Spider Assemblages and Diversity in Rice–Crab Cocropping Production Fields[1]

Xiao-Hui Ma, Li Guo[2], and Zhi-Qiang Li[3]

Liaoning Provincial Saline–Alkali Land Utilization and Research Institute, Panjin, Liaoning, 124000, China

J. Entomol. Sci. 60(4): 000–000 (Month 2024)
DOI: 10.18474/JES24-48

Abstract Rice–crab cocropping refers to a new type of ecological aquaculture technology that involves raising crabs (*Eriocheir sinensis* H. Milne Edwards) in rice fields. To investigate whether crabs affect the community of spiders in the rice fields, we surveyed the species composition of spiders in two types of rice production fields—a rice–crab cocropping paddy and a conventional paddy—over two growing seasons. The fields were representative of the rice fields in Panjin City, Liaoning Province, China. We collected a total of 3,406 spiders representing 27 genera and 10 families over the duration of the study. The number of spiders in rice–crab cocropping paddy fields was significantly higher than in conventional paddy fields, but there was no significant difference in the types of spiders in the two types of paddy fields. An analysis of spider community diversity using Simpson's index, Shannon–Wiener diversity index, Pielou's index, and Margalef's index revealed no significant differences between the rice–crab cocropping paddy and the conventional paddy throughout the survey period. The evenness index and the richness index exhibited a positive relationship, whereas the dominance index showed a negative relationship. The dominant species in the two cropping systems was *Pirata subpiraticus* Boes. et Str. (Araneae, Lycosidae). Overall, we found no impact of cocropping with crabs on the composition and characteristics of the spider community.

Key Words rice–crab cocropping, conventional paddies, spiders, community, diversity

Rice–crab cocropping is an innovative approach that involves planting and breeding simultaneously in paddy fields and has been encouraged in advancing eco-friendly agricultural initiatives. The rice field setting is a suitable home for various economically valuable species like crabs, fish, shrimp, ducks, and more (Fernando 1993, Halwart 2006). Various regions have developed distinct methods of growing rice on the basis of their climate and production features. In the southern regions of China, eco-agriculture in rice fields primarily involves raising ducks, fish, and shrimp alongside rice cultivation. On the other hand, in the northern regions of China, the main eco-agricultural practice in rice paddy fields is the cocropping of rice with crabs. The practice of cultivating these economically valuable species alongside rice in flooded fields has been a longstanding tradition in various rice-producing regions, including Panjin City in Liaoning Province, as documented by Michael and Klaus (2005) and David et al.

[1]Received 19 May 2024; accepted for publication 22 July 2024.
[2]Corresponding author (email: guolipj2021@126.com).
[3]Liaoning Academy of Agricultural Sciences, Shenyang, Liaoning, 110161, China.

(1996). In Panjin City, the common rice–crab cocropping model involves the cultivation of rice and crabs (*Eriocheir sinensis* H. Milne Edwards), which has shown significant progress in the past decade through the combination of crab farming techniques and rice cultivation methods (Ma et al. 2019, Xu et al. 2014). The practice of cocropping rice with crabs can efficiently provide yields of *E. sinensis* and provide substantial economic advantages for rice farmers in the area (Chen et al. 2001, Fei and Zeng 2002).

At present, research on the cocultivation of rice and crabs primarily focuses on boosting the crab population; controlling pests, diseases, and weeds in rice–crab ecosystems; and improving rice production. There is limited research on arthropods in the rice–crab cocropping system in Asian countries, as noted by Ahmed and Garnett (2011), Radheyshyam et al. (2013), and Shams (2007). Spiders are among the most common predatory arthropods in agricultural environments, as noted by several studies (Nyffeler and Benz 1987, Nyffeler and Sunderland 2003, Pearce and Zalucki 2006, Riechert and Lockley 1984), are abundant in rice fields, and are the second most numerous group after insects (Shi et al. 2012). Spiders are one of the most important natural enemies of rice pests and play a crucial role in reducing pest numbers because of their abundance and high predatory potential (Tahir and Abida 2009). This study sought to identify the types and numbers of spiders present in rice–crab cocropping paddy fields compared with conventional paddy fields. It also examined the community traits of spiders in both production systems.

