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Diversity of aquatic insects in irrigated rice fields of South India with reference to mosquitoes (Diptera: Culicidae)

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Abstract
Rice field supports a variety of living organisms as algae, macroinvertebrates, vertebrates and a plethora of microorganisms and also it supports vector species of mosquitoes. In this study, we examined the diversity and distribution of aquatic insects in irrigated rice fields and compared the colonization pattern of aquatic insect predators with mosquito larvae. Diversity indices were analyzed for aquatic insects. A total of 25656 individuals were collected during this study belong to 35 morpho-species of aquatic insects. The highest diversity was observed in site 4 (Chellampatti). Among aquatic insects, the dipterans were occupied the highes percentage (94%). Trophic analysis revealed that the collectors were dominated over (80%) than other functional groups. The colonization pattern showed that co-existent pattern was observed between predators and collectors, which indicate that larval abundance of mosquitoes can be controlled naturally by aquatic insect predators. Thus, aquatic insects in rice field are probably a crucial factor in the control of mosquito larvae. This study suggests that natural practice like integrated pest management (IPM) is necessary to ecosystem health as well as control of mosquito larvae.

Keywords: Diversity, trophic analysis, dipterans, rice field

1. Introduction

India is an important center of rice cultivation and has the world's largest rice harvesting area. Rice farming is practiced in several agro-ecological zones in India and it can be classified into four distinct types of ecosystem based on the water sources as irrigated, rain-fed upland and lowland and flood prone rice ecosystems. In rice field ecosystem, a variety of aquatic organisms are colonized and they are considered as ecosystem engineers, as to play a vital role in food web dynamics [1]. Aquatic invertebrates that inhabit the soil-floodwater ecosystem of wetland rice-fields are considered important as nutrient recyclers, rice pests, biological control agents, food items and vectors of human and animal diseases [2]. The functionality of this aquatic community depends on the relative and absolute population densities of the various groups as grazers/detritivores, predators and collectors [1, 3].

Mosquitoes generally exploit shallow water bodies with higher nutrient and salinity levels and with low dissolved oxygen content [4]. Flood irrigated rice fields serve as an ideal breeding site for potential vector mosquito species resulting in negative impact on human health, which cause vector borne diseases [4]. In recent years, aquatic insect diversity and mosquito population in rice fields have attracted attention because of their function as biocontrol [4-6]. In this study, we examined the assemblage structure of mosquitoes and aquatic insect predators in rice fields. Thus this study would provide to identify the potential predators to control vector species of mosquitoes and it may offer functional information to mitigate the negative impacts of irrigated rice cultivation on human health.

2. Materials and methods

Sampling was done in Madurai district, Tamil Nadu, South India during Kuruvai season between June and October 2013. Paddy (*Oryza sativa*) is the major crop, followed by pulses, millet, oil seed, cotton and sugarcane. The rice varieties grown in this area include CO36, ADT36, Kalsar ponni, Ambai 16, Chellaponni and Komatha Being equidistant from mountains and the sea, it experiences similar monsoon pattern with Northeast monsoon and Southwest monsoon (June to September), with the former providing more rain during October to December. Temperature during summer generally reaches a maximum of 40 °C and a minimum of 26.3 °C. Winter temperature ranges between 29.6 °C and 18 °C. Madurai district is divided into 13 blocks. Of these, 6 blocks were selected for the present study namely Tirumangalam (site 1), Vadipatti (site 2), Madurai west (site 3), Chellampatti (site 4), Alanganallur (site 5) and Tirupparankundram (site 6).

