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Abstract: This paper describes how aquatic insect diversity in major natural habitats of Agusan marsh relates with nearby ricefields to determine the interdependence between them for sustainable rice production through natural pest control and for conservation of aquatic fauna in the marsh. Sampling for one year including two cropping seasons of rice production was conducted in various natural habitats of the marsh and in the adjoining ricefields. Both the natural habitats and ricefields were characterized in relation to determining habitat suitability for aquatic insects. The sedge-dominated swamp had the highest diversity among the natural habitats, while the fern-dominated swamp had the lowest. In the adjacent ricefields, diversity was similarly highest in the site near the sedge-dominated swamp, while the lowest was in the ricefields adjoining the Sago forest. Species composition of aquatic insects among the habitats differed between the wet and dry seasons. However, similarity patterns exist between natural habitats and ricefields. The closer similarity in species composition between natural habitats and ricefields indicates habitat connectivity which is an important consideration in planning and effective pest management and ecologically sound rice farming in the marsh.

Key words: Ricefields, aquatic biodiversity, alternative habitat, pest management.

1. Introduction

The increasing population and its changing lifestyle result to massive conversion of many natural habitats for the earth's biodiversity into food production areas, human settlements and other land uses. This leads to habitat fragmentation and eventually biodiversity loss. However, more people are becoming aware of the need to conserve biodiversity thus strategies that minimize disturbance to biodiversity have been promoted to strike a balance between the need to increase food production and the need to protect and sustain biodiversity and the natural environment.

In the Agusan marsh, located in southern Philippines, agricultural development had encroached into many natural habitats. Agusan marsh is one of the economically and ecologically important wetlands in Asia. It houses a rich biodiversity with a considerable number of endemic species [1]. It is a transitory home for waterfowls from neighboring places during winter. Aside from its rich biodiversity, it offers immeasurable environmental services. It serves as the catch basin for Agusan del Sur, Davao, Bukidnon and provides irrigation water to nearby agricultural ecosystems, particularly ricefields. Thus, vast rice lands can be seen in the floodplains of the marsh particularly in the northern and eastern sides. It is also home to people dependent on its natural resources for livelihood. Likewise, rice farming encroaches into natural habitats resulting to fragmentation.

In the conservation of biodiversity, habitat fragmentation is a cause for concern. This is especially true for animal species that require wide

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home ranges. Nonetheless, studies pointed out that provision of corridors to interconnect patchy habitats offer solutions to this concern. The present-day dilemma of habitat fragmentation can be alleviated through effective habitat management and providing corridors to facilitate movement between patches [9]. Corridors are important to interconnect one patch with another [5] especially for many groups of animals.

With the continued migration of people to Agusan marsh looking for livelihood, the marsh biodiversity is threatened. Hence, a study to assess the diversity of aquatic insects in Agusan marsh and its movement across the patchy habitats was made because aquatic insects occupy the base of food webs in the wetlands. This paper, therefore, describes how aquatic insect diversity in major natural habitats of Agusan marsh is linked with nearby ricefields. This specifically outlines the possible contribution of the aquatic insect diversity in rice pest management to improve food production. Many aquatic insect species inhabiting the natural habitats of Agusan marsh move into ricefields when water in natural habitats is insufficient. Water in ricefields, in general, is managed to supply the needs of plants at various stages of development. While aquatic insects inhabit the ricefields, they perform ecological roles that promote rice production through increasing the organic matter or minimizing pests through predation. Efficient water management in ricefields would, therefore, benefit not only rice production but also the conservation of aquatic fauna.

2. Materials and Methods

2.1 Research Site

The study was conducted across the Agusan marsh, particularly in the distinct habitat types. One sampling station was established in each of the various natural habitats representing the fern-dominated herbaceous swamp, sedge-dominated herbaceous swamp, sago forest, *Terminalia* forest, bangkal forest, mixed forest and other habitats.

2.2 Sampling

Water temperature, depth, pH, turbidity, conductivity and DO (dissolved Oxygen) level were determined monthly in various stations established in the natural habitats of Agusan marsh and nearby ricefields.