Materials and Methods

Survey area. Surveys were conducted in Tangjia Town, Panjin Municipality, Liaoning Province, from June to October in both 2022 and 2023, within the geographic coordinates of N 40°39′–41°27′, E 121°25′–122°31′. The rice used for this study was Yangfeng47, which was transplanted in late May and harvested in early October. In conventional paddy fields, 30 kg of mixed fertilizer was applied per 0.0667 ha when harrowing the land. Butachlor and pyrazosulfuron were applied in traditional rice paddies to control *Echinochloa crus-galli* P. Beauv by applying them 5–7 d before transplanting rice seedlings. Thiamethoxam was applied in mid-June to control leaf miners and *Lissorhoptrus oryzophilus* (Kuschel). Sheath blight was controlled by applications of validamycin in early July.

Chilo suppressalis (Walker) was controlled by chlorantraniliprole applied in mid-July. Rice blast was controlled by pyraclostrobin applied once at the booting stage and heading stage, respectively. Rice planthoppers and aphids were controlled with pymetrozine.

The same rice and fertilizers were used in the rice–crab fields. Juvenile Chinese mitten crabs (*Er. sinensis*) were introduced into rice–crab cocropping paddy fields on 1 June of each growing season, and they were harvested on 30 September. The density of crabs released was 600–800/0.0667 ha. Before transplanting rice seedlings, we used butachlor for weeding and did not use any herbicides thereafter. Applications of azoxystrobin and propiconazole were used to control rice blast and sheath blight in the rice.

Study design. Six rice fields were chosen for the study, each covering an area of 0.1 ha. Of these, three fields were rice–crab fields and three were traditional rice production fields. Each paddy field was surrounded by a 50-cm dammed ridge. Rice was planted using a mechanical transplanting method, with plants placed 18 cm apart within rows and 30 cm apart between adjacent rows. Sampling points were arranged in a X pattern within each field. Four of the survey points (forming the outer points of the X) were placed 5 m from each edge of the field, two of which were in the same row six rows in from the sampling area margins and 15 m from each other. The fifth survey point was in the center of the field. For each sample, three rice plants were collected at each of the survey points, with a total of 45 rice plants collected from each of the two types of cropping systems.

Samples. The sampling method was based on a beat bucket method described by Knutson and Wilson (1999). We used a white plastic bucket, 30-cm diameter × 20 cm deep, to improve the efficiency of spider collection from the rice plants. The rice plants collected at each sample point were manually beat against the inner sides of the bucket, and collected spiders were placed in 75% ethanol and transported to the lab for eventual identification. Spider egg sacs were not included in the counts or identifications.

Sampling was conducted twice a month, on the 15th and 30th, from 15 June to 15 October each growing season. In all, 18 surveys were conducted over the duration of the study in 2022 and 2023.

Species classification and ecological traits. Fully developed adult and easily recognizable young specimens were identified to the species using the taxonomic keys of Heimer and Nentwig (1991) and Nentwig et al. (2019). The nomenclature followed the latest version of the World Spider Catalog (2019). Species that could not be identified were forwarded to Liaoning Academy of Agricultural Sciences for further identification.

Statistical analysis. All data for 2022 and 2023 were evaluated separately. The community diversity analysis was evaluated using Simpson's index (D), Shannon–Wiener index (H'), Pielou's index (J), and Margalef's index (D_{Ma}). These indices were calculated with the aid of Excel 2019. The specific formulae (Hurlbert 1971, Magurran 1989) were:

(1) Simpson's index (D) was used for dominance analysis, with $D = \Sigma(\mathrm{Pi}) = \Sigma(n_i/N)^2$. Note: n_i is the ratio of the number of the ith species to the total number of individuals; N is the total number of individuals of all species.
(2) Shannon–Wiener diversity index (H') was used for species diversity analysis, with $H' = -\sum_{i=1}^{s} P_i \ln P_i,\ \ P_i = \frac{n_i}{N}$. Note: n_i is the ratio of the number of the ith species to the total number of individuals; N is the total number of individuals of all species, and S is the number of species.
(3) Pielou's index (J) was used for evenness analysis, with $J = H'/H_{max}$. Note: $H_{max} = \ln S$ (S is the total number of species in the community), H' is Shannon–Wiener index, and J is evenness index.
(4) Margalef's index ($D_{Ma)}$ was used for species richness analysis, with $D_{Ma} = (S - 1)/\ln N$. Note: S is the number of species and N is the total number of individuals of all species.

