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Interspecific Relationship Between *Monochamus alternatus* Hope and *Arhopalus rusticus* (L.) in *Pinus thunbergii* Affected by Pine Wilt Disease

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Abstract: *Monochamus alternatus* Hope and *Arhopalus rusticus* (L.) are important stem-boring pests that co-occur on weakened *Pinus* spp. Their larvae damage the xylem and phloem of the trunks and branches. At present, the consequences of the interspecific relationship between two longicorn beetles on the same host of *Pinus* trees are unclear. The population dynamics and spatial distribution of these two species on *Pinus thunbergii* trees were investigated to clarify the ecological niches and interspecific relationship of two longicorn beetles on the different degrees of decline in *P. thunbergii* trees. The results showed temporal niche overlap values from 0.02 ± 0.01 to 0.05 ± 0.02, suggesting a very high degree of temporal ecological niche segregation and no competition in temporal niche resources. There is significant interspecific competition between the two longicorn beetles in spatial distribution, and the spatial niche overlap values are 0.67 ± 0.11 and 0.61 ± 0.09 in the middle and late stages of the decline in *P. thunbergii* trees, respectively.

Keywords: interspecific relationship; ecological niche; *Monochamus alternatus*; *Arhopalus rusticus*

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1. Introduction

Pinus thunbergii, renowned for its rapid growth, robust wind resistance, and resilience to drought and infertile soil, has emerged as a key species in the coastal protection forests of Shandong Province, China [1,2]. Regrettably, in recent years, the coastal protection forests have suffered considerable damage from stem-boring pests and pine wilt disease (PWD), resulting in huge economic and ecological losses [3].

Monochamus alternatus Hope and *Arhopalus rusticus* (L.) are stem borers that often occur together and cause damage on the weakened trees of *P. thunbergii* in Shandong Province, China [3–5]. *M. alternatus* is an important vector insect of PWD, which is a highly dangerous and destructive pine forest disease caused by *Bursaphelenchus xylophilus* (Steiner & Buhere, 1934) Nickle 1970 in China [6,7]. Adult *M. alternatus* feed on healthy pine trees, causing wounds in the bark where nematodes can enter and spread throughout the tree [8,9]. Meanwhile, the larvae of *M. alternatus* feed inside the xylem of the weakened wood, accelerating the death of the tree [7]. *A. rusticus* is another important stem-boring pest of *P. thunbergii* [5]. In recent years, the number of weakened *P. thunbergii* has increased dramatically due to a major outbreak of PWD, which has provided favorable conditions for *A. rusticus* [10]. *A. rusticus* lays eggs on weakened pine trees, and the hatched larvae bore and feed on the stem and root–stem junctions [4,11]. The early instar larvae burrow under the phloem of the host plant, and after 3–4 instars, they burrow into the xylem, which accelerates the decline and even the death of the host plant [12].

The larvae of both *M. alternatus* and *A. rusticus* bore and feed on the xylem, competing for resources [3,4]. According to the principle of competitive exclusion, two similar species cannot occupy similar ecological niche [13,14]. In fact, there is a spectrum of interspecific competition intensity, ranging from the weakest, stable coexistence to the strongest, no coexistence [15]. Unstable coexistence represents a significant point along this spectrum, characterized by ongoing direct interactions between species that could potentially favor one competitor due to disproportionate exploitation of resources [16,17]. At present, it is not clear whether the utilization of pine resources and the degree of interspecific competition between the two species of longhorn beetle will change in pine trees with different degrees of weakness. Therefore, the population dynamics of two adult beetles in the same pine forest and the spatial distribution of their larvae on the trunk and stumps (including underground roots) of the same pine tree were investigated to clarify the level of interspecific competition between these two species of longhorn beetles on pine trees with different degrees of weakness.

2. Materials and Methods

2.1. Study Sites

The study site is located at the coastal protection forest in Muping District in Yantai (37.45 °N, 121.87 °E), Shandong Province. The coastal protection forest mainly consists of *P. thunbergii* as the main tree species. The average breast diameter and average height of *P. thunbergii* are 30.35 ± 3.08 cm and 10.43 ± 1.76 m, respectively. Since 2015, this pine forest has been infected with PWD, causing noticeable tree mortality. The attraction area of the experimental site is 500 hm^2.

