INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 9, No. 1, p. 140-147, 2016

RESEARCH PAPER OPEN ACCESS

# Aquatic Insect Similarity Connecting Natural Wetland Habitat and Ricefield for Ecological Rice Production in Agusan Marsh in Mindanao, Philippines

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**Article published on July 29, 2016**

**Key words:** Diversity, Species richness, Natural wetland, Lowland rice field, Species similarity.

## Abstract

This study describes the relationship of the natural wetland habitats in Agusan Marsh to nearby rice fields and its implication to ecological rice production. Aquatic insects play multiple roles in the ecosystem such as predators, prey to other animals and decomposers which help in maintaining ecological balance. Results revealed that the diversity of odonates was highest in the sedge-dominated swamp among natural habitats which corresponds to the adjoining ricefields. The pattern of clustering of odonates show 3 groups; the rice-sago and rice-sedges sub-cluster, the rice-bangkal, rice-*Terminalia*, rice-fern, bangkal, sago and sedges sub-cluster, and the *Terminalia* forest as the outlier. The diversity of semi-aquatic and aquatic bugs was highest in the Bangkal forest while the lowest was in the fern-dominated swamp. The pattern of clustering shows 2 sub-clusters and the outlier Bangkal forest. On aquatic beetles, highest diversity was in the *Terminalia* forest. The sub-cluster consists of *Terminalia* habitat and rice-fern, while the other sub-cluster includes rice-Bangkal and rice-*Terminalia*. The resulting patterns of similarity in diversity and distribution of species in natural habitats and nearby ricefields indicate that ricefields are important temporary habitats for some aquatic insect species and serve as stepping stones for the movement of the insects.

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## Introduction

Lowland ricefields are originally natural wetlands, thus the natural wetland and adjacent ricefields are expected to be ecologically related in many ways. However, ecological studies in ricefields for biodiversity conservation have been conducted recently. According to Roger (1996), the ecology of wetland ricefield ecosystems is less studied since it is regarded as artificial and temporary. Thus only limited information is available on the sharing of biodiversity between ricefields and neighboring ecosystems. There have been reports on ecology of ricefields citing aquatic insects and their roles in nutrient cycling and other ecological processes (Lawler, 2001; Bambaradeniya, *et al.*, 2004). The high faunal diversity in ricefields has been attributed to the rapid re-colonization by fauna from contiguous water bodies after the disturbances caused by cultural practices or drying during the fallow period. In contrast, frequent disturbances and the use of agrochemicals in this ecosystem disrupt the natural community structure, energy flow, nutrient cycling, and population dynamics of component species. Additionally, the considerable decrease in the aquatic biodiversity in ricefields has been ascribed to the loss of permanent water reservoirs near ricefield.

The colonization of aquatic insects in ricefields from adjoining water bodies is a clear indication of the relationship between natural wetlands and ricefields. However, studies conducted on the relationship of flora and fauna of ricefields to adjacent habitats gave emphasis only to the terrestrial and canopy-dwelling species (Marcos, *et al.*, 2001). Some studies on agro biodiversity in relation to other habitats have recommended the need to consider the landscape approach (Liu, *et al.*, 2013; Lan, *et al.*, 2001). Movement of aquatic insects between and within habitats is an important aspect to consider in agro biodiversity, however, studies on this remain inadequate. Many aquatic insects are strong flyers. Movement through flight may be one of the mechanisms relating the diversity of the natural wetland habitats and ricefields.

Due to their flight capability, these insects readily move from one aquatic habitat to another, especially when conditions are not favorable for survival. However, most aquatic insects move through passive dispersal. In passive dispersal of animals, corridors are important. Corridors are units of the landscape that interconnect one patch with another (Foreman and Godron, 1986; Foreman, 1995). One interesting study by Fairchild, *et al.* (2003) focused on the influence of microhabitat and landscape on aquatic beetle assemblages in temporary and permanent ponds. Indeed, the aquatic beetle assemblages were strongly correlated with the characteristics of landscape and microhabitats. In ricefields, for instance, where habitats change with the application of cultural practices, aquatic insects may disperse in search of suitable habitats. Thus this study was done to determine the relationship of the natural wetland habitats in Agusan Marsh to the continuing expansion of ricefields in the vicinity. This study likewise intends to examine if ricefields have the potential role as corridors for biodiversity movement.

