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Article

# Insect Community Structure and Diversity Patterns in Zhanjiang's Saline-Alkali Tolerant Rice Ecosystems

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## Abstract

Against the backdrop of global warming and expanding saline-alkali land, cultivating salt-tolerant rice is critical for safeguarding China's food security. As a major coastal agricultural region, Zhanjiang in Guangdong Province provides an important study site to explore insect diversity in salt-tolerant rice ecosystems, which is key to understanding local species diversity. This study aims to conduct research on the insect diversity of the salt-tolerant rice meadow in Zhanjiang, to understand the species composition and transmission of insects in this ecosystem. This study uses hemp nets to simultaneously collect insects from the Haihong Aromatic Rice, wild sea rice, and the growth areas of conventional rice in the Zhanjiang area. After collecting the insects and conducting classification and discovery, The social structures of these insects and the diversity existing among them were studied. Based on classification results, a total of 270 insect species were identified across nine orders (Coleoptera, Diptera, Hymenoptera, Lepidoptera, Hemiptera, Orthoptera, Odonata, and Alata). Diversity analysis showed rich insect diversity in salt-tolerant rice fields, where Diptera and Hemiptera dominated the overall population.

**Keywords:** salt-tolerant rice; insect diversity; ecological diversity; insect community structure

## 1. Introduction

Global warming and the increasing spread of saline-alkali soils present substantial hurdles to agricultural productivity [1–4], underscoring the urgent need to develop salt-tolerant crop varieties to ensure food security [5]. Salt-tolerant rice has become a key solution because of its capacity to grow well in high-salinity settings. Zhanjiang City, located in Guangdong Province, China, is a coastal agricultural area with large stretches of saline-alkali land. It serves as an ideal natural testing site for cultivating salt-tolerant rice. Researching the insect diversity in these distinctive ecosystems is vital for comprehending biodiversity patterns, the stability of the ecosystem, and sustainable farming methods in saline-alkali conditions [6]. This kind of research can offer important information for creating farming strategies that can adjust to environmental changes and maintain ecological balance [7–9].

Recent studies on salt-tolerant rice ecosystems have highlighted the interplay between insect communities and crop resilience [10–12]. While China has made notable progress in identifying salt-tolerant genes and ecological adaptation mechanisms of insects, research remains fragmented [13], particularly regarding the composition, dynamics, and functional roles of insect communities in saline-alkali rice fields. Internationally, efforts have focused on ecosystem restoration and biodiversity enhancement through salt-tolerant crops, yet comprehensive data on species-specific

interactions and community structures are still lacking. This knowledge gap limits the formulation of targeted strategies for ecological management and pest control [14–18].

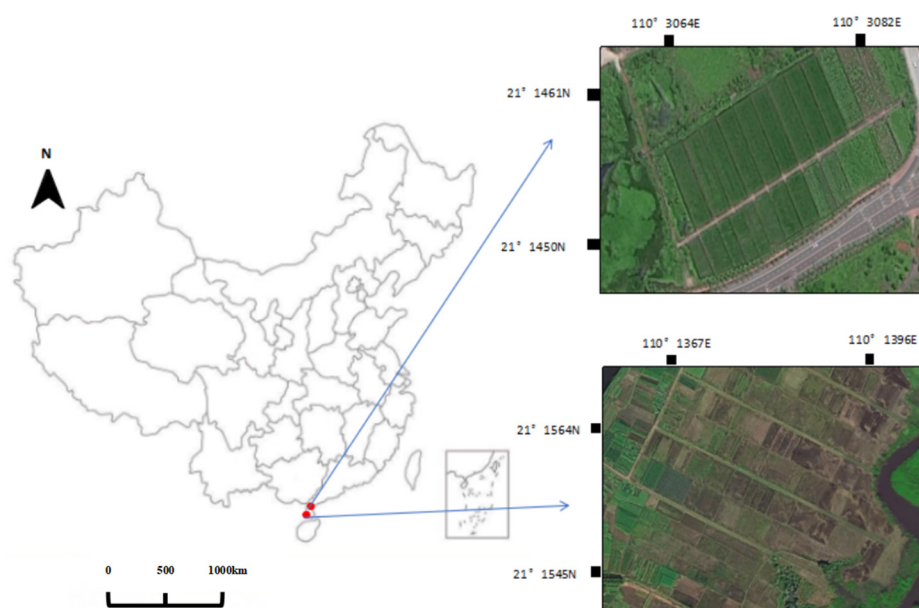
Zhanjiang's salt-tolerant rice strains, including Haihong Aromatic Rice and wild sea rice, show strong adaptability to saline soils [19]. They can regulate ions and exclude salt to thrive in harsh conditions. These rice types are planted in different places, from coastal tidal flats to inland saline-alkali areas. Such diverse environments form unique habitats that influence the makeup of insect communities [20]. But how these rice varieties interact with insects - including pests, pollinators, and natural enemies - is still not well studied. More research could help improve pest control and ecosystem balance in salt-affected farmland [21,22].