In each site, three replicates samplings were done. All the observations were made between 10 A.M.-12 P.M. Samples were taken at random along a transect through rice fields, using a circular plastic pipe (length 45 cm, diameter 24 cm) driven into the sediment to form a watertight seal. The water within the sampler was manually removed and passed through a 500 µm sieve. The dip net and visual examination was also done for sampling. Captured specimens were transferred to plastic containers containing 80% ethanol. The preserved specimen in plastic containers were brought to the laboratory, and examined at low magnification microscope. Morpho-species were counted and voucher specimen were identified either family or genus level whichever possible. The collected aquatic insects were identified according to Dudgeon [7] and grouped as grazers/decomposers, collectors and predators [7]. In each study site, the physico-chemical parameters were measured according to APHA [8]. In each sampling station, diversity indices (Shannon-Weiner, Simpson, Evenness and Margalef indices) were estimated for aquatic insects according Ludwig and Reynolds [9] and their results were graphically presented.

3. Results

The physico-chemical parameters of rice field for sampling sites are given in Table 1. A total of 25656 individuals were collected during this study, with 35 morpho-species being identified (Table 2). The higher number of taxa was found at site 4 and 5. The alpha diversity indices of Shannon, Simpson and evenness indices values were high in the site 4 and 5, while, the richness index of Margalef was high in the site 4 followed by site 5 and site 6 (Table 3). Among the distribution of different orders of aquatic insects, dipterans were occupied the higher percentage (94%) (Fig. 1).

The order Diptera consisted of 10 species, followed by Odonata 8 species, Hemiptera and Coleoptera 7 species. In rice field, aquatic insects can be grouped into three types based on their feeding strategy as grazers/decomposers, collectors and predators according Dudgeon [9]. In the present study, collectors were dominant (80%) than other functional groups (grazers and predators) (Fig. 2).

Aquatic insect assemblage pattern was studied in an irrigated rice field. This study was conducted during Kuruvai season between June and October. The colonization of Coleopteran, Odonate and Diptera were increased during early phase (up to 45 days after transplantation) of paddy growth and they were gradually decreased after early phase till harvesting of plant (Figs. 3-5).

The population density of Hemiptera was high during 2nd week and decreased gradually from 2nd week to harvesting of plant (Fig. 6). The result of this study indicates that the population of collectors was peaked at midphase (45 days). The growth of predators was similar to that of collectors and the grazers/decomposers rate was stable from early phase to harvesting phase (Fig. 7).

Table 1: Physico-chemical parameters of rice field in six sampling sites.

	Sites					
	1	**2**	**3**	**4**	**5**	**6**
Latitude (N)	10.07	10.84	9.93	9.94	9.82	9.88
Longitude (E)	78.05	77.96	78.11	77.89	77.98	78.07
Altitude (m)	133	133	133	133	133	133
Rainfall (mm)	58.23 (18.4)	58.23 (18.4)	58.23 (18.4)	58.23 (18.4)	58.23 (18.4)	58.23 (18.4)
Atmosphere temperature (°C)	33.0 (4.1)	33.5 (4.2)	32.5 (5.0)	33.9 (3.8)	34.2 (3.4)	33.8 (4.1)
Water temperature (°C)	29.5 (3.9)	30.0 (4.1)	28.4 (3.5)	30.4 (4.1)	31.5 (4.5)	29.5 (5.1)
Water depth (cm)	4.0 (0.2)	3.9 (0.1)	3.5 (0.3)	4.0 (0.5)	3.5 (0.3)	3.8 (0.2)
Dissolved oxygen (mgL^{-1})	18.5 (4.6)	16.4 (2.5)	13.6 (5.4)	14.8 (4.4)	15.5 (2.4)	16.4 (2.6)
pH	7.9 (0.5)	7.9 (0.3)	7.8 (0.1)	7.9 (0.4)	7.9 (0.2)	7.9 (0.4)
Conductivity (µs/cm)	0.73 (0.01)	0.64 (0.05)	0.50 (0.02)	0.61 (0.01)	0.75 (0.03)	0.71 (0.02)
Total dissolved solids (mgL^{-1})	7.8 (0.4)	7.7 (0.3)	7.8 (0.1)	7.9 (0.6)	7.8 (0.5)	7.6 (0.4)
Alkalinity (mg HCo_3L^{-1})	55 (15)	58 (14)	55 (15)	53 (10)	52 (10)	54 (13)
Hardness (mg $CaCo_3L^{-1}$)	69 (12)	47 (8)	64 (10)	47 (9)	49 (10)	50 (10)
Phosphate (mg $P_2O_5L^{-1}$)	0.16 (0.01)	0.20 (0.02)	0.15 (0.01)	0.15 (0.01)	0.15 (0.01)	0.15 (0.01)
Ammonia ((mg NH_4L^{-1})	0.11 (0)	0.08 (0)	0.12 (0.01)	0.12 (0.01)	0.14 (0.01)	0.12 (0.01)

Table 2: List of genera collected in irrigation rice fields of Madurai district.