Aquatic insects were collected monthly from the various habitats of Agusan marsh. Dip net and sweep net were used to sample aquatic insects. For insects dwelling on the water surface (e.g., water striders, pond skaters), the net was swept over the water swiftly. Flying adults were swept near aquatic vegetation and handpicked from debris found in water. Specimens were sorted immediately based on morphological features and placed in vials containing 80% ethyl alcohol for later identification. These were identified up to the genus or species level using taxonomic keys.

2.3 Data Analysis

The numbers of species and number of individuals per species were used for the calculation of the species richness, species diversity and abundance. The similarities of species composition among habitat types with regards to time were determined using the cluster analysis.

3. Results and Discussion

3.1 Characteristics of the Water Habitats

The water temperature and DO (Dissolved Oxygen) across the various habitats differed only slightly (Table 1). Water depth, however, differed between the natural habitats and ricefields. Water in ricefields is lower than in natural habitats, on the average, because irrigation water is maintained at a depth of 5-10 cm during the vegetative stage, and is later gradually drained as the crop approaches harvest [4]. In contrast, water depth in natural habitats is dependent on the amount of rainfall received and accumulated. The water pH varied slightly between natural habitats and ricefields due probably to the use

Table 1 Mean values of water quality parameters in Agusan marsh habitats.

Habitats	Water quality mean values			
	Temp (℃)	Depth (cm)	pH	DO (mg/L)
Wet season				
Natural habitat				
Fern	29.6	21.0	5.9	2.50
Sedge	30.0	18.6	5.8	2.80
Sago	30.0	21.8	5.6	2.80
Terminalia	28.8	24.0	5.3	2.80
Bangkal	29.0	26.0	5.1	2.70
Adjoining ricefield				
Rice-Fern	30.2	7.4	5.6	2.40
Rice-Sedge	29.8	8.6	5.4	2.30
Rice-Sago	29.8	6.8	5.2	2.30
Rice-*Terminalia*	29.0	7.2	5.3	1.90
Rice-Bangkal	29.0	6.4	5.1	2.00
Dry Season				
Natural habitat				
Fern	30.0	17.8	6.1	2.20
Sedge	30.0	18.2	5.8	2.60
Sago	29.6	17.0	5.6	2.60
Terminalia	28.3	13.6	5.3	2.70
Bangkal	28.8	13.6	5.2	2.60
Adjoining ricefield				
Rice-Fern	29.5	5.0	5.3	2.30
Rice-Sedge	30.3	5.2	5.5	2.30
Rice-Sago	30.3	5.0	5.2	2.30
Rice-*Terminalia*	28.8	4.6	5.3	2.20
Rice-Bangkal	29.0	4.2	5.1	2.20

of agrochemicals in ricefields. The weed vegetation in the natural habitats and the adjoining ricefields are relatively similar in terms of species particularly in newly opened rice areas. This suggests habitat continuity particularly for those aquatic fauna closely associated to plants.

3.2 Aquatic Insect Diversity across Seasons

Among the natural habitats, the sedge-dominated swamp had the highest diversity, while the fern-dominated swamp had the lowest (Table 2). In the adjacent ricefields, diversity was similarly highest in the site near the sedge-dominated swamp, while the lowest was in the ricefields adjoining the Sago forest.

The aquatic insect diversity, considering the cropping season, departed from the overall diversity

Table 2 Species diversity of aquatic insects in natural habitats and adjacent ricefields of Agusan marsh floodplain.

