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Niche of insect borers within *Pinus massoniana* infected by pine wood nematode

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Abstract In November 2003 and June 2004, the insect borers and their spatial distribution within *Pinus massoniana* were investigated in Zhoushan City, in East China's Zhejiang Province, where pine wood nematode (*Bursaphelenchus xylophilus*) are typically found. The niche width, proportional similarity of niche and the niche overlap of dominant species of dying trees were computed. Results show that five insect species infect and damage *Pinus massoniana*, which had been infected by pine wood nematodes, among which four are wood boring beetles and one termite. Species within host trees vary from winter to summer and all the species have their own niche width, proportional similarity of niche and the niche overlap. They can achieve competitive equilibrium and coexistence according to their biological characteristics and life habits.

Keywords pine wood nematode, insect borer, niche

1 Introduction

The concept of niche, which was initially defined by Grinnell in 1917, has been studied further by lots of researchers (Pang and You, 1996). To sum up, niche describes how the species use resources in their environment and how they compete for the resources against others. Directed by this

theory, Chen et al. (1999) studied the niche of bark beetles within *Pinus armandi* in the Qinling mountains, and discussed the mechanism of coexistence between the bark beetles in the pine and explored the theory of stability of ecosystem. Yan et al. (2003) discovered the competitive relation and following effect between *Aphis gossypii* in *Hibiscus syriacus* and their predaceous natural enemies by analyzing population fluctuation of the two groups.

Pine wilt disease, which is caused by pine wood nematode (*Bursaphelenchus xylophilus*) that is regulated as an internal and external quarantinable object, is a fatal calamity to pine forests. Since the disease was first found in Zhongshan Musoleum in Nanjing, it has now widely spread in pine forests in lots of areas such as Jiangsu, Zhejiang, Anhui, Shandong, Guangdong, Taiwan and Hong Kong. In addition, the nematode has infected some pine forests in some places like Hunan, Hubei, Guizhou, Guangxi, and Fujian Provinces these years. All this had resulted in enormous loss economically and ecologically (Chai and Jiang, 2003).

In China, the nematode mainly damages two host trees, namely, *Pinus massoniana* and *P. thunbergii*. It transfers and spreads by attaching itself to a vector *Monochamus alternatus* in forests. When the longhorn beetle gnaws at pine twigs or oviposits on trunks, the nematode intrudes into the pine tree through the wounds in pine. When infected by pine wood nematode, pines will become weak and less resistive so that insect borers can live in them. In dying pines, insect borers utilize mutually and efficaciously all kinds of nutrition and space resources because of their different bioecological characters and restrictive relation with host trees (Miller, 1980; Hassell et al., 1991; Pickett and Cadenasso, 1995).

Taking vectors as objects and choosing a typical pine forest ecosystem intruded by pine wood nematode as sites, this paper will study the diversification of insect structure and diversity, then finally reveal the time-space fluctuation rule of insect borers' niches. Using natural forestry and by the way of ecological control, the authors hope to build an optimized ecosystem by ameliorating the former ecosystem structure to improve the resistance of the forest ecosystem

Translated from *Journal of Beijing Forestry University*, 2005, 27(6): 108–111 [译自: 北京林业大学学报, 2005, 27(6): 108–111]

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itself.

2 Materials and methods

2.1 Introduction of sample plot

Zhoushan City is located in the south of the northern subtropical zone and has a monsoon climate. The annual average climate temperature is 15.6–16.6°C, and monthly average temperature is 25.6°C in June, July and August. The annual average precipitation is 936–1,330 mm, and the annual sunlight time is about 1,940–2,257 h. Its condition of warm winter and cold summer, snugness and clouding, plentiful illumination, and abundant heat is very beneficial to the existence of pine wood nematode.

A special sample plot of 30 m×30 m was chosen at Xianglian Village (29°55'54"N and 122°23'60"E), Zhoushan City of Zhejiang Province, with an elevation of 62.3 m. The site was selected at a southwestern upper slope with a degree of 25°. The main species in the forest is middle-aged Masson pines whose average diameter at breast height is 6.84 cm and average tree height is 4.33 m. In 1997, pine wilt disease broke out in this forest, and then dead trees were cut down and moved.

2.2 Methods

In November 2003 and June 2004 when insect borers were winter larvae and of adult ages, respectively, three pine trees were randomly selected and cut into 1-m long segments. Then, the segments were split to investigate species and numbers of insect borers in them. Finally, the species were determined by identifying their adults that were collected with attractant M99.

2.3 Parameter

Description of niche width and niche overlap cites formulas that Levins put forward in 1968:

$$B = 1 / \sum_{i=1}^s p_i^2 (S) \quad (1)$$

where B is the niche, P_i is the probability of some species in some resource and S is the sum of the resource.

$$a_{ij} = \sum_{h=1}^n p_{ih} p_{jh} (B_i) \quad (2)$$

where a_{ij} is the niche overlap of species i and j , p_{ih} and p_{jh} are probabilities of some insect borers in some resources respectively, and B_i is the niche width of species i .

