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Research Article

The community structure of beneficial and harmful arthropod fauna in rice field ecosysterms in lower Northern Thailand

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Abstract

Studies to understand the diversity of insect and spider species related to rice cultivation and determine their ecological guilds can provide information concerning the composition and structure of such ecosystems, which can be applied to integrated pest management. Herein, the purpose of this current survey was to monitor the community structure of beneficial and harmful arthropod including insects and spiders which inhabit rice paddy fields. Six major locations of rice-growing areas were selected in lower northern Thailand, including Nakhon Sawan, Phetchabun, Phichit, Phitsanulok, Sukhothai and Uttaradit provinces. In each survey site, six sampling plots of paddy field were chosen and insects and spiders were caught using sweeping nets at 20 times/sampling plot during 2017-2019. All samples were identified based on morphology. A total of 6,459 individuals of insects and spiders were collected, representing 102 species in 69 families and 11 orders. The rice paddies of Phitsanulok showed the highest species richness (73 species). In this regard, the species diversity (H') for all insects and spiders of all rice-growing areas was considered relatively high (3.038). Meanwhile, the Evenness (J') and Simpson index (1-D) in all rice paddies from the pooled data set out in this survey were 0.765 and 0.919, respectively. Phichit) H' = 3.234(showed the highest species diversity index, whereas Phetchabun and Sukhothai) H' = 2.895(had the lowest levels of diversity. Significant differences in species diversity indeces of six rice-growing sites were detected (P < 0.05) in all comparisons. The insect order of Coleoptera had the highest recorded number of species (21 species or 20.59%). It was found that the insect pests namely, *Edwardsiama hergmanni* (F. Cicadellidae), *Dyscinetus morator* (F. Scarabaeidae) and *Nilaparvata lugens* (F. Delphacidae) were the dominant species. Meanwhile, *Micraspis discolor* (F. Coccinellidae), *Agriocnemis pygmaea* (F. Coenagrionidae) *Oxyopes javanus* (F. Oxyopidae), *Temelucha philippinensis* (F. Ichneumonidae), *Tropobracon schoenobii* (F. Braconidae) and *Goniozus nr. triangulifer* (F. Bethylidae) were mainly exhibited as natural enemies. Additionally, the distribution of insects and spiders was aggregated for all rice-planting areas, as indicated by the values of variance to mean ratio ($S^2/\bar{x}$) and the index of aggregation ($I\delta$). This pattern could result in increase the efficiency of natural enemies for controlling those arthropod pests.

Keywords: Species composition, rice pests, natural enemies, rice ecosystem

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Introduction

In terms of numbers and the diversity of species, arthropods are the most biologically successful group of animals (Triplehorn and Johnson, 2005). Almost three-quarters of all described animal species are insects and spiders (Borror et al., 1989; Gullan and Cranston, 2004; Triplehorn and Johnson, 2005). Their numbers far exceed all other terrestrial animal species, and are found in almost every terrestrial habitat on the Earth's surface. They have diversified to fill almost every environmental niche imaginable (Putman, 1983; Gullan and Cranston, 1994), making them one of the most crucial components of most terrestrial ecosystems. In agroecosystems, biodiversity performs a variety of ecological services beyond the production of food, including recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of undesirable organisms and detoxification of noxious chemicals (Scherr and McNeely 2008; Fritz et al., 2011; Ane and Hussain, 2015). Likewise, the rice field agroecosystem is able to serve as a repository for the benefical arthropods and harmful pests in rice paddy during all phases of rice growth (vegetative, reproductive and ripening) (Siregar et al., 2017).

