

The species diversity of an herbivore-natural enemy associated with brown planthopper outbreaks at red river delta, Vietnam

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Abstract

Production of rice has been a traditional source of income for small-scale farmers in Vietnam. Some results were conducted in rice fields at Red River Delta. 242 species of arthropods were collected in Rice fields in Ha Noi, Ha Nam, Vinh Phuc provinces. Among them, 36 species of insects have been recorded as pest feeding on rice, 147 are natural enemies during 2004 - 2005. The quantity of collected species of arthropods associated with rice crop under extensive farming condition in Ha Noi was the largest (159 species). In contrast, the number of species of arthropods collected in rice mixed with other crops in Vinh Phuc was the fewest (106 species). Brown planthopper outbreaks (BPH) results in hopper burn, indices describing biological diversity and structure of community go through a lot of changes in comparison to case without Brown planthopper outbreaks. All samples collected from rice fields associate with Brown planthopper outbreaks have a very high total abundance and vary from 602.6 in sample of Vu Ban (Nam Dinh) to 3529.2 in sample of Dong Anh (Ha Noi). The Shannon's index H' in rice fields associate with BPH outbreaks was very low, and reached only 0.04- 0.21 in comparison to 0.82 in rice fields without BPH outbreaks. Our surveys suggest that change in species composition, population density of herbivore- natural enemy communities in rice at Red River Delta due to human activity.

Key words: Species diversity, herbivore- natural enemy, insecticides, Brownplanthopper outbreak

1. Introduction

Viet Nam is known as an agricultural country. Two rice crops can be grown in the Northern provinces. Hybrid rice was introduced into Viet Nam in the 1990s from China. The growing area for commercial hybrid rice increased from 11,094 ha in 1992 to 584.200 ha in 2006 (MARD, 2007). The average yield of hybrid rice is 6.5 tons per ha. The intensification of rice growth of high- yield rice varieties, overuse of nitrogenous fertilizers, the highest amount of insecticides and sprayed most frequently against pests will be left some bad effects such as environmental pollution, pest resistance and outbreak. The occurrence of outbreaks of insect pests is importance such as the Brown planthopper (BPH). In Viet Nam have been many studies on species composition of pest and natural enemies in rice (V. Q. Con 1989, 1990, H. Q. Hung, 1986; P. V.Lam, 1989, 1992, 2002...). This paper provides some research results on the biology diversity of an herbivore - natural enemy community in different rice ecosystems associated with brown planthopper outbreaks in the Red River Delta of Viet Nam.

2. Material and methods

Data collection: General data on hybrid rice growing areas was gathered from Statistical Year books of MARD. The paper was investigated from field research in 2004- 2005 and 2006 at some rice –growing provinces in RRD such as Ha Nam, Ha Noi, Ha Tay, Nam Dinh, Vinh Phuc, and secondary data stems from review of literature cited.

Rice cultivar including Hybrid rice (Nhi Uu 838, Nhi Uu 63, D. Uu 527, VN 20, TH3-3, HC1...), Inbred rice (Khang Dan, C70, C71, Q5), Local sticky rice.

- To determine species composition: surveys and collections were carried out at weekly interval from rice fields located in the Red River Delta. Samples were collected and estimated by sweeping, aspirators, picking up insects by hand, pitfall traps, sticky traps set up in the study site from rice fields of all life stages of insects, spider. For immature stage it is then necessary to rear them to the adult stage to obtain a precise identification. The collected specimens were brought to the laboratory for specimen preservation, mounting. All samples collected were analyzed in the Lab. Identification of arthropods was carried out with the references. Experts identified any unidentified specimens to an appropriate level.
- Population Dynamics: every seven days at five sampling points in two diagonal of each the field. Each point four plants were randomly sampled. Visual counting the number of insects Brown planthoppers (BHP), White back plant hoppers (WBPH) was collected from field using the sticky board methods.
- The field surveys were carried out in sites with brown planthopper outbreaks. In each site, 3-5 homogenous fields were selected for taking samples. Samples were taken freely in rice field with or without brown planthopper outbreaks. All collected samples based on brown planthopper density and status of hopper burn, were categorized into 4 groups
 - Sample I: From fields with hopper burn
 - Sample II: from fields in which hopper burn happened after the survey for 1- 2 days
 - Sample III: from fields with high density of brown plant hopper but no hopper burn
 - Sample IV: from fields with low density of BPH and no hopper burn.
- In order to calculate the species diversity of an herbivore- natural enemy community in rice fields according to the equation given by Colwell (2000)