2.2. Population Dynamics of Two Longicorn Beetles in the Forest of P. thunbergii

From 1 May to 15 November, a total of 40 traps were hung at the forest's edge, interior, and slope crest to monitor population changes in the longicorn beetles. The traps were hung so that the bottom of the collection bottle was 1.5 m from the ground and the distance between two adjacent traps was >50 m. The attractant used was an APF-I persistent enhanced pheromone (purchased from Fujian Chenkang Agriculture and Forestry Technology Co., Ltd. (Quanzhou, China)), with the main components being the *M. alternatus* aggregation pheromone combined with pine terpenoids. The traps were checked every 15 days, and the number and species of longicorn beetles in the trap were recorded. In addition, a micro temperature recorder (MIK-TH802, Hangzhou Meacon automation technology Co., Ltd., Hangzhou, China) was used to record the temperature changes in the study pine forest.

2.3. Spatial Distribution of Two Longicorn Beetle Larvae in P. thunbergii

In the spring of 2019 and 2020, a total of 20 weakened *P. thunbergii* trees were investigated to determine the spatial distribution of two species of longicorn beetle larvae, including 5 individuals each in the early, middle, late stages of decline, plus 5 wilting death trees (Figure 1). The symptoms in the early stage of decline manifest as some discoloration in the pine needles. The symptoms in the middle stage of decline include 1/3 to 2/3 of the branches and needles turning yellow and the needles at the tips beginning to wilt. The symptoms in the late stage of decline are characterized by the majority of needles turning yellow, losing their luster, and turning reddish brown. The symptoms of wilting death are characterized by yellowing of the top shoots, wilting of the branches, and a grayish brown transformation of the needles.

The selected trees were harvested, and the trunk was cut into 0–1 m, 1–2 m, 2–3 m, 3–4 m, 4–5 m, and more than 5 m long wood segments. Additionally, the root was extracted and dissected, and the spatial distribution of the two species of longicorn beetle larvae was recorded section by section. The larvae of the two species of longicorn beetles were distinguished by their pronotum surface morphology (Figure 2A,B).

Figure 1. The characteristics of the four decline stages of *P. thunbergia*: (**A**) early stage of decline, (**B**) middle stage of decline, (**C**) later stage of decline, and (**D**) wilting death stage.

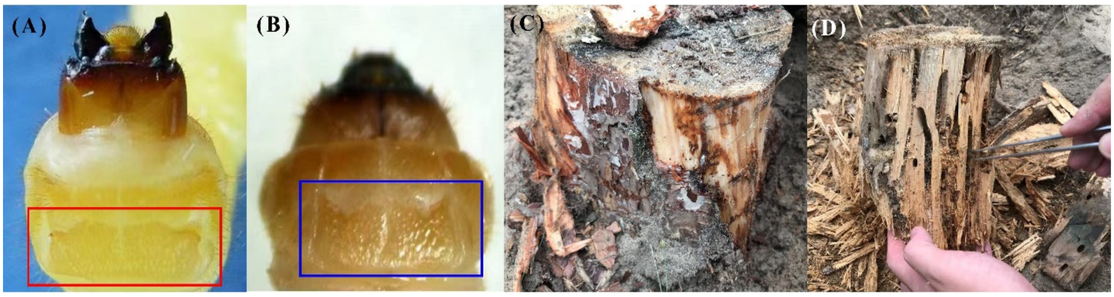

Figure 2. Two longicorn beetle larvae and the stump of *Pinus thunbergii*. (**A**) *M. alternatus* larvae, (**B**) *A. rusticus* larvae, (**C**) stump in the current year, and (**D**) stump in the next year.