## Materials and method

*Study Site*

The study was conducted in the Agusan Marsh, in the northeastern part of the island of Mindanao in Southern Philippines in July 2010 to June 2011 (Fig. 1). The marsh has an area of 111,540 hectares which is categorized into 7 habitat types that include freshwater swamp forests, secondary scrubs, herbaceous swamps, lakes, pools and rivers, and the human-dominated habitats such as rice paddies and other agricultural lands (AMWS Master Plan, 2001).

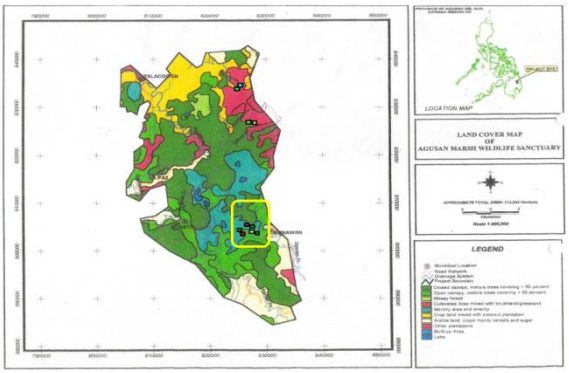


**Fig. 1.** Land cover map of Agusan Marsh in Mindanao, Philippines showing the study sites (enclosed in yellow box).

*Insect sampling and processing of specimens*

Aquatic insects with emphasis on Hemiptera, Odonata, and Coleoptera were sampled from the major aquatic habitats of Agusan Marsh and adjacent ricefields. The sampled area measured approximately 500 sq. meters in each study site. Insects that actively swim were collected from the sites using a dip net, while those that cling on aquatic vegetation and other debris within the 1 sq m quadrat were collected by washing them off in a container with water.

For insects dwelling on the water surface (e.g. water striders, pond skaters), the net was swept over the water swiftly. Sampling was done for two rice cropping seasons.

Aquatic insects were identified using taxonomic keys. Aquatic and semi-aquatic bugs were identified using Chen *et al*. (2005) and Zettel and Gapud (1999). Aquatic beetles were determined using Balke, *et al*. (2002), and the hydrophilids using Hansen (1999).

*Community structure analysis*

Trends in community structure of aquatic insects were analyzed using the corresponding measurements. *Species richness* involved actual counts of species collected for the different insect groups in the natural habitats and adjoining ricefields. *Species diversity* indices were measured using the Shannon-Wiener function which accounts for the number of species and the number of individuals in each species, and is expressed as:

$$H' = \sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where $H'$ = index of species diversity ; $\log_2$ = 3.321928

$s$ = number of species

$p_i$ = proportion of total sample belonging to $i$th species

In determining equitability of distribution of individuals in each species, the Jaccard's index of evenness was computed as follows:

$$J' = \frac{H'}{H'_{MAX}}$$

where $J'$ = evenness measure (range 0 – 1)

$H'$ = Shannon-Wiener function

$H'_{MAX}$ = maximum value of $H'$ = log $S$ (no. of species in sample)

The similarities in species compositions among the natural habitats and ricefelds were analyzed using the Pearson's coefficient of similarity. To accomplish this, the single linkage cluster analysis in the Multivariate Statistical Package (MVSP) was used.

**Results and discussion**

*Diversity of dragonflies and damselflies between natural habitat and rice fields.*

The diversity of dragonflies and damselflies (Order Odonata) was highest in the sedge-dominated swamp among the natural habitats (Table 1).

The lowest was in the Bangkal forest at 2.077. In adjacent ricefields, the diversity was similarly highest in site near the sedge-dominated swamp. The lowest diversity index was in ricefield adjoining the fern-dominated swamp.

The result reflects the physical characteristics of the habitats. In the sedge-dominated swamp, water is generally present even during the dry months. A similar characteristic is also noted in the *Terminalia* forest, where sedges also grow in between the *Terminalia* trees.