The Shannon diversity index (H') was calculated as follows $H' = -\sum P_i \ln P_i$ (Where $P_i = n_i/N$; n_i is number of individuals of the i^{th} species; N is total number of individuals of the collection)

Simpson's index: D is calculated as $D = \sum P_i^2$

Calculate some indices by describing the structure of a herbivore- natural enemy community in rice field by Hill (1973) Total number of species: $N_0 = S$ (where S is total number of species)

Number of abundant species in the sample: $N_1 = \exp(H')$ (Where H' is Shannon's index)

Number of very abundant species: $N_2 = 1/\lambda$ (Where λ is Simpson's index)

Species evenness or equitability $E5 = (N_2 - 1) / (N_1 - 1)$

3. Results and discussion

* The species diversity of an herbivore-natural enemy community in the rice fields

Researches had been done in 2004- 2005 at Nhat Tan - Van Xa (Kim Bang - Ha Nam), Duc Tu (Dong Anh, Ha Noi), Tien Phong (Me Linh, Vinh Phuc), Co Nhue (Tu Liem, Ha Noi). The hybrid is mainly grown in the RRD with rice that is planted twice a year (spring rice and summer rice). At Tien Phong (Vinh Phuc) hybrid rice intercropping flowers and vegetables (50% rice) and spray insecticides 5 – 7 times/season. The results showed that 242 species arthropod belong to 11 genera were recorded in different rice ecosystems. Among them, 36 species of insect as rice insect pests, 147 species were natural enemies. In Co Nhue (Ha Noi), the quantity of collected species of arthropods is associated with rice crops under extensive farming condition (extensive cultivation) with applying insecticides 1-2 times/season was the biggest (159 species). In contrast, the number of collected species of arthropods in rice mixed with other crops in Vinh Phuc was the fewest (106 species). The number of rice insect pests was recorded in Co Nhue (Ha Noi), Duc Tu (Ha Noi), Nhat Tan - Van Xa (Ha Nam) and Tien Phong (Vinh Phuc) (Table 1) as 27, 29, 26 and 18, respectively. Number of natural enemies was 97, 95, 86, 60, respectively.

Table 1. Species composition of pests and natural enemies collected in rice fields in 2004- 2005

Criteria	Co Nhue (Ha Noi)	Duc Tu (Ha Noi)	Nhat Tan - Van Xa (Ha Nam)	Tien Phong (Vinh Phuc)	Total
Number of species	159	158	143	106	242
Rice pests	27	29	26	18	36
Natural enemies	97	95	86	60	147
Different species	35	34	31	28	59

All species composition collected all season of these researches was fewer species than previous studies in literature. At Ha Noi, Ha Nam, Vinh Phuc in earlier researches species composition collected were 67, 53 and 65, respectively (Tables 2) there were rice pests recorded in references. However, a recent investigation in 2004- 2005 in rice fields did not find the species for example *Aiolopus tamulus*, *locusta migratoria manilensis*, *Stenocatantops spendes*, *leptocorisa costalis*, *L. varicornis*, *Plautia crossota*, *Tetroda histeroides*, *Chilo auricilius*, *Phloeothrips oryzae*, *Mythimna loreyi*, and for natural enemies as *Coccygomimus aethiops*, *C. nipponisus*, *Enicospillus* sp., *Eriborus ryukuensis*, *E. vulgaris*, *Stenobracon nicevillei*.

Table 2. Species composition of pests and natural enemies collected in rice fields in 2004-2005 Compared with another documents

Criteria	Ha Noi		Ha Nam		Vinh Phuc	
	References	2004- 2005	References	2004- 2005	References	2004- 2005
Order	8	7	7	6	7	6
Family	25	16	19	11	15	12
Species	67	29	53	26	65	8

Structure of arthropod community in the rice fields

There are few species of arthropods in the rice fields associated with the rice – based on ecosystems in summer rice 2005 is presented in the table 3, the number of collected species (index N_0) obtained the highest species (135 species) in rice fields in Co Nhue province, the total number of the recorded species in Tien Phong was the lowest 72. The number of abundant species (index N_1) in the rice fields was from 10.7 species in Tien Phong to 19.5 species in Co Nhue. The number of very abundant species (index N_2) was from 4.4 species in Tien Phong to 11.0 species in Co Nhue. Species equitability in the rice fields was at a low rate of 0.35 - 0.54. This study also finds out the reasons the application of insecticides on abundant species. Insecticides that are applied for the control of insect pests can be toxic to predaceous and parasitic arthropods. Biodiversity of natural enemies in agro ecosystems may be substantially affected by the use of pesticides. This indicates the abundance of discovery of an herbivore- natural enemy community (N_1) in Sticky rice fields with intensive cultivation was 17.8 and 11.9 in extensive cultivation at Duc Tu (Ha Noi).