2.4. Spatial Distribution of A. rusticus Larvae in the Stump of P. thunbergii

When the pine trees infected with PWD were harvested in October 2019, the 30 stumps were randomly selected and marked (the average diameter of the stumps was 28.58 ± 2.62 cm, and the average height was 9.86 ± 0.54 cm). These 30 stumps were divided into 3 groups of 10 stumps each and investigated in October 2019, June 2020, and October 2020, respectively (Figure 2C,D). The species, number, and position of longicorn beetle larvae in the stump were recorded, and the method of *A. rusticus* larval age division was used to determine the larval stage [18].

2.5. Data Analysis

Levin's index of niche breadth (B) [19] and Pianka's niche overlap index (O_{jk}) [20] were used to calculate the niche breadth and niche overlap values of *M. alternatus* and *A. rusticus*. The Levin's index and Pianka's niche overlap index are calculated using the following expressions (1) and (2), respectively.

$$\text{Niche breadth } (B) = 1/\sum_{i=1}^{n} P_i^2 \tag{1}$$

$$\text{Niche overlap } \left(O_{jk}\right) = \sum_{i=1}^{n} P_{ij}P_{ik}/\sqrt{\sum_{i=1}^{n} {P_{ij}}^2 \sum_{i=1}^{n} {P_{ik}}^2} \tag{2}$$

where P_i represents the proportion of a given resource i, and P_{ij} and P_{ik} represent the proportion of resource i among the total resources used by species j and k. n is the total number of resources (12 for temporal niche and 7 for spatial niche). The values of niche breadth and niche overlap range from 1 to n and 0 (no overlap) to 1 (complete overlap), respectively [19,20]. A niche overlap value from 0.3 to 0.6 indicates that niche overlap has some significance and there is a certain degree of overlap in resource utilization. $O_{jk} > 0.6$ indicates that niche overlap is significant.

One-way analysis of variance (ANOVA) was used to test the differences in the number of the two species of longicorn beetles in different weakness stages and the distribution proportion at different heights of trunk and stump. In addition, an independent sample t-test was used to test the difference in the number and niche breadth of the two species of beetle larvae during the same weakness stages of *P. thunbergii*. The experimental results were analyzed in IBM SPSS software (version 20.0, Armonk, New York, NY, USA).

3. Results

3.1. Population Dynamics and Temporal Niche of Two Species of Longicorn Beetles

The total number of trapped adult *M. alternatus* and *A. rusticus* were 23,892 (11,117 in 2019 and 12,775 in 2020) and 16,656 (12,035 in 2019 and 4621 in 2020), respectively. The temporal overlap values were 0.05 ± 0.02 in 2019 and 0.02 ± 0.01 in 2020, indicating a high degree of separation of the temporal ecological niches of the two species of adults (Table 1). The adults of newly emerged *M. alternatus* and *A. rusticus* can be trapped in late May in Yantai (daily average temperature 19.5 °C, minimum temperature 13 °C, and maximum temperature 26 °C) (Figure 3). The trapping numbers peaked for *M. alternatus* in mid-July (daily average temperature 26 °C, minimum 20 °C, and maximum 32 °C) and decreased as the temperature increased. By the end of September, when the daily average temperature was lower than 19 °C, *M. alternatus* were no longer trapped. The first trapping peak of *A. rusticus* was mid-June (daily average temperature 21.5 °C, minimum 16 °C, and maximum 27 °C), but when the average temperature of the day exceeded 25 °C, the number of trapped adults of *A. rusticus* gradually decreased as the temperature increased. The second peak of the *A. rusticus* was mid-September (daily average temperature 22 °C, minimum 16 °C, and maximum 26 °C), and *A. rusticus* adults could not be trapped by mid-October when the daily average temperature was below 14 °C.