Habitat	Overall diversity	Wet season diversity	Dry season diversity
Natural habitat			
Fern	3.43	3.46	3.40
Sedge	3.71	3.79	3.64
Sago	3.47	3.65	3.28
Terminalia	3.62	3.90	3.28
Bangkal	3.65	3.69	3.55
Adjoining ricefield			
Rice-fern	3.18	3.24	3.09
Rice-sedge	3.45	3.53	3.38
Rice-sago	3.15	3.42	2.88
Rice-*Terminalia*	3.39	3.49	3.26
Rice-bangkal	3.29	3.41	3.13

setting. The diversity was generally higher in the wet season than in the dry season. This trend simply shows that more favorable sites within habitats were available for resource utilization during the wet season. Likewise, the *Terminalia* forest had the highest diversity, while the fern-dominated swamp had the lowest during the wet season among natural habitats. Nonetheless, in ricefields, the highest diversity remained in the site near the sedge-dominated swamp, while the lowest was in the field near the fern-dominated swamp, following the overall trend for ricefields. In the dry season, the sedge-dominated swamp had the highest diversity, but both the sago forest and *Terminalia* forest had the lowest among natural habitats. In ricefields, the sites near sago and fern-dominated swamp showed low diversity.

In terms of the cropping seasons, similarity pattern in species composition of aquatic insects among the habitats differed considerably between the wet and dry seasons. During the wet season, two main clusters were evident, as follows: The rice habitats were clustered with the *Terminalia* habitat in the first cluster, while the rest of the natural habitats were assembled in the second cluster. This is notwithstanding the distance between a number of habitats from each other, e.g., the Bangkal and Sago sub-cluster, and the fern and sedge sub-cluster (Fig. 1). In the dry season, the pattern showed two clusters formed as follows: the first cluster, consisting of the rice-*Terminalia* and *Terminalia* sub-cluster joined by the Sago habitat, then by the rice-Bangkal habitat and the rice-Sago habitat (Fig. 2). The second cluster, consisting of rice-fern and rice-sedge sub-cluster, is joined by the sedge habitat, and the fern habitat. The Bangkal forest is an outgroup, sharing the least similar species with the rest of the group.

3.4 Role of Aquatic Insect Diversity in Agusan Marsh to Pest Management in Ricefields

The high population of predatory aquatic insects in the Agusan marsh floodplain shown in Table 3 may contribute to the management of certain insect pests of rice as natural control agents. The aquatic insects moving from the natural habitats to ricefields and vice versa may be useful in regulating the pest populations in ricefields, while at the same time, using the ricefields as temporary habitats during unfavorable conditions in the natural habitats.

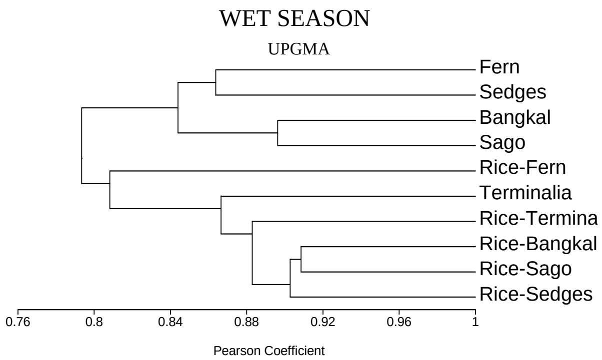

Fig. 1 Species similarities of aquatic insects among natural habitats and adjacent ricefields of Agusan marsh in the wet season.

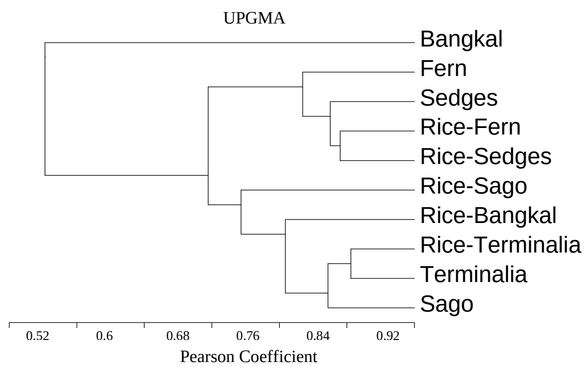

Fig. 2 Species similarities of aquatic insects among natural habitats and adjacent ricefields of Agusan marsh in the dry season.