Rice (*Oryza sativa* L.) is a staple cereal that nurtures the lives of the Thai people and of more than half the world's population. In economic terms, rice is a commodity ensuring prosperity and food security. In agriculture, rice is the second most cultivared cereal in the world, after wheat and more than 90% of the world's production is consumed in Asia. Nonetheless, to date, the total planting areas and rice production in Thailand has been declining overtime. The rice fields are considered as temporary humid areas characterized by rapid physical, chemical and biological alterations and they host a rich biodiversity especially of arthropods. In rice field ecosystems arthropods are found in an intermediary position in the food-chain and include herbivores, saprophytes, parasites and the predators of other animals. Subsequently they themselves are consumed as food by other predators, parasitoids and parasites (Siregar et al., 2017). Over 800 species of insects are able to damage the rice plant in several ways, although the majority of them caused minor damage (Pathak, 1968; 1970; Pathak and Khan, 1994; Way and Heong, 1994). Rice cultivation is a rapid changing ecosystem due to the change of activities during plantation. These activities affect the pest population and also the abundance of their natural enemies in the rice field (Tsutsui et al., 2018; Jauharlina et al., 2019). Some of the insect pests that are known to harm the rice plantation are brown plant hopper *Nilaparvata lugens* (Stål), rice shoot fly *Atherigona oryzae* (Malloch), white grub, *Leucopholis rorida* (Fabr.), white stem borer *Scirpophaga innotata* (Walker), and rice bug *Leptocorisa oratorius* (Thunberg) (Thorburn, 2015). As a result of heavy insect pressure, the control of rice pests has relied heavily on insecticides (Magallona, 1989). Nontheless, overuse and misuse of these insecticides have led to increasing problems of insecticide resistance, resurgence of pests and introduction of new pests, as well as beneficial insects' destruction (Pathak and Khan, 1994).

Natural control of insect pests is one of the strategies of the integrated pest management concept (IPM), which has been widely adopted in Thailand since the early 1970s (Wright et al., 2005). It has played a vital role in controlling most potential rice pests (Jervis, and Kidd, 1996). Several species of insect pests and natural enemies (predators & parasites) have been surveyed and reported in Thailand (Jairin et al., 2001; Wongsiri and Kovitvadhi, 1967; Wongsiri et al., 1981). Species diversity concerning abundance and species richness is a quantitative parameter of community structure (Magurran, 1988; May, 1975). Understanding of the species present and their role in the ecosystem could be significant in deciding whether or not to apply pesticides (van Emden and Williams, 1974). In general, species diversity and complexity of association among species are important to the stability of the community. In view of the changing cultural practices the pest and natural enemy population dynamics needs closely monitoring for suitable amendments in rice IPM strategies. Information on distribution patterns of insect pests is used for data analysis to determine appropriate sampling plans and sample size, and to construct sequential sampling programs. Reliable sampling plans are necessary for periodic screening of pest-population densities where timely pest management decisions are essential (Kuno, 1991). Because the number of samples could vary with the distribution pattern of the pest, it is significant to determine the distribution pattern of rice key pests for specific areas and different seasons (Southwood, 1978). The data acquired are still insufficient to form a foundation and for developing an effective integrated pest management system in Thailand. The purpose of this current study was to determine species composition, together with determining the distribution pattern of arthropods (insects and spiders) that act as pests, predators, parasites or others in an organic rice paddy field.

Materials and methods

The experimental areas are located in the rice paddies of six major locations of lower Northern Thailand including Nakhonsawan, Phetchabun, Phichit, Phitsanulok, Sukhothai and Uttaradit provinces, respectively (Figure 1).