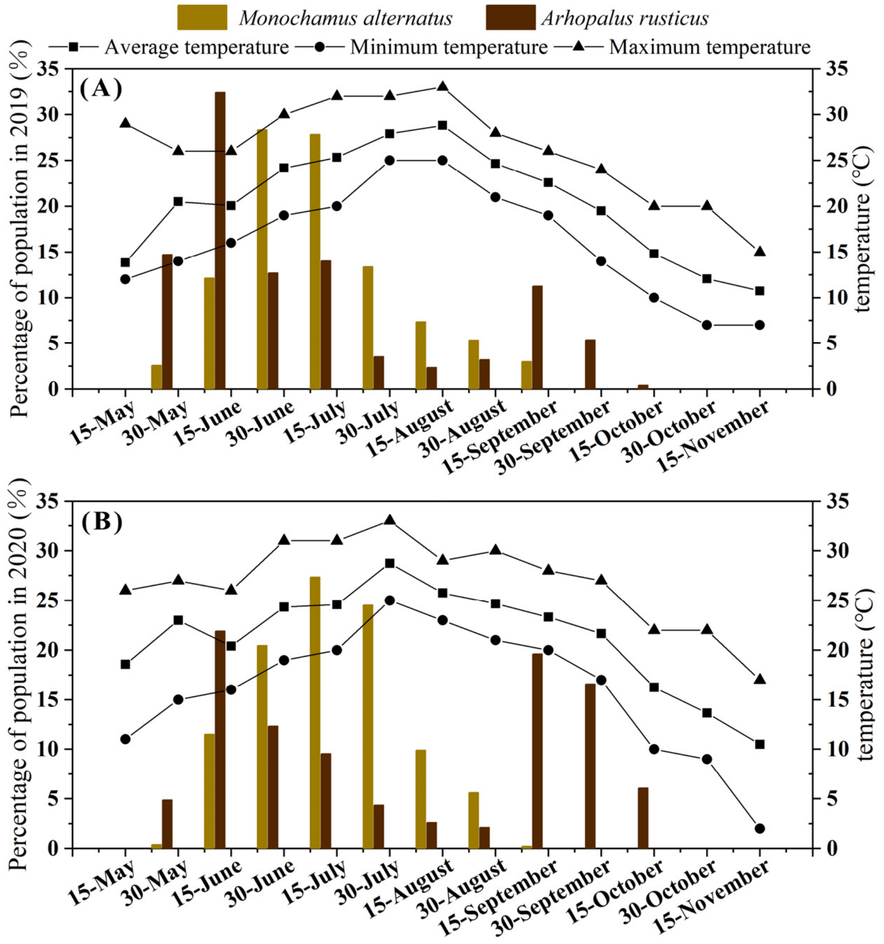

Figure 3. Seasonal dynamics of the two species of longicorn beetles in a *P. thunbergii* forest: (**A**) population in 2019; (**B**) population in 2020.

Table 1. Comparison of Levin's temporal niche breath (*Bte*) and Pianka's temporal niche overlap (*Ote*) values between *M. alternatus* and *A. rusticus*.

Years	**Species**	***n***	***Bte* Mean ± SD**	***Ote* Mean ± SD**
2019	*Monochamus alternatus*	11,117	4.98 ± 0.10	0.05 ± 0.02
	Arhopalus rusticus	12,035	5.52 ± 0.21	
2020	*Monochamus alternatus*	12,775	4.92 ± 0.09	0.02 ± 0.01
	Arhopalus rusticus	4621	6.77 ± 0.34	

3.2. Spatial Distribution of Two Longicorn Beetle Larvae in *P. thunbergii*

A total of 535 *M. alternatus* larvae and 744 *A. rusticus* larvae were collected. No other species of beetle larvae were found during this study. As the pine trees weakened, the number of *M. alternatus* larvae decreased (54.40 per tree to only 3.60), while the number of *A. rusticus* larvae increased (8.20 per tree to 55.80) (Table 2). There were significant differences in the average proportion of larvae of the two species at different host decline stages ($p < 0.05$) (Figure 4).

Table 2. Levin's spatial niche breath (*Bsn*) and Pianka's spatial niche overlap (*Osn*) values between two species of longicorn beetle larvae. Data in the table are mean ± SD of five replications ($n = 5$). Lowercase letters indicate significant differences in the number of *M. alternatus* larvae between four decline weakness stages of *P. thunbergii* ($p < 0.05$). Capital letters indicate significant differences in the number of *A. rusticus* larvae between four weakness stages of *P. thunbergii* ($p < 0.05$).