The damselflies *Agriocnemis* femina and *A. pygmaea* and a variety of dragonflies have been reported to prey on planthoppers and leafhoppers [6], and possibly small moths such as stemborers and leaffolders. Likewise, aquatic bugs have been reported to be very useful in the management of rice planthoppers and leafhoppers [6, 8, 10]. Although their predatory behavior is opportunistic, their contribution to the management of the mentioned rice insects may be substantial due to their abundance. Gerrids, veliids, mesoveliids, hydrometrids, pleids and saldids exist in the natural habitats and in ricefields in Agusan marsh.

The dytiscids, which are predaceous in the larval and adult stages, have been reported to prey on several invertebrates in aquatic habitats [2]. In the survey, species of dytiscids found in ricefields were similar to those in the natural habitats. Some species of dytiscids have been listed among insects in ricefields [3]. Likewise, *Laccophilus*, *Agabus* and *Cybister* have been recorded [6] among the predators of rice planthoppers and rice caseworm. Since most of the insect pests are found in tillers and the canopy, the impact of *Dytiscid* predation may not be as great. Nonetheless, their existence is still important to the overall balance of the ricefields as an ecosystem.

The hydrophilids, which dominated in terms of number and species richness, were among the insects with multiple roles in the marsh. Being scavengers in the adult stage, they probably made the habitat more favorable to other organisms by converting the organic debris into more readily available food. Besides, they also are food themselves to other organisms in the system. By converting organic debris into organic matter, this group likewise plays an important role in the nutrient production of the system. As predators during the larval stage, the hydrophilids also help regulate the populations of their prey, thus in so doing, they help minimize competition in the system.

Table 3 Relative abundance of predaceous aquatic insects in natural habitats of Agusan marsh floodplain and adjoining ricefields.

Order	Species	Fern	Sedges	Sago	Terminalia	Bangkal	Rice-Fern	Rice -Sedges	Rice -Sago	Rice -Termina	Rice -Bangkal
Odonata	Coenagrionidae										
	Acisoma panorpoides	0	2	0	0	0	0	3	0	1	0
	Agriocnemis femina	10	10	9	10	8	8	14	11	5	9
	Agriocnemis pygmaea	12	17	14	13	12	15	16	11	16	15
	Chlorocyphidae										
	Rhinocypha sp.	4	0	0	0	0	0	0	0	0	0
	Libellulidae										
	Brachydiplax chalybea	1	8	2	2	0	0	5	1	0	0
	Diplacina sp	0	4	1	1	2	0	3	1	1	0
	Diplacodes trivialis	2	1	0	0	0	1	2	0	0	3
	Gynacantha sp	0	5	0	0	0	0	3	0	0	0
	Neurothemis sp	8	18	12	10	15	17	12	8	10	10
	Tetrathemis	0	3	0	6	0	0	0	0	0	0
	Tholymis tillarga	9	5	5	9	5	0	3	5	2	2
Hemiptera	Notonectidae										
	Anisops sp.	6	28	17	16	11	4	17	0	1	2
	Nepidae										
	Cercotmetus vittipes	0	2	0	0	0	0	0	0	0	0
	Ranatra stali	0	4	0	1	0	0	0	0	0	0
	Gerridae										
	Cylindrosthetus brevipes	0	0	3	0	6	0	0	0	0	0
	Limnogonus fossarum	1	1	0	0	0	4	0	2	0	4
	Limnometra ciliata	0	3	4	0	0	0	0	0	0	0
	Rhagadotarsus kraepelini	4	0	8	0	0	0	0	0	0	0
	Saldula uichancoi	0	0	0	1	0	0	0	0	0	0
	Strongylovelia sp.	0	0	1	0	0	0	0	0	0	0
	Tenagogonus	9	6	1	4	2	1	3	1	4	1
	Belostomatidae										
	Diplonychus rusticus	2	18	9	14	11	2	4	3	3	5
	Hydrometridae										
	Hydrometra lineata	0	3	0	1	3	0	0	0	0	0
	Helotrephidae										
	Hydrotrephes	0	0	0	2	0	0	0	0	0	0
	Mesoveliidae										
	Mesovelia vittigera	0	3	3	2	5	1	1	5	4	0
	Corixidae										
	Micronecta quadristrigata	141	97	62	116	23	106	88	54	106	69
	Veliidae										
	Microvelia douglasi	24	25	17	22	18	14	19	18	20	10
	Pleidae										
	Paraplea liturata	27	30	24	28	26	4	14	13	13	24