Table 3. Affect of the rice –based ecosystems on the structure of an herbivore-natural enemy Community in summer season 2005

Sampling sites	Type of rice fields for sampling	N_0	N_1	N_2	E_5
Co Nhue:	Rice	135	19.5	11.0	0.54
Tien Phong	Rice - Flower and vegetable	72	10.7	4.4	0.35
Duc Tu	Sticky rice with intensive cultivation	128	17.8	9.4	0.50
	Sticky rice with extensive cultivation	101	11.9	6.6	0.51
	Rice	100	12.2	6.0	0.45
Van Xa	Sticky rice with intensive cultivation	129	15.4	8.6	0.50
	Sticky rice with extensive cultivation	102	10.8	5.3	0.40

Note: N_0 : Total number of species

N_1 : Number of abundant species in the sample

N_2 : Number of very abundant

E_5 : Species evenness or equitability

Results of quantitative and qualitative analysis showed in table 4 that the species composition of pest-natural enemy communities residing in the base of rice stems is very poor in the case of brown plant hopper outbreaks. Very few species of rice insect pests were found in collected samples. There are only 3 species of pests which have been found in all samples, except sample II taken from Binh Luc (Ha Nam province) and Vu Ban (Nam Dinh) province. The number of discovered species of natural enemies in collected samples is different. This number depends upon location and status of BPH population density in surveyed rice fields. Samples II and samples III taken from Dong Anh (Ha Noi) contained 14 and 10 species of natural enemies, respectively. The number of species of natural

enemies in samples taken from Phuc Tho (Ha Tay province) varied from 10 species in samples IV to 13 species in sample I and sample II. Samples were taken from Binh Luc (Ha Nam province) contained 8- 10 species of natural enemies. From Vu Ban (Nam Dinh province), samples I contained 10 species of natural enemies, but samples II contained only 4 species of natural enemies. The discovered number of species of natural enemies in surveyed samples increased with the increase in BPH population density.

Spider constitutes a large group of predators in rice fields. According to P.V.Lam et al. 2002, about 18 species of spiders preyed upon BPH and they are key predators of BPH in Viet Nam. However, only a few species were found in the base of rice stems in the case of brown plant hopper outbreaks. The number of discovered species of spiders in collected samples varied from 5 species to 8 species. But, sample II taken from Vu Ban contained only 2 species of spiders. The frequency of occurrences of discovered species in herbivore- natural enemy communities varies and is depend upon collected species, location and status of BPH population density in surveyed rice fields. Only the brown plant hopper *Nilaparvata lugens* appeared at maximum frequency (100%). The green leafhopper, *Nephotettix virescens*, did not occur in sample II in Binh Luc and Vu Ban. Among natural enemies, the spider *Tetragnatha javana* was not in many collected samples

Table 4. Species composition of pests and natural enemies collected in the rice fields with brown plant hopper outbreaks in some sites at RRD