Weakness Stages	**Species**	***n* Mean ± SD**	***Bsn* Mean ± SD**	***Osn* Mean ± SD**
Early stage	*Monochamus alternatus*	54.40 ± 9.44 a	4.12 ± 0.57	0.39 ± 0.11
	Arhopalus rusticus	8.20 ± 5.64 C	1.79 ± 0.22	
Middle stage	*Monochamus alternatus*	37.80 ± 11.72 b	4.28 ± 0.57	0.67 ± 0.11
	Arhopalus rusticus	35.20 ± 8.11 B	3.62 ± 0.41	
Later stage	*Monochamus alternatus*	11.20 ± 6.97 c	3.24 ± 0.98	0.61 ± 0.09
	Arhopalus rusticus	49.60 ± 10.03 AB	4.60 ± 0.38	
Wilting death stage	*Monochamus alternatus*	3.60 ± 4.45 c	1.99 ± 0.14	0.29 ± 0.04
	Arhopalus rusticus	55.80 ± 13.29 A	5.05 ± 0.57	

In the early stage of decline, *M. alternatus* larvae were mainly distributed in the lower part of the trunk (63.27% of the total number of larvae < 3 m from the ground), while *A. rusticus* larvae were present from 0 (ground) to 2 m (Figure 4A). However, the distribution range occupied by *M. alternatus* larvae was larger than that of *A. rusticus* larvae (spatial niche breath value 4.12 ± 0.57 for *M. alternatus* larvae and 1.79 ± 0.22 for *A. rusticus* larvae, $p < 0.001$, $t = 7.65$), and the spatial niche overlap value was 0.39 ± 0.11, suggesting a certain degree of separation between the two species. At the middle stage of decline, 75.62% of *M. alternatus* larvae were 1–4 m from the ground, while the distribution of *A. rusticus* larvae did not change (Figure 4B), creating significant overlap (niche overlap value 0.67 ± 0.11) between the two species. With further host tree weakening, the distribution range of *M. alternatus* larvae narrowed to 2–4 m from the trunk (71.29% of the total number of larvae) while those of *A. rusticus* expanded to include the roots (16.84%), as well as to the lower (ground to 1 m, 32.76%) and higher (24.01% of larvae at 3–4 m) parts of the trunk (Figure 4C). Similar to the previous situation, there was significant overlap between the two species. However, there was a clear separation (niche overlap value 0.29 ± 0.04) on the withered and dead trees: *M. alternatus* larvae occurred in the branches and >5 m in the trunk, while *A. rusticus* larvae were in the roots (21.87%) or the low parts (ground −2 m, 45.81%) (Figure 4D).

