American Journal of Agriculture and Forestry
2023; 11(6): 228-232
http://www.sciencepublishinggroup.com/j/ajaf
doi: 10.11648/j.ajaf.20231106.13
ISSN: 2330-8583 (Print); ISSN: 2330-8591 (Online)

Analysis of the Evolution of Scale-Free Properties in the Complex Network of American White Moths in Liaoning Area

Sun Xiaojuan[1], Feng Ying[1, *], Liu Jun[2]

[1]Scientific Research Department, Liaoning Vocational College of Ecological Engineering, Shenyang, China
[2]Sankuaishi Forest Farm of Fushun County, Fushun, China

Email address:
1140786450@qq.com (Feng Ying)
[*]Corresponding author

To cite this article:
Sun Xiaojuan, Feng Ying, Liu Jun. Analysis of the Evolution of Scale-Free Properties in the Complex Network of American White Moths in Liaoning Area. *American Journal of Agriculture and Forestry*. Vol. 11, No. 6, 2023, pp. 228-232. doi: 10.11648/j.ajaf.20231106.13

Received: October 7, 2023; **Accepted**: November 1, 2023; **Published**: November 17, 2023

Abstract: Pest infestation is the most severe forestry biological disaster, causing not only huge economic losses worldwide but also damaging the ecological environment. Evaluating the mechanism and spatial structure changes of pest population distribution in forests scientifically is crucial for understanding and solving the problem of forest pest disasters. With the continuous deepening of research on the niche principle and spatial patterns of insect populations, a research orientation that emphasizes dynamic-multidimensional-three-dimensional and cross-disciplinary integration has become the trend in future forestry biological disaster research. Applying network science analysis methods to the field of forest pest research can help explore the distribution characteristics, affected areas, and temporal and spatial changes in the spread and transmission of forest pests, effectively curb their rampant spread, and provide scientific data support for predicting and forecasting forest pests. This will have far-reaching implications for the comprehensive implementation of integrated pest management strategies. In this paper, based on a spatial influence domain network model, we selected monitoring data of the globally quarantined harmful organism, American white moth in Liaoning Province from 2009 to 2013 as the data source. We constructed a complex network of American white moth pest relationships and focused on studying the overall network's indegree and outdegree network characteristic quantities, as well as the network evolution of the peak larval months and the average degree of the network.

Keywords: American White Moth, Complex Network, Scale-Free Properties, Evolutionary Analysis

1. Introduction

The American white moth has the characteristics of a wide range of food sources, hosts, rapid spread, strong reproductive ability, extensive transmission routes, long starvation tolerance, and heavy damage. These characteristics make it a world-wide quarantined harmful organism. Forests in Liaoning region are severely damaged by the American white moth pests. In order to provide a scientific basis for the effective development of comprehensive prevention and control strategies for the American white moth, network science analysis methods were adopted [1]. A complex network of American white moth pest relationships based on the spatial influence domain network model was established, and network characteristic quantities and evolutionary analyses were conducted to find out the laws of occurrence and development of American pests.

2. Materials and Methods

2.1. Basic Definitions

Degree: Node [2-3] degree refers to the number of other nodes connected to it.

Out-degree [4]: For directed networks, the out-degree of a node refers to the number of edges starting from that node.

In-degree: For directed networks, the in-degree of a node refers to the number of edges ending at that node.

Clustering coefficient [5]: In a network, the clustering coefficient of a node refers to the ratio between the actual number of connections between that node and its neighbors and the maximum possible number of connections. The clustering coefficient of the entire network is the average value of all node clustering coefficients in the network. The clustering coefficient is a parameter used to measure the closeness of nodes in a network with their neighbors.

The average path length: The average path length of a network is defined as the average distance between any two nodes. The distance between two nodes refers to the number of edges in the shortest path connecting them.

The scale-free property: The distribution of node degrees in a network follows a power-law distribution, i e., the number of nodes with a specific degree can be approximately represented by a power function, and this degree-dependent distribution is known as the scale-free property [6-8].

Small-world network: A network with high clustering coefficient and short global average path length is called a small-world network [9].

2.2. Network Construction

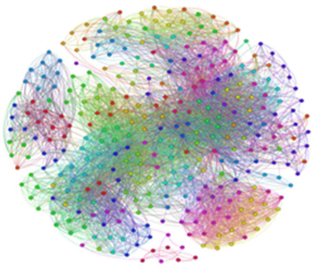


Figure 1. *American White Moth Pest Network in Liaoning Province from 2009 to 2013.*

The data in this article are from the 2009-2013 report data of the Forest Protection and Insect Pest Management Information Management System of the State Forest Protection General Station. The complex network of American white moth pests is constructed based on the spatial influence domain network model [10-13]. The distribution map of the network in 2013 is shown in Figure 1.