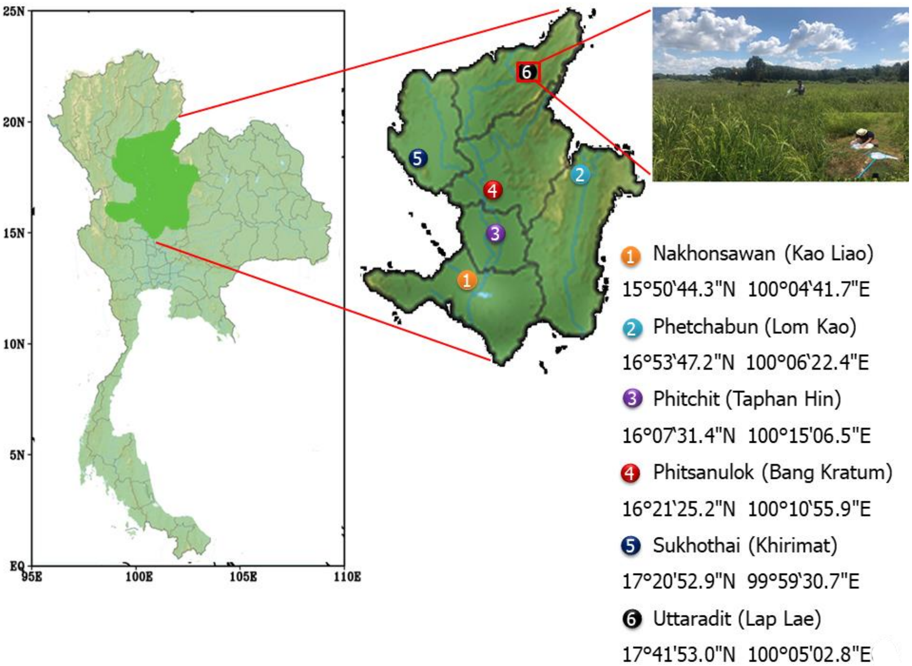

Figure 1 Map showing collection localities of insects and spiders inhabiting rice paddies in lower Northern Thailand, consisting of 1) Nakhonsawan, 2) Phetchabun, 3) Phichit, 4) Phitsanulok, 5) Sukhothai and 6) Uttaradit provinces.

The Khao Dawk Mali 105, a rice variety/line, was cultivated by farmers whose permission was sought to use as sample sites in this study. Samplings were conducted for each site across three years (2017-2019). Six plots were randomly sampled each having an area of

±1 hm^2 (100 m × 100 m each). Rice insect pests and natural enemies, predators and parasites, were gathered from each plot in the rice paddy during flowering stage. Airborne samples were collected using sweeping nets at 20 times/sampling surveyed spot. The surveyed line in each rice plot was walked as a diagonal. In addition to airborne samples, aquatic samples were also gathered from the water edge, surface and below the surface up to 30 cm. All insects and spiders collected were preserved in 95% alcohol. Afterwards, all samples were sorted and identified morphologically using the following references: Pathak and Khan (1994), Maloney et al. (2003), Rouyaree (2001) and Shepard et al. (1987).

For analysis of the insects and spiders, the assemblage data from rice paddies were gathered from six localities. All assemblage parameters (i.e. species richness, diversity) in this study were computed based on the average density of each arthropod species in each locality. The Shannon diversity index (H') was computed to measure diversity within a locality (Shannon, 1948) using the formula $H' = -\sum_{i=1}^{s} pi \ln pi$ where s is number of species and P_i is the proportion of the total sample belonging to i^{th} species. The diversity index criteria are as follows: H' less than or equal to 1 ($H' \leq 1$) means low diversity; H' greater than 1 and less than or equal to 3 ($1 < H' \leq 3$) means moderate diversity; and H' greater than or equal to 3 ($H' \geq 3$) means high diversity, respectively. Pielou's evenness index (J') was used to quantify differences in relative abundance using the formula $J' = H'/\ln S$, where S is the number of species (Ludwig & Reynolds, 1988). The evenness index (J') is categorized as follows: J' less than or equal to 0.05 ($0.00 < J' \leq 0.50$) indicates a depressed community; J' higher than 0.05 but less than or equal to 0.75 ($0.50 < J' \leq 0.75$) indicates an unstable community; and J' higher than 0.75 but less than or equal to 1.00 ($0.75 < J' \leq 1.00$) indicates a stable community, respectively. The Simpson diversity index (1-D) was also employed to measure the community diversity (Simpson, 1949) using the fourmula $D = 1 - [\Sigma\, n(n\text{-}1)]/[\, N(N\text{-}1)]$, where n is the number of individuals displaying one trait and N = the total number of all individuals. Index values (1-D) range from 0 - 1 by the following categories: the value less than 0.05 ($0.00 < 1\text{-}D < 0.50$) shows low dominance; the value higher than 0.05 but less than or equal to 0.75 ($0.50 < 1\text{-}D \leq 0.75$) shows moderate dominance; and the value higher than 0.75 but less than or equal to 1.00 ($0.75 < 1\text{-}D \leq 1.00$) shows high dominance, respectively. For species composition or relative abundance of different arthropods found, the similarity in species composition among the flowering stage of rice was determined by a cluster analysis with Sørensen distance measurement (Bray and Curtis, 1957; Sørensen, 1948). The distribution pattern of arthropods was statistically classified by calculating the Variance–to–mean ratio ($S^2/\bar{x}$) and Morisita's Index (I_δ) (Morisita, 1959; 1962). For the distribution pattern, the value higher than 1.0 (> 1.0) shows the aggregated distribution; the value equal to 1.0 (= 1.0) indicates the random distribution; and the value lower than 1.0 (< 1.0) means the regular pattern of arthropods.