This research project systematically explores the insect life in Zhanjiang's salt-tolerant rice fields. We're comparing three types of rice: Haihong Aromatic Rice, wild sea rice, and regular rice. By looking at the kinds of insects present, how their populations change over time, and using ecological measures [22–24], our goal is to figure out how these salty environments stay balanced. Specifically, we want to understand how pest populations are kept in check naturally [25]. The results of this study will be really important for farmers. They'll help us come up with better ways to manage farms, use fewer pesticides [26], and promote farming methods that can last in the long run, especially in coastal areas where soil salinity [27] is becoming a bigger problem [28–30].

## 2. Materials and Methods

### 2.1. Study Site

The research of this article was carried out in two places in Guangdong Province, China. One is the Haihong Aromatic Rice Planting Base, which is located in Buchao Village, Jianxin Town, Suixi County, Zhanjiang City, on County Road 644. The other is No. 1 Haida Road, which is located in Mazhang District, Zhanjiang City (Figure 1). The planting period of salt-tolerant rice began in late June 2021 and continued until 2023. The investigation of the insect community began on May 12, 2021 and ended on December 15, 2023. Under appropriate community management conditions, the total planting area is approximately 200 acres. In a series of increased events, the use of pesticides was not required. Insect samples were classified according to the varieties of rice. The samples of conventional rice were collected from No. 1 Haida Road, while the samples of wild sea rice and Haihong Aromatic Rice were collected from Haihong Aromatic Rice planting base. All the planting operation habits, such as irrigation and fertilization, were carried out in accordance with the local agricultural conduct norms, and certain agreements were reached during the testing period.



**Figure 1.** Map showing the study region and the specimen areas.

## 2.2. Methods

To collect insects, this study employed Malaise traps in multiple rice fields across Zhanjiang throughout the experimental period. The insect samples that had calmed down were placed under a dissection microscope for observation and calculation to carry out classification and identification work. Then, an analysis of insect diversity was conducted according to the methods adopted in the research, and thus the insect diversity index of the region for that year was obtained [31]. Based on relevant analyses in this paper, the current status of insect diversity in Zhanjiang Haihong Aromatic Rice, wild sea rice and conventional rice is finally obtained.

Based on the specific geographical location and soil salinity [32] of the rice fields in Zhanjiang, this article selected representative sample plots. Insect aggregation tools such as net brushing and insect traps were used in this article. Then, insect classification was carried out. For the collected insects, this article classified them with the help of relevant insect classification works. During the classification process, this paper recorded information such as the types and quantities of insects. Finally, the samples were processed and preserved.