In the rest of the natural habitats, water becomes scarce during the drier months thus some insect species move to where water is available. In ricefield near the sedge-dominated swamp, the characteristic is very similar to that of the natural habitat because these ricefields are originally sedge-dominated swamps. Elphick (2001) studied the potential for human-disturbed habitats to act as surrogates for the natural habitats they replace.

He noted that flooded fields seemingly provide comparable foraging habitat to seminatural wetlands for waterbirds. Thus flooded ricefields, if managed properly, can provide valuable waterbird habitat.

**Table 1.** Diversity of dragonflies and damselflies in natural habitats and adjacent ricefields of Agusan Marsh, Mindanao, Philippines.

| Sampling Site | Shannon Diversity | Evenness | Species Richness |
|---|---|---|---|
| Fern-dominated swamp | 2.507 | 0.893 | 7 |
| Sedge-dominated swamp | 2.906 | 0.875 | 10 |
| Sago forest | 2.206 | 0.853 | 6 |
| Terminalia forest | 2.524 | 0.899 | 7 |
| Bangkal forest | 2.077 | 0.895 | 5 |
| Rice-Fern | 1.648 | 0.824 | 4 |
| Rice-Sedges | 2.768 | 0.873 | 9 |
| Rice-Sago | 2.190 | 0.847 | 6 |
| Rice-Terminalia | 1.963 | 0.759 | 6 |
| Rice-Bangkal | 2.026 | 0.873 | 5 |

Species composition of aquatic insects in the different natural habitats of the Agusan Marsh was expected to have closer similarities with their adjacent rice fields. However, the pattern of clustering of the odonates show 3 groups: the rice-sago and rice-sedges sub-cluster, then the rice-bangkal, rice-*Terminalia*, rice-fern, bangkal, sago and sedges sub-cluster, and the *Terminalia* forest as the outlier (Fig. 2).

A large sub-cluster consisting of the rice-bangkal, rice-*Terminalia*, rice-fern, bangkal, sago and sedges has a similarity index of about 91%.

The rice-sago and rice-sedges have 94% similarity and joined to the other sub-cluster by a similarity index of about 90%. The outlier habitat, the *Terminalia* forest, joins the 2 sub-clusters at 83% level of similarity. This suggests that the *Terminalia* forest was more dissimilar in the odonate species composition. This can be attributed to the characteristics of the habitat where open spaces are smaller resulting to less sunlight reaching the ground.

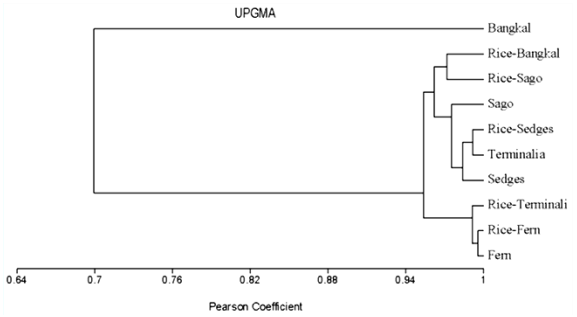


**Fig. 2.** Similarity of Odonatan species in the different natural habitats and adjoining ricefields in Agusan Marsh.

*Similarity of semi-aquatic and aquatic bug diversity between natural habitat and rice fields.*

The diversity of semi-aquatic and aquatic bugs (Order Hemiptera) in natural habitats and their adjacent ricefields was highest in the Bangkal forest (Table 2). The lowest was in the fern-dominated swamp, which is very similar to the diversity indices of ricefield habitats.

The result can be attributed to the behavior of the insects and natural habitat characteristics. In Bangkal forest, the water is a combination of stagnant and moving which attracted different species of aquatic and semi-aquatic bugs. A closer characteristic was noted in the *Sago* forest, thus species that dwells on both stagnant and slowly moving water were also found.

The diversity indices are generally low in all habitats due to the uneven distribution of the population. In the sedge-dominated swamp, sago and Bangkal forests, the indices of evenness are relatively higher resulting from the higher species richness and populations that are more evenly distributed. Species composition of aquatic and semi-aquatic bugs in the different natural habitats of the Agusan Marsh was expected to have closer similarities. Nonetheless, the clustering pattern shows 2 sub-clusters and the outlier Bangkal forest (Fig. 3).