A pairwise t-test of Shannon diversity index (H') among different study sites of rice-growing areas was compared using the SPSS program (IBM Corp., 2017). The cluster analysis was carried out using PC-ORD 5.10 software (McCune and Mefford, 2006). A rarefaction model was used to compare arthropod diversity among these stages of rice growth. The Rarefaction Value and its 95% confidence interval were computed by EcoSim version 7.72 software (Gotelli and Entsminger, 2004). Afterwards, the values of every survey area were plotted as a function of sampling effort. With this plot, significant difference in species diversity is indicated by an absence of overlap in the confidence interval of rarefaction curves among eight different rice growth stages at maximum sampling effort (Colwell et al., 2004)

Results and discussion

From the rice paddies during the flowering stage in all six rice-planting areas over three years of surveys (2017-2019), a total of 6,459 individual rice pests and their natural enemies from 69 families (11 orders) were sorted from 36 sampling plots. The diversity and abundance of arthropod fauna varied in the paddy ecosystem as well as the growth stages of the paddy cultivation (Siregar et al., 2017). As results, of all the rice paddy-utilizing insects and spiders found, approximately 20.59% (21 out of 102 species) were Coleoptera, followed by Hemiptera (18 species), Diptera (17 species), Hymenoptera (15 species), Lepidoptera (14 species), Araneae (6 species), Orthoptera (5 species), Odonata (3 species) and the insect orders of Blattodea, Ephemeroptera and Thysanoptera held the lowest recored species (only one species each), respectively (Figure 2).

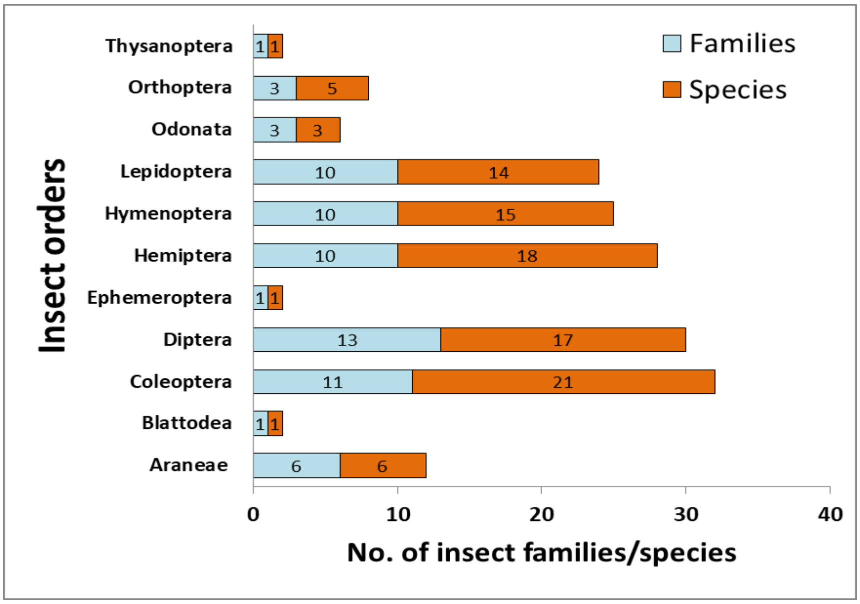

Figure 2 Taxonomic diversity of families and species of insects and spiders in rice field ecosysterms in lower northern Thailand using the sweeping technique.