At this stage of field investigation, it is a very crucial step to strictly process the insect samples collected from the salt-tolerant rice fields in Zhanjiang. To ensure the integrity of the specimens and avoid interfering with the ecological environment of the insects during the collection process, we carry out the collection work in accordance with the standard entomological collection methods [33]. We put the collected insects into specially made 80% alcohol solution boxes [34]. This is done to maintain the physiological activity and morphological characteristics of the insects. After bringing the specimens back to the laboratory, we will carry out a comprehensive classification work. This step requires consulting relevant literature and specimen illustrations, and applying professional knowledge in insect taxonomy. Classify insects at the corresponding levels of families, genera and species [35].

During the insect classification process, we employed a microscope to closely examine the insects' intricate morphological features, including wing venation patterns, antennal structures, and mouthpart characteristics. These detailed observations were crucial for accurate taxonomic identification. Following classification, we preserved the insect specimens in a dehydrated environment with controlled temperature conditions [36]. This storage method helps prevent microbial contamination and other biological degradation factors during long-term preservation. Additionally, each specimen is accompanied by comprehensive metadata documenting species-level identification, collection location, and relevant ecological parameters. This standardized documentation ensures the specimens remain valuable resources for future research and facilitates comparative analyses across different datasets. With such a set of sample processing procedures, the relevant information of each insect can be accurately recorded, providing a solid and powerful foundation guarantee for the subsequent diversity analysis work.

In this paper, the insect community in salt-tolerant rice fields was investigated by using the sampling method of insect traps. When choosing the location for installing the insect traps, the core area with good ventilation and abundant sunlight was selected. The installed insect traps were provided by the Coastal Agriculture College of Guangdong Ocean University. When installing the insect traps, the fixing ropes should be tightened to make all the net surfaces tight and flat. And keep the ridge inclination Angle of the net between 35° and 45°. To seamlessly connect the black barrier screen with the ground, it will be more convenient to collect crawling insects. The work of collecting insect communities will continue until the development stage of salt-tolerant rice ears ends [39]. After the insects collected in the paddy field are brought indoors, the debris inside should be removed first to pick out the insects, and then the insects should be preserved with 80% alcohol. Then discover and count these insects. For common insects, this paper will try its best to identify them at the species position, while for other insects, this paper will identify them at the relationship level b [27,40].

### 2.3. Data Statistics and Analysis

This article will conduct statistical analysis on the collected insect data to obtain environmental indicators such as species richness and difference index. This article will use statistical computer programs such as SPSS and R to analyze the data, and then carry out research on the relationship between insect diversity and environmental factors such as salinity and soil nutrients. Based on the results obtained from the analysis, This article will draw insect diversity distribution maps, correlation analysis diagrams, etc., to visually present the research results in this way. Based on obtaining these results, this paper explores the impact of insect diversity on the growth of rice in Zhanjiang and the influence of saline-alkali land in Zhanjiang on insect diversity. According to the contents of these discussions, some improvement measures that can promote the healthy development of the rice field ecosystem in Zhanjiang. When conducting data analysis, This paper adopts the Shannon-Wiener diversity index, whose calculation formula is  $H = -\sum[\times \ln(\pi)]$ , as well as the Margalef richness index, whose calculation formula is  $D = 1 - \Sigma^2$ , and the Simpson evenness index and so on. Its calculation formula includes various environmental diversity indicators such as  $J = H' / \ln S$ , and these indicators are used to determine the richness and evenness of the insect community. These environmental diversity indicators can help us discover the structure and complexity of insect populations [38].

## 3. Results

Based on the data from the six tables below, we have found that in different types of rice fields—such as those growing Haihong Aromatic Rice, wild sea rice, and Conventional Rice—we've noticed clear differences in the kinds of insects present, what they do in the environment, and what influences their populations. Flies (Diptera) and true bugs (Hemiptera) are the most common insects across all these rice systems. However, there are also some differences in the insect communities depending on the type of rice field. Understanding these similarities and differences is important for managing pests and keeping the rice ecosystem healthy. For example, knowing which insects are more common in certain rice fields can help farmers decide the best ways to control pests without harming beneficial insects.