Phylum	Order	Family	Genus
Arhtropoda	Coleoptera	Hydrophilidae	*Hydrophilus*
		Hydrophilidae	*Berosus*
		Dytiscidae	*Copelatus*
		Dytiscidae	*Hydraticus*
		Dytiscidae	*Dytiscus*
		Dytiscidae	*Laccophilus*
		Gyrinidae	*Dineutus*
	Odonata	Coenagrionidae	*Ischnura*
		Coenagrionidae	*Agriocnemis*
		Aesgbudae	*Anux guttatus*
		Libellulidae	*Crocothemis servilia*
		Libellulidae	*Diplacodes*
		Libellulidae	*Orthertrum sabina*
		Libellulidae	*Pantala*

		Libellulidae	*Trapezostigma*
	Hemiptera	Nepidae	*Laccotrephes*
		Nepidae	*Ranatra*
		Hydromatridae	*Hydrometra*
		Notonectidae	*Anisops bouvieri*
		Corixidae	*Arctocoxica*
		Belostomatidae	*Lethocerus indicus*
		Gerridae	*Limnogonus*
	Ephemeroptera	Baetidae	*Cloeon*
		Baetidae	*Baetis*
		Caenidae	*Caenis*
	Diptera	Culicidae	*Culex tritaeniorhynchus*
		Culicidae	*Culex vishnui*
		Culicidae	*Culex fuscanus*
		Culicidae	*Culex pseudovishnui*
		Culicidae	*Anopheles subpictus*
		Culicidae	*Anopheles annularis*
		Culicidae	*Anopheles vagus*
		Culicidae	*Anopheles barbirostris*
		Culicidae	*Anopheles peditaeiatus*
		Chironomidae	*Chironomous*

Table 3: Diversity indices of aquatic insects between sampling sites

	Sites					
	1	**2**	**3**	**4**	**5**	**6**
Taxa	42	40	28	45	45	42
Dominance	0.1019	0.1138	0.2219	0.03263	0.03263	0.09601
Shannon	2.719	2.625	2.063	3.544	3.544	2.873
Simpson	0.8981	0.8862	0.7781	0.9674	0.9674	0.904
Evenness	0.3371	0.3451	0.2812	0.8241	0.8241	0.393
Margalef	5.943	5.391	4.098	7.085	6.621	5.99