The total number of insect and spider species in each study site, from the highest to the lowest, was as follows: 73 species in Phitsanulok; 67 species in Nakhonsawan; 62 species in Uttaradit; 59 species in Phichit; 56 species in Phetchabun and 52 species in Sukhothai (Table 1). These findings correspond to Sorapongpaisal et al. (2011) who carried out research regarding species diversity of rice insect pests and natural enemies in an organic rice paddy field at Environmental Entomology Reseach and Development Center, Kasetsart University, Kampaengsaen Campus, Nakhon Pathom province. It was found that 52 species of insects and spiders comprising 20 species of insect pests, 25 speices of insect natural enemies and 7 species of spiders were encounted. In this case, *Micraspis discolor* from the family Coccinellidae (O. Coleoptera) showed the highest number of individuals for the entire surveys, probably due to the high adaptive capacity of this lady beetle. It was revealed that the longevity of the *M. discolor* varied from 35 to 53 days with an average of 40.20 ± 1.00 days and 47.50 ± 0.82 days in male and female beetles, respectively (Chowdhury et al., 2008). During its lifespan, *M.*

discolor predated on rice insect pests such the brown planthopper (BPH), *Nilaparvata lugens* at the various rice stage of its development (Rouyaree, 2001; Sorapongpaisal et al., 2011), but it was most predominant at the active tillering or flowering stage of the paddy plants.

Table 1 Insect and spider diversity in different study sites.

Study sites	Ecological indices				
	S	***H′***	**H_{max}**	**E**	**1-D**
Nakhonsawan	67	3.110	4.205	0.740	0.935
Phetchabun	56	2.895	3.497	0.877	0.897
Phichit	59	3.234	4.078	0.793	0.940
Phitsanulok	73	3.055	4.290	0.712	0.919
Sukhothai	52	2.895	3.951	0.733	0.911
Uttaradit	62	3.040	4.127	0.737	0.911
Overall	**102**	**3.677**	**4.625**	**0.795**	**0.945**

Note: S = Number of species; *H′* = Shannon Wiener Index of diversity; H_{max} = lnS; E = Evenness (H′/H_{max}); 1-D = Simpson's diversity index

Apart from its longevity, *M. discolor* is more adaptive than any other insects because some factors such temperature might be influenced by its age-specific fecundity. Reprodution is a vital factor governing its ability to successfully invade new habitats (Omkar and Pervez, 2000; 2002). The age-specific fecundity is the most overlooked aspect of reproduction in ladybeetles, although female age plays a crucial role in progeny production and influences reproductive vigour (Jalali et al., 1999). Herein, the influence of temperature on age-specific fecundity of *M. discolor* was determined. It was revealed that the oviposition peak tended to shift towards younger females and the oviposition rate rose with increase in temperature from 20 °C to 27 °C (Omkar and Pervez, 2002). In the paddy fields observed in lower northern Thailand, the *M. discolor* collection contained as many as 1,068 individuals, or (16.535%) among insects and spiders collected. From these results, *M. discolor* could be improved in agricultural ecosystems to achieve biological control of pests.

