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RICE PADDIES AS CORRIDORS FOR CONSERVATION OF AQUATIC FAUNA
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Abstract

The issue on the complementation of food security and conservation of biodiversity is a major challenge to agriculturalists at present times. Increasing food production to feed the rapidly-growing population without endangering biodiversity requires tough decisions and strategies. Information on the status of biodiversity and how this relates with other factors in the ecosystem are vital to support decisions for sustainable ecosystem management. This paper describes how aquatic insect diversity in major natural habitats of Agusan Marsh relates with nearby rice paddies to determine the potential of this ecosystem as corridor for conservation of aquatic fauna in the marsh. Likewise, this also outlines the possible contribution of the aquatic insect diversity in rice pest management to improve food production. Several species of aquatic insects in the natural habitats of Agusan Marsh move into rice paddies especially during the dry season when water in natural habitats is insufficient. Water in rice paddies, in general, is managed to supply the needs of plants at various stages of development. This water provides an alternative habitat to aquatic insects. While aquatic insects inhabit the rice paddies, they perform ecological roles that promote rice production through increasing the organic matter or minimizing pests through predation. Efficient water management through irrigation in rice paddies would, therefore, benefit not only rice production but also the aquatic fauna that utilize the paddies as temporary habitat.

Keywords: rice paddies, aquatic biodiversity, corridor, alternative habitat, water management, sustainable ecosystem, pest management

1. Rice Paddies as Corridors for Conservation of Aquatic Fauna

Food security and biodiversity conservation are among the major concerns today not only in the Philippines but in many countries of the world, which may be directly or indirectly associated with the explosive human population growth. Due to the increasing population, many natural habitats for the earth's biodiversity have been converted into food production areas, human settlements, and other uses. However, with more governments increasingly becoming aware of the need to conserve biodiversity in natural habitats, food production strategies which minimize disturbance to biodiversity, such as ecological agriculture or nature farming, 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.

The situation in the Agusan Marsh located in Mindanao, Philippines is a typical example. Agusan Marsh is one of the ecologically important wetlands in Asia. It houses a rich biodiversity, in which a considerable number of endemic species have been identified (AMWS, 2001). It likewise provides a temporary home for transient waterfowls from neighboring places during winter. Aside from its rich biodiversity, it is also an economically important ecosystem. Moreover, it also offers other environmental services. It serves as the catch basin for Agusan del Sur, Davao, and Bukidnon that provides irrigation water to nearby agricultural ecosystems, particularly rice paddies. 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. Hence, due to its rich natural resources, human settlements continue to expand every year, threatening the biodiversity therein.

To harmonize the existence of humans with the natural resources, Agusan Marsh was declared a Protected Area in 1996. As a protected area, the residents are tasked to be the stewards of the marsh and given the opportunity to utilize the marsh resources sustainably. However, as human population grows, many of the natural habitats in the wetland were cleared and drained to give way to rice paddies. This resulted to habitat fragmentation, with the natural habitats becoming patchy.

In the conservation of biodiversity, habitat fragmentation is a cause for concern. This is especially for fauna that require wide home ranges. Nonetheless, studies pointed out that provision of corridors to interconnect patchy habitats offer solutions to this concern. Sutherland (1995) stated that the present-day dilemma of habitat fragmentation can be alleviated through effective habitat management and providing corridors to facilitate movement between patches. Corridors are important to interconnect one patch with another (Foreman and Godron, 1986), especially for many groups of animals. In fact, the Critical Ecosystem Partnership Fund adopts this approach in biodiversity conservation (CEPF, 2003).

In the Agusan Marsh, where water is the most abundant and important resource, managing this resource for purposes of promoting ecological and economic sustainability is vital. Efficient and effective management of water in rice paddies likewise become an important component in the marsh ecology in as much as this provides alternative habitats to aquatic organisms.

Humans come to Agusan Marsh to look for livelihood. Their existence may impact positively or negatively to the marsh, depending on how they manage its resources. Hence, a study focusing on the diversity of aquatic insects in the natural habitats of Agusan Marsh and in adjacent rice paddies was done. Aquatic insects occupy the base of food webs in the wetlands. Understanding their basic ecology, therefore, may give insights on how rice paddies can be utilized as corridors for the conservation of wetland biodiversity, specifically the aquatic fauna.