The bigger sub-cluster includes 6 habitats: rice-sago and rice-Bangkal, the sago, rice-sedges, *Terminalia* and sedges. The other sub-cluster is composed of rice-fern, the rice- *Terminalia* forest and fern.

**Table 2.** Diversity of semi-aquatic and aquatic bugs in natural habitats and adjacent ricefields of Agusan Marsh, Mindanao, Philippines.

| Sampling Site | Shannon Diversity | Evenness | Species Richness |
|---|---|---|---|
| Fern-dominated swamp | 1.286 | 0.458 | 7 |
| Sedge-dominated swamp | 2.277 | 0.658 | 11 |
| Sago forest | 2.340 | 0.705 | 10 |
| *Terminalia* forest | 1.769 | 0.533 | 10 |
| Bangkal forest | 2.645 | 0.882 | 8 |
| Rice-Fern | 1.101 | 0.392 | 7 |
| Rice-Sedges | 1.504 | 0.582 | 6 |
| Rice-Sago | 1.505 | 0.582 | 6 |
| Rice-*Terminalia* | 1.164 | 0.450 | 6 |
| Rice-Bangkal | 1.274 | 0.493 | 6 |

The same is true for the other sub-cluster, consisting of rice-fern, the rice-*Terminalia* forest and fern, having a similarity index of almost 100%. The outlier habitat, the Bangkal forest, joins the 2 sub-clusters at 70% level of similarity. This suggests that the species composition of Bangkal forest was more different than the rest of the habitats.

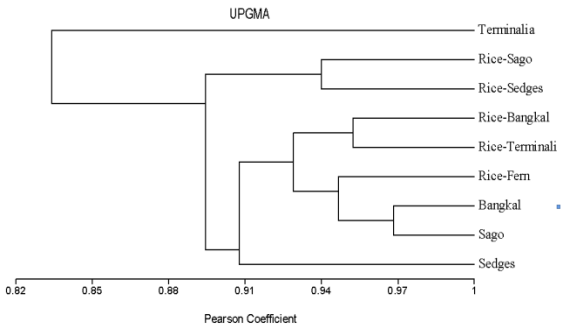


**Fig. 3.** Similarity of Hemipteran species in the different natural habitats and adjoining ricefields in Agusan Marsh.

The rice fields have generally lower diversity indices than the natural habitats resulting from the fewer number of species. In the study of Ma *et al.* (2004), they found that natural wetlands are better habitats for water birds than artificial wetlands on Chongming Island, while the artificial ones are suitable habitats for water birds in winter.

The birds use artificial wetlands only when natural wetlands are unavailable or of poor quality. However, they cautioned that overemphasis on suitability of artificial wetlands for water birds might encourage land managers to convert natural wetlands into the artificial ones which may result in considerable loss of bird diversity.

*Similarity of aquatic beetle diversity between natural habitat and ricefields.*

The diversity of aquatic beetles in natural habitats and adjacent ricefields was highest in the *Terminalia* forest (Table 3). The result can be attributed to the presence of some unique species found only in *Terminalia* forest.

All other natural habitats have diversity indices closer to that of the *Terminalia* forest. The lowest was in the Bangkal forest, which has generally similar diversity indices with ricefield habitats. This suggests that the various species of aquatic beetles differed in habitat requirements thus there are species that are not found in certain habitats. In Bangkal forest, the diversity index of aquatic beetles is closer to the diversity of ricefield habitats.

This can be attributed to the habitat requirements of certain beetle species, such as the water scavenger beetles that thrive in microhabitats where decaying materials abound. The indices of evenness are generally higher in all habitats due to the relatively even distribution of various populations,except for the unique species. In *Terminalia* forests and its adjoining ricefield, the number of species is higher, leading to a relatively higher diversity index for both habitats.