Take the different months of monitoring for American white moth pests from 2009 to 2013 as nodes, and connect the different months where American white moth occurred as edges. The statistics of node and edge numbers in each network are shown in Table 1:

Table 1. *Statistics of American White Moth Pest Complex Network from 2009 to 2013.*

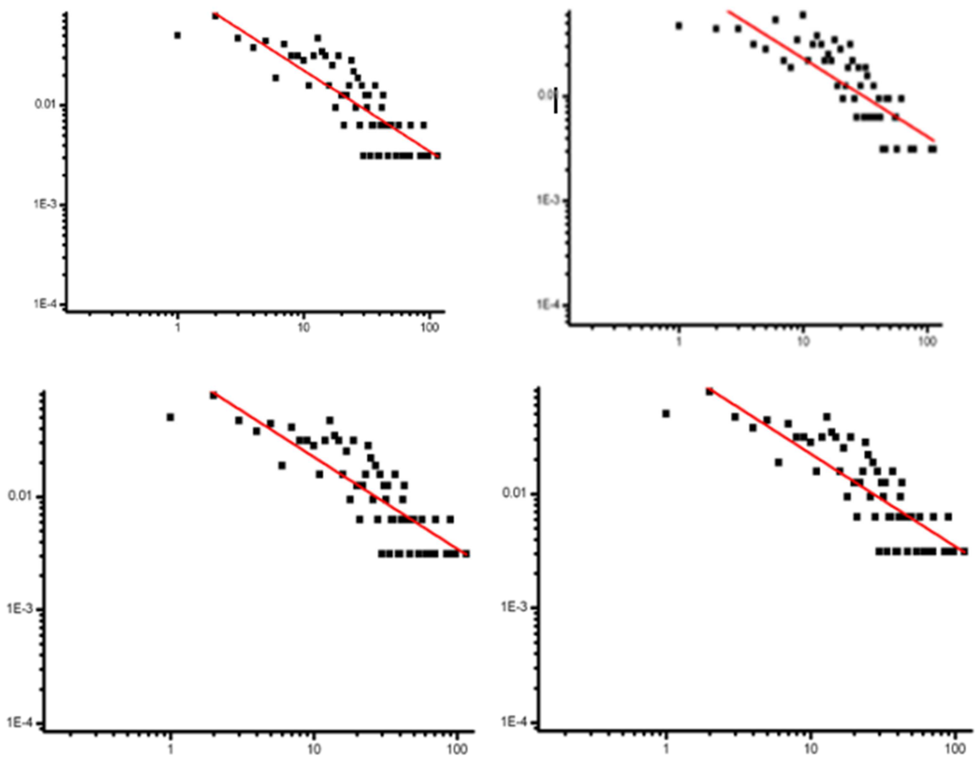
Year	Node Count	Edge Count
2009	320	5513
2010	247	3043
2011	176	1745
2012	238	2230
2013	327	4329

Among the five-year networks, in 2009, the number of connected nodes was the highest, and the impact was the greatest. In 2011, the number of nodes and edges was the smallest, and the affected area was small, resulting in the smallest scale network with the smallest impact.

3. Results and Analysis

3.1. Analysis of In-Degree and Out-Degree of the Overall Network

The in-degree and out-degree distribution of the American white moth pest complex network in 2009 is shown in Figure 2.



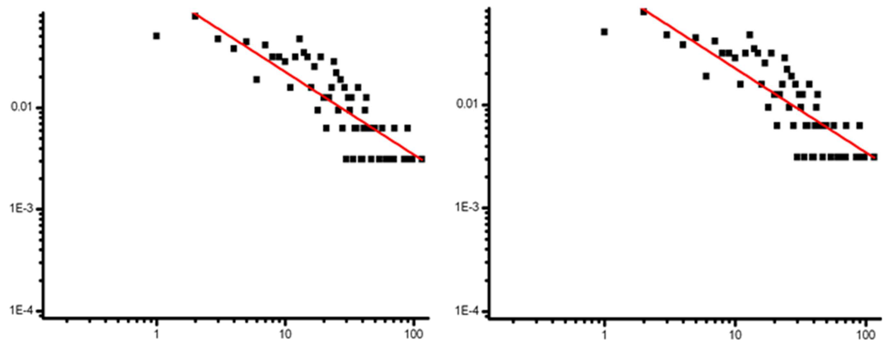


Figure 2. *In-degree and Out-degree Distribution of the American White Moth Pest Complex Network in 2009.*