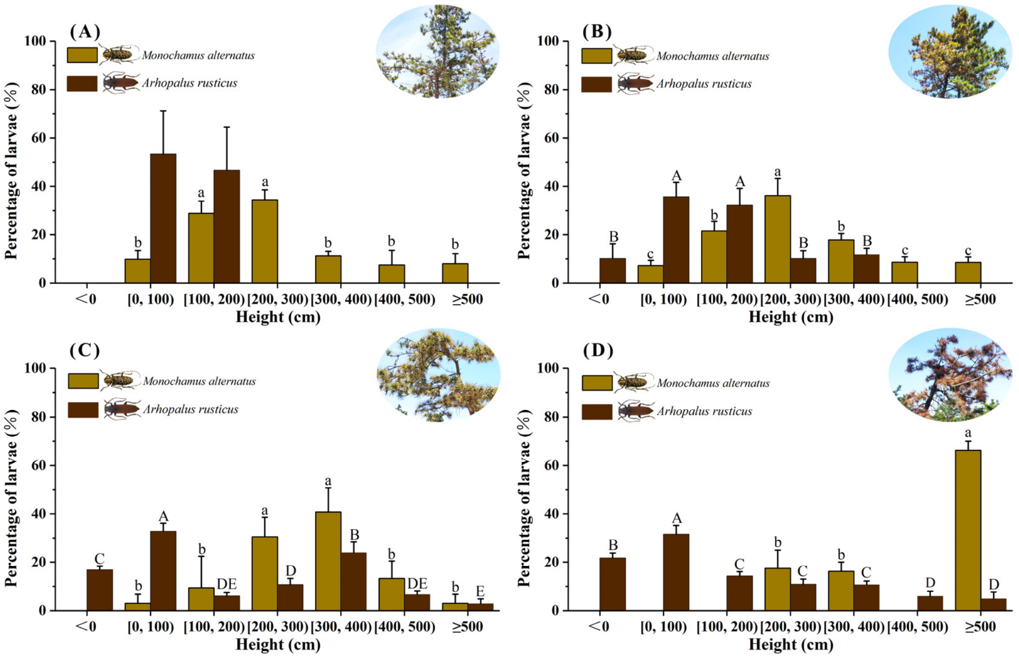

Figure 4. The within-trunk distribution of *Monochamus alternatus* and *Arhopalus rusticus* larvae in their host plant *P. thunbergii* at various vigor levels: (**A**) early stage of decline, (**B**) middle stage of decline, (**C**) stage of decline, and (**D**) dead. Data in the figure are mean ± SD of five replications ($n = 5$). Lowercase letters and capital letters indicate significant differences of distribution proportion at different heights for *M. alternatus* and *A. rusticus* larvae, respectively ($p < 0.05$).

3.3. Spatial Distribution of A. rusticus Larvae in the Stump of P. thunbergii

The survey showed that only *A. rusticus* larvae and no *M. alternatus* larvae were found in the stumps of *P. thunbergii*. The larvae of *A. rusticus* had different spatial distribution characteristics in the stump of *P. thunbergii* at different times (Table 3). At the beginning of felling, *A. rusticus* larvae were mainly concentrated 0~5 cm above the ground of the *P. thunbergii* stump, and the deepest distribution was in the roots 10 cm underground. In June of the next year, *A. rusticus* larvae were widely distributed on the roots 0~68 cm underground, below the stumps, with the deepest distribution reaching 68 cm underground. In October of the next year, the larvae of *A. rusticus* distributed on the roots 0~25 cm underground, below the stumps, with the deepest reaching 28 cm underground. In addition, there were also some differences in the larval age of *A. rusticus* at different times (Table 4). The larval ages of *A. rusticus* at the beginning of felling *P. thunbergii* were mainly 1–3 instars, 3–11 instars in June of the next year, and 4–11 instars in October of the next year.

Table 3. Spatial distribution of *Arhopalus rusticus* larvae at different periods in the stump of *P. thunbergii*. Data in the table are mean ± SD of ten replications ($n = 10$). Different lowercase letters in the same column indicate significant differences in the distribution proportion at different heights for *A. rusticus* larvae ($p < 0.05$).

Height (cm)	Percentage of Larvae of *A. rusticus*		
	October 2019	June 2020	October 2020
≥10	4.86 ± 1.33 c	0.00	0.00
[5, 10)	27.70 ± 0.85 b	0.00	0.00
[0, 5)	60.70 ± 2.31 a	0.00	0.00
[−5, 0)	3.72 ± 1.46 c	10.83 ± 1.35 b	27.89 ± 3.05 a
[−10, −5)	1.50 ± 0.57 d	13.45 ± 1.82 b	25.66 ± 3.17 a

Table 3. *Cont.*

Height (cm)	Percentage of Larvae of *A. rusticus*		
	October 2019	June 2020	October 2020
[−15, −10)	1.51 ± 1.62 d	7.85 ± 0.88 c	14.20 ± 2.55 b
[−20, −15)	0.00	26.24 ± 1.80 a	18.05 ± 2.97 b
[−25, −20)	0.00	7.14 ± 2.39 c	11.76 ± 1.83 b
[−30, −25)	0.00	5.62 ± 1.12 d	2.44 ± 1.44 c
[−35, −30)	0.00	8.99 ± 1.16 c	0.00

Table 4. *A. rusticus* larval instars in the stump at different periods. Data in the table are mean ± SD of ten replications ($n = 10$). Different lowercase letters in the same column indicate significant differences in the proportion of *A. rusticus* larvae at different ages ($p < 0.05$).