Lepidoptera, though less abundant ( $\leq 1.93$ – $20.91\%$  across systems), contribute substantially to crop damage via larval feeding. Represented by noctuids and pyralids, their larvae (e.g., rice leaf stem borers, stem borers) target leaves and stems, causing yield losses. However, their impact is partially regulated by parasitoid wasps, a key component of Hymenoptera communities. Hymenoptera, despite low individual abundance ( $4.63$ – $9.51\%$  across systems), exhibit high taxonomic diversity, with parasitoid wasps (e.g., Braconidae, Chalcididae) playing a critical but underutilized role in natural pest control. Their limited abundance—attributed to pesticide use and habitat simplification—restricts their potential to suppress Lepidoptera and Hemiptera pests, emphasizing the need for strategies to enhance their populations (e.g., reducing broad-spectrum pesticides, adding floral resources) [41].

Rare taxa, including Orthoptera, Neuroptera, and Thysanoptera, are consistently scarce across ecosystems ( $\leq 3.54\%$ ), with proportions often below  $1.72\%$ . Their decline reflects broader biodiversity loss linked to intensive monoculture practices, habitat homogenization, and chemical pesticide use, positioning them as indicators of ecological stress in rice agroecosystems.

Collectively, these patterns underscore the dominance of pest groups (Diptera and Hemiptera) across rice systems, driven by environmental adaptability (e.g., humidity tolerance) and human-induced factors (e.g., pesticide use) [42]. Meanwhile, beneficial taxa like parasitoid wasps remain underrepresented, limiting natural pest regulation. To balance crop protection and ecosystem health, management strategies should prioritize reducing pesticide impacts, enhancing habitat complexity (e.g., flower strips, weeding belts), and promoting targeted biological control—ultimately fostering more resilient insect communities that support sustainable rice production.

**Table 1.** Overall situation of the insect community of Haihong Aromatic Rice.

Insect Order	Haihong Aromatic Rice					
	Family	Percentage%	Species	Percentage%	Quantity	Percentage%
Orthoptera	1	1.72	15	11.27	14	0.78
Coleoptera	10	17.24	11	8.27	17	0.95
Hymenoptera	12	20.68	30	22.55	170	9.51
Lepidoptera	5	8.62	12	9.02	154	8.61
Diptera	19	32.75	51	38.34	983	55.00
Blattaria	1	1.72	1	0.75	3	0.17
Hemiptera	9	15.51	12	9.02	445	24.09
Neuroptera	1	1.72	1	0.75	1	0.05
Sum	58	100	133	100	1787	100

**Table 2.** Insect Community Composition of Haihong Aromatic Rice.

Diptera		Hemiptera		Hymenoptera		Lepidoptera		Orthoptera	
Family	Percent age%	Family	Percent age%	Family	Percentage %	Family	Percentage%	Family	Percentage%
Tachinidae	30.72	Fulgoridae	77.52	Scelionidae	26.47	Noctuidae	76.47	Gryllidae	100
Chloropidae	25.73	Cicadellidae	19.32	Braconidae	21.76	Pyralidae	20.91		
Pipunculidae	12.00	Aphididae	1.79	Ichneumonidae	15.29	Lymantriidae	0.65		
Culicidae	8.14	Miridae	0.45	Ceraphronidae	13.53				
Tipulidae	6.51	Lygaeidae	0.22	Diapriidae	8.24				
Psychodidae	5.49	Reduviidae	0.22	Formicidae	3.53				
Cecidomyiidae	3.46	Pentatomidae	0.22	Xiphiidae	2.94				
Mycetophilidae	2.95			Trichogrammatidae	1.76				
Calliphoridae	1.73			Evaniidae	1.76				
Muscidae	1.63			Trigonalidae	1.76				
Anthomyiidae	0.61			Torymidae	1.76				
Tabanidae	0.61			Tenthredinidae	0.59				
Syrphidae	0.20								
Bombyliidae	0.10								

