A Comparative assessment of select faunal taxa with reference to various growth stages of paddy in organic and non-organic fields of Kathiramangalam, Tanjavur District, Tamil Nadu

Thesis submitted to the Bharathiar University
in partial fulfilment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

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This is to certify that the thesis entitled "**A Comparative assessment of select faunal taxa with reference to various growth stages of paddy in organic and non-organic fields of Kathiramangalam, Tanjavur District, Tamil Nadu**" submitted to the Bharathiar University, in partial fulfilment of the requirements for the award of Degree of **Doctor of Philosophy in Zoology** is a record of original research work done by **Ms. Chaithra Shree J** during the period November 2014 – April 2021 of her study in the Department of Zoology at Sálim Ali Centre for Ornithology and Natural History under my supervision and guidance and the thesis has not formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or other similar title to any candidate of any University.

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I, **Chaithra Shree J.**, hereby declare that the thesis, entitled "**A Comparative assessment of select faunal taxa with reference to various growth stages of paddy in organic and non-organic fields of Kathiramangalam, Tanjavur District, Tamil Nadu**" submitted to the Bharathiar University, in partial fulfilment of the requirements for the award of Degree of **Doctor of Philosophy in Zoology** is a record of original and independent research work done by me during November 2014 – April 2021 under the supervision and guidance of **Dr. P. Pramod,** Principal Scientist, Division of Nature Education, Sálim Ali Centre for Ornithology and Natural History and it has not formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or other similar title to any candidate of any University.

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CHAPTER 1

GENERAL INTRODUCTION

India, a mega-biodiversity country is home for rich wildlife due to the wide range of climatic conditions across different bio-geographic zones. This biodiversity is the basis of India's rich diversity in culture and traditions. Wildlife Protection Act (1972) is one of the strongest instruments which protect Indian wildlife through various Reserve Forests and other Protected Areas (PA) across the country. But, the presence of wildlife is not restricted to the designated forest regions. India's forest cover at present is only 23%, whereas 46% of our land is used for agriculture (Statistical Yearbook India, 2017). These vast areas of agro-ecosystems harbour a variety of wildlife associated with the cultivation practices and hence are of significant conservation concern (McNealy, 1995). The wildlife studies in agro-ecosystems, so far in our country, are based on the merits and demerits of presence or absence of a species/ community to the farmer (Beri *et al*, 1968; Jotwani *et al*, 1969; Chahal *et al* 1973; Jain and Prakash, 1974; Bhatnagar, 1976; Dhindsa and Toor, 1980; Dhindsa *et al*, 1984; Subramanya, 1987; Saini and Toor, 1991). In the recent times, various taxa apart from the pest species in agro-ecosystems are being studied. Most of these studies revolve around specific species or taxa that are beneficial to the farmers in biological control of pest species or enrich the soil fertility. Very few studies that document the diversity associated with agro-ecosystems exist. In this world, heading towards sustainable living, the knowledge and understanding of our bio-resources become imperative. The diversity associated with agro-ecosystems with the changing trends need to be explored and understood well to achieve our wildlife conservation and Sustainable Developmental Goals.

Agro-ecosystems can be classified based on the crops cultivated. In India the major food crops grown are rice, wheat, maize, ragi, jowar, bajra, barley and many cereals. Of these, rice cultivation is an integral part of Indian village life since time immemorial. With speculations on its origin to be from India, China or South-east Asian region, paddy cultivation has spread across the world and currently cultivated in 80 countries (IRRI). India is the second largest producer of rice in the world with the largest area under paddy cultivation. In India, 43.38 million hectares is under paddy cultivation spread across 20 agro-ecological zones (Sebastian *et al*, 2014). The importance of paddy fields as a unique ecosystem to support biodiversity has come to light since the early 1990s (Kurihara, 1989; Roger *et al* 1991; Borad *et al*, 2000; Bambaradeniya and Amarasinghe, 2003). The cultivation practices used for paddy have led to the formation of a unique wet/dry dynamic ecosystem that is cyclic in its changes. A short term ecological succession cycle is seen in the paddy field biological community as the conditions vary from wetland, wet to dry (Bambaradeniya, 2000; Heong *et al*, 1991; Subramanya, 1987; Heckman, 1974). This dynamic habitat variability has made paddy field a unique agro-ecosystem supporting rich wildlife. In other words, an ecosystem unto itself that varies with paddy cultivation cycle.

In the last century, traditional cultivation practices have been largely replaced by modern technology oriented practices. The mechanization of agricultural practices has changed the wildlife communities associated with agro-ecosystems (Fuller, 2000). Smallman (1964) brought to attention the impact of pesticides to the agro-ecosystems and their long term infeasibility. The idea of sustainability along with understanding of health impacts of the chemicals (Pimentel *et al*, 1993) used in farming led to the recurrence of organic farming in the early 1990's across the world and many farmers emerged as organic cultivars in agriculture and horticulture sectors. In the late 1990's, yield and input based comparative studies were undertaken among the organic and conventional farming systems for various crops (Pimental *et al*, 2005). Later on, the diversity supported by organic agro-ecosystems came into focus. In the last two decades diversity oriented comparative studies in different parts of the world on plants, arthropods, invertebrates, bats and birds (Beecher *et al*, 2002; Wickramasinghe *et al*, 2003; Wickramasinghe *et al*, 2004; Holzschuh *et al*, 2008; Letorneau and Bothwell, 2008; Smith *et al*, 2010; Danhardt *et al*, 2010; Jonason *et al*, 2011; Zhang *et al*, 2013; Linke *et al*, 2014) have shown that organic agro-ecosystems harbour higher species richness and abundance in most of the cases.

Paddy is a unique most widespread agro-ecosystem compared to other crops or orchards in India. Also, very little biodiversity associated studies in paddy fields and their cultivation regimes are available here. Hence, it is important to understand the diversity harboured by paddy fields in our country and also the biodiversity perspective of the cultivation regimes in view of sustainability and biodiversity conservation. This study is an attempt for that. A study on all taxa in paddy fields is out of scope for a limited period research work. For this, bio-indicator or ecological indicator taxa have been selected. This study focuses on the community-ecosystem level (Noss, 1990). Broad objectives of the study are the following:

1. To study the Community structure and variability of select faunal indicator taxa supported by the paddy fields.
2. To compare the changes in the community of select faunal taxa across paddy growth stages between organic and non-organic paddy cultivation regimes.

To achieve these objectives three faunal indicator taxa have been selected. They are

1. Birds: Birds are well known, accepted and identified ecological indicators (Pramod *et al*, 1997; Gregory *et al*, 2003) with a wider usage of areas and habitats. A study of their community would give a basic understanding on the habitat, resources and its changes at a wider scale.
2. Odonata: Dragonflies and damselflies are predatory insects that are well known wetland indicators. They are also territorial in nature. Paddy fields are also temporary wetlands and the odonate community and its variability will shed light on the microclimatic conditions of the field. Their specificity and sensitivity to water parameters make them good indicators (Oertli, 2008).
3. Butterflies: Butterflies indicate the overall plant community of a region (Nimbalkar *et al*, 2011). The dependency of butterflies on specific plant species for larval and adult food makes them a good indicator of vegetation in the man-made ecosystem.

1.1 Thesis Structure

The thesis is organised into eight chapters. The first chapter introduces the thesis and includes objectives of the study and thesis structure. This is followed by a chapter on literature review wherein the background on biodiversity in paddy fields and studies on organic and conventional farming practices and their impact on various taxa are discussed. The third chapter describes the study area and explains the methodology used for data collection and analyses in detail. The fourth chapter describes the habitat in detail along with vegetation profile of the study area. The next three chapters are technical chapters that address the above objectives of the study for each select faunal indicator taxa in each chapter separately wherein the community characteristics and their relationship with cultivation regime are explored. The last chapter summarizes the results.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Perspectives on agroecology

Agro-ecosystems are man-managed ecosystems that have traditionally been perceived as existing solely for the benefit of humans. Other living organisms in agro-ecosystems are considered as pests by practice. Maximising the crop yield with labour reduction has been the major objective of agricultural research. Maximising yield has become so prominent that it is an objective of any crop under research although it is unnecessary for certain crops. A classic example is the Costa Rican Coffee Crisis (1989) which was solely based on the overproduction of coffee (in Vandermeer, 2011). This view is changing slowly among the scientific community. Any agro-scientist's objective is to help the farmers produce healthy yielding crop involving minimal efforts. But, one tends to forget, although agro-ecosystems are socio-economic zones, they are also associated with wildlife that are part of larger functional ecological systems. There is a misconception that agro-ecosystems cannot sustain any biodiversity. They may serve as habitats of dispersion or transient habitats or in some cases support wildlife. For example the natural shade coffee plantations across the world, especially in the tropics, serve as good habitats for diverse organisms. Recent studies have also shown that increase in management intensity of shade coffee plantations, from natural forests to mono-cultured shade, lead to decrease in abundance of bats, ants, birds, butterflies and small mammals (Gillison *et al*, 2004; Williams-Guillen and Perfecto, 2010). In the last 15 years we have come to the realisation that, with the ever-expanding areas of agro-ecosytems, increase in use of chemical inputs leading to higher production costs, impacts of climate change on farmers (Bargout, 2012), all need a scientific solution inclusive of ecological factors. The seeds of thought to shift our focus from profit-oriented farming to sustainable agriculture have been sown (Way and Heong, 1994; Vandermeer and Perfecto, 1997). This idea has gained momentum and is reflected in the form of rise in alternative agricultural practices and their research (Matteson, 2000; Nicholls *et al*, 2000; Pfiffner and Wyss, 2004; Keitt, 2009; Nicholls and Altieri, 2012; Al Hassan *et al*, 2012; Benayas and Bullock, 2012; Balvanera *et al*, 2014; Prasannakumar *et al*, 2015;

Saunders *et al*, 2016; Peters *et al*, 2016; Pauli *et al*, 2016; Herzog and Franklin, 2016) including the ecology of pest species (Baskaran *et al*, 2017; Kanagaraj *et al*, 2019).

In the current socio-political and economic conditions, the farming philosophy of the last century is becoming questionable day by day and demands a more ecological perspective. There has also been loss of local ecological knowledge down the generations which does not help boost farmer's confidence in alternative sustainable farming practices. But, it is important for us to understand the ecological functionality of agro-ecosystems for sustainable future (Altieri, 1999). It is known that the biodiversity supported by agro-ecosystems provide ecosystem services to the farmers and the scale of management influences the functionality of biodiversity in agro-ecosystems (Tscharntke *et al*, 2008). There is also a general viewpoint that sustainable farming practices or environmental friendly practices will reduce crop yields and a general fear of the same permeating the society, including the scientific group. But, Organic farming has the potential to manage the world's food supply including ecosystem services (Badgley *et al*, 2007; Cavigelli *et al*, 2013). Increase in labour and efforts are expected in organic farming as conventional farming methods were derived to decrease labour (Vandermeer, 2011, Vandermeer, 2003).

Many of the problems faced by farmers have sound ecological solutions, if implemented correctly. This is proved by the study of Morales and Perfecto (2000), where, the researchers had to reframe their objectives as the local farmers did not have pest problems, which was the focus of their study. But, the agro-ecosystems in India vary significantly from each other in their ecological functionality due to the variation in weather and climatic conditions. This increases the habitat variability even among similar agro-ecosystems in different regions, thereby supporting biological diversity. Hence, a 'one size fits all' ecological approach does not serve a country like India. Region specific studies are mandatory for sound ecological knowledge base in agro-ecosystems in Indian context. Paddy fields, being unique agro-ecosystems, are also seen in 20 agro-ecological zones of India (Sebastian *et al*, 2014). They are known to support biodiversity worldwide (Edirisinghe and Bambaradeniya, 2006).

2.2 Biodiversity in Paddy fields

The biodiversity associated with rice ecosystem have been documented extensively across the globe. The earlier accounts are based mostly on the pests of rice (Joy, 1978; Manjunath and Urs, 1979, Pawar, 1981; Pathak, 1968; Ghai *et al*, 1979; Reddy, 1967; Mishra, 1986) , be it invertebrates or vertebrates. In the later studies, the focus has been on species beneficial to farmers and their ecological role in biological control of pests (Mohanraj *et al*, 1995; Ambikadevi, 1998; Beevi *et al*, 2000; Singh *et al*, 1998). Few recent studies have focused on documenting the biodiversity supported by paddy fields globally (Bambaradeniya *et al*, 1998; Bambaradeniya *et al*, 2004; Schoenly *et al*, 2010; Ranjith *et al*, 2015, Kathirvelu, 2019).

The plants associated with paddy fields have been mostly documented as weed species. Mishra (1986) has documented 57 plant species from rice fields of Bilaspur recognised as weeds with Cyperaceae and Poaceae being more abundant families.

Algal diversity in rice fields are considered important due to their ecological role of nitrogen fixation, maintenance of soil fertility, water holding capacity in rice fields and their use in bioremediation, especially by cyanobacteria. In the rice fields of Assam, 92 algal species belonging to 39 genera and four groups, of which, 23 species were cyanophyceae belonging to 13 genera, were documented (Thajamanbi, 2016). Kumar and Sahu (2012) recorded 24 species of Chloprophyceae belonging to five orders from rice fields of Ranchi. Cyanobacteria are also known to be relatively more abundant in rice fields compared with other ecosystems. They are also influenced by pH and Phosphorous levels of the soil in rice fields (Kumar, 2012)

2.2.1: Invertebrate diversity in paddy fields

Among the invertebrates, arthropods have been documented and reviewed well in the rice fields across the world. Their diversity and distribution along with cropping patterns have been studied globally (Bambaradeniya and Edirisinghe, 2008; Kandibane *et al*, 2007). Their ecological roles as pests or biological control of pests are reasonably well known (Birthal and Sharma, 2004).

Forty species of orthopterans are known from rice fields of the world (Chitra, 2000). In India, Chitra (2000) has documented seven Coleopteran species, one Dermapteran species, six Hymenopterans, six Odonates, six Orthopterans and four Aranae species as natural enemies of pest orthopterans in rice fields. She observed twenty Coleopteran species belonging to six families as pests in rice fields including short and long-horned grasshoppers and crickets. In the rice fields of Tamil Nadu, Diraviam (2005) has studied the arthropod diversity and composition. He has documented 382 arthropod species from rice fields. Of these 316 species were insects and 66 species were arachnids. The class Insecta constituted of 15 orders *viz.* Orthoptera (six families, 14 species), Hemiptera (20 families, 40 species), Homoptera (11 families, 41 species), Thysanoptera (two families, 10 species), Lepideoptera (eight families, 23 species), Coleoptera (20 families, 71 species), Diptera (13 families, 21 species), Hymenoptera (23 families, 84 species), Odonata (two families, five species), Dermaptera (one family, one species), Neuroptera (two families, two species) and Mantodea, Ephimeroptera, Collembola and Psocoptera represented by one species each. The arachnids were represented by orders Cryptostigmata (one species), Mesostigmata (two families, two species) and Protostigmata (two families, two species) under the sub-class Acari and order Aranae (15 families, 64 species). Among the Aranae, the common families were Araneidae, Lycoridae, Salicitidae and Tetragnathidae. Sixty species of Chalcidids belonging to 14 families have been recorded and detailed from rice fields of Thrissur and Palakkad districts of Kerala (Menon, 2012).

In the rice fields of central Kerala, Sebastian *et al.* (2005) documented 92 species of spiders belonging to 47 genera and 16 families with orb weavers being dominant. In Aduthurai, five spider species belonging to five families were documented from different transplantation techniques and pest management methods. A fluctuation in population of spiders was seen to coincide with prey insect populations (Jayakumar and Sankari, 2010). Eleven species of spiders from seven families were documented from rice fields of Gudalur, Tamil Nadu (Vinothkumar, 2012). Twenty four spider species belonging to nine families were recorded from rice fields of Nagapattinam district, Tamil Nadu (Sankari, 2011). From rice fields in Uttar Pradesh 14 spider species belonging to 12 genera and eight families were recorded (Chandra, 2007). Thirty seven spider species belonging to 10 families and 21 genera were recorded from rice fields in Gujarat (Patel *et al*, 2013). Most of these studies showcased the dominance of orb weavers.

Kundu (2015) has documented 30 arthropod species belonging to 16 families and six orders of class Insecta, six Annelid species belonging to four families and three orders, two Platyhelminthes species, six molluscan species belonging to five families from rice fields of Burdwan concentrating on predatory species of mosquito for biological control of the same. Aquatic macroinvertebrates in rice ecosystems are considered ecologically important for nutrient recycling and biological control agents. They also play the role of pests and vectors for diseases. This group of organisms comprising of adults, nymphs and larvae of various invertebrates are either residents or colonisers in rice fields with their diversity and composition varying between fields based on source of irrigation (Ponraman, 2013). Vinothkumar (2013) has documented 13 species of Coccinellids from upland rice fields of Tamil Nadu. From rice fields of Kashmir 21 species of arthropods, two molluscan species have been recorded (Bahaar and Bhat, 2011a). Bahaar and Bhat (2011b) have also recorded 23 taxa of zooplanktons and 28 taxa of phytoplanktons from the same region. From the Apatani plateau in Assam, Saikia (2017) recorded 68 taxa of zooplanktons belonging to 21 families and five groups with Cladocerans being most dominant and Rotifers the least dominant throughout the study. Saikia (2017) also studied the spatio-temporal variation in the zooplankton community of high altitude rice fields.

The role of odonate larvae as biological pest control in rice fields is studied (Salmah *et al*, 2017; Kundu, 2015; Ghahari *et al*, 2009; Siregar *et al*, 2016; Bhusner and Sathe, 2017). Ten species of Zygopterans were recorded as insect predators from rice fields of Eastern India (Satpathi and Mondal, 2016). Very recently Pavithran *et al* (2020) have prepared a checklist of odonates in paddy fields of India. They have listed 127 odonate species belonging to 13 families of which 81 species belonging to six families were Anisopterans and 45 species belonging to seven families were Zygopterans. Pavithran *et al* (2020) have recorded 21 odonate species from rice fields of Tamil Nadu.

2.2.2 Vertebrate diversity in paddy fields

Anuran diversity has been documented from rice fields (Dure *et al*, 2008; Moreira *et al*, 2014). There are differences in anuran species composition between natural wetlands and rice fields, especially in the off-season (Moreira and Maltchik, 2014). Transformed rice fields are able to harbour only resilient Anuran species (Piatti *et al*, 2010, Tumushimire *et al*, 2020). The Anuran community composition varies across paddy cropping season and can be grouped based on their breeding season (Seock Do *et al*, 2021). They even contribute to biological pest control in rice fields (Rajkhatiwada *et al*, 2016). Native frog species consume rice pests and invasive toads feed on beneficial insects in rice fields (Shuman-Goodier *et al*, 2019). Functional and phylogenetic diversity among rice field Anurans increases with proximity to natural water bodies (Ribeiro *et al*, 2017). Bahaar and Bhat (2011a) have recorded one Anuran species, and two Piscean species from rice fields of Jammu and Kashmir. Aditya *et al* (2010) documented 19 fish species from rice fields of West Bengal.

Birds in rice fields have been documented extensively globally (Tanalgo *et al*, 2015; Narayana *et al*, 2013; Borad *et al*, 2000; Norling *et al*, 2012; Elphick, 2010; Taylor and Schultz, 2010; Fujioka *et al*, 2010; Stafford *et al*, 2010; Navedo *et al*, 2015). In the initial stages the pests species (Werner *et al*, 2005, Werner *et al*, 2008; Cummings *et al*, 2002; Borad *et al,* 2001; Tourenq *et al*, 2001) were given importance, but recently the biological control agents are given priority (Borkhataria *et al*, 2012). Rice fields are also seen as areas of bird conservation concern (Dias *et al*, 2014; Marco-Mendez *et al*, 2015; Valente *et al*, 2012; Gopisundar, 2009). The reducing population trend of Greater Painted-Snipe in rice paddies of Japan and Korea is known (Amano *et al*, 2010; Fujioka *et al*, 2010).

Special focus has been on waterbirds (species that are completely dependent on presence of wetlands/wetland species) or wetland dependent birds (species adaptable to terrestrial conditions but prefer wetlands) in rice fields. Rice field is a major stopover habitat for migratory bird species (Lourenco *et al*, 2010; Fujioka *et al*, 2010). The waterbird diversity and abundance in rice fields is influenced by water level, flooding period, crop structure with highest diversity during intermediate water levels (Ibanez *et al*, 2010). Waterbirds in rice fields chose their foraging area based on the ease of catching prey and species presence/absence was also influenced by crop density and size of the bird (Nam *et al*, 2015). Use of rice fields by waterbirds for foraging and their distribution is dependent on bird size and crop growth. Smaller sized waterbirds were more specific towards prey diversity whereas larger sized waterbirds were inclined towards prey density (Otieno *et al*, 2015). Though broadly the bird species composition in paddy fields is more similar to agro-forests (Tanalgo *et al*, 2015), they prefer wide open plain rice fields rather than ones surrounded by forests (Fujioka *et al*, 2010). Sixty seven bird species survived by feeding on crop residues in rice fields (Borad *et al*, 2000). Wintering ducks use rice fields as an important feeding habitat (Pernollet *et al*, 2017). The nutritional requirement of Little Blue Herons was met by the rice fields. The rice fields served as a good transitional habitat during resource scarcity for Great Egrets (Sicemore and Maine, 2012). Chestnut-capped Blackbirds have a high breeding success in rice fields and clutch size decreases as the nest site moves away from water (Cirne and Lopez-Iborra, 2005). Kentish Plovers and Black-winged Stilt had equal nest success rates between natural wetlands and rice fields (Toral and Figuerola, 2012).

Gopisundar and Subramanya (2010) have reviewed the birds in paddy fields of Indian subcontinent. They have listed 351 bird species from rice fields of various agro-ecological zones in India. They have also recognised the gaps in understanding of bird community in rice fields of India. Recently, 42 bird species belonging to 25 families and eight orders have been recorded from the rice fields in Chattisgarh (Rahalker and Patel, 2015).

2.3 Impact of farming practices on biodiversity associated with agro-ecosystems

Biodiversity associated with agro-ecosystems are known to be influenced by agriculture practices. Since green revolution, the technical and technological knowledge gained and applied, have adversely impacted the biodiversity in agro-ecosystems (Singh and Sharma, 2004; Concepcion and Diaz, 2011). Traditional agricultural practices which support landscape complexity have been biodiversity friendly (Gabriel *et al*, 2006; Poggio *et al*, 2010; Jose-Maria *et al*, 2010, Henckel *et al*, 2015). But the advent of green revolution undermined those practices and has lead to loss of local ecological knowledge (Altieri, 1999). This can be perceived in three ways. The major shifts that came in the form of use of chemical inputs for better crop yields, moving on to use of other chemicals to control phytophagous insects, larger pests and weeds and then reduction of labour by introducing machinery. These changes have impacted the biodiversity associated with agro-ecosystems at various levels based on the taxa under consideration. Intensification of agricultural practices and land-use has resulted in loss of species richness and biodiversity (Beckmann *et al,* 2019).

Application of chemical fertilizers was found to reduce the plant species diversity in semi-natural grasslands. High fertilizer inputs remain in soil for long periods and do not allow other plant growth on fallow land, thereby affecting faunal diversity (Sotherton and Self, 1999). Long term excessive use of nitrogen fertilizers has increased the population of rice pests like plant-hoppers and stem-borers (Zhong-xian *et al*, 2007). Sudden peaks in arthropod diversity, especially of rice pests were observed with application of fertilizer. The increased population of pests resulted in increase of predatory arthropods when pesticides were not applied (Diraviam, 2005).

Herbicide applications are predicted to facilitate outbreaks of diseases and pests due to disruption of soil and aquatic fauna in agro-ecosystems (Ishibashi *et al*, 1983). The applications of herbicides have targeted arthropods that are dependent on weed species in agro-ecosystems (Sotherton and Self, 1999). Herbicide application in rice fields have a positive effect on odonate diversity, as they are non-target organisms and decomposing plants provide them with richer organic matter (Rawi *et al*, 2012).

Pesticides are known to impact biodiversity negatively in farmlands, not only during application but by persisting in the environment (Geiger *et al*, 2010). Parsons *et al.* (2010) reviewed the impact of pesticide use on birds in rice fields of the world.

Birds in agricultural lands have been monitored for long period in Europe (Vickery *et al*, 2009). Their population trends were observed to be declining. The major causative agent for this decline was found to be the intensive farming practices during the 1990's (Schifferli, 1999). The impact of mechanisation, fertilizer and insecticide inputs on birds were found to be species specific and season specific in European farmlands. This was based on their ecological needs at a given period (Wakeham-Dawson and Smith, 1999).The application of pesticides, especially seed treatments are known to be of higher risk among birds. The pesticides that inhibit acetylcholinesterase activity in birds are known to affect most of the physiological and behavioural function of birds. Detrimental changes in life cycle activities like thermoregulation, food consumption, reproductive activity, migratory and territorial behaviour are seen among birds, affecting individual survival capacity. These biocides also have indirect impacts on bird survival by targeting their prey species availability or ingestion of contaminated prey (Erwin, 1991; Burn, 1999; Nagy and Smith, 1997).

In paddy fields around the world, various studies have been conducted in the last two decades. Tourenq *et al* (2003) found that intensive soil management and pesticide applications reduced prey resources for aquatic birds in rice fields. Mesleard *et al* (2005) found that insecticide treatment in rice fields of France reduced the abundance of six macroinvertebrate families (Baetidae, Corixidae, Dysticidae, Hydrophilidae, Coenagrionidae and Libellulidae) and most of them were predatory insects. Two molluscan families (Lymnaeidae and Physiidae) were negatively correlated with use of fungicides. Reduced use of pesticide in Indonesian rice fields by 65% resulted in 12% increase in rice yield (Pimentel *et al*, 1993). They also suggested mortality risk among birds due to the most toxic five compounds in rice fields could be reduced to 8% from 64% if lower amounts of pesticides were used. In Phillipine rice fields, insecticide use was seen to impact the food web functionality. Some pest species increased in density after insecticide treatment. The predatory insects were found in higher density in insecticide untreated areas than in treated areas (Cohen *et al*, 1994). Recently, Nofyan *et al* (2017) reported the lethal effects of carbofurans on earthworm by causing changes to their feeding and assimilation behaviour. Most of the pesticides used in tropical paddy fields were seen to have lethal impacts on fishes. The toxicity varied based on pesticide and species combination also causing histo-pathological variations. Organophosphate insecticides were seen to reduce Acetylcholine-esterase activity in fish brain and muscles by 75% (Abdullah *et al*, 1997).

Arthropods have been a major group studied in agro-ecosystems globally. Effects of insecticides on beneficial arthropods in agro-ecosystems have been studied since 1949 (Sudhikumar, 2008; Sharanappa *et al*, 2019). In agricultural landscape of Turkey butterfly diversity was seen to be negatively influenced by pesticides use, especially the species in threatened categories of that region (Pekin, 2013). Arachnids have been in focus in agro-ecosystems as they are known to be major regulators of pests in various agro-ecosystems, especially in context of effects of insecticides on beneficial insects in paddy fields (Sudhikumar, 2008). There is a decrease in spider population and diversity in rice fields after insecticide and pesticide application (Kim, 1992; Yun, 1997; Lee *et al*, 1993; Sankari, 2011). Fagan *et al* (1998), found that insecticide use in combination with biological agents (spiders) for pest control in rice fields did not result in pest reduction but the two worked well individually. Even insecticides selected to protect natural predators contribute to declines in spider diversity in agro-ecosystems (Samu and Vollrath, 1992). Similar trends have been observed in spider diversity in orchards and other agro-ecosystems, where the spiders colonise unsprayed areas and leave the insecticide sprayed plots. The hunting species are seen to be affected more when compared with the web species (Bostanian *et al*, 1984). Spiders are also highly sensitive to pesticides like acephate, BPMC [fenobucarb], ethofenprox, quinalphos, chlorpyrifos, monocrotophos , cypermethrin, deltamethrin, dimethoate, malathion and carbaryl with effects through food chain also (Kumar and Velusamy, 1996; Tanaka *et al*, 2000; Holland *et al*, 2000). The decrease in spider populations due to pesticide use can also result in outbreak of pest species in agro-ecosystems (Sudhikumar, 2008). Chandra (2007), reported that carbofuran 3G @ 1 kg a.i/ha and BPMC 50 EC @ 0.5 kg a.i/ha were the most effective insecticides on plant hoppers with least effect on spiders in rice fields of Uttar Pradesh.

Adalia bipunctata, an aphidophagous coccinellid, has been tested for toxicity from biocides. All the biocides were lethal to it, and also affected the species indirectly through persistance in their environment or through food chain (Olszak, 1999). When modern insecticides, chlorantraniliprole, emamectin benzoate, spinosad, and spirotetramat, were tested for toxicity on *Adalia bipunctata*, the predatory arthropod suffered lethal and sub-lethal effects based on the specific insecticide in larval as well as adult stages (Depalo *et al*, 2017).

Fish diversity in irrigation ditches and rice fields have decreased due to change in management practices (Katano *et al*, 2003). Impact of pesticides and insecticides on Anurans are known (Wu *et al*, 2012 and Ganesan *et al*, 2014). Practice of fallow period in rice cultivation strongly influences Anuran diversity in rice fields (Cunha *et al*, 2015).

2.4 Comparison of associated biodiversity in organic and non-organic agro-ecosystems

Globally, the comparison between organic and non-organic agro-ecosystems have been analysed frequently since 2005 using meta-analytical tools (Bengtsson *et al*, 2005; Mondelears *et al*, 2009; Batary *et al*, 2011; Seufert *et al*, 2012; Tuomisto *et al*, 2012; Tuck *et al*, 2014). These analyses have compared the yield, associated biodiversity and environmental impacts of organic and conventional agro-ecosystems. All these meta-analyses are based on studies mostly from European countries and American continent. They also concur that organic methods have a positive effect on farmland biodiversity and health of agro-ecosystem. Hole *et al* (2005) have reviewed the biodiversity associated with organic and conventional agro-ecosystems in European and American farmlands in detail. Among plants, the weed abundance and species richness was higher under organic regime, in different cropping systems, with differences being greater for broad leaved species that were highly intolerant to conventional de-weeding practices. The soil microbe community showed elevated activity in organic regime. Among the invertebrates, earthworms and arthropods were more abundant and diverse under organic regime. Butterflies showed conflicting results. The beetle diversity results were inconsistent due to similar impacts of chemical use and deep tillage on this taxa. Among vertebrates, the birds were seen to be more abundant in organic farms and the wood mouse was more active on organic farmlands with preference to margins over fields. Organic farmlands support 30% higher diversity than conventional farmlands, but the responses are taxa specific (Bengtsson *et al*, 2005; Fuller *et al*, 2005).

Further studies have shown that plant diversity under organic farms are higher in all different agro-ecosystems (Clough *et al*, 2007; Winqvist *et al*, 2011; Armengot *et al*, 2012; Jonason *et al*, 2011; Solomou and Sfougaris, 2011; Henckel *et al*, 2015), especially in the arable fields (Gibson *et al*, 2007). Organic farmlands enhance bird diversity (Winqvist *et al*, 2011; Jonason *et al*, 2011; Beecher *et al*, 2002), especially the invertebrate feeders (Smith *et al*, 2010). Landscape heterogeneity is a major factor affecting avian diversity when comparing organic and conventional agro-ecosystems (Wolnicki *et al*, 2009, Smith *et al*, 2010). It also affects plant diversity positively (Rader *et al*, 2014). The biodiversity in organic agro-ecosystems are higher and show more variation from conventional agro-ecosystems in simple than in complex landscapes

(Batary *et al*, 2011), but do not influence pollinator diversity in isolated patches (Brittain *et al*, 2010). Parasitoid diversity is positively influenced by organic farming at various spatial scales, including their service as biological pest control in arable fields (Inclan *et al*, 2015)

Bat activity was higher in organic fields (Wickramasinghe *et al*, 2004, Put *et al*, 2018) but the bat diversity does not seem to be influenced by organic management practices (Froidevaux *et al*, 2017). Similarly spiders and rove beetles are more abundant in organic farmlands but do not show any difference in species richness and composition (Rusch *et al*, 2014). Small mammals in Argentinian farmlands did not show significant differences in their abundance between organic and conventionally regimes. But organically managed border habitats harboured more specialist species (Coda *et al* 2015).

Soil microbes show higher diversity in terms of species as well as phylogeny in organically managed agro-ecosystems (Lupatini *et al* 2017). Low microbial functional diversity was seen in chemically managed farmlands in comparison with organically managed farmlands and fallow lands. Beneficial bacteria that improve soil quality were found to be more abundant in organic farmlands and fallow land (Chaudhry *et al*, 2012; Dongre *et al*, 2018; Wang *et al*, 2012; Hartmann *et al*, 2014; Goel *et al*, 2020). Soil arthropods in organic agro-ecosystems have lower heavy metal accumulation than in conventional agro-ecosystems (Chinnaraj *et al*, 2018). Organic rice farming enhances the chances of colonization by wetland macrofauna in the fields (Dalzochio *et al*, 2016). The insect diversity in rice ecosystems are enhanced by organic cultivation (Ovawanda *et al*, 2016)

In India, soil, soil related parameters and microbial comparison between organic and conventional farming methods have been in focus in the past decade (Kumar, 2017; Jothimani, 2016; Chidambaram, 2013; Suganthi, 2015; Chhotaray, 2011; Shekh, 2015; Paul, 2011; Sudhakaran, 2016; Padmavathy and Poyyandi, 2013; Selvi, 2016; Nawn, 2012; Gosavi, 2010; Masum, 2019; Annakamu, 2014). These studies have also focused on yield and economic comparisons in various agro-ecosystems under organic and conventional regimes. But there is a dearth on biodiversity comparisons between the management regimes in the Indian context.

CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1 Study Area

3.1.1: Location: This study was conducted in Kathiramangalam village, Thiruvidaimarudur taluk, Thanjavur District, Tamil Nadu (11° 4' N and 79° 31' E) bordering Nagapattinam district. This is part of the Cauvery delta region known for paddy cultivation in Tamil Nadu with the river flowing in the nearest aerial distance of 10 kms towards North-west. One of the tributaries of Cauvery known as Vikraman river also flows within three kms South-west of the study area. The land here is made up of rich alluvial soil.

3.1.2: Rainfall: Annual rainfall varies between 600 mm and 1500 mm with an average of 1000 mm (Figure 3.1 a) (Data Source: India water portal meteorological data and Customised Rainfall Information System). The maximum rainfall is received from August to December with peak in October and November (Figure 3.1 b). Major source of rainfall to this region is the North-east monsoon.

3.1.3: Landuse: Tamil Nadu is one of the top five rice producing states in India with 2.04 million hectares (4.7% of India's paddy cultivar land) under paddy cultivation, producing 7.65% of India's rice (Agristat, 2016). Thanjavur district is a major contributor with an average of more than 1,60,000 hectares under paddy cultivation in the last 18 years (Figure 3.2) (Data Source: Web based land use statistics information system). In Kadhiramangalam, the whole low lying plains are intensive agricultural areas with the major crop being paddy interspersed with very small patches of sugarcane and timber wood. The main source of water for these paddy fields is bore well although it is a part of fertile Cauvery delta. The complete delta region is dominated by the paddy fields with interspersed human habitations and woodlands (Figure 3.3). This reduces the influence of landscape (Ranganathan *et al*, 2010) on the species composition in the paddy fields and the diversity observed in this region may be considered as the true community of paddy field ecosystem.

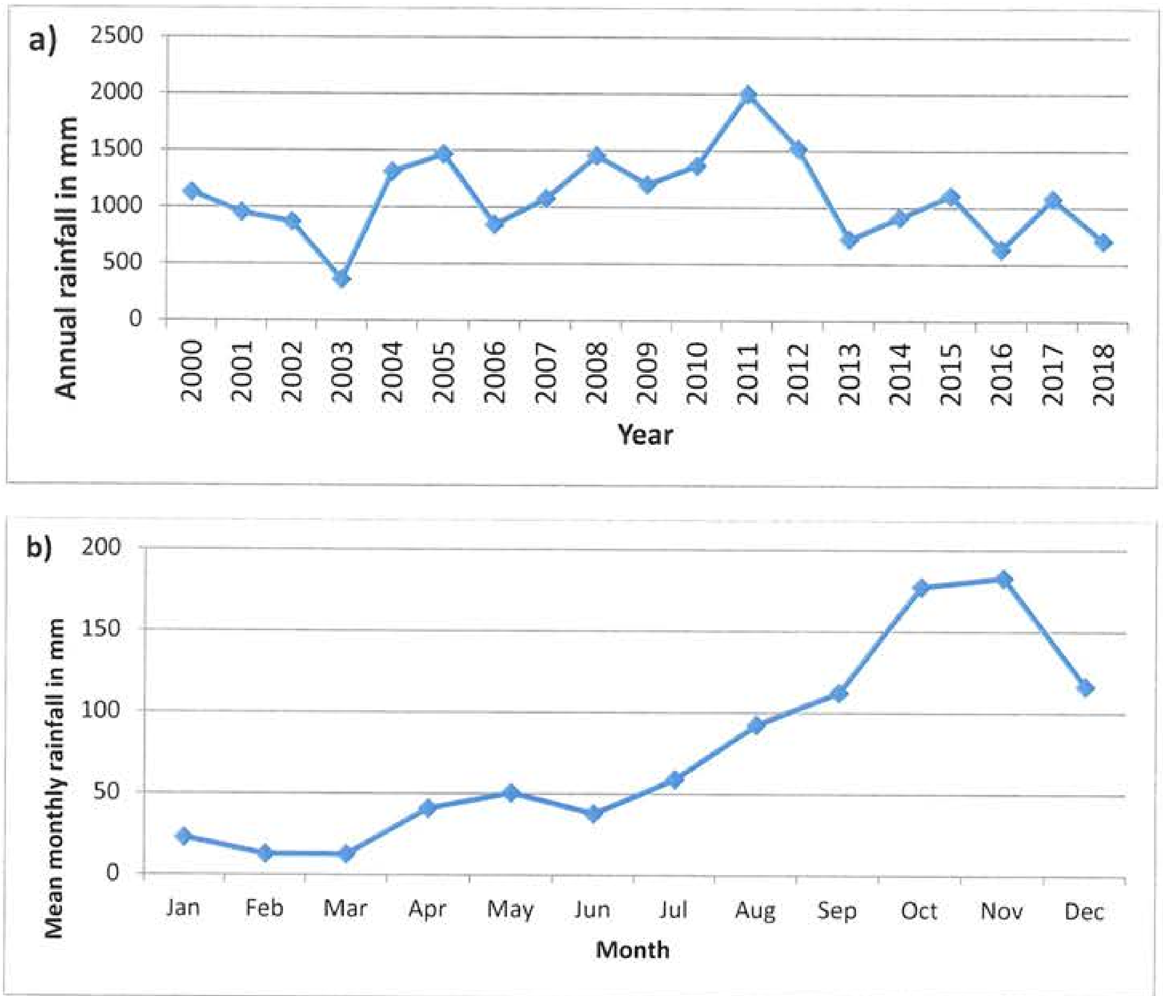


Figure 3.1: a) Annual rainfall in Thanjavur district from 2000 to 2018. b) Mean monthly rainfall in Thanjavur district

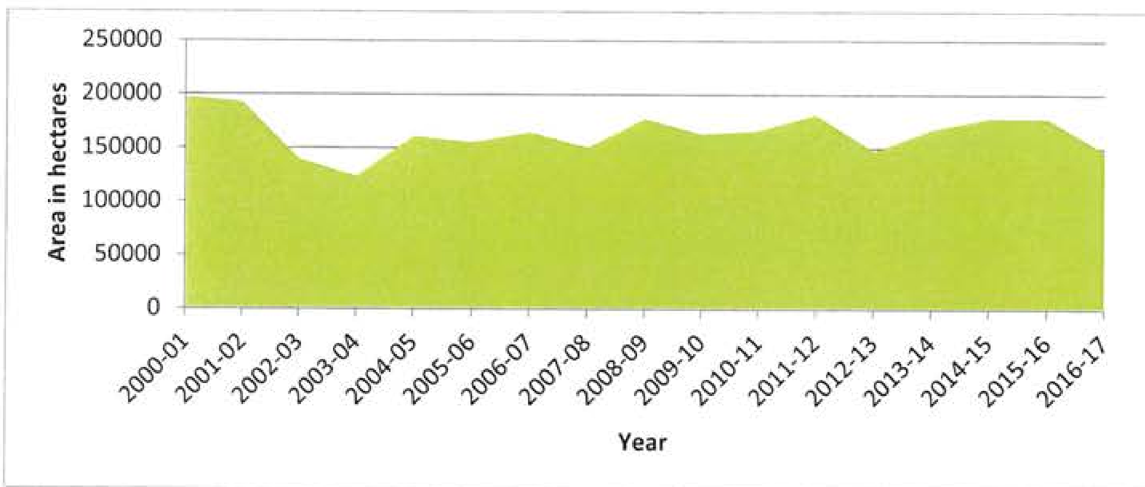


Figure 3.2: Area under paddy cultivation in Thanjavur district from 2000 to 2017

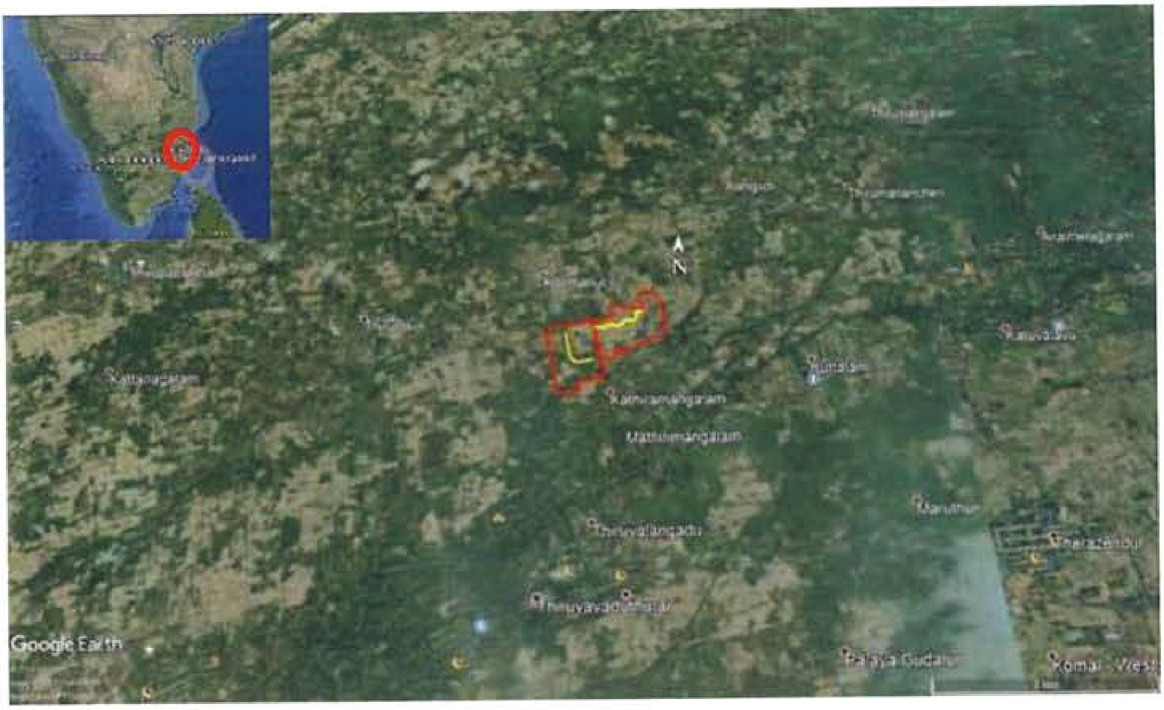


Figure 3.3: An overview of study area with marked transects

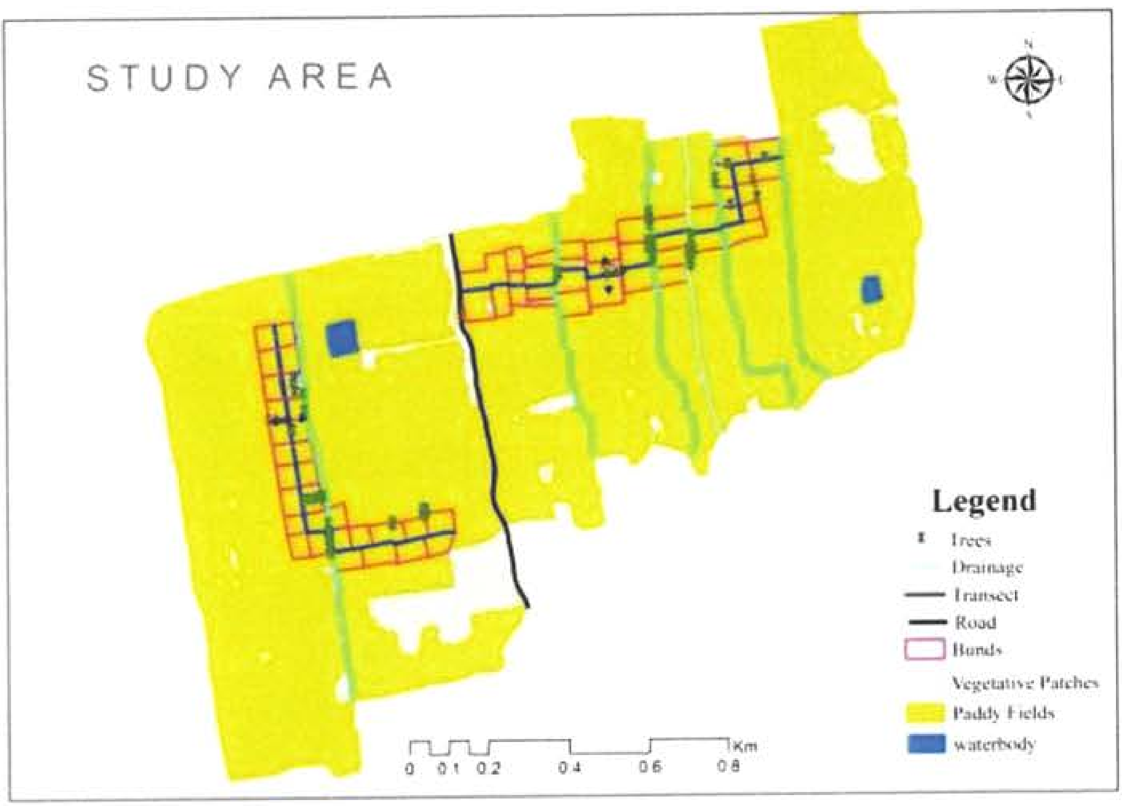


Figure 3.4: Detailed map of the study area with the two selected study sites marked

3.2 Methodology

3.2.1 Field Methodology

3.2.1.1 Selection of study sites: Two study sites (observation locations) were selected in the region with at least half a km aerial distance to avoid overlap of species during the period of observation. A transect of one km was marked in each study site (Figure 3.4). A straight line transect method could not be followed as it was not feasible to cut across fields and collect data. As the objective was to compare the diversity and community of select indicator taxa between organic and non-organic cultivation regime, each study site was selected based on their cultivation regimes. The study sites were also near enough to reduce variations due to weather, climate and landscape between the sites. The two cultivation regimes are

a) **Organic cultivation**: A transect of one km marked in 28.33 ha of land under organic paddy cultivation. The cultivated area is cut off from external water sources that flow from other fields. The water used to irrigate is mainly from bore-well apart from the rainwater. The fallow land plants are tilled into the soil to decompose and produce green manure. Natural fertilizers and growth stimulators like Panchagavya and cow dung are used in the fields. Pesticides are not used. The land is cultivated with hybrid as well as traditional paddy varieties. Transplantation is done using single saplings with a distance of 50x25 cm between saplings. De-weeding is done manually. Tilling and harvest are mechanical. A single cropping cycle ranges from 120 to 130 days based on the varieties transplanted. The area under organic cultivation will be referred to as organic fields from here on.

b) **Non-organic cultivation**: A transect of one km laid in contiguous paddy cultivation stretch under non-organic regime. The cultivated area is irrigated by bore-well and water channels apart from rain water. The fallow land is used for grazing and bund grasses are cut as fodder. Fertilizers like urea and NPK (nitrogen, phosphorous, potash) are used in large quantities. Pesticide use is under farmer's discretion. De-weeding is done manually. Tilling and harvest are mechanical. Four to five saplings transplanted as a bunch. The distance between two bunches of saplings is 20x20 cm. A single cropping cycle ranges from 95 to

105 days. Here onwards the study site under non-organic cultivation will also be referred to as non-organic fields.

The differences between the cultivation regimes in a habitat perspective are discussed in detail in chapter 4.

3.2.1.2: Paddy growth stages: Paddy, as a crop, in a cultivation cycle, undergoes physical and physiological changes over time. Being a managed ecosystem, it also shows variation in field condition based on the management. This leads to a change in substratum. This change has been documented by dividing the cropping cycle into seven paddy growth stages. The seven paddy growth stages identified are

1. Land preparation and sapling phase (PS-1) – Tilling and levelling are done and seed sown for saplings. Inundated wetlands. This phase takes up to 15 days. 20% land area used for mother-bed.
2. Transplantation phase (PS-2) – This stage includes transplantation and crop growth up to one feet in height. Inundated wetlands. This phase lasts from 18 to 20 days
3. Growth phase (PS-3) – This phase encompasses tillering and growth of the crop till the crop is ready for flowering. Inundated wetlands. Later stages water starts drying. Duration-25 to 30 days.
4. Flowering phase (PS-4) – Panicle formation and flowering. Wet fields. Pockets of water clogging. Short phase lasts from 5 to 7 days.
5. Milking phase (PS-5) – During the milking period. Moist/ dry fields. Duration-around 15 days.
6. Maturing phase (PS-6) - The panicles get mature. Moist/ dry fields. Lasts around 15-20 days.
7. Drying and harvesting phase (PS-7) – The mature crop starts drying. Later harvested. Dry fields.

3.2.1.3: Sampling Strategy: Select indicator taxa data was collected for two cropping seasons of paddy cultivated from August 2016 to January 2017 and September 2017 to March 2018 from both the sites. A minimum of five data samples in each paddy growth stage from each study site was aimed at to attain a minimum sampling size of 35 data samples (1/3rd of 100 days) from each study site in two cultivar seasons for each select indicator taxa.

3.2.1.4: Sampling of focal taxa: Data on birds were collected using strip transect method (Sutherland, 2000) of one km length and 100 m width between 6.00 am and 6.00 pm. The physical structures like electric poles, electric lines and other permanent structures that serve as perches for birds were also noted. Data on odonates was collected using strip transect method (Oertli, 2008). The data included species, number, activity and microhabitat observations within 1.524 m on the either side of transect between 9.00 am and 4.00 pm. The data on butterflies was collected using line transect method between 9.00 am- 12.00 pm and 2.00 - 4.00 pm in their high activity period (Kunte, 1997; as in Kunte *et al*, 1999). The data included species, number, activity and microhabitat observations within 1.524 m on the either side of transect.

Species were identified in field by observation as well as through photographic identification using standard field guides (Ali and Ripley, 1978; Grimmett *et al*, 1998; Subramanian, 2009; Kehimkar, 2008). Environmental and habitat variables such as field condition (wetland, dryland, wet) and weather conditions (cloudy, sunny, rainy, misty) were observed and noted during each sampling. The physico-chemical parameters such as water level, water temperature, pH and TDS (Total dissolved salts) were noted using a measuring scale and EUTECH- Multipurpose meter. This data was collected to compare the habitat variability between the two regimes and also to see their contribution towards influencing the indicator taxa community.

3.2.1.5: Vegetation sampling: The vegetation apart from paddy in the study area was also recorded. This included the trees on the bunds and also other vegetation on the bunds. The trees were counted and identified from the area covered by transect in each study site. The bund vegetation was recorded by using 1x1 m quadrat count method (Kindt and Coe, 2005) by laying 10 plots that were 100 m apart in each transect. Flora identification is based on Gamble and Fischer (1915-1936) and Henry *et al* (1987, 1989) and classified based on APG IV.

3.2.2: Methods of analysis

3.2.2.1: The select indicator taxa analysis: Data compiled, tabulated and subjected to basic descriptive statistics for studying the community characteristics using PAST 3.1(Hammer *et al*, 2001). To check the sufficiency of data Species Accumulation (Rarefaction) Curves (Colwell *et al*, 2004; Colwell *et al*, 2012; Chao *et al*, 2005) has been plotted using Estimate S 9 (Colwell, 2013). To explore the community variability and patterns based on community characteristics relative abundance has been used as a measure along with species richness. Graphs have been constructed using MS Excel 2007. Richness and diversity indices (Magurran, 1988; Morris *et al*, 2014) have been used as community parameters for testing relationship with environmental and habitat factors. The indices used are

i. Species Richness: The number of species as an indicator of diversity.

ii. Shannon Index: This is a measure of diversity which takes into consideration both the number of species and their abundance. Shannon index is calculated as

   $H = -\sum_I n_i/n \ln n_i/n$

iii. Dominance: Dominance has been calculated as $D = \sum_I (n_i/n)^2$ where n_i is the number of individuals of taxon i. The values of D range from 0 to 1. This index takes into account the abundance of each species in a community. If the D value is 0 it means the community has even distribution of all taxa and as the D value tends towards 1 it denotes the community is dominated by one or few species.

iv. Simpson's index : Simpson's index is a diversity/ evenness measure calculated as 1-D.

v. Evenness: Buzas and Gibson's evenness is calculated as $e^{H/S}$ where H is Shannon index, S is the total number of species.