Proportional similarity is introduced with the following formula by Schoener in 1968:

$$C_{ij} = 1 - 1/2 \sum_{h=1}^s |p_{ih} - p_{jh}| \quad (3)$$

where C_{ij} is the proportional similarity of species i and j and $C_{ij}=C_{ji}$.

3 Result and analysis

Pines always die at the end of summer if they are invaded by pine wood nematode at the beginning of summer when no symptoms appear on the exterior of pines. Most of the dying trees died in the same year, while a few died in the middle of the following year because the pines were infected later. According to the survey, the diversity of insect borers in dying pines is largest. In the trees, there are five species, namely *Shirahoshizo insisiosus*, *Monochamus alternatus*, *Tomicus minor*, *T. piniperda* and *Odontotermes formosanus*. They utilize all kinds of resources rationally and efficaciously for their different life characters by some ways such as choosing special habitat, different niches and inter-specific competition etc. (Thompson and Gaston, 1999).

3.1 Niche width

Analyses were carried out with trunks and crowns of *Pinus massoniana* as habitats and height marked as resource sequence. The results (Table 1) show that distribution and niche width of the insect borers were quite different between different seasons and different insects' stages. Based on the data of November, *M. alternatus*, whose niche width was the widest at 0.939,3, can distribute vertically and well-proportionally in whole trunks. In contrast, in June, the beetle can live in dying pines sporadically. In the east of Zhejiang Province, *M. alternatus* lives in trunks as larvae in November while most of them fly in forests as adults in June. Therefore, in June, there were only a few pupae in wood, especially in the moist xylem lower than 2 m. *T. piniperda* could only be found on the top of crowns for they distribute in twigs as adults to over winter in November. Whereas most of *S. insisiosus* as larvae live in the phloem lower than 1 m, and its niche width is narrow. Furthermore, there are plenty of *O. formosanus* that incubate in the phloem in trunks near the ground.

Table 1 Spatial distribution and niche width of insect borers within dying pines

| Species | November, 2003 | | June, 2004 | |
|--------------------------------|----------------|-------------|--------------|-------------|
| | Distribution | Niche width | Distribution | Niche width |
| <i>Shirahoshizo insisiosus</i> | Phloem, xylem | 0.200,0 | Phloem | 0.200,0 |
| <i>Monochamus alternatus</i> | Xylem | 0.939,3 | Phloem | 0.337,9 |
| <i>Tomicus minor</i> | | | Phloem | 0.350,7 |
| <i>Tomicus piniperda</i> | Twig | 0.444,7 | | |
| <i>Odontotermes formosanus</i> | Phloem | 0.200,0 | Phloem | 0.200,0 |

3.2 Proportional similarity of insect borers

Proportional similarity reflects the similar degree of two species using the same resource. After computing and analyzing proportional similarity of insect borers in dying pines, results are shown in Tables 2 and 3.

Based on Table 2, in winter, the proportional similarity between *M. alternatus* and *T. piniperda* is higher because the longhorn beetle live through winter in some branches and in treetops. The proportions of using space resource are the same between *S. insisiosus* and *O. formosanus*.

Table 3 shows that in June, the proportional similarities of *M. alternatus* with the other three species *S. insisiosus*, *T. minor*, *O. formosanus* are all high. The proportions of using space resource are the same between *S. insisiosus* and *O. formosanus*, which were the same as those in November.

3.3 Niche overlap

The concept of niche overlap comes down to several issues

like harmonious coexistence, competitive repulsion and restrictive similarity among species, and expresses resemblance of the species' ecological characters, and shows a situation of separation and overlap of species' niches.

Table 4 indicates the niche overlap of 4 insect borer species. In winter, the locations of *T. piniperda*, *S. insisiosus*, *O. formosanus* were discrepant prodigiously. There is no competition to strive for space and nutrition so that the niches of these species were separated entirely. But to *M. alternatus*, which has the widest niche width and location throughout dying trunks, the niche overlaps with other species more or less. The niche overlap of *S. insisiosus* and *O. formosanus* was the biggest for the two species living in the same resource sequence and their niche widths were uniform.

Table 5 shows the result from data of June. The three species *M. alternatus*, *S. insisiosus* and *O. formosanus* coexisted provisionally because they can use the conjunct space and nutrition resource by competition and their niche overlap is big, while *T. minor* can compete for resources with *O. formosanus*.