**Table 3.** Insect communities in wild sea water rice paddies in general.

Insect Order	wild sea rice					
	Family	Percentage%	Species	Percentage%	Quantity	Percentage%
Orthoptera	2	3.84	6	3.24	93	3.54
Coleoptera	10	19.23	18	9.72	45	1.71
Hymenoptera	12	23.07	45	24.32	185	7.05
Lepidoptera	4	7.69	16	8.64	105	4.00

Diptera	17	32.69	89	48.10	1903	72.52
Blattaria	1	1.92	3	1.62	6	0.22
Hemiptera	6	11.53	8	4.32	287	10.93
Sum	52	100	185	100	2624	100

**Table 4.** Insect community composition in wild sea water rice.

Diptera Family	Percenta ge%	Hemiptera Family	Percenta ge%	Hymenoptera Family	Percenta ge%	Lepidoptera Family	Percenta ge%	Orthoptera	
								Family	Percenta ge%
Chloropidae	29.07	Cicadellid ae	53.31	Ichneumoni dae	38.58	Noctuida e	76.47	Gryllide a	88.17
Tachinidae	26.07	Fulgoridae	40.76	Formicidae	16.30	Satyridae	20.91	Acridid ae	11.82
Pipunculida e	10.35	Aphididae	3.83	Braconidae	14.13	Hesperiid ae	1.96		
Psychodida e	8.46	Cercopida e	1.04	Scelionidae	9.78	Pyralidae	0.65		
Culicidae	6.52	Miroidea	0.67	Diapriidae	5.43				
Cecidomyii dae	3.78	Pentatomi dae	0.35	Torymidae	4.34				
Muscidae	3.63			Scoliidae	3.26				
Tipulidae	2.52			Evaniidae	2.71				
Drosophilid ae	2.21			Xiphiidae	1.63				
Calliphorid ae	2.15			Hydatidae	1.63				
Syrphidae	1.94			Ceraphroni dae	1.63				
Anthomyiid ae	1.36			Bethyloidea	0.54				
Tephritidae	0.74								
Tabanidae	0.37								
Asiloidea	0.21								
Aspididae	0.05								
Ephydridae	0.05								

**Table 5.** General situation of insect community in conventional rice field.

Insect Order	Conventional Rice					
	Family	Percentage%	Species	Percentage%	Quantity	Percentage%
Orthoptera	2	3.63	2	1.32	2	0.08
Coleoptera	11	20.00	22	14.56	59	2.53
Hymenoptera	11	20.00	22	14.56	108	4.63
Lepidoptera	5	9.09	19	12.58	45	1.93
Diptera	17	30.9	64	42.38	1565	67.13
Blattaria	1	1.81	1	0.66	1	0.04
Hemiptera	7	12.72	20	13.24	550	23.59
Odonata	1	1.81	1	0.66	1	0.04
Sum	55	100	151	100	2331	100

**Table 6.** Composition of conventional rice insect community.

Diptera		Hemiptera		Hymenoptera		Coleoptera		Lepidoptera	
Family	Percentage%	Family	Percentage%	Family	Percentage%	Family	Percentage%	Family	Percentage%
Culicidae	19.74	Cicadellidae	58	Diapriidae	29.35	Chrysomelidae	35.08	Noctuidae	48.88
Pipunculidae	15.07	Aphididae	30.9	Formicidae	28.44	Calypteridae	24.56	Satyridae	26.66
Tachinidae	12.71	Fulgoroidea	5.81	Ichneumonidae	14.67	Cicindelidae	12.28	Pyralidae	20.0
Muscidae	9.01	Reduviidae	3.63	Trigonidae	7.33	Hydrophilidae	10.52	Lymantriidae	2.22
Psychodidae	7.92	Pentatomidae	0.90	Braconidae	7.33	Melolonthidae	8.77	Arctiidae	2.22
Chloropidae	6.07	Miroidea	0.18	Torymidae	4.58	Silphidae	3.50		
Mycetophilidae	4.79			Ceraphronidae	3.66	Curculionidae	1.75		
Cecidomyiidae	4.72			Scoliidae	1.83	Carabidae	1.75		
Calliphoridae	4.34			Trichogrammatidae	0.91	Lampyridae	1.75		
Tipulidae	3.00			Hydatidae	0.91	Brentidae	1.75		
Tephritidae	3.00								
Anthomyiidae	2.93								
Bombyliidae	2.42								
Tabanidae	1.85								
Aspididae	0.76								
Syrphidae	0.25								