Pair-wise ANOSIM (Analysis of Similarity) (Clarke and Green, 1988) with Bray-curtis similarity index was used to test the significance and understand the extent of variation in the community composition between the paddy growth stages and between the cultivation regimes (Anderson and Walsh, 2013; Muhil, 2017). The Bray Curtis index takes into account the presence and absence of species and their numbers while calculating. The R value of ANOSIM ranges between 0 and 1 indicating decrease in similarity between groups from 0 to 1 (Clarke and Warwick, 2001). To explore the species- wise contribution to dissimilarity, SIMPER (Similarity percentage) was used. All these analyses were performed with PAST 3.1 (Hammer *et al*, 2001).

Multiple stepwise regression using the community parameters as dependent variables and environment and habitat variables as independent variables was modelled to know the extent of influence of the environment and habitat variables on the diversity. This was performed using IBM SPSS Statistics version 20.

3.2.2.2: Vegetation Analysis: Important Value index and Diversity indices (Magurran, 1988) have been used in comparing bund vegetation. Past 3.1 (Hammer *et. al*., 2001) has been used to derive the diversity indices. Detailed methodology is given in chapter 4.

CHAPTER 4

PADDY FIELD – AS A HABITAT FOR SELECT FAUNAL TAXA

4.1 Introduction

Habitat is a decisive factor in the wildlife a region harbours (Tews *et al*, 2004). Paddy field, as a habitat, is dynamic and also influenced by man. The variables in this habitat like the crop, the water level maintained, the bund vegetation, trees, water channels, buildings, electric wires and towers and posts may influence the presence of species and the ways in which the paddy field ecosystem is used by them. Hence, the understanding of habitat as a background is important in understanding the biodiversity of a region. So, this chapter aims to analyse the characteristics of paddy field as a habitat to the select indicator taxa under consideration in this study.

4.2 Methodology

4.2.1 Field Methodology: The number of trees and the species in the transect area were recorded. The bund vegetation was recorded by using 1x1 m quadrat count method (Kindt and Coe, 2005). Ten plots were laid 100 m apart in each study site. Flora identification was based on Gamble and Fischer (1915-1936) and Henry *et al* (1987, 1989) and classified based on APG IV (phylogenetic classification of angiosperms approved by Kew Botanical Society, London). The variables of crop and field condition such as the height of crop, the growth cycle, water level in field and water parameters namely pH, Total Dissolved Salts (TDS) and Water Temperature were recorded using pH meter for each transect sampled during the study period.

4.2.2 Analytical Methodology: GIS Mapping techniques have been used to create maps of the study site demarcating the physical variables (ArcGIS, 2017; qGIS, 2018). The crop cycle, bund vegetation, water parameters have been described in tables and graphs made using MS excel. Important Value index and Diversity indices (Magurran, 1988) have been used in comparing bund vegetation. Past 3.1(Hammer *et. al*., 2001) has been used to derive the diversity indices. Important value Index has been calculated using the following methodology (Curtis and McIntosh, 1950; Curtis, 1959):

1. Using the 1x1m quadrat count data, Density, frequency and abundance of each flowering plant species were calculated using the formulae

Density (D) = Number of Individuals of a species/ Total Area

Frequency (F) = Number of quadrats Species Occurred/ Total number of quadrats

Abundance (A) = Number of individuals of a species in all quadrats/Number of quadrats occurred in

2. Relative Frequency, Relative Density and Relative Abundance were calculated using the formulae

Relative Density (RD) = (Density of a species/Total Density) x 100

Relative Frequency (RF) = (Frequency of a species/Total Frequency) x 100

Relative Abundance (RA) = (Abundance of a species/Total Abundance) x 100

3. Important Value Index (IVI) of a species was calculated using the formula

IVI = RA+RF+RD

4.3 Results

Ninety four replicate samples were taken along with the transect counts of select taxa for the environmental and habitat variables in the two study sites. Twenty quadrats were sampled to quantify bund vegetation.

4.3.1 Mapping: The maps (Figures 4.1 and 4.2) show the two transects and the sampling area covered in the study site. The transect in the organic cultivation regime (Site A) had 31 trees , three electric lines, five electric poles, one vegetation patch and one water channel running parallel to the transect area. The transect in the non-organic cultivation regime (Site B) had 31 trees, three electric lines, eight electric poles, two vegetation patches and five water channels cutting across the transect.

4.3.2 Crop and Field Management: The crop condition and field conditions show variations between both the cultivation regimes as below:

PS-1. Land preparation and sapling stage: During this stage, the organic fields were tilled along with the plants grown during the fallow period with water and then levelled with levellers for seed dispersion. Different varieties of paddy seeds are used here. In the same period the non-organic fields were filled with water and sapling beds created for seed dispersal (Plate 1).

Figure 4.1: Map of study area under organic regime (site A) with sampling area

Figure 4.2: Map of study area under Non-organic regime (site B) with sampling area

Table 4.1: The crop and field condition variability across the paddy cultivation phases

Paddy growth stages		PS-1	PS-2	PS-3	PS-4	PS-5	PS-6	PS-7
Crop Duration in days	Organic	15	20-22	40-42	5-8	21	11-13	-
	Non Organic	15	18-21	25-27	5-7	20	14-16	-
Crop height in feet	Organic	0.75	1	3	3.5- 5	5	5	No crop
	Non Organic	0.75	1	2.5	2.5- 3	3	3	No crop
Mean water level in cm	Organic	1.8± 1.2	1.4± 0.69	1.5± 0.81	1.7± 0.7	1.2± 0.44	0.8± 0.5	0
	Non Organic	0.9± 0.8	2.6± 1	1.1± 0.4	1.5± 0.3	1.3± 0.75	0.9± 0.4	0
Mean Water Temp in °C	Organic	30.8± 3.5	29.3± 2.9	29.3± 2.5	28.7± 2.9	25.7± 3.5	26.8± 3.7	NA
	Non Organic	30.2 ± 3.5	30.2± 2.1	28.4± 2.17	26.8± 0.7	25.2± 2.15	27.3± 2.4	NA
Mean Water pH	Organic	8.5± 0.7	8.3± 0.39	8± 0.4	8.5± 0.2	8.3± 0.14	8.3± 0.1	NA
	Non Organic	8.4± 0.3	8.6± 0.36	8.4± 0.34	8.4± 0.13	8.4± 0.27	8.2± 0.36	NA
Mean Water TDS in ppm	Organic	390± 203	495.16± 136	586.11± 139	469.11± 86.4	510.6± 62	526.66± 32.4	NA
	Non Organic	459.8± 222	455.55± 149	472.66± 40.6	433.16± 6.8	459.4± 35.3	543± 84	NA

PS-2. Transplantation Period: Transplantation is done using 15 day old single saplings with a distance of 50x25 cm in the organic fields. In the non-organic fields multiple saplings are transplanted together within 15 cms. Both the fields are wetlands (Plate 2).

PS-3. Growth phase: The crops tillered well in the organic fields as they grew between 3-5 feet in height, varying among the varieties. The crops in the non-organic fields grow up to 3 feet and did not tiller strongly when compared (Plate 3).

PS-4 Flowering and PS-5 Milking period: During this period the crop did not show many differences between the two regimes. In the organic cultivation regime the spacing between each plant is more visible than in the non-organic cultivation (Plate 4 and 5).

PS-6.Maturing: During the maturing phase the bent panicles went lower than the flag leaves in the organic fields for some tall varieties. Rest both the fields were similar (Plate 6).

PS-7. Harvest Period: Both the fields were harvested using machines and straw was heaped or rolled on the fields (Plate 7).

The variations of physical and physiochemical parameters of the field in sites A (organic) and B (Non-organic) are given in the table 4.1

4.3.3: Vegetation Profile

A total of 64 flowering plant species from 60 genera and 32 families were documented from the area covered by transect in site A and site B of which 48 species were herbs, 11 species were trees, four shrub species and one climber. Most speciose family was Poaceae (11 species) followed by Fabaceae (8 Species), Cyperaceae and Euphorbiaceae (5 species each) Seventeen species belonging to 15 genera and 11 families were Invasive Alien Species (Prakash and Balasubramanian, 2018; Reddy *et al*, 2008). Twenty six plant species belonging to 15 families and 26 genera were known nectar plants for butterflies. Thirty species belonging to 28 genera and 15 families were larval host plants for butterflies of which nine species were also invasive alien (Nithin *et al*, 2018). Five species were aquatic and 14 species belonging to nine families were semi-aquatic. Rest were terrestrial (Table 4.2).

Table 4.2: Checklist of plant species in the paddy fields of Kadhiramangalam; + indicates presence under organic and non-organic heads and positive quality for the rest of the heads. Habitat: A- Aquatic, T- Terrestrial, SA- Semi-aquatic

Sl. No.	Species	Habit	Organic	Non- Organic	Habitat	Invasive Alien Species	Butterflies	
							Larval host plant	Nectar plant
	Family Acanthaceae							
1	*Hygrophila schulli* (Buch.-Ham.)	Herb	+	+	A	-	+	yes
2	*Rungia repens* Nees.	Herb	+	-	T	-	+	yes
	Family Alismataceae							
3	*Sagittaria guyanensis* Kunth.	Herb	+	-	A	-	-	-
	Family Amaranthaceae							
4	*Gomphrena celosioides* Mart.	Herb	+	+	T	-	-	yes
	Family Apiaceae							
5	*Centella asiatica*	Herb	-	+	SA	-	-	-
	Family Araceae							
6	*Colocasia esculenta* (L.) Schott in Schott &Endl.	Herb	+	+	SA	-	-	-
	Family Arecaceae							
7	*Phoenix sylvestris* (L.) Roxb.	Tree	+	-	T	-	-	-
8	*Cocos nucifera*(L.)	Tree	+	+	T	-	+	yes
	Family Apocynaceae							
9	*Calotropis gigantea* (L.) R. Br.	Shrub	+	-	T	Tropical Africa	+	yes
	Family Asteraceae							
10	*Eclipta prostrata* (L.)	Herb	+	+	SA	Tropical America	-	yes
11	*Parthenium hysterophorus* L.	Herb	+	-	T	South America	-	yes

Sl. No.	Species	Habit	Organic	Non- Organic	Habitat	Invasive Alien Species	Butterflies	
							Larval host plant	Nectar plant
Family Boraginaceae								
12	*Heliotropium indicum* L.	Herb	+	+	T	-	+	yes
Family Cleomaceae								
13	*Cleome viscosa* L.	Herb	+	+	T	Tropical America	-	-
14	*Cleome felina*L.f	Herb	+	+	T	-	-	-
Family Commelinaceae								
15	*Commelina benghalensis* L.	Herb	+	+	SA	-	-	-
Family Convolvulaceae								
16	*Ipomoea aquatica* Forssk.	Herb	+	+	SA	-	-	-
Family Cucurbitaceae								
17	*Mukia maderaspatana* (L.) Roem.	Climb er	+	-	T	-	-	-
Family Cyperacae								
18	*Cyperus difformis* L.	Herb	+	+	T	Tropical America	+	-
19	*Fimbristylis quinquangularis* (Vahl) Kunth sp.	Herb	+	+	T	-	-	-
20	*Kyllinga brevifolia* Rottb.	Herb	+	-	T	-	-	-
21	*Cyperus compactus* Retz.	Herb	+	-	SA	-	-	-
22	*Fimbristylis dichotoma* (L.) Vahl	Herb	+	+	T	-	-	-
Family Euphorbiaceae								
23	*Phyllanthus reticulates* Poir. in Lam.	Herb	+	+	T	-	-	yes
24	*Jatropha gossypifolia* L.	Shrub	+	+	T	-	-	yes
25	*Acalypha indica* L.	Herb	+	+	T	-	-	yes
26	*Ricinus communis* L.	Shrub	+	-	T	-	+	yes
27	*Euphorbia hirta*	Herb	-	+	T	-	-	yes
Family Fabaceae								

Sl. No.	Species	Habit	Organic	Non- Organic	Habitat	Invasive Alien Species	Butterflies	
							Larval host plant	Nectar plant
28	*Cassia tora* (L.) Roxb.	Herb	+	-	T	Tropical America	+	yes
29	*Albizia saman* (Jacq.) F.Muell.	Tree	+	+	T	-	+	yes
30	*Crotalaria quinquefolia* L.	Herb	+	+	T	-	+	yes
31	*Dalbergia latifolia* Roxb.	Tree	+	+	T	-	+	-
32	*Indigofera linifolia* (L.f.) Retz. sp.	Herb	+	-	T	Tropical America	+	yes
33	*Indigofera linnaei* Ali.	Herb	-	+	T	Tropical Africa	-	-
34	*Peltophorum pterocarpum* (DC.) Backer ex Heyne	Tree	+	-	T	-	+	yes
35	*Pongamia pinnata*(L.) Pierre	Tree	+	+	T	-	+	yes
	Family Malvaceae							
36	*Sida rhomboidea*	Herb	-	+	T	-	-	yes
	Family Marsileceae							
37	*Marsilea quadrifolia* L.	Herb	+	+	A	-	-	-
	Family Meliaceae							
38	*Azadirachta indica*	Tree	-	+	T	-	-	yes
	Family Mimosiaceae							
39	*Mimosa pudica* L.	Herb	+	+	T	Brazil	+	yes
40	*Acacia nilotica* (L.) Willd. ex Del.	Tree	+	+	T	-	+	yes
	Family Moraceae							
41	*Ficus benghalensis* L.	Tree	+	-	T	-	+	-
	Family Nyctaginaceae							
42	*Boerhavia diffusa* L.	Herb	+	-	T	-	-	-
	Family Onagraceae							
43	*Ludwigia peruviana* (L.) H. Hara	Shrub	+	+	SA	-	-	-

Sl. No.	Species	Habit	Organic	Non- Organic	Habitat	Invasive Alien Species	Butterflies	
							Larval host plant	Nectar plant
Family Oxalidaceae								
44	*Oxalis corniculata* L.	Herb	+	+	T	Europe	+	yes
Family Phyllanthaceae								
45	*Phyllanthus amarus* Schum.	Herb	+	+	T	-	+	yes
Family Poaceae								
46	*Cynodon dactylon* (L.) Pers.	Herb	+	+	T	-	+	-
47	*Echinochloa colona* (L.) Link	Herb	+	+	SA	Tropical America	+	-
48	*Ischaemum muticum* L.	Herb	+	+	T	-	+	-
49	*Leersia hexandra* Sw.sp.	Herb	+	+	T	-	-	-
50	*Leptochloa fusca* (L.) Kunth	Herb	+	-	SA	-	-	-
51	*Panicum repens* L.	Herb	+	+	SA	-	+	-
52	*Saccharum spontaneum* L.	Herb	+	-	SA	Tropical W. Asia	+	-
53	*Sacciolepis indica* (L.) A. Chase	Herb	+	-	SA	-	-	-
54	*Stenotaphrum dimidiatum* (L.) Brongn. In Duperr.	Herb	+	+	T	-	-	-
55	*Chloris barbata*	Herb	-	+	T	Tropical America	-	-
56	*Oryza sativa*	Herb	-	+	SA	-	+	-
Family Pontederiaceae								
57	*Monochoria vaginalis* (Burm. f.) Presl	Herb	+	-	A	Tropical America	-	-
58	*Eichhornia crassipes* (Mart.) Solms.	Herb	+	-	A	Tropical America	-	-
Family Rubiaceae								
59	*Morinda citrifolia* L.	Tree	+	+	T	-	-	-

Sl. No.	Species	Habit	Organic	Non- Organic	Habitat	Invasive Alien Species	Butterflies	
							Larval host plant	Nectar plant
Family Scrophulariaceae								
60	*Stemodia verticillata* (Mill.) Sprague	Herb	+	+	T	-	-	-
61	*Lindernia antipoda* (L.) Alston in Trimen	Herb	-	+	T	-	+	yes
Family Typhaceae								
62	*Typha angustifolia* L.	Herb	+	-	SA	Tropical America	-	-
Family Lamiaceae								
63	*Tectona grandis* L.	Tree	+	+	T	-	-	yes
Family Zygophyllaceae								
64	*Tribulus terrestris*	Herb	+	-	T	Tropical America	+	yes

4.3.4 Bund Vegetation

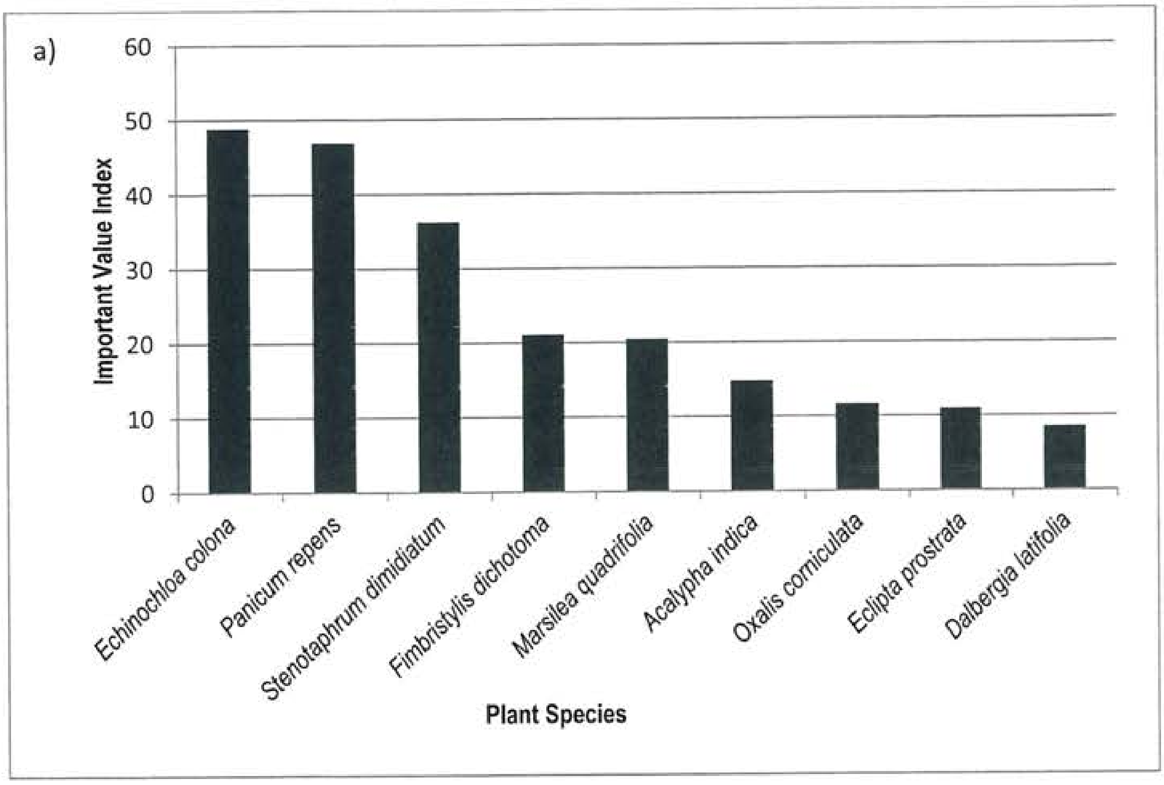
The plant species and abundance data from 10 quadrats laid on the bunds in each site were analysed to find the dominant plant species on the bunds (Figure 4.3) and also measure the bund vegetation diversity (Table 4.3). A total of 1207 individuals belonging to 39 species, 37 genera and 24 families were recorded from 20 quadrats. Of these 39 species, three species were trees, two shrub species, one climber and 33 species were herbs. Nine species were semi-aquatic, four species were aquatic and 26 species were terrestrial.

From the 10 plot counts carried out on the bunds of organic cultivation regime (site A), 535 individuals belonging to 26 species, 25 genera and 20 families were recorded. Five of these 26 species were invasive alien species namely *Tribulus terrestris, Eichornia crassipes, Echinochloa colona, Oxalis corniculata* and *Eclipta prostrata*; three species were aquatic (*Sagittaria guyanensis, Marselia quadrifolia, Eichornia crassipes*), six species were semi-aquatic (*Colocasia esculenta, Eclipta prostrata, Commelina* *benghalensis, Echinochloa colona, Leptochloa fusca, Panicum repens*) and 17 terrestrial species. Out of the 26 species three were nectar plants for butterflies namely *Eclipta prostrata, Acalypha indica, Azadirachta indica*; five were larval food plants for butterflies namely *Panicum repens, Echinochloa colona, Cynodon dactylon, Phyllanthus amarus, Dalbergia latefolia* and four species were larval food and nectar plants for butterflies namely *Calotropis gigantea, Crotalaria quinquefolia, Oxalis corniculata* and *Tribulas terrestris*.

From the 10 plot counts carried out on the bunds of non-organic cultivation regime (site B), 672 individuals belonging to 23 species from 23 genera and 13 families were recorded. Six of these 23 species were invasive alien species namely *Cleome viscosa, Cyperus difformis, Mimosa pudica, Chloris barbata, Echinochloa colona* and *Eclipta prostrata*; one aquatic species (*Hygrophylla schulli*), seven species were semi-aquatic (*Eclipta prostrata, Commelina benghalensis, Echichloa colona, Panicum repens, Centella asiatica, Ipomea aquatica and Oryza sativa*) and 15 terrestrial species. Four of the 23 species were nectar plants for butterflies namely *Eclipta prostrata, Euphorbia hirta, Jatropha gossypifolia, Azadirachta indica*; Six species were larval food plants for butterflies namely *Panicum repens, Echinochloa colona, Cynodon dactylon, Phyllanthus amarus, Cyperus difformis, Oryza sativa* and four species namely *Lindernia antipoda, Mimosa pudica, Sida rhomboidea* and *Hygrophila schulli* were larval food and nectar plants for butterflies.

According to Important Value Index, the dominant species in site A (organic) is *Echinocloa colona* (IVI 48.79) which is closely followed by *Panicum repens* (IVI 46.87). But in site B (non-organic) *Echinochloa colona* (IVI 78.57) is the most dominant species followed by *Centella asiatica* (IVI 21.76) with a huge gap in IVI (Figure 4.3).

When comparing the diversity indices (Table 4.3), the paddy fields under organic regime appear to be more diverse with more species, higher evenness, lower dominance and higher values for Shannon Index and fisher alpha diversity.



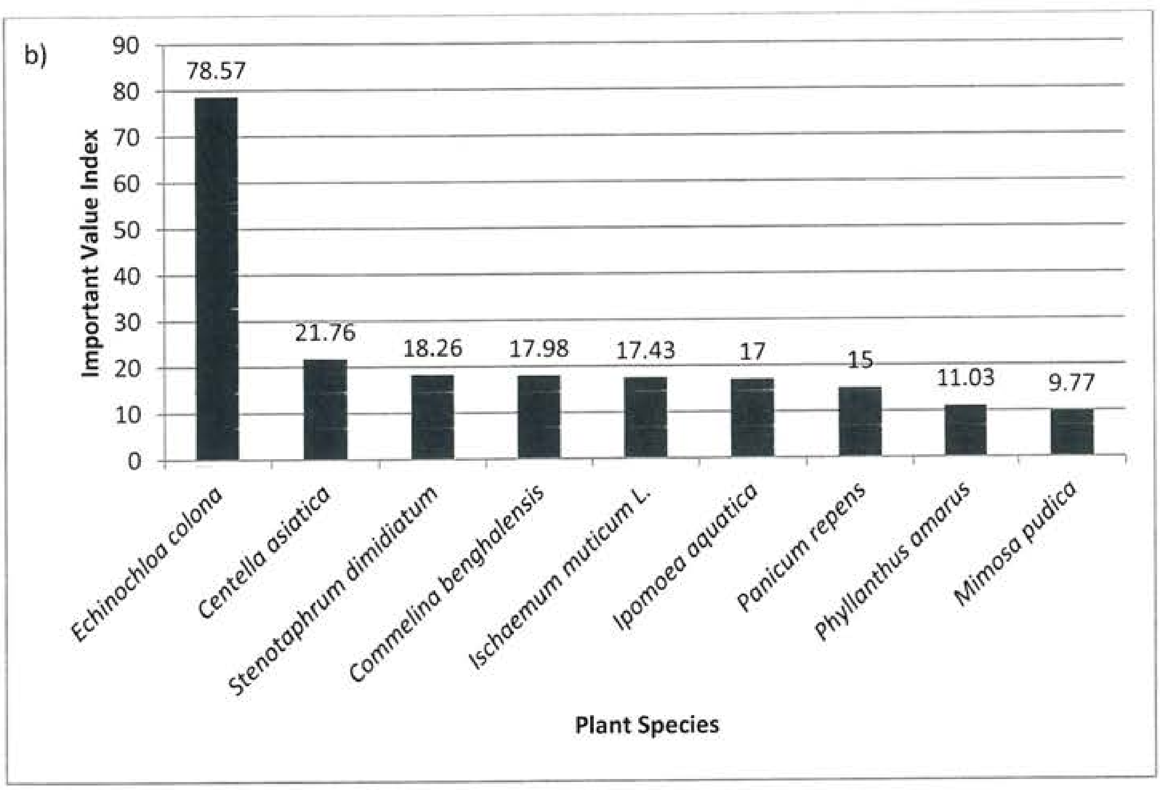


Figure 4.3: Ten most dominant plant species of the bund vegetation in a) Organic site b) Non-organic site

Table 4.3: Diversity measures of bund vegetation in paddy fields of Kadhiramangalam

Plant diversity	Total	Organic	Non-Organic
Species Richness	39	26	23
Individuals	1207	535	672
Dominance_D	0.1677	0.1552	0.2371
Simpson_1-D	0.8323	0.8448	0.7629
Shannon_H	2.476	2.29	2.068
Evenness_e^H/S	0.305	0.38	0.3437
Fisher_alpha	7.707	5.714	4.61

Table 4.4: Important Value Index of bund vegetation in paddy fields of Kadhiramangalam

Family	Plant Species	Important Value Index	
		Organic	Non-organic
Acanthaceae	*Hygrophila schulli*	-	3.1178
Alismataceae	*Sagittaria guyanensis*	4.7339	-
Apiaceae	*Centella asiatica*	-	21.7672
Araceae	*Colocasia esculenta*	7.2456	-
Asclepidaceae	*Calotropis gigantea*	3.478	-
Asteraceae	*Eclipta prostrata*	10.9632	3.1178
Capparaceae	*Cleome felina*	3.478	-
Capparaceae	*Cleome viscosa*	-	3.1178
Commelinaceae	*Commelina benghalensis*	6.8889	17.9895
Convolvulaceae	*Ipomoea aquatica*	-	17.0008
Cucurbitaceae	*Mukia maderaspatana*	3.478	-
Cyperacae	*Cyperus difformis*	-	6.016
Cyperaceae	*Fimbristylisdichotoma*	21.0601	-

Family	Plant Species	Important Value Index	
		Organic	Non-organic
Cyperaceae	*Fimbristylisquinquangularis*	3.478	7.9269
Cyperaceae	*Kyllingabrevifolia*	8.1112	-
Euphorbiacea	*Acalypha indica*	14.7808	-
Euphorbiaceae	*Jatropha gossypifolia*	-	3.1178
Euphorbiaceae	*Euphorbia hirta*	-	7.1141
Fabaceae	*Crotalaria quinquefolia*	4.106	-
Fabaceae	*Dalbergia latifolia*	8.5015	-
Malvaceae	*Sida rhomboidea*	-	4.7937
Marsileceae	*Marsilea quadrifolia*	20.4784	-
Meliaceae	*Azadirachta indica*	7.70382	4.4499
Mimosiaceae	*Mimosa pudica*	-	9.7783
Nyctaginaceae	*Boerhavia diffusa*	2.8501	-
Oxalidaceae	*Oxalis corniculata*	11.6411	-
Phyllanthaceae	*Phyllanthus amarus*	6.4815	11.0365
Poaceae	*Cynodon dactylon*	3.478	3.1178
Poaceae	*Echinochloa colona*	48.7946	78.5745
Poaceae	*Leptochloa fusca*	5.9898	-
Poaceae	*Panicum repens*	46.8765	15.1067
Poaceae	*Stenotaphrum dimidiatum*	36.2234	18.2676
Poaceae	*Chloris barbata*	-	8.4605
Poaceae	*Ischaemum muticum L.*	-	17.4332
Poaceae	*Oryza sativa*	-	31.1272
Pontederiaceae	*Eichhornia crassipes*	3.478	-
Rubiaceae	*Morinda citrifolia*	2.8501	3.1178
Scrophulariaceae	*Lindernia antipoda*	-	4.4499
Zygophyllaceae	*Tribulus terrestris*	2.8501	-

4.4 Discussion

Paddy fields are known to follow a succession cycle from wetland, wet and dry conditions (Bambaradeniya *et al*, 1998). Along with this, the changes in crop density gives scope for variations in the community of select indicator taxa based on species specific preferences as the paddy growth progresses. The vegetation in the field, bund and nullahs will also provide different niches. Earlier studies across the world project the vegetation apart from paddy in fields as weeds (Chandrasena, 1989; Dangwal *et al*, 2012; Bhatt *et al*, 2009; Nithya and Ramamoorthy, 2015; Sharma *et al*, 2017; Golmohammadi *et al*, 2018; Singh and Singh, 2019). But many of these weeds have medicinal, food and fodder values locally although categorised as weeds (Gaekwad, 2013; Dhanam and Elayaraj, 2014; Parameswaran and Anil, 2017). The organic field has higher species richness, Shannon, Simpson, Evenness and Fisher-alpha values and also expresses lower dominance (Table 4.3). This may also be reflected in complete dominance by *Echinocloa colona* based on the IVI in non-organic fields, a known semi-aquatic alien invasive grass. Whereas in the organic field *Panicum repens* also has a nearly even IVI with *E. Colona* species. *Panicum repens* is an indigenous semi-aquatic grass species (Figure 4.3). *E. Colona* is also a larval host plant for butterflies such as bush browns whereas *P. repens* is larval host plant for evening browns and palm dart species (Nithin *et al*, 2018). *Oryza sativa* is also a major host plant for Bush browns. The organic fields support more aquatic plant species of which *Marselia quadrifolia* is also part of the top ten species with an IVI of 20.47 (Figure 4.3 a). The single aquatic species recorded (*Hygrophila schulli*) from non-organic fields has a very low IVI of 3.11 (Table 4.4). The organic system, on the whole, has a higher diversity of plants when compared with non-organic field (Gabriel *et al*, 2006; Kleijn *et al*, 2006; Belfrage *et al*, 2005; Rundolf *et al*, 2010).It also supports more aquatic species.

As a habitat for Birds

From the mapping of the study sites the availability of perch sites for birds in the form of electric lines, poles, bund trees which were utilised by different species in various ways (Subramanya, 1987) were seen. For example, aggregation of Munias, Weavers and Swallows on the electric lines (Plate 8), Kites using poles and bund trees as perches for foraging (Plates 9 and 10), Kingfishers and Drongos using pipes, electric lines, bund plants for sighting prey (Plate 9), Asian Openbills, Owlets and Egrets using the bund trees as roosting sites (Plate 11) etc. were recorded.

The fields were extensively used for foraging by most of the bird species seen here. Certain species like Munias and Warblers flourish as the paddy crop becomes denser providing more cover. Crepuscular species like Moorhens and Waterhens also use the habitat to full advantage.

Some species like Cisticolas and Prinias nest among paddy blades whereas species like Weaver, Babbler and Avadavats nest in bund vegetation. Weavers and Avadavats were also seen collecting nesting materials from field. Crows and Kites were observed to use higher structures like trees and electric poles to nest (Plate 12).

As a habitat for Odonates

Apart from the wet fields, the water in nullahs also provide viable habitats for odonates. The pH and water temperature (Muhil, 2017) are known to influence the odonates species assemblage along with the vegetation cover and water availability that varies across the paddy growth stages. These variations result in many possibilities of odonate assemblages in the paddy fields across the paddy growth stages. The odonates are well known predators of insects (Crumrine *et al*, 2008). For example *Orthretrum sabina* is a very good hunter with lots of records of feeding. Also some less common species in paddy fields like *Ischnura senegalensis* preying on very common species like *Ischnura rubilio* (Plate 14). Odonates are known to lay eggs in paddy fields during the wetland conditions (Ueda, 1998) (Plate 13).

As a habitat for Butterflies

The bund vegetation and other plants in the field along with paddy act as larval host plants and nectar plants for butterflies (Nithin *et al*, 2018; Nimbalkar *et al*, 2011) attracting various species to the habitat. Species like bush hoppers and bush browns were seen mating among the paddy. Evening browns and bush browns were also seen mud puddling in the wet fields (Plate 15). So, paddy fields are a source of food, minerals and host plants for many butterfly species.

CHAPTER 5

BIRD COMMUNITY OF PADDY FIELDS IN KADHIRAMANGALAM

5.1 Introduction

Many studies on the bird use of paddy fields with focus on wetland species have been undertaken in the last two decades worldwide (Elphick *et al*, 2010; Sicemore and Maine, 2012; Nam *et al*, 2015; Marco-Mendez *et al*, 2015).

Paddy cultivation is known to support 351 bird species (Gopisundar and Subramanya 2010) throughout India. The bird species using the paddy fields were seen to vary regionally. As such, the bimodality in the activity pattern of birds in paddy fields during a day are known (Sridhara *et al*, 1983). Paliwal and Bhandarkar (2014) have documented 22 bird species and the temporal variations in their abundance in paddy fields but do not shed light on the community. Paddy field is a dynamic habitat and it goes through different structural changes in a single crop cycle. The habitat variations also lead to changes in resource availability for birds (Bambaradeniya *et al*, 2004). This would have an impact on the bird community composition and its changes over time. This chapter addresses two objectives of the study for bird community with the following null hypotheses

1. There are no differences in the bird assemblages of the seven paddy growth stages.
2. There are no differences in the bird assemblages of organic and non-organic paddy cultivation regimes.

5.2 Results

Data was collected in 94 transect counts during the study period. Eighty Seven species of birds were recorded in 19622 encounters. The species accumulation/ rarefaction curve plotted (Figure 5.1) reached asymptote. The chao 2 mean predicted slightly higher number of species than the actual data. But the sampling done was area restricted, hence the sample was adequate.

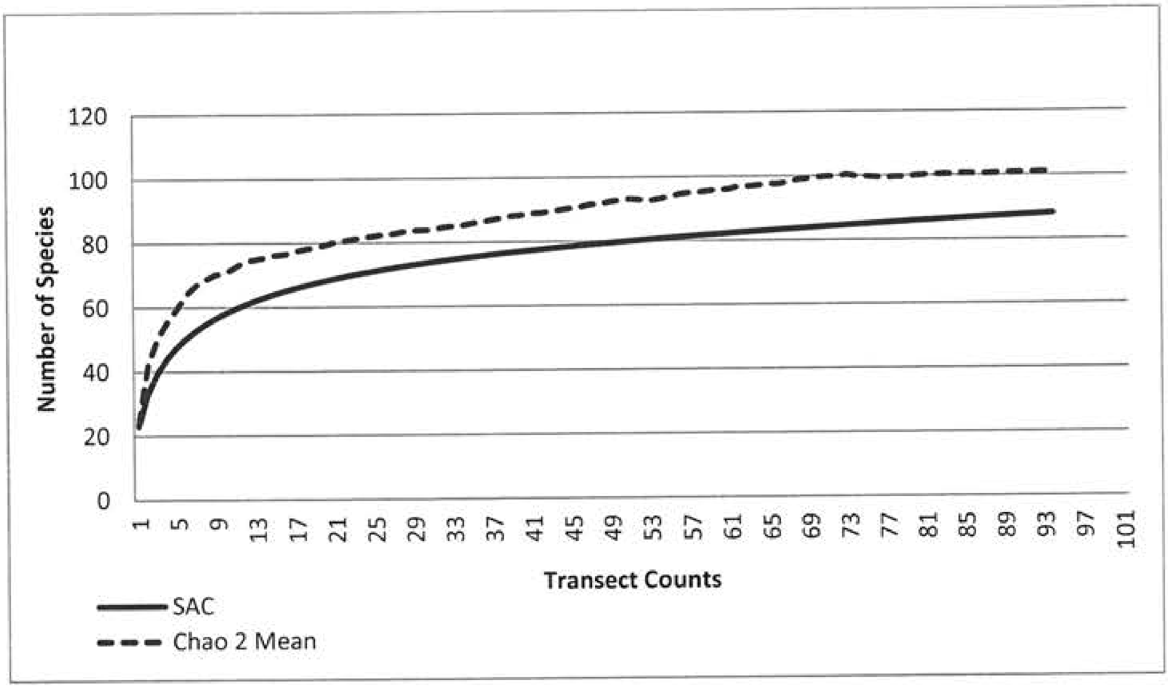


Figure 5.1: Species Accumulation Curve of Birds

To achieve the objectives the results are explained as answers for four research questions which are

1. What is the species composition and population distribution of bird community in paddy fields
2. How do the bird community parameters correlate with the water level and water quality?
3. How do the bird community parameters correlate with the different stages of crop growth?
4. Does the bird community vary between the two cultivation regimes? If so what are the influencing factors?

5.2.1 The bird community composition

5.2.1.1 Species composition and Population distribution

Eighty seven bird species belonging to 13 orders and 41 families were recorded from the study area (Appendix 1) (Figure 5.2 a and b). Overall data showed that the Passerines were the most abundant birds, both, in terms of species and population abundance. All the species recorded were in the least concern category of IUCN threatened criteria except Black-headed Ibis (*Threskiornis melanocephala*) and Red-necked Falcon (*Falco chicquera*), that were in the near threatened category.

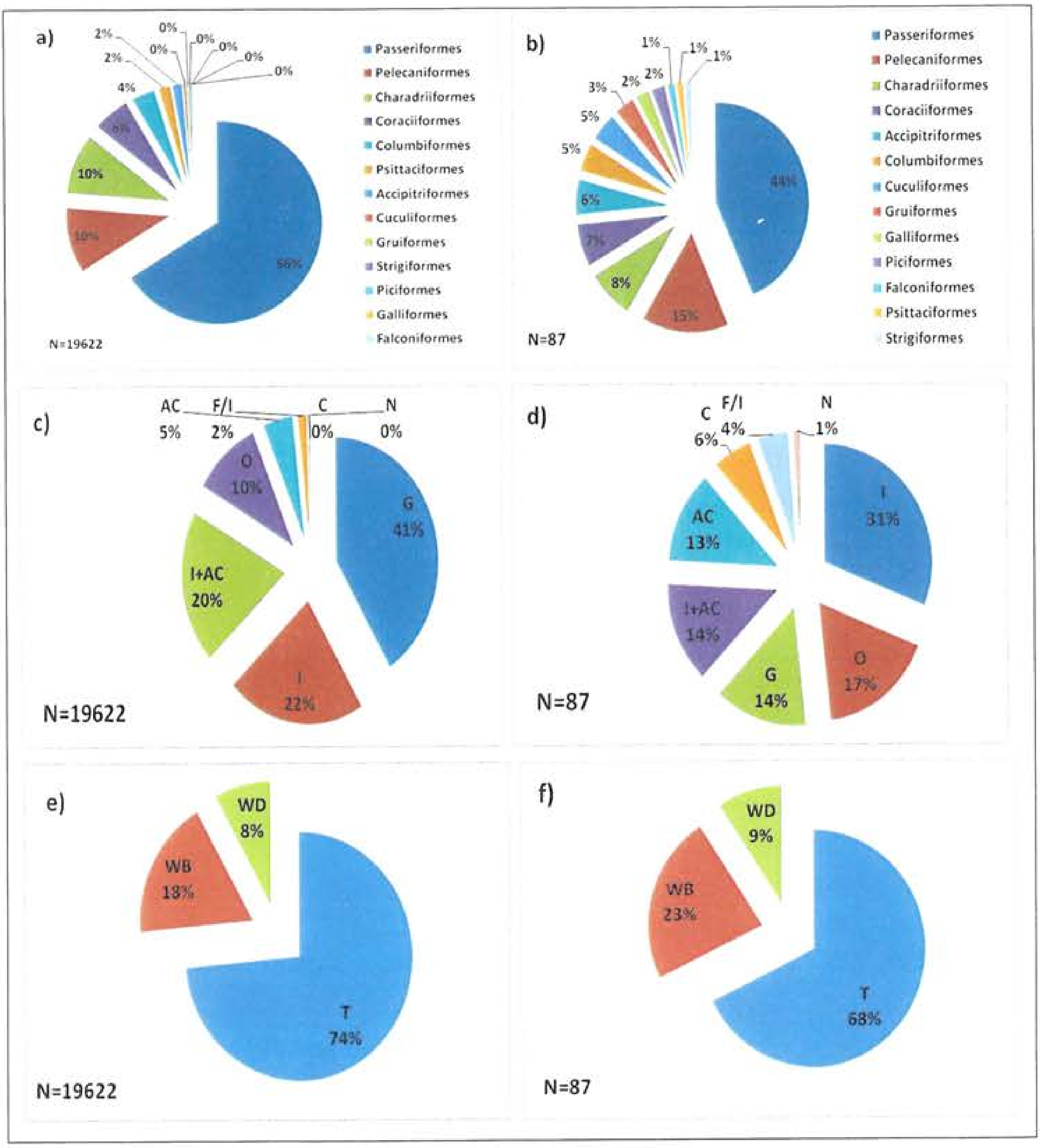


Figure 5.2: Bird community population distribution in paddy fields based on a) Order c) guild e) habitat preferences and bird species composition in paddy fields based on b) order d) guild f) Habitat preferences. AC- Aquatic Carnivore; C- Carnivore; F- Frugivore; G- Granivore; I-Insectivore; N- Nectarivore; O-Omnivore. Habitat Dependency: WB- Waterbird; WD – Wetland Dependent; T- Terrestrial.

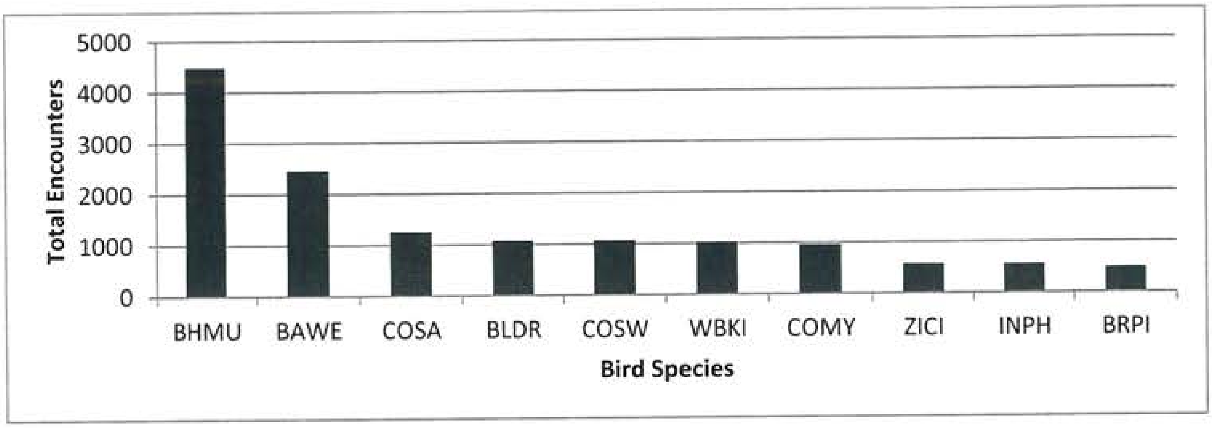


Figure 5.3: Most abundant bird species in the paddy fields of Kadhiramangalam

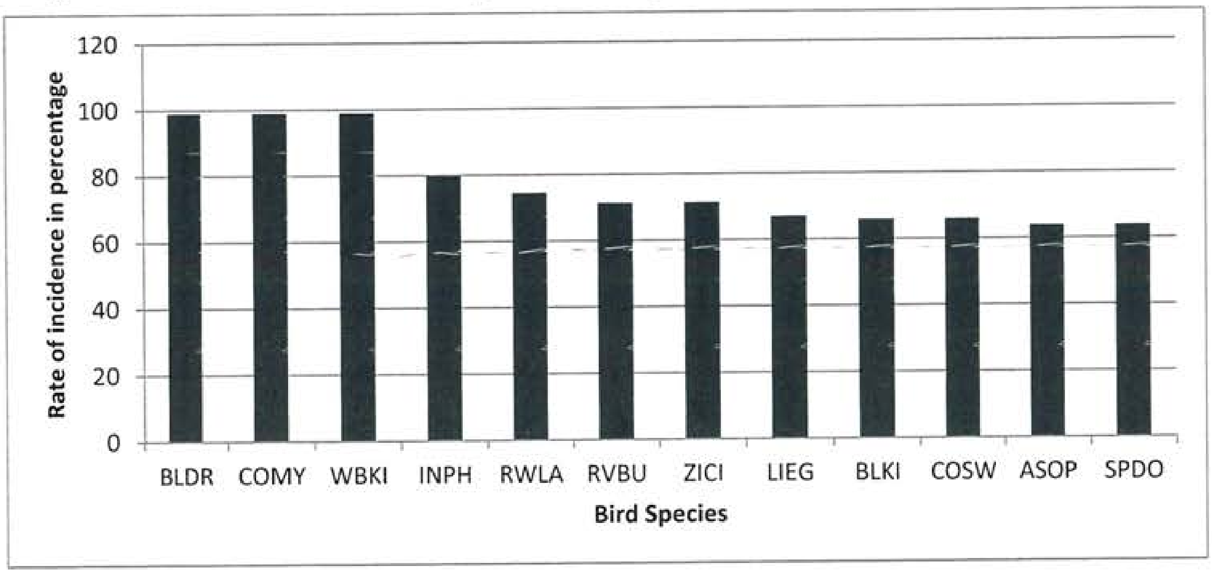


Figure 5.4: Most common birds in the paddy fields of Kadhiramangalam

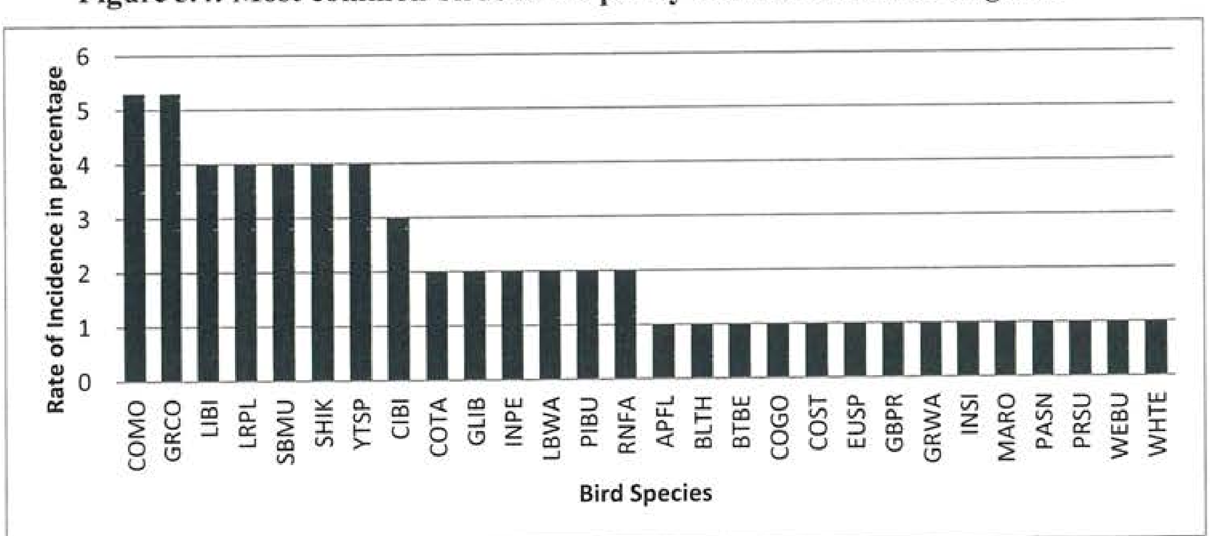


Figure 5.5: Rare bird species in the paddy fields of Kadhiramangalam

Of the top 10 most abundant bird species (Figure 5.3) seen in the paddy fields, six species, *i.e.* Black Drongo, Common Swallow, White-breasted Kingfisher, Common Myna, Zitting Cisticola and Indian Pond Heron, were also the most common species (Figure 5.4). The species code used are given in appendix 2.

5.2.1.2 Guild Structure

The birds were categorised into eight broad feeding guilds (Figure 5.2 c and d) *viz.* Insectivores, granivores, Frugivores+Insectivores, Carnivores, Omnivores, Aquatic Carnivores, Nectarivore and Insectivores + Aquatic Carnivores (Ali and Ripley, 1978). Guilds were assigned based on the data available in literature on feeding and foraging habits of adult bird species in the Indian subcontinent, such as Ali and Ripley's observation. Any bird species, be it granivore or frugivore, feed their chicks with insects during breeding season. Hence only the adult's habits have been considered here. Considering the species richness as the factor, insectivore guild dominates (32%) as in any terrestrial habitat. However, dominance of the gregarious granivorous birds is evident in the abundance pattern showing the 41 percent of total abundance.

5.2.1.3 Habitat Preferences

The 87 bird species recorded from the study were classified into three categories [*viz.* Waterbirds (wetland birds), wetland - dependent birds and terrestrial birds] and analysed.

Of these, 28 bird species (Relative abundance - 20 %) were wetland associated belonging to seven orders and 13 families. Twenty of these 28 bird species were waterbirds belonging to three orders *viz.* Charadriiformes – 6 species (5 families), Gruiiformes- 2 species (1 family), Pelecaniformes- 12 species (4 families). Eight species were wetland dependent belonging to six orders *viz.* Charadriiformes – 1 species (1 family), Pelecaniformes – 1 species (1 family), Coraciiformes – 3 species (1 family), Accipitricformes – 1 species (1 family), Gruiformes- 1 species (1 family). The rest were terrestrial (Figure 5.2 e and f).

Twenty two species were migrants (25.2%) of which 12 species (54.5%) were wetland dependent. Nineteen species were partial migrants (21.8%) of which 10 species (52.6%) were wetland dependent.

5.2.2 The water quantity and quality and bird community parameters

The bird diversity data was condensed into five community parameters *viz.* Species Richness, abundance, Simpson's index, Shannon index and Evenness for 94 transects. The corresponding water parameters *viz.* water level, water temperature, water pH and Total Dissolved Salts (TDS) in water were tested for correlation to understand the relationships between these parameters. The Shannon index shows a slightly negative correlation with water pH and Evenness shows a slightly negative correlation with water pH and total dissolved salts in water. The rest of the parameters are not significantly correlated (Table 5.1).

Table 5.1: Correlation between bird community parameters and water parameters

The significant Pearson's Correlation value ($p \leq 0.05$) is given in bold.

Pearson correlation	Species Richness	Simpson_1-D	Shannon_H	Evenness_e^H/S
Water Temp in ° C	-0.1129	-0.10614	-0.15787	-0.12954
Water pH	-0.035444	-0.16811	**-0.20355**	**-0.19644**
Total Dissolved Salts in water	0.14569	-0.13588	-0.12981	**-0.19937**
Water level	-0.12938	0.01678	-0.05846	-0.06613

5.2.3: The variability in bird community across paddy growth stages

The basic species and population demographics of the data across the paddy growth stages were compiled and summarized (Table 5.2 and 5.3). The maximum variance and standard deviation in population was observed in PS-5.

Diversity and Species Richness indices (Table 5.4) showed that PS-3 (Growth stage) was the most diverse with 60 species although PS-4 (flowering stage) had highest species richness and PS-2 (Transplanted paddy stage) seemed to be the most even. The observed values showed higher species richness than PS-3 in PS-6. But the effort required to document two more species was comparatively high (abundance). Hence, PS-3 was considered more diverse. Even the derived indices like Shannnon, Evenness, and Dominance values indicate PS-3 was more diverse than PS-6. These indices also showed that PS-5 (Milking stage) was the least diverse stage with low evenness and high dominance.

The null hypothesis, 'There are no differences in the bird communities of paddy growth stages', was rejected by ANOSIM. The R value of ANOSIM being significant (at 95% confidence), confirmed that there was a significant difference in the bird community composition between the seven paddy growth stages (Table 5.5). The average dissimilarity among the seven phases was 71.41% (SIMPER). The R values between two consecutive stages were significant except PS-5 and PS-6 ranging from 0.16 to 0.21. Between two non-consecutive stages the values range from 0.21 to 0.71.

Ninety percent of this change was accounted by 29 species of the total 87 bird species recorded (Appendix 1). The major contributors were, *Lonchura malacca* (19.67%) followed by *Ploceus phillipinus* (11.16%), *Actitis hypoleucos* (8.06 %), *Hirundo rustica* (6.554%), *Acridotheres tristis* (3.86%) and *Dicrurus macrocercus* (3.499%) (Figure 5.6 a and b) contributing to over 50 % of the variations seen.

Table 5.2: Bird community species demographics across paddy growth stages

Paddy Growth Phases	Species Richness	Number of transects	Abundance	Mean species/ transect	Standard Deviation	Co-efficient of variance in %age	Min. Species/ transect	Max. Species/ transect
PS-1	53	14	2106	19.71	±3.47	17.61	12	27
PS-2	55	16	2536	21.13	±2.7	12.8	15	27
PS-3	60	15	2097	21.86	±4.03	18.44	16	31
PS-4	65	15	3591	25.33	±3.59	14.21	19	32
PS-5	58	10	4296	24.8	±4.75	19.18	18	33
PS-6	62	14	3871	25	±3.78	15.14	20	32
PS-7	54	10	1125	21	±6.43	30.61	9	31

Table 5.3: Bird community population demographics across paddy growth stages

Paddy Growth Phases	Species Richness	Number of transects	Abundance	Mean encounters/ transect	Standard Deviation	Co-efficient of variance in %age	Min. Encounters/ transect	Max. Encounters/ transect
PS-1	53	14	2106	150.42	± 68.14	45.2	71	304
PS-2	55	16	2536	158.5	± 48.44	30.5	97	264
PS-3	60	15	2097	139.8	± 54.33	38.86	88	246
PS-4	65	15	3591	239.4	± 149.79	62.56	111	659
PS-5	58	10	4296	429.6	± 308.37	71.78	105	1065
PS-6	62	14	3871	276.5	± 179.91	65.06	75	784
PS-7	54	10	1125	112.5	± 63.07	56.62	32	216

Table 5.4: Community parameters of birds across paddy growth stages. The values indicating highest diversity are in bold and least diversity are underlined * is the most diverse

	PS-1	PS-2	PS-3*	PS-4	PS-5	PS-6	PS-7	Total
Species Richness	<u>53</u>	55	60	**65**	58	62	54	87
Individuals	2106	2536	2097	3591	**4296**	3871	<u>1125</u>	19622
Dominance_D	0.0915	0.0720	0.0606	0.1294	<u>0.2419</u>	0.1943	**0.0601**	0.0884
Simpson_1-D	0.9085	0.9279	0.9393	0.8706	<u>0.7581</u>	0.8057	**0.9399**	0.9116
Shannon_H	2.885	3.039	3.181	2.7	<u>2.065</u>	2.514	**3.234**	3.073
Evenness_e^H/S	0.3379	0.3796	0.4011	0.2289	<u>0.136</u>	0.1992	**0.4702**	0.2483

Table 5.5: Analysis of Similarity using Bray-Curtis index between pairs of paddy growth stages. Permutation N = 9999, R= 0.3357, p= 0.0001. p value is less than 0.05 between all pairs in bold.

R values	PS1	PS2	PS3	PS4	PS5	PS-6
PS2	**0.1787**					
PS3	**0.2151**	**0.1635**				
PS4	**0.2768**	**0.3761**	**0.2107**			
PS5	**0.5038**	**0.6299**	**0.5546**	**0.1823**		
PS6	**0.4555**	**0.6366**	**0.4452**	0.0877	0.1128	
PS-7	**0.3778**	**0.7102**	**0.5029**	**0.2252**	**0.3781**	**0.1641**

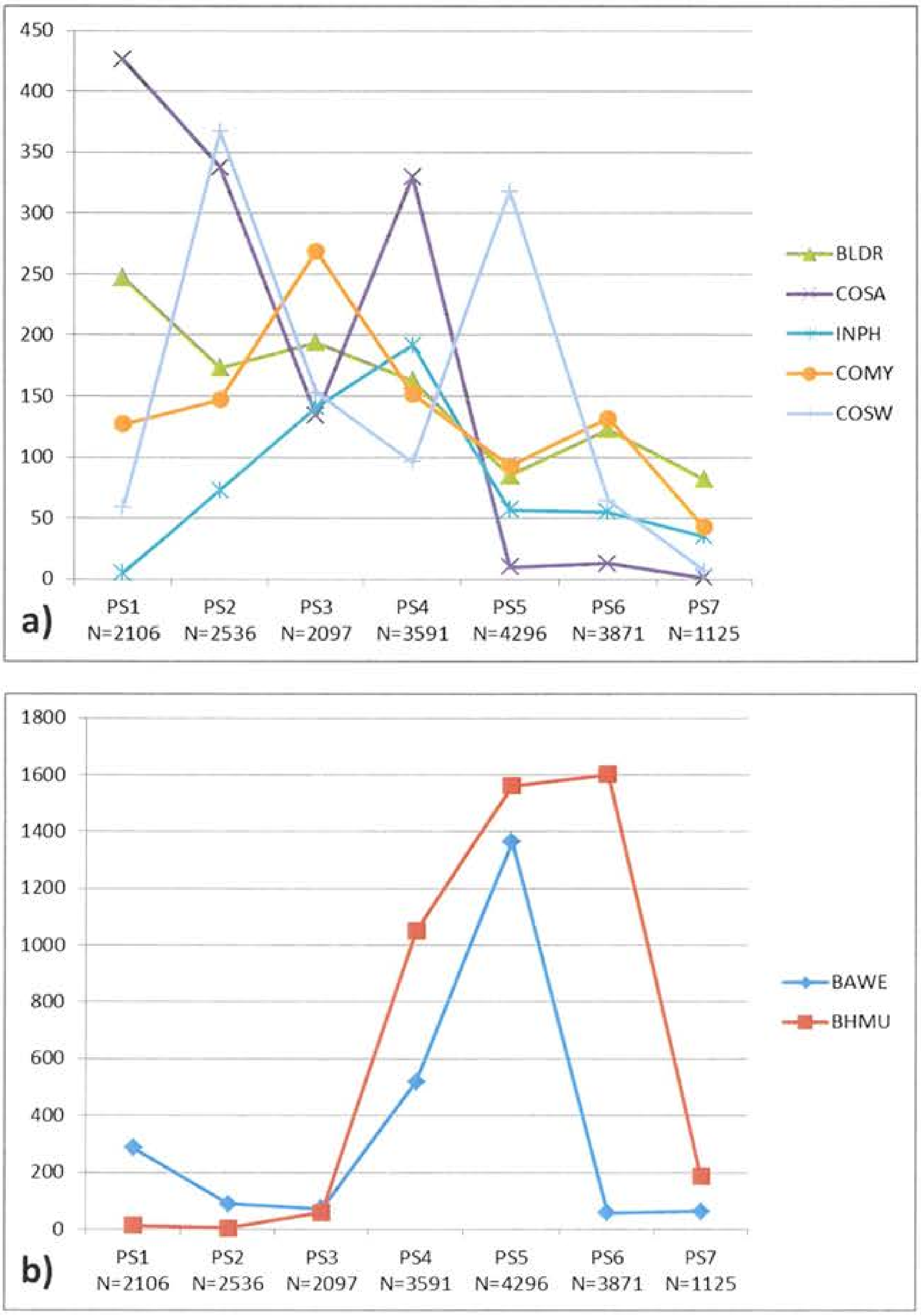


Figure 5.6: Variation of top contributors to change across paddy cultivation phases. a) COSA- Sandpiper spp.; COSW - Barn Swallow; COMY - Common Myna; BLDR - Black Drongo; INPH - Indian Pond Heron. b) BAWE – Baya Weaver; BHMU – Black-headed Munia

5.2.3.1 Relative Abundance patterns in taxonomic, guild and habitat association composition of birds across paddy growth stages

As per the orders, a steady decline in number of birds belonging to the orders Charadriiformes, Pelecaniformes and Coraciiformes was observed across the paddy growth stages. Similarly, an increase and steep decline of the birds belonging to Accipitriformes and Falconiformes were also observed with time. A steep increase in Passerines and Psittaciforms after PS-4 was seen. Strigiforms increased after PS-3. The Galliforms and Gruiforms remained steady across the stages (Figure 5.7).

The relative abundance of guilds across the paddy growth phases showed four times increase in granivores from PS-3 to PS-4 (Figure 5.8). More than 50% omnivores declined from PS-3 to PS-4. Carnivores also declined from PS-2 onwards. The frugivores were negligible in paddy field ecosystem. The insectivores and aquatic carnivores + insectivores were observed to increase in PS-3, decrease in PS-4 and 5 (40% decrease) and again increase in PS-6 probably an artefact of this miscellaneous classification.

Bird community of paddy fields were analysed as per their known habitat association. More than 80% decrease in waterbirds and wetland dependent species from PS-2 to PS-6 with a 50% drop between PS-3 and PS-4 was observed in the relative abundance trends across the paddy growth stages (Appendix 3).

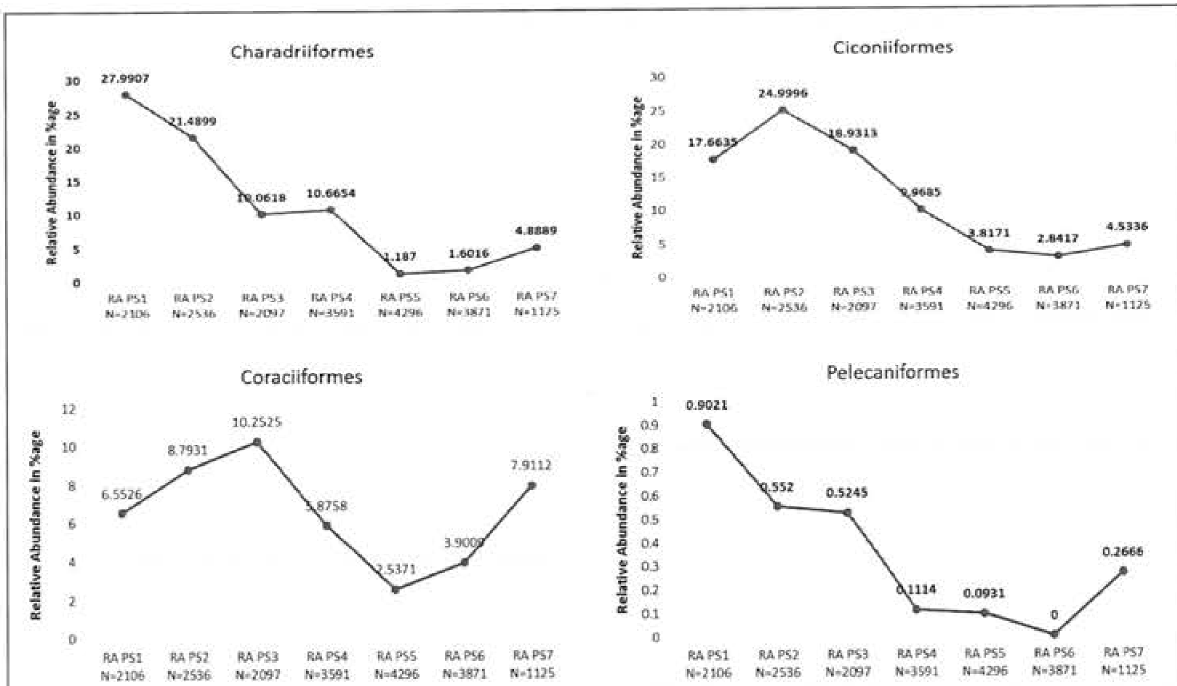


Figure 5.7: Relative abundance trends of bird orders across paddy growth stages

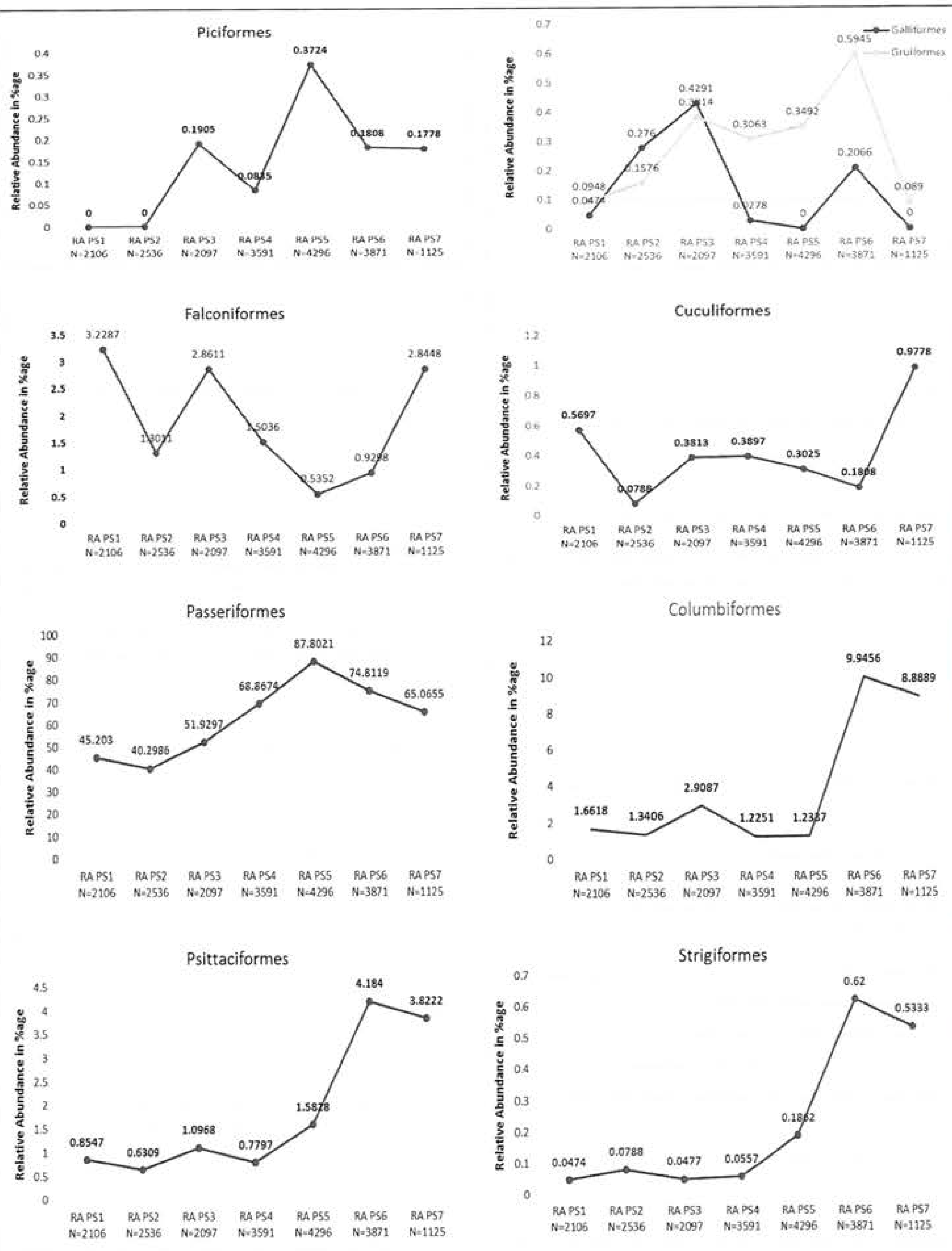


Figure 5.7: Relative abundance trends of bird orders across paddy growth stages

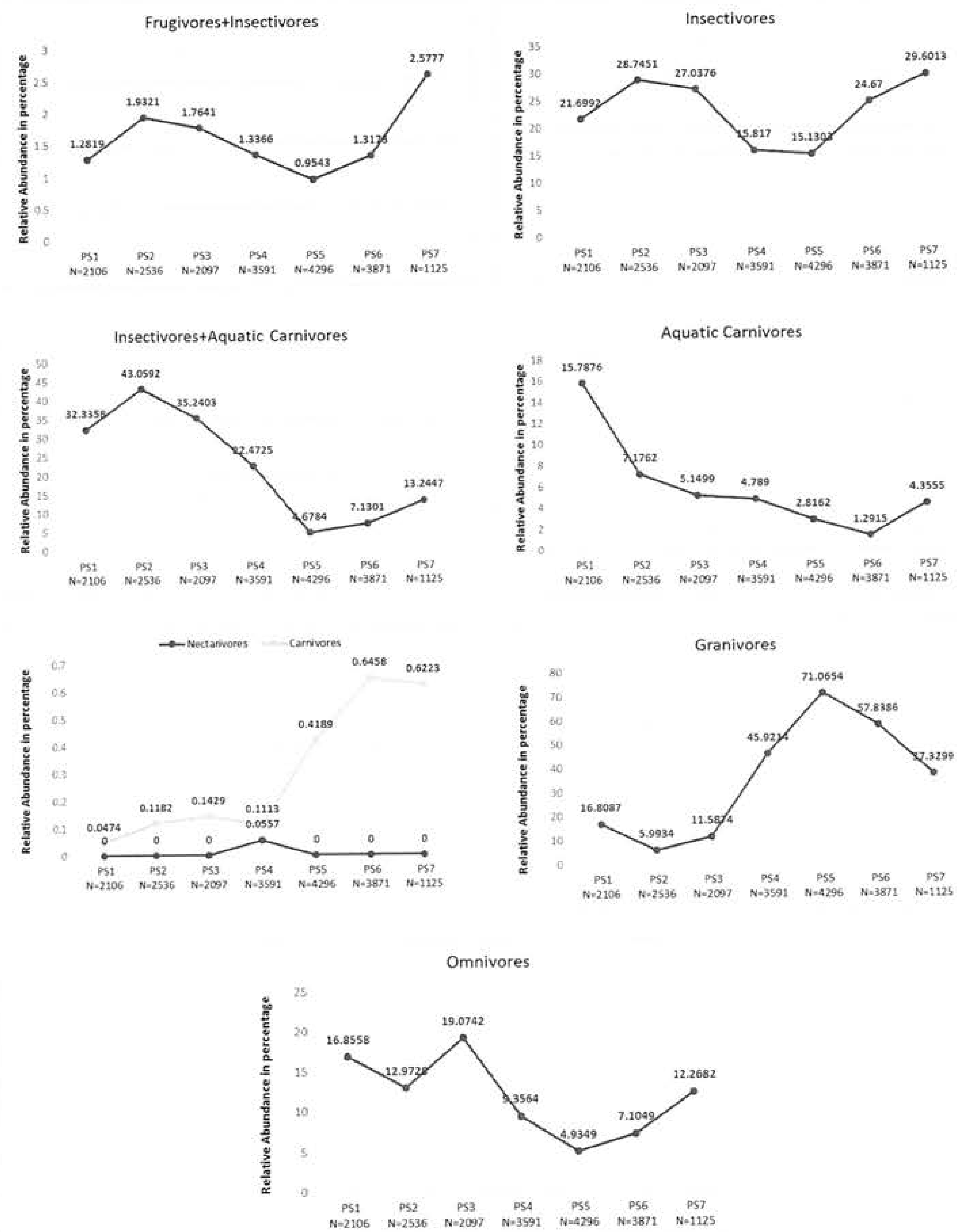


Figure 5.8: Trends in the relative abundance of bird guild across paddy growth stages

5.2.4 Variations in the bird community of paddy fields in the two cultivation regimes

5.2.4.1 The bird species and community composition

Eighty two bird species belonging to 41 families were recorded from organic fields in 12648 encounters, whereas, 69 bird species belonging to 35 families were recorded from non-organic fields in 6974 encounters (Appendix 6). The Passerines constitute more than 65% of the bird community in both organic and non-organic paddy fields followed by birds belonging to orders Pelecaniformes, Charadriiformes and Coraciiformes respectively. Higher abundance of birds belonging to all the orders except Pelecaniformes were observed in organic fields (Figure 5.9 a).

Passerines were also the most speciose group with organic fields having nearly 1/3rd higher richness than non-organic fields. This was followed by Pelecaniforms, Charadriiforms and Coraciiforms respectively with even species in Pelecaniforms, higher in Charadriiforms and lower in Coraciiforms in organic fields. Strigiforms were absent in non-organic fields (Figure 5.9 b).

Granivores constitute the most abundant feeding guild in the organic fields with a relative abundance of 56% whereas insectivores were the most abundant guild in non-organic fields. The second most abundant guild was Insectivores+ Aquatic carnivores in both the regimes. This was followed by insectivores, aquatic carnivores and omnivores respectively in organic fields. In non-organic fields omnivores were followed by granivores and aquatic carnivores respectively (Figure 5.9 c). The organic fields had higher species richness in each guild in comparison with non-organic fields. Insectivores were the most speciose followed by omnivores, granivores and aquatic carnivores respectively. Carnivores and Frugivores+ Insectivores were even in both regimes. One nectarivore species (Purple-rumped Sunbird) has been recorded from organic field (Figure 5.9 d).

It should be noted that the abundance of passerines and granivores may appear dominating in the organic fields by a large extent. As total number of birds recorded in organic fields was nearly double than that of non-organic fields, the other orders, and guilds have comparable numbers in non-organic field and organic fields.

Terrestrial species were more speciose and abundant in both the cultivation regimes and were highly similar. The waterbirds and wetland dependent birds constitute only around 20 % of the abundance (Figure 5.9 e and f).

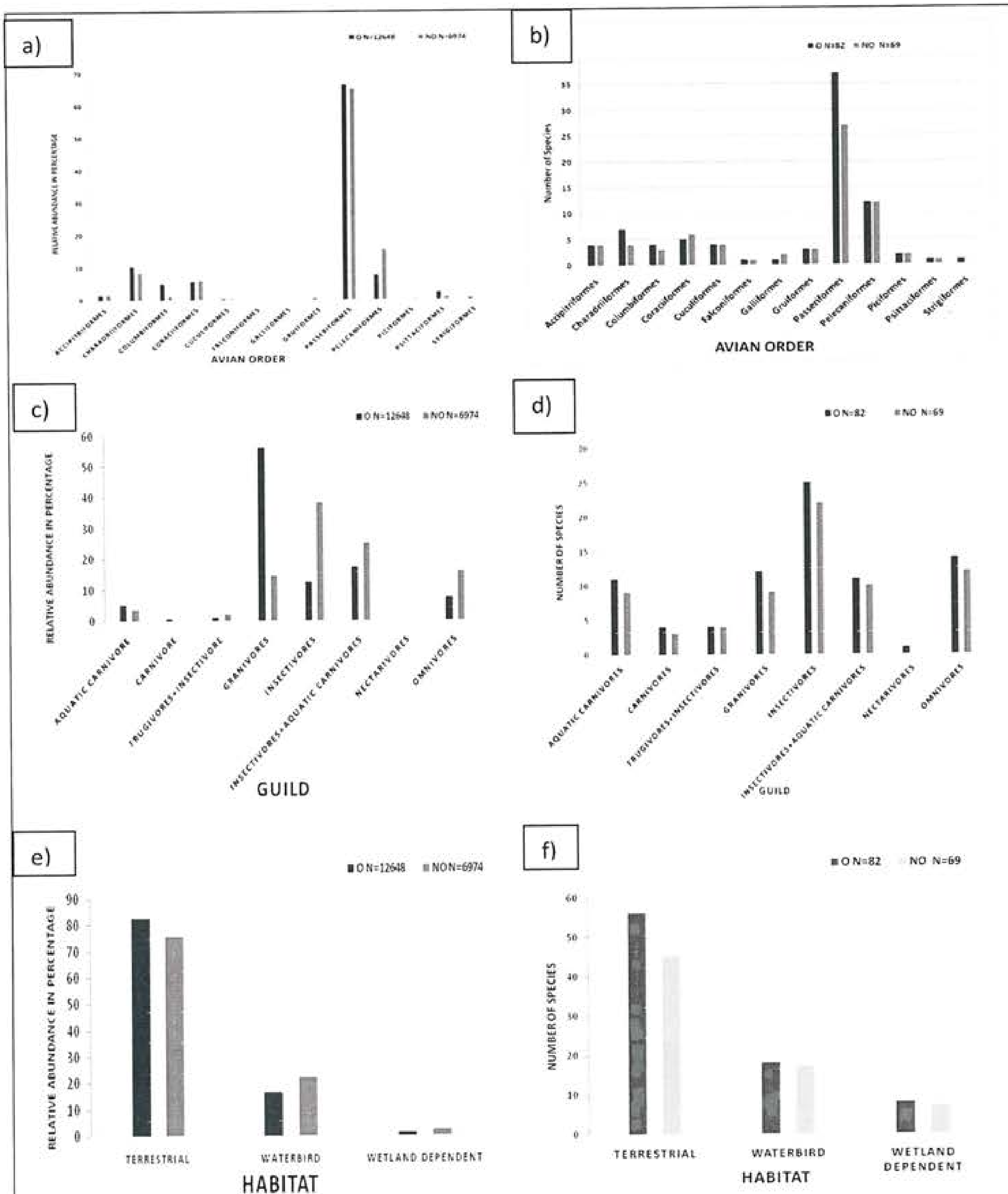


Figure 5.9: The bird abundance in organic and non-organic paddy fields based on a) order c) guild and e) habitat preferences. The bird species composition in organic and non-organic paddy fields based on b) order d)guild and f) habitat preferences O- organic field; NO- Non-organic field.

Five bird species were singletons of which three were recorded from organic fields (*Terpsiphone paradisi, Saxicola maurus, Platalea leucorodia*) and two from non-organic fields (*Copsychus saularis, Batastur teesa*). Nine bird species were recorded only twice, of which seven species were only from organic fields (*Prinia hodgsonii, Luscinia svecica, Saxicola caprata, Leptocoma zeylonica, Rostratula benghalensis, Chlidonias hybrida, Iduna rama*) and the other two are *Orthotomus sutorius* and *Falco chiquera*. Apart from the 10 species mentioned above eight more species were recorded solely from organic fields. They were *Gymnoris xanthocollis, Motacilla cinerea, Euodice malabarica, Columba livia, Himantopus himantopus, Amandava amandava, Accipiter badius* and *Athene brama*. Three more species were recorded from non-organic fields alone. They were *Pavo cristatus, Ixobrychus cinnamomeus* and *Merops philippinus*.

When comparing the diversity between the two regimes the species richness was consistently higher in the organic field on the whole as well as in each paddy growth stages. But there were variations in Dominance, Evenness and Shannon diversity measures. In the first three growth stages *viz.* Land preparation/sapling, transplantation and growth stage, the Shannon, Simpson and Evenness Index values were higher in organic fields indicating they were much more diverse than non-organic fields. But in PS-4 the dominance increased, evenness and diversity indices decreased in the organic fields. This was maintained till PS-6. Again in PS-7 organic fields had comparatively lower dominance, higher evenness and diversity indices values (Table 5.6)

5.2.4.2 The significance of variation in bird community between the cultivation regimes across the paddy growth stages.

The ANOSIM test on the bird community composition of the two cultivation regimes rejected the null hypothesis, which states, 'There are no differences in the bird communities of the organic and non-organic cultivation regime'. The variation in the community parameters observed between the two regimes was proved significant by ANOSIM. The R value showed an overall 25% variation in bird community composition between the two regimes. The change in community composition between each paddy stage is very drastic with R values varying above 0.79 in PS-2, 3, 4, 5 and 6 and ranging between 0.45 and 0.56 in PS-1 and 7 (Table 5.7). All these values are significant at 95 % confidence level.

Table 5.6: The bird community parameters across paddy growth stages in organic and non-organic regimes

Paddy Growth Stages		Number of Transects	Number of encounters	Species Richness	Number of Families	Dominance _D	Simpson_ 1-D	Shannon _H	Evenness _e^H/S
PS1	Organic	7	1041	47	30	0.1142	0.8858	2.761	0.3365
	Non-Organic	7	1065	40	28	0.1311	0.8689	2.529	0.3135
PS2	Organic	7	835	46	29	0.07003	0.93	3.049	0.4587
	Non-Organic	9	1701	40	25	0.09753	0.9025	2.728	0.3825
PS3	Organic	9	1040	50	32	0.058	0.942	3.208	0.4947
	Non-Organic	6	1057	43	27	0.09278	0.9072	2.745	0.3619
PS4	Organic	9	2791	52	28	0.1965	0.8035	2.324	0.1966
	Non-Organic	6	800	46	28	0.09	0.91	2.818	0.3638
PS5	Organic	5	3039	47	27	0.347	0.653	1.653	0.1111
	Non-Organic	5	1257	45	28	0.198	0.802	2.301	0.2218
PS6	Organic	8	2980	55	30	0.3067	0.6933	2.058	0.1424
	Non-Organic	6	891	46	31	0.1266	0.8734	2.784	0.3519
PS7	Organic	6	922	50	28	0.07135	0.9286	3.138	0.461
	Non-Organic	4	203	26	23	0.07981	0.9202	2.806	0.6362
Total	Organic	51	12648	82	41	0.1545	0.8455	2.725	0.1861
	Non-Organic	43	6974	69	35	0.06673	0.9333	3.106	0.3237

Table 5.7: Analysis of Similarity in bird community composition between the organic and non-organic regime across the paddy growth stages using Bray-cutis index. Permutation N = 9999, R= 0.2508, p= 0.0001

Paddy growth stages	R value	p value
PS1	0.4553	0.0027
PS2	0.8318	0.0002
PS3	0.8279	0.0001
PS4	0.8925	0.0001
PS5	0.796	0.0076
PS6	0.7984	0.0006
PS7	0.5635	0.0143

5.2.4.3 The pattern of variation in bird community composition between the cultivation regimes among each paddy growth stage

The orderial composition trends of bird community of paddy growth stages in the organic and non-organic regime were analysed (Figure 5.10). During the Land preparation and sapling stage (PS-1), it was seen that the order Charadriiformes constitute 40% of the bird community in organic field, whereas, the Passerines dominated the non-organic cultivation bird community with 68.54% relative abundance. Pelecaniforms followed in organic field with 23.7%. The next abundant order in organic fields was Passeriformes (21.32%) followed by Coraciiformes (7.68%). But in the non-organic field next abundant order was Charadriiformes (15.55%) followed by Coraciiformes (5.44%) and then Pelecaniformes (4.13%). The species responsible for the variations seen between the regimes in PS-1 contributing over 60% of the dissimilarity seen are *Actitis hypoleucos, Ploceus philippinus, Dicrurus macrocercus, Threskiornis melanocephalus, Acridotheres tristis* and *Himantopus himantopus*. Apart from *Actitis hypoleucos* all the other species are more abundant in the non-organic fields (Appendix 3).

During the transplantation stage (PS-2) Charadriiforms (31.9%) continued to be dominant order followed by Passerines (27.4%) and then by Pelecaniforms (19.4%) and Coraciiformes (13.77%) in the organic field. Passerines (46.62%) continued to be dominant in the non-organic field, followed by Pelicaniforms (28.569%), Charadriiforms (16.34%) and Coraciiforms (13.77%). Accipittriforms were more in the organic field than in the non-organic field, where, it was negligible. In this stage, the total abundance in organic field was half that of non-organic field. The species responsible for the variations seen between the regimes in PS-2 contributing over 50% of the dissimilarity seen were *Hirundo rustica, Ardea intermedia, Actitis hypoleucos, Himantopus himantopus, Dicrurus macrocercus, Acridotheres tristis, Vanellus indicus,* and *Ploceus philippinus*. *Himantopus himantopus* was absent from non-organic fields. *Vanellus indicus* had higher mean abundance in organic fields. The rest of the species had higher mean abundance in the non-organic fields (Appendix 3).

In the crop growth stage (PS-3) Passerines dominated both organic and non-organic fields with a relative abundance of 44.9% and 58.84% respectively. This was followed by Pelecaniforms, Coraciiforms and Charadriiforms (14.8%) in the non-organic field. But, Charadriiforms and Coraciiforms were more abundant than Pelecaniforms (12.4%) in organic field. The species responsible for the variations seen between the regimes in PS-3, contributing over 50% of the dissimilarity seen were *Acridotheres tristis, Hirundo rustica, Ardeola grayii, Egretta garzetta, Dicrurus macrocercus, Actitis hypoleucos* and *Cisticola juncidis*. All the species except *Actitis hypoleucos* have higher mean abundance in the non-organic fields (Appendix 3).

In the flowering stage (PS-4) Passerines dominated in both of the regimes with relative abundance of 64.9% and 70.8% in non-organic and organic fields respectively. This wass followed by Pelecaniforms with relative abundance of 18.97% in non-organic field and then Coraciiforms (7.37%) and very less Charadriiforms (2.97%). In organic field Charadriforms (14.11%) were more dominant followed by Pelecaniforms (6.09%) and Coraciiforms (5.2%). The species responsible for the variations seen between the regimes in PS-4 contributing over 50% of the dissimilarity seen are *Lonchura malacca, Actitis hypoleucos* and *Ploceus philippinus*. They are also absent from non-organic fields.

Ardeola grayii and *Acridotheres tristis* increase the cumulative contribution to dissimilarity up to 68% and they have higher mean abundance in non-organic fields (Appendix 3).

During the milking stage (PS-5) Passerines dominated the whole community with relative abundance of 87% in both regimes making the rest of the order negligible in abundance except for Coraciiformes and Pelicanifomes whose presence were noted. The species responsible for the variations seen between the regimes in PS-5 contributing over 73% of the dissimilarity seen were *Lonchura malacca* and *Ploceus philippinus*. Both the species were completely absent in non-organic fields but had high mean abundance in organic fields (Appendix 3).

In the maturing stage (PS-6) Passerines still dominate both the regimes with around 75% relative abundance. Coraciiforms and Pelecaniforms maintained their abundance from previous stage in both the regimes. Psittaciforms and Columbiforms increased in both the regimes. The species responsible for the variations seen between the regimes in PS-6 contributing over 60% of the dissimilarity seen were *Lonchura malacca, Cecropis daurica* and *Columba livia*. *Lonchura malacca* had very high mean abundance in organic cultivation and *Cecropis daurica* had higher mean abundance in non-organic cultivation. *Columba livia* was observed only in organic cultivation (Appendix 3).

The drying and harvesting stage (PS-7) was also dominated by Passerines in both the regimes with a relative abundance of 65%. In the organic cultivation, Columbiiforms (10.7%) followed them, whereas, in non-organic field Coraciiforms (14.77%) were more abundant. This was followed by Accipitriforms (4.9%), Psittaciforms, Pelecaniforms, Charadriiforms and Cuculiforms (2.46%) in non-organic fields. Columbiforms were negligible in non-organic fields. Coraciiforms were less abundant and Pelecaniforms were more abundant in organic fields than in non-organic fields. The species responsible for the variations seen between the regimes in PS-4 contributing over 50% of the dissimilarity seen were *Lonchura Malacca, Ploceus philippinus, Cisticola juncidis, Columba livia, Prinia inornata* and *Streptopelia chinensis*. *Lonchura malacca, Ploceus philippinus* and *Columba livia* were absent in non-organic fields. All the other species had higher mean abundance in the organic regime (Appendix 3).

The guild composition of the bird community across the paddy growth stages were compared between the two cultivation regimes (Figure 5.11). In the Land preparation and sapling stage (PS-1) insectivores + aquatic carnivores and aquatic carnivores dominated the organic field followed by omnivorous and insectivores. But the insectivores (31.4%) dominated the non-organic field closely followed by granivores (26.07%) and then by insectivores + aquatic carnivore (22.7%) followed by omnivores (16.89%). Omnivores were evenly abundant in both the regimes but aquatic carnivores were negligible in the non-organic fields.

During the transplantation stage (PS-2), the insectivores + aquatic carnivore were dominant in both organic and non-organic fields with relative abundance of 43%. Insectivores (35.68%) followed in non-organic fields continued by Omnivores (11.9%), granivores (3.5%), aquatic carnivore (3.46%) and very little insectivores + aquatic carnivore (1.99%), whereas the guild composition in organic field was in congruence with the composition of PS-2 in global pattern, with a slight decrease in the granivores and aquatic carnivores.

In the crop growth stage (PS-3) insectivores + aquatic carnivore dominated both the fields with 35% relative abundance. This was closely followed by insectivores (33%), then omnivores (23%), and very low aquatic carnivore (4.6%) in non-organic fields. In the organic fields granivores (21.2 %) were more abundant than insectivores (20.9%) followed by omnivores (14.42%) and aquatic carnivore (5.67%).

In the flowering stage (PS-4) There was a clear domination of granivores (58%) in organic field followed by insectivores + aquatic carnivore (22.62%), insectivores (9.92%), omnivores (4.64%) and aquatic carnivore (3.3%) whereas in the non-organic field insectivores dominated (28.95%) clearly. It was followed by insectivores + aquatic carnivore (22.63%) then omnivores (19.87%) and granivores (19.33%).

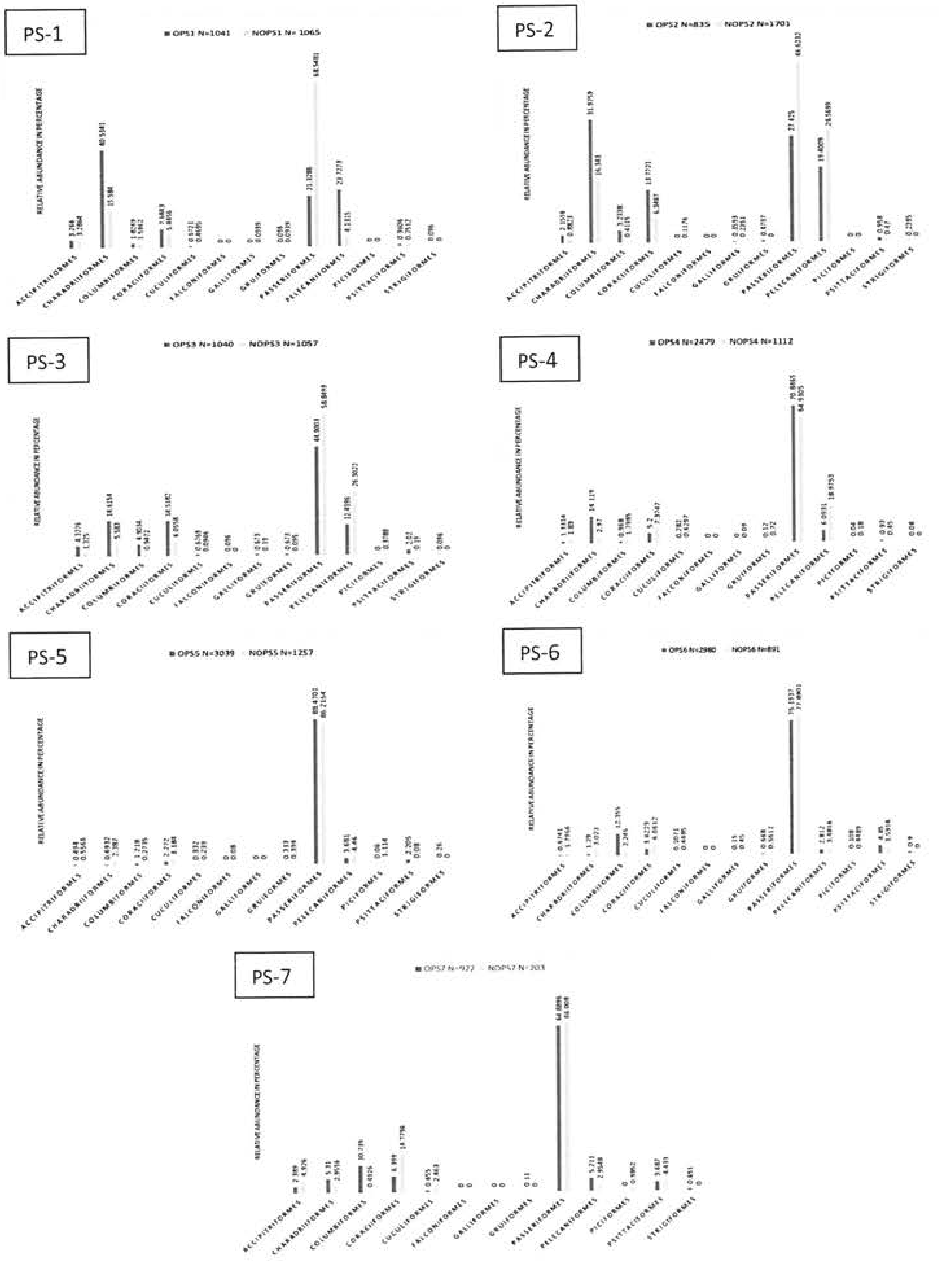


Figure 5.10: Comparison of bird community composition of paddy growth stages between organic and non-organic cultivation regime. NO- Non-organic; O- Organic

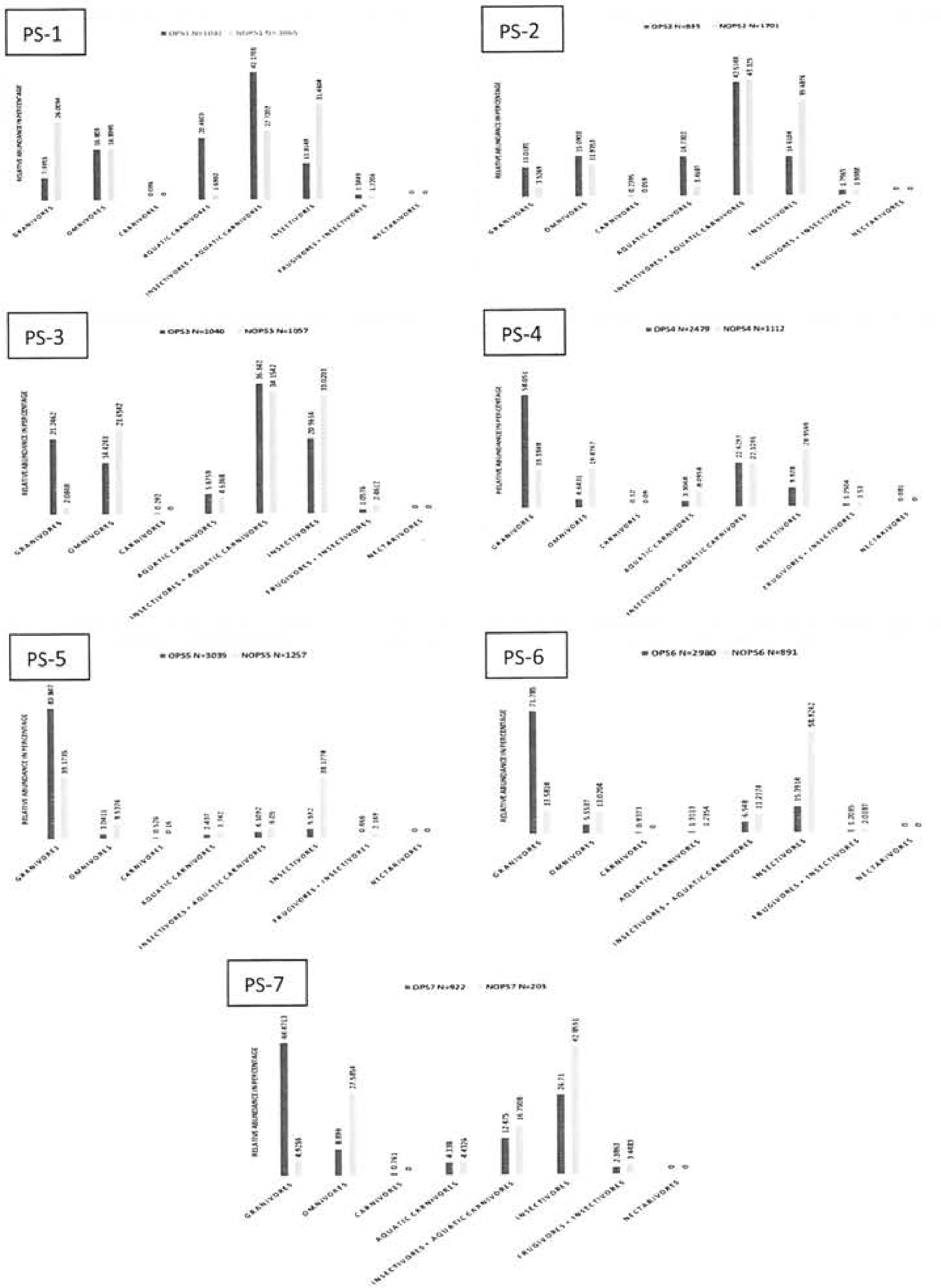


Figure 5.11: Comparison of bird guild composition of paddy growth stages between organic and non-organic cultivation regime. NO- Non-organic; O- Organic

During the milking stage (PS-5), granivores dominated in both the regimes but was around the double the abundance of non-organic field in the organic field. In the non-organic field insectivores closely followed with a relative abundance of 38.17%, then omnivores (9.5%). Insectivores+aquatic carnivores and Insectivores make their presence known in both the regimes.

In the maturing stage (PS-6), granivores (71.7%) dominated the organic cultivation followed by insectivores (15.39%), Insectivores+aquatic carnivores (6.5%) and then omnivores (5.55%). Insectivores dominated the non-organic fields with 58.92% followed by granivores and omnivores (13% each) and Insectivores+aquatic carnivores (11.2%). But the abundance in organic fields was three times that of non-organic fields.

In the drying and harvesting stage (PS-7), granivores dominated in the organic fields, whereas, insectivores dominate non-organic cultivation with around 43% relative abundance. Omnivores were the next abundant group in non-organic fields, whereas, insectivores follow in organic fields with a relative abundance around 27%. This was followed by insectivores+aquatic carnivores in both regimes with a slightly higher relative abundance in non-organic fields. This was followed by granivore, aquatic carnivores, and frugivores+aquatic carnivores in non-organic fields with relative abundance around 4% for all. In organic fields omnivores (8.8%) was followed by Aquatic carnivores and then frugivore+insectivores. The abundance in organic field was nearly four times that of non-organic fields.

5.2.5 The influence of environmental and habitat variables on the bird community of paddy fields

The environmental variables and habitat parameters recorded (Appendix 7) during each sampling were used as independent variables and the community parameters *viz* Species Richness, Number of Encounters, Shannon index, Simpson index, Dominance and Evenness were used as dependent variables and multiple stepwise regression models were developed. The variance in Species Richness, Number of Encounters, Shannon diversity and Evenness were explained by the regression models (Table 5.8).

5.2.5.1 Factors influencing Species Richness of bird community

There was a significant variation in the species richness which was explained by the regression model (Table 5.8 and 5.9). The factors that influenced the species richness were Cultivation regime, Total Dissolved Salt (TDS) in water, water pH and water temperature. These factors explained up to 40% of the variation seen in the bird species richness.

According to the regression model, as the cultivation regime shifts from organic to non-organic the species richness reduces by a factor of 0.484 when the rest of the variables stay constant. A single part per million increase in TDS in water increases the species richness by a factor of 0.46 when the rest of the variables do not change. Increase of pH by 1 increases the species richness by 1.004 when other variables are unchanged. Change in water temperature by a degree inversely influences the species richness by a factor of 1.416 when the other variables in the model remain unchanged (Table 5.10).

5.2.5.2 Factors influencing Number of birds encountered

The regression model explained 16% of variation seen in bird abundance. The factors responsible were cultivation regime and weather (Table 5.8 and 5.11). According to the regression model, as the cultivation regime shifts from organic to non-organic bird encounters reduce by a factor of 0.303 when the rest of the variables stay constant. Clear weather increases bird encounters by a factor of 0.336 when the rest of the variables do not change. (Table 5.12).

Table 5.8: The bird community parameters and the extent of variation and its significance explained by the regression model

Dependent variables	Species Richness	Abundance	Shannon Diversity	Evenness
No. of Samples	94	94	94	94
R squared	0.423	0.177	0.0987	0.2034
Adjusted R squared	0.398	0.159	0.0789	0.1676
Root MSE	3.495	152.783	0.3929	0.1593

Table 5.9: Analysis of Variance in Species Richness of bird community

ANOVA			
Species Richness	Sum of Squares	df	Mean Square
Regression	798.378	4	199.594
Residual	1086.867	89	12.212
Total	1885.245	93	
F	16.344	p	0

Table 5.10: The co-efficients of explanatory variables for Species richness variation and their significance in bird community

Coefficients							
Species Richness	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
Constant	24.521	0.965		25.417	0.000	22.604	26.438
Cultivation regime	-4.350	0.734	-0.484	-5.925	0.000	-5.808	-2.891
Total dissolved Salts in water	0.010	0.003	0.460	3.292	0.001	0.004	0.016
Water Temperature	-0.602	0.134	-1.416	-4.511	0.000	-0.868	-0.337
pH of water	1.498	0.492	1.004	3.046	0.003	0.521	2.475

Table 5.11: Analysis of Variance in encounters of birds

ANOVA			
Encounters	**Sum of Squares**	**df**	**Mean Square**
Regression	457278.307	2	228639.154
Residual	2124179.565	91	23342.633
Total	2581457.872	93	
F	9.795	p	0

Table 5.12: The co-efficients of explanatory variables for variation in bird encounters and their significance

Coefficients							
Encounters	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
Constant	216.495	23.213		9.326	0.000	170.385	262.606
Weather	30.316	8.669	0.336	3.497	0.001	13.096	47.536
Cultivation regime	-100.841	31.922	-0.303	-3.159	0.002	-164.250	-37.431

Table 5.13: Analysis of Variance in Shannon diversity of bird community

ANOVA			
Shannon diversity	**Sum of Squares**	**df**	**Mean Square**
Regression	1.539	2	0.769
Residual	14.050	91	0.154
Total	15.589	93	
F	4.984	p	0.009

Table 5.14: The co-efficients of explanatory variables for Shannon diversity variation and their significance in bird community

Coefficients							
Shannon diversity	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Constant	2.825	0.169		16.675	0.000	2.489	3.162
pH of water	-0.056	0.018	-0.411	-3.121	0.002	-0.091	-0.020
Habitat	-0.182	0.076	-0.317	-2.405	0.018	-0.333	-0.032

Table 5.15: Analysis of Variance in Evenness of bird community

ANOVA			
Evenness	Sum of Squares	df	Mean Square
Regression	0.577	4	0.144
Residual	2.259	89	0.025
Total	2.836	93	
F	5.6817	p	0

Table 5.16: The co-efficients of explanatory variables for Evenness variation and their significance

Coefficients							
Evenness	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Constant	0.649	0.069		9.364	0.000	0.511	0.787
Cultivation Regime	0.099	0.033	0.284	2.969	0.004	0.033	0.165
pH of water	-0.076	0.022	-1.320	-3.522	0.001	-0.119	-0.033
Water Temperature	0.016	0.006	0.960	2.601	0.011	0.004	0.028
Habitat	-0.063	0.031	-0.258	-2.048	0.043	-0.124	-0.002

5.2.5.3 Factors influencing Shannon diversity of bird community

There was a significant variation in the Shannon diversity which was explained by this regression model (Table 5.13). The factors that influenced the Shannon diversity were water pH and Habitat. These factors explain up to 8% (Table 5.8) of the variation seen in the Shannon diversity.

According to the regression model, pH of water inversely influences Shannon diversity by a factor of 0.411 when other variables were constant. As the habitat changes from wetland to dry, the Shannon diversity decreases by a factor of 0.317 when other variables do not change (Table 5.14).

5.2.5.4 Factors influencing Evenness in bird community

There was a significant variation in the Evenness which was explained by this regression model (Table 5.15). The factors that influence evenness were Cultivation regime, habitat, water pH and water temperature. These factors explained up to 17% (Table 5.8) of the variation seen in the evenness.

According to the regression model, as the cultivation regime shifted from organic to non-organic the evenness increased by a factor of 0.284 when the rest of the variables stayed constant. As habitat changed from wetland to dry condition the evenness was reduced by a factor of 0.258 when the rest of the variables did not change. Increase of pH by 1 decreased the evenness by a factor of 1.32 when other variables were unchanged. Change in water temperature by a degree directly influenced evenness by a factor of 0.96 when the other variables in the model remained unchanged (Table 5.16).

5.3 Discussion

5.3.1 Bird Community in paddy fields

According to Subramanya (1987), the temporal distribution of bird community in paddy fields within a cycle is bimodal across paddy cultivation phases with peaks during tillering/levelling phase and growth phase of paddy. This pattern was observed by considering only the species richness in each of the stages. Along with the species richness the number of birds in each of the species (population abundance) is also a significant factor to explore in understanding the bird life of paddy fields. As the availability of prey is known to affect the bird abundance in paddy fields (Bambaradeniya *et al*, 1998, Rajashekara and Venkatesha, 2014), it is the feeding guilds and the opportunity provided by the changing ecosystem, as a substratum, for feeding in the paddy fields, that determined the life of birds in this ecosystem. Hence, for the better understanding of temporal variation and its significance, abundance of each species is important along with the species richness in the paddy fields.

The number of Passerines increased across the cultivation phases from PS-1 till PS-5 and reduced in PS-6 and PS-7. Simultaneously, birds belonging to Charadriiformes, Pelecaniformes and Coraciiformes decreased from PS-1 through PS-5 and recovered slightly from PS-6 to PS-7. Columbiiformes showed a fourfold increase from PS-5 to PS-6 and Psittaciformes also showed a threefold increase from PS-5 to PS-7 (Figure 5.7). These results also coincided with the trends observed in the guild composition variations where the Aquatic Carnivores, Insectivores+Aquatic carnivores decrease through PS-2 to PS-5 with peak in PS-2. The same trends could be visualised in the wetland and wetland dependent species from PS-1 through PS-7. The granivores showed a drastic increase from PS-3 with peak in PS-5 and decrease in PS-6 and 7. The insectivores maintained a minimal of 15% across all the stages, although the abundance increased, which denotes their rise in abundance also across PS-1 and PS-7 (Figure 5.8).

Thus, the current study shows that there is a (Table 5.5) significant change in bird community composition in paddy fields along with the changes in paddy growth stages. This change is gradual. The richness (Table 5.4) did not show significant variation between the seven paddy cultivation phases considered here. So, during a cropping cycle of paddy a variety of niches are available that are also dynamic in nature. Hence, the temporal variation in bird community is due to niche variability across the different paddy growth stages.

The differences in bird community observed between two consecutive phases among PS-1- PS-2 and PS-3 - PS-4 with R values between 0.178 and 0.21 (Table 5.5) indicate the changes of available niches in the same area during that time frame. This may be because of the sudden change in habitat; a) In case of PS-1 and PS-2, the presence of transplanted paddy in an open wetland kind of ecosystem b) In the case of

PS-3 and PS-4, the changes in crop density and start of panicles and drying of lands, opens avenues for new available niches. Simultaneously the process displaces a few niches already present. Increase in granivores till PS-5 and decrease only 50% till PS-7 seems to coincide with the increase in Columbidae and Psittaculidae that were seen to flock to feed on fallen grains after harvest.

The best examples of the dependency on the availability and accessibility of niches can be seen in PS-5 (milking phase) and PS-3 (growth phase). The high dominance Index value in the milking phase of paddy can be attributed to the increase in relative abundance of Passerines especially granivores and decrease of Insectivores +aquatic carnivores (Figure 5.7 and 5.8). The low evenness may also be because of drastic increase in two species *viz*. *Lonchura malacca* and *Ploceus philippinus*. The steep decline in omnivores may be due to loss of open wetland condition (Nam *et al*, 2015) and the crop density hinders the activities of raptors like *Milvus migrans* and *Haliastur indus*. The insectivores and insectivore+aquatic carnivores maintain 20% of the overall abundance across the stages although there is an increase in abundance. This shows there is an increase in the abundance of insectivores and Aquatic carnivores+insectivores along the paddy stages which follow the arthropod abundance in rice fields (Bambaradeniya, 1998) and changes with the habitat variations.

5.3.2 Comparison of the bird community in paddy fields of organic and non-organic regimes and across paddy growth stages

The organic regime area bird community appear more diverse with 82 species from 41 families compared to 69 species from 35 families recorded from non-organic fields. This is similar to studies in cornfields that elucidates the mean species richness and abundance of birds was twice the amount in organic fields (Beecher *et al*, 2002). But 10 out of 18 species recorded solely from organic fields are singletons or doubletons. The passerines dominate both the organic and non-organic regimes in congruence with the diversity of birds of the world. The dominance of passerines is supplemented by granivores in the organic field, whereas in the bird community of non-organic regime insectivores are the major contributors. The dominance and evenness indices also substantiate this. This again suggests lower diversity is due to the population dominance of a few bird species in the organic cultivation area. The bird orders constituting wetland dependent species are the next abundant group in the paddy fields of both regimes, but their mean abundance is higher in organic regime.

When the bird community parameters, like species richness, relative abundance, and diversity indices, of each growth stage is compared between the two regimes, the initial three stages showcase higher diversity in the organic regime. The flourish of wetland dependent bird species is expected in a paddy ecosystem (Fujioka *et al*, 2010; Acosta *et al*, 2010). But, in the non-organic regime Passerines and insectivores dominate (Figure 5.10 and 5.11). Contrastingly, in the bird community of organic regime organic wetland dependent species dominate with higher mean abundance of these species than in non-organic regime .This indicates the better holding capacity of organic fields because of higher organic content in the land (Mondelears *et al*, 2009; Beecher *et al*, 2002). This is substantiated by the high mean abundance of *Actitis hypoleucos, Himatopus himantopus* and *Vanellus indicus* in the organic regime during these stages. The complete dominance of Passerines and granivores from Milking (PS-4) to maturing (PS-6) stages of paddy in the organic regime is brought about by two species, *Lonchura malacca* and *Ploceus philippinus* (Figure 5.10) (Appendix 3). These two species are the major contributors to increase in dominance and decrease in evenness and diversity indices in the organic regime compared to the non-organic regime in these stages. Their aggregation in organic regime increases the encounter numbers drastically masking the diversity of bird community in organic regime during these stages. This bloom in granivores during these stages in organic regime may be because of the longer flag leaves that provide cover for feeding from the crop plants (Subramanya, 1994). They were observed to prefer feeding on certain patches of traditional varieties, that have longer flag leaves than panicles, cultivated in the organic fields, in huge numbers at a time (plate 16). Half the population of these large groups were observed to be constituted by juveniles. Although the non-organic regime does not support granivores in high numbers, passive granivores that feed on grain spill like *Columba livia* have not been recorded from the non-organic fields. This is probably because the field is prepared for the next paddy crop cycle immediately after harvesting in the non-organic fields. Wherever the dominance decrease and evenness increases in organic regime, wetland dependent species contribute to the increase in stability of diversity. A major contributing wetland species for this difference between organic and non-organic regimes is *Himantopus himantopus* whose mean abundance is high in the organic regimes but is not recorded from non-organic regime. Similarly a well known paddy bird *Ardeola grayii* has lower mean abundance in organic regime and contributes to the differences between these two regimes. *Himantopus himantopus* shares the feeding and foraging niche of *Ardeola grayii.* They essentially compete with Ardeola grayii. This competition for the specific niches by the migratory species might have displaced the resident birds. *Himantopus himantopus* may also have preferred the organic regime and may serve as an indicator of the environmental quality.

Along with the granivore dominance in organic fields, the bird encounters increase drastically from flowering to maturing stage of paddy (Table 5.6). Even then, the insectivores hold their own, showing their increase in number during these stages that is masked. But in the non-organic regime, although insectivores dominate they show a decreasing trend across the growth stages when there is good crop cover and supposed to have good prey abundance (Bambaradeniya, 1998). This is probably a result of chemical inputs given to the non-organic field (Beecher *et al*, 2002).

All the differences seen in the bird community composition of paddy fields between the two regimes are highly significant with dissimilarity ranging from 45% to 80% between the paddy growth stages.

5.3.3 The factors influencing the bird community in paddy fields

Previous studies show that organic farmlands have higher species richness and abundance than non-organic farmlands (Beecher *et al*, 2002, Batary *et al*, 2010) especially in homogeneous landscapes (Danhardt *et al*, 2010; Belfrage *et al*, 2005). The regression models, using community parameters as dependent variables and environment and habitat variables as independent variables (Table 5.10, 5.12, 5.14, and 5.16) , done to know whether the regime influences bird diversity in paddy fields shows that organic paddy field harbours higher bird diversity. We know the bird community vary significantly between the two regimes (Table 5.7 and 5.8) but, a community is not influenced only by a single factor. The species richness, number of encounters and evenness are higher in the organic regime. Shannon diversity index of the bird community is influenced by the habitat. As the habitat changes from wetland to dry condition the diversity also decreases. The number of bird encounters is influenced by weather clarity. Weather plays a role in bird activity and detection of birds (Robbins, 1981). Among the water parameters, water pH seems to play a major role in influencing the bird diversity parameters positively. Total Dissolved Salts in water and water temperature influence the bird diversity in paddy fields inversely.

5.4 Conclusion

Paddy fields, especially the organically cultivated ones, support a significant diversity (87 species) of birds in a human dominated landscape. There is a significant change in the paddy field bird composition ina a paddy cultivation cycle with peak diversity during the plant growth phase (PS-3). This change in bird community composition can be attributed to the dynamic habitat variability happening during paddy cultivation. Twenty nine bird species contribute to 90 % of the bird community temporal changes seen in Kadhiramangalam region. The major contributing species are Black-headed Munia, Baya Weaver, Sandpiper spp., Barn Swallow, Common Myna and Black Drongo in this region. All these except Black Drongos are colonial/ flocking birds. Hence, their presence or absence gives the major contributions. The temporal variability in the microhabitats of the paddy fields provide varied substratum in support of various bird species of different feeding guilds. This makes paddy fields a good candidate to be considered as a 'keystone habitat' for the bird community.

The bird community composition in paddy fields shows significant variations between organic and non-organic regimes. There are also significant differences in the bird community composition between the paddy growth stages of organic and non-organic regimes. The paddy fields under organic regime does support higher bird diversity than non-organic regime. The dominance of granivores during the milking and maturing stages is being managed by planting hybrid varieties or varieties with bare panicles and shorter flag leaves. This deprives the birds of much required cover and compromises their safety.

CHAPTER 6

BUTTERFLY COMMUNITY OF PADDY FIELDS IN KADHIRAMANGALAM

6.1 Introduction

Butterfly community of agro-ecosystems have not been studied extensively (Ganvir *et al*, 2017) in India. So far, very few studies documented butterflies from paddy fields in India. In 1999, Kunte *et al*, have documented a few species from paddy fields of Western Ghats. After that in 2002, Soniya and Palot have documented the butterflies from rice fields of Palakkad. Mathew *et al* (2014) , have recorded the butterflies from paddy fields of Western Ghats. Recent studies by Ganvir *et al* (2017) and Ganvir and Khaparde (2018), have focused on butterfly community of agro-ecosystems in Maharashtra with paddy as the predominant crop. All these studies are focused in Western Ghats. Dwari and Mondal (2015) have documented butterflies from agro-ecosystems of West Bengal. All these studies so far have documented 100 butterfly species (Appendix 5) from paddy fields of India concentrated mostly in Western Ghats. Among these hundred species, members of family Nymphalidae (37 species, 23 genera) are dominant followed by Pieridae (22 species 16 genera). The other three families represented were Lycaenidae (17species 13 genera), Hesperiidae (13 species, 10 genera) and Papilionidae (10 species 6 genera). Family Riodinidae was represented by one species. But there are not much studies on understanding the community aspects of butterflies in the paddy fields. This chapter aims to address the two objectives of the study from butterfly perspective with the following null hypotheses

1. There is no difference in the butterfly community composition across growth stages of paddy.
2. There is no difference in the butterfly community of the paddy fields with reference to cultivation regime.

To achieve the objectives the results are explained as answers for four research questions which are

1. What is the species composition and population distribution of butterfly community in paddy fields
2. How do the butterfly community parameters correlate with the water level and water quality?
3. How do the butterfly community parameters correlate with the different stages of crop growth?
4. Do the butterfly community vary between the two cultivation regimes? If so what are the influencing factors?

6.2 Results

In 94 transects, 48 butterfly species in 1460 encounters were recorded during the study from the paddy fields. The species accumulation curve reaches asymptote showing the sufficiency of data. The chao 2 index predicts a few more species but, as the study was area bound the difference is not significant (Figure 6.1).

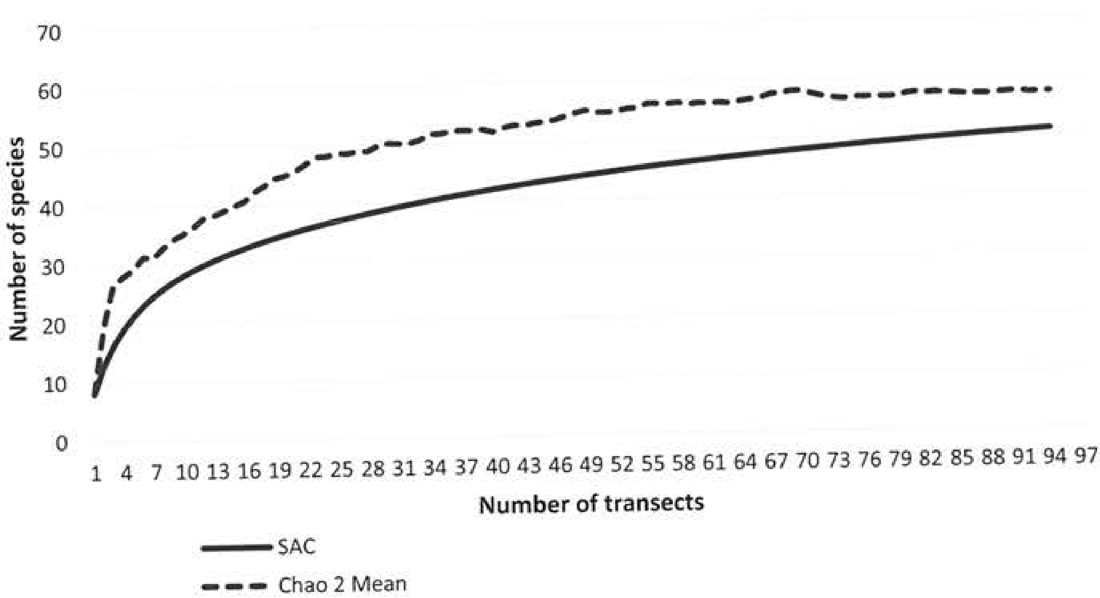


Figure 6.1: Species accumulation curve of butterflies in paddy fields

6.2.1 Butterfly community in paddy fields.

6.2.1.1 Species Composition and Population distribution

Forty eight butterfly species belonging to five families were recorded from the study area. Nymphalidae was the most dominant family in terms of species (16 species) and abundance. Pieridae were the next abundant family followed by Hesperiidae and Lycaenidae. Lycaenidae (10 species) were more speciose followed closely by Hesperiidae (8 species) and Pieridae (8 species). The least speciose and abundant family was Papilionidae (6 species) (Figure 6.2 a and b).

The most abundant species was gram blue followed closely by Common emigrant (Figure 6.3). The common species were Common Evening Brown, Peacock Pansy, Bush Hopper and Common Bushbrown (Figure 6.4), but these species were comparatively low in abundance.

Twenty two butterfly species had records of presence of their larval host plants in the paddy fields. Six Hesperiid species, five Lycaenid species, nine Nymphalid species and two Pierid species had their larval host plants in the field. Of these, rice was the larval host plant for eight butterfly species. They are *Ampittia dioscorides*, *Melanitis phedima*, *Mycalesis perseus*, *Melanitis leda*, *Telicota colon*, *Borbo cinnara*, *Pelopidas mathias* and *Parnara* species (Appendix 1).

6.2.1.2 Variations in butterfly community across paddy growth stages

The butterfly community was compared across the paddy growth stages (Table 6.1). Major changes across the paddy cultivation phases were seen in the relative abundance of butterflies belonging to the families Hesperiidae, Lycaenidae and Pieridae. The Pierids showed a 90% decrease from PS1 to PS4 and recovered 60% from PS4 to PS6. The Hesperiids showed 90% increase from PS1 and PS4 and decreased from PS4 to PS7. The Nymphalids varied between 40 to 60 % across the paddy growth stages with peak during PS-2 (Figure 6.5).

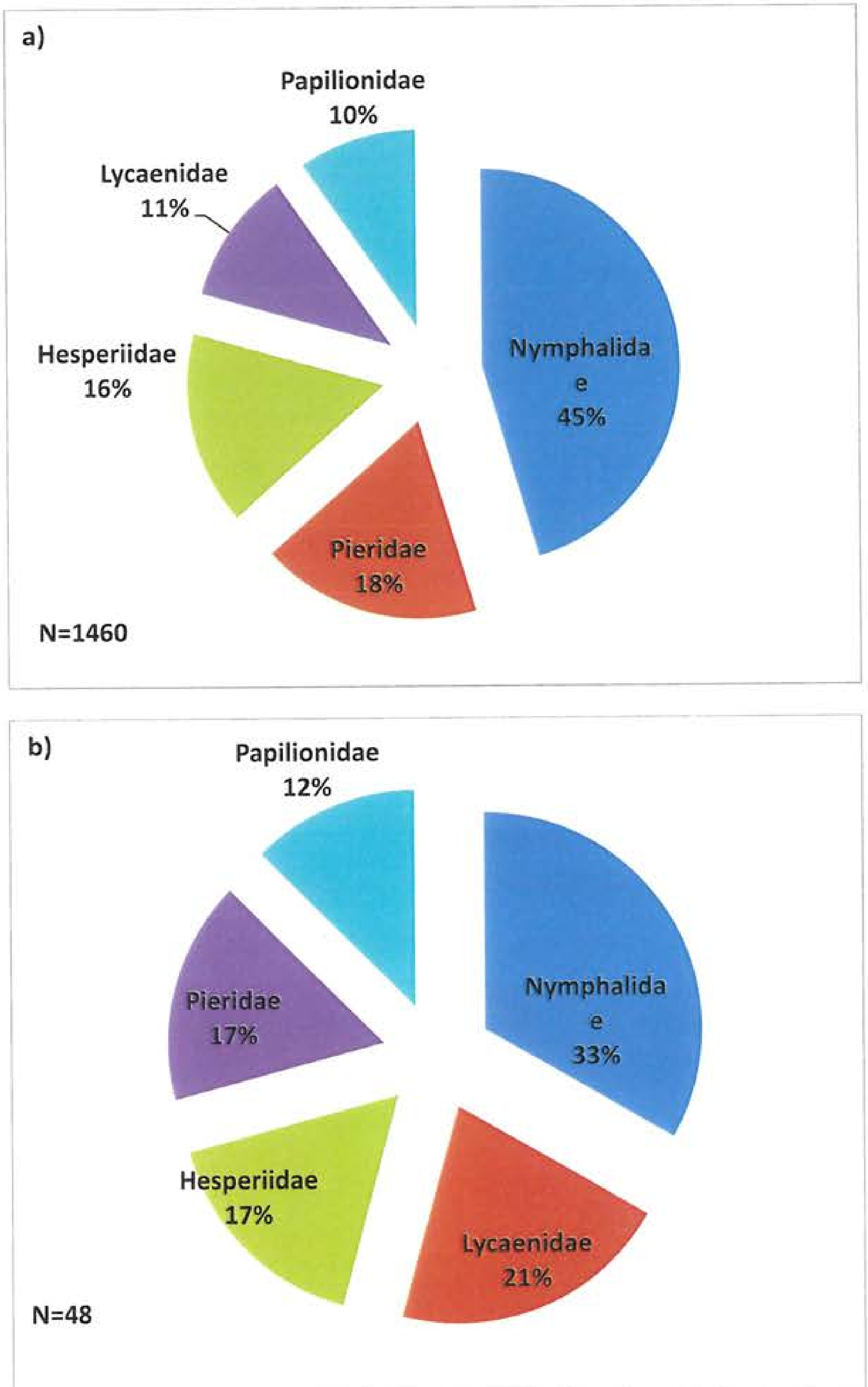


Figure 6.2: Family level classification of butterfly community in paddy fields based on a) relative abundance b) species richness

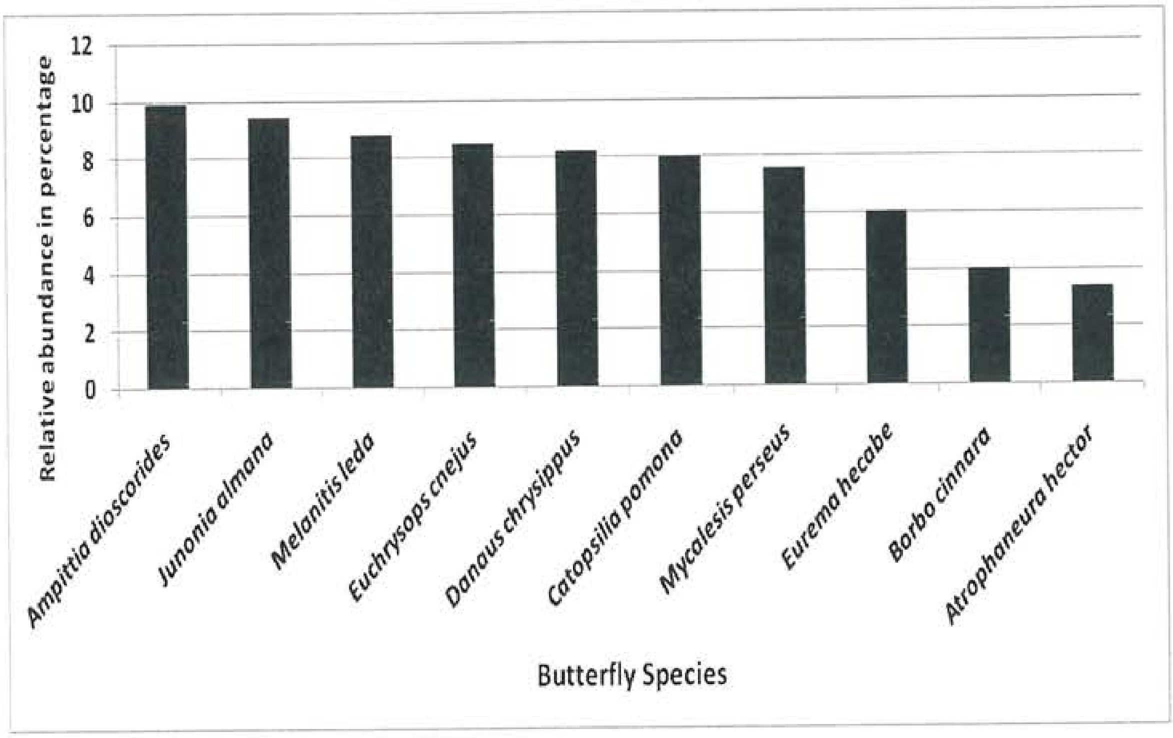


Figure 6.3: Most abundant butterfly species in the paddy fields of Kadhiramangalam

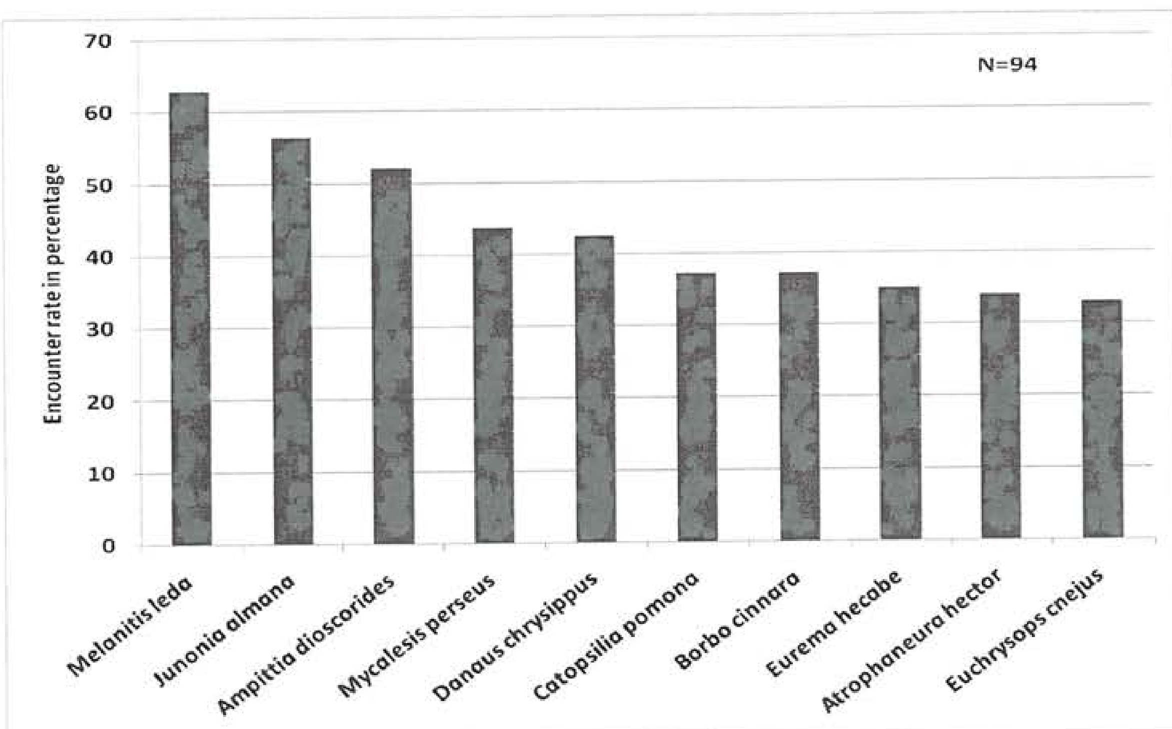


Figure 6.4: Common butterfly species in the paddy fields of Kadhiramangalam

The species richness did not show major variations across the paddy cultivation phases. The Nymphalidae was the most speciose family varying from eight to 12 species with PS-2 being most speiose. The Hesperiids varied from two to six species with PS-4 being the most speciose (6 species) and PS-7 being the least speciose (2 species). The Lycaenids varied from two species to seven species with PS-6 being the most speciose. Pierids did not vary much across the paddy growth stages with least species richness being four species in PS-4 , 5 and 7 and PS-2, 3 and 6 with five species each and PS-1 having six species. Only the Papilionids showed a decreasing trend across paddy growth stages in species richness with six, five and four species respectively in the first three stages, later on with three species from PS-4 to PS-6 and four species in PS-7.

PS-6 had the highest species richness and abundance followed by PS-1 with 30 species and 264 encounters. Although the species richness and abundance were low in PS-5 and PS-6 the dominance remained almost same across the paddy growth stages and high evenness (Table 6.2).

Analysis of Similarity in butterfly community across paddy growth stages using Bray-Curtis index resulted in the R value being significant. This rejected the null hypothesis that states, 'There is no difference in the butterfly communities of paddy growth stages'. The R value showed a significant difference in butterfly community composition across the paddy growth stages. These changes were negligible between the consecutive paddy growth stages but were significant among non-consecutive paddy growth stages varying between 0.25 and 0.68 (Table 6.3). The species contributing to over 85% of these changes were *Ampittia dioscorides* (9.697%), *Euchrysops cnejus* (9.198 %), *Junonia almana* (8.396 %), *Danaus chrysippus* (7.983 %), *Mycalesis perseus* (7.548 %), *Melanitis leda* (7.415 %), *Catopsilia Pomona* (7.095 %), *Eurema hecabe* (6.384 %), *Borbo cinnara* (4.308 %) and *Atrophaneura hector* (3.53 %) (Appendix 3).

Table 6.1: Species and population demographics of butterflies across paddy growth stages

Paddy growth stages	PS1	PS2	PS3	PS4	PS5	PS6	PS7
No. of Species	30	28	26	26	24	31	21
Abundance	264	192	223	163	162	285	171
No. Of Transects	14	16	15	15	10	14	10
Min species/ transect	2	0	2	0	6	4	2
Max species/ transect	16	14	15	13	10	16	11
Mean (Species)	7.85	7.125	7.13	5.53	8	8.78	6
Stand. Dev (Species)	4.016	4.014	4.3	3.46	1.15	3.11	3.19
Coeff. Var (in %age) (Species)	51.11	56.34	59.91	62.55	14.43	34.48	53.28
Min encounters/transect	3	0	5	0	10	7	4
Max encounters/ transect	60	23	40	28	22	34	43
Mean (Abundance)	18.85	12	14.86	10.86	16.2	20.35	17.1
Stand. Dev (Abundance)	15.02	6.97	10.58	7.95	3.42	6.9	12.24
Coeff. Var(in %age) (Abundance)	79.69	58.13	71.18	73.19	21.14	33.9	71.59

Table 6.2: The Species richness and diversity of butterflies across paddy growth stages

Paddy growth stages	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Species richness	30	28	26	26	24	31	21
Encounters	264	192	223	163	162	285	171
Dominance_D	0.1164	0.09814	0.07374	0.1367	0.1059	0.08826	0.199
Simpson_1-D	0.8836	0.9019	0.9263	0.8633	0.8941	0.9117	0.801
Shannon_H	2.623	2.719	2.866	2.463	2.573	2.752	2.153
Evenness_e^H/S	0.4593	0.5418	0.6753	0.4517	0.5463	0.5054	0.4101

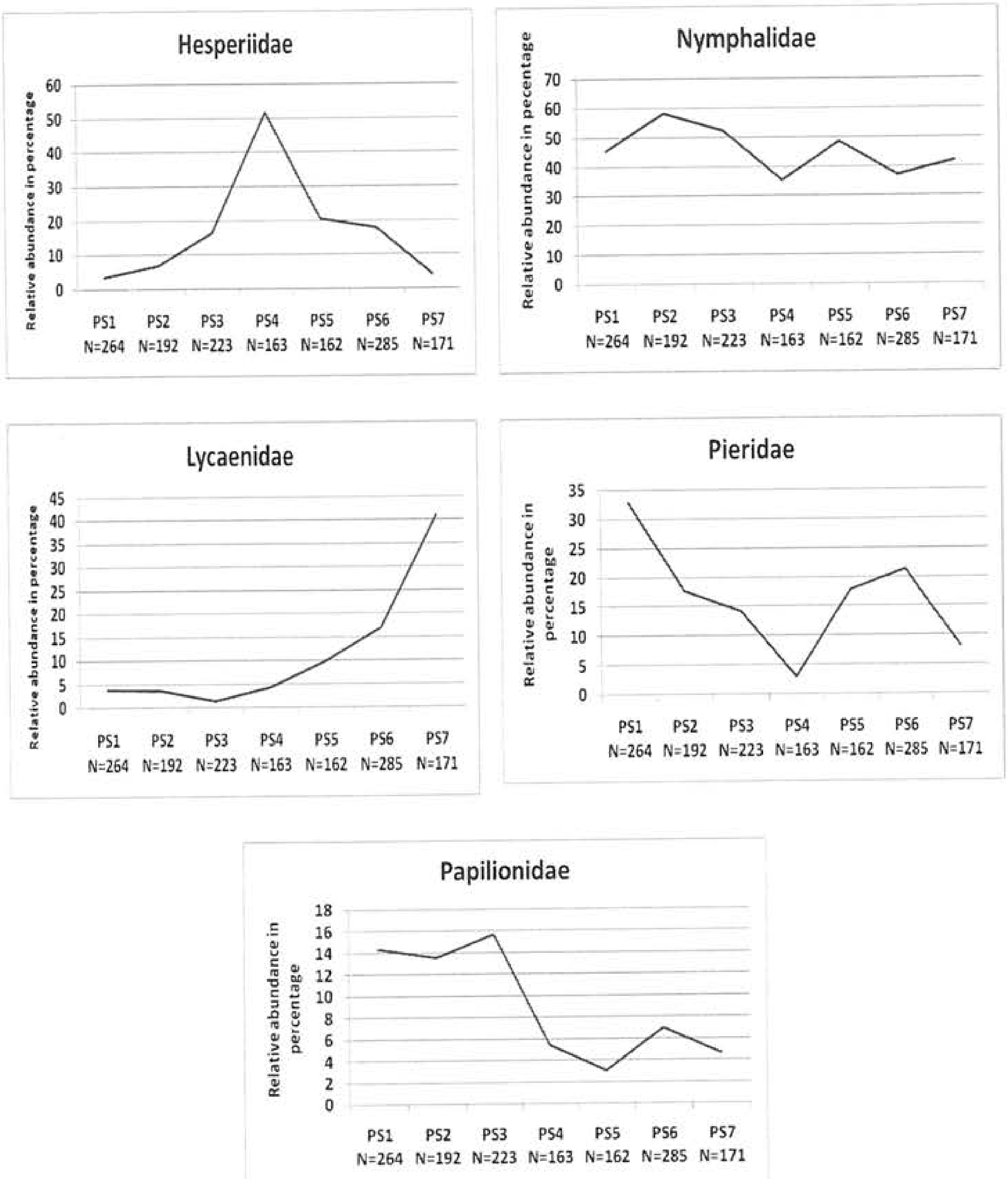


Figure 6.5: Relative abundance trends of butterfly families across paddy growth stages

Table 6.3: Analysis of Similarity using Bray-Curtis index between pairs of paddy growth stages. Permutation N = 9999, R= 0.3488, p= 0.0001. p value is less than 0.05 between all pairs in bold.

R values	PS1	PS2	PS3	PS4	PS5	PS6
PS2	**0.125**					
PS3	**0.2722**	**0.09607**				
PS4	**0.6283**	**0.4452**	**0.1279**			
PS5	**0.6878**	**0.5326**	**0.236**	0.113		
PS6	**0.4976**	**0.4807**	**0.2851**	**0.3161**	0.06176	
PS7	**0.5285**	**0.5356**	**0.4792**	**0.5641**	**0.3886**	**0.2023**

6.2.2: Relationship between Butterfly diversity and water parameters

The community parameters were tested for correlation with the water parameters considered in the study. Species Richness and abundance showed slight positive correlation with Total Dissolved Salts in water and Shannon and Simpson diversity were slightly positively correlated with water level (Table 6.4).

Table 6.4: Correlation between butterfly community parameters and water parameters. The significant Pearson's Correlation value ($p \leq 0.05$) is given in bold.

Community parameters	Species Richness	Encounters	Dominance _D	Simpson _1-D	Shanno n_H	Evenness_e ^H/S
Water Temp in° C	-0.056845	0.029811	0.13105	-0.20355	-0.15625	-0.087663
pH of water	-0.1315	-0.01689	0.023139	-0.11362	-0.15734	-0.19976
Total Dissolves Salts in water in ppm	**0.24929**	**0.23627**	-0.16844	0.14801	0.20093	0.0011449
Water level in cms	0.19648	0.049218	-0.18312	**0.2529**	**0.24458**	0.15668

6.2.3 Variations in butterfly community between the cultivation regimes and among paddy growth stages

6.2.3.1 Species composition and community profile of butterflies in the two regimes

Forty-one butterfly species belonging to five families were recorded from organic regime 805 encounters and 51 transect counts.

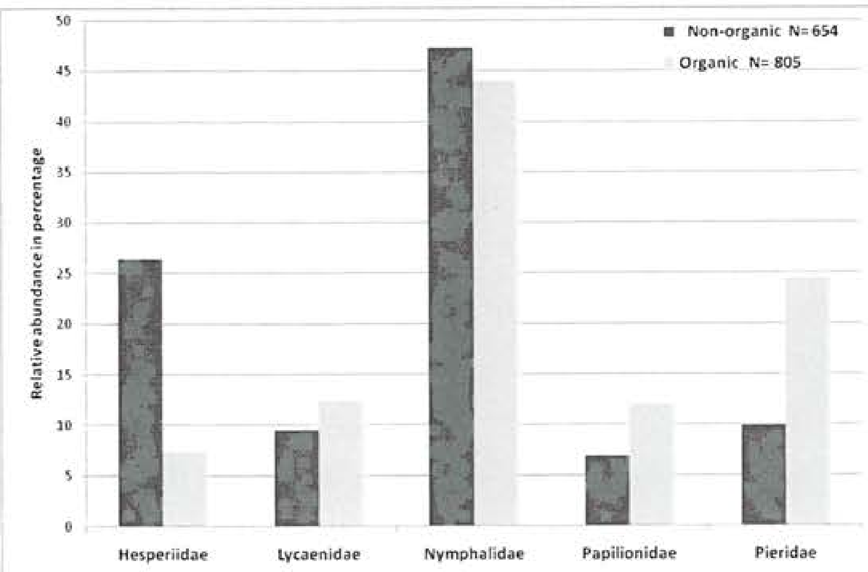


Figure 6.6: Butterfly community composition in organic and non-organic regimes

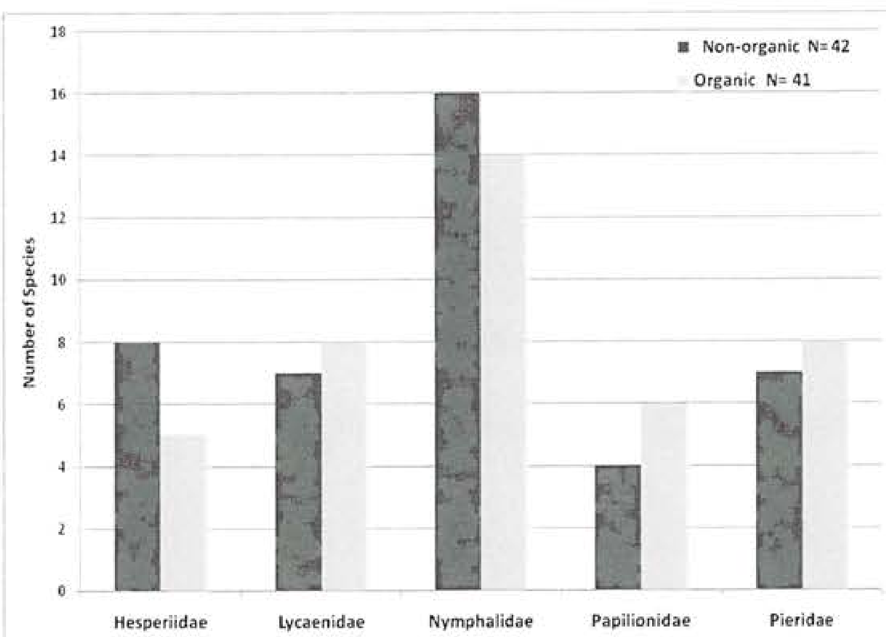


Figure 6.7: Butterfly species composition in organic and non-organic regime

Table 6.5: The diversity indices of butterfly community in organic and non-organic regimes

Cultivation regime	Number of Transects	Number of encounters	Number of Species	Number of Families	Dominance_D	Simpson_1-D	Shannon_H	Evenness_e^H/S
Organic	51	806	41	5	0.06484	0.9352	3.005	0.4921
Non-organic	43	654	42	5	0.08132	0.9187	2.919	0.4412

Forty-two species belonging to five families were recorded from non-organic regime in 654 encounters and 43 transects. When the butterfly diversity was compared between the two regimes, the Species richness, Shannon, Simpson and Evenness indices values did not vary much (Table 6.5). Nymphalidae was the most abundant and speciose family in both the regimes with slightly more abundance and species number in non-organic regime. Hesperiids were more abundant and speciose in non-organic than in organic. Pierids were more abundant in organic regime and also more speciose compared with non-organic regime. Papilionids and Lycaenids were more speciose and abundant in organic regime (Figure 6.6 and 6.7). From the organic regime, the larval host plants of 20 butterfly species were recorded which constituted five Hesperiid species, two Pierid species, five Lycaenid species and eight Nymphalid species. Of these, six species were dependent on *Oryza sativa* as larval host plant. From the non-organic regime, the larval host plants of 21 butterfly species were recorded, which constituted, six Hesperiid species, two Pierid species, four Lycaenid species and nine Nymphalid species. Of these, eight species were dependent on *Oryza sativa* as larval host plant.

The ANOSIM test using Bray-Curtis Index was performed comparing the butterfly communities of the organic and non-organic cultivation regimes. It resulted in a significant R value, thus rejecting the null hypothesis which states, 'there is no difference in the butterfly communities of organic and non-organic regimes'. But, the R value (0.06) is very low, indicating the butterfly communities of the two regimes are highly similar (Table 6.7).

6.2.3.2 Species composition and community profile among each paddy growth stage between the two regimes

The butterfly community composition was compared between each paddy growth stage and its counterpart in the two cultivation regimes. The diversity patterns emerged as given below.

During the Land preparation/ sapling stage (PS-1), Nymphalids and Pierids were predominant in both the regimes with slightly more abundance in organic regime. But the Pierids were more speciose in non-organic regime. This was followed by Papilionids, Lycaenids and Hesperiids in both abundance and species richness in both the regimes. Lycaenids and Hesperiids were more speciose and abundant in non-organic regime (Figure 6.8). The diversity indices were slightly higher in non-organic regime with lower dominance although organic regime had higher encounters (Table 6.6). But the variations in composition between the two regimes in this stage were not significant (Table 6.7).

During the transplantation stage (PS-2), the butterfly community predominantly constituted of Nymphalids in both the regimes with non-organic regime being more speciose and abundant. The Pieridae were the next abundant family in the organic regime followed by Papilionidae and then Hesperiidae in the organic regime. Lycaenidae have not been recorded. Papilionidae was the more abundant family in non-organic regime followed by Pieridae, Hesperiidae and Lycaenidae. In terms of species richness, Pieridae and Papilionidae constituted equal number of species in both the regimes (Figure 6.9). The non-organic regime had higher Species richness as well as diversity indices but the dominance was higher in non-organic regime with lower evenness (Table 6.6). There was no significant change in composition between the two regimes in this stage (Table 6.7).

In the growth stage (PS-3) there was a significant difference in butterfly community composition between the two regimes (Table 6.7). The species richness and abundance were very high in the organic regime when compared with non-organic regime with higher diversity indices, very low dominance and high evenness in the organic regime (Table 6.6). The organic regime was more speciose and abundant in Nymphalidae, Pieridae and Papilionidae than the non-organic regime. The Lycaenidae were more speciose in organic but low in abundance. The Hesperiidae were more speciose and abundant in non-organic regime (Figure 6.10). The species contributing to more than 60% of these differences were Bush hopper, Plain tiger, Common Evening Brown, Peacock Pansy, Common Emigrant, Crimson Rose, Lime Butterfly and Blue Tiger. All the species have higher mean abundance in organic than non-organic regime except Bush Hopper and Common Evening Brown (Appendix 4).

In the flowering stage (PS-4), there was a significant similarity in community composition between the two regimes with a low R value (0.2) (Table 6.7). Nymphalidae was the most abundant and speciose family in the organic regime followed by Hesperiidae, Papilionidae, Pieridae and Lycaenidae. In the non-organic regime, Hesperiidae was the most abundant family followed by Nymphalidae, Lycaenidae, Papilionidae and Pieridae. But Nymphalidae was more speciose than Hesperiidae (Figure 6.11). The species richness was higher in non-organic regime with high Shannon value but lower Evenness and Simpson values (Table 6.6). The species contributing to over 60% of these variations are Bush Hopper, Rice Swift, Common Bushbrown and Common Evening Brown. All the species have higher mean abundance in non-organic regime except Common Bushbrown (Appendix 4).

Table 6.6: The community parameters of butterflies across the paddy growth stages in the two cultivation regimes

Paddy growth Stages		Number of Transects	Number of encounters	Number of Species	Number of Families	Dominance _D	Simpson _1-D	Shannon _H	Evenness _e^H/S
PS1	Organic	7	186	22	5	0.1313	0.8687	2.439	0.5208
	Non-organic	7	78	24	5	0.09665	0.9034	2.698	0.619
PS2	Organic	7	70	19	4	0.1012	0.8988	2.571	0.6886
	Non-organic	9	122	25	5	0.1164	0.8836	2.632	0.5559
PS3	Organic	9	170	23	5	0.08021	0.9198	2.761	0.6878
	Non-organic	6	53	11	5	0.2424	0.7576	1.792	0.5456
PS4	Organic	9	57	15	5	0.1382	0.8618	2.257	0.6366

Paddy growth Stages		Number of Transects	Number of encounters	Number of Species	Number of Families	Dominance _D	Simpson _1-D	Shannon _H	Evenness _e^H/S
	Non-organic	6	106	21	5	0.1707	0.8293	2.313	0.4813
PS5	Organic	5	73	17	5	0.1115	0.8885	2.44	0.675
PS5	Non-organic	5	89	15	5	0.1438	0.8562	2.245	0.6292
PS6	Organic	8	135	18	5	0.1579	0.8421	2.272	0.5107
PS6	Non-organic	6	150	26	5	0.1026	0.8974	2.649	0.5439
PS7	Organic	6	115	18	5	0.2832	0.7168	1.857	0.3557
PS7	Non-organic	4	56	15	5	0.1524	0.8476	2.196	0.5993

Table 6.7: Analysis of Similarity using Bray-Curtis index between pairs of paddy growth stages of the two cultivation regimes. Permutation N = 9999, R= 0.0653, p= 0.002.

	R values	p values
PS-1	0.1118	0.109
PS-2	0.1055	0.0916
PS-3	**0.7582**	0.0005
PS-4	**0.2066**	0.0382
PS-5	**0.584**	0.0243
PS-6	**0.8081**	0.0005
PS-7	0.05754	0.356

In the milking stage (PS-5), the organic regime has higher diversity, being more speciose, with higher Simpson and Evenness values and lower Dominance. Shannon index was almost equal between the two (Table 6.6). There was a significant difference in the butterfly community composition between the two regimes (Table 6.7). Nymphalidae was the most abundant and speciose family in both the regimes. This is followed by Pieridae, Hesperiidae, Papilionidae and Lycaenidae in the organic regime. Hesperiidae were more speciose in the organic regime but are less abundant. Lycaenidae were more abundant and speciose in the non-organic regime (Figure 6.12). More than 60% of the differences seen in the community between the two regimes is due to Common Bushbrown, Common Grass Yellow, Bush Hopper, Gram Blue, Angled Castor and Common Evening Brown (Appendix 4).

In the maturing stage (PS-6), Nymphalidae was the most speciose family in both the regimes with higher species richness and abundance in the non-organic regime. Pieridae was the most abundant family in the non-organic regime but was less speciose than in non-organic. The Hesperiids were more abundant and speciose than Pierids, in the non-organic regime. The Lycaenids and Papilionids were more abundant in the organic regime. The Papilionids were more speciose in the non-organic regime (Figure 6.13). The non-organic regime was more diverse in this stage with higher species richness, diversity index values, Evenness and lower Dominance (Table 6.6). There was a significant difference in the butterfly community composition between the two regimes at this stage (Table 6.7). The species contributing to over 60% of these differences were Common Grass Yellow, Bush Hopper, Peacock Pansy, Gram Blue, Common Bushbrown and Common Evening Brown. Except Common Grass Yellow and Gram Blue, all the species have higher mean abundance in non-organic regime (Appendix 4).

In the drying and harvesting stage (PS-7), the Lycaenids were very highly abundant in the organic field followed by Nymphalids. The Nymphalids were predominant in the non-organic regime in terms of abundance as well as species richness. Hesperiids and Papilionids were more abundant in non-organic regime. Pierids were more speciose and abundant in organic regime (Table 6.14). The species richness was comparatively high in the organic regime but dominance was higher with lower diversity indices and Evenness (Table 6.6). There was no significant difference in the butterfly community composition in this stage between the two regimes (Table 6.7).

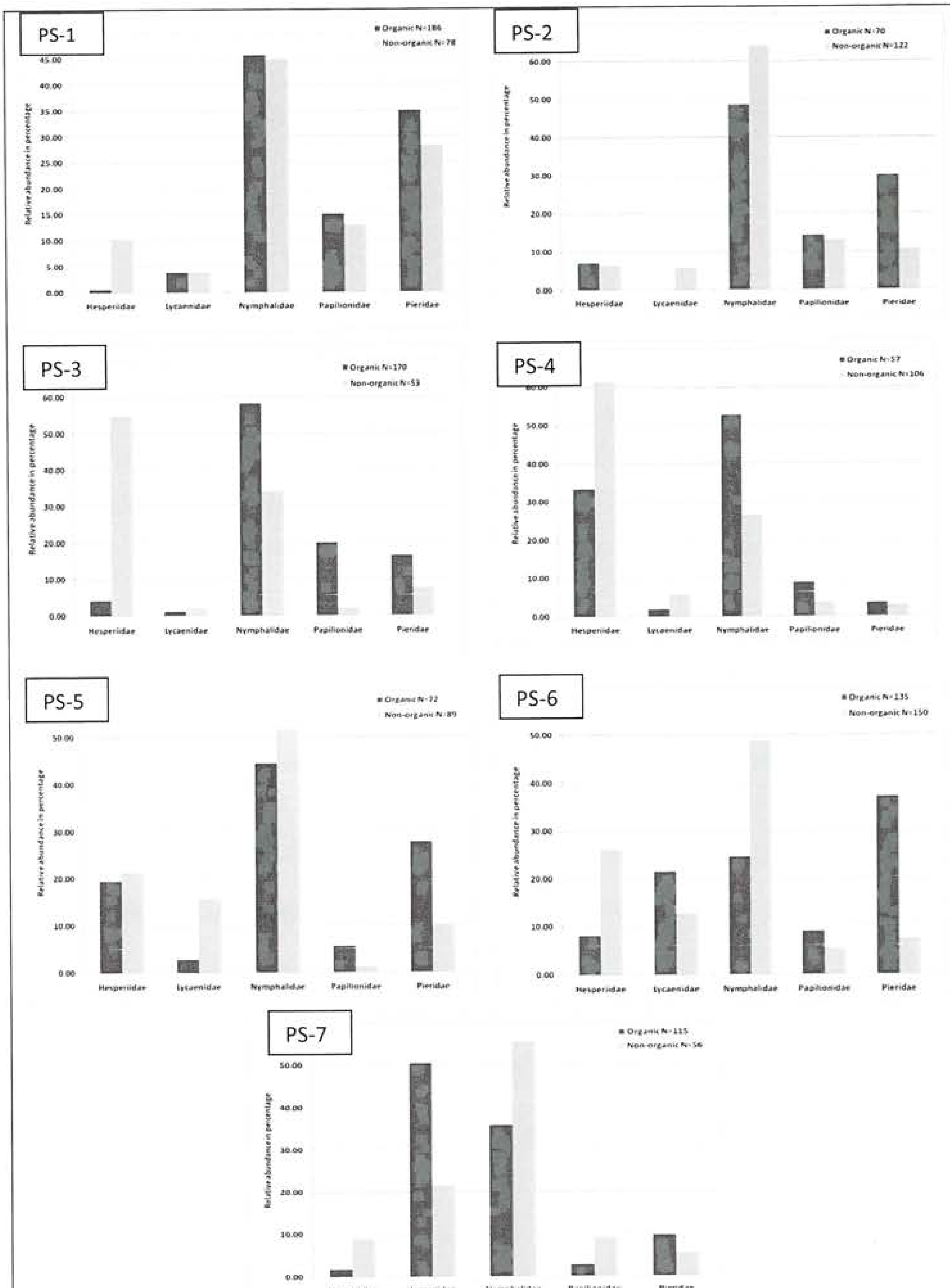


Figure 6.8: The family level comparison of abundance of butterfly community in the organic and non-organic cultivation regimes

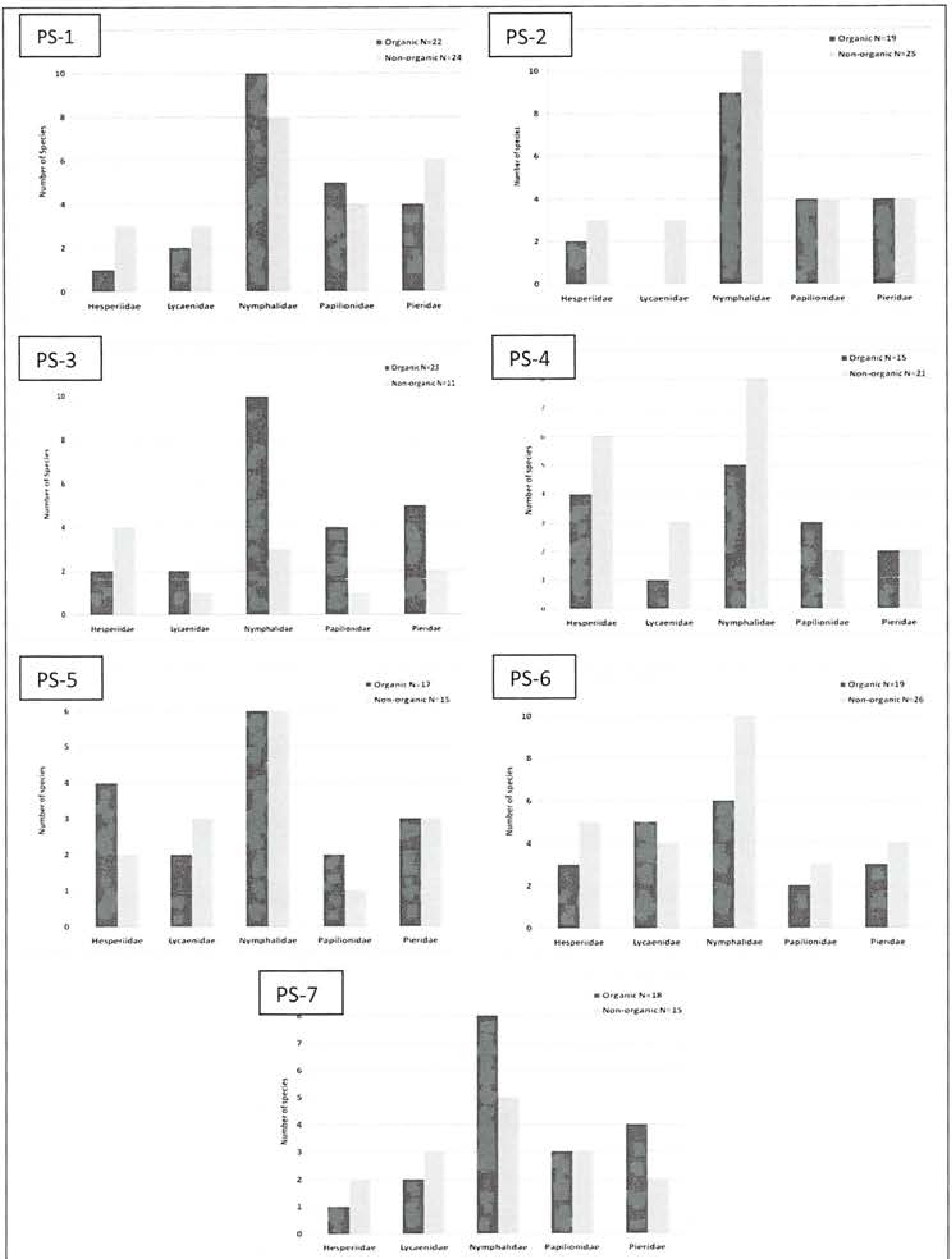


Figure 6.9: The family level comparison of species richness in butterfly communities of organic and non-organic regimes

6.2.4: Factors influencing butterfly community composition in paddy fields

The environmental variables and habitat parameters recorded (Appendix 7) during each sampling were used as independent variables and the community parameters *viz* Species Richness, Abundance, Shannon index, Simpson index, Dominance and Evenness were used as dependent variables and multiple stepwise regression models were developed. 5.5 to 9 % of the variance in Species Richness, Shannon diversity, Simpson diversity and dominance were explained by the regression models (Table 6.8 and 6.9). With every unit increase in total dissolved salts in water diversity was influenced positively. The species richness increased by a factor of 0.284, Shannon increased by a factor of 0.316, Simpson increased by a factor of 0.310 and Dominance decreased by a factor of 0.255 (Table 6.10).

Table 6.8: The butterfly community parameters and the extent of variation and its significance explained by the regression model

Dependent variables	Species Richness	Shannon	Simpson	Dominance
N	94	94	94	94
R	0.284	0.316	0.31	0.255
R Square	0.081	0.100	0.096	0.065
Adjusted R Square	0.071	0.090	0.086	0.055
Root MSE	3.476	0.548	0.1788	0.1538

Table 6.9: Analysis of Variance in community parameters of butterfly community

ANOVA						
Dependent variables		Sum of Squares	df	Mean Square	F	Sig.
Species Richness	Regression	97.854	1	97.854	8.101	.005
	Residual	1111.305	92	12.079		
	Total	1209.160	93			

ANOVA						
Dependent variables		Sum of Squares	df	Mean Square	F	Sig.
Shannon	Regression	3.074	1	3.074	10.228	.002
	Residual	27.650	92	0.301		
	Total	30.724	93			
Simpson	Regression	0.313	1	0.313	9.780	.002
	Residual	2.943	92	0.032		
	Total	3.256	93			
Dominance	Regression	0.152	1	0.152	6.424	.013
	Residual	2.176	92	0.024		
	Total	2.328	93			

Table 6.10: The co-efficients of explanatory variables for butterfly community parameter variations and their significance

Coefficients								
Dependent variables		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
Species Richness	(Constant)	5.170	0.799		6.472	0.000	3.584	6.757
	TDS	0.005	0.002	0.284	2.846	0.005	0.001	0.008
Shannon	(Constant)	1.257	0.126		9.978	0.000	1.007	1.508
	TDS	0.001	0.000	0.316	3.198	0.002	0.000	0.001
Simpson	(Constant)	0.606	0.041		14.749	0.000	0.525	0.688
	TDS	0.000	0.000	0.310	3.127	0.002	0.000	0.000
Dominance	(Constant)	0.338	0.035		9.549	0.000	0.267	0.408
	TDS	0.000	0.000	-0.255	-2.535	0.013	0.000	0.000

6.3 Discussion

6.3.1 Butterfly Community in paddy fields

The butterfly composition of any ecosystem is primarily influenced by the vegetation of that region. In the agro-ecosystems the butterflies also serve as pollinators and nutrient recyclers for crops (Borges *et al*, 2003; Schmidt and Roland, 2006; Marchiori and Romenowski, 2006). The paddy field ecosystem, although being a mono-cropping ecosystem, harbours quite a good number of species. The most common species are also the species that have paddy as their larval host plant. Most of the Hesperiids and few Nymphalids fall under this category. Soniya and Palot (2002), in their survey recorded 44 species of butterflies from paddy fields. The community they recorded is similar to this study with Nymphalidae being most speciose family and most of the Hesperiids recorded had paddy as larval host plants. A recent study in Maharashtra (Ganvir *et al*, 2017) also has similar composition with Nymphalids and Hesperiids dominating the ecosystem with low species number in Papilionids.

According to Siregar *et al* (2017) the insect diversity decreases across paddy growth stages. But in this study the butterfly diversity does not show the decreasing trend. There is variation in the butterfly species composition between the paddy growth stages. The increase in Hesperiids during flowering stage (PS-4) of paddy is probably due to dense vegetation of paddy in the fields, along with the flowers and the wet condition of the fields, all suitable conditions for their breeding. The Pierids are more in the initial stages of paddy growth and Lycaenids increase in the later stages. This is probably related to bund management practices and the change in bund vegetation during the cropping season (Giuliano *et al*, 2018).

6.3.2 The butterfly community in the paddy fields of the two cultivation regimes

There is significant similarity in the butterfly community composition between the two regimes. This is expected as the butterfly diversity seems to be more dependent on the vegetation at a larger scale than the fields themselves. But, when the paddy growth stages are compared there are significant differences in the butterfly composition between the two regimes in growth, flowering, milking and maturing stages. In the growth stage and milking stage, the organic regime is more diverse. But in both the stages, Hesperiids are more abundant in the non-organic regime. The Hesperiids recorded constitute the major group of species that have *Oryza sativa* as larval host plants. But, the family Hesperiidae is more speciose in the organic regime. The community composition during the flowering stage is significantly similar between the two regimes. The species responsible for most of the differences between the two regimes are Bush Hopper, Common Evening Brown, Bushbrown and Swifts. These are also species that are dependent on paddy as larval host plants. Few species belonging to Lycaenidae, Papilionidae and Pieridae were recorded only in organic regime. This makes organic regime more even and diverse. This is probably because of the bund vegetation variation between the two regimes.

6.3.3 Factors influencing the butterfly diversity in paddy fields

The total dissolved salts in water seems to be the only environmental factor effecting the butterfly diversity positively in the paddy fields and explains within 10 % of the variations seen in the Species Richness, evenness and abundance in the butterfly community. As the community is highly similar between the two regimes, probably the levels of Total Dissolved Salts in water in the field is the reason for the higher abundance of the rice dependent species in the non-organic regime after the growth stage due to fertilizer applications as they increase the salt content.

6.44: Conclusion

The paddy field ecosystem supports excellent butterfly diversity (48 species). The most common and abundant species are also species that depend on rice as larval food plant or species that have their larval food plants or preferred nectar plants. The butterfly community changes slightly across the paddy growth stages, based mostly on their seasonality. The butterfly community is highly similar between the organic and non-organic regime. The slight differences seen may be attributed to higher vegetation diversity in organic fields. Total dissolved salts in water influences the butterfly diversity positively in choosing their microhabitats. But none of the environmental and habitat variables considered in this study influenced the butterfly community extensively. The major influencing factor of the butterfly community is vegetation of the region. This makes the bund vegetation and other plants among the crop invaluable resources in terms of butterfly diversity conservation.

CHAPTER 7

ODONATA COMMUNITY OF PADDY FIELDS IN KADHIRAMANGALAM

7.1 Introduction

Odonates, being the predatory insects, are known to be beneficial and also use rice ecosystems as breeding grounds (Ueda, 1998, Chitra *et al*, 2002). Of the 482 species of odonates (Subramanian and Babu, 2017) seen in India, 57 species have been recorded from the rice fields of India (Appendix 5). Twenty six species of Zygopterans (Coenagrionidae – 19, Lestidae -4, Platycnemididae -1, Calopterigidae -1) and 32 species of Anisopterans (Libellulidae – 26, Aeshnidae- 4, Gomphidae- 2) (Sebastian *et al*, 2014; Ragnekar *et al*, 2010; Nair, 2011; Kandibane *et al*, 2003; Muhil, 2017; Arulprakash *et al*, 2017; Gunathilagaraj *et al*, 1999; Asaithambi and Manickavasagam, 2002; Talmale and Kulkarni, 2003; Rohmare *et al*, 2016; Saikia *et al*, 2016; Majumder *et al*, 2014; Palot *et al*, 2005; Emiliyamma *et al*, 2005, Kandibane *et al*, 2005) have been recorded from the paddy fields across India. Most of these studies are from Southern India especially in the Western Ghats region.

Most of these studies are works of species distribution of odonates, except for a few, (Arulprakash *et al*, 2017; Gunathilagaraj *et al*, 1999; Chitra *et al*, 2002) which look into the influence of environment and habitat on odonates. This chapter addresses two objectives of the study for odonate community with the following null hypotheses

1. There is no difference in the odonate community composition among the growth stages of paddy.
2. There is no difference in the odonate community of the paddy fields with reference to cultivation regime.

To achieve the objectives the results are explained as answers for four research questions which are

1. What is the species composition and population distribution of odonate community in paddy fields

2. How do the odonate community parameters correlate with the water level and water quality?
3. How do the odonate community parameters correlate with the different stages of crop growth?
4. Do the Odonate community vary between the two cultivation regimes? If so what are the influencing factors?

7.2 Results

The data collected in 94 transects over a period of two paddy cultivation cycles have been analyzed. The species accumulation curve reaches asymptote and Chao-2 estimates slightly higher number of species (Figure 7.1). This is expected as the data has been collected from a defined area.

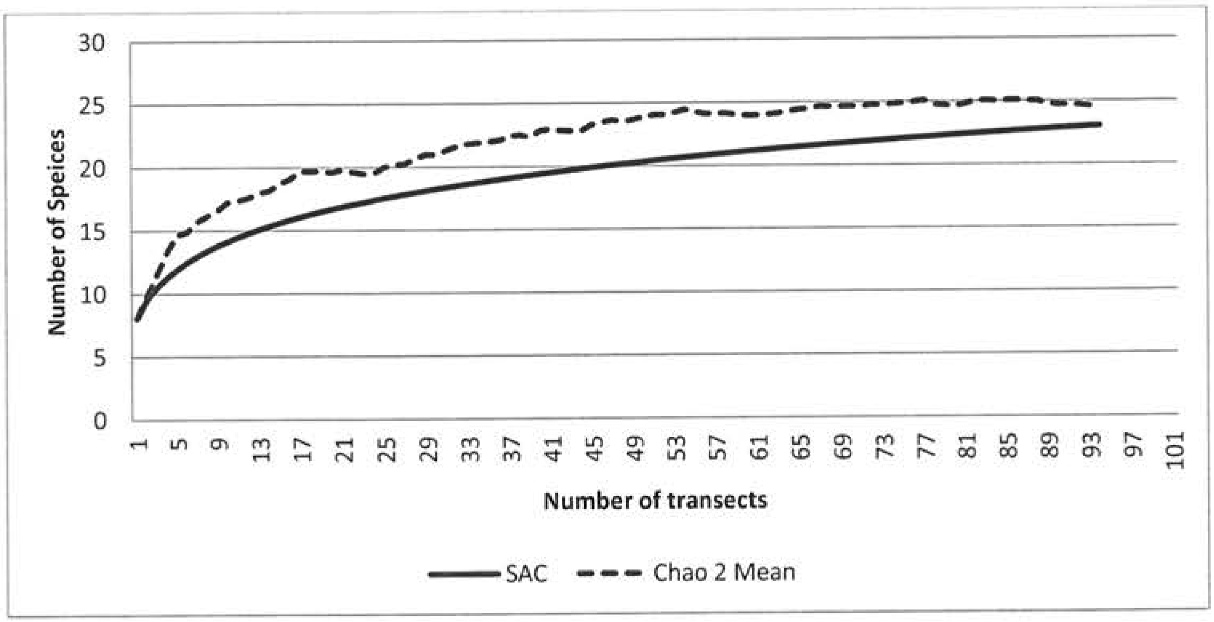


Figure 7.1: Species Accumulation Curve of Odonates in paddy fields

7.2.1 Odonate community in paddy fields.

7.2.1.1 Species Composition and Population distribution

Twenty three species belonging to five families were recorded from the paddy fields in Kadhiramangalam in 15526 encounters (Appendix 1). Of the 23 species recorded, 14 species (61%) fell under the sub-order Anisoptera and nine species (39%)

under Zygoptera. Among the families three were Anisopterans (Libellulidae, Gomphidae and Aeshnidae) and two were Zygopterans (Coenagrionidae and Lestidae). Libellulidae and Coenagrionidae were the most dominant families in terms of species richness and abundance.

Anisopterans dominated the paddy field ecosystem, with the family Libellulidae constituting 70% of the abundance followed by Zygopteran family Coenagrionidae with relative abundance of 30 %. The other three families have negligible abundance (Figure 7.2 a).

Libellulidae were the most speciose family with 12 species (52%), followed by Coenagrionidae with 8 species (35%) and the rest of the families represented by one species each (5%) (Figure 7.2 b). The dominance of Libellulids and Coenagrionids follow the global diversity patterns of odonates.

In the paddy fields, the most abundant species were *Ischnura rubilio* (Coenagrionidae) and *Pantala flavescens* (Libellulidae) with around 24% relative abundance each. These were followed by *Diplacodes trivialis* (22%), *Orthetrum sabina* (14%), *Crocothemis servilia* (8%), *Agriocnemis pygmaea* (5%) and the rest of species had below 1% relative abundance (Figure 7.3). The most common species were *Diplacodes trivialis* and *Orthetrum sabina* (100%) followed closely by *Ischnura rubilio, Crocothemis servilia, Pantela flavescens and Agriocnemis pygmeae* (Figure 7.4). Some species that had very low relative abundance (< 1%) had higher encounter rate. They were *Ceriagrion coromandelianum, Brachythemis contaminata, Tramea basilaris, Ischnura senegalensis, Rhyothemis variegata, Potamarcha congener, Tholymis tillarga* and *Trithemis pallidinervis* (Figure 7.5). All these constitute four Zygopteran species and 10 Anisopteran species. Two Anisopteran species, *Paragomphus lineatus* and *Urothemis signata* and three Zygopteran species, *Aciagrion occidentale, Pseudagrion rubriceps* and *Pseudagrion decorum* were recorded only once during the study. *Acisoma ponorpoides* was recorded twice during the whole study. One new addition to the list of species recorded from paddy fields in India (Appendix 6) was *Paragomphus lineatus*. The global diversity in the paddy fields is 1.759 (Shannon H) with Gibson's Eveness 0.2529 and dominance 0.197.

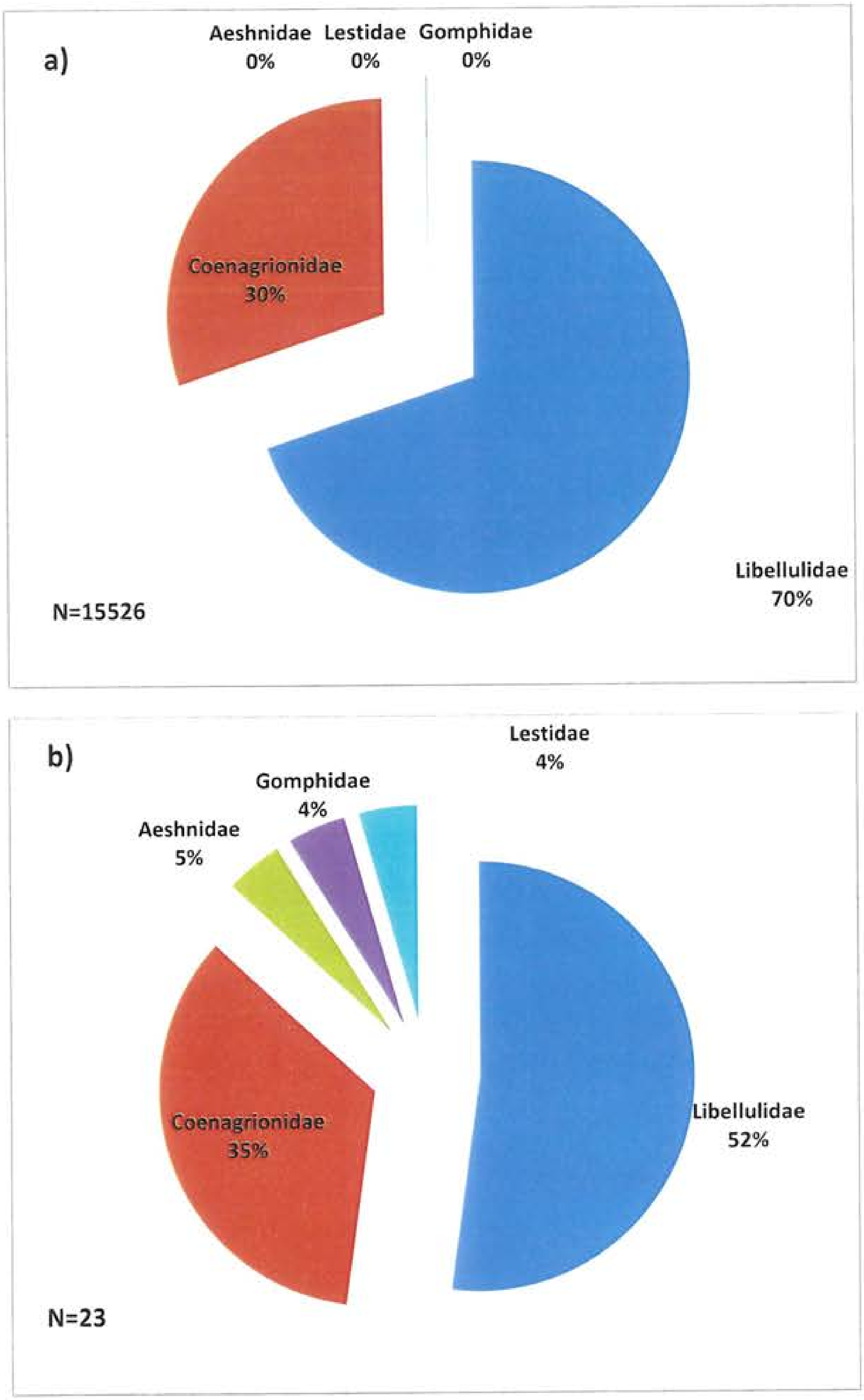


Figure 7.2: Family level classification of odonates in paddy fields based on (a) relative abundance and (b) species richness

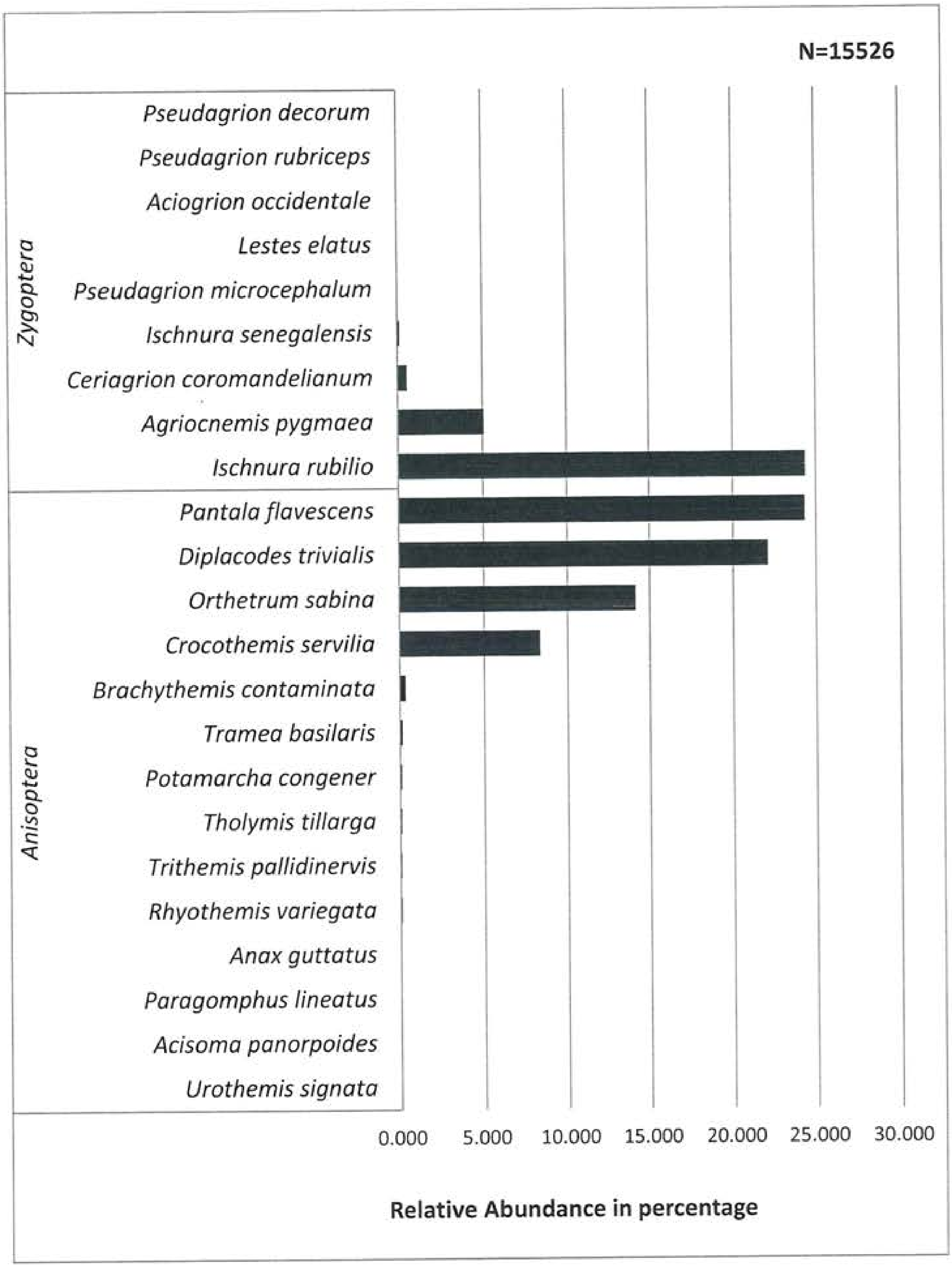


Figure 7.3: Relative abundance of odonates in paddy fields

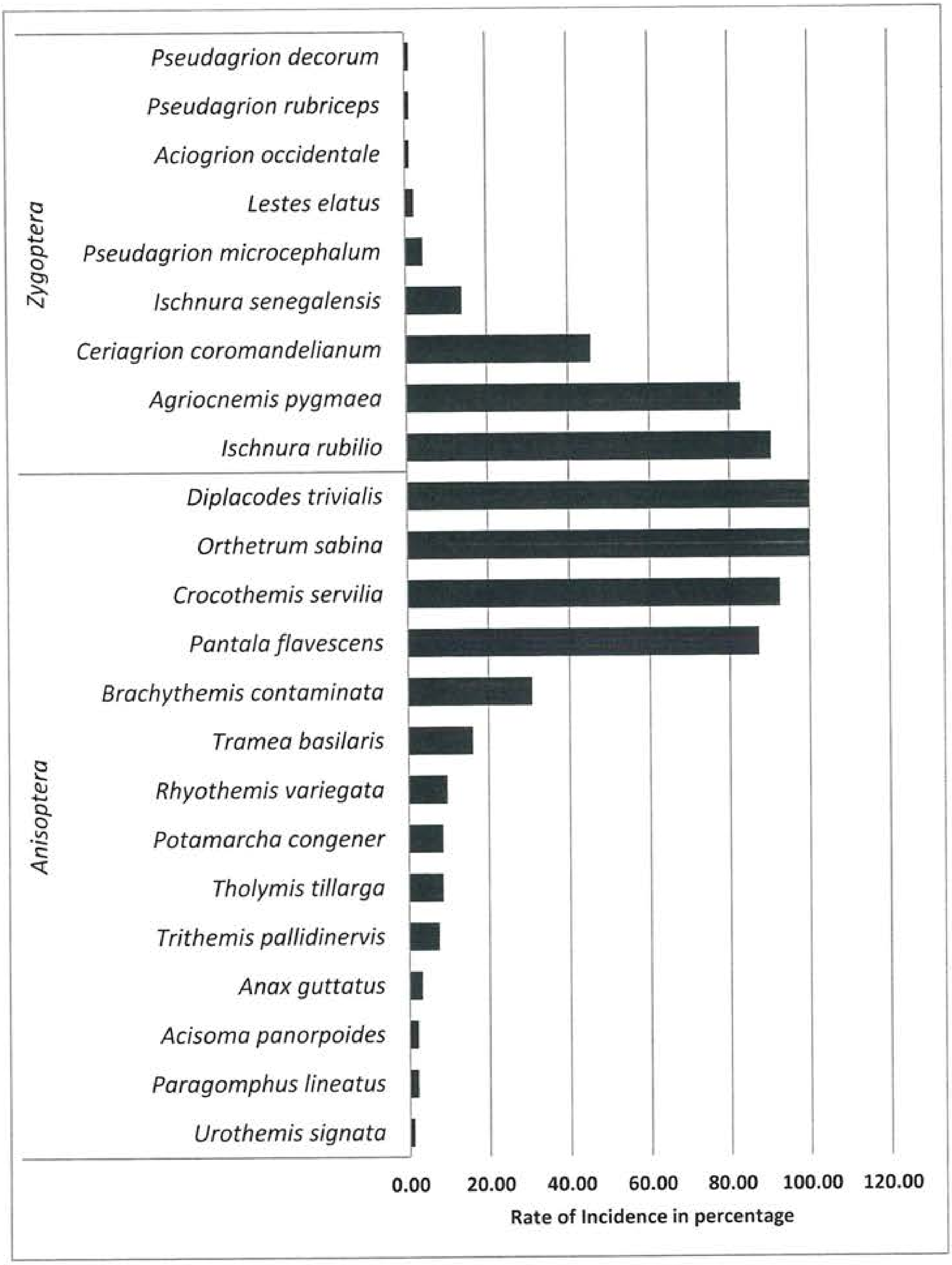


Figure 7.4: The Rate of incidence of odonate species in paddy fields sampled in 94 transect counts

7.2.1.2 Variations in odonate community across paddy growth stages

When the odonate community profile and diversity were compared across the paddy growth stages the following results were obtained.

The initial four stages, PS-1 through PS-4, contributed to over 80% of the odonate abundance in the fields. The initial three growth stages of paddy (PS-1 to PS-3) had higher species richness compared to the rest with the least abundant and speciose stage being PS-7.The mean encounter was highest in PS-3, the growth stage of paddy and the highest species/ transect in PS-2 followed by PS-1. PS-7 had least species richness, abundance and their means with higher variance (Table 7.1)

When the diversity indices were compared across the paddy growth stages PS-1 had the highest species richness with 17 species closely followed by PS-2 with 16 species. But the Shannon and evenness were higher in PS-2. So, PS-2 supports higher Odonate diversity among the seven paddy growth stages. The abundance and also the numbers of Anisopterans and Zygoterans increased from PS-1 through PS4 and showed a drastic decrease from PS-5 to PS-7. The Anisopterans were predominant in each growth stage of the paddy over the Zygopterans in terms of species richness as well as abundance (Table 7.2).

Table 7.1: Species and population demographics of odonates across paddy growth stages

Paddy growth stages	PS1	PS2	PS3	PS4	PS5	PS6	PS7
No. of transects	14	16	15	15	10	14	10
Abundance	2034	2905	4742	3215	1263	1093	274
Species Richness	17	16	15	13	9	11	8
Min encounters/ transect	50	11	120	71	76	23	5
Max encounters/ transect	290	297	502	487	161	138	71
Min species/ transect	4	5	6	5	5	4	2
Max species/ transect	11	11	11	9	8	9	7
Mean encounters/ transect	145.28 ±65.06	181.56 ±79.84	316.13 ±121.81	214.33 ±128.42	126.3 ±23.92	78.07 ±30.35	27.4 ±21.25
Coeff. Var (encounters) in %age	44.78	43.97	38.53	59.91	18.94	38.87	77.57
Mean species/ transect	7.64 ± 1.9	8.62 ± 1.7	7.6 ± 1.35	7.53 ± 1.2	6.6 ± 0.96	6.21 ± 1.36	4.4 ± 1.34
Coeff. Var (species) in % age	24.93	19.8	17.7	16.53	14.63	22.02	30.67

Table 7.2: The Species richness and diversity of odonates across paddy growth stages

Paddy growth stages	PS-1	PS-2	PS-3	PS-4	PS-5	PS-6	PS-7
No. of transects	14	16	15	15	10	14	10
Species Richness	17	16	15	13	9	11	8
Anisopteran Species Richness	12	10	10	8	6	6	5
Zygopteran species Richness	5	6	5	5	3	5	3
Abundance	2034	2905	4742	3215	1263	1093	274
No. Of Anisopterans	1790	2229	3027	1680	990	879	243
No. Of Zygopterans	244	676	1715	1535	273	214	31
Dominance_D	0.2526	0.2333	0.2326	0.3164	0.3246	0.2297	0.3923
Simpson_1-D	0.7474	0.7667	0.7674	0.6836	0.6754	0.7703	0.6077
Shannon_H	1.631	1.699	1.645	1.409	1.365	1.649	1.31
Evenness_e^H/S	0.3006	0.3418	0.3453	0.3148	0.4352	0.4727	0.4632

The relative abundance trends in the odonate families also showed the domination of two families Libellulidae (Anisoptera) and Coenagrionidae (Zygoptera) across the paddy growth stages making up to 98% of the odonate abundance in each of the paddy growth stages. The Libellulids showed a decreasing trend from PS-1 through PS-4 as the Coenagrionids expressed an increasing trend from PS-1 to PS-4 with both the families having 50% relative abundance each in PS-4. Then the Coenagrionids reduced and Libellulids increased from PS-5 to PS-7. The rest of the families were represented from PS-1 to PS-4 and absent later on (Figure 7.5).

7.2.1.3 Testing of similarity in odonate assemblages across paddy growth stages

The Analysis of Similarity (ANOSIM) using Bray-curtis index showed the global variation of R=0.41 which was significant. This rejected the null hypothesis, which states, 'there is no change in the odonate community composition between the paddy growth stages'. There was a negligible change in the odonate community composition between PS-1 and 2 and PS-2 and 3 with very low significant R values (<0.2) and a drastic significant change from PS-3 to PS-4 (R= 0.31), PS-5 to PS-6 (R=0.26) and between PS-6 and PS-7 (R=0.37) with R values above 0.25 (Table 7.3).

Over 75% of the dissimilarity was influenced by three species *viz. Pantela flavescens* (29.95%), *Ischnura rubilio* (26.81%) and *Diplacodes trivialis* (20.06%). Other species that influence were *Crocothemis servilia* (8.748%), *Orthetrum sabina* (7.859%), *Agriocnemis pygmaea* (4.59%) and *Pseudagrion coromandelianum* (0.54%) (Appendix 1).

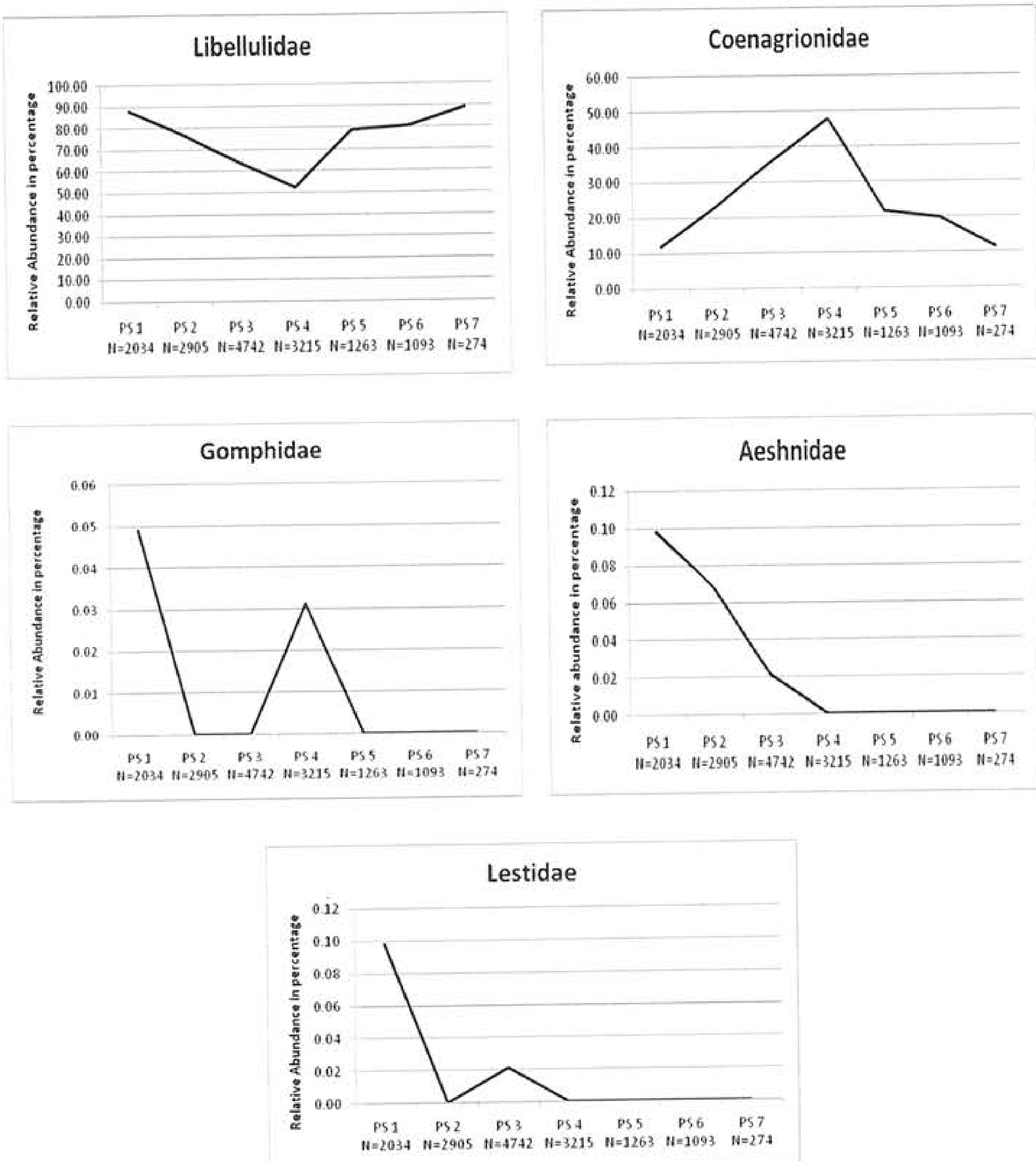


Figure 7.5: Relative abundance trends of odonate families across paddy growth stages

Table 7.3: Analysis of Similarity using Bray-Curtis index between pairs of paddy growth stages. Permutation N = 9999, R= 0.4124, p= 0.0001. p value is less than 0.05 between all pairs in bold.

R values	PS1	PS2	PS3	PS4	PS5	PS6
PS2	**0.1007**					
PS3	**0.3007**	**0.1631**				
PS4	**0.5102**	**0.3896**	**0.3142**			
PS5	**0.5199**	**0.5889**	**0.4697**	0.1225		
PS6	**0.2161**	**0.4291**	**0.5771**	**0.4653**	**0.2643**	
PS7	**0.66**	**0.7388**	**0.8198**	**0.7764**	**0.6772**	**0.3773**

7.2.2 Relationship between odonate diversity and water parameters

Table 7.4: Correlation between odonate community parameters and water parameters. The significant Pearson's Correlation value ($p \leq 0.05$) is given in bold.

	Species Richness	Encounters	Dominance _D	Shannon_ H	Evenness e^$\bar{H}$/S
Water Temp in °C	0.088003	0.12033	0.008795	0.076657	0.047463
pH in water	-0.12037	0.030599	-0.12167	0.036702	0.13576
Total dissolved salt in water in ppm	-0.048131	-0.079436	**0.25793**	-0.18501	-0.12071
Water level in cms	0.47816	**0.23314**	-0.1811	0.28603	**-0.23982**

The community parameters were tested for correlation with the water parameters. The species richness and Shannon diversity did not correlate significantly with any of the water parameters. Dominance was slightly positively influenced by Total dissolved salts in water. Water level was seen to influenced encounters proportionately and evenness inversely (Table 7.4).

7.2.3 Variations in odonate community between the cultivation regimes and among paddy growth stages

7.2.3.1: Species composition and community profile of odonates in the two regimes

Nineteen odonate species belonging to five families were recorded from 51 transects and 6253 encounters in organic regime. Of the nineteen species, 15 were Anisopterans belonging to three families and four were Zygopterans from two families. In the non-organic fields, 21 odonate species belonging to five families were recorded from 43 transects in 9273 encounters. Among these 14 species were Anisopterans belonging to three families and nine species were Zygopterans belonging to two families.

Both the regimes were predominated by Libellulids, followed by Coenagrionids in abundance as well as species richness (Figure 7.6). The Aeshnidae (*Anax guttatus*), Gomphidae (*Paragomphus lineatus*) and Lestidae (*Lestes elatus*) families were even in both regimes with one species each. The organic regime had one Libellulid species more and the non-organic regime had three more Coenagrionid species than the other (Figure 7.7).

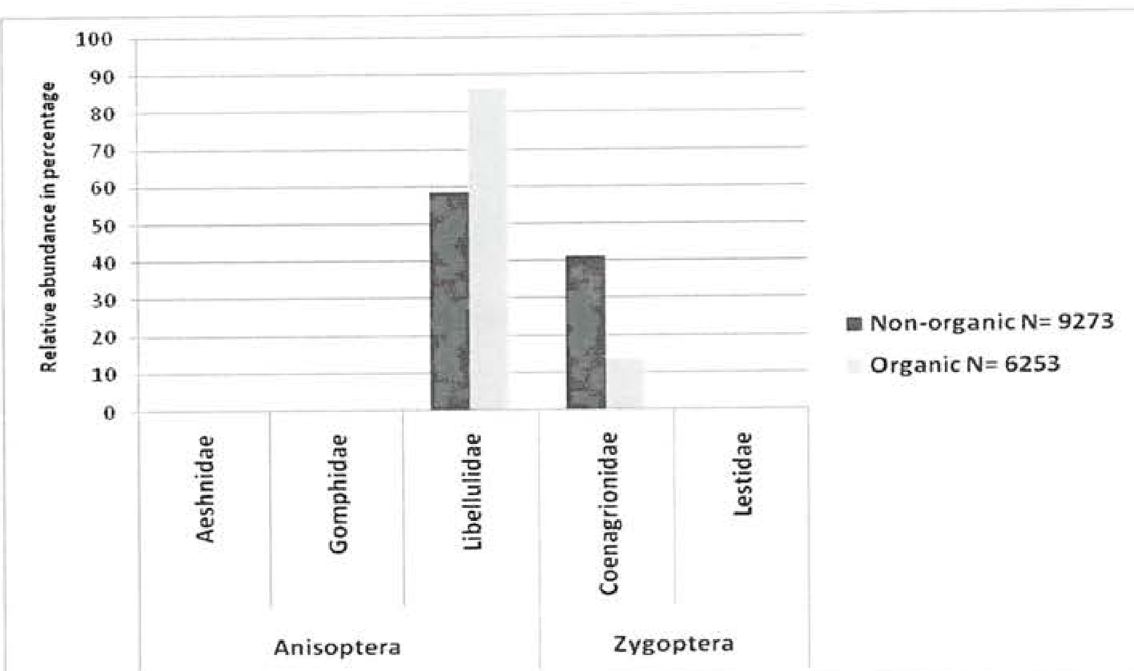


Figure 7.6: Family level comparison of Odonates in organic and non-organic regimes

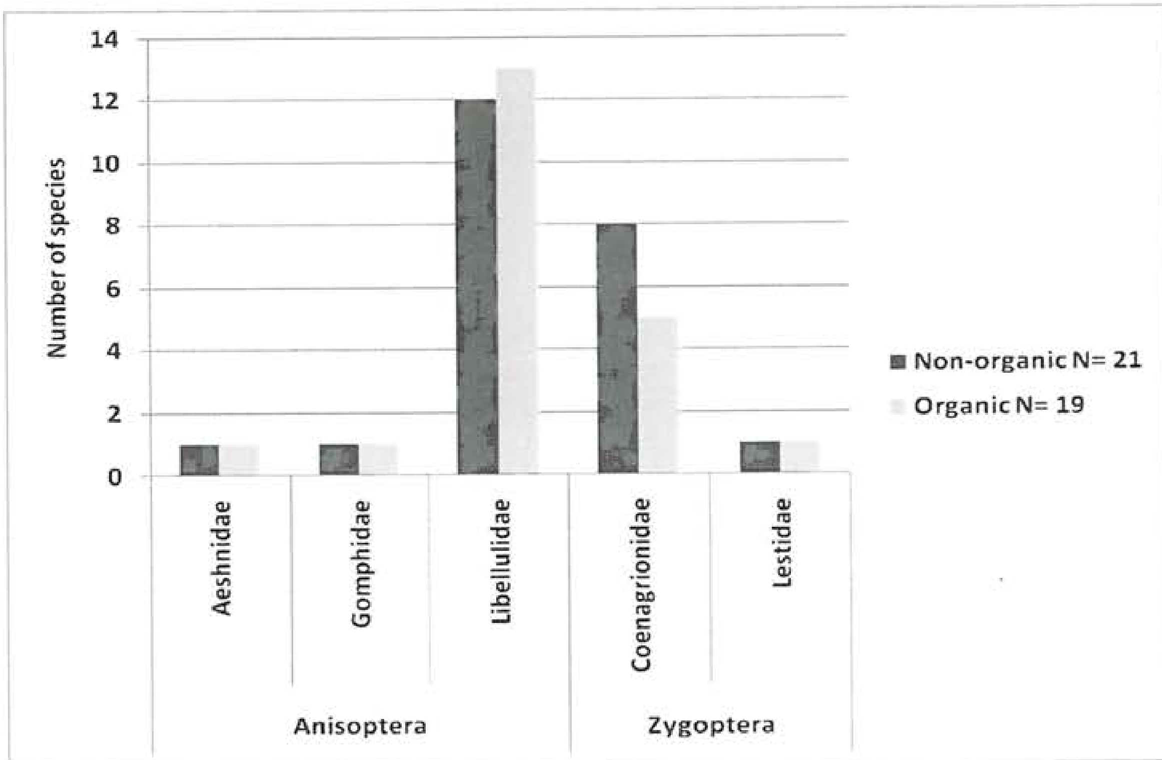


Figure 7.7: The odonate species composition in organic and non-organic regimes.

The two Libellulid species, recorded solely from organic regime, *Urothemis signata* and *Acisoma ponorpoides*, were singleton and doubleton records respectively. *Potamarcha congener* was recorded only from non-organic regime.

The diversity indices showed lower species richness in odonate community of organic regime, with a difference of two species only. But it had higher Shannon and Evenness values with lower Dominance than non-organic field odonate community. The abundance was lower with higher sample size in the organic fields (Table 7.5).

Table 7.5: The diversity indices of odonate community in organic and non-organic regimes

	Number of Transects	Number of encounters	Species Richness	Number of Families	Dominance_D	Simpson_1-D	Shannon_H	Evenness_e^H/S
Organic	51	6253	19	5	0.2003	0.7997	1.765	0.3073
Non-organic	43	9273	21	5	0.2378	0.7622	1.625	0.2418

7.2.3.2 Species composition and community profile among each paddy growth stage between the two regimes

The odonate community had higher species richness and Shannon values in the organic regime in the initial three paddy growth stages (Land preparation/ sapling, transplantation and growth stages) with lower dominance and higher evenness in PS-1 and PS-2 only. In PS-3 organic regime has higher dominance and lower evenness than non-organic field odonate community. In the organic field the odonate abundance was very low in PS-1 and PS-2 and increased to be nearly even with non-organic regime in PS-3 and again reduced gradually along with non-organic from PS-4 to be slightly higher in PS-7. Other community parameters like species richness, Shannon and Evenness indices were lower in organic regime in PS-5 and PS-6 with higher dominance than in non-organic regime. PS-4 had lower species richness and abundance in organic regime but also had very high evenness and higher Shannon index with lower Dominance. The odonate community of organic regime had higher species richness, abundance, evenness and Shannon values with lower dominance than non-organic regime in PS-7 (Table 7.6).

When the null hypothesis, 'there is no change in odonate community composition between organic and non-organic cultivation regimes' was tested using ANOSIM with Bray-curtis index between the two regimes, the R value was significant.

Table 7.6: The community parameters of odonata across the paddy growth stages in the two cultivation regimes

Paddy growth stages		Number of Transects	Number of encounters	Number of Species	Number of Families	Dominance _D	Simpson _1-D	Shannon_ H	Evenness_e ^H/S
PS1	Organic	7	766	13	4	0.2969	0.7031	1.55	0.3623
	Non-organic	7	1268	12	2	0.3261	0.6739	1.47	0.3625
PS2	Organic	7	846	15	2	0.1898	0.8102	1.821	0.4753
	Non-organic	9	2059	14	3	0.2698	0.7302	1.578	0.3461
PS3	Organic	9	2322	12	2	0.3872	0.6128	1.305	0.3073
	Non-organic	6	2420	11	3	0.367	0.633	1.289	0.3298

Paddy growth stages		Number of Transects	Number of encounters	Number of Species	Number of Families	Dominance _D	Simpson _1-D	Shannon_ H	Evenness_e ^H/S
PS4	Organic	9	1095	10	3	0.2264	0.7736	1.682	0.5374
	Non-organic	6	2120	13	4	0.4187	0.5813	1.122	0.2559
PS5	Organic	5	612	8	2	0.4118	0.5882	1.235	0.4296
	Non-organic	5	651	7	2	0.296	0.704	1.347	0.5495
PS6	Organic	8	460	9	2	0.3285	0.6715	1.373	0.4384
	Non-organic	6	633	11	2	0.2111	0.7889	1.705	0.4999
PS7	Organic	6	152	7	2	0.3013	0.6987	1.43	0.597
	Non-organic	4	122	6	2	0.6059	0.3941	0.887	0.4046

Table 7.7: Analysis of Similarity using Bray-Curtis index between pairs of paddy growth stages of the two cultivation regimes. Permutation N = 9999, R= 0.1264, p= 0.0003.

Paddy growth stages	R values	p values
PS-1	**0.6327**	0.0003
PS-2	**0.3782**	0.0017
PS-3	**0.9877**	0.0004
PS-4	**0.8736**	0.0002
PS-5	**0.636**	0.0134
PS-6	**0.3915**	0.0045
PS-7	-0.0019	0.4079

This rejected the null hypothesis. The R value of 0.12 was very low, indicating the community composition was highly similar between the two regimes. But, when each stage was tested against their counterpart in the two regimes, PS-1, 2, 3, 4, 5 and 6 show significant variation with R values ranging from 0.3 to 0.98 (Table 7.7).

The relative abundance (Figure 7.9) seen during each growth stage showed predominance of Libellulids and Coenagrionids in both the regimes. The other families like Aeshnidae, Gomphidae and Lestidae were recorded in very low numbers in PS-1, 2 and 4. The variations in species richness between the cultivation regimes in each paddy growth stage were also compared (Figure 7.8).

In the Land preparation/sapling (PS-1) the Libellulids were more abundant and less speciose in the organic regime, whereas, the Coenagrionids were more abundant and less speciose in the non-organic regime. Species belonging to Lestidae and Gomphidae were recorded from organic field during this stage. The species contributing to over 80% of these changes were *Pantela flavescens, Orthetrum sabina, Diplacodes trivialis* and *Ischnura rubilio*. All the species had higher mean abundance in non-organic fields (Appendix 4).

In the transplantation stage (PS-2) the Libellulids were higher in number as well as more speciose in organic regime, whereas, the Coenagrionids were more abundant and speciose in non-organic regime. Lestidae and Aeshidae were recorded in very low numbers from non-organic fields. There was around 45% dissimilarity between the two regimes influenced by *Pantela flavescens, Ischnura rubilio, Diplacodes trivialis* and *Orthetrum sabina*. All the species except *Orthetrum sabina* had higher mean abundance in non-organic regime (Appendix 4).

In the growth stage the Coenagrionids dominate the non-organic regime constituting over 60% of the abundance, whereas, it is less than 10% in the organic field. The Libellulids dominated the organic fields with very high abundance and also higher species richness in organic fields. Only these two families were seen in this stage. There was more than 75% dissimilarity in the odonate composition between the two regimes. Over 40% of this difference was due to the very high mean abundance of *Ischnura rubilio* in non-organic fields with a 20 % contribution from *Pantela flavescens* having very high mean abundance in organic fields and another 15% contribution by *Diplacodes trivialis* with a higher mean abundance in non-organic fields.

In the flowering stage (PS-4), a similar trend to PS-3 was maintained in abundance. Non-organic fields were more speciose among both Libellulidae and

Coenagrionidae. Aeshnidae and Gomphidae were represented by very low numbers in organic and non-organic regime respectively. Sixty percent of dissimilarity (58%) seen between the two regimes was influenced by *Ischnura rubilio* with additional 20% by *Diplacodes trivialis*. Both the species had higher mean abundance in non-organic regime than in the organic regime.

In the milking stage (PS-5) the Libellulids dominated both the regimes with over 70% abundance in organic and lower abundance in non-organic regime with even species richness in both. The Coenagrionids were more abundant and less speciose in non-organic regime when compared with organic. There was an overall 36% dissimilarity was odonate composition between the regimes. Over 80% of this dissimilarity was due to three species *Diplacodes trivialis, Ischnura rubilio* and *Orthetrum sabina* with all having higher mean abundance in non-organic regime.

In the maturing stage (PS-6), the abundance of Libellulids and Coenagrionids followed the pattern seen in PS-5. But the Coenagrionids were more speciose in non-organic regime. This stage shows an overall average dissimilarity in odonate community composition between the two regimes. Over 80% of the difference is due to higher mean abundance of *Pantela flavescens, Orthetrum sabina, Ischura rubilio* and *Agriocnemis pygmaea* in the non-organic regime (Appendix 4).

In the drying and harvesting (PS-7) stage, both the regimes were dominated by Libellulidae with over 90% abundance. But Coenagrionids were more abundant in organic fields, whereas, they have very low abundance in non-organic fields. They were also more speciose in organic fields. Libellulids were more speciose in non-organic fields. The difference seen in composition between the two regimes in this stage was not significant (Table 7.7).

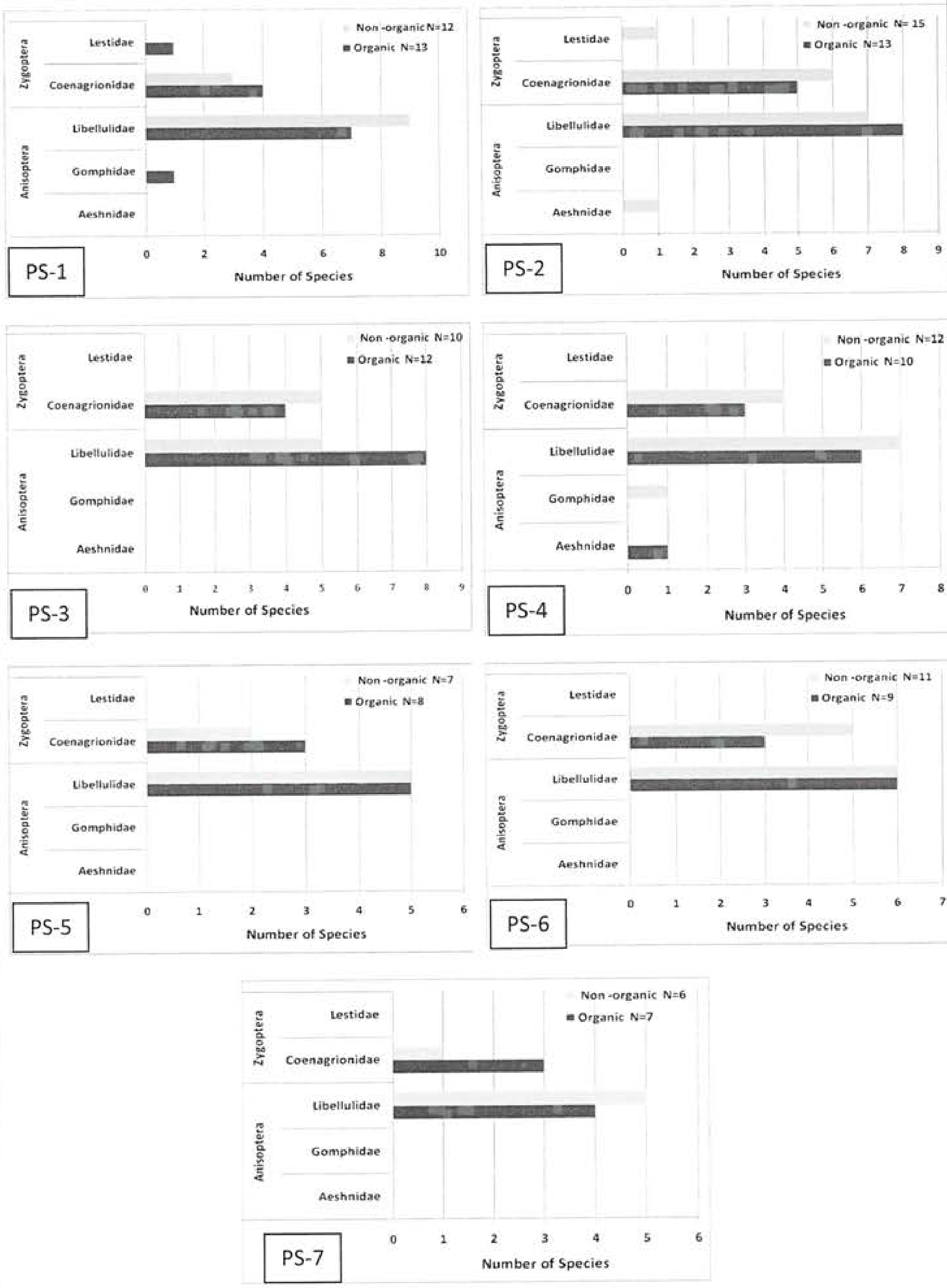


Figure 7.8: Family level comparison of species composition of odonate community in organic and non-organic regimes across the paddy growth stages

Table 7.9: Analysis of Variance in Species Richness of Odonate community

ANOVA					
Species Richness	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	122.255	2	61.127	27.889	.000[c]
Residual	199.458	91	2.192		
Total	321.713	93			

Table 7.10: The co-efficients of explanatory variables for Species richness variation in odonate community and their significance

Coefficients							
Species Richness	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
(Constant)	7.932	0.507		15.647	0.000	6.925	8.939
Paddy growth stages	-0.412	0.087	-0.433	-4.714	0.000	-0.585	-0.238
Water level	0.568	0.182	0.287	3.127	0.002	0.207	0.930

Table 7.11: Analysis of Variance in number of encounters of Odonate community

ANOVA					
Encounters	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	489278.282	3	163092.761	17.895	.000[d]
Residual	820266.994	90	9114.078		
Total	1309545.277	93			

Table 7.12: The co-efficients of explanatory variables for Encounter numbers variation in odonate community and their significance

Coefficients							
Encounters	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	100.340	43.038		2.331	0.022	14.837	185.843
Water temperature	3.385	1.065	0.302	3.179	0.002	1.270	5.501
Cultivation regime	84.205	19.828	0.355	4.247	0.000	44.812	123.598
Paddy growth stages	-14.757	5.763	-0.243	-2.561	0.012	-26.206	-3.309

Table 7.13: Analysis of Variance in Shannon of Odonate community

ANOVA					
Shannon	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.031	1	1.031	15.862	.000[b]
Residual	5.980	92	0.065		
Total	7.012	93			

Table 7.14: The co-efficients of explanatory variables for Shannon variation in odonate community and their significance

Coefficients							
Shannon	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	1.522	0.057		26.524	0.000	1.408	1.636
Paddy growth stages	-0.054	0.014	-0.383	-3.983	0.000	-0.081	-0.027

Table 7.15: Analysis of Variance in Evenness of Odonate community

ANOVA					
Evenness	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	0.542	2	0.271	14.296	.000[c]
Residual	1.724	91	0.019		
Total	2.266	93			

Table 7.16: The co-efficients of explanatory variables for Evenness variation in odonate community and their significance

Coefficients							
Evenness	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
(Constant)	0.729	0.034		21.360	0.000	0.661	0.796
Total dissolved salts in water	0.000	0.000	-0.383	-4.187	0.000	0.000	0.000
Cultivation Regime	-0.094	0.029	-0.300	-3.283	0.001	-0.150	-0.037

7.3: Discussion

7.3.1: Odonate community in paddy fields

Odonates are generally known to be less diverse in a defined area when compared with other indicator macro-invertebrate species (Oertli, 2008). The twenty three species recorded from the paddy fields during the study is a result of exhaustive sampling of odonates from a single ecosystem in a limited area. The Anisopterans are more speciose and abundant than Zygopterans. This follows the global trend of odonate composition.

The Libellulidae is the most speciose and abundant family followed by Coenagrionidae which is a character of global odonate community composition (Muhil, 2017). But, in the paddy fields these two families predominated to the point of exclusion of all other families. Probably because Coenagrionid and Libellulid species prefer slow-moving water and emergent vegetation (McPeek, 2008)

The new addition to the paddy fields of India from this study, *Paragomphus lineatus*, was recorded in the paddy fields during the growing season of 2015-16, when the canals and rivers were dry in that season. *Paragomphus lineatus* being a riverine species, probably used the fields as alternative habitat. Studies have shown that odonate composition is dissimilar between lentic and lotic systems with few common species distributed between the two (McPeek, 2008). Most of the species recorded from paddy fields are eurotypic and colonise any wetland habitat easily.

Iscnhura rubilio and *Pantela flavescens* are the most predominant species. This is probably because *Pantala flavescens* were recorded in swarms during their migratory period. Species like *Diplacodes trivialis* and *Orthetrum Sabina* are the most common species in the paddy fields among the Anisopterans and *Ischnura rubilio* among the Zygopterans. Species like *Ceriagrion coromandelianum*, *Brachythemis contaminata*, *Tramea basilaris*, *Ischnura senegalensis*, *Rhyothemis variegata*, *Potamarcha congener*, *Tholymis tillarga*, *Trithemis pallidinervis* and *Agriocnemis pygmaea* were fairly common. These 13 species (9 Libellulids and 4 Coenagrionids) can be categorised as paddy field species. Rest of the Zygopterans were recorded in very low numbers.

Across the paddy growth stages, there is a gradual significant change in the odonate community composition. The initial three stages are more speciose and abundant and deplete later on. This is probably because of the wetland condition in the initial stages of paddy growth. Throughout the stages Libellulids are predominant but the abundance of Coenagrionids increase from PS-1 through PS-3 going even with Libellulidae in PS-4. Vegetation cover is known to positively influence the use of a habitat by odonates, especially Zygopterans (Muhil, 2017). The lower species richness and abundance during drying/ harvesting stage (PS-7) is probably because of lack of water or moisture and also dense vegetation cover in the fields (Remsburg, 2008), where only a few species are accommodated. This is also seen in the correlation (Table 7.4) where encounters increase with increase in water level.

7.3.2 Comparison of the odonate community in paddy fields of organic and non-organic regimes and across paddy growth stages

Soniyagandhi and Kumar (2014) have studied that the application of pesticides impacts the odonate populations negatively in paddy fields. But when the overall community composition is compared between two regimes, in this study, it seems very similar, with low R value which is also significant. The organic regime with 19 species has lower number of species than non-organic regime (21 species), but Evenness and Shannon indices are higher in organic regime with lower dominance. The difference in species richness can also not be considered significant here as three Coenagrionid species recorded in non-organic regime only and two Libellulid species recorded from organic fields were in very low numbers (including singletons and doubletons) except *Acisoma panorpoides*. Arulprakash and Gunathilagaraj (2011) have suggested few species as indicators of agrochemical usage and *Acisoma panorpoides* is one of them. This indicates that the organic regime has higher diversity than non-organic regime but also more even, providing a more stable habitat.

When each paddy growth stage from one regime was compared with their counterparts in the other regime, there was a significant difference in community composition between the two in all growth stages except drying/ harvesting (PS-7) stage. In all the stages, Coenagrionids were dominant in the non-organic regime, whereas, the Libellulids were dominant in the organic regime, going along with the global community patterns. This is probably because of the way both the regimes are managed. In the organic regime, the land is prepared earlier with stagnant water and tilling the land with water of around 3 cms. The transplanted saplings are also spaced farther away in the organic fields. In the non-organic regime, the dry fields are let with water and tilled in a short time just before transplantation. The rush of flowing water into the fields and higher vegetation cover in the non-organic regime probably encourages the Coenagrionids to colonise more in this area. Libellulids are known to be effected by higher shade cover (Remsburg *et al*, 2008), reducing their numbers in non-organic field. The differences seen in the community through PS-1 to PS-6 are due to variations in species *Ischnura rubilio, Pantela flavescens, Orthetrum sabina* and *Agriocnemis pygmaea*. Of these *Pantela flavescens* and *Orthretum sabina* vary in the mean abundance being higher in both organic and non-organic alternatively. *Ischnura rubilio* is consistently higher in non-organic regime.

7.3.3 The factors influencing the odonate community in paddy fields

As the paddy growth progress the species richness, abundance, evenness and Shannon diversity of odonate community reduces. Species richness is also influenced positively by water level. From this we can associate that availability of water is a major influencing factor in deciding the odonate community composition in the paddy fields (McPeek, 2008). As the habitat goes drier certain eurotypic species dominate the ecosystem contributing to increase in dominance. Water temperature positively influences encounters whereas Total dissolved salts in water inversely influence the evenness. Water temperature is considered the most positively influencing environmental variable of odonate diversity (Kietzka *et al*, 2016). The odonates in lentic systems are known to be positively influenced by water temperature and negatively by conductivity (Muhil, 2017). As conductivity is directly proportional and correlated to Total dissolved salts in water (Marandi *et al*, 2013) the increase in Total Dissolved Salts leading to decrease in evenness of the odonate community in paddy field ecosystem is in tandem with previous study (Muhil, 2017). The change of regime from organic to non-organic increases the abundance but decrease the evenness. This shows that the organic regime has more stable populations and community composition than non-organic regime.

7.4 Conclusion

Paddy fields support a decent odonate diversity. This is mostly composed of eurotypic species dominated by Libellulids and Coenagrionids and a few seasonal colonisers. Paddy field ecosystem can serve as a temporary habitat for riverine species but not as an alternative habitat. The cultivation regime is a factor influencing the odonate diversity in paddy fields. The organic regime supports higher and more stable odonate assemblages than the non-organic regime.

CHAPTER 8

SUMMARY

Agro-ecosystems cover 43% of India's land area and also harbour wildlife. The paddy is a unique ecosystem that is known to support diverse wildlife in a short period, being a man-managed ecosystem. The change in management practices are known to impact the biodiversity of agro-ecosystems. The biodiversity supported by the paddy fields of Kadhiramanagalam were studied using select indicator taxa *viz.* birds, butterflies and odonates and their communities were compared between two cultivation regimes *viz.* Organic and non-organic, with the following objectives

1. To study the Community structure and variability of select faunal indicator taxa supported by the paddy fields.
2. To compare the changes in the community of select faunal taxa across paddy growth stages between organic and non-organic paddy cultivation regimes.

These objectives were achieved by collecting species abundance data on birds, butterflies and odonates, during two cropping cycles of paddy by strip transect method. One Km transect with 50 m breadth was marked in paddy fields under organic and non-organic cultivation regimes each. The vegetation in the sampling area was recorded. The environmental, habitat conditions and physico-chemical water parameters were recorded during each sampling.

Eighty seven species of birds belonging to 41 families and 13 orders were recorded from the study area. Passerines were the predominant group in terms of species and abundance. Two near threatened species were recorded, viz. *Threskiornis melanocephala* and *Falco chiquera*. Black Drongo, Common Swallow, White-breasted Kingfisher, Common Myna, Zitting Cisticola and Indian Pond Heron were the most common and abundant species in the paddy fields of Kadhiramangalam. Granivores constitute 14% of the species but 63 % of total encounters. 32% of the bird species recorded were wetland dependent species constituting 20% of total encounters belonging to 13 families and seven orders. Twenty two species were migrants to the study area and 19 species were partial migrants. Of these, 22 species were wetland dependent.

There is a significant change in the bird community composition across the paddy cultivation cycle. The wetland dependent species, granivores and insectivores play a major role in these changes. These changes in community composition can be attributed to change in field condition, crop growth stage and food and foraging options for insectivores.

There is a significant difference in the bird community between organic and non-organic cultivation regimes. The organic regime is much diverse and more populated in comparison with non-organic regime in the overall community composition as well as between corresponding paddy growth stages. The factors influencing the bird community in paddy fields are the cultivation regime, Total Dissolved Salts in water, water temperature, weather and habitat (wetland, wet and dry). The organic regime influences the Species richness, encounters and Shannon index positively. So, we can say that organic regime supports higher bird diversity than non-organic paddy fields. The changes in the micro and macro-habitat, or niche variation, in the paddy field ecosystem is a major factor in determining the bird community composition in the paddy fields.

Forty eight butterfly species belonging to five families have been recorded from the paddy fields of Kadhiramangalam. It constitutes 16 species of family Nymphalidae, 10 Lycaenidae species, eight Hesperiidae and Pieridae species each and six species belonging to family Papilionidae. The common species were Common Evening Brown, Peacock Pansy, Bush Hopper and Common Bushbrown. These species either had *Oryza sativa* as larval host plants or dependent on bund larval host plants. When compared with previous studies from Western Ghats paddy fields it could be observed that the commonality in species composition was limited to butterfly species dependent on rice as host plants. Other species composition was influenced highly by the natural vegetation of the region. Twenty two species recorded in this study had the presence of their larval host plants in the study area. Rice was the larval host plant for eight species.

There is a significant change in butterfly community composition across the paddy growth stages. This is negligible between consecutive stages, but the changes are more prevalent between non-consecutive growth stages of paddy. Butterfly species richness and encounters in paddy fields are influenced positively by Total Dissolved Salts in water. The Shannon diversity is influenced by water level. This would be because of their nutrient requirements being fulfilled with higher salt content and water level during mud-puddling.

The cultivation regime does not influence the butterfly community in the paddy fields. Microhabitat variations like total dissolved salts in water and water level have comparatively more influence on the butterfly community. Major influencing factor for butterfly community composition is vegetation of a region. This factor makes the bunds, levees, ditches and other landscape vegetation important habitats for butterfly diversity and community composition in paddy fields. Higher diversity among butterflies in paddy fields would certainly indicate a richer, diverse landscape.

Twenty three species of odonates belonging to five families were recorded from the paddy fields of Kadhiramangalam. Of these 61% belong to the sub-order Anisoptera and 39% to Zygoptera. Libellulidae followed by Coenagrionidae are the predominant families in terms of species richness as well as abundance. Four Zygopterans and 10 Anisopterans are the most common species found in paddy fields. These are mostly Eurotypic in nature. *Paragomphus lineatus* (Common Hooktail) is an addition to the odonates recorded from paddy fields in India from the current study. Along the paddy cultivation cycle the odonate abundance and species richness reduces. Especially after the growth stage (PS 3). The transplanted paddy stage has the highest odonate diversity with a more even composition. The Anisopterans maintain predominance across the cultivation cycle.

There is a significant change in the odonata community composition between the paddy growth stages. Especially, more differences between the consecutive pairs of a) Growth stage and flowering stage, b) Milking stage and maturing stage and c) Maturing stage and drying and harvesting stage. This corresponds to water level in the field where the field changes from wetland to wet and then dry.

Nineteen odonate species belonging to five families were recorded from the organic paddy fields whereas 21 species were recorded from non-organic fields. The Shannon diversity and evenness were higher in the organic fields but abundance was lower in comparison with non-organic fields. This indicates a well distributed population of odonates in the organic fields giving rise to a stabler community across a paddy cultivation cycle. There are significant differences in odonate community composition between the two cultivation regimes among each corresponding paddy growth stage except for drying and harvesting stage. A major factor is higher mean abundance of eurotypic species in the non-organic fields. The record of *Acisoma ponorpoides* only from the organic fields also indicates the better habitat health of the organic fields.

The environmental variables included in the study explains 36% of variations seen in the species richness of odonates in the paddy fields, 35% of the variations shown in abundance, 13% of variation seen in Shannon diversity and 22% of evenness variation in odonate community. Paddy growth stages, water level and cultivation regime are the major influencing factors of odonata community composition in paddy fields in terms of species richness, abundance and Shannon diversity. But evenness is influenced by Total Dissolved Salts in water and cultivation regime.

Conclusion

Paddy fields, being a managed ecosystem, can still harbour a good variety of wildlife. There is variation in the composition of organisms supported by paddy fields based on the period in a cultivation cycle. This is because of the influence or change in habitat conditions *viz.* change from complete wetlands to dry, change from no vegetation to crop covered area. This influences the micro and macro habitat conditions that result in niche variability. This is a major contributor in deciding the community composition of paddy field ecosystem. Be it water level for odonates and butterflies or water temperature for birds, the microhabitat variation does play a role in determining the community composition and diversity in paddy fields. The organic regime supports higher diversity than non-organic regime. The two indicator taxa (Birds and odonata) communities showcase higher diversity in organic regime and are apex predators in their food and foraging habits, it can be said the organic fields support higher biodiversity. At the same time the bunds, levees and regional vegetation also contribute to maintain the diversity of paddy fields. This makes them important areas for biodiversity management. The record of a stream or riverine odonate species *Paragomphu slineatus* during drought year and the percentage of wetland dependent and migrant bird species are a testament to paddy fields being good alternate habitats for wetland dependent species. At the same time, the need for colonization of paddy fields during every crop cycle by odonates is an example of how paddy fields cannot act as source for wetland dependent species. All this makes the paddy field and its associated habitats, a unique ecosystem of conservation importance.

Future directions

For the future, in a farmer's perspective, studies on addressing the ground issues of organic management regime need to be encouraged. This will also aid the biodiversity conservation perspective of paddy field ecosystem. A study on bund and field vegetation and butterfly habitat usage/ behaviour in paddy fields would give more insight on suitable bund management practices in conserving local butterfly diversity. Studying the common insectivorous and granivorous bird behavior in paddy fields will aid in bio-management of pest species. The conservation and management practices should go hand in hand to reach sustainable development goals.

Organic field Saplings

Organic field Land Preparation

Non-organic field Saplings

Non-organic field Land Preparation

Plate 1: Land Preparation and Sapling Phase


Organic field


Non-organic field

Plate 2: Transplantation Phase


Organic field


Non-organic field

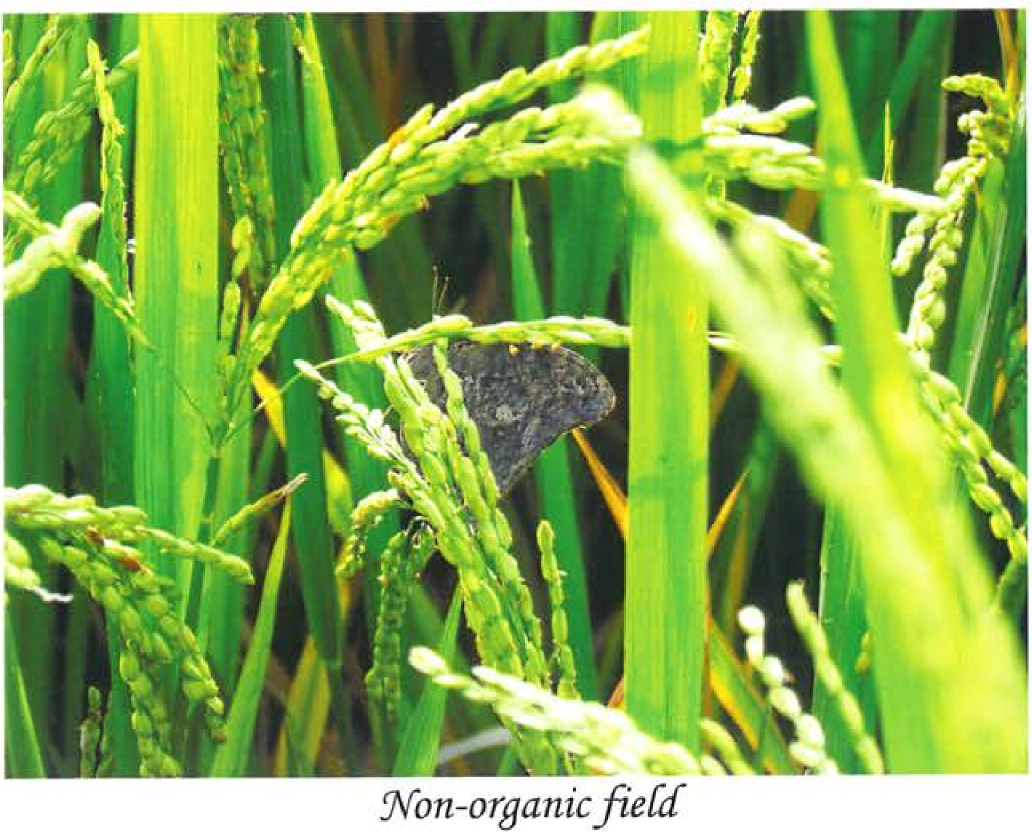
Plate 3: Growth Phase

Organic field

Non-organic field

Plate 4: Flowering Phase

Organic field



Non-organic field

Plate 5: Milking Period

Organic field

Non-organic field

Plate 6: Maturing Phase


Organic field - Drying


Organic field - Harvested


Non-organic field- Drying


Non-organic field-Harvested

Plate 7: Drying and Harvesting Phase

Plate 8 :Weavers and Munias on electric lines

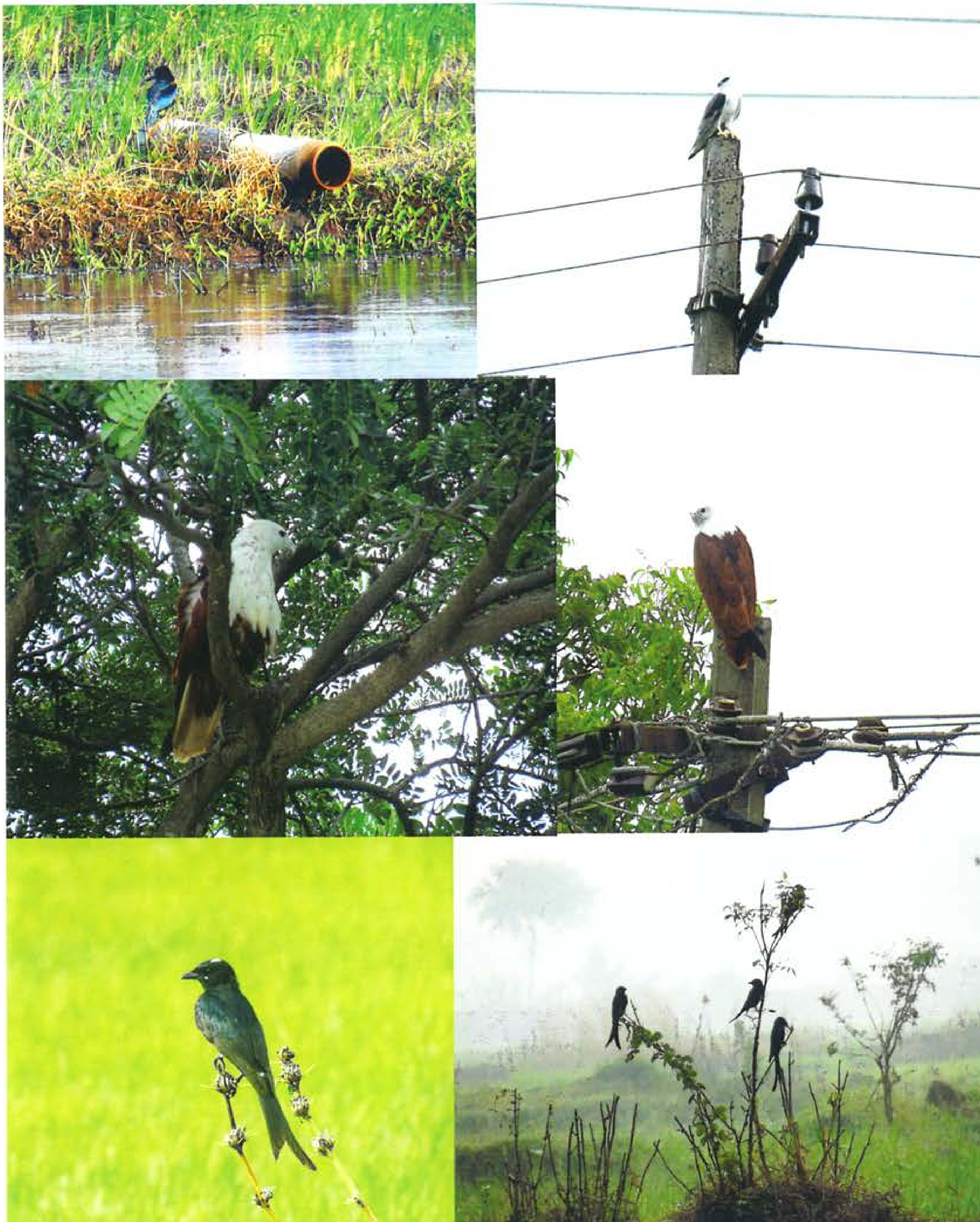


Plate 9 : Perches used by birds in paddy fields

Plate 10: Bird activity in paddy fields

Plate 11:Birds roosting on bund trees in paddy fields

Plate 12: Birds nesting in paddy field ecosystem

Plate 13:Reproductive behaviour of odonates in paddy fields

Plate 14 : Feeding behaviour of odonates in paddy fields

Plate 15 : Butterfly activity in paddy field ecosystem

Plate 16: Black-headed Munias feeding from traditional paddy variety

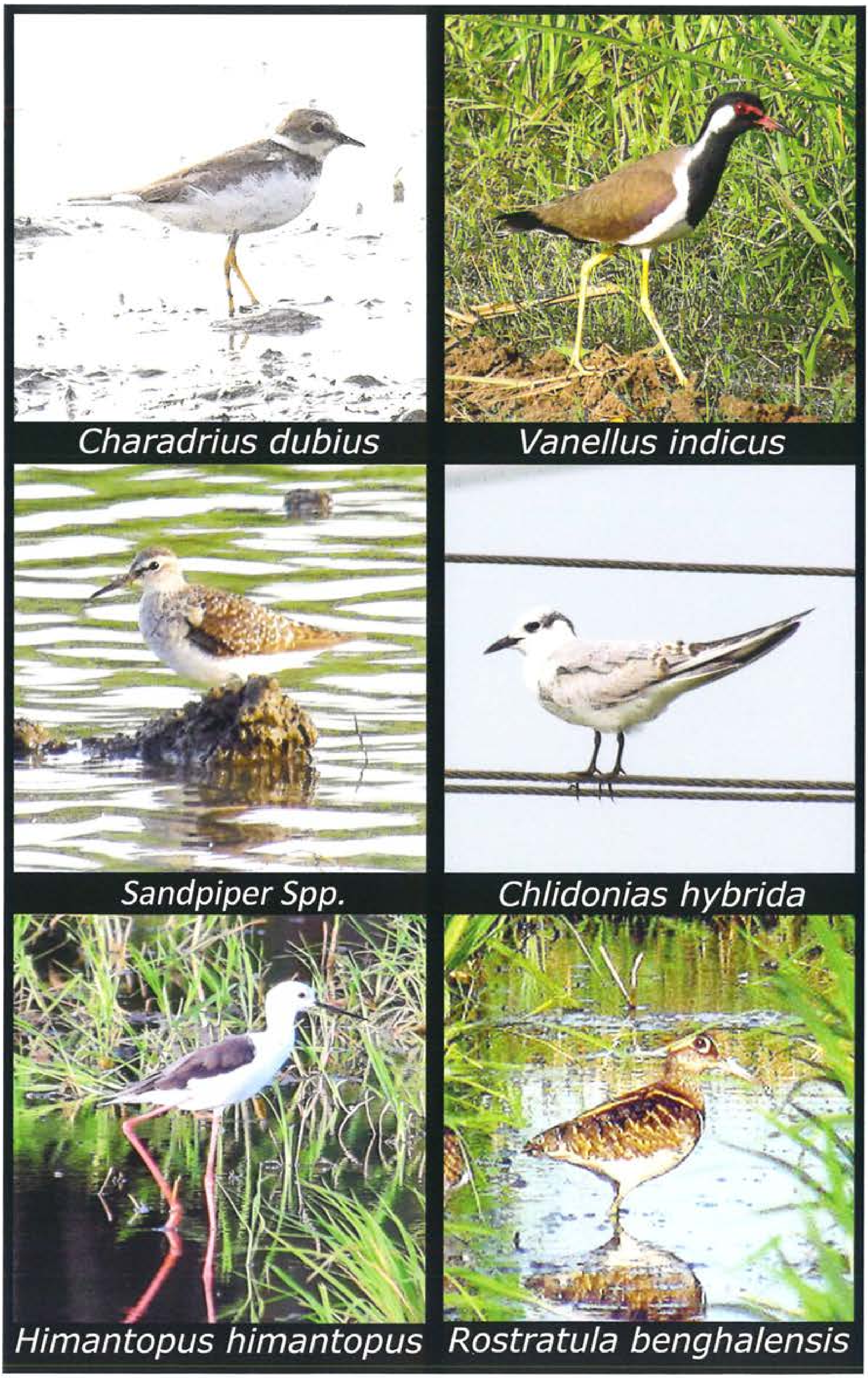


Plate 17 : Birds recorded from paddy fields

Plate 18: Birds recorded from paddy fields

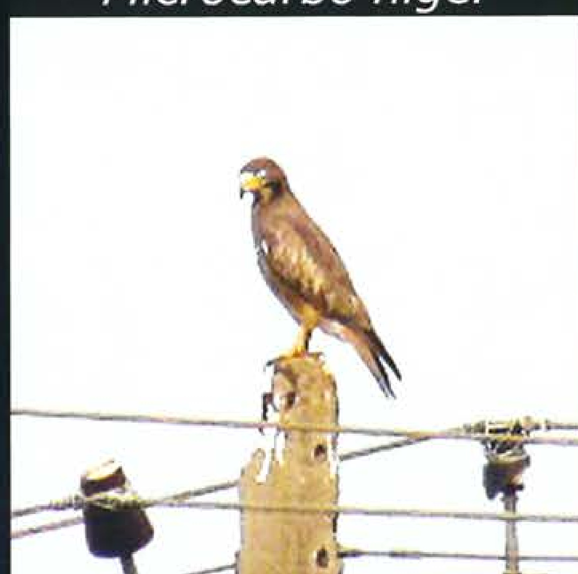
Amaurornis phoenicurus

Anastomus oscitans

Threskiornis melanocephalus

Microcarbo niger

Haliastur indus



Butastur teesa

Plate 19: Birds recorded from paddy fields

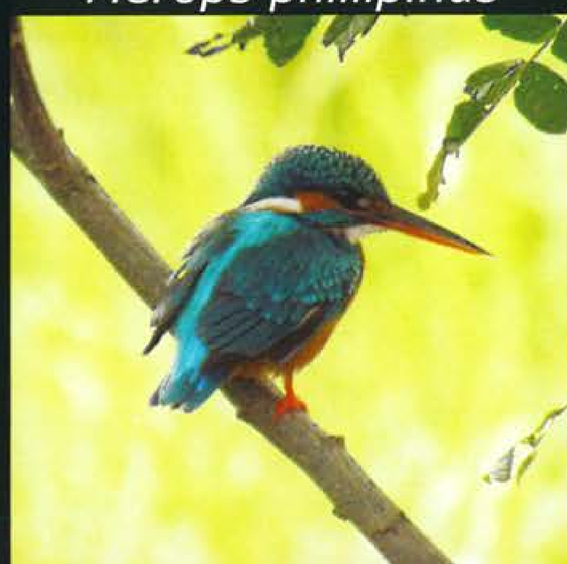
Athene brama

Dinopium benghalense

Psilopogon haemacephala

Merops phillipinus

Coracias benghalensis



Alcedo atthis

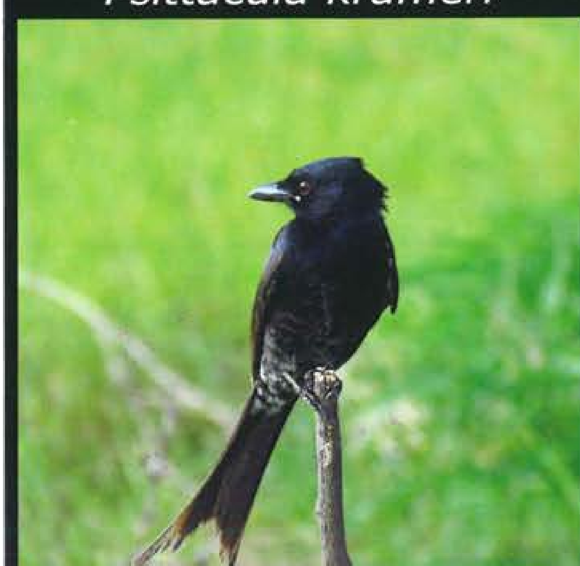
Plate 20: Birds recorded from paddy fields

Ceryle rudis

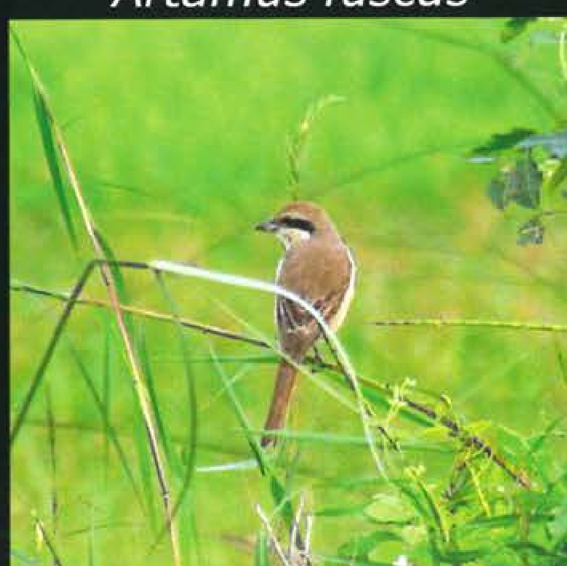
Halcyon smyrnensis

Psittacula krameri

Artamus fuscus



Dicrurus macrocercus



Lanius cristatus

Plate 21: Birds recorded from paddy fields

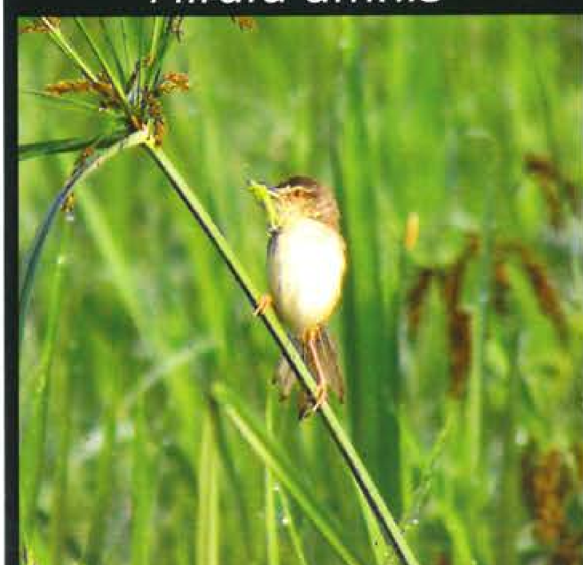
Plate 22: Birds recorded from paddy fields

Anthus rufulus

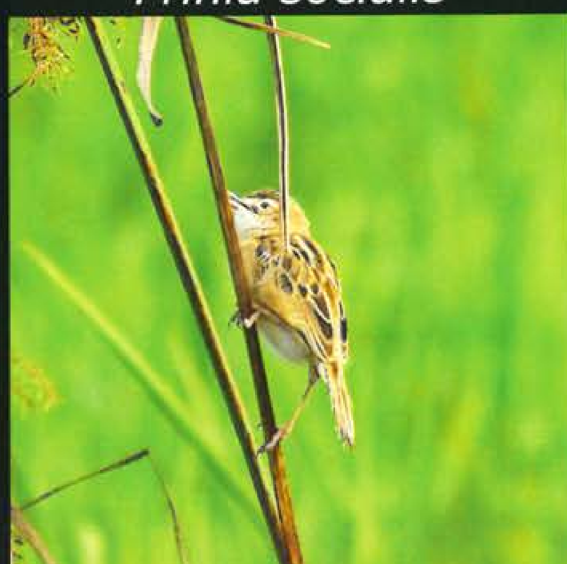
Motacilla maderaspatensis

Mirafa affinis

Prinia socialis



Prinia inornata



Cisticola juncidis

Plate 23: Birds recorded from paddy fields

Plate 24 : Birds recorded from paddy fields

Plate 25: Butterflies recoded from paddy fields

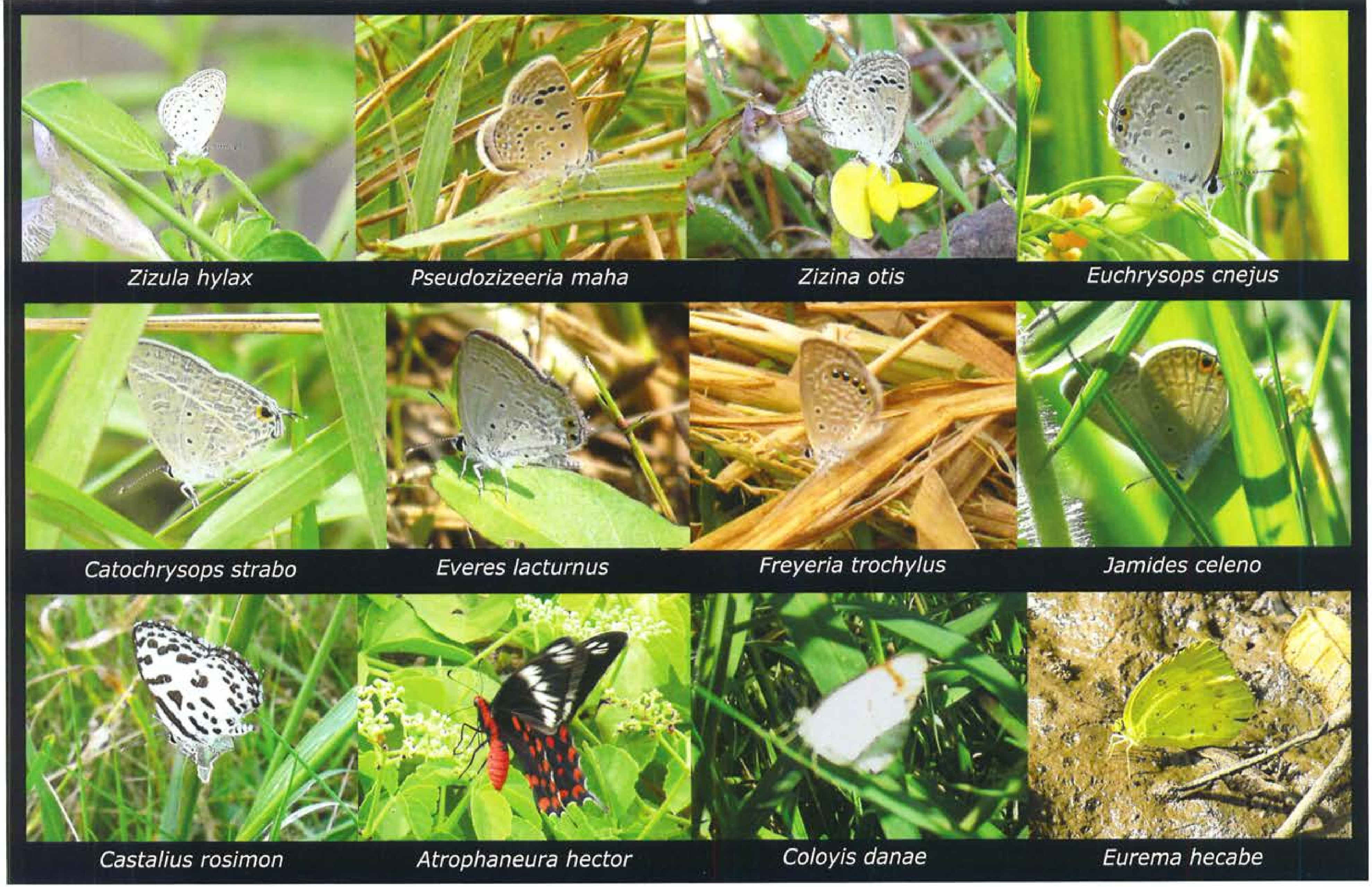


Plate 26: Butterflies recorded from paddy fields

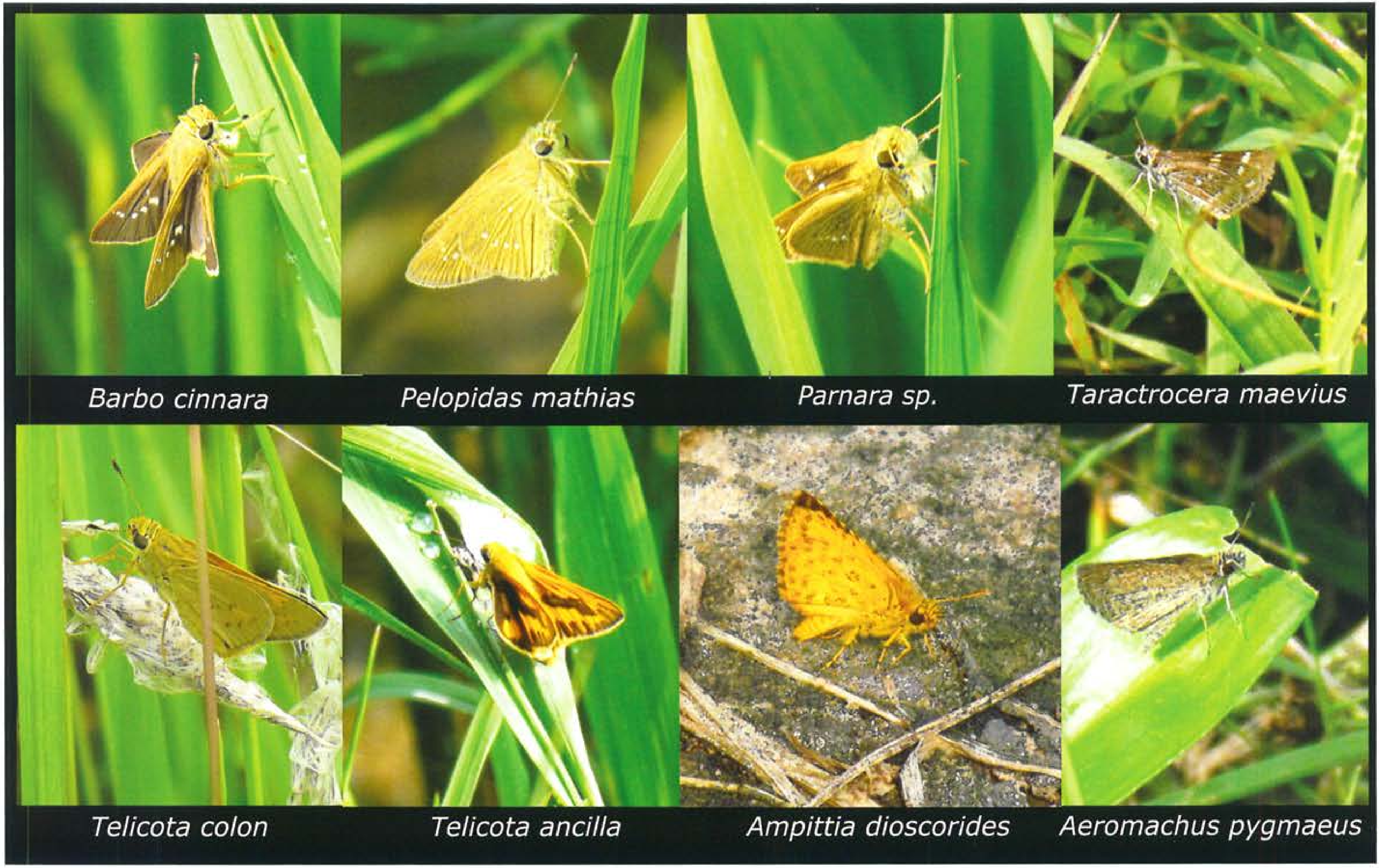


Plate 27: Butterflies recorded from paddy fields

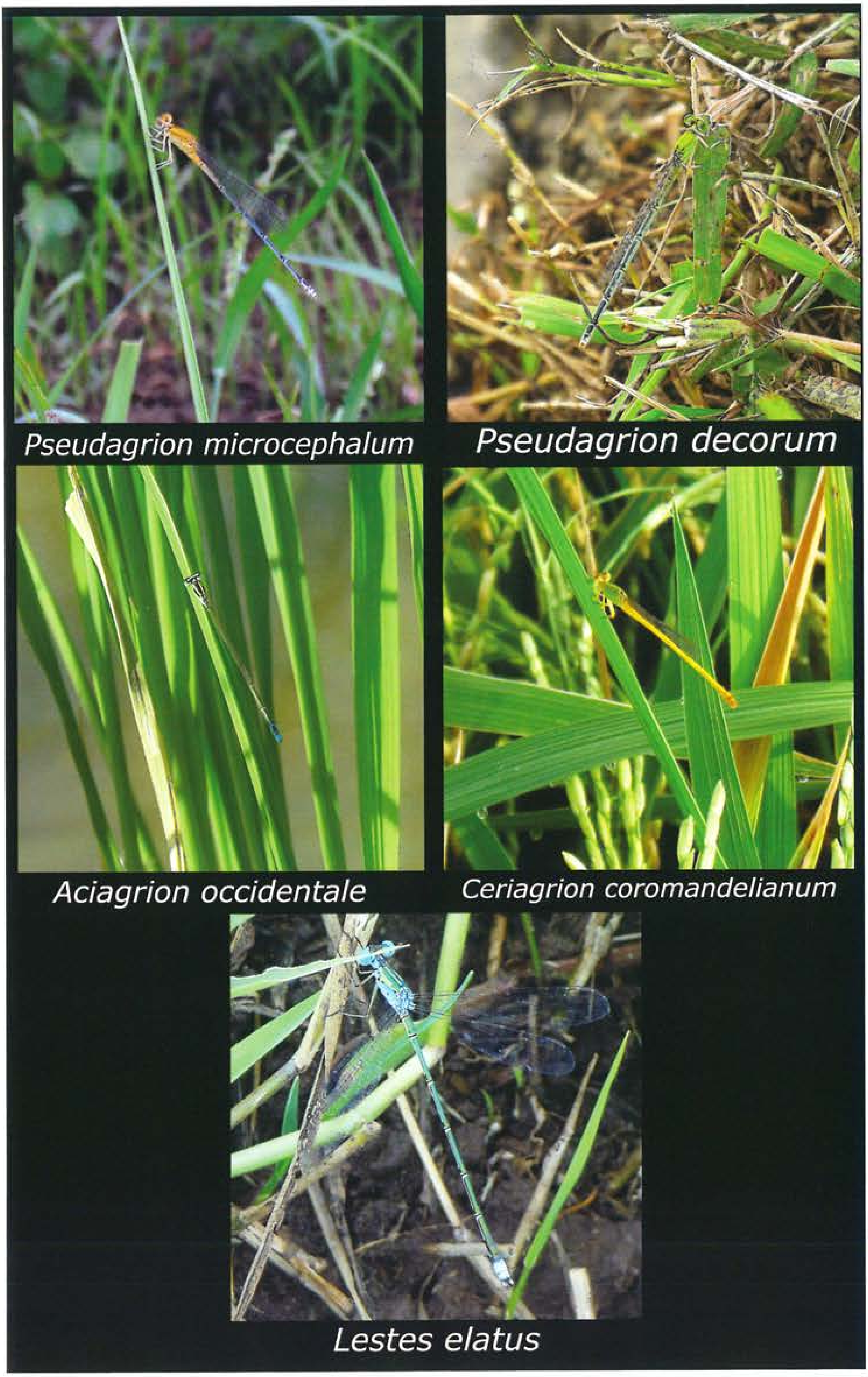


Plate 28: Damselflies recorded from paddy fields

Agriocnemis pygmeae male

Agriocnemis pygmeae female heteromorph

Ischnura rubilio male

Ischnura rubilio female Andromorph

Ischnura senegalensis male

Ischnura senegalensis female heteromorph

Plate 29: Damselflies recorded from paddy fields

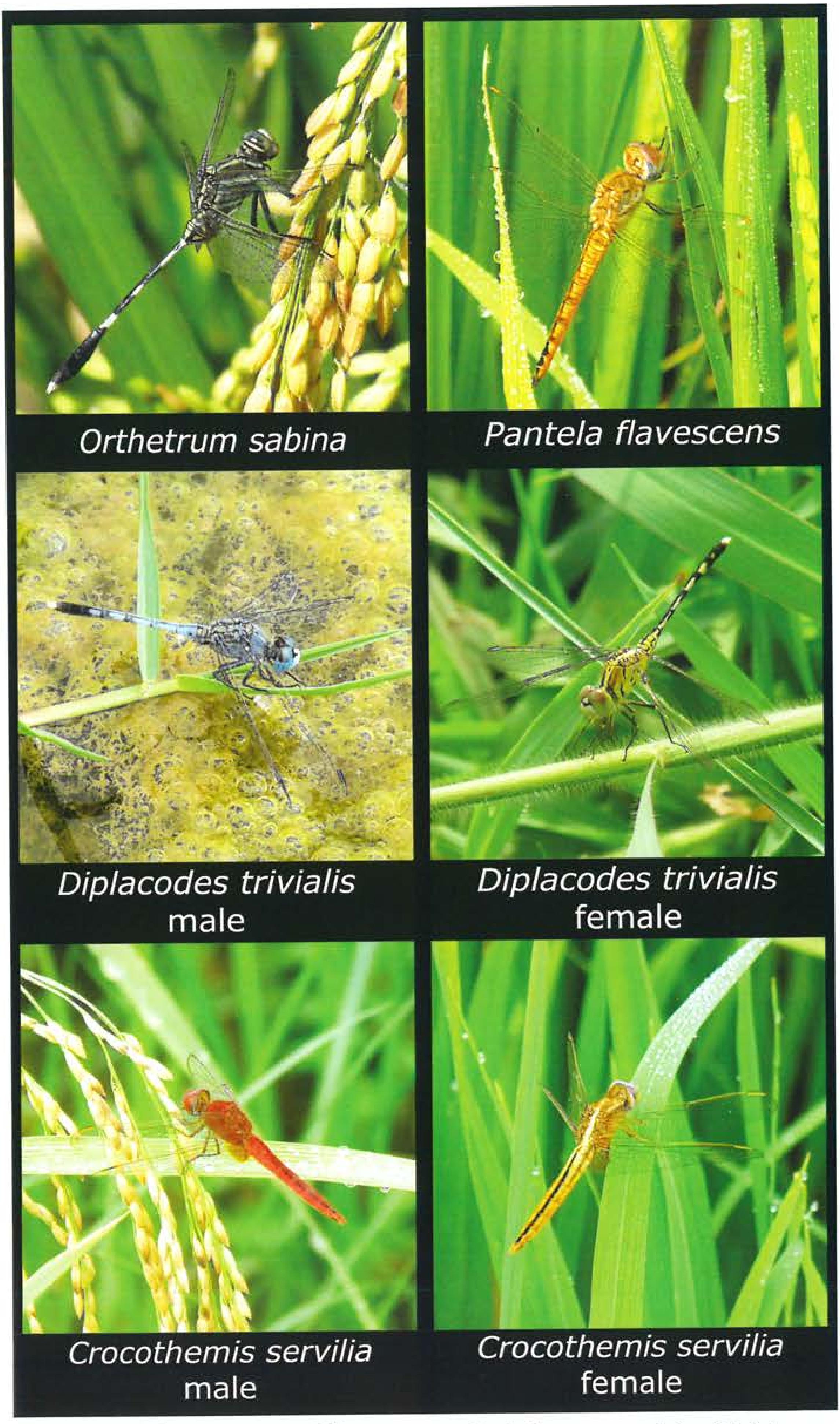
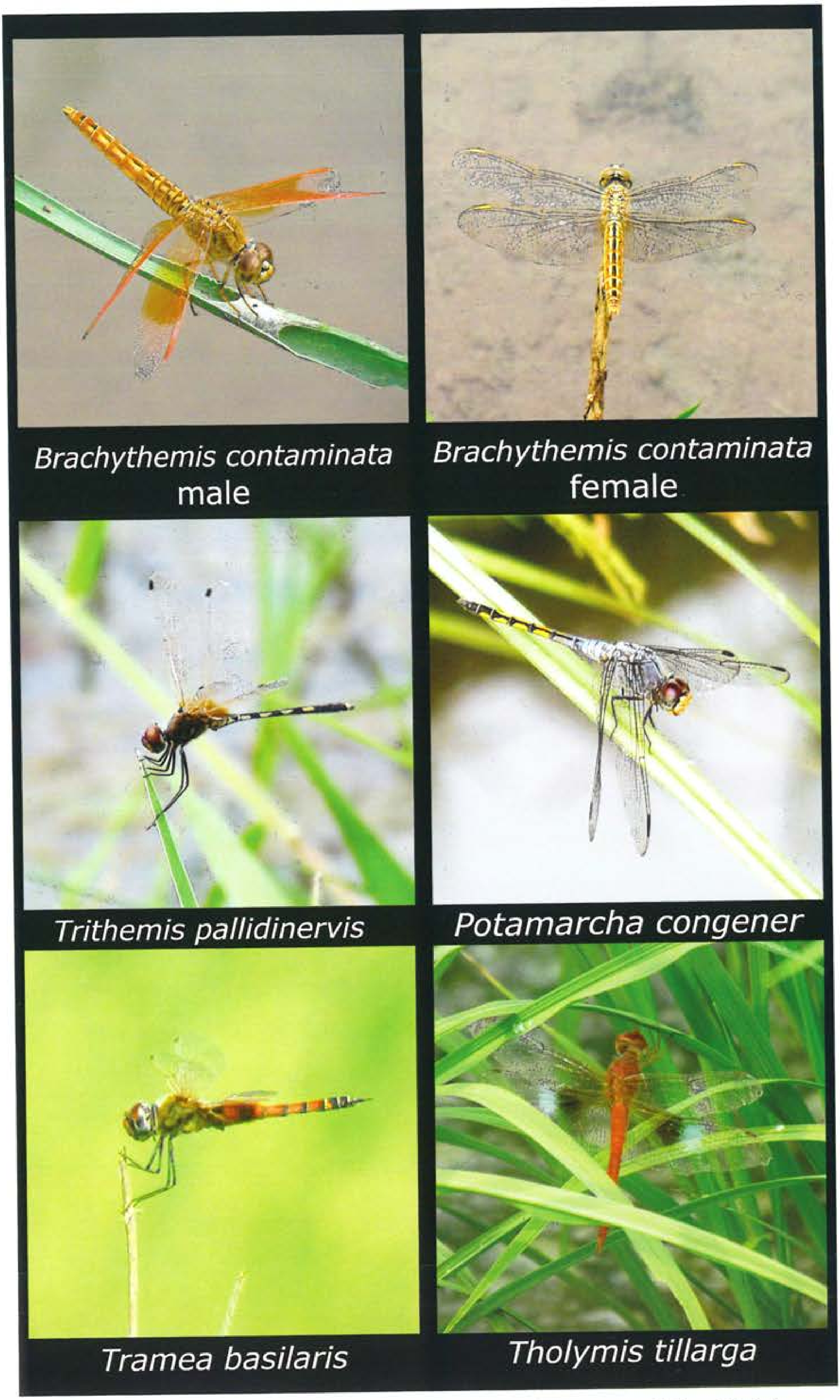


Plate 30: Dragonflies recorded from paddy fields



Brachythemis contaminata male

Brachythemis contaminata female

Trithemis pallidinervis

Potamarcha congener

Tramea basilaris

Tholymis tillarga

Plate 31: Dragonflies recorded from paddy fields

Plate 32: Dragonflies recorded from paddy fields

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APPENDIX 1

Checklist of indicator taxa species in paddy fields of Kadhiramangalam

Checklist of birds

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
I	**Order Galliformes**							
	Family Phasianidae							
1	*Francolinus pondicerianus*	Grey Francolin	R	G	T	LC	0.1729	0.112
2	*Pavo cristatus*	Indian Peafowl	R	O	T	LC	0.04625	0.02
II	**Order Columbiformes**							
	Family Columbidae							
3	*Columba livia*	Rock Pigeon	R	G	T	LC (dec)	2.88	2.461
4	*Streptopelia decaocto*	Eurasian Collared Dove	R	G	T	LC (inc)	0.127	0.076
5	*Streptopelia senegalensis*	Laughing Dove	PM	G	T	LC	0.1919	0.097
6	*Streptopelia chinensis*	Spotted Dove	R	G	T	LC (inc)	0.9167	0.993
III	**Order Cuculiformes**							
	Family Cuculidae							
7	*Eudynamys scolopaceus*	Asian Koel	PM	O	T	LC	0.2126	0.178
8	*Hierococcyx varius*	Common Hawk Cuckoo	PM	I	T	LC	0.09703	0.046
9	*Centropus sinensis*	Greater Coucal	R	C	T	LC	0.0452	0.046
10	*Clamator jacobinus*	Pied Cuckoo	M	I	T	LC	0.1241	0.071

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
IV	**Order Gruiformes**							
	Family Rallidae							
11	*Gallinula chloropus*	Common Moorhen	M	O	WB	LC	0.05449	0.035
12	*Zapornia fusca*	Ruddy-breasted Crake	PM	O	WD	LC (dec)	0.06516	0.046
13	*Amaurornis phoenicurus*	White-breasted Waterhen	R	O	WB	LC	0.2928	0.245
V	**Order Pelecaniformes**							
	Family Ciconiidae							
14	*Anastomus oscitans*	Asian Openbill	PM	AC	WB	LC	1.895	1.844
	Family Ardeidae							
15	*Ixobrychus flavicollis*	Black Bittern	PM	I+AC	WB	LC (dec)	0.05399	0.04
16	*Bubulcus ibis*	Cattle Egret	PM	I	WD	LC (inc)	0.5555	0.377
17	*Ixobrychus cinnamomeus*	Cinnamon Bittern	PM	I+AC	WB	LC	0.03129	0.015
18	*Ardea intermedia*	Intermediate Egret	PM	I+AC	WB	LC (dec)	2.691	1.926
19	*Ardeola grayii*	Indian Pond Heron	R	I+AC	WB	LC	3.057	2.84
20	*Ixobrychus minutus*	Little Bittern	PM	I+AC	WB	LC (dec)	0.02426	0.02
21	*Egretta garzetta*	Little Egret	PM	I+AC	WB	LC (inc)	2.249	1.849
22	*Ardea purpurea*	Purple Heron	M	AC	WB	LC	0.07015	0.056

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
	Family Threskiornithidae							
23	*Platalea leucorodia*	Eurasian Spoonbill	M	AC	WB	LC	0.008825	0.005
24	*Plegadis falcinellus*	Glossy Ibis	M	AC	WB	LC (dec)	0.1489	0.122
25	*Threskiornis melanocephalus*	Black-headed Ibis	PM	AC	WB	NT (dec)	1.437	1.019
	Family Phalocrocaracidae							
26	*Microcarbo niger*	Little Cormorant	PM	AC	WB	LC	0.4764	0.28
VI	**Order Charadriiformes**							
	Family Recurvirostridae							
27	*Himantopus himantopus*	Black- winged Stilt	M	O	WB	LC (inc)	1.522	0.958
	Family Charadriidae							
28	*Charadrius dubius*	Little Ringed Plover	M	I+AC	WB	LC	0.3769	0.28
29	*Vanellus indicus*	Red-wattled Lapwing	R	I+AC	WD	LC	1.591	1.554
	Family Rostratulidae							
30	*Rostratula benghalensis*	Greater Painted Snipe	M	AC	WB	LC (dec)	0.01222	0.01
	Family Scolopacidae							
31		Sandpiper spp.	M	I+AC	WB	LC (dec)	8.067	6.38
32	*Gallinago gallinago*	Common Snipe	M	AC	WB	LC (dec)	0.6628	0.464

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
	Family Laridae							
33	*Chlidonias hybrida*	Whiskered Tern	M	I+AC	WB	LC	0.02225	0.01
VII	**Order Accipitriformes**							
	Family Accipitridae							
34	*Milvus migrans*	Black Kite	R	O	T	LC	0.7647	0.724
35	*Haliasturindus*	Brahminy Kite	R	AC	WD	LC (dec)	0.6436	0.591
36	*Elanus caeruleus*	Black-winged Kite	R	I	T	LC	0.2424	0.204
37	*Accipiter badius*	Shikra	R	C	T	LC	0.0268	0.025
38	*Butastur teesa*	White- eyed Buzzard	R	C	T	LC	0.009357	0.005
VIII	**Order Strigiformes**							
	Family Strigidae							
39	*Athene brama*	Spotted Owlet	R	C	T	LC	0.251	0.224
IX	**Order Piciformes**							
	Family Picidae							
40	*Dinopium benghalense*	Lesser Golden-backed Woodpecker	R	I	T	LC	0.09068	0.061
	Family Ramphastidae							
41	*Psilopogon haemacephalus*	Coppersmith Barbet	R	F/I	T	LC (inc)	0.2115	0.102
X	**Order Coraciiformes**							
	Family Meropidae							
42	*Merops philippinus*	Blue-tailed Bee -eater	PM	I	T	LC	0.039	0.015

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
43	*Merops orientalis*	Green Bee-eater	PM	I	T	LC (inc)	0.2097	0.158
	Family Coraciidae							
44	*Coracias benghalensis*	Indian Roller	PM	I	T	LC (inc)	0.2962	0.183
	Family Alcedinidae							
45	*Cerylerudis*	Pied Kingfisher	R	AC	WD	LC	0.2425	0.183
46	*Alcedoatthis*	Common Kingfisher	PM	AC	WD	LC	0.1167	0.076
47	*Halcyon smyrnensis*	White-throated Kingfisher	R	I+AC	WD	LC	2.207	5.172
XI	**Order Falconiformes**							
	Family Falconidae							
48	*Falco chicquera*	Red-necked Falcon	R	C	T	NT (dec)	0.02114	0.01
XII	**Order Psittaciformes**							
	Family Psittaculidae							
49	*Psittacula krameri*	Rose-ringed Parakeet	R	G	T	LC (inc)	1.93	1.824
XIII	**Order Passeriformes**							
	Family Oriolidae							
50	*Oriolus oriolus*	Eurasian Golden Oriole	M	F/I	T	LC (inc)	0.161	0.132
	Family Artamidae							
51	*Artamus fuscus*	Ashy Woodswallow	R	I	T	LC	0.4899	0.326
	Family Dicruridae							
52	*Dicrurus macrocercus*	Black Drongo	R	I	T	LC	3.499	5.407

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
	Family Laniidae							
53	*Lanius cristatus*	Brown Shrike	M	I	T	LC (dec)	0.07865	0.051
	Family Corvidae							
54	*Corvus splendens*	House Crow	R	O	T	LC	0.2367	0.158
55	*Dendrocitta vagabunda*	RufousTreepie	R	O	T	LC	0.375	0.362
56	*Corvus macrorhynchos*	Large-billed Crow	R	O	T	LC	0.6461	0.189
	Family Monarchidae							
57	*Terpsiphone paradisi*	Asian Paradise Flycatcher	M	I	T	LC	0.01098	0.005
	Family Nectariniidae							
58	*Leptocoma zeylonica*	Purple-rumped Sunbird	R	N	T	LC	0.01199	0.01
	Family Ploceidae							
59	*Ploceus philippinus*	Baya Weaver	R	G	T	LC	11.16	12.491
	Family Estrildidae							
60	*Lonchura malacca*	Black-headed Munia	R	G	T	LC	19.67	22.826
61	*Euodice malabarica*	Indian Silverbill	R	O	T	LC	0.09012	0.066
62	*Amandava amandava*	Red Munia	R	G	T	LC	0.1149	0.076
63	*Lochura punctulata*	Scaly-breasted Munia	R	G	T	LC	0.1346	0.107
64	*Lonchura striata*	White-rumpedMunia	R	G	T	LC	0.2203	0.153
	Family Passeridae							
65	*Gymnoris xanthocollis*	Yellow-throated Sparrow	PM	O	T	LC	0.2035	0.138
	Family Motacillidae							
66	*Motacilla cinerea*	Grey Wagtail	M	I+AC	WD	LC	0.01241	0.01
67	*Anthus rufulus*	Paddyfield Pipit	R	I	T	LC	0.6765	0.464

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
68	*Motacilla maderaspatensis*	White-browed Wagtail	R	I	T	LC	0.2047	0.132
	Family Alaudidae							
69	*Mirafra affinis*	Jerdon'sBushlark	R	O	T	LC	0.5862	0.418
	Family Cisticolidae							
70	*Prinia socialis*	Ashy Prinia	R	I	T	LC	1.079	0.902
71	*Orthotomus sutorius*	Common Tailorbird	R	I	T	LC	0.01861	0.01
72	*Prinia hodgsonii*	Grey-breasted Prinia	R	I	T	LC	0.02298	0.01
73	*Prinia inornata*	Plain Prinia	R	I	T	LC	1.592	1.391
74	*Cisticola juncidis*	ZittingCisticola	R	I	T	LC	2.917	2.899
	Family Acrocephalidae							
75	*Acrocephalus dumetorum*	Blyth's reed Warbler	M	I	T	LC (inc)	0.6365	0.499
76	*Iduna rama*	Syke's Warbler	M	I	T	C	0.008166	0.01
77	*Acrocephalus agricola*	Paddyfield Warbler	M	I	T	LC (dec)	1.595	1.386
	Family Hirundinidae							
78	*Hirundo rustica*	Barn Swallow	M	I	T	LC (dec)	6.554	5.422
79	*Cecropis daurica*	Red-rumped Swallow	M	I	T	LC	2.49	1.62
	Family Pycnonotidae							
80	*Pycnonotus cafer*	Red-vented Bulbul	R	F/I	T	LC (inc)	0.8179	0.958
	Family Leiothrichidae							
81	*Turdoides affinis*	Yellow-billed Babbler	R	O	T	LC	1.961	1.804

SL No.	Scientific Name	Common Name	Move-ment	Feeding Guild	Habitat	IUCN Status	%age contribution to overall dissimilarity (SIMPER)	Relative Abundance (%)
	Family Sturnidae							
82	*Sturnia pagodarum*	Brahminy Starling	R	F/I	T	LC	0.3347	0.245
83	*Acridotheres tristis*	Common Myna	R	O	T	LC (inc)	3.858	4.907
	Family Muscicapidae							
84	*Luscinia svecica*	Bluethroat	M	I	T	LC	0.01241	0.01
85	*Saxicola maurus*	Siberian Stonechat	M	I	T	LC	0.002521	0.005
86	*Copsychus saularis*	Oriental Magpie Robin	R	I	T	LC	0.009394	0.005
87	*Saxicola caprata*	Pied Bushchat	PM	O	T	LC	0.01659	0.01

Movement: M - Migrant; PM - Partial Migrant; R – Resident. Habitat: WB - Waterbird; WD - Wetland dependent bird; T - Terrestrial bird. Guild: AC- Aquatic Carnivore; I- Insectivore, F- Frugivore; G- Granivore; C- Carnivore; N- Nectarivore; O- Omnivore. IUCN Status: LC - Least Concern; (dec) - decrease in populaion; (inc) - increase in population; NT - Near Threatened. IUCN status Source: http://www.iucnredlist.org 2017 – 2, Version 3.1(Nomenclature: Praveen *et al.*, 2016)

Checklist of odonates in paddy fields of Kadhiramangalam

Sl No.	Common Name	Scientific Name	Relative Abundance in %age	SIMPER %age contribution to overall dissimilarity
Sub-order Zygoptera or Damselflies				
Family Lestidae				
1	Emerald Spreadwing	*Lestes elatus*	0.019	0.03364
Family Coenagrionidae				
2	Blue Grass Dartlet	*Pseudagrion microcephalum*	0.026	0.03848
3	Coromandel Marsh Dart	*Ceriagrion coromandelianum*	0.560	0.5488
4	Golden Dartlet	*Ischnura rubilio*	24.378	26.81
5	Green-striped Slender Dartlet	*Aciagrion occidentale*	0.006	0.01866
6	Pigmy Dartlet	*Agriocnemis pygmaea*	5.069	4.594
7	Saffron-faced Blue Dart	*Pseudagrion rubriceps*	0.006	0.01866
8	Senegal Golden Dartlet	*Ischnura senegalensis*	0.122	0.1457
9	Three-lined Dart	*Pseudagrion decorum*	0.006	0.0114
Sub-order Anisoptera or Dragonflies				
Family Gomphidae				
10	Common Hooktail	*Paragomphus lineatus*	0.013	0.02136
Family Aeshnidae				
11	Blue-tailed Green Darner	*Anax guttatus*	0.032	0.04706

Sl No.	Common Name	Scientific Name	Relative Abundance in %age	SIMPER %age contribution to overall dissimilarity
Family Libellulidae				
12	Common Picturewing	*Rhyothemis variegata*	0.077	0.1311
13	Coral-tailed Cloudwing	*Tholymis tillarga*	0.077	0.1128
14	Ditch Jewel	*Brachythemis contaminata*	0.348	0.3357
15	Greater Crimson Glider	*Urothemis signata*	0.006	0.01399
16	Green Marsh Hawk	*Orthetrum sabina*	14.138	7.859
17	Ground Skimmer	*Diplacodes trivialis*	22.079	20.06
18	Long-legged Marsh Glider	*Trithemis pallidinervis*	0.077	0.1004
19	Red Marsh Trotter	*Tramea basilaris*	0.155	0.195
20	Ruddy Marsh Skimmer	*Crocothemis servilia*	8.341	8.748
21	Trumpet Tail	*Acisoma panorpoides*	0.013	0.03519
22	Wandering Glider	*Pantala flavescens*	24.340	29.95
23	Yellow-tailed Ashy Skimmer	*Potamarcha congener*	0.097	0.1662

Checklist of Butterflies in paddy fields of Kadhiramangalam

Sl. No.	Butterfly Species	Common Name	Status (Isaac kehimkar)	Relative Abundance in percentage	Contribution to overall average dissimilarity in percentage (SIMPER)	Larval host plant recorded from field
Family Hesperiidae						
1	*Ampittia dioscorides* (Fabricius)	Bush Hopper	Locally common	9.932	9.697	*Cynodon dactylon, Oryza sativa*
2	*Taractrocera maevius* (Fabricius)	Common Grass Dart	Locally common	0.068	0.063	
3	*Telicota ancilla* (Herrich-Schaffer)	Dark Palm Dart	Common	0.411	0.443	*Panicum repens*
4	*Telicota colon* (Fabricius)	Pale Palm Dart	Not rare	0.548	0.870	*Oryza sativa*
5	*Aeromachus pygmaeus* (Fabricius)	Pygmy Scrub Hopper	Common	0.274	0.425	
6	*Borbo cinnara* (Wallace)	Rice Swift	Common	4.041	4.308	*Oryza sativa*
7	*Pelopidas mathias* (Fabricius)	Small Branded Swift	Locally Common	0.411	0.595	*Oryza sativa*
8	*Parnara sp.*	Straight Swift		0.205	0.262	*Oryza sativa*

Sl. No.	Butterfly Species	Common Name	Status (Isaac kehimkar)	Relative Abundance in percentage	Contribution to overall average dissimilarity in percentage (SIMPER)	Larval host plant recorded from field
			Family Lycaenidae			
9	*Jamides celeno* (Cramer)	Common Cerulean	Common	0.479	0.651	*Crotolaria quinquefolia, Pongamia pinnata*
10	*Castalius rosimon* (Fabricius)	Common Pierrot	Common	0.068	0.070	
11	*Catochrysops strabo* (Fabricius)	Forget me-not	Common	0.068	0.093	*Pongamia pinnata*
12	*Euchrysops cnejus* (Fabricius)	Gram Blue	Common	8.493	9.198	*Pongamia pinnata*
13	*Freyeria trochylus* (Freyer)	Grass Jewel	Locally common	0.068	0.112	*Heliotropium indicum, Indigofera linifolia*
14	*Everes lacturnus* (Godart)	Indian Cupid	Not rare	0.411	0.504	
15	*Zizina otis* (Fabricius)	Lesser Grass Blue	Common	0.274	0.357	
16	*Pseudozizeeria maha* (Kollar)	Pale Grass Blue	Common	0.205	0.248	*Rungia repens, Oxalis corniculata*

Sl. No.	Butterfly Species	Common Name	Status (Isaac kehimkar)	Relative Abundance in percentage	Contribution to overall average dissimilarity in percentage (SIMPER)	Larval host plant recorded from field
17	*Curetis thetis* (Drury)	Indian Sunbeam	Not rare	0.068	0.079	
18	*Zizula hylax* (Fabricius)	Tiny Grass Blue	Common	0.890	0.958	*Hygrophila schulli*
Family Nymphalidae						
19	*Ariadne ariadne* (Linnaeus)	Angled Castor	Uncommon	1.438	1.888	*Ricinus communis*
20	*Junonia orithiya* (Linnaeus)	Blue Pansy	Common	0.137	0.208	
21	*Tirumala limniace* (Cramer)	Blue Tiger	Common	1.438	1.371	*Calotropis gigantea*
22	*Melanitis leda* (Linnaeus)	Common Evening Brown	Common	8.836	7.415	*Cynodon dactylon, Panicum repens, Oryza sativa*
23	*Junonia atlites* (Cramer)	Chocolate Pansy	Common	0.479	0.465	
24	*Mycalesis perseus* (Fabricius)	Common Bushbrown	Common	7.603	7.548	*Oryza sativa*
25	*Ariadne merione* (Cramer)	Common Castor	Common	1.370	1.761	

Sl. No.	Butterfly Species	Common Name	Status (Isaac kehimkar)	Relative Abundance in percentage	Contribution to overall average dissimilarity in percentage (SIMPER)	Larval host plant recorded from field
26	*Euploea core* (Cramer)	Common Crow	Common	0.822	0.772	*Calotropis gigantea, Ficus benghalensis*
27	*Hypolimnas misippus* (Linnaeus)	Danaid Eggfly	Common	1.712	1.686	
28	*Melanitis phedima* (Cramer)	Dark Evening Brown	Not rare	0.068	0.068	*Ischaemum muticum, Oryza sativa*
29	*Byblia ilithyia* (Drury)	Joker	Locally Common	0.137	0.106	
30	*Junonia lemonias* (Linnaeus)	Lemon Pansy	Common	0.137	0.194	
31	*Junonia almana* (Linnaeus)	Peacock Pansy	Common	9.452	8.396	*Hygrophila schulli*
32	*Danaus chrysippus* (Linnaeus)	Plain Tiger	Common	8.219	7.983	*Calotropis gigantea*
33	*Danaus genutia* (Cramer)	Striped Tiger	Common	1.233	1.091	*Calotropis gigantea*
34	*Acraea violae* (Fabricius)	Tawny Coster	Common	2.397	2.405	

Family Papilionidae						
Sl. No.	**Butterfly Species**	**Common Name**	**Status (Isaac kehimkar)**	**Relative Abundance in percentage**	**Contribution to overall average dissimilarity in percentage (SIMPER)**	**Larval host plant recorded from field**
35	*Graphium sarpedon* (Linnaeus)	Common Bluebottle	Common	0.205	0.147	
36	*Graphium doson* (C. and R. Felder)	Common Jay	Locally Common	0.068	0.061	
37	*Papilio polytes* (Linnaeus)	Common Mormon	Very Common	1.438	1.498	
38	*Atrophaneura aristolochiae* (Fabricius)	Common Rose	Common	1.644	1.838	
39	*Atrophaneura hector* (Linnaeus)	Crimson Rose	Common	3.425	3.530	
40	*Papilio demoleus* (Linnaeus)	Lime Butterfly	Very Common	2.877	2.979	
Family Pieridae						
41	*Eurema hecabe* (Linnaeus)	Common Grass Yellow	Common	6.027	6.384	*Cassia tora, Albizia saman, Mimosa pudica*
42	*Appias albina* (Boisduval)	Common Albatross	Common	1.575	1.619	

Sl. No.	Butterfly Species	Common Name	Status (Isaac kehimkar)	Relative Abundance in percentage	Contribution to overall average dissimilarity in percentage (SIMPER)	Larval host plant recorded from field
43	*Catopsilia pomona* (Fabricius)	Common Emigrant	Common	8.014	7.095	*Cassia tora*
44	*Cepora nerissa* (Fabricius)	Common Gull	Common	0.137	0.161	
45	*Delias eucharis* (Drury)	Common Jezebel	Common	1.712	1.806	
46	*Pareronia valeria* (Cramer)	Common Wanderer	Common	0.137	0.162	
47	*Colotis danae* (Fabricius)	Crimson Tip	Not rare	0.068	0.132	
48	*Catopsilia pyranthe* (Fabricius)	Mottled Emigrant	Common	0.274	0.299	

APPENDIX 2

Species code used for the select indicator taxa

Species code for birds

Bird Species code	Scientific Name	Common Name
APFL	*Terpsiphone paradisi*	Asian Paradise Flycatcher
ASKO	*Eudydnamys scolopaceus*	Asian Koel
ASOP	*Anastomus oscitans*	Asian Openbill
ASPR	*Prinia socialis*	Ashy Prinia
AWSW	*Artamus fuscus*	Ashy Woodswallow
BAWE	*Ploceus phillipinus*	Baya Weaver
BHMU	*Lonchura malacca*	Black-headed Munia
BLBI	*Ixobrychus flavicollis*	Black Bittern
BLDR	*Dicrurus macrocercus*	Black Drongo
BLKI	*Milvus migrans*	Black Kite
BLTH	*Luscinia svecica*	Bluethroat
BRKI	*Haliastur indus*	Brahminy Kite
BRMY	*Sturnia pagodarum*	Brahminy Starling
BRPI	*Columba livia*	Rock Pigeon
BRSH	*Lanius cristatus*	Brown Shrike
BRWA	*Acrocephalus dumetorum*	Blyth's reed Warbler
BSKI	*Elanus caeruleus*	Black-winged Kite
BTBE	*Merops phillipinus*	Blue-tailed Bee -eater
BWST	*Himantopus himantopus*	Black- winged Stilt
CAEG	*Bubulcus ibis*	Cattle Egret
CHCU	*Hierococcyx varius*	Common Hawk Cuckoo
CIBI	*Ixobrychus cinnamomeus*	Cinnamon Bittern
COBA	*Psilopogon haemacephala*	Coppersmith Barbet
COMO	*Gallinula chloropus*	Common Moorhen
COMY	*Acidotheres tristis*	Common Myna
COSA		Sandpiper spp.
COSN	*Gallinago gallinago*	Common Snipe
COST	*Saxicola maurus*	Siberian Stonechat
COSW	*Hirundo rustica*	Barn Swallow
COTA	*Orthotomus sutorius*	Common Tailorbird
ECDO	*Streptopelia decaocto*	Eurasian Collared

		Dove
EUSP	*Platalea leucorodia*	Eurasian Spoonbill
GBPR	*Prinia hodgsonii*	Grey-breasted Prinia
GLIB	*Plegadis falcinellus*	Glossy Ibis
GOOR	*Oriolus oriolus*	Eurasian Golden Oriole
GRCO	*Centropus sinensis*	Greater Coucal
GRFR	*Francolinus pondicerianus*	Grey Francolin
GRWA	*Motacilla cinerea*	Grey Wagtail
HOCR	*Corvus splendens*	House Crow
IBLA	*Mirafra affinis*	Jerdon's Bushlark
IMEG	*Ardea intermedia*	Intermediate Egret
INPE	*Pavo cristatus*	Indian Peafowl
INPH	*Ardeola grayii*	Indian Pond Heron
INRO	*Coracias benghalensis*	Indian Roller
INSI	*Euodice malabarica*	Indian Silverbill
INTR	*Dendrocitta vagabunda*	Rufous Treepie
JUCR	*Corvus macrorhynchos*	Large-billed Crow
LADO	*Streptopelia senegalensis*	Laughing Dove
LBWA	*Iduna rama*	Syke's Warbler
LEGO	*Dinopium benghalense*	Lesser Golden-backed Woodpecker

LIBI	*Ixobrychus minutus*	Little Bittern
LICO	*Microcarbo niger*	Little Cormorant
LIEG	*Egretta garzetta*	Little Egret
LRPL	*Charadrius dubius*	Little Ringed Plover
MARO	*Copsychus saularis*	Oriental Magpie Robin
OWIB	*Threskiornis melanocephalus*	Black-headed Ibis
PASN	*Rostratula bnghalensis*	Greater Painted Snipe
PCCU	*Clamator jacobinus*	Pied Cuckoo
PFPI	*Anthus rufulus*	Paddyfield Pipit
PFWA	*Acrocephalus agricola*	Paddyfield Warbler
PIBU	*Saxicola caprata*	Pied Bushchat
PIKI	*Ceryle rudis*	Pied Kingfisher
PIWA	*Motacilla maeraspatensis*	White-browed Wagtail
PLPR	*Prinia inornata*	Plain Prinia
PRSU	*Leptocoma zeylonica*	Purple-rumped Sunbird
PUHE	*Ardea purpurea*	Purple Heron
RBCR	*Zapornia fusca*	Ruddy-breasted Crake
REVA	*Amandava amandava*	Red Munia
RNFA	*Falco chicquera*	Red-necked Falcon
RRPA	*Psittacula krameri*	Rose-ringed Parakeet
RRSW	*Cecropis daurica*	Red-rumped Swallow

RVBU	*Pycnonotus cafer*	Red-vented Bulbul
RWLA	*Vanellus indicus*	Red-wattled Lapwing
SBKI	*Alcido atthis*	Common Kingfisher
SBMU	*Lochura punctulata*	Scaly-breasted Munia
SGBE	*Merops orientalis*	Small green Bee-eater
SHIK	*Accipiter badius*	Shikra
SPDO	*Streptopelia chinensis*	Spotted Dove
SPOW	*Athene Brama*	Spotted Owlet
WBKI	*Halcyon smyrnensis*	White-throated Kingfisher
WBWH	*Amaurornis phoenicurus*	White-breasted Waterhen
WEBU	*Butastur teesa*	White- eyed Buzzard
WHBA	*Turdoides affinis*	Yellow-billed Babbler
WHTE	*Chlidonias hybrida*	Whiskered Tern
WRMU	*Lonchura striata*	White-rumped Munia
YTSP	*Gymnoris xanthocollis*	Yellow-throated Sparrow
ZICI	*Cisticola juncidis*	Zitting Cisticola

Species code for Odonata

Odonata Species Code	Scientific Name	Common Name
BGDR	*Anax guttatus*	Blue-tailed Green Darner
BGDT	*Pseudagrion microcephalum*	Blue Grass Dartlet
CMDT	*Ceriagrion coromandelianum*	Coromandel Marsh Dart
COHO	*Paragomphus lineatus*	Common Hooktail
COPI	*Rhyothemis variegata*	Common Picturewing
CTCW	*Tholymis tillarga*	Coral-tailed Cloudwing
DIJE	*Brachythemis contaminata*	Ditch Jewel
EMSW	*Lestes elatus*	Emerald Spreadwing
GCGL	*Urothemis signata*	Greater Crimson Glider
GODL	*Ischnura aurora*	Golden Dartlet
GRMH	*Orthetrum sabina*	Green Marsh Hawk

GRSK	*Diplacodes trivialis*	Ground Skimmer
GSDL	*Aciogrion occidentale*	Green-striped Slender Dartlet
LLMG	*Trithemis pallidinervis*	Long-legged Marsh Glider
PYDL	*Agriocnemis pygmaea*	Pigmy Dartlet
RMTR	*Tramea basilaris*	Red Marsh Trotter
RUMH	*Crocothemis servilia*	Ruddy Marsh Skimmer
SBDT	*Pseudagrion rubriceps*	Saffron-faced Blue Dart
SGDL	*Ischnura senegalensis*	Senegal Golden Dartlet
TLDT	*Pseudagrion decorum*	Three-lined Dart
TRTA	*Acisoma panorpoides*	Trumpet Tail
WAGL	*Pantala flavescens*	Wandering Glider
YASK	*Potamarcha congener*	Yellow-tailed Ashy Skimmer

APPENDIX 3

Relative abundance data of select indicator taxa across paddy growth stages

Relative abundance of birds in paddy fields of Kadhiramangalam across paddy growth stages

Bird Species	Common Name	RA PS1 N=2106	RA PS2 N=2536	RA PS3 N=2097	RA PS4 N=3591	RA PS5 N=4296	RA PS6 N=3871	RA PS7 N=1125
Himantopus himantopus	Black- winged Stilt	5.033	2.8785	0.4291	0	0	0	0
	Sandpiper spp.	20.2279	13.328	6.39	9.1896	0.2327	0.3358	0.089
Gallinago gallinago	Common Snipe	0	0.1971	0.763	0.4455	0.675	0.0258	2.1333
Charadrius dubius	Little Ringed Plover	0.0474	2.129	0	0	0	0	0
Rostratula bnghalensis	Greater Painted Snipe	0.1658	0	0	0	0	0	0
Vanellus indicus	Red-wattled Lapwing	2.5166	2.8785	2.4797	1.0303	0.2793	1.24	2.6666
Chlidonias hybrida	Whiskered Tern	0	0.0788	0	0	0	0	0
Anastomus oscitans	Asian Openbill	2.2792	3.2334	1.5259	2.45	1.5595	0.9816	0.6222
Dupetor flavicollis	Black Bittern	0	0	0	0.1392	0	0.0517	0.089
Bubulcus ibis	Cattle Egret	0	2.6813	0.2861	0	0	0	0
Ixobrychus cinnamomeus	Cinnamon Bittern	0.0474	0	0	0.0278	0	0.0258	0
Platalea leucorodia	Eurasian Spoonbill	0	0.0394	0	0	0	0	0
Plegadis falcinellus	Glossy Ibis	0	0	0.0953	0.6126	0	0	0
Mesophoyx intermedia	Intermediate Egret	0.3323	10.2917	3.7195	0.5012	0.2327	0.0775	0.089
Ardeola grayii	Indian Pond Heron	0.2374	2.8785	6.7238	5.3467	1.3268	1.421	3.1111
Ixobrychus minutus	Little Bittern	0	0	0.0476	0.0278	0.0465	0	0
Egretta garzetta	Little Egret	3.5612	4.2192	6.5331	0.5569	0.3258	0.2583	0
Threskiornis melanocephalus	Black-headed Ibis	11.1111	1.6167	0	0.1949	0.256	0.0258	0.5333
Ardea purpurea	Purple Heron	0.0949	0.0394	0	0.1114	0.0698	0	0.089

Bird Species	Common Name	RA PS1 N=2106	RA PS2 N=2536	RA PS3 N=2097	RA PS4 N=3591	RA PS5 N=4296	RA PS6 N=3871	RA PS7 N=1125
Columba livia	Rock Pigeon	0.5223	0.276	2.0028	0.0835	0.4655	8.7057	63
Streptopilia decaocto	Eurasian Collared Dove	0	0	0.0953	0.167	0.0233	0.0775	0.2666
Stigmatopelia senegalensis	Laughing Dove	0.1899	0.0788	0.143	0	0.0233	0.2066	0.089
Stigmatopelia chinensis	Spotted Dove	0.9496	0.9858	0.6676	0.9746	0.7216	0.9558	2.9333
Merops phillipinus	Blue-tailed Bee -eater	0	0	0	0	0	0	0.2666
Coracias benghalensis	Indian Roller	0.7597	0.5126	0	0	0.0233	0.1292	0.089
Ceryle rudis	Pied Kingfisher	0.1899	0.4731	0.5245	0.0557	0.0698	0.0517	0.1778
Alcido atthis	Common Kingfisher	0	0.2365	0.2384	0.0557	0.0465	0	0
Merops orientalis	Small green Bee-eater	0.2374	0.3154	0.143	0.1114	0.1629	0.0517	0.1778
Halcyon smyrnensis	White-throated Kingfisher	5.3656	7.2555	9.3466	5.653	2.2346	3.6683	7.2
Eudydamys scolopacea	Asian Koel	0.3798	0.0394	0.2384	0.2784	0.1396	0.1033	0.089
Hierococcyx varius	Common Hawk Cuckoo	0	0.0394	0	0.0557	0	0	0.5333
Centropus sinensis	Greater Coucal	0	0	0.0476	0.0278	0.1629	0	0
Clamator jacobinus	Pied Cuckoo	0.1899	0	0.0953	0.0278	0	0.0775	0.3555
Milvus migrans	Black Kite	1.8518	0.3943	1.0968	0.6683	0.1629	0.465	1.867
Haliastur indus	Brahminy Kite	1.0446	0.7886	1.4783	0.7518	0.0465	0.2066	0.5333
Elanus caeruleus	Black-winged Kite	0.3323	0.0788	0.2384	0.0557	0.256	0.2324	0.3555
Falco chicquera	Red-necked Falcon	0	0	0.0476	0	0.0233	0	0
Accipiter badius	Shikra	0	0	0	0.0278	0.0465	0.0258	0.089
Butastur teesa	White- eyed Buzzard	0	0.0394	0	0	0	0	0
Francolinus pondicerianus	Grey Francolin	0.0474	0.276	0.4291	0.0278	0	0.1033	0
Pavo cristatus	Indian Peafowl	0	0	0	0	0	0.1033	0
Gallinula chloropus	Common Moorhen	0	0	0	0.0278	0.1164	0.0258	0
Porzana fusca	Ruddy-breasted Crake	0.0474	0.0394	0	0.1114	0.0233	0.0517	0

Bird Species	Common Name	RA PS1 N=2106	RA PS2 N=2536	RA PS3 N=2097	RA PS4 N=3591	RA PS5 N=4296	RA PS6 N=3871	RA PS7 N=1125
Amaurornis phoenicurus	White-breasted Waterhen	0.0474	0.1182	0.3814	0.1671	0.2095	0.517	0.089
Terpsiphone paradisi	Asian Paradise Flycatcher	0	0	0.0476	0	0	0	0
Prinia socialis	Ashy Prinia	1.6619	0.7097	2.2889	0.5291	0.2327	0.6974	1.778
Artamus fuscus	Ashy Woodswallow	0.5223	0.4731	0.2861	0.3063	0	0.1549	1.6
Ploceus phillipinus	Baya Weaver	13.5802	3.5094	3.4334	14.4527	31.75	1.4983	5.6
Lonchura malacca	Black-headed Munia	0.6172	0.1577	2.8135	29.2676	36.3826	41.41	16.53
Dicrurus macrocercus	Black Drongo	11.7283	6.8217	9.2513	4.5391	1.9785	3.1774	7.289
Luscinia svecica	Bluethroat	0	0	0	0	0	0.0517	0
Sturnia pagodarum	Brahminy Starling	0.1899	0.3943	0.7629	0.1949	0.0233	0.2066	0.1778
Lanius cristatus	Brown Shrike	0	0	0.143	0.167	0	0.0258	0
Acrocephalus dumetorum	Blyth's reed Warbler	0.0474	0.0394	0.143	0.2506	0.1862	1.6533	1.0666
Acidotheres tristis	Common Myna	6.0303	5.7965	12.8278	4.2328	2.1648	3.4099	3.8222
Saxicola torquatus	Siberian Stonechat	0	0	0	0	0.0233	0	0
Hirundo rustica	Barn Swallow	2.8015	14.4716	7.2961	2.6735	7.4022	1.6533	0.6222
Orthotomus sutorius	Common Tailorbird	0	0	0	0.0278	0	0	0.089
Prinia hodgsonii	Grey-breasted Prinia	0.0949	0	0	0	0	0	0
Oriolus oriolus (kundoo)	Eurasian Golden Oriole	0.0474	0.1183	0.0953	0.2785	0.0465	0.1033	0.3555
Motacilla cinerea	Grey Wagtail	0	0	0	0	0	0.0517	0
Corvus splendens	House Crow	0.2849	0.1577	0.3814	0.1114	0.0233	0.0517	0.5333
Mirafa erythroptera	Jerdon's Bushlark	0.1899	0	0.2384	0.362	0.3957	0.3875	2.49
Euodice malabarica	Indian Silverbill	0	0	0	0.362	0	0	0
Dendrocitta vagabunda	Rufous Treepie	0.2849	0.5126	0.5722	0.4734	0.2327	0.181	0.5333
Corvus macrorhynchos (culminatus)	Large-billed Crow	1.282	0.4337	0.5245	0.3898	0.2327	0.3617	0.8

Bird Species	Common Name	RA PS1 N=2106	RA PS2 N=2536	RA PS3 N=2097	RA PS4 N=3591	RA PS5 N=4296	RA PS6 N=3871	RA PS7 N=1125
Iduna rama	Syke's Warbler	0	0	0	0	0.0233	0.0258	0
Copsychus saularis	Oriental Magpie Robin	0	0	0	0.0278	0	0	0
Anthus rufulus	Paddyfield Pipit	0	0.4731	0.4768	0.2784	0.0233	0.6975	2.7555
Acrocephalus agricola	Paddyfield Warbler	1.7568	0.4731	1.2875	1.3645	0.9078	2.6091	0.6222
Saxicola caprata	Pied Bushchat	0.0474	0	0.0476	0	0	0	0
Motacilla maeraspatensis	White-browed Wagtail	0.1424	0.7885	0.143	0	0	0	0
Prinia inornata	Plain Prinia	0.4748	0.1182	0.4291	1.1974	1.5828	2.454	4
Leptocoma zeylonica	Purple-rumped Sunbird	0	0	0	0.0557	0	0	0
Amandava amandava	Red Munia	0	0	0.3814	0.0014	0	0.0517	0
Cecropis daurica	Red-rumped Swallow	0	0	0	0.0835	0.2095	7.5174	1.3333
Pycnonotus cafer	Red-vented Bulbul	1.0446	1.4195	0.8583	0.8354	0.5586	0.9041	2.0444
Lochura punctulata	Scaly-breasted Munia	0	0	0.0477	0	0.0465	0.3358	0.4444
Turdoides affinis	Yellow-billed Babbler	1.377	2.6025	2.3366	2.172	1.234	1.447	2.0444
Lonchura striata	White-rumped Munia	0.0474	0.0788	0.4768	0.1671	0.0698	0.2066	0
Gymnoris xanthocollis	Yellow-throated Sparrow	0	0	0	0	0	0.1033	2.0444
Cisticola juncidis	Zitting Cisticola	0.9496	0.7492	4.3395	4.0657	2.072	3.3841	6.49
Phalacrocorax niger	Little Cormorant	0.9021	0.552	0.5245	0.1114	0.0931	0	0.2666
Megalaima haemacephala	Coppersmith Barbet	0	0	0.0476	0.0278	0.3259	0.1033	0
Dinopium benghalense	Lesser Golden-backed Woodpecker	0	0	0.1429	0.0557	0.0465	0.0775	0.1778
Psittacula krameri	Rose-ringed Parakeet	0.8547	0.6309	1.0968	0.7797	1.5828	4.184	3.8222
Athene brama	Spotted Owlet	0.0474	0.0788	0.0477	0.0557	0.1862	0.62	0.5333

Relative abundance of birds in organic fields across paddy growth stages

Bird Species	Common Name	PS1 N=1041	PS2 N=835	PS3 N=1040	PS4 N=2479	PS5 N=3039	PS6 N=2980	PS 7 N=922
Milvus migrans	Black Kite	1.633	0.479	2.02	0.686	0.132	0.369	1.735
Haliastur indus	Brahminy Kite	1.153	1.4371	1.923	0.5244	0	0.1	0.11
Elanus caeruleus	Black-winged Kite	0.48	0.2395	0.3846	0.081	0.296	0.1678	0.434
Accipiter badius	Shikra	0	0	0	0.04	0.066	0.0373	0.11
Butastur teesa	White- eyed Buzzard	0	0	0	0	0	0	0
Himantopus himantopus	Black- winged Stilt	10.18	8.7425	0.8654	0	0	0	0
	Sandpiper spp.	26.8	15.2095	9.9	13.312	0.2632	0.1	0.11
Gallinago gallinago	Common Snipe	0	0	0.1	0	0.1	0.033	2.6
Charadrius dubius	Little Ringed Plover	0.096	0	0	0	0	0	0
Rostratula bnghalensis	Greater Painted Snipe	0.1921	0	0	0	0	0	0
Vanellus indicus	Red-wattled Lapwing	3.266	7.7844	3.75	0.807	0.33	1.157	2.6
Chlidonias hybrida	Whiskered Tern	0	0.2395	0	0	0	0	0
Columba livia	Rock Pigeon	1.0567	0.8383	4.0384	0	0.658	11.31	6.833
Streptopelia decaocto	Eurasian Collared Dove	0	0	0	0	0	0.112	0.325
Streptopelia senegalensis	Laughing Dove	0.48	0.2395	0.192	0	0	0	0.11
Streptopelia chinensis	Spotted Dove	0.2882	2.156	0.673	0.968	0.56	0.933	3.471
Merops phillipinus	Blue-tailed Bee -eater	0	0	0	0	0	0	0
Coracias benghalensis	Indian Roller	0.096	0.2395	0	0	0	0.04	0
Ceryle rudis	Pied Kingfisher	0.2882	0.7185	0.7692	0.04	0	0.0373	0.217
Alcido atthis	Common Kingfisher	0	0.2395	0.48	0	0.066	0	0
Merops orientalis	Small green Bee-eater	0.1921	0.359	0.096	0	0.1	0	0.217

Bird Species	Common Name	PS1 N=1041	PS2 N=835	PS3 N=1040	PS4 N=2479	PS5 N=3039	PS6 N=2980	PS 7 N=922
Halcyon smyrnensis	White-throated Kingfisher	7.108	12.2156	13.173	5.16	2.106	3.545	5.965
Eudynamys scolopaceus	Asian Koel	0.48	0	0.3846	0.242	0.132	0.0671	0.11
Hierococcyx varius	Common Hawk Cuckoo	0	0	0	0.04	0	0	0.11
Centropus sinensis	Greater Coucal	0	0	0.1	0	0.2	0	0
Clamator jacobinus	Pied Cuckoo	0.1921	0	0.1923	0	0	0.04	0.435
Falco chicquera	Red-necked Falcon	0	0	0.096	0	0	0	0
Francolinus pondicerianus	Grey Francolin	0	0.3593	0.673	0	0	0.15	0
Pavo cristatus	Indian Peafowl	0	0	0	0	0	0	0
Gallinula chloropus	Common Moorhen	0	0	0	0	0.1	0.033	0
Zapornia fusca	Ruddy-breasted Crake	0	0.1197	0	0.08	0.033	0.075	0
Amaurornis phoenicurus	White-breasted Waterhen	0.096	0.36	0.673	0.04	0.2	0.56	0.11
Terpsiphone paradisi	Asian Paradise Flycatcher	0	0	0.0961	0	0	0	0
Prinia socialis	Ashy Prinia	2.4976	1.7964	4.423	0.605	0.132	0.44	2.061
Artamus fuscus	Ashy Woodswallow	0.096	0.599	0.5769	0.444	0	0.134	1.735
Ploceus phillipinus	Baya Weaver	3.46	5.7485	6.92	17.51	29.615	0	6.833
Lonchura malacca	Black-headed Munia	1.25	0.479	5.48	38.443	50.71	53.52	20.17
Dicrurus macrocercus	Black Drongo	3.17	4.79	7.596	2.46	0.95	2.483	5.43
Luscinia svecica	Bluethroat	0	0	0	0	0	0.067	0
Sturnia pagodarum	Brahminy Starling	0.2882	0	0	0.2824	0.033	0.2	0.217
Lanius cristatus	Brown Shrike	0	0	0.2885	0.202	0	0	0
Acrocephalus dumetorum	Blyth's reed Warbler	0.096	0.1197	0	0.121	0.132	1.946	1.2

Bird Species	Common Name	PS1 N=1041	PS2 N=835	PS3 N=1040	PS4 N=2479	PS5 N=3039	PS6 N=2980	PS 7 N=922
Acidotheres tristis	Common Myna	2.21	3.2335	7.02	1.01	0.954	2.92	2.277
Saxicola maurus	Siberian Stonechat	0	0	0	0	0.033	0	0
Hirundo rustica	Barn Swallow	0.7685	4.1916	2.404	1.775	1.185	0.671	0.434
Orthotomus sutorius	Common Tailorbird	0	0	0	0	0	0	0.11
Prinia hodgsonii	Grey-breasted Prinia	0.1921	0	0	0	0	0	0
Oriolus oriolus	Eurasian Golden Oriole	0	0.2395	0	0.363	0.033	0.075	0.434
Motacilla cinerea	Grey Wagtail	0	0	0	0	0	0.075	0
Corvus splendens	House Crow	0.096	0.479	0.7692	0.121	0.04	0.075	0.217
Mirafra affinis	Jerdon's Bushlark	0.096	0	0.3846	0.202	0.1	0.373	2.06
Euodice malabarica	Indian Silverbill	0	0	0	0.5244	0	0	0
Dendrocitta vagabunda	Rufous Treepie	0.096	0.479	0.577	0.4033	0.1	0.186	0.65
Corvus macrorhynchos	Large-billed Crow	1.345	1.1976	0.8653	0.5244	0.2961	0.112	0.98
Iduna rama	Syke's Warbler	0	0	0	0	0.033	0.04	0
Copsychus saularis	Oriental Magpie Robin	0	0	0	0	0	0	0
Anthus rufulus	Paddyfield Pipit	0	0	0.0961	0	0	0.82	2.17
Acrocephalus agricola	Paddyfield Warbler	2.4976	0.599	1.827	1.13	0.53	2.686	0.76
Saxicola caprata	Pied Bushchat	0.096	0	0.096	0	0	0	0
Motacilla maeraspatensis	White-browed Wagtail	0	0.599	0	0	0	0	0
Prinia inornata	Plain Prinia	0.9606	0.1197	0	0.93	1.45	3.1716	3.687
Leptocoma zeylonica	Purple-rumped Sunbird	0	0	0	0.081	0	0	0
Amandava amandava	Red Munia	0	0	0.7692	0.2	0	0.075	0
Cecropis daurica	Red-rumped Swallow	0	0	0	0	0	0.41	1.627
Pycnonotus cafer	Red-vented Bulbul	1.0567	1.557	1.0576	0.565	0.4	0.8955	1.7353

Bird Species	Common Name	PS1 N=1041	PS2 N=835	PS3 N=1040	PS4 N=2479	PS5 N=3039	PS6 N=2980	PS 7 N=922
Lochura punctulata	Scaly-breasted Munia	0	0	0.096	0	0	0.485	0.5423
Turdoides affinis	Yellow-billed Babbler	0.48	0	0.7692	0.81	0.954	0.7836	0.76
Lonchura striata	White-rumped Munia	0	0.2395	0.3846	0	0.099	0.2	0
Gymnoris xanthocollis	Yellow-throated Sparrow	0	0	0	0	0	0.15	2.5
Cisticola juncidis	Zitting Cisticola	0.5763	0.958	2.404	2.14	0.691	2.2	6.3
Anastomus oscitans	Asian Openbill	4.226	5.8683	1.346	2.3	1.843	1.141	0.651
Ixobrychus flavicollis	Black Bittern	0	0	0	0.121	0	0.067	0.11
Bubulcus ibis	Cattle Egret	0	0	0.5769	0	0	0	0
Ixobrychus cinnamomeus	Cinnamon Bittern	0	0	0	0	0	0	0
Platalea leucorodia	Eurasian Spoonbill	0	0.1197	0	0	0	0	0
Plegadis falcinellus	Glossy Ibis	0	0	0	0	0	0	0
Ardea intermedia	Intermediate Egret	0.2882	1.1976	1.923	0.484	0.23	0.075	0.11
Ardeola grayii	Indian Pond Heron	0.1921	2.8742	2.596	2.02	0.79	1.306	3.58
Ixobrychus minutus	Little Bittern	0	0	0	0.04	0.06	0	0
Microcarbo niger	Little Cormorant	1.633	1.3174	1.0577	0	0	0	0
Egretta garzetta	Little Egret	4.42	2.994	5	0.6857	0.33	0.223	0
Threskiornis melanocephalus	Black-headed Ibis	12.872	4.91	0	0.2824	0.362	0	0.65
Ardea purpurea	Purple Heron	0.096	0.1197	0	0.16	0.066	0	0.11
Psilopogon haemacephala	Coppersmith Barbet	0	0	0	0.04	0	0.033	0
Dinopium benghalense	Lesser Golden-backed Woodpecker	0	0	0	0	0.06	0.075	0
Psittacula krameri	Rose-ringed Parakeet	0.9606	0.958	2.02	0.93	2.205	4.85	3.687
Athene brama	Spotted Owlet	0.096	0.2395	0.096	0.08	0.26	0.9	0.651

Relative abundance of birds in non-organic fields across paddy growth stages

Bird Species	Common Name	PS1 N= 1065	PS2 N=1701	PS3 N=1057	PS4 N=1112	PS5 N=1257	PS6 N=891	PS7 N=203
Milvus migrans	Black Kite	2.0657	0.353	0.19	0.63	0.2386	0.7856	2.463
Haliastur indus	Brahminy Kite	0.939	0.4703	1.04	1.26	0.159	0.561	2.463
Elanus caeruleus	Black-winged Kite	0.2817	0	0.095	0	0.159	0.45	0
Accipiter badius	Shikra	0	0	0	0	0	0	0
Butastur teesa	White- eyed Buzzard	0	0.059	0	0	0	0	0
Himantopus himantopus	Black- winged Stilt	0	0	0	0	0	0	0
	Sandpiper spp.	13.8	12.4044	2.933	0	0.159	1.123	0
Gallinago gallinago	Common Snipe	0	0.294	1.42	1.44	2.068	0	0
Charadrius dubius	Little Ringed Plover	0	3.1746	0	0	0	0	0
Rostratula bnghalensis	Greater Painted Snipe	0	0	0	0	0	0	0
Vanellus indicus	Red-wattled Lapwing	1.784	0.47	1.23	1.53	0.16	1.9	2.9556
Chlidonias hybrida	Whiskered Tern	0	0	0	0	0	0	0
Columba livia	Rock Pigeon	0	0	0	0.27	0	0	0
Streptopelia decaocto	Eurasian Collared Dove	0	0	0.19	0.5395	0.0795	0	0
Streptopelia senegalensis	Laughing Dove	0	0	0.095	0	0.08	0.898	0
Streptopelia chinensis	Spotted Dove	1.5962	0.4115	0.6622	0.989	0.114	1.347	0.4926
Merops phillipinus	Blue-tailed Bee -eater	0	0	0	0	0	0	1.477
Coracias benghalensis	Indian Roller	1.408	0.6467	0	0	0.08	0.45	0.4926
Ceryle rudis	Pied Kingfisher	0.0939	0.353	0.2838	0.09	0.24	0.1122	0
Alcido atthis	Common Kingfisher	0	0.2351	0	0.18	0	0	0
Merops orientalis	Small green Bee-eater	0.2817	0.2939	0.19	0.3597	0.318	0.224	0
Halcyon smyrnensis	White-throated Kingfisher	3.662	4.82	5.582	6.745	2.546	5.275	12.81

Bird Species	Common Name	PS1 N= 1065	PS2 N=1701	PS3 N=1057	PS4 N=1112	PS5 N=1257	PS6 N=891	PS7 N=203
Eudynamys scolopaceus	Asian Koel	0.2817	0.0588	0.0946	0.3597	0.159	0.2245	0
Hierococcyx varius	Common Hawk Cuckoo	0	0.0588	0	0.09	0	0	2.463
Centropus sinensis	Greater Coucal	0	0	0	0.09	0.08	0	0
Clamator jacobinus	Pied Cuckoo	0.1878	0	0	0.09	0	0.224	0
Falco chicquera	Red-necked Falcon	0	0	0	0	0.08	0	0
Francolinus pondicerianus	Grey Francolin	0.0939	0.2351	0.19	0.09	0	0	0
Pavo cristatus	Indian Peafowl	0	0	0	0	0	0.45	0
Gallinula chloropus	Common Moorhen	0	0	0	0.09	0.159	0	0
Zapornia fusca	Ruddy-breasted Crake	0.0939	0	0	0.18	0	0	0
Amaurornis phoenicurus	White-breasted Waterhen	0	0	0.095	0.45	0.24	0.5612	0
Terpsiphone paradisi	Asian Paradise Flycatcher	0	0	0	0	0	0	0
Prinia socialis	Ashy Prinia	0.845	0.1764	0.19	0.3597	0.477	1.571	0.4926
Artamus fuscus	Ashy Woodswallow	0.939	0.4115	0	0	0	0.224	0.9852
Ploceus phillipinus	Baya Weaver	23.4742	2.4103	0	7.6438	36.91	6.51	0
Lonchura malacca	Black-headed Munia	0	0	0.19	8.813	1.75	0.898	0
Dicrurus macrocercus	Black Drongo	20.1	7.82	10.88	9.173	4.455	5.5	15.7635
Luscinia svecica	Bluethroat	0	0	0	0	0	0	0
Sturnia pagodarum	Brahminy Starling	0.0939	0.5879	1.514	0	0	0.224	0
Lanius cristatus	Brown Shrike	0	0	0	0.09	0	0.1122	0
Acrocephalus dumetorum	Blyth's reed Warbler	0	0	0.2838	0.5395	0.318	0.6734	0.4926
Acidotheres tristis	Common Myna	9.765	7.0547	18.543	11.421	5.09	5.05	10.8374
Saxicola maurus	Siberian Stonechat	0	0	0	0	0	0	0
Hirundo rustica	Barn Swallow	4.788	19.518	12.11	4.676	22.4344	4.94	1.477

Bird Species	Common Name	PS1 N= 1065	PS2 N=1701	PS3 N=1057	PS4 N=1112	PS5 N=1257	PS6 N=891	PS7 N=203
Orthotomus sutorius	Common Tailorbird	0	0	0	0.09	0	0	0
Prinia hodgsonii	Grey-breasted Prinia	0	0	0	0	0	0	0
Oriolus oriolus	Eurasian Golden Oriole	0.0939	0.0588	0.19	0.09	0.08	0.224	0
Motacilla cinerea	Grey Wagtail	0	0	0	0	0	0	0
Corvus splendens	House Crow	0.469	0	0	0.09	0	0	1.97
Mirafra affinis	Jerdon's Bushlark	0.2817	0	0.095	0.72	1.114	0.5611	4.433
Euodice malabarica	Indian Silverbill	0	0	0	0	0	0	0
Dendrocitta vagabunda	Rufous Treepie	0.469	0.53	0.5676	0.63	0.557	0.224	0
Corvus macrorhynchos	Large-billed Crow	1.22	0.0588	0.19	0.09	0.08	1.234	0
Iduna rama	Syke's Warbler	0	0	0	0	0	0	0
Copsychus saularis	Oriental Magpie Robin	0	0	0	0.09	0	0	0
Anthus rufulus	Paddyfield Pipit	0	0.7055	0.8514	0.9	0.08	0.5611	5.4187
Acrocephalus agricola	Paddyfield Warbler	1.033	0.4115	0.757	1.888	1.83	3.255	0
Saxicola caprata	Pied Bushchat	0	0	0	0	0	0	0
Motacilla maeraspatensis	White-browed Wagtail	0.2817	0.881	0.2838	0	0	0	0
Prinia inornata	Plain Prinia	0	0.12	0.8515	1.798	1.9	1.1223	5.4187
Leptocoma zeylonica	Purple-rumped Sunbird	0	0	0	0	0	0	0
Amandava amandava	Red Munia	0	0	0	0	0	0	0
Cecropis daurica	Red-rumped Swallow	0	0	0	0.27	0.716	31.425	0
Pycnonotus cafer	Red-vented Bulbul	1.0328	1.3521	0.6622	1.44	0.955	1.234	3.4483
Lochura punctulata	Scaly-breasted Munia	0	0	0	0	0.16	0	0
Turdoides affinis	Yellow-billed Babbler	2.2535	3.88	3.879	5.216	1.9	3.93	7.882
Lonchura striata	White-rumped Munia	0.0939	0	0.5676	0.5395	0	0.337	0

Bird Species	Common Name	PS1 N= 1065	PS2 N=1701	PS3 N=1057	PS4 N=1112	PS5 N=1257	PS6 N=891	PS7 N=203
Gymnoris xanthocollis	Yellow-throated Sparrow	0	0	0	0	0	0	0
Cisticola juncidis	Zitting Cisticola	1.3145	0.6467	6.244	8.363	5.41	8.08	7.389
Anastomus oscitans	Asian Openbill	0.3756	1.94	1.703	2.7877	0.875	0.45	0.4926
Ixobrychus flavicollis	Black Bittern	0	0	0	0.18	0	0	0
Bubulcus ibis	Cattle Egret	0	3.9976	0	0	0	0	0
Ixobrychus cinnamomeus	Cinnamon Bittern	0.0939	0	0	0.09	0	0.1122	0
Platalea leucorodia	Eurasian Spoonbill	0	0	0	0	0	0	0
Plegadis falcinellus	Glossy Ibis	0	0	0.19	1.9784	0	0	0
Ardea intermedia	Intermediate Egret	0.3756	14.756	5.487	0.5395	0.24	0.1122	0
Ardeola grayii	Indian Pond Heron	0.2817	2.88	10.7852	12.77	2.625	2.245	0.9852
Ixobrychus minutus	Little Bittern	0	0	0.095	0	0	0	0
Microcarbo niger	Little Cormorant	0.1878	0.1763	0	0.3597	0.32	0	1.477
Egretta garzetta	Little Egret	2.723	4.82	8.042	0.27	0.32	0.45	0
Threskiornis melanocephalus	Black-headed Ibis	0	0	0	0	0	0.1122	0
Ardea purpurea	Purple Heron	0.0939	0	0	0	0.08	0	0
Psilopogon haemacephala	Coppersmith Barbet	0	0	0.095	0	1.114	0.3367	0
Dinopium benghalense	Lesser Golden-backed Woodpecker	0	0	0.2838	0.18	0	0.1122	0.9852
Psittacula krameri	Rose-ringed Parakeet	0.7512	0.47	0.19	0.45	0.08	3.5914	4.433
Athene brama	Spotted Owlet	0	0	0	0	0	0	0

Relative abundance of odonates in paddy fields of Kadhiramangalam across paddy growth stages

Family	Odonate Species	PS 1 N=2034	PS 2 N=2905	PS 3 N=4742	PS 4 N=3215	PS 5 N=1263	PS 6 N=1093	PS 7 N=274
Aeshnidae	*Anax guttatus*	0.10	0.07	0.02	0.00	0.00	0.00	0.00
Gomphidae	*Paragomphus lineatus*	0.05	0.00	0.00	0.03	0.00	0.00	0.00
Libellulidae	*Rhyothemis variegata*	0.29	0.00	0.06	0.00	0.00	0.27	0.00
Libellulidae	*Tholymis tillarga*	0.00	0.10	0.19	0.06	0.00	0.00	0.00
Libellulidae	*Brachythemis contaminata*	0.69	0.65	0.06	0.22	0.40	0.18	1.46
Libellulidae	*Orthetrum sabina*	26.01	11.12	5.02	7.93	25.18	33.94	58.76
Libellulidae	*Trithemis pallidinervis*	0.15	0.10	0.13	0.00	0.00	0.00	0.00
Libellulidae	*Tramea basilaris*	0.05	0.34	0.21	0.09	0.00	0.00	0.00
Libellulidae	*Crocothemis servilia*	6.05	9.47	12.19	7.19	3.96	2.29	4.74
Libellulidae	*Acisoma panorpoides*	0.00	0.00	0.00	0.00	0.16	0.00	0.00
Libellulidae	*Pantala flavescens*	38.79	39.07	32.62	2.30	1.03	18.94	5.11
Libellulidae	*Potamarcha congener*	0.25	0.34	0.00	0.00	0.00	0.00	0.00
Libellulidae	*Urothemis signata*	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Libellulidae	*Diplacodes trivialis*	15.54	15.46	13.33	34.43	47.66	24.79	18.61
Coenagrionidae	*Ceriagrion coromandelianum*	0.34	0.31	0.21	0.78	1.35	1.65	0.36
Coenagrionidae	*Ischnura aurora*	5.51	18.28	29.52	42.92	17.74	10.61	8.03
Coenagrionidae	*Aciogrion occidentale*	0.00	0.00	0.00	0.00	0.00	0.09	0.00
Coenagrionidae	*Pseudagrion microcephalum*	0.00	0.07	0.00	0.06	0.00	0.00	0.00
Lestidae	*Lestes elatus*	0.10	0.00	0.02	0.00	0.00	0.00	0.00
Coenagrionidae	*Agriocnemis pygmaea*	5.95	4.41	6.22	3.89	2.53	7.14	2.92
Coenagrionidae	*Pseudagrion rubriceps*	0.00	0.00	0.00	0.00	0.00	0.09	0.00
Coenagrionidae	*Ischnura senegalensis*	0.10	0.17	0.19	0.09	0.00	0.00	0.00
Coenagrionidae	*Pseudagrion decorum*	0.00	0.03	0.00	0.00	0.00	0.00	0.00

Relative abundance of odonates in organic fields across paddy growth stages

Family	Odonate Species	PS 1 N=767	PS 2 N=847	PS 3 N=2323	PS 4 N=1096	PS 5 N=613	PS 6 N=461	PS7 N=153	Organic N= 6260
Aeshnidae	*Anax guttatus*	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.18
Coenagrionidae	*Pseudagrion microcephalum*	0.26	0.12	0.00	0.00	0.00	0.00	0.00	0.38
Coenagrionidae	*Ceriagrion coromandelianum*	0.91	0.12	0.22	1.92	2.78	1.96	0.66	8.56
Gomphidae	*Paragomphus lineatus*	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Libellulidae	*Rhyothemis variegata*	0.65	0.00	0.13	0.00	0.00	0.22	0.00	1.00
Libellulidae	*Tholymis tillarga*	0.00	0.35	0.39	0.09	0.00	0.00	0.00	0.83
Libellulidae	*Brachythemis contaminata*	0.39	1.54	0.00	0.00	0.00	0.22	0.00	2.15
Lestidae	*Lestes elatus*	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.26
Libellulidae	*Urothemis signata*	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Coenagrionidae	*Ischnura aurora*	2.74	8.87	3.62	18.90	8.82	5.22	13.16	61.33
Libellulidae	*Orthetrum sabina*	48.43	21.16	8.23	15.62	18.63	41.09	44.08	197.23
Libellulidae	*Diplacodes trivialis*	13.58	18.20	2.97	37.17	60.29	38.70	28.95	199.86
Coenagrionidae	*Aciogrion occidentale*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Libellulidae	*Trithemis pallidinervis*	0.00	0.35	0.26	0.00	0.00	0.00	0.00	0.61
Coenagrionidae	*Agriocnemis pygmaea*	4.31	8.51	3.53	5.94	1.63	3.04	5.26	32.23
Libellulidae	*Tramea basilaris*	0.00	0.12	0.43	0.09	0.00	0.00	0.00	0.64
Libellulidae	*Crocothemis servilia*	11.49	11.23	23.08	14.52	6.86	2.17	3.95	73.31
Coenagrionidae	*Pseudagrion rubriceps*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	*Ischnura senegalensis*	0.00	0.47	0.26	0.00	0.00	0.00	0.00	0.73
Coenagrionidae	*Pseudagrion decorum*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Libellulidae	*Acisoma panorpoides*	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33
Libellulidae	*Pantala flavescens*	16.71	28.96	56.89	5.57	0.65	7.39	3.95	120.12
Libellulidae	*Potamarcha congener*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Relative abundance of odonates in non-organic fields across paddy growth stages

Family	Odonate Species	PS 1 N=1268	PS 2 N= 2059	PS 3 N=2420	PS 4 N=2120	PS 5 N=651	PS 6 N=633	PS 7 N=122	Non-organic N= 9273
Aeshnidae	*Anax guttatus*	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.10
Coenagrionidae	*Pseudagrion microcephalum*	0.00	0.05	0.04	0.00	0.00	0.00	0.00	0.09
Coenagrionidae	*Ceriagrion coromandelianum*	0.00	0.39	0.21	0.19	0.00	1.42	0.00	2.21
Gomphidae	*Paragomphus lineatus*	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05
Libellulidae	*Rhyothemis variegata*	0.08	0.00	0.00	0.00	0.00	0.32	0.00	0.39
Libellulidae	*Tholymis tillarga*	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05
Libellulidae	*Brachythemis contaminata*	0.87	0.29	0.12	0.33	0.77	0.16	3.28	5.82
Lestidae	*Lestes elatus*	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.04
Libellulidae	*Urothemis signata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	*Ischnura aurora*	7.18	22.15	54.38	55.33	26.11	14.53	1.64	181.32
Libellulidae	*Orthetrum sabina*	12.46	6.99	1.94	3.96	31.34	28.75	77.05	162.50
Libellulidae	*Diplacodes trivialis*	16.72	14.33	23.26	33.02	35.79	14.69	5.74	143.55
Coenagrionidae	*Aciogrion occidentale*	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16
Libellulidae	*Trithemis pallidinervis*	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Coenagrionidae	*Agriocnemis pygmaea*	6.94	2.72	8.80	2.83	3.38	10.11	0.00	34.78
Libellulidae	*Tramea basilaris*	0.08	0.44	0.00	0.09	0.00	0.00	0.00	0.61
Libellulidae	*Crocothemis servilia*	2.76	8.74	1.74	3.40	1.23	2.37	5.74	25.97
Coenagrionidae	*Pseudagrion rubriceps*	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16
Coenagrionidae	*Ischnura senegalensis*	0.16	0.05	0.12	0.14	0.00	0.00	0.00	0.47
Coenagrionidae	*Pseudagrion decorum*	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.05
Libellulidae	*Acisoma panorpoides*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Libellulidae	*Pantala flavescens*	52.13	43.22	9.34	0.61	1.38	27.33	6.56	140.58
Libellulidae	*Potamarcha congener*	0.39	0.49	0.00	0.00	0.00	0.00	0.00	0.88

Relative abundance of butterflies in paddy fields of Kadhiramangalam across paddy growth stages

Family	Common Name	Butterfly species	PS1 N=264	PS2 N=192	PS3 N=223	PS4 N=163	PS5 N=162	PS6 N=285	PS7 N=171
Hesperiidae	Bush Hopper	*Ampittia dioscorides* (Fabricius)	1.52	3.65	10.76	27.61	12.96	13.33	3.51
Hesperiidae	Common Grass Dart	*Taractrocera maevius* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.35	0.00
Hesperiidae	Dark Palm Dart	*Telicota ancilla* (Herrich-Schaffer)	0.38	0.00	0.00	1.23	0.00	1.05	0.00
Hesperiidae	Pale Palm Dart	*Telicota colon* (Fabricius)	0.00	0.00	0.90	2.45	1.23	0.00	0.00
Hesperiidae	Pygmy Scrub Hopper	*Aeromachus pygmaeus* (Fabricius)	0.00	0.00	1.35	0.00	0.00	0.35	0.00
Hesperiidae	Rice Swift	*Borbo cinnara* (Wallace)	1.52	2.60	3.14	15.95	5.56	2.46	0.58
Hesperiidae	Small Branded Swift	*Pelopidas mathias* (Fabricius)	0.00	0.52	0.00	2.45	0.62	0.00	0.00
Hesperiidae	Straight Swift	*Parnara sp.*	0.00	0.00	0.00	1.84	0.00	0.00	0.00
Lycaenidae	Common Cerulean	*Jamides celeno* (Cramer)	0.38	1.56	0.90	0.61	0.00	0.00	0.00
Lycaenidae	Common Pierrot	*Castalius rosimon* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.35	0.00
Lycaenidae	Forget me-not	*Catochrysops strabo* (Fabricius)	0.00	0.00	0.00	0.00	0.62	0.00	0.00
Lycaenidae	Gram Blue	*Euchrysops cnejus* (Fabricius)	2.65	0.00	0.00	2.45	6.17	12.63	39.18
Lycaenidae	Grass Jewel	*Freyeria trochylus* (Freyer)	0.00	0.00	0.00	0.00	0.00	0.35	0.00
Lycaenidae	Indian Cupid	*Everes lacturnus* (Godart)	0.38	0.00	0.00	0.61	1.85	0.35	0.00
Lycaenidae	Lesser Grass Blue	*Zizina otis* (Fabricius)	0.00	0.00	0.00	0.00	0.62	0.70	0.58
Lycaenidae	Pale Grass Blue	*Pseudozizeeria maha* (Kollar)	0.00	0.00	0.00	0.61	0.62	0.35	0.00
Lycaenidae	Indian Sunbeam	*Curetis thetis* (Drury)	0.00	0.52	0.00	0.00	0.00	0.00	0.00
Lycaenidae	Tiny Grass Blue	*Zizula hylax* (Fabricius)	0.38	1.56	0.45	0.00	0.00	2.11	1.17
Nymphalidae	Angled Castor	*Ariadne ariadne* (Linnaeus)	0.00	0.00	0.00	0.00	6.79	1.75	2.92
Nymphalidae	Blue Pansy	*Junonia orithiya* (Linnaeus)	0.38	0.00	0.00	0.00	0.00	0.00	0.58
Nymphalidae	Blue Tiger	*Tirumala limniace* (Cramer)	0.76	2.60	5.83	0.00	0.00	0.35	0.00
Nymphalidae	Common Evening Brown	*Melanitis leda* (Linnaeus)	1.89	7.29	13.90	12.88	11.11	8.07	9.94
Nymphalidae	Chocolate Pansy	*Junonia atlites* (Cramer)	0.00	0.00	0.45	0.00	0.62	1.75	0.00
Nymphalidae	Common Bushbrown	*Mycalesis perseus* (Fabricius)	1.89	1.04	1.35	10.43	21.60	9.82	12.28

Family	Common Name	Butterfly species	PS1 N=264	PS2 N=192	PS3 N=223	PS4 N=163	PS5 N=162	PS6 N=285	PS7 N=171
Nymphalidae	Common Castor	*Ariadne merione* (Cramer)	0.00	2.08	1.35	4.91	1.23	0.35	1.17
Nymphalidae	Common Crow	*Euploea core* (Cramer)	1.89	1.04	2.24	0.00	0.00	0.00	0.00
Nymphalidae	Danaid Eggfly	*Hypolimnas misippus* (Linnaeus)	3.41	4.69	2.69	0.61	0.00	0.00	0.00
Nymphalidae	Dark Evening Brown	*Melanitis phedima* (Cramer)	0.00	0.00	0.00	0.61	0.00	0.00	0.00
Nymphalidae	Joker	*Byblia ilithyia* (Drury)	0.38	0.52	0.00	0.00	0.00	0.00	0.00
Nymphalidae	Lemon Pansy	*Junonia lemonias* (Linnaeus)	0.00	0.52	0.00	0.00	0.00	0.35	0.00
Nymphalidae	Peacock Pansy	*Junonia almana* (Linnaeus)	17.42	8.33	6.73	2.45	4.94	10.18	11.70
Nymphalidae	Plain Tiger	*Danaus chrysippus* (Linnaeus)	12.88	21.88	12.56	2.45	1.23	2.46	1.75
Nymphalidae	Striped Tiger	*Danaus genutia* (Cramer)	2.27	1.56	2.24	0.61	0.00	1.05	0.00
Nymphalidae	Tawny Coster	*Acraea violae* (Fabricius)	2.27	6.77	3.14	0.61	1.23	1.05	1.75
Papilionidae	Common Bluebottle	*Graphium sarpedon*(Linnaeus)	0.76	0.52	0.00	0.00	0.00	0.00	0.00
Papilionidae	Common Jay	*Graphium doson* (C. and R. Felder)	0.38	0.00	0.00	0.00	0.00	0.00	0.00
Papilionidae	Common Mormon	*Papilio polytes* (Linnaeus)	2.27	1.04	2.24	2.45	1.85	0.00	0.58
Papilionidae	Common Rose	*Atrophaneura aristolochiae* (Fabricius)	0.38	1.04	2.24	1.84	0.62	3.51	1.17
Papilionidae	Crimson Rose	*Atrophaneura hector* (Linnaeus)	3.79	9.38	4.93	1.23	0.62	2.11	1.17
Papilionidae	Lime Butterfly	*Papilio demoleus* (Linnaeus)	6.82	1.56	6.28	0.00	0.00	1.40	1.75
Pieridae	Common Grass Yellow	*Eurema hecabe* (Linnaeus)	3.41	0.52	3.14	1.23	11.11	14.74	5.26
Pieridae	Common Albatross	*Appias albina* (Boisduval)	4.17	2.60	1.79	0.00	0.62	0.70	0.00
Pieridae	Common Emigrant	*Catopsilia pomona* (Fabricius)	23.48	13.02	7.62	0.61	1.85	3.16	0.00
Pieridae	Common Gull	*Cepora nerissa* (Fabricius)	0.38	0.00	0.00	0.00	0.00	0.00	0.58
Pieridae	Common Jezebel	*Delias eucharis* (Drury)	0.76	1.04	1.35	0.61	4.32	2.46	1.75
Pieridae	Common Wanderer	*Pareronia valeria* (Cramer)	0.00	0.00	0.00	0.00	0.00	0.35	0.58
Pieridae	Crimson Tip	*Colotis danae* (Fabricius)	0.00	0.00	0.00	0.61	0.00	0.00	0.00
Pieridae	Mottled Emigrant	*Catopsilia pyranthe* (Fabricius)	0.76	0.52	0.45	0.00	0.00	0.00	0.00

Relative abundance of butterflies in organic fields across paddy growth stages

Family	Butterfly species	PS1 RA N=186	PS2 RA N=70	PS3 RA N= 170	PS4 RA N=57	PS5 RA N= 72	PS6 RA N= 135	PS7 RA N= 115
Hesperiidae	*Ampittia dioscorides* (Fabricius)	0.00	2.86	1.76	14.04	9.72	5.93	1.74
Hesperiidae	*Taractrocera maevius* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hesperiidae	*Telicota ancilla* (Herrich-Schaffer)	0.00	0.00	0.00	1.75	0.00	1.48	0.00
Hesperiidae	*Telicota colon* (Fabricius)	0.00	0.00	0.00	3.51	2.78	0.00	0.00
Hesperiidae	*Aeromachus pygmaeus* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hesperiidae	*Borbo cinnara* (Wallace)	0.54	4.29	2.35	14.04	5.56	0.74	0.00
Hesperiidae	*Pelopidas mathias* (Fabricius)	0.00	0.00	0.00	0.00	1.39	0.00	0.00
Hesperiidae	*Parnara sp.*	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Jamides celeno* (Cramer)	0.54	0.00	0.59	1.75	0.00	0.00	0.00
Lycaenidae	*Castalius rosimon* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.74	0.00
Lycaenidae	*Catochrysops strabo* (Fabricius)	0.00	0.00	0.00	0.00	1.39	0.00	0.00
Lycaenidae	*Euchrysops cnejus* (Fabricius)	3.23	0.00	0.00	0.00	0.00	18.52	49.57
Lycaenidae	*Freyeria trochylus* (Freyer)	0.00	0.00	0.00	0.00	0.00	0.74	0.00
Lycaenidae	*Everes lacturnus* (Godart)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Zizina otis* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.74	0.00
Lycaenidae	*Pseudozizeeria maha* (Kollar)	0.00	0.00	0.00	0.00	1.39	0.74	0.00
Lycaenidae	*Curetis thetis* (Drury)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Zizula hylax* (Fabricius)	0.00	0.00	0.59	0.00	0.00	0.00	0.87
Nymphalidae	*Ariadne ariadne* (Linnaeus)	0.00	0.00	0.00	0.00	13.89	3.70	4.35
Nymphalidae	*Junonia orithiya* (Linnaeus)	0.00	0.00	0.00	0.00	0.00	0.00	0.87
Nymphalidae	*Tirumala limniace* (Cramer)	0.54	2.86	7.65	0.00	0.00	0.00	0.00
Nymphalidae	*Melanitis leda* (Linnaeus)	1.08	5.71	10.00	19.30	11.11	5.19	1.74
Nymphalidae	*Junonia atlites* (Cramer)	0.00	0.00	0.59	0.00	0.00	0.74	0.00
Nymphalidae	*Mycalesis perseus* (Fabricius)	2.15	2.86	1.18	22.81	12.50	10.37	14.78

Family	Butterfly species	PS1 RA N=186	PS2 RA N=70	PS3 RA N= 170	PS4 RA N=57	PS5 RA N= 72	PS6 RA N= 135	PS7 RA N= 115
Nymphalidae	*Ariadne merione* (Cramer)	0.00	1.43	0.00	5.26	2.78	0.00	0.87
Nymphalidae	*Euploea core* (Cramer)	1.08	1.43	2.94	0.00	0.00	0.00	0.00
Nymphalidae	*Hypolimnas misippus* (Linnaeus)	4.84	4.29	3.53	0.00	0.00	0.00	0.00
Nymphalidae	*Melanitis phedima* (Cramer)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nymphalidae	*Byblia ilithyia* (Drury)	0.54	0.00	0.00	0.00	0.00	0.00	0.00
Nymphalidae	*Junonia lemonias* (Linnaeus)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nymphalidae	*Junonia almana* (Linnaeus)	17.74	11.43	8.82	0.00	1.39	2.96	8.70
Nymphalidae	*Danaus chrysippus* (Linnaeus)	11.83	11.43	16.47	3.51	0.00	1.48	1.74
Nymphalidae	*Danaus genutia* (Cramer)	3.23	0.00	2.94	0.00	0.00	0.00	0.00
Nymphalidae	*Acraea violae* (Fabricius)	2.69	7.14	4.12	1.75	2.78	0.00	2.61
Papilionidae	*Graphium sarpedon*(Linnaeus)	1.08	1.43	0.00	0.00	0.00	0.00	0.00
Papilionidae	*Graphium doson* (C. and R. Felder)	0.54	0.00	0.00	0.00	0.00	0.00	0.00
Papilionidae	*Papilio polytes* (Linnaeus)	2.69	0.00	2.94	3.51	4.17	0.00	0.87
Papilionidae	*Atrophaneura aristolochiae* (Fabricius)	0.00	1.43	2.35	1.75	0.00	6.67	0.87
Papilionidae	*Atrophaneura hector* (Linnaeus)	3.76	10.00	6.47	3.51	1.39	2.22	0.87
Papilionidae	*Papilio demoleus* (Linnaeus)	6.99	1.43	8.24	0.00	0.00	0.00	0.00
Pieridae	*Eurema hecabe* (Linnaeus)	3.76	0.00	2.35	0.00	20.83	31.11	6.09
Pieridae	*Appias albina* (Boisduval)	4.30	5.71	2.35	0.00	1.39	0.00	0.00
Pieridae	*Catopsilia pomona* (Fabricius)	26.34	21.43	10.00	1.75	0.00	2.22	0.00
Pieridae	*Cepora nerissa* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.00	0.87
Pieridae	*Delias eucharis* (Drury)	0.00	1.43	1.18	0.00	5.56	3.70	1.74
Pieridae	*Pareronia valeria* (Cramer)	0.00	0.00	0.00	0.00	0.00	0.00	0.87
Pieridae	*Colotis danae* (Fabricius)	0.00	0.00	0.00	1.75	0.00	0.00	0.00
Pieridae	*Catopsilia pyranthe* (Fabricius)	0.54	1.43	0.59	0.00	0.00	0.00	0.00

Relative abundance of butterflies in non-organic fields across paddy growth stages

Family	Scientific Name	PS1 RA N=78	PS2 RA N=122	PS3 RA N=53	PS4 RA N= 106	PS5 RA N=89	PS6 RA N= 150	PS7 RA N=56
Hesperiidae	*Ampittia dioscorides* (Fabricius)	5.13	4.10	39.62	34.91	15.73	20.00	7.14
Hesperiidae	*Taractrocera maevius* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.67	0.00
Hesperiidae	*Telicota ancilla* (Herrich-Schaffer)	1.28	0.00	0.00	0.94	0.00	0.67	0.00
Hesperiidae	*Telicota colon* (Fabricius)	0.00	0.00	3.77	1.89	0.00	0.00	0.00
Hesperiidae	*Aeromachus pygmaeus* (Fabricius)	0.00	0.00	5.66	0.00	0.00	0.67	0.00
Hesperiidae	*Borbo cinnara* (Wallace)	3.85	1.64	5.66	16.98	5.62	4.00	1.79
Hesperiidae	*Pelopidas mathias* (Fabricius)	0.00	0.82	0.00	3.77	0.00	0.00	0.00
Hesperiidae	*Parnara sp.*	0.00	0.00	0.00	2.83	0.00	0.00	0.00
Lycaenidae	*Jamides celeno* (Cramer)	0.00	2.46	1.89	0.00	0.00	0.00	0.00
Lycaenidae	*Castalius rosimon* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Catochrysops strabo* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Euchrysops cnejus* (Fabricius)	1.28	0.00	0.00	3.77	11.24	7.33	17.86
Lycaenidae	*Freyeria trochylus* (Freyer)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Everes lacturnus* (Godart)	1.28	0.00	0.00	0.94	3.37	0.67	0.00
Lycaenidae	*Zizina otis* (Fabricius)	0.00	0.00	0.00	0.00	1.12	0.67	1.79
Lycaenidae	*Pseudozizeeria maha* (Kollar)	0.00	0.00	0.00	0.94	0.00	0.00	0.00
Lycaenidae	*Curetis thetis* (Drury)	0.00	0.82	0.00	0.00	0.00	0.00	0.00
Lycaenidae	*Zizula hylax* (Fabricius)	1.28	2.46	0.00	0.00	0.00	4.00	1.79
Nymphalidae	*Ariadne ariadne* (Linnaeus)	0.00	0.00	0.00	0.00	1.12	0.00	0.00
Nymphalidae	*Junonia orithiya* (Linnaeus)	1.28	0.00	0.00	0.00	0.00	0.00	0.00
Nymphalidae	*Tirumala limniace* (Cramer)	1.28	2.46	0.00	0.00	0.00	0.67	0.00
Nymphalidae	*Melanitis leda* (Linnaeus)	3.85	8.20	26.42	9.43	11.24	10.67	26.79
Nymphalidae	*Junonia atlites* (Cramer)	0.00	0.00	0.00	0.00	1.12	2.67	0.00

Family	Scientific Name	PS1 RA N=78	PS2 RA N=122	PS3 RA N=53	PS4 RA N= 106	PS5 RA N=89	PS6 RA N= 150	PS7 RA N=56
Nymphalidae	*Mycalesis perseus* (Fabricius)	1.28	0.00	1.89	3.77	28.09	9.33	7.14
Nymphalidae	*Ariadne merione* (Cramer)	0.00	2.46	5.66	4.72	0.00	0.67	1.79
Nymphalidae	*Euploea core* (Cramer)	3.85	0.82	0.00	0.00	0.00	0.00	0.00
Nymphalidae	*Hypolimnas misippus* (Linnaeus)	0.00	4.92	0.00	0.94	0.00	0.00	0.00
Nymphalidae	*Melanitis phedima* (Cramer)	0.00	0.00	0.00	0.94	0.00	0.00	0.00
Nymphalidae	*Byblia ilithyia* (Drury)	0.00	0.82	0.00	0.00	0.00	0.00	0.00
Nymphalidae	*Junonia lemonias* (Linnaeus)	0.00	0.82	0.00	0.00	0.00	0.67	0.00
Nymphalidae	*Junonia almana* (Linnaeus)	16.67	6.56	0.00	3.77	7.87	16.67	17.86
Nymphalidae	*Danaus chrysippus* (Linnaeus)	15.38	27.87	0.00	1.89	2.25	3.33	1.79
Nymphalidae	*Danaus genutia* (Cramer)	0.00	2.46	0.00	0.94	0.00	2.00	0.00
Nymphalidae	*Acraea violae* (Fabricius)	1.28	6.56	0.00	0.00	0.00	2.00	0.00
Papilionidae	*Graphium Sarpedon* (Linnaeus)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papilionidae	*Graphium doson* (C. and R. Felder)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Papilionidae	*Papilio polytes* (Linnaeus)	1.28	1.64	0.00	1.89	0.00	0.00	0.00
Papilionidae	*Atrophaneura aristolochiae* (Fabricius)	1.28	0.82	1.89	1.89	1.12	0.67	1.79
Papilionidae	*Atrophaneura hector* (Linnaeus)	3.85	9.02	0.00	0.00	0.00	2.00	1.79
Papilionidae	*Papilio demoleus* (Linnaeus)	6.41	1.64	0.00	0.00	0.00	2.67	5.36
Pieridae	*Eurema hecabe* (Linnaeus)	2.56	0.82	5.66	1.89	3.37	0.00	3.57
Pieridae	*Appias albina* (Boisduval)	3.85	0.82	0.00	0.00	0.00	1.33	0.00
Pieridae	*Catopsilia pomona* (Fabricius)	16.67	8.20	0.00	0.00	3.37	4.00	0.00
Pieridae	*Cepora nerissa* (Fabricius)	1.28	0.00	0.00	0.00	0.00	0.00	0.00
Pieridae	*Delias eucharis* (Drury)	2.56	0.82	1.89	0.94	3.37	1.33	1.79
Pieridae	*Pareronia valeria* (Cramer)	0.00	0.00	0.00	0.00	0.00	0.67	0.00
Pieridae	*Colotis danae* (Fabricius)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pieridae	*Catopsilia pyranthe* (Fabricius)	1.28	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX 4

The SIMPER analysis of the select indicator taxa between organic and non-organic regimes among each paddy growth stage

SIMPER Analysis of birds

PS 1 Average Dissimilarity = 72.33%							
Order	**Family**	**Bird Species**	**Average Dissimilarity**	**Contribution %**	**Cumulative contribution %**	**Mean Abundance**	
						Organic	**Non-Organic**
Charadriiformes	Scolopacidae	*Actitis hypoleucos*	12.87	17.79	17.79	39.9	21
Passeriformes	Ploceidae	*Ploceus phillipinus*	11.5	15.91	33.7	5.14	35.7
Passeriformes	Dicruridae	*Dicrurus macrocercus*	8.454	11.69	45.38	4.71	30.6
Pelecaniformes	Threskiornithidae	*Threskiornis melanocephalus*	4.969	6.87	52.25	19.1	0
Passeriformes	Sturnidae	*Acidotheres tristis*	3.994	5.522	57.78	3.29	14.9
Charadriiformes	Recurvirostridae	*Himantopus himantopus*	3.929	5.432	63.21	15.1	0
Passeriformes	Hirundinidae	*Hirundo rustica*	2.509	3.469	66.68	1.14	7.29
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	1.918	2.652	69.33	10.6	5.57
Pelecaniformes	Ciconiidae	*Anastomus oscitans*	1.835	2.538	71.87	6.29	0.571
Pelecaniformes	Ardeidae	*Egretta garzetta*	1.803	2.492	74.36	6.57	4.14
Passeriformes	Motacillidae	*Anthus rufulus*	1.54	2.129	76.49	3.71	1.57
Charadriiformes	Charadriidae	*Vanellus indicus*	1.396	1.93	78.42	4.86	2.71
Accipitriformes	Accipitridae	*Milvus migrans*	1.2	1.659	80.08	2.43	3.14
Passeriformes	Leiothricidae	*Turdoides affinis*	1.099	1.52	81.6	0.714	3.43
Passeriformes	Cisticolidae	*Prinia socialis*	1.035	1.431	83.03	3.71	1.29
Pelecaniformes	Phalocrocaracidae	*Microcarbo niger*	0.9737	1.346	84.37	2.43	0.286
Passeriformes	Corvidae	*Corvus macrorhynchos*	0.9147	1.265	85.64	2	1.86

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Columbiformes	Columbidae	*Streptopelia chinensis*	0.8622	1.192	86.83	0.429	2.43
Passeriformes	Pycnonotidae	*Pycnonotus cafer*	0.8436	1.166	88	1.57	1.57
Passeriformes	Estrildidae	*Lonchura malacca*	0.7891	1.091	89.09	1.86	0
Coraciiformes	Coraciidae	*Coracias benghalensis*	0.7543	1.043	90.13	0.143	2.14
PS 2 Average Dissimilarity = 67.6%							
Passeriformes	Hirundinidae	*Hirundo rustica*	10.47	15.6	15.6	5	36.9
Pelecaniformes	Ardeidae	*Ardea intermedia*	8.561	12.75	28.34	1.43	27.9
Charadriiformes	Scolopacidae	*Actitis hypoleucos*	5.506	8.198	36.54	18.1	23.4
Charadriiformes	Recurvirostridae	*Himantopus himantopus*	3.494	5.202	41.74	10.4	0
Passeriformes	Dicruridae	*Dicrurus macrocercus*	3.099	4.615	46.36	5.71	14.8
Passeriformes	Sturnidae	*Acidotheres tristis*	3.098	4.612	50.97	3.86	13.3
Charadriiformes	Charadriidae	*Vanellus indicus*	2.871	4.274	55.24	9.29	0.889
Passeriformes	Ploceidae	*Ploceus phillipinus*	2.784	4.145	59.39	6.86	4.56
Passeriformes	Leiothricidae	*Turdoides affinis*	2.388	3.556	62.94	0	7.33
Pelecaniformes	Ciconiidae	*Anastomus oscitans*	2.318	3.451	66.39	7	3.67
Pelecaniformes	Ardeidae	*Egretta garzetta*	2.296	3.418	69.81	3.57	9.11
Pelecaniformes	Ardeidae	*Bubulcus ibis*	2.236	3.329	73.14	0	7.56
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	2.133	3.175	76.32	14.6	9.11
Pelecaniformes	Threskiornithidae	*Threskiornis melanocephalus*	1.788	2.663	78.98	5.86	0
Charadriiformes	Charadriidae	*Charadrius dubius*	1.655	2.465	81.44	0	6

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Pelecaniformes	Ardeidae	*Ardeola grayii*	1.502	2.236	83.68	3.43	5.44
Columbiformes	Columbidae	*Streptopelia chinensis*	0.738	1.099	84.78	2.57	0.778
Passeriformes	Cisticolidae	*Cisticola juncidis*	0.6948	1.035	85.81	1.14	1.22
Passeriformes	Cisticolidae	*Prinia socialis*	0.6591	0.9814	86.79	2.14	0.333
Passeriformes	Pycnonotidae	*Pycnonotus cafer*	0.6331	0.9427	87.74	1.86	2.56
Passeriformes	Motacillidae	*Motacilla maeraspatensis*	0.5383	0.8015	88.54	0.714	1.67
Pelecaniformes	Phalocrocaracidae	*Microcarbo niger*	0.5156	0.7676	89.31	1.57	0.333
Psittaciformes	Psittacidae	*Psittacula krameri*	0.5138	0.765	90.07	1.14	0.889
PS 3 Average Dissimilarity = 65.49%							
Passeriformes	Sturnidae	*Acidotheres tristis*	8.113	12.39	12.39	8.11	32.7
Passeriformes	Hirundinidae	*Hirundo rustica*	6.668	10.18	22.57	2.78	21.3
Pelecaniformes	Ardeidae	*Ardeola grayii*	5.424	8.283	30.86	3	19
Pelecaniformes	Ardeidae	*Egretta garzetta*	4.073	6.22	37.07	5.78	14.2
Passeriformes	Dicruridae	*Dicrurus macrocercus*	3.897	5.951	43.03	8.78	19.2
Charadriiformes	Scolopacidae	*Actitis hypoleucos*	3.553	5.426	48.45	11.4	5.17
Passeriformes	Cisticolidae	*Cisticola juncidis*	3.032	4.63	53.08	2.78	11
Pelecaniformes	Ardeidae	*Ardea intermedia*	2.673	4.081	57.16	2.22	9.67
Passeriformes	Ploceidae	*Ploceus phillipinus*	2.561	3.911	61.07	8	0
Passeriformes	Leiothricidae	*Turdoides affinis*	2.457	3.751	64.83	0.889	6.83
Passeriformes	Estrildidae	*Lonchura malacca*	2.154	3.29	68.12	6.33	0.333
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	2.042	3.118	71.23	15.2	9.83

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Passeriformes	Cisticolidae	*Prinia socialis*	1.8	2.749	73.98	5.11	0.333
Columbiformes	Columbidae	*Columba livia*	1.75	2.672	76.65	4.67	0
Charadriiformes	Charadriidae	*Vanellus indicus*	1.343	2.052	78.71	4.33	2.17
Pelecaniformes	Ciconiidae	*Anastomus oscitans*	1.09	1.665	80.37	1.56	3
Charadriiformes	Scolopacidae	*Gallinago gallinago*	0.9663	1.476	81.85	0.111	2.5
Passeriformes	Sturnidae	*Sturnia pagodarum*	0.812	1.24	83.09	0	2.67
Passeriformes	Acrocephalidae	*Acrocephalus agricola*	0.7974	1.218	84.3	2.11	1.33
Accipitriformes	Accipitridae	*Milvus migrans*	0.7795	1.19	85.49	2.33	0.333
Psittaciformes	Psittacidae	*Psittacula krameri*	0.7485	1.143	86.64	2.33	0.333
Passeriformes	Pycnonotidae	*Pycnonotus cafer*	0.6478	0.9892	87.63	1.22	1.17
Accipitriformes	Accipitridae	*Haliastur indus*	0.6438	0.9831	88.61	2.22	1.83
Passeriformes	Cisticolidae	*Prinia inornata*	0.4851	0.7408	89.35	0	1.5
Passeriformes	Motacillidae	*Anthus rufulus*	0.4742	0.7241	90.07	0.111	1.5
PS 4 Average Dissimilarity = 74.62%							
Passeriformes	Estrildidae	*Lonchura malacca*	23.76	31.84	31.84	117	0
Charadriiformes	Scolopacidae	*Actitis hypoleucos*	10.21	13.68	45.52	36.7	0
Passeriformes	Ploceidae	*Ploceus phillipinus*	9.461	12.68	58.2	57.7	0
Pelecaniformes	Ardeidae	*Ardeola grayii*	4.169	5.587	63.78	5.89	23.2
Passeriformes	Sturnidae	*Acidotheres tristis*	3.254	4.361	68.15	5.44	17.2
Passeriformes	Cisticolidae	*Cisticola juncidis*	2.285	3.063	71.21	6.33	14.8
Passeriformes	Hirundinidae	*Hirundo rustica*	2.149	2.879	74.09	5.78	7.33

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Passeriformes	Dicruridae	*Dicrurus macrocercus*	2.068	2.771	76.86	7.78	15.5
Passeriformes	Leiothricidae	*Turdoides affinis*	1.93	2.587	79.45	2.78	8.83
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	1.461	1.957	81.4	15.9	10
Pelecaniformes	Ciconiidae	*Anastomus oscitans*	1.321	1.77	83.17	6.67	4.67
Charadriiformes	Charadriidae	*Vanellus indicus*	0.8535	1.144	84.32	3.33	1.17
Passeriformes	Motacillidae	*Motacilla maeraspatensis*	0.7591	1.017	85.33	3.22	3.33
Psittaciformes	Psittacidae	*Psittacula krameri*	0.6747	0.9042	86.24	3	0.167
Charadriiformes	Scolopacidae	*Gallinago gallinago*	0.5783	0.7749	87.01	0.222	2.33
Passeriformes	Cisticolidae	*Prinia inornata*	0.551	0.7383	87.75	2.67	3.17
Pelecaniformes	Threskiornithidae	*Plegadis falcinellus*	0.5494	0.7363	88.49	2.44	0
Columbiformes	Columbidae	*Streptopelia chinensis*	0.5194	0.696	89.18	3.11	1.17
Passeriformes	Cisticolidae	*Prinia socialis*	0.5019	0.6726	89.86	1.78	0.5
Pelecaniformes	Ardeidae	*Egretta garzetta*	0.4929	0.6606	90.52	2.11	0.167
PS 5 Average Dissimilarity = 84.85 %							
Passeriformes	Estrildidae	*Lonchura malacca*	39.89	47.01	47.01	308	0
Passeriformes	Ploceidae	*Ploceus phillipinus*	22.2	26.17	73.18	180	0
Pelecaniformes	Ardeidae	*Ardeola grayii*	2.659	3.134	76.31	4.8	23.2
Psittaciformes	Psittacidae	*Psittacula krameri*	2.03	2.392	78.7	13.4	0.167
Passeriformes	Hirundinidae	*Hirundo rustica*	1.771	2.087	80.79	7.2	7.33
Passeriformes	Sturnidae	*Acidotheres tristis*	1.685	1.986	82.78	5.8	17.2
Passeriformes	Cisticolidae	*Cisticola juncidis*	1.66	1.956	84.73	4.2	14.8

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Passeriformes	Dicruridae	*Dicrurus macrocercus*	1.555	1.832	86.56	5.8	15.5
Pelecaniformes	Ciconiidae	*Anastomus oscitans*	1.155	1.362	87.93	11.2	4.67
Passeriformes	Leiothricidae	*Turdoides affinis*	1.074	1.266	89.19	5.8	8.83
Passeriformes	Cisticolidae	*Prinia inornata*	1.07	1.261	90.45	8.8	3.17
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	0.7502	0.8842	91.34	12.8	10
PS 6 Average dissimilarity = 78.81%							
Passeriformes	Estrildidae	*Lonchura malacca*	34.57	43.87	43.87	199	1.33
Passeriformes	Hirundinidae	*Cecropis daurica*	8.568	10.87	54.74	1.38	46.7
Columbiformes	Columbidae	*Columba livia*	8	10.15	64.9	42.1	0
Psittaciformes	Psittacidae	*Psittacula krameri*	2.52	3.198	68.09	16.3	5.33
Passeriformes	Ploceidae	*Ploceus phillipinus*	2.071	2.628	70.72	0	9.67
Passeriformes	Cisticolidae	*Prinia inornata*	2.041	2.59	73.31	10.6	1.67
Passeriformes	Acrocephalidae	*Acrocephalus agricola*	1.634	2.074	75.39	9	4.83
Passeriformes	Cisticolidae	*Cisticola juncidis*	1.616	2.05	77.44	7.38	12
Passeriformes	Acrocephalidae	*Acrocephalus dumetorum*	1.592	2.021	79.46	7.25	1
Passeriformes	Hirundinidae	*Hirundo rustica*	1.417	1.798	81.25	2.5	7.33
Passeriformes	Sturnidae	*Acidotheres tristis*	1.397	1.773	83.03	10.9	7.5
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	1.266	1.607	84.63	11.9	7.83
Passeriformes	Dicruridae	*Dicrurus macrocercus*	1.085	1.377	86.01	9.25	8.17
Passeriformes	Leiothricidae	*Turdoides affinis*	0.9244	1.173	87.18	2.63	5.83
Pelecaniformes	Ardeidae	*Ardeola grayii*	0.7375	0.9358	88.12	4.38	3.33

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Charadriiformes	Charadriidae	*Vanellus indicus*	0.6901	0.8757	89	3.88	2.83
Pelecaniformes	Ciconiidae	*Anastomus oscitans*	0.653	0.8287	89.82	4.25	0.667
Passeriformes	Motacillidae	*Anthus rufulus*	0.6193	0.7859	90.61	2.75	0.833
PS 7 Average Dissimilarity = 68.21%							
Passeriformes	Estrildidae	*Lonchura malacca*	13.45	19.72	19.72	31	0
Passeriformes	Ploceidae	*Ploceus phillipinus*	6.068	8.895	28.61	10.5	0
Passeriformes	Cisticolidae	*Cisticola juncidis*	4.513	6.616	35.23	9.67	3.75
Columbiformes	Columbidae	*Columba livia*	4.149	6.082	41.31	10.5	0
Passeriformes	Cisticolidae	*Prinia inornata*	2.79	4.09	45.4	5.67	2.75
Columbiformes	Columbidae	*Streptopelia chinensis*	2.463	3.611	49.01	5.33	0.25
Pelecaniformes	Ardeidae	*Ardeola grayii*	2.247	3.295	52.31	5.5	0.5
Charadriiformes	Scolopacidae	*Gallinago gallinago*	2.076	3.043	55.35	4	0
Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	1.963	2.878	58.23	9.17	6.5
Psittaciformes	Psittacidae	*Psittacula krameri*	1.866	2.736	60.96	5.67	2.25
Passeriformes	Dicruridae	*Dicrurus macrocercus*	1.734	2.543	63.51	8.33	8
Passeriformes	Leiothricidae	*Turdoides affinis*	1.702	2.495	66	1.17	4
Passeriformes	Cisticolidae	*Prinia socialis*	1.683	2.467	68.47	3.17	0.25
Passeriformes	Sturnidae	*Acidotheres tristis*	1.555	2.28	70.75	3.5	5.5
Passeriformes	Artamidae	*Artamus fuscus*	1.487	2.18	72.93	2.67	0.5
Passeriformes	Passeridae	*Gymnoris xanthocollis*	1.466	2.15	75.08	3.83	0

Order	Family	Bird Species	Average Dissimilarity	Contribution %	Cumulative contribution %	Mean Abundance	
						Organic	Non-Organic
Charadriiformes	Charadriidae	*Vanellus indicus*	1.421	2.083	77.16	4	1.5
Passeriformes	Motacillidae	*Anthus rufulus*	1.42	2.081	79.24	3.33	2.75
Accipitriformes	Accipitridae	*Milvus migrans*	1.028	1.508	80.75	2.67	1.25
Passeriformes	Alaudidae	*Mirafra affinis*	1.019	1.494	82.24	3.17	2.25
Passeriformes	Hirundinidae	*Cecropis daurica*	0.9826	1.441	83.68	2.5	0
Passeriformes	Pycnonotidae	*Pycnonotus cafer*	0.9433	1.383	85.07	2.67	1.75
Passeriformes	Acrocephalidae	*Acrocephalus dumetorum*	0.8645	1.267	86.33	1.83	0.25
Passeriformes	Corvidae	*Corvus macrorhynchos*	0.7188	1.054	87.39	1.5	0
Passeriformes	Corvidae	*Dendrocitta vagabunda*	0.608	0.8914	88.28	1	0
Cuculiformes	Cuculidae	*Hierococcyx varius*	0.5913	0.8668	89.15	0.167	1.25
Accipitriformes	Accipitridae	*Haliastur indus*	0.5487	0.8044	89.95	0.167	1.25
Pelecaniformes	Threskiornithidae	*Threskiornis melanocephalus*	0.5416	0.794	90.75	1	0

SIMPER Analysis of Odonates

PS 1- Overall average dissimilarity: 53.55%					
Odonate Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean abundance	
				Non-organic	Organic
Pantala flavescens	24.17	45.14	45.14	94.4	18.3
Orthetrum sabina	11.18	20.88	66.02	22.6	53
Diplacodes trivialis	6.01	11.22	77.24	30.3	14.9
Ischnura aurora	3.686	6.883	84.12	13	3
Agriocnemis pygmaea	3.558	6.645	90.77	12.6	4.71
Crocothemis servilia	2.995	5.593	96.36	5	12.6
Brachythemis contaminata	0.557	1.04	97.4	1.57	0.429
Ceriagrion coromandelianum	0.3314	0.6189	98.02	0	1
Rhyothemis variegata	0.2514	0.4695	98.49	0.143	0.714
Potamarcha congener	0.2417	0.4514	98.94	0.714	0
Trithemis pallidinervis	0.1622	0.3029	99.24	0.429	0
Ischnura senegalensis	0.09026	0.1685	99.41	0.286	0
Lestes elatus	0.08666	0.1618	99.57	0	0.286
Pseudagrion microcephalum	0.08666	0.1618	99.74	0	0.286
Urothemis signata	0.05398	0.1008	99.84	0	0.143
Paragomphus lineatus	0.04952	0.09247	99.93	0	0.143
Tramea basilaris	0.03819	0.07132	100	0.143	0
PS 2 - Overall average dissimilarity: 49.37%					
Pantala flavescens	20.95	42.44	42.44	98.9	35
Ischnura aurora	11.04	22.37	64.81	50.7	10.7

Odonate Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean abundance	
				Non-organic	Organic
Diplacodes trivialis	5.461	11.06	75.87	32.8	22
Orthetrum sabina	4.807	9.737	85.61	16	25.6
Crocothemis servilia	3.456	7	92.61	20	13.6
Agriocnemis pygmaea	1.727	3.497	96.1	6.22	10.3
Brachythemis contaminata	0.4824	0.977	97.08	0.667	1.86
Potamarcha congener	0.3176	0.6433	97.73	1.11	0
Tramea basilaris	0.2927	0.5929	98.32	1	0.143
Ceriagrion coromandelianum	0.2393	0.4846	98.8	0.889	0.143
Ischnura senegalensis	0.1607	0.3256	99.13	0.111	0.571
Tholymis tillarga	0.1346	0.2726	99.4	0	0.429
Trithemis pallidinervis	0.1182	0.2394	99.64	0	0.429
Anax guttatus	0.07707	0.1561	99.8	0.222	0
Pseudagrion microcephalum	0.06858	0.1389	99.94	0.111	0.143
Pseudagrion decorum	0.03183	0.06447	100	0.111	0
PS 3- Overall average dissimilarity: 78.36%					
Ischnura aurora	32.66	41.69	41.69	219	9.33
Pantala flavescens	17.72	22.62	64.3	37.7	147
Diplacodes trivialis	13.34	17.02	81.32	93.8	7.67
Crocothemis servilia	7.49	9.559	90.88	7	59.6
Agriocnemis pygmaea	4.131	5.272	96.15	35.5	9.11
Orthetrum sabina	2.106	2.688	98.84	7.83	21.2
Tramea basilaris	0.1771	0.226	99.07	0	1.11

Odonate Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean abundance	
				Non-organic	Organic
Ischnura senegalensis	0.1464	0.1868	99.25	0.5	0.667
Tholymis tillarga	0.1355	0.173	99.43	0	1
Ceriagrion coromandelianum	0.1341	0.1711	99.6	0.833	0.556
Trithemis pallidinervis	0.1185	0.1512	99.75	0	0.667
Brachythemis contaminata	0.0909	0.116	99.86	0.5	0
Rhyothemis variegata	0.06147	0.07845	99.94	0	0.333
Pseudagrion microcephalum	0.02312	0.02951	99.97	0.167	0
Lestes elatus	0.0223	0.02846	100	0.167	0
PS 4- Overall average dissimilarity : 58.56%					
Ischnura aurora	35.32	60.31	60.31	196	23
Diplacodes trivialis	15.63	26.69	87	117	45.2
Agriocnemis pygmaea	1.897	3.24	90.24	10	7.22
Orthetrum sabina	1.827	3.119	93.36	14	19
Crocothemis servilia	1.65	2.818	96.18	12	17.7
Pantala flavescens	1.283	2.192	98.37	2.17	6.78
Ceriagrion coromandelianum	0.3841	0.6558	99.02	0.667	2.33
Brachythemis contaminata	0.2432	0.4153	99.44	1.17	0
Ischnura senegalensis	0.1129	0.1927	99.63	0.5	0
Tramea basilaris	0.08506	0.1452	99.78	0.333	0.111
Tholymis tillarga	0.05155	0.08802	99.87	0.167	0.111
Anax guttatus	0.04386	0.07489	99.94	0	0.222
Paragomphus lineatus	0.0346	0.05908	100	0.167	0

Odonate Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean abundance	
				Non-organic	**Organic**
PS 5- Overall average dissimilarity: 36.81%					
Diplacodes trivialis	14.03	38.13	38.13	46.6	73.8
Ischnura aurora	8.998	24.45	62.57	34	10.8
Orthetrum sabina	7.432	20.19	82.77	40.8	22.8
Crocothemis servilia	2.664	7.238	90	1.6	8.4
Ceriagrion coromandelianum	1.32	3.586	93.59	0	3.4
Agriocnemis pygmaea	1.243	3.376	96.97	4.4	2
Pantala flavescens	0.5702	1.549	98.52	1.8	0.8
Brachythemis contaminata	0.3738	1.016	99.53	1	0
Acisoma panorpoides	0.1727	0.4693	100	0	0.4
PS 6- Overall average dissimilarity : 50.22%					
Pantala flavescens	16.16	32.19	32.19	28.8	4.25
Orthetrum sabina	10.77	21.46	53.65	30.3	23.6
Ischnura aurora	8.426	16.78	70.43	15.3	3
Agriocnemis pygmaea	5.893	11.73	82.16	10.7	1.75
Diplacodes trivialis	5.767	11.48	93.64	15.5	22.3
Crocothemis servilia	1.365	2.717	96.36	2.5	1.25
Ceriagrion coromandelianum	1.241	2.47	98.83	1.5	1.13
Rhyothemis variegata	0.2219	0.4418	99.27	0.333	0.125
Brachythemis contaminata	0.1627	0.3239	99.6	0.167	0.125
Pseudagrion rubriceps	0.1162	0.2314	99.83	0.167	0
Aciogrion occidentale	0.0859	0.1711	100	0.167	0

SIMPER Analysis of Butterflies

PS 3 - Overall average dissimilarity - 84.47%					
Butterfly Species	**Average dissimilarity**	**Contribution in %**	**Cumulative contribution in %**	**Mean Abundance**	
				Non-organic	**Organic**
Ampittia dioscorides	13.34	15.79	15.79	3.5	0.333
Danaus chrysippus	12.02	14.23	30.02	0	3.11
Melanitis leda	6.609	7.823	37.84	2.33	1.89
Junonia almana	6.254	7.404	45.25	0	1.67
Catopsilia pomona	5.016	5.938	51.18	0	1.89
Atrophaneura hector	4.558	5.396	56.58	0	1.22
Papilio demoleus	4.319	5.113	61.69	0	1.56
Tirumala limniace	3.592	4.253	65.95	0	1.44
Borbo cinnara	3.005	3.557	69.5	0.5	0.444
Eurema hecabe	3.003	3.555	73.06	0.5	0.444
Hypolimnas misippus	2.375	2.812	75.87	0	0.667
Acraea violae	2.259	2.674	78.54	0	0.778
Ariadne merione	2.248	2.661	81.2	0.5	0
Atrophaneura aristolochiae