Table 2 Proportional similarity of insect borers within dying pines in November

| Species | <i>Shirahoshizo insisiosus</i> | <i>Tomicus piniperda</i> | <i>Monochamus alternatus</i> | <i>Odontotermes formosanus</i> |
|--------------------------------|--------------------------------|--------------------------|------------------------------|--------------------------------|
| <i>Shirahoshizo insisiosus</i> | 1 | 2.29×10 ⁻⁷ | 2.33×10 ⁻⁷ | 1 |
| <i>Tomicus piniperda</i> | | 1 | 0.545 | 2.29×10 ⁻⁷ |
| <i>Monochamus alternatus</i> | | | 1 | 2.33×10 ⁻⁷ |
| <i>Odontotermes formosanus</i> | | | | 1 |

Table 3 Proportional similarity of insect borers within dying pines in June

| Species | <i>Shirahoshizo insisiosus</i> | <i>Monochamus alternatus</i> | <i>Tomicus minor</i> | <i>Odontotermes formosanus</i> |
|--------------------------------|--------------------------------|------------------------------|----------------------|--------------------------------|
| <i>Shirahoshizo insisiosus</i> | 1 | 0.712,1 | 0 | 1 |
| <i>Monochamus alternatus</i> | | 1 | 0.644,8 | 0.712,7 |
| <i>Tomicus minor</i> | | | 1 | 0 |
| <i>Odontotermes formosanus</i> | | | | 1 |

Table 4 Niche overlap of wood insect borers within dying pines in November

| Species | <i>Shirahoshizo insisiosus</i> | <i>Tomicus piniperda</i> | <i>Monochamus alternatus</i> | <i>Odontotermes formosanus</i> |
|--------------------------------|--------------------------------|--------------------------|------------------------------|--------------------------------|
| <i>Shirahoshizo insisiosus</i> | 1 | 0 | 0.038,6 | 0.2 |
| <i>Tomicus piniperda</i> | 0 | 1 | 0.010,5 | 0 |
| <i>Monochamus alternatus</i> | 0.085,8 | 0.022,2 | 1 | 0.085, 8 |
| <i>Odontotermes formosanus</i> | 0.2 | 0 | 0.038,6 | 1 |

Table 5 Niche overlap of wood insect borers in dying pines in June

| Species | <i>Shirahoshizo insisiosus</i> | <i>Monochamus alternatus</i> | <i>Tomicus minor</i> | <i>Odontotermes formosanus</i> |
|--------------------------------|--------------------------------|------------------------------|----------------------|--------------------------------|
| <i>Shirahoshizo insisiosus</i> | 1 | 0.142,9 | 0 | 0.200,0 |
| <i>Monochamus alternatus</i> | 0.241,4 | 1 | 0.030,2 | 0 |
| <i>Tomicus minor</i> | 0 | 0.030,2 | 1 | 0.197,3 |
| <i>Odontotermes formosanus</i> | 0.200,0 | 0.241,4 | 0 | 1 |

4 Conclusions

1. The study on the niche of insect borers opened out their inter-specific relationship. All kinds of insect borers habitat steadily in hosts, and they utilize mutually and efficaciously all kinds of the nutrition and space resources because of their different bioecological characters and restrictive relation with host trees. All the little animals collectively accelerated the death of the hosts and stimulated the succession of the pine forests ecosystem.

2. In dying trees of pine forests that were invaded by *B. xylophilus* in the Putuo region, Zhoushan City, Zhejiang Province, there were 5 species: *S. insisiosus*, *M. alternatus*, *T. minor*, *T. piniperda* and *O. formosanus*. There were on average 11.7 *S. insisiosus*, 34 *M. alternatus*, 10.66 *T. minor*, 93 *T. piniperda* and quite a number of *O. formosanus* in a tree.

3. Species, amount and the character exponents of niches were very different between the groups in dying pines of June and November. It was tightly correlative with the diversity of insects' life histories and behaviors. In November, beetles lived through the winter as adults in pine twigs, so there were no competitors for them. However, in June, they lived in trunks as larvae, pupae and adults, and strived for space and nutrition resource against other species. In summer, large numbers of *T. minor* existed in dying trees as larvae, pupae and adults while sporadic *T. piniperda* hid in twigs as adults. This situation was caused by histories of the two species. In east of Zhejiang, the cycle of *T. minor* advances that of *T. piniperda* for about 20 days. In the middle of June, it was the eclosion end of *T. minor* whereas it was only the middle for *T. piniperda*. Up to now, *T. minor* has already bored in trunks and oviposited in it, which damage the transporting organism of the trees' phloem and xylem. The condition of the host is then not fit for *T. piniperda* because of the less water and nutrition in the trees.

4. *Monochamus alternatus* as the uppermost vector of pine wood nematodes, was the preponderant species in typical forests infected by the disease. In winter, they well-proportionally distributed along dying trunks, which was consistent with the locations of eclosion holes in summer. In June, the longhorn beetle rarely lived in trunks lower than 2 m

as pupae and larvae, which can hardly damage the pines. They inclined to live in the middle-lower trunks as eggs, larvae and pupae than in branches and lower. Furthermore, it is likely that the amount of water in dying trees was relative to eclosion of longhorn beetles (Zhao and Ying, 1988).

5. At present, time fluctuation of insect borers' invasion to pines needs more study.

Acknowledgements We thank Mr. Zhao Jinnian and Xu Tiansen from Chinese Academy of Forestry and Ying Songkang from the Forest Insects Quarantine Station of Zhoushan City, Zhejiang Province for their kind help in the investigation.

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