**Table 3.** Diversity of aquatic beetles in natural habitats and adjacent ricefields of Agusan Marsh, Mindanao, Philippines.

| Sampling Site | Shannon Diversity | Evenness | Species Richness |
|---|---|---|---|
| Fern-dominated swamp | 2.394 | 0.798 | 8 |
| Sedge-dominated swamp | 2.411 | 0.761 | 9 |
| Sago forest | 2.343 | 0.781 | 8 |
| Terminalia forest | 2.578 | 0.776 | 10 |
| Bangkal forest | 2.174 | 0.774 | 7 |
| Rice-Fern | 2.075 | 0.739 | 7 |
| Rice-Sedges | 2.118 | 0.754 | 7 |
| Rice-Sago | 1.930 | 0.688 | 7 |
| Rice-Terminalia | 2.173 | 0.685 | 9 |
| Rice-Bangkal | 1.831 | 0.708 | 6 |

The water beetles, which constitute about half of the total species, have a very visible pattern of species similarities (Fig. 4). Two clusters are apparent, with 2 sub-clusters splitting at 96%. The first cluster consists of *Terminalia* habitat and rice-fern, while the second cluster includes rice-Bangkal and rice-Terminalia, joining with rice-sago, Bangkal, sago, sedges and rice-sedges. The first cluster consisting of *Terminalia* habitat and rice-fern is separated by a considerable distance from the other sub-cluster. It is apparent that the species similarities within the two sub-clusters are not due to proximity but possibly on the similarity in physical characteristics or vegetation structure in these habitats.

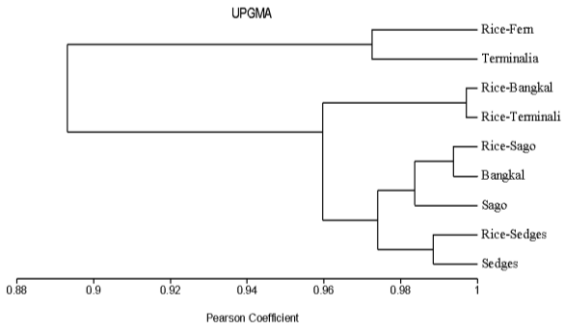


**Fig. 4.** Similarity of Coleopteran species in the different natural habitats and adjoining ricefields in Agusan Marsh.

Land-use is an important factor that influences faunal distribution and diversity. According to Bennett *et al.* (2007), the extent of habitat is usually an important influence on single species existence or the richness of assemblages defined by habitat type. Similarly, the composition of the land-use mosaic, based on the proportions of elements, strongly influences the species composition of faunal assemblages and that heterogeneity of elements is often positively correlated with the richness of taxonomic assemblages. Wilby *et al.* (2006) reported that the arthropod community associated with rice revealed characteristic seasonal differences in guild structure due to patterns in community assembly through the cropping season. Moreover, the arthropod diversity across all land-use types generally declined with the land use gradient towards extensive rice monoculture. They added that with particular reference to diversity and community structure in rice, landscape diversity influenced the processes of community assembly in rice largely through effects on abundance rather than diversity and that the predator guild was least affected. This finding is a necessary input for planning the ecological production of rice where diversity of arthropods is viewed to contribute in bringing equilibrium resulting from the interactions in the ecosystem.

**Conclusion**

The resulting patterns of similarity in diversity and distribution of aquatic insect species in natural habitats and nearby ricefields indicate that indeed ricefields are important temporary habitats for certain species of aquatic insects. Although in some cases no close similarities in species composition is apparent between natural habitats and rice fields, the rice fields can still be regarded as corridors or stepping stones for the movement of aquatic insects from one natural habitat to the next. It is evident that the major reasons in the similarity of species composition between natural habitats and the associated rice fields are those pertaining to resource availability.

In addition, the similarity relationships clearly demonstrate the active movement of aquatic insects, regardless of habitat proximity. The similarity of species between the natural wetland habitats and ricefields indicates that the aquatic insect communities are important factors for check and balance in ricefields thereby controlling increase in insect pest populations. This condition is important in understanding ecological rice pest management.

**Acknowledgment**

The author acknowledges the research grant from the Commission on Higher Education (CHED) for the financial support.

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