Scientific name of insect pests/natural enemies	Frequency of occurrence (%)									
	Dong Anh		Phuc tho				Binh luc		Vu Ban	
	Sam-ple I	Sam-ple II	Sam-ple I	Sam-ple II	Sam-ple III	Sam-ple IV	Sam-ple I	Sam-ple II	Sam-ple I	Sam-ple II
<i>Nilaparvata lugens</i> (Stal) ¹	100	100	100	100	100	100	100	100	100	100
<i>Sogatella furcifera</i> (Horv.) ¹	90.0	66.7	80.0	87.5	90.0	50.0	90.0	87.5	60.0	28.6
<i>Nephotettix virescens</i> (Dist.) ¹	60.0	66.7	70.0	87.5	90.0	37.5	30.0	-	50.0	-
<i>Lycosa</i> sp. ²	50.0	33.3	80.0	87.5	-	50.0	80.0	37.5	10.0	-
<i>Pardosa pseudoannulata</i> B.&Str. ²	30.0	66.7	90.0	87.5	90.0	75.0	90.0	62.5	50.0	42.9
<i>Tetragnatha maxillosa</i> Thorell ²	50.0	66.7	30.0	87.5	90.0	75.0	30.0	37.5	40.0	-
<i>Tetragnatha javana</i> Thorell ²	10.0	-	20.0	-	-	-	-	-	-	-
<i>Oxyopes javanus</i> Thorell ²	10.0	33.3	20.0	50.0	-	-	-	-	-	-
<i>Dyschiriognatha tenera</i> Kars. ²	20.0	-	40.0	62.5	40.0	12.5	30.0	12.5	20.0	-
<i>Araneus inustus</i> (Koch.) ²	90.0	66.7	90.0	87.5	90.0	75.0	90.0	87.5	50.0	71.4
<i>Clubiona japonicollae</i> B.&Str. ²	40.0	66.7	60.0	87.5	80.0	75.0	60.0	37.5	30.0	-
<i>Micraspis discolor</i> (Fabr.) ²	80.0	33.3	80.0	87.5	80.0	50.0	80.0	62.5	60.0	28.6
<i>Cyrtorhinus lividipennis</i> Reut. ²	90.0	66.7	80.0	87.5	90.0	62.5	90.0	87.5	80.0	85.7
<i>Paederus fuscipes</i> Curtis ²	10.0	33.3	50.0	75.0	70.0	37.5	30.0	25.0	20.0	-
<i>Paederus tamulus</i> Erich. ²	20.0	-	40.0	62.5	50.0	-	-	-	-	-
<i>Ophionea indica</i> (Thunb.) ²	10.0	-	-	62.5	50.0	-	20.0	-	-	-
<i>Anagrus optabilis</i> (Perk.) ²	20.0	33.3	30.0	50.0	50.0	37.5	-	-	10.0	-
Total species	17	13	16	16	14	13	13	11	13	6

Note: 1= Rice pests, 2= Natural enemy

*** Indices of biological diversity of arthropods in the rice fields with brown planthopper outbreaks**

Results of the analysis indicate in table 5 shown that all samples taken from rice fields associated with brown planthopper outbreaks have a very high total abundance. The total abundance changes from 602.6 in samples I of Vu Ban (Nam Dinh province) to 3529.2 in samples II of Dong Anh (Ha Noi). Shannon's index H' is very low in all collected samples taken in the year with brown planthopper outbreaks. Especially, this index in the rice fields associated with brown planthopper outbreaks is

much lower than that in the rice fields without brown planthopper outbreaks. Shannon's index H' reached from only 0.04 in sample II of Dong Anh to 0.21 in samples I of Phuc Tho and Vu Ban. Meanwhile, Shannon's index H' in sample IV taken from the rice fields without brown planthopper outbreaks in Phuc Tho (Ha Tay province) was higher and reached 0.82. Simpson's index D in the rice fields associated with brown planthopper outbreaks reached very high. It varied from 0.92 in sample I of Vu Ban to 0.99 in sample II of Dong Anh, Such value of the Simpson's index D is really high and reached the maximum (approximation of 1). In comparison to the rice fields without brown planthopper outbreaks, this index was lower and obtained 0.64 as shown in samples IV taken from Phuc Tho

Table 5. some main indices describing the species diversity of an herbivore- natural enemy community associated with brown planthopper outbreak

No	Types of rice fields for sampling	Total abundance	Shannon's index (H')	Simpson's index (D)
1.	Sample I in Phuc Tho	946.9	0.21	0.93
2.	Sample II in Phuc Tho	3111.7	0.16	0.95
3.	Sample III in Phuc Tho	387.3	0.61	0.76
4.	Sample IV in Phuc Tho	122.0	0.82	0.64
5.	Sample II in Dong Anh	3529.2	0.04	0.99
6.	Sample III in Dong Anh	866.7	0.11	0.97
7.	Sample I in Vu Ban	602.6	0.21	0.92
8.	Sample II in Vu Ban	625.8	0.05	0.98
9.	Sample I in Binh Luc	2256.9	0.11	0.96
10.	Sample II in Binh Luc	1898.4	0.08	0.98

Note: I - Hopper burn is happening

II - Hopper burn happened after surveys

III - High density of BPH, but no hopper burn

IV – No Hopper burn

In comparison to a year without brown planthopper outbreaks (year 2005), the main indices describing the species diversity of a herbivore- natural enemy community in some sites in Red River Delta illustrated another picture. The total abundance was not so high and varied from 194.0 in Dong Anh to 334.8 in Tu Liem. Shannon's index H' in some sites was varied from 2.37 to 2.97. Simpson's index D reached very low and was only 0.12- 0.28 (table 6).