(Table 3 continued)_

Order	Species	Fern	Sedges	Sago	Terminalia	Bangkal	Rice	Rice	Rice	Rice	Rice
Coleoptera	Dytiscidae										
	Copelatus sp. 1	12	16	7	12	5	5	12	5	12	7
	Copelatus sp. 2	10	4	2	11	5	0	5	0	6	5
	Eretes sticticus	0	0	7	0	0	0	0	0	0	0
	Hydaticus sp.	0	5	0	2	0	0	3	0	0	0
	Hyphydrus xanthomelas	40	30	22	52	25	43	47	34	17	12
	Hyphydrus sp.	14	0	6	7	3	10	0	4	2	0
	Hydroglyphus sp.	72	66	69	55	57	55	86	89	73	66
	Laccophilus sp. 1	15	22	26	23	21	18	23	29	14	12
	Laccophilus sp. 2	6	9	14	10	8	2	11	7	10	6
	Platynectes sp.	0	2	0	0	0	0	0	0	0	0
	Rhantus sp.	0	0	0	3	0	0	0	0	1	0
	Noteridae										
	Hydrocantus semperi	3	2	0	1	0	2	0	2	1	0
Total		432	449	345	431	271	312	394	303	321	262

Similar species of hydrophilids were collected in ricefields adjacent to the natural habitats of Agusan marsh. *Berosus* and *Enochrus* were the most abundant, especially when rice straws were left in the field with little water. This results to the enrichment of the ecosystem through the addition of organic matter. An organic matter-driven ricefields ecosystem is more diverse and has greater stability [7]. Hydrophilids were abundant in the field even in the fallow period when little water is available. Moreover, the abundance of these detritivores provides food to the early colonizing predators in ricefields. Besides, [6] listed some hydrophilids such as *Berosus, Sternolophus rufipes* and *Hydrophilus* preying on rice caseworm and planthoppers. However, the precise contribution of these predators has not been measured. In this context, the existence of predaceous aquatic insects contributes to the overall insect pest management in ricefields largely as components of natural control in the ecosystem. The scavenger beetles that help in converting organic residues into fertilizers are important factors in making the plants resistant to pest pressures. In fact, the primary principle in IPM (integrated pest management) is growing a healthy crop to resist pressures from pests. Although critical quantification on the role of these predaceous insects to rice pest management still needs to be conducted, their contribution to rice pest management may be considerable when predation is viewed as a community effort among various insect groups.

5. Conclusions

The similarity pattern in species composition of aquatic insects among the habitats differed between the wet and dry seasons. The closer similarity indicating interconnectivity between natural habitats and ricefields is an important consideration in planning ecologically sound rice farming in the marsh.

Several species of aquatic insects are predaceous and useful in planning an effective integrated pest management program. Nonetheless, the precise contribution of these predators has not been measured. The diverse groups of aquatic insects contribute to the overall insect pest management in ricefields largely as components of natural control in the ecosystem. Although critical quantification on the role of these predaceous insects to rice pest management still needs to be conducted, their contribution to rice pest management may be considerable when predation is viewed as a community effort among various insect groups.

The existence of ricefields between and across natural habitats in the marsh floodplain may be useful to address both food production and biodiversity conservation. With the interdependence between these 2 types of habitats, the issues on food security and conservation of biodiversity are answered inasmuch as ricefields may serve as bridges which facilitate the movement of aquatic insects and associated fauna from one natural habitat to another and the migrating aquatic insects and their associated fauna may be contributors in rice pest management.

Acknowledgment

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