Analysis of variance was performed using SPSS 26.0. An independent-samples t test was conducted to examine the differences in spider populations between the rice–crab cocropping paddy and the conventional paddy. Additionally, Duncan's new complex polarity method was used to assess variations in the number of different spider species found in these two types of fields.

A species was considered dominant when its population size (*N*) was >10% of the total spider assemblage, abundant when *N* was 5–10%, common when *N* was 1–5%, and rare when *N* was <1%.

Results

Spider assemblages. Our survey collected a combined total of 3,406 spiders representing 10 families and 27 species within two distinct categories of rice fields for the duration of this study. Of those, 1,917 spiders were collected from rice–crab cocropping paddy fields; 1,489 spiders were collected from the conventional paddy fields. The number of spiders in the rice–crab cocropping paddies was significantly greater than the number collected from the conventional paddies (2022: $t = 3.401$, $P < 0.001$; 2023: $t = 2.210$, $P < 0.028$).

In both 2022 and 2023, the populations of Lycosidae, Linyphiidae, and Tetragnathidae spider families accounted for over 10% of the total number of spiders in both types of rice fields. The dominant spider species identified in rice–crab cocropping paddy fields and traditional paddy fields was *Pirata subpiraticus*. Conversely, *Hylyphantes graminicola* Sundevall was abundant in rice–crab cocropping paddy fields but was the predominant species in conventional paddy fields. In rice–crab cocropping paddy fields, there were four dominant and abundant species in 2022 and six in 2023, whereas in conventional paddy fields there were three such species in both 2022 and 2023. The variations in spider species counts are detailed in Table 1.

The pattern of fluctuation of spider species in rice–crab cocropping paddy fields over time was found to be similar to that observed in traditional paddy fields, exhibiting comparable trends (Fig. 1). The lowest number of species observed was between four and five on 15 June, whereas the greatest number of species (ranging from 25 to 27) was recorded from 30 July to 15 September for both cropping systems in 2022 and 2023, with no statistically significant differences observed between the systems.

Characteristics of spider community diversity. The Shannon–Wiener index for rice–crab cocropping paddy fields and traditional paddy fields was similar in 2022 and 2023. Initially, the lowest values recorded were 1.4708 (2022) and 1.4648 (2023) for rice–crab cocropping paddy fields, and 1.2149 (2022) and 1.5596 (2023) for conventional paddy fields. Afterward, this index remained within the range of 2.0–3.0 from the end of June until the last sampling of each season, revealing a high abundance of spider species in 2022 and 2023. However, the index was low in early June, indicating that the spider community reconstruction was not complete at that time and diversity was low. The Shannon–Wiener indices between rice–crab cocropping paddy fields and conventional paddy fields did not differ significantly (Fig. 2).

Simpon's index of the two cropping systems differed from the Shannon–Wiener index, which yielded values of 0.2600 (2022) and 0.2593 (2023) in the rice–crab cocropping paddy fields and 0.3333 (2022) and 0.2188 (2023) in conventional paddy fields at the beginning of the surveys. Later, the values remained at about 0.1. There was no significant difference in Simpson's index between rice–crab cocropping paddy fields and conventional paddy fields for 2 yr, thus indicating that the dominance of spiders was not obvious in either rice–crab cocropping paddy fields or conventional paddy fields from the end of rice tillering until rice harvest (Fig. 3).

Table 1. Spider species in rice–crab cocropping and conventional rice paddy fields in Panjin City, China, 2022–2023.