Instar	Percentage of Larvae of *A. rusticus*		
	October 2019	June 2020	October 2020
1	46.32 ± 3.03 a	0.00	0.00
2	26.90 ± 4.99 b	0.00	0.00
3	24.18 ± 0.34 b	9.52 ± 2.73 ab	0.00
4	2.60 ± 2.41 c	5.56 ± 1.50 b	12.89 ± 4.67 a
5	0.00	5.75 ± 2.41 b	7.20 ± 4.64 b
6	0.00	12.40 ± 1.94 a	11.57 ± 1.58 a
7	0.00	10.52 ± 2.09 ab	13.64 ± 2.70 a
8	0.00	14.48 ± 2.09 a	14.51 ± 1.19 a
9	0.00	15.67 ± 1.24 a	14.02 ± 5.20 a
10	0.00	13.00 ± 2.23 a	12.49 ± 5.22 a

4. Discussion

Significant progress has been made in the research on the biology, ecology, occurrence, behavior, monitoring, and control techniques of *M. alternatus* and *A. rusticus*. The adult of *M. alternatus* appeared in the middle and late May, and its peak was in the middle of July. The initial stage of emergence of *A. rusticus* in the forest was in early and middle May, and the population density was very high from June to August from 2015 to 2017 in Yantai City, Shandong Province, China [4,21]. There are two peak flight periods of *A. rusticus* adults in mid-June and mid-September in this study, which can be considered the optimal trapping period for *A. rusticus*. The distribution of entrance holes by *M. alternatus* larvae and emergence holes of adults on pine trees infected with PWD follows a pattern of middle trunk > lower trunk > upper trunk, with the greatest number observed at a height of 2–3 m [22,23]. There is a significant difference in the number of occurrences of *A. rusticus* in the pine forests with different degrees of damage, with the most severe damage occurring in forests with severe damage, and the insect infestation rate can reach 78.3% [10]. However, in fact, there are significant differences in the occurrence and distribution of the two species on *P. thunbergii* with different degrees of decline, and the interspecific relationships of *M. alternatus* and *A. rusticus* on the same pine tree of *P. thunbergii* are unclear.

The population dynamics and spatial distribution of these two species in *P. thunbergii* trees with different degrees of decline were investigated in this study. The number of adult beetles captured by traps at different times was used to study the temporal niche overlap of two species of longicorn beetles, and the number and distribution of larvae of these two species on *P. thunbergii* trees with different degrees of decline were investigated to clarify the spatial niche overlap. We found a certain degree of separation in the early stage of decline and wilting death stage, and a significant ecological niche overlap in the middle and late stages of decline. Combining the temporal ecological niche separation of the two species of adults monitored by the traps in 2019 and 2020, the temporal overlap values were 0.05 ± 0.02 in 2019 and 0.02 ± 0.01 in 2020, indicating a high degree of separation of the temporal ecological niches of the two species of adults. This indicates that there is ecological niche separation between the two species of longicorn beetles in both temporal and spatial niche resources. Limited resources are typically unevenly distributed among consumers, leading to a more significant negative impact on some consumers while having a relatively weaker effect on others [24,25]. Species with similar ecological niches may experience interspecific competition due to their shared utilization of the same resources, which can lead to mutual interference or suppression, complicating the situation and potentially resulting in species replacement [26]. With the intensification of PWD and the increased control efforts, the number of vector insects *M. alternatus* has decreased, while the number of *A. rusticus* has sharply increased, and it has become the dominant species in pine forests.

