that affect the spread of bee species, such as the distribution of female bees in space According to the conditions, the suitable environment of the environment, the degree of population competition, the influence of the reproductive potential, the probability of the emergence of new hive in each region in the second year is obtained through the calculation of propagation dynamics, and the number and location of the Asian giant hornet are predicted on this basis.

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