		2022				2023			
		Rice–Crab Cocropping Paddy		Conventional Paddy		Rice–Crab Cocropping Paddy		Conventional Paddy	
Family	Species	Individual Number	Percent (%)	Individual Number	Percent (%)	Individual Number	Percent (%)	Individual Number	Percent (%)
Larval spiders		191a*	19.22	120a	16.19	154a	16.68	124a	16.58
Lycosidae	*Pirata subpiraticus* Boes. et Str.	114b	11.47	88ab	11.88	105b	11.38	105b	14.04
	Pirala practices (Clerck)	54d	5.43	34de	4.59	26efghi	2.82	15def	2.01
	Pardosa laura (Karsch)	13hi	1.31	15de	2.02	9hijk	0.98	12bcde	1.6
	Pardosa pseudoannulata (Bösenberg & Strand)	49de	4.93	38cd	5.13	54d	5.85	36b	4.81
Linyphiidae	*Hylyphantes graminicola* (Sundevall)	91bc	9.15	93b	12.55	89bc	9.64	88bcd	11.76
	Gnathonarium dentatum (Wider)	46defg	4.63	30de	4.05	30efgh	3.25	22cdef	2.94
	Oedothorax insecticeps (Bose et Str.)	32defgi	3.22	21de	2.83	18fghijk	1.95	13cdef	1.74
Clubionidae	*Clubiona japonicola* (Bose et Str.)	47def	4.73	27de	3.67	47de	5.09	34bc	4.55
Tetragnathidae	*Dyschiriognatha quabrimaculata* (Bose et Str.)	81def	8.15	75bc	10.12	81c	8.78	74bcdef	9.89
	Tetragnatha shikokiana Yaginuma	42defgh	4.23	20de	2.7	30efgh	3.25	17def	2.27
	Tetragnatha maxillosa Thoren	13hi	1.31	7de	0.94	16ghijk	1.73	9ef	1.2
	Tetragnatha extensa (L.)	13hi	1.31	4de	0.54	6hijk	0.65	4ef	0.53
	Tetragnatha squamata Karsch	8i	0.8	7de	0.94	9hijk	0.98	6def	0.8
Araneidae	*Larinioides cornuta* (Clerck)	25defgh	2.52	18de	2.43	20fghijk	2.17	21def	2.81
	Neoscone doenitzi (Boes. et Str.)	9i	0.91	10de	1.35	5ijk	0.54	6def	0.8
	Singa hamata Clervk	22efghi	2.21	10de	1.35	55d	5.96	34cdef	4.55
	Hypsosinga pygmaea (Sundevall)	19efghi	1.91	13de	1.75	25efdhij	2.71	22cdef	2.94
	Argiope bruennichi (Scopoli)	4i	0.4	4de	0.54	4ijk	0.43	4def	0.53

Table 1. Continued.

		2022				2023			
		Rice–Crab Cocropping Paddy		Conventional Paddy		Rice–Crab Cocropping Paddy		Conventional Paddy	
Family	Species	Individual Number	Percent (%)	Individual Number	Percent (%)	Individual Number	Percent (%)	Individual Number	Percent (%)
Theridiidae	*Theridion octomaculatum* (Bose et Str.)	16fghi	1.61	12de	1.62	39edf	4.23	35cdef	4.68
Thomisidae	*Misumenops tricuspidatus* F.	29defgh	2.92	17de	2.29	36edfg	3.9	21def	2.81
	Xysticus ephippium Simon	17fghi	1.71	17de	2.29	14ghijk	1.52	9ef	1.2
	Xysticus croceus (Fox)	11hi	1.11	20de	2.7	9higk	0.98	9def	1.2
Salticidae	*Marpissa magister* (Karsch)	20efghi	2.01	16 e	2.16	18fghijk	1.95	13ef	1.74
	Phintella popovi (Proszynski)	15fghi	1.51	14de	1.89	12hijk	1.3	6ef	0.8
	Plexippus setipet Karsch	6i	0.6	3e	0.4	9h	0.98	4ef	0.53
Agelenidae	*Agelena difficilis* (Fox)	2i	0.2	2e	0.27	1k	0.11	1e	0.13
Dictynidae	*Dictyna arundinacea* (L.)	5i	0.5	6de	0.81	2jk	0.22	4e	0.53

* Numbers followed by different lowercase letters represent significant differences ($P < 0.05$) among different spider species discovered in rice–crab cocropping paddy or the conventional paddy during the survey period. These differences were analyzed using Duncan's new complex polarity method.

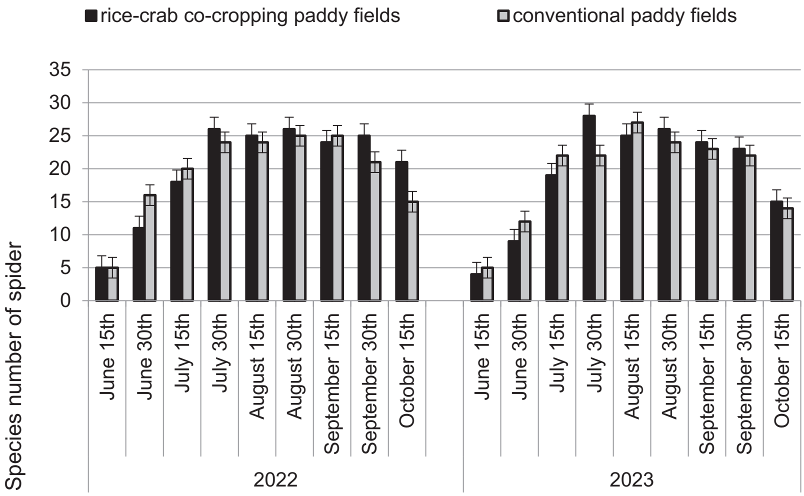

Fig. 1. Trends in the number of spider species over time in rice–crab cocropping paddy fields and conventional paddy fields.

Pielou's index (Fig. 4) indicates how individual numbers of different species are distributed within a community or habitat. It indirectly highlighted the significance of the dominant species in the spider community. The index was high for both types of rice fields in 2022 and 2023 and remained within the range of 0.82–0.95 for rice–crab cocropping paddy fields and 0.81–0.97 for conventional paddy fields throughout the entire year. Overall, the trend of Pielou's index changed gradually, indicating that there was not a high dominance of different spider species in both rice–crab cocropping paddy fields and traditional paddy fields.

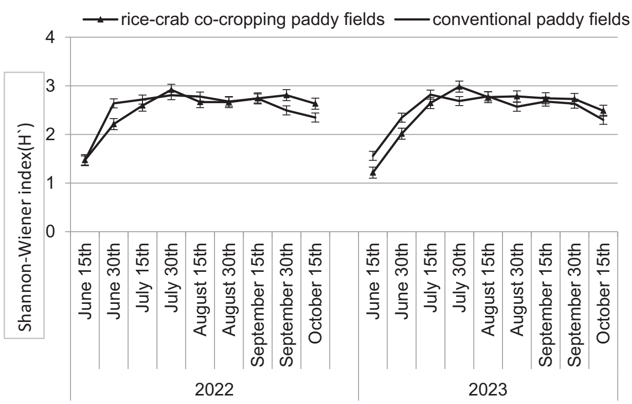

Fig. 2. Variation of the Shannon–Wiener index (H') over time in rice–crab cocropping paddy fields and conventional paddy fields.

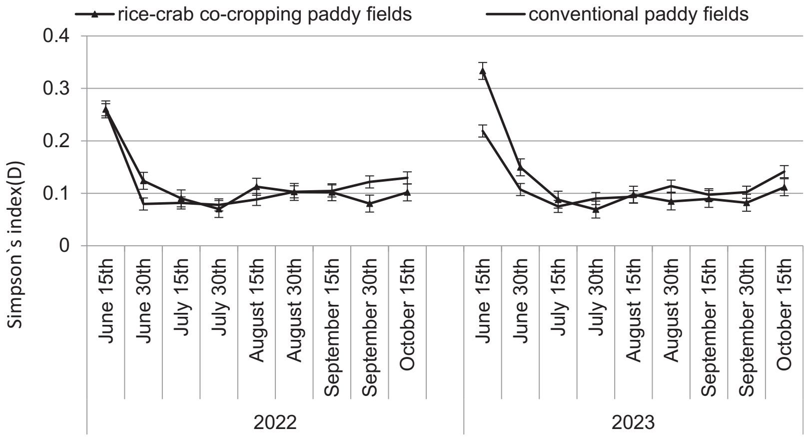

Fig. 3. Variation of Simpson's index (*D*) over time in rice–crab cocropping paddy fields and conventional paddy fields.

The trend of variation in Margalef's index generally aligned with the Shannon–Wiener index. However, there were some differences between the rice–crab cocropping paddy fields and conventional paddy fields in 2022. The key distinction was that Margerlef's index in rice–crab cocropping paddy fields was notably greater than in traditional paddy fields on 15 October. There also were variations in the index for the years 2022 and 2023. On 15 October 2022, the paddy fields where rice and crabs were cocropped had a Margalef's index value of 5.3857, which was the highest recorded. Similarly, on 30 July 2023, the same fields had the highest value of 5.8135. In general, there was a high number of spider species present

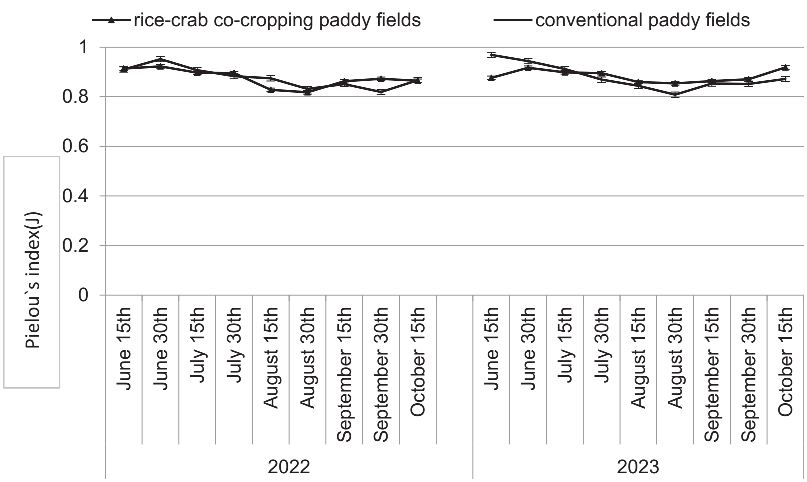

Fig. 4. Variation of Pielou's index (*J*) over time in rice–crab cocropping paddy fields and conventional paddy fields.

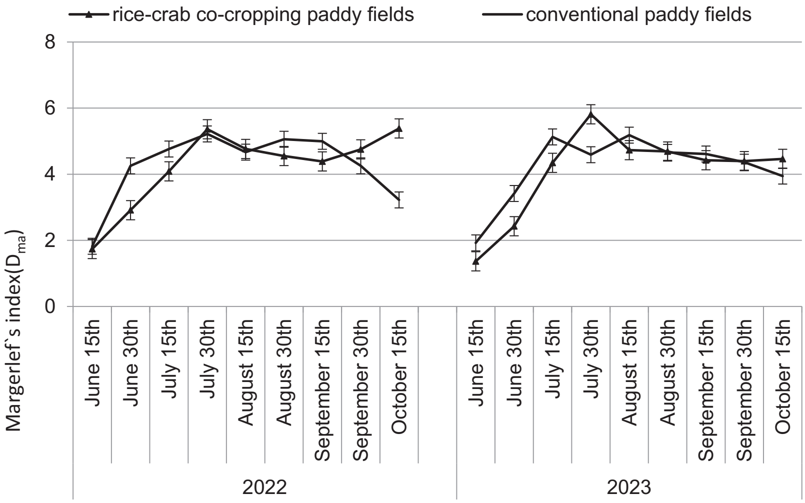

Fig. 5. Variation of Margerlef's index (D_{Ma}) over time in rice–crab cocropping paddy fields and conventional paddy fields.

in both types of rice fields from 15 July until the time of the rice harvest each season (Fig. 5).

The Shannon–Wiener index fluctuated over time, indicating the general trend of changes in community diversity from when the spider population entered the paddy field to the rice being harvested. With the rise in diversity, there was a corresponding increase in evenness and richness levels, leading to a decrease in the Simpson's index, suggesting that the dominant species held less significance within the community. This indicates that there is a specific relationship between the factors. Pielou's index and Margalef's index showed a general positive relationship with the Shannon–Wiener index, whereas the Simpson index exhibited a notable negative correlation with the Shannon–Wiener index.

Discussion

As a new cultivation model, rice–crab cocultivation offers greater advantages than the conventional rice cultivation model in terms of economic, social, and ecological benefits (Xu et al. 2014). Rice–crab cocropping patterns are mainly concentrated in the northern coastal areas of China. According to statistics from 2006, the production of crab species in Liaoning Province reached 19,020 tons, ranking first in China (Wang 2008). Previous research has primarily focused on weed management, disease control, safe pesticide use, stocking density of mitten crabs, and the impact of rice cultivation methods on both rice and mitten crabs within the rice–crab cocropping system. Studies by Gong et al. (2010), Lv et al. (2011), Xu et al. (2014), Yan et al. (2008), and Yu et al. (2011, 2013) have explored these aspects. The diversity of spider populations in the cocropping system of rice and crabs has not been studied or reported.

Our study reveals that there were many spider species present in both rice–crab cocropping paddy fields and conventional paddy fields, with a notably higher number of spiders found in the rice–crab cocropping paddy fields. Of the 3,406 spider specimens collected, the greatest number belonged to the families Lycosidae, Linyphiidae, and Tetragnathidae. There were more spiders in the rice–crab cocropping paddy fields area compared with conventional paddy fields, with both areas being dominated by the *P. subpiraticus* species. This differs slightly from the findings of the study conducted by Wang et al. (2015) on spider-dominant species in the Panjin rice region.

We found a slight variation in the number of spider species found in the two types of rice fields. In rice–crab cocropping paddy fields, the percentage of *H. graminicola* was 9.15% in 2022 and 9.64% in 2023, both below 10%. In contrast, the proportion of *H. graminicola* in traditional paddy fields was 12.55% in 2022 and 11.76% in 2023. The typical percentage of *H. graminicola* remained at 10.85% in 2022 and 10.70% in 2023, indicating that it can be considered a prevalent species.

The examination of the spider diversity index revealed that the diversity of the spider community was slightly reduced in early June but remained consistently high in other periods. The evenness index and the richness index exhibited a positive relationship, whereas the dominance index showed a negative relationship. The diversity index of rice–crab fields exhibited a similar trend to that of conventional fields. Xu et al. (2018) found no significant differences in spider community diversity, evenness, and dominance between rice fields where pesticides were used and those where they were not applied in 2018, reflecting the results of the present study.

Research has indicated that the ongoing application of chemicals on traditional farms decreases the population of pests and their natural predators, hinders the process of ecosystem recovery, and ultimately results in a decrease in biodiversity. This, in turn, restricts the effectiveness of natural predators in managing pest populations. Since no chemical substances are used in rice–crab fields, the amount of plant and animal life in these fields is greater compared with traditional fields, even though mitten crabs consume some pests and natural predators. River crabs in rice fields help control weeds and insects by feeding on insects, grass, and digging soil. These phenomena promote rice growth to a certain extent.

Our findings identified the types and quantities of spiders present in the rice–crab field to determine the composition of the spider community and serve as a basis for further research. By raising mitten crabs in the rice field and reducing the use of pesticides, the diversity of the ecosystem in the rice field was altered. The relationship between mitten crabs and herbivorous, predatory, and neutral arthropods in rice fields remains not fully understood. Additional research is needed on the hunting abilities of various spider species, pest management in rice fields, and the ecological role of spiders.

Acknowledgments

This study was supported by Liaoning Province Science and Technology Plan project, which is a study of the potential of *Haplogonatopus oratorius* to control *Laodelphax striatellus* and influencing factors in the northern rice region (2022-MS-063); project of the Presidential Fund of Liaoning Academy of Agricultural Sciences, “Influence of rice volatiles on the selection behavior of *Laodelphax striatellus*” (2023QN2413); project of Liaoning Provincial Science and Technology Programme “Creation and Application of Ecological Pollution Control System for Optimising Biodiversity Structure in Rice Field Ecosystems” (2022JH2/101300161). Mention of a commercial or proprietary product does not constitute an endorsement of the product by the Liaoning Provincial Saline–Alkali Land Utilization and Research Institute.

References Cited

Ahmed, N. and S.T. Garnett. 2011. Integrated rice–fish farming in Bangladesh: Meeting the challenges of food security. J. Food Secur. 3: 81–92.

Chen, L.S., W. Wang and Z.Z. Chen. 2001. Cultural tendency of *Eriocheir sinensis* by market analysis. J. Shanghai Fish. Univ. 10: 81–85.

David, C.L., S. Pimjai and N. I. Taylor. 1996. Fish culture in the rainfed rice field of northeast Thailand. Aquaculture 140(4): 295–321.

Fei, X.C. and J.Z. Zeng. 2002. Ecological economic analysis of a rice–crab model. J. Appl. Ecol. 13: 323–326.

Fernando, C.H. 1993. Rice field ecology and fish culture overview. Hydrobiologia 259: 91–113.

Gong, L.L., L.P. Fan, F. Gao, Z.F. Huang and B. Zhao. 2010. Safe use the technology of rice drugs in the rice–crab cultural system. Aquat. Sci. Technol. Inform.37(4): 202–203.

Halwart, M. 2006. Biodiversity and nutrition in rice-based aquatic ecosystems. J. Food Comp. Anal.19: 747–751.

Heimer, S. and W. Nentwig. 1991. SpinnenMitteleuropas: EinBestimmungbusch. Paul Parey, Berlin.

Hurlbert, S.H. 1971. The nonconcept of species diversity: A critique and alternative parameters. Ecology 52(4): 577–586.

Knutson, A.E. and W.T. Wilson. 1999. The beat bucket: A rapid, reliable method for sampling predatory insects and spiders in cotton, Pp. 1120–1125. *In* Dugger, P. and D. Richter (eds.), Proceedings of the 1999 Beltwide Cotton Conference, Memphis, TN.

Lv, D.F., W. Wang, X.Z. Ma, Q.Wang, A. Wang, Z.Z. Chen and S.Q. Tang. 2011. Ecological prevention and control of weeds in the rice–crab poly-cultured field. Hubei Agric. Sci. 50(8): 1574–1578.

Ma, X.H., X.Q. Che, J.S.Wang and H.X. Sang. 2019. The structure of spider communities in crab paddies and conventional paddies. Chin. Eco-Agric. 47: 1157–1162.

Magurran, A. E. 1989. Ecological diversity and its measurement. Springer, Dordrecht.

Michael, F. and B. Klaus. 2005. Integrated rice–fish culture: Coupled production saves resources. Nat. Res. Forum 29: 135–143.

Nentwig, W., T. Blick, D. Gloor, A. Hangi and C. Kropf. 2019. Spiders of Europe. Version 03.2019. 15 March 2019. (http://araneae.nmbe.ch/).

Nyffeler, M. and G. Benz. 1987. Spiders in natural pest control: A review. J. Appl. Entomol. 103: 321–339.

Nyffeler, M., and K.D. Sunderland. 2003. Composition, abundance and pest control potential of spider communities in agroecosystems: A comparison of European and US. studies. Agric. Ecosys. Environ. 95: 579–612.

Pearce, S. and P.M. Zalucki. 2006. Do predators aggregate in response to pest density in agroecosystems? Assessing within-field spatial patterns. J. Appl. Ecol. 43: 128–140.

Radheyshyam, G.S., S.Lekha, A.E. Safui, S. Eknath, H.K. Adhikari, N.K. De, S. Barik and S. Chandra. 2013. Status and economy of community fish farming in rural Odisha. Indian J. Fish. 60: 59–67.

Riechert, S.E. and T. Lockley.1984. Spiders as biological control agents. Annu. Rev. Entomol. 29: 299–320.

Shams, N. 2007. Contribution of rice field ecosystems to food security strategies in Northwest Cambodia. J. Sustain. Agric. Environ.29: 109–133.

Shi, S.S., Y.B. Gao, L.S. Zang, W. Yang and J.W. Gao. 2012. Effects of several insecticides on the arthropod community in soybean fields. Chin. J. Appl. Entomol. 49(5): 1249–1254.

Tahir, M.H. and B. Abida. 2009. Predatory potential of three hunting spiders inhabiting the rice ecosystems. J. Pest Sci. 82(3): 217–225.

Wang, J.S., X.H. Ma and H.X. Sang. 2015. Investigation and analysis of dominant natural enemies in Liaohe River Delta. Plant Prot. 41(1): 163–165.

Wang, W. 2008. The development train of thought on crab industry in paddy fields in north China. China Fish. (10): 11–13.

World Spider Catalog. 2019. World Spider Catalog, Version 20.0. Natural History Museum Bern. 15 March 2019. (http://wsc, nmbe.ch/).

Xu, M., X.Z. Ma and W. Wang. 2014. Effects of different cultivation patterns on rice yield and crab in the rice–crab culture system. Sci. Agric. Sin. 47(9): 1828–1835.

Xu, X.L, Z.R. Liu, F.S. Wang, X.H. Wng, Y.J. Yao, N. Li, X.Y. Ji and J.X. Jiang. 2018. Effects of different control measures on spider subcommunity structure in rice field. Chinese Agric. Sci. Bull. 43(1): 118–123.

Yan, L.Z., R.M. Lin, J.Y. Niu and J.H. Liu. 2008. Current status and prospectives of rice–crab production technique research in China. Reclaim. Rice Cult. 38(2): 5–9.

Yu, F.Q., Z.Q. Li, X. Zhao, L.Y. Shao, M. Yang, F.Y. Sun and F. Song. 2013. Study on the control effect of different chemicals on rice blast in rice–crab paddy. Liaoning Agric. Sci. 1: 78–79.

Yu, F.Q., F.Y. Sun, Z.Q. Li, M. Yang, L.Y. Shao, X. Zhao and Y.Q.Yu. 2011. Drug screening for Spirogyra controls the rice–crab culture system. Liaoning Agric. Sci. 4: 75–76.