The results of various ecological indices of rice in different habitats (Figure 2) reveal that the ecological indices of the insect communities in the three rice habitats present a relatively prominent pattern. The species richness of wild sea rice is the highest, specifically  $S$  equal to 188, and its total number of individuals is also the highest,  $N$  equal to 2628. This might be because its natural habitat is least disturbed by pesticides. And it is caused by the relatively high environmental heterogeneity. However, its Shannon-Wiener diversity index is  $H7$  equal to 0.2753, slightly lower than  $H7$  equal to 0.2962 of the sea red fragrant rice. Although the  $S$  of the Haihong Aromatic Rice is 135 and the  $N$  is 1774, which are relatively low values, its Margalef richness  $d9$  equal to 12.6767 is the highest. The individual species diversity of Haihong Aromatic Rice is relatively high. The biodiversity of conventional rice has undergone severe degradation. Its  $H7$  is equal to 0.1419, the Simpson evenness is the lowest, and  $E$  is equal to 0.0344. This reflects that under the intensive farming method, pest groups such as hemiptera are in a dominant position. The dominance index of wild sea rice is the highest,  $J$  is equal to 0.0398. Dominant species like Diptera have potential ecological risks. To address these issues, in the future, priority should be given to protecting the natural habitats of wild sea rice. Some ecological measures should be taken in conventional rice cultivation, such as reducing the use of pesticides and diversifying the habitats. Moreover, the unique potential of Haihong Aromatic Rice should be explored through functional diversity assessment. These strategies aim to coordinate the relationship between agricultural productivity and the conservation of biodiversity in rice ecosystems.

This paper, by conducting a detailed analysis of these data, explores the structure of insect communities and their interactions. During the research process, it was found that some insect species may form a mutualistic symbiotic relationship with rice. Just like bees pollinate rice, those natural enemy insects can control the number of pests to maintain the balance of the ecosystem. The results obtained from these studies are of great value for us to understand the planting situation of salt-tolerant rice and optimize the planting and management strategies of salt-tolerant rice.