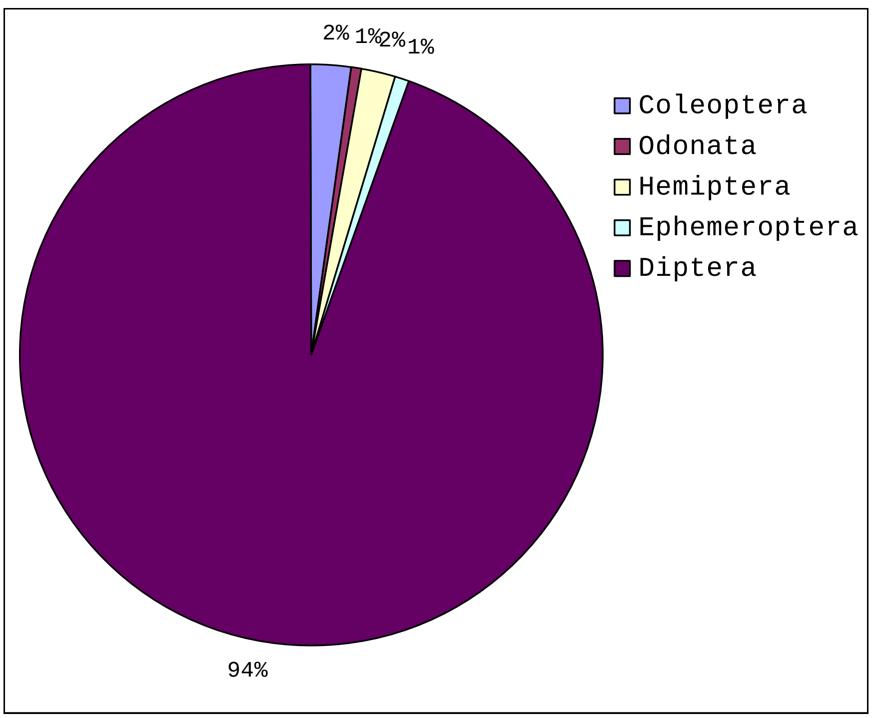

Fig 1: Relative abundance of aquatic insects in an irrigated rice field.

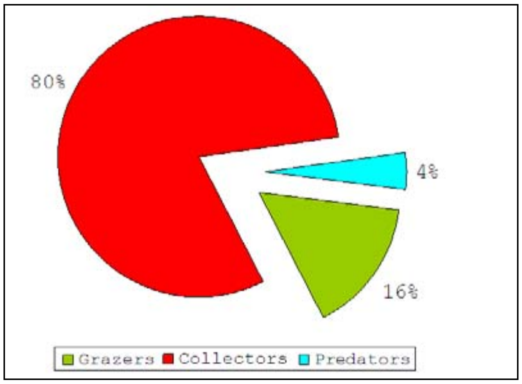

Fig 2: Trophic categorization of aquatic insects in an irrigated rice field

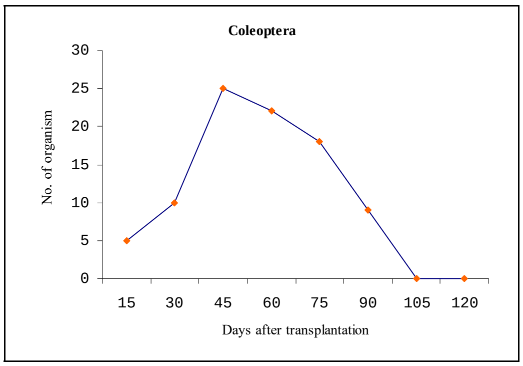

Fig 3: Graph showing the colonization of coleopterans during paddy growth in canal irrigation type

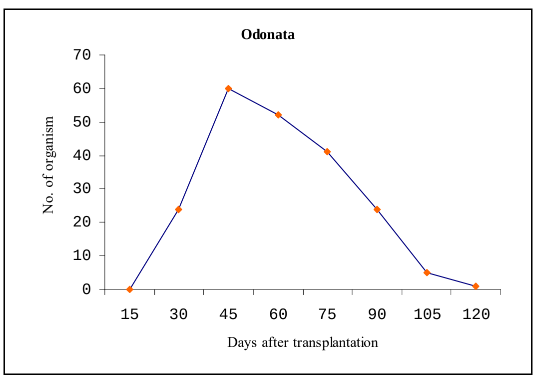

Fig 4: Graph showing the colonization of odonates during paddy growth in canal irrigation type

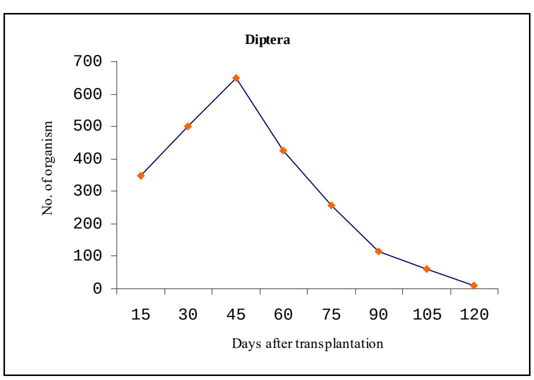

Fig 5: Graph showing the colonization of dipterans during paddy growth in canal irrigation type