Moreover, the three most common arthropod groups (Relative Abundance; RA) are 1) pests including *Edwardsiama hergmanni* (O. Hemiptera: F. Cicadellidae) (4.149%), *Dyscinetus morator* (O. Coleoptera: F. Scarabaeidae) (2.013%) and *Nilaparvata lugens* (O.Hemiptera: F. Delphacidae) (1.858%), 2) predators including *Micraspis discolor* (O. Coleoptera Coccinellidae) (16.535%), *Agriocnemis pygmaea* (O. Odonata: F. Coenagrionidae) (4.443%) and *Oxyopes javanus* (O. Araneae: F. Oxyopidae) (5.032%) and 3) parasites including *Temelucha philippinensis* (O. Hymenoptera: F. Ichneumonidae) (0.897%), *Tropobracon schoenobii* (O. Hymenoptera: F. Braconidae) (0.712%) and *Goniozus nr. triangulifer* (O. Hymenoptera: F. Bethylidae) (0.650%), respectively. On the other hand, it is quite different from the relative abundance of insect and spider species on Boro rice ranked as ladybird beetle (45.85%)>damselfly (12.95%)> ant (9.46%)> wolf spider (8.24%)> jumping spider (4.90%)> ground beetle (4.36%)> wasp (4.22%)> tachinid fly (3.63%)> lynx spider (2.76%)> carabid beetle (2.18%)> mirid bug (1.40%); whereas in Aman rice it was ranked as ladybird beetle (39.30%)> damselfly (16.72%)> longjawed spider (14.85%)> dipteran fly (7.07%)> jumping spider (6.70%)> lynx spider (4.71%)> ant (3.91%)> wasp (3.80%)>carabid beetle (2.89%). Surprisingly, of all 11 beneficial insect and spider species, 8 species were benefical insects, whereas 3 species were mite species (Rahman et al., 2017). In actual fact, ninety nine species of parasites and 88 species of predators of rice insect pests have so far been discovered in Bangladesh (Wahiduzzaman, 1993). In this case, because rice fields are strictly monoculture with less diverse ecosystem consequently the diversity of beneficial insect and spider under different orders was relatively low (Rahman et al., 2017).

In general, twenty out of 70 rice insect species are considered as pests in the rice paddy fields of Thailand (Jaroenpol, 2008). Furthermore, over 800 species of insect in rice fields have been reported worldwide (Ane and Hussain, 2015). Of these, about 100 species attack rice and the rest are benefical insects (Pathak, 1970). However, with more than 100 predactory and parasitic insect species –natural enemies- in the rice field, only 5-6 insect pests were found. This indicated that the ability of natural enemies to suppress insect pests to be under the economic threshold level (ETL) or economic injury level (EIL) in the organic rice paddy field (Jaroenpol, 2008).

Insect and spider (alpha) diversity is also shown in Table 1. The Shannon-Wiener index (*H'*) for all insects and spiders of all sampling rice plots obtained by calculating the pooled data set of this study was considered relatively high (3.677), with high evenness (E = 0.795), and dominance by the Simpson index was high for all samplings (1-D = 0.945). *H'* values in each study sites ranged from 2.859 to 3.234. The highest index (*H'*) was in Phitchit (*H'* = 3.324), following by Nakhonsawan (*H'* = 3.110), Phitsanulok (*H'* = 3.055), Uttaradit (*H'* = 3.040); and Phetcahbun and Sukhothai (*H'* = 2.895), respectively. A set of individual t-tests of index values (*H'*) among the five different locations of rice-growing areas was compared. Results of the comparison in each set of *H'* values were significantly different ($P < 0.05$) (Table 2).

Table 2 Grouped comparision of differences of species diversity indices (H') obtained from rice-growing areas, using the pairwise *t*-test.

Paires	t	df	Sig.
Na-Phet	-3.014	122.994	0.005*
Na-Phic	1.913	118.041	0.004*
Na-Phit	-0.9163	102.882	0.004*
Na-Su	-3.286	115.308	0.004*
Na-Utt	-1.001	127.632	0.005*
Phet-Phic	5.556	107.748	0.004*
Phet-Phit	2.880	92.844	0.003*
Phet-Su	0.001	104.746	0.004*
Phet-Utt	-3.272	117.817	0.004*
Phic-Phit	-3.7991	114.238	0.002*
Phic-Su	-6.278	110.215	0.003*
Phic-Utt	-0.282	105.045	0.003*
Phit-Su	-3.351	101.581	0.002*
Phit-Utt	2.421	113.253	0.004*
Su-Utt	2.421	113.253	0.004*

Note: Na = Nakhonsawan; Phet = Phetchabun; Phic = Phichit; Phit = Phitsanulok; Su = Sukhothai and Utt = Uttaradit
* = Significant difference ($p < 0.05$) and ns = not significantly different.

Differences in the arthropod (insect and spider) communities were evaluated according to the Bray-Curtis similarity (Figure 3) from qualitative-quantitative point of view. Hierarchical classification divided the arthropod communities into two groups. First group represented the

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arthropod communities at Nakhonsawan and Phetchabun. The arthropods in Phichit (with a high dominance (%RA) of *Prodiplosis longifila* (Diptera: Cecidomyiidae) (12.619%), *Limnogonus nitidus* (Hemipetra: Gerridae) (12.024%) and *Agriocnemis pygmaea* (Odonata: Agrionidae) (8.929%) joined these two communities. The insect and spider communities of Phitsanulok, Uttaradit and Sukhothai represented the second group. It was found that the two surveyed sites in Phitsanulok and Uttaradit formed a sister group in which the communities of arthropod species were more similar to each other than those found at the various other sites. *Chaoborus astictopus* (Diptera: Culicidae) eudominated in the arthropod communities at Phitsanulok and Uttaradit. Meanwhile, *Chaoborus astictopus* (Diptera: Culicidae) (19.303%), *Agriocnemis pygmaea* (Odonata: Agrionidae) (11.642%) and *Prodiplosis longifila* (Diptera: Cecidomyiidae) (11.045%), demonstrated as a predominace in the arthropod communites at Sukhothai.

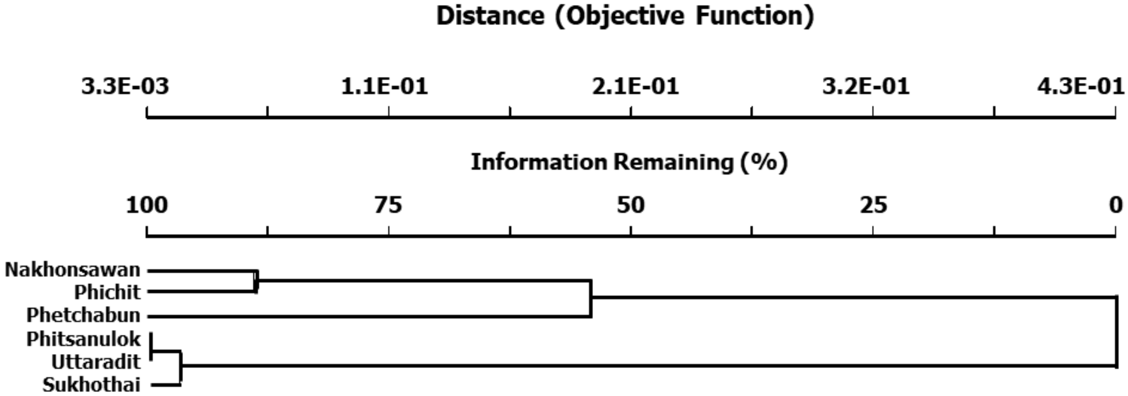

Figure 3 Dendrogram of the communities of insects and spiders in the various sites of rice-growing areas, obtained by cluster analysis.

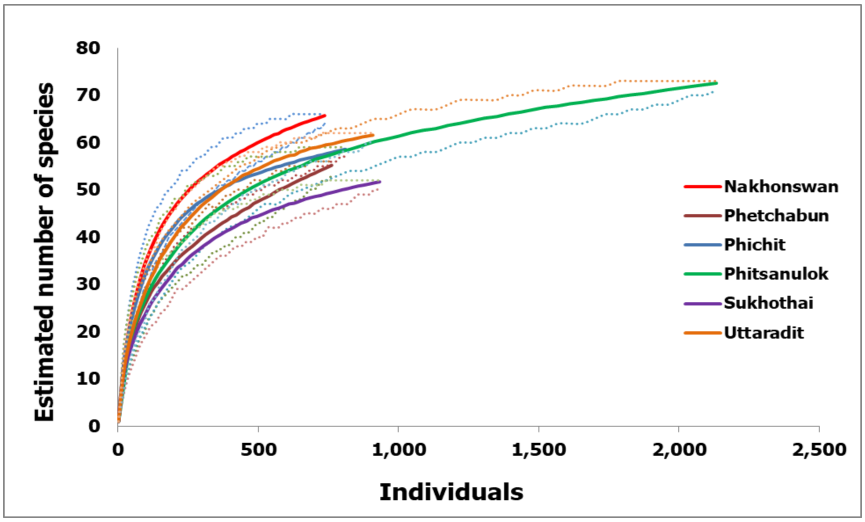

Figure 4 Species richness in the different localities of rice-growing areas by rarefaction curve with ± 95% confidence intervals shown as dotted lines.

Additionally, the accumulation curves (observed and expected) in the several localities of rice paddy (Figure 4) exhibited a divergence between 95% confidence interval of these curves, with the curve gradually increasing when the survey ended. However, no such species-accumulation curve illustrated reaching an asymptote when all survey sites were pooled. Some beneficial insect and spider species are awaiting discovery. To obtain more arthropod fauna or the occurrence of them in the rice paddy during all stages of rice growth, i.e. seedling, tillering and heading should be further initiated. Additionally, numerous subplots or different techniques, namely sweep net, malaise trap or light trap should also be considered for rice arthropod sampling.

Table 3 Evaluation of spatial distribution pattern of insects and spiders for rice paddy field ecosystem in different locality.

Localities	Variance to mean ratio ($S^2/\bar{x}$)	Morisita's Index ($I\delta$)	Distribution pattern
Nakhonsawan	17.62	1.61	Clumped
Phetchabun	30.43	1.70	Clumped
Phichit	17.18	1.73	Clumped
Phitsanulok	22.31	4.67	Clumped
Sukhothai	19.67	2.14	Clumped
Uttaradit	31.02	1.93	Clumped
Total	**268.02**	**5.18**	**Clumped**

For the spatial distribution pattern of insects and spiders, the distribution indices -- Variance-to-mean ratio ($S^2/\bar{x}$) and Morisita's Index ($I\delta$) -- held significantly greater than 1.0 for all sites, indicating clumped distribution (Table 3). Most rice arthropods were exhibited an aggregated pattern of dispersal. This result was similar to the report of Poolprasert and Jongitvimol (2014) which recorded that all rice insect populations on the paddy plants at different phases of its development displayed clumped or aggregated distributions. This pattern might be caused by several factors such as intrinsic behavior of the individuals, response to the food and habitat resources distribution, level of water and hill density of the rice paddy field (Gogoi and Bora, 2012). In addition, a resource concentration in some areas has been proposed as the general cause of assemblage of most living things (Ricklefs and Miller, 2000; van Emden and Williams, 1974).

Conclusion

The current results indicated that such biodiversity parameters as richness, abundance, diversity and composition of these beneficial insect and spider and harmful pest communities differred among different localities of rice-growing zones. This might be caused from rice paddy management or other physical factors. However, all indices exhibited relatively high values in the rice field ecosystem in lower northern Thailand. Indicating that the rice ecosystem could be utilized as a great reservoir of beneficial insect and mite species and therefore it would foster a natural biological control process in rice-based agroecosystems throughtout Thailand, especially in the lower northern region. The overall spatial distribution form of insects and spiders observed in this study mainly showed an aggregated distribution pattern. Subconsequently, this pattern is able to enrich the efficiency of natural enemies for controlling those rice arthropod pests. In addition, the use of a sampling strategy that incorporates spatial distribution would be beneficial to provide the essential information for the development of an appropriate sampling

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plan and an optimum sample size for rice integrated pest management (IPM). It would also reduce the cost of pest management strategies, together with decreasing the toxicity risk from synthetic insecticide application.

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