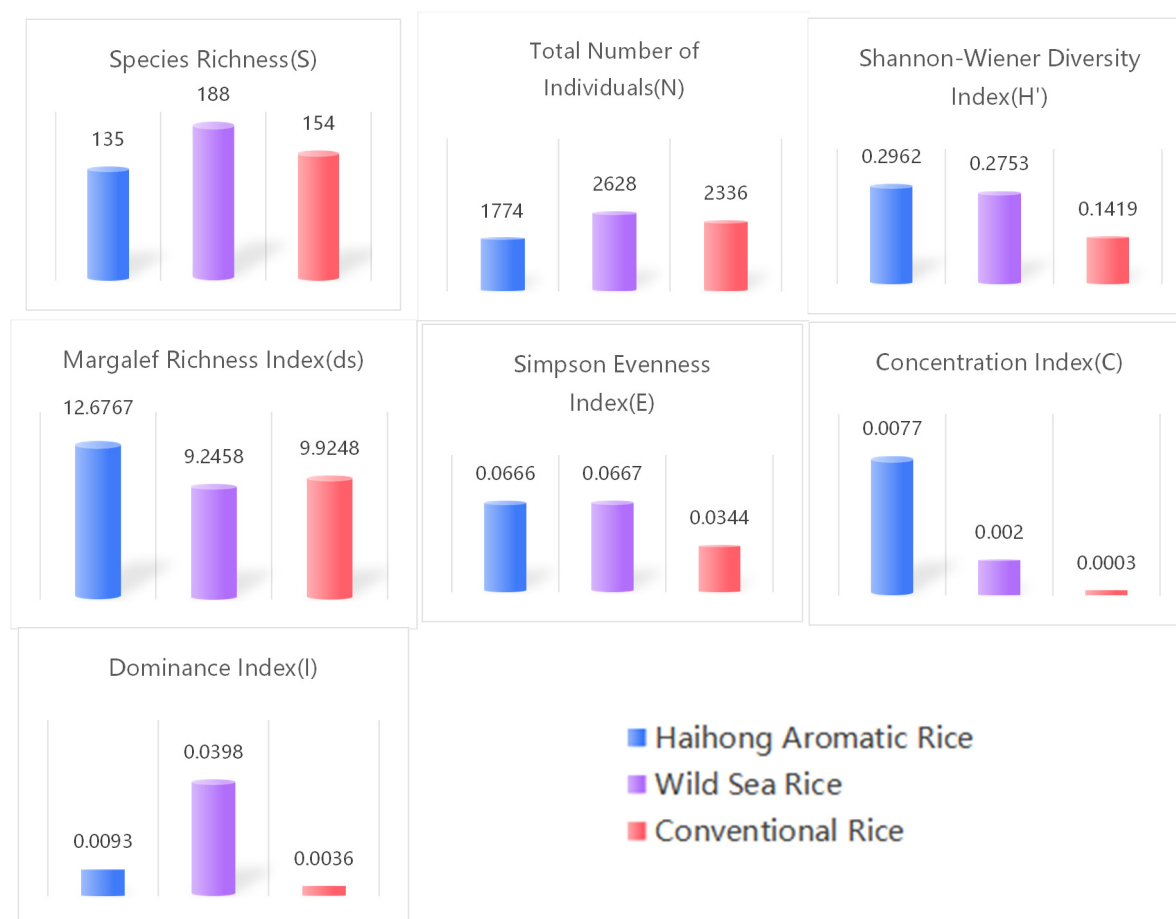


Figure 2. Various ecological indices of rice in different habitats.

#### 4. Discussion

The issue of global warming and the continuous expansion of saline-alkali land have posed significant challenges to agricultural productivity [4–7]. It is necessary to develop salt-tolerant crops to ensure food security. Among various crops, salt-tolerant rice, also known as “sea rice”, has become a crucial solution. This is because it has the ability to grow healthily in an environment with relatively high salinity. Zhanjiang City is located in the coastal agricultural area of Guangdong Province, China. The saline-alkali land there is widely distributed and can be regarded as a natural experimental site for cultivating salt-tolerant rice. Conducting research on the insect diversity in these ecosystems with unique characteristics is of great significance for us to understand the biodiversity patterns, ecological stability and sustainable agricultural practices in saline-alkali environments that is very crucial [10,43,44].

In recent studies on salt-tolerant rice ecosystems, the interaction between insect communities and crop stress resistance has been emphasized. Although China has made considerable progress in identifying the salt-tolerant genes of insects and their ecological adaptation mechanisms, research on the composition, dynamic changes, and actual roles of insect communities in salt-alkali rice fields has been conducted [45]. So far, it is still very incomplete. Internationally, the efforts made by all have mainly focused on restoring ecosystems and enhancing biodiversity by growing salt-tolerant crops.

However, comprehensive data on species-specific interactions and community structures are still relatively scarce. This knowledge gap has imposed certain limitations on formulating target strategies for ecological management and pest control.

The salt-tolerant rice varieties in Zhanjiang, such as Haihong Aromatic Rice and wild sea rice, can demonstrate remarkable adaptability to saline-alkali land through mechanisms like ion regulation and salt rejection. These rice varieties can be cultivated in a wide variety of environments, ranging from tidal flats along the coast to saline-alkali land in the inland areas. After growing in these places, they create unique habitats and also shape the community structure of insects. However, there are unique interactions between these rice varieties and insect populations, which include pests, pollinators, and natural enemies, etc. But currently, this unique interaction has not been fully explored and studied.