The x-axis of the graph represents the logarithm value of in-degree (out-degree) of network nodes; the y-axis represents the logarithm value of the proportion of a certain in-degree (out-degree) node count to the total node count. The black dots on the graph represent the in-degree (out-degree) distribution of nodes. The diagonal lines on the graph are the fitted lines of the in-degree (out-degree) distribution. The closer the black dots are to the fitted lines, the larger the fitting coefficient. The statistics of fitting coefficients for American white moth pest complex networks from 2010 to 2013 in terms of in-degree and out-degree values can be found in Table 2.

Table 2. *Statistics of Fitting Coefficients for American White Moth Pest Complex Network in In-Degree and Out-Degree Values.*

Year	In-degree fitting coefficient	Out-degree fitting coefficient
2009	0.700	0.665
2010	0.831	0.653
2011	0.681	0.705
2012	0.797	0.772
2013	0.808	0.717

Through the analysis of data in Figure 1 and Table 2, it can be concluded that both in-degree and out-degree of the American white moth pest complex network from 2009 to 2013 obey power law distribution, indicating that the overall network has scale-free properties.

3.2. Analysis of the Evolution of Networks During Peak Months of American White Moth Larvae

The American white moth generally occurs in two generations in Liaoning Province, with the peak of the first generation in June and the peak of the second generation in September. We analyzed the degree distribution of June and September networks from 2009 to 2013 separately, as shown in Table 3 and Table 4.

Table 3. *Data statistics of American white moth pest complex network.*

Year	Node Count	Edge Count
2009-06	48	129
2010-06	41	98
2011-06	26	58
2012-06	15	18
2013-06	21	35

Table 4. *Statistics of American White Moth Pest Complex Network Data.*

Year	Node Count	Edge Count
2009-09	61	204
2010-09	61	198
2011-09	61	198
2012-09	65	200
2013-09	66	213

The analysis of the American white moth pest complex network in June of each year from 2009 to 2013 shows that the number of nodes and edges in the American white moth network was the highest in 2009, indicating that the first generation of American white moth larvae occurred frequently in many places with great impact between nodes. In contrast, in 2012, the number of nodes in the first generation network was only 15, which was the smallest number of nodes in any June since 2009. Generally speaking, the number of nodes and regions of second-generation American white moth larvae in September in Liaoning Province each year during five years were about the same.

The evolution of the American white moth pest complex network from June 2009 to September 2013 shows that the number and impact of infestation areas for American white moths in June were less than those in September, indicating that the range and density of the first generation of American white moths were smaller than those of the second generation. From the analysis of the degree distribution of the two generations of American white moth larvae at their peak periods in June and September, it can be concluded that it does not obey power law distribution.

3.3. The Evolution of the Average Degree of the Network

The average degree of a network refers to the average value of all node degrees in the network [14-15]. The evolution of the overall average degree of the American white moth pest complex network over five years and the average degree of the second generation larvae peak period are shown in Figure 3 and Figure 4.

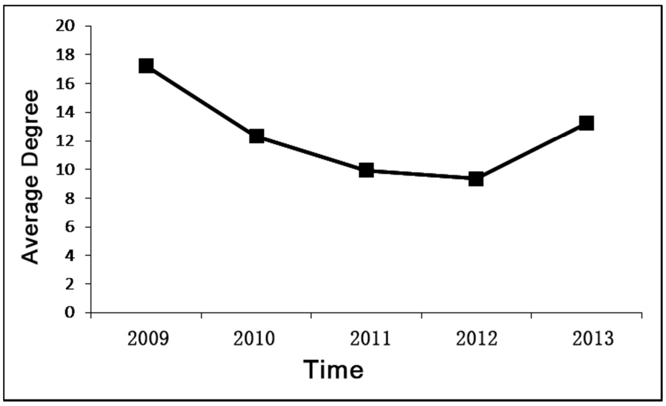


Figure 3. *The evolution of the average degree value of the American white moth pest complex network from 2009 to 2013.*