Table 6. Some main indices describing the species diversity of an herbivore- natural enemy community in the rice fields without brown planthopper outbreaks (2005)

Sampling sites	Total abundance	Shannon's index (H)	Simpson's index (D)
Tu Liem district	334.8	2.97	0.14
Me Linh district	292.5	2.37	0.28
Dong Anh district	194.0	2.51	0.12

*** Structure of arthropod community in the rice fields associated with brown planthopper outbreaks**

There are a few species of arthropods in the rice fields associated with brown planthopper outbreaks in Red River Delta. The number of discovered species (Index N_0) in all collected samples varied from 6 to 17 species.

Table 7. Some main indices describing the species diversity of an herbivore- natural enemy community associated with brown planthopper outbreak

No	Types of rice fields for sampling	N_0	N_1	N_2	E_5
1.	Sample I in Phuc Tho	16	1.23	1.07	0.31
2.	Sample II in Phuc Tho	16	1.18	1.05	0.30
3.	Sample III in Phuc Tho	14	1.83	1.31	0.37
4.	Sample IV in Phuc Tho	13	2.26	1.57	0.45
5.	Sample II in Dong Anh	17	1.04	1.01	0.25
6.	Sample III in Dong Anh	13	1.11	1.03	0.28
7.	Sample I in Vu Ban	13	1.23	1.09	0.39
8.	Sample II in Vu Ban	6	1.06	1.02	0.30
9.	Sample I in Binh Luc	13	1.12	1.03	0.30
10.	Sample II in Binh Luc	11	1.08	1.02	0.29

Note: N_0 : Total number of species

N_1 : Number of abundant species in the sample

N_2 : Number of very abundant

E_5 : Species evenness or equitability

The number of abundant species (Index N_1) in the rice fields associated with brown planthopper outbreaks also is very few and reached only 1.04- 1.23 species. This index in the rice fields without brown planthopper outbreaks is higher and obtained 2.26 species in samples IV taken from Phuc Tho. The number of very abundant species (Index N_2) reached lower and was only 1.01- 1.09 species in samples taken from rice fields associated with brown planthopper outbreaks. In comparison to rice fields without brown planthopper outbreaks (samples IV in Thuc Tho), index N_2 reached higher 1.57 species. Species equitability in rice fields associated with brown planthopper outbreaks was at a very low rate of 0.28- 0.39 (table 7). This mean the rice- based ecosystems associated with brown planthopper outbreaks became very unsustainable

Meanwhile, in the years without brown planthopper outbreaks, these above mentioned indices are much higher. The number of discovered species (Index N_0) in the rice fields without brown planthopper outbreaks (years 2005) varied from 65 to 135 species. The number of abundant species (Index N_1) is higher and reached 10.7- 19.5 species. The number of very abundant species (Index N_2) was from 4.4 species in Me Linh to 11.0 species in Tu Liem. Species equitability is at a medium rate of 0.45- 0.60, except for the Me Linh site, where rice used to intercrop with flower- crops (tables 8). This means the rice- based ecosystems in the years without brown planthopper outbreaks are more sustainable than in case of brown planthopper outbreaks.

Table 8. Some main indices describing the species diversity of an herbivore- natural enemy community in the rice fields without brown planthopper outbreaks (2005)

Sampling sites	Values of some indices			
	N ₀	N ₁	N ₂	E ₅
Tu Liem district	135	19.5	11.0	0.54
Me Linh district	72	10.7	4.4	0.35
Dong Anh district	100	12.2	6.0	0.45
Kim bang district	65	11.6	7.1	0.60

Note: N₀: Total number of species

N₁: Number of abundant species in the sample

N₂: Number of very abundant

E₅: Species evenness or equitability

Upon occurrence of brown planthopper outbreaks, the most abundant species in arthropod population is the brown planthopper, *Nilaparvata lugens*. Other species in herbivore- natural enemy community have a low population density. The green mired bug *Cyrtorhinus lividipennis* is a professional relative predator of brown planthopper. Whenever the brown planthopper is observed, the *Cyrtorhinus lividipennis* will appear afterwards. However, in the event that brown planthopper develop to the population density resulting in hopper burn, *Cyrtorhinus lividipennis* reach a low population density of only 0.2- 5.3 individuals/hill. Similarly, spiders are indispensable components of an herbivore-natural enemy community in the rice fields. They are always present in rice fields. Nevertheless, upon occurrence of brown planthopper outbreaks, the population density of these spiders reached a low level, only 0.9- 2.8 individuals/hill. Above- mentioned numbers indicated that when the brown planthopper outbreaks happen, the population density of brown planthopper was very high, averaging 103.6- 548.4 individuals/hill. Such population density of the brown planthopper is higher than population density of *Cyrtorhinus lividipennis* and spiders about 9.3- 937.0 and 21.3- 1399.0 times, respectively.