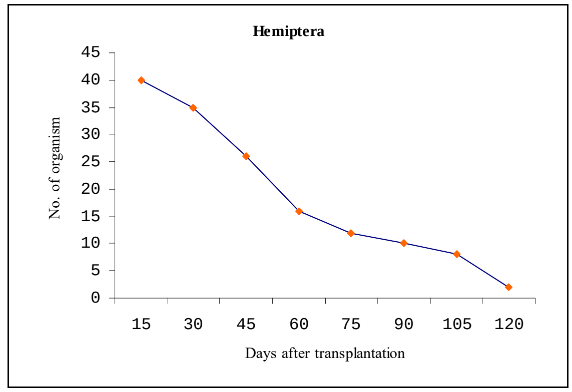

Fig 6: Graph showing the colonization of hemipterans during paddy growth in canal irrigation type

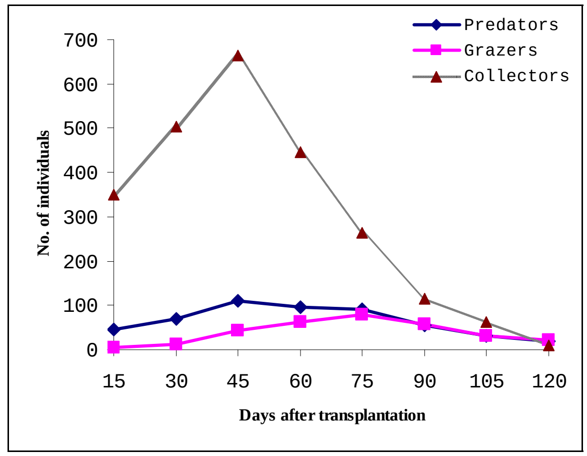

Fig 7: Colonization of functional feeding groups in canal irrigation type of paddy field

4. Discussion

Paddy fields were originally wetlands and artificially constructed devices for rice production [10, 11]. Irrigated rice fields, being temporary aquatic habitats with a generally predictable dry phase, can be scientifically defined as an agronomically managed temporary wetland ecosystem [12]. They are temporary and seasonal aquatic habitats, managed with a variable degree of intensity. Many aquatic organisms like hemipterans, coleopterans, dipterans are known to reproduce in paddy fields [11]. A preliminary study on fauna and flora of a rice field in Sri Lanka by Bambaradeniya *et al.* [12] has documented 77 species of invertebrates, 45 species of vertebrates and 34 species of plants. In the present study, 35 insect species belonging to five orders were documented. Similar trend was observed in the rice field of Japan by Ohba *et al.* [5]. Further, the family of Culicidae (order: Diptera) hold the high number of species than the other groups [5]. This finding supports to the present study that 9 mosquito species were collected in the family of Culicidae and their percentage was also abundant than the other groups.

Based on the species abundant, collectors were dominated over the other functional groups. Among collectors, the blood worm (*Chironomous*) occupied the greatest percentage. This result evident to Settle *et al.* [13] that the true midges vastly outnumbered the mosquitoes. In Asia, Heong *et al.* [2] suggests that increased the amount of all the chironomids as "root feeders" under the heading of "phytophagous" insects. However, no reports were observed from tropical Asia implicating a chironomid species as causing serious damage to rice. Followed by the second abundant species were mosquitoes from rice field in the present study. In relation to mosquito abundance in the rice fields, the less number of predator diversity was present. The colonization study indicates that the growth of predators was similar to that of collectors from early phase to harvesting phase. This similarity may be attributable to agricultural chemical use in all of the rice fields, which in turn to affect fish and other non-target aquatic animals [14, 15]. Although irrigated rice field become breeding habitats for vector mosquitoes, establishing awareness in rice fields in order to protect various aquatic insects predators, may help to control mosquito breeding.

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