This paper describes how aquatic insect diversity in major natural habitats of Agusan Marsh relates with nearby rice paddies to determine the potential of paddies as corridor for conservation of aquatic fauna. Likewise, this also 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 rice paddies when water in natural habitats is insufficient. Water in rice paddies, in general, is managed to supply the needs of plants at various stages of development. While aquatic insects inhabit the rice paddies, they

perform ecological roles that promote rice production through increasing the organic matter or minimizing pests through predation. Efficient water management through irrigation in rice paddies would, therefore, benefit not only rice production but also the conservation of aquatic fauna.

2. Physico-chemical Characteristics of the Water Habitats.

The water temperature and Dissolved Oxygen (DO) across the various habitats differed only slightly (Table 1). Water depth, however, differed between the natural habitats and rice paddies. Water in rice paddies 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 (De Datta 1981). 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 rice paddies due probably to the use of agrochemicals in rice paddies.

Table 1: Mean values of water quality parameters in Agusan Marsh habitats

HABITATS	MEAN VALUES			
	Temp (^{0}C)	Depth (cm)	pH	DO (mg/L)
		WET SEASON		
Fern	29.6	21.0	5.9	2.50
Rice-Fern	30.2	7.4	5.6	2.40
Sedge	30.0	18.6	5.8	2.80
Rice-Sedge	29.8	8.6	5.4	2.30
Sago	30.0	21.8	5.6	2.80
Rice-Sago	29.8	6.8	5.2	2.30
Terminalia	28.8	24.0	5.3	2.80
Rice-*Terminalia*	29.0	7.2	5.3	1.90
Bangkal	29.0	26.0	5.1	2.70
Rice-Bangkal	29.0	6.4	5.1	2.00
		DRY SEASON		
Fern	30.0	17.8	6.1	2.20
Rice-Fern	29.5	5.0	5.3	2.30
Sedge	30.0	18.2	5.8	2.60
Rice-Sedge	30.3	5.2	5.5	2.30
Sago	29.6	17.0	5.6	2.60
Rice-Sago	30.3	5.0	5.2	2.30
Terminalia	28.3	13.6	5.3	2.70
Rice-*Terminalia*	28.8	4.6	5.3	2.20
Bangkal	28.8	13.6	5.2	2.60
Rice-Bangkal	29.0	4.2	5.1	2.20

This overall consistency in water properties in the marsh strongly suggests habitat continuity. The existence of rice paddies between and across natural habitats in the marsh may have served as corridors or bridges which facilitate the movement of aquatic insects and associated fauna from one natural habitat to another. The main function of the corridors is to connect biodiversity areas through a patchwork of sustainable land uses, increasing mobility and genetic exchange among individuals of fauna and flora even in the absence of large extensions of a continuous natural habitat (CEPF, 2003). In this sense, the maintenance of these corridors would become more difficult if these rice paddies were to be converted suddenly into the production of high-value upland crops, a very real threat to the survival of the aquatic insects and associated fauna in Agusan Marsh.

Species Diversity of Aquatic Insects Across Seasons.

As a whole, the diversity values for the aquatic insects in both the natural habitats and adjoining rice paddies were moderately high (Table 2). Among the natural habitats, the sedge-dominated swamp had the highest diversity, while the fern-dominated swamp had the lowest. In the adjacent rice paddies, diversity was similarly highest in the site near the sedge-dominated swamp, but the lowest was in the rice paddies adjoining the Sago forest.

Table 2: Species diversity of aquatic insects in natural habitats and adjacent rice paddies of Agusan Marsh.

HABITAT	OVERALL DIVERSITY	WET SEASON DIVERSITY	DRY SEASON DIVERSITY
Fern	3.43	3.46	3.40
Rice-fern	3.18	3.24	3.09
Sedge	3.71	3.79	3.64
Rice-sedge	3.45	3.53	3.38
Sago	3.47	3.65	3.28
Rice-sago	3.15	3.42	2.88
Terminalia	3.62	3.90	3.28
Rice-*Terminalia*	3.39	3.49	3.26
Bangkal	3.65	3.69	3.55
Rice-bangkal	3.29	3.41	3.13

When viewed in relation to the cropping season, certain trends departed from the overall diversity setting. Firstly, 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. Secondly, the *Terminalia* forest had the highest diversity, while the fern-dominated swamp had the lowest during the wet season. Thirdly, similar to the overall trend for rice paddies, the highest diversity remained in the rice paddy near the sedge-dominated swamp, while the lowest was in the rice paddy near the fern-dominated swamp. Fourthly, in the dry season, the sedge-dominated swamp had the highest diversity, but both the sago forest and *Terminalia* forest had the lowest.