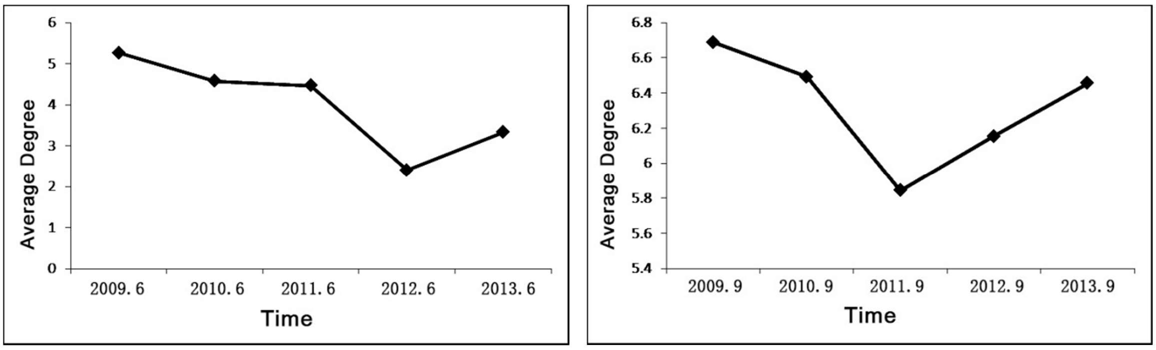


Figure 4. *The evolution of the average degree value of the American white moth pest complex network in June and September.*

Based on the analysis, the overall change in degree value of the American white moth pest complex network over five years was relatively stable, indicating that there were not significant changes in the distribution nodes of American white moths in Liaoning Province. In 2012, during the peak period of the first generation larvae in June, the average degree value decreased significantly, reaching a five-year low of 2.4. The average degree value of nodes during the second generation larvae peak period was relatively stable, remaining at around 6.0 with small fluctuations.

4. Conclusions and Discussion

The global degree distribution of the American White Moth pest complex network follows power-law distribution, and has scale-free feature; the global network is closely connected, the average degree value of regional nodes evolves relatively smoothly, and the change range is not large. However, the network in June and September during the two generations of juvenile peak periods has the characteristics of small world, with concentrated occurrence sites, close interconnection, aggregation, short network paths, and fast pest transmission.

References

[1] Liu Jianxiang. A review of complex networks and their research progress in China. Journal of Systems Science, 2009, 17 (4): 31-35.

[2] Feng Ying, Zhao Hai. Analysis of the hierarchical characteristeristics of IP-level topology dynamic node [J], IHMSC, 2014: 338-341.

[3] Feng Ying, Zhao Hai. Research on the Preference of Internet New Nodes' Connectivity. Computer Development and Applications, 2014 (12): 22-26.

[4] Zhang Wenbo. Research on the Life Characteristics of the Macroscopic Topology of Internet, Doctoral Dissertation, Northeastern University, 2006.

[5] Mi Xue. Research on Key Issues of Embedded Internet Time Characteristics Based on Complex Networks, Doctoral Dissertation, Northeastern University, 2014.

[6] Caldarelli G, Capocci A. Scale-free networks from varying vertex intrinsic fitness [J]. Phys Rev Lett. 2002, 89 (25): 258702.

[7] Newman M E J. The spread of epidemic disease on network [J]. Complexity Digest, 2002, 23, 420-425.

[8] Kim B J, Yoon C N. Path finding strategies in scale-free networks [J]. Physics Review E, 2002, 65.

[9] Amaral L A N, Scala A, Barthelemy M, et al. Classes of small-world networks. Proceedings of the National Academy of Sciences, USA. 2000, 97 (21): 11149-11152.

[10] Li Guangguang; Zhao Hai et al. Feature analysis of seismic activity network based on k-core decomposition [J], Journal of Earthquake Science, 2015, 37 (2): 239-248.

[11] He Xuan, Zhao Hai et al. Construction method of earthquake network based on spatiotemporal influence domain [J], Journal of Northeastern University (Natural Science Edition), 2014, 35 (10): 1395-1399.

[12] Liu Xiao, Zhao Hai, Feng Ying et al. Network science analysis method for forest pest big data, Journal of Northeast University (Natural Science Edition), 2016, 37 (10): 1255-1257.

[13] Wang Jinfa, et al. Construction and Analysis of Pest Relationship Network Based on Spatial Influence Domain, Journal of Northeast University (Natural Science Edition), 2016, 37 (12): 1701-1704.

[14] Feng Ying. Evolutionary analysis of network nodes in the American white moth pests, Fujian Computer, 2020 (4): 42-46.

[15] Feng Ying, Zhu Lin et al. Evolutionary analysis of scale-free characteristics of complex networks in American white moth pests in Liaoning Province, Liaoning Forestry Technology, 2020 (3): 31-33.