Biodiversity of natural enemies in agro ecosystems may be substantially affected by the use of pesticides. Nonselective treatments are toxic to beneficial. They decrease populations, contributing to pest outbreak.

In Viet Nam pesticides may have an influence to population abundance or composition of herbivore-natural enemy communities. The use of large amounts of pesticides creates pollution and health problems, destroys natural habitats, Decline of bio-diversification and contributes to high energy consumption and unsustainable agricultural systems. Total quantify of pesticides used in Viet Nam increased from 20.389 tons in 1994 to 71.345 tons in 2006. Many insecticides have a strong effect on natural enemies. It is important to investigate effects on the species level rather than on the genus or family level, as different species may react very differently to different factors.

These facts indicate that discovered number of species arthropod community in this research were fewer species than earlier researches. Some of natural enemies have been reported present in references but did not record in 2004 - 2005 such as *Euberteterus alternecoloratus*, *Coccygomimus aethiops*, *Coccygomimus nipponicus*, *Enicospillus* sp.; *Eriborus ryukuensis*, *Eriborus vulgaris*, *Mesochorus* sp., *Bracon hispae*, *Stenobracon maculate*, *Tetrastichus ayyari*, *Cuphacera varia*,

Rhinocoris fuscipes, *Eocanthecona furcellata*, *Ophionea interstitialis*. There were some earlier attempts to list arthropod community records but there could have been a misidentification and distribution in Viet Nam of rice pests such as *Leptocorisa costalis*, *Leptocorisa varicornis* and *Phloeothrips oryzae*. The true identity of *L. varicornis* (Fabr.) was shown to be a junior synonym of *L. acuta* (Thunb.). Species in the genus have various color forms, so three *Nezara viridula* forms were described as different species, the names *Nezara viridula*, *N. torquata* and *N. aurantiaca* appear in the literature. These species indications have been emerged under the single name *N. viridula*

3. Conclusion

All discovered species from different rice ecosystems in Ha Noi, Ha Nam, Vinh Phuc were 242 species. The quantity of collected species of arthropods associated with rice crops during 2004 - 2005 was fewer than previous studies in published literature. Number of discovered species in rice field interplant with flowers in Tien Phong was the fewest (106 species). Mean Shannon diversity Index (H') was lower and in sample taken from Van Xa was 2.59 in 2004 and Tien Phong was 2.37 in 2005. Number of recorded species in local sticky rice was higher than hybrid rice. Pesticides influenced the population abundance and composition of herbivore- natural enemy communities. . Populations were generally the higher in hybrid rice than inbred rice.

Brown planthopper outbreaks result in hopper burn, indices describing biological diversity and structure of community go through a lot of changes in comparison to case without brown planthopper outbreaks. Such indices change in terms of reduction in biological diversity in the rice- based ecosystem. Making these ecosystems unsustainable and increasing the severity of insect pest problems.

All samples collected from rice fields associated with BPH outbreaks have very high total abundance and varies from 602.6 to 3529.2. The Shannon's index H' in rice fields associated with BPH outbreaks was very low, only 0.04- 0.21 in comparison with 0.82 in rice fields without BPH outbreaks. In the years without BPH outbreaks, the Shannon index H' in rice fields in the Red River Delta can reach 2.37- 2.97. The Simpson's index D in rice fields associated with BPH outbreaks was very high, and reached an approximation of 1. The index D in the rice fields without BPH outbreaks was lower, only 0.12- 0.28.

Species richness in the rice fields associated with BPH outbreaks was not high. A total of 6- 17 species were encountered from all studies sites. Both diversity indices N_1 (the number of abundant species) and N_2 (the number of very abundant species) were very low, and reach only 1.04- 2.26 and 1.01- 1.57, respectively. The index E_5 (species evenness) also was very low because only a single species becomes more dominant in the rice fields associated with brown planthopper outbreaks.

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