In terms of the cropping seasons, the pattern of similarities in species composition of aquatic insects among the habitats differed considerably between the wet and dry seasons (Fig. 1). During the wet season, two main clusters were apparent, as follows: the rice habitats were grouped with the *Terminalia* habitat in the first cluster, while the rest of the natural habitats were grouped in the second cluster, despite the distance that separates a number of them from each other, e.g., the Bangkal and Sago subcluster, and the fern and sedge subcluster. In the dry season, the pattern changed considerably, with two clusters formed as follows: the first cluster, consisting of the rice-*Terminalia* and *Terminalia* subcluster joined by the Sago habitat, then by the rice-Bangkal habitat, and the rice-Sago habitat. The second cluster, consisting of rice-fern and rice-sedge subcluster, is joined by the sedge habitat, and the fern habitat. The Bangkal forest shared the least similar species with the rest of the group.

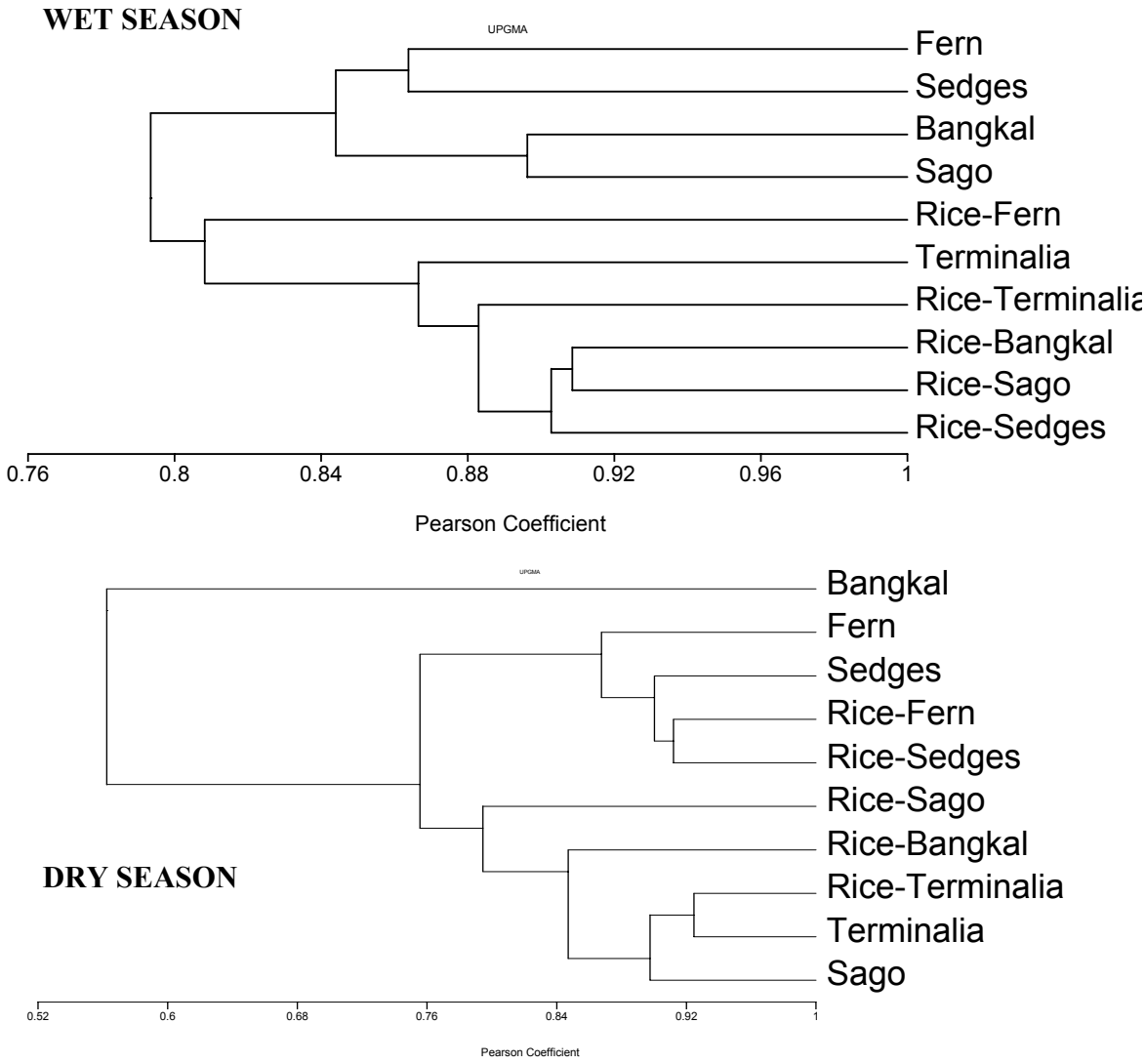

Figure 1: Species similarities of aquatic insects (all groups) among natural habitats and adjacent rice paddies of Agusan Marsh in the wet and dry seasons.

Implications of Aquatic Insect Diversity in Agusan Marsh to Pest Management in Rice Paddies.

The rich diversity of predacious 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 damselflies *Agriocnemis femina* and *A. pygmaea* and a variety of dragonflies have been reported to prey on planthoppers and leafhoppers (Reissig, et al., 1986), 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 (Yano, et al., 1981; Reissig, et al., 1986, Shepard, et al., 2000). 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 rice paddies 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 (Balke, et al., 2002). In the survey, species of dytiscids found in rice paddies were similar to those in the natural habitats. Some species of dytiscids have been listed among insects in rice paddies (Barrion and Litsinger 1994). Likewise, Reissig, et al. (1986) recorded *Laccophilus*, *Agabus* and *Cybister* 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 rice paddies 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.

Similar species of hydrophilids were collected in rice paddies 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 rice paddies ecosystem is more diverse and has greater stability (Settle, et al. 1998). 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 rice paddies. Besides, Reissig, et al. (1986) listed some hydrophiulids 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, predacious aquatic insects contribute to the overall insect pest management in rice paddies 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.

Table 3: Relative abundance of predaceous and non-predaceous aquatic insects in natural habitats and ricefields of Agusan Marsh.

HABITATS	PREDACEOUS		NON-PREDACEOUS	
	No. of Species	No. of Individuals	No. of Species	No. of Individuals
		WET SEASON		
Fern	18	185	12	362
Rice-Fern	13	71	12	225
Sedge	25	179	13	293
Rice-Sedge	16	147	11	217
Sago	20	142	11	234
Rice-Sago	16	123	11	185
Terminalia	24	197	14	242
Rice-Terminalia	14	95	10	196
Bangkal	16	137	12	220
Rice-Bangkal	11	109	8	182
		DRY SEASON		
Fern	16	103	14	392
Rice-Fern	14	111	13	347
Sedge	22	176	15	468
Rice-Sedge	19	159	14	306
Sago	19	145	13	361
Rice-Sago	13	124	15	371
Terminalia	18	120	14	394
Rice-Terminalia	16	120	14	390
Bangkal	18	111	14	239
Rice-Bangkal	16	84	12	242

Conservation and Management of Biodiversity.

For aquatic insects, sharing of species seemed common between the natural and their adjacent rice paddies. The strong similarities among the habitats can be explained in two ways. First, the contiguous water across habitats during the wet season may have served as the major corridor for movement of aquatic insects. Second, these similarities have not been hampered by the fragmentation of habitats due to lower water level in the dry season, because of their capacity for flight and the existence of rice paddies with managed water levels. For the diversity of aquatic insects to persist in rice paddies, corridors particularly waterways, e.g, canals, must be maintained. Sutherland (1995) mentioned that corridors in managed habitats must conform to the characteristics of the natural habitats.

The presence of unique species may be a guide for management of biodiversity. Areas such as the sedge-dominated habitat and *Terminalia* forest, where most of the unique aquatic insects are found, could be given priority for biodiversity conservation. Likewise, the water in adjoining rice paddies must be given attention especially during the dry season to provide an alternative habitat. Moreover, monitoring activities must be sustained to account for other unique and endemic species existing in the marshy floodplain. The information from these efforts can be useful inputs to policy formulations concerning sustainable management of the AMWS.

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