Interspecific competition is a crucial ecological relationship among species and plays a significant role in influencing their distribution and population size [24,25]. It is an important factor in the establishment and succession of insect communities. Competition is a widespread phenomenon in nature, primarily manifesting as the contention for limited resources and environments required by different species [27,28]. *M. alternatus* and *A. rusticus* are two important stem-boring pests on pine trees, and both species caused harm due to their larvae boring into the sapwood [3,4]. There will inevitably be interspecific competition between two species of longhorn beetles that feed on the same host plant of *P. thunbergii*. The physiological state of the host plant is an important factor affecting the interspecific interactions of herbivorous insects [29]. The results showed that *A. rusticus* larvae tend to colonize the lower part of the trunk, but this tendency for *M. alternatus* is the opposite. Meanwhile, *A. rusticus* prefer deadwood, but *M. alternatus* develop in relatively healthy pine trees. In addition, the spatial distribution and instars at different periods of *A. rusticus* larvae also indicate that *A. rusticus* larvae tends to prefer lower parts of the trunk and pine trees with a higher degree of decline. *Pinus* trees infected with PWD are subjectively divided into four stages: the early, middle, and late stages of decline and the wilting death stage [30,31]. Therefore, in this study, the spatial distribution characteristics of two longhorn beetles on *P. thunbergii* with different degrees of decline were investigated to clarify the interspecific competition relationship between the two longhorn beetles. The results showed that with the change in the degree of host decline, the degree of competition between the two species also changed.

There are many reasons for this ecological niche separation, such as volatiles or nutrients from pine trees at different stages of decline [32,33]. Plant volatiles pose great significance for herbivorous insects in their search for and location of hosts, their laying of eggs, and their search for mates [34]. Ren [35] found that the total amount of volatile compounds decreased as PWD progressed, with the lowest amounts in the late stages of the disease. The volatilization of limonene and 3-carene in the volatiles of the trunk, branches, and leaves showed an upward trend in the early stage of the disease, and the main volatile components of the trunk of *P. massoniana* in the middle stage of the disease were α-pinene, β-pinene, limonene, and 3-carene. From the healthy period to the middle stage of the disease, the proportion of α-pinene in the volatiles of *P. massoniana* trunk increased, the proportion of β-pinene decreased, and the proportion of limonene and 3-carene increased first and then decreased. Plants mediate their interactions with the same and different organisms in the surrounding environment through the release of volatile substances [36]. The difference in pine volatiles in different stages of decline may be an important reason for the niche overlap and interspecific competition of the two longicorn beetles. In nature, plants can continuously release volatile compounds into the environment during their growth and development, and the composition and content of plant volatiles in different physiological states are different. These changes will have varying degrees of repellent or attractant effects on individual herbivorous insects of the same species, as well as on the behavior of different herbivorous insects [37,38]. Therefore, clarifying the olfactory electrophysiological and behavioral responses of the two species of longhorn beetle to the volatiles released by pine trees with different degrees of decline will help to elucidate the role of volatiles changes in the interspecific relationship between the two species of longhorn beetle.

In addition, the species and distribution of beetle larvae were clarified through surveys on logging piles in this study: only *A. rusticus* larvae and no *M. alternatus* larvae were found in the stumps of *P. thunbergii*. This survey further proves that simple methods can be used to treat the stumps of pine tree infected with PWD. Although no vector *M. alternatus* of pine wood nematode was found in the stump of *P. thunbergii*, the method of peeling treatment can effectively reduce the population of *A. rusticus*, which has practical significance for the control and treatment of original wooden piles. At the same time, it also meets the prevention and control requirements of PWD in China; therefore, the stump treatment of pine tree infected with PWD is an indispensable step in the process of PWD control [39].

5. Conclusions

In this study, we conducted a survey on the temporal ecological niche of *M. alternatus* and *A. rusticus* in Yantai City, Shandong Province, for two consecutive years. The temporal niche overlap values were 0.05 ± 0.02 in 2019 and 0.02 ± 0.01 in 2020, indicating that the temporal ecological niches were highly separated. The investigation results of the ecological niche of both larvae on the weakened pine trees showed that *M. alternatus* was generally on the trunk, while *A. rusticus* was mainly concentrated in the underground part, and spatial ecological niche of the larvae was also separated to a certain extent. As the population of *A. rusticus* far exceeded that of *M. alternatus* in pine forests in Yantai, Shandong, the distribution of *A. rusticus* larvae in the stumps was investigated. The age and depth of *A. rusticus* in the stumps varied with the time of felling and generation overlap.

Author Contributions: Y.J. and Y.L. contributed to the study design. L.C., C.S. and C.J. supervised the experiments. L.C., X.Z. and Y.J. contributed to data acquisition. Y.J. contributed to original draft writing. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

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