This paper takes Zhanjiang salt-tolerant rice as the research object and conducts a comparative study on Haihong Aromatic Rice, wild sea rice and conventional rice. By analyzing the species composition, community dynamic changes and ecological index contents in the saline-alkali environment, it explores the ecosystem stability and insect-eating balance mechanism in the saline-alkali environment. The findings of these studies can provide crucial insights for optimizing agricultural management, reducing reliance on pesticides, and promoting sustainable practices in coastal farmlands to address the escalating salinity challenge.

There was a comparative study that systematically revealed the ecological diversity between the salt-tolerant rice ecosystem and the conventional rice ecosystem in Zhanjiang area. The research results showed that in salt-tolerant rice fields, such as those where Haihong Aromatic Rice and wild sea rice are located, the species diversity and richness of insect communities were 28-34% higher than those in conventional rice fields. Among these insect communities, the relative richness of the diptera insect community reached 42.7%, and that of the hemiptera insect community was 31.2% [46]. From the perspective of mechanism, the stable predator-prey balance state observed in these two systems, that is, the ratio of natural enemies to pests, was within the range of 1:1.2-1.5. There exists an inherent ecological regulation situation, which is related to the 19% reduction in pesticide dependence in salt-tolerant plots. In fact, the insights drawn from these studies advocate the adoption of bio-intensive pest management strategies. Such strategies include purposefully increasing some natural enemies, such as *Trichoma* wasps, conducting precise spraying based on thresholds, and applying habitat diversification techniques. The adoption of these strategies can reduce chemical input in coastal saline-alkali land by 40-60%. In salt-tolerant systems, parasitic activity has increased by 45%, and organic matter decomposition has also accelerated by 17%. This proves that they have multi-functional ecological benefits [15]. However, it must be admitted that there are spatial limitations because the assessment of soil-microbial interactions is not complete enough when only a single subtropical coastal site is studied. These circumstances limit the universality of the research conclusions. To make up for these deficiencies, future research should carry out ten-year scale monitoring of transcontinental salinity gradients, integrate metagenomic analysis of the rhizosphere microbiota, and establish a prediction model that can link water quality parameters with insect community dynamics [49]. This research has established a basic framework, which can optimize the cultivation of salt-tolerant rice through ecological intensification. At the same time, the necessity of using interdisciplinary methods to interpret the interactions of complex agricultural ecosystems was also emphasized.

## 5. Conclusions

In this study, both salt-tolerant rice and conventional rice grown in Zhanjiang have relatively long growth cycles, which attract a substantial number of insects and contribute to more stable and diverse insect community structures. Experimental findings indicate that Diptera and Hemiptera insects dominate the insect communities in salt-tolerant rice fields, likely playing a role in maintaining equilibrium within the rice-insect ecosystem. Overall, the community structures of salt-tolerant rice varieties—specifically Haihong Aromatic Rice and wild sea rice—are more diverse than

those of conventional rice, featuring richer insect species and consistently stable species evenness. As the first investigation into insect diversity in Zhanjiang's salt-tolerant rice fields, this research reveals that these fields support rich insect communities and demonstrate more prominent ecological functions compared with conventional rice fields. Since insects play a vital role in rice crop growth, clarifying the insect community structure of salt-tolerant rice will aid in the scientific management and yield enhancement of salt-tolerant rice in the region.

**Author Contributions:** Conceptualization, Z.W.; methodology, Z.W. and H.Z.; validation, H.Z. and X.L.; resources, H.Z.; data curation, H.Z. and X.L.; writing original draft preparation, H.Z., X.L. and Z.W.; writing review and editing: Z.W, H.R, Z,Y and Z.H; supervision, Z.W.; funding acquisition Z.W. All authors have read and agreed to the published version of the manuscript.

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**Data Availability Statement:** Due to privacy regulations and the large volume of data, the original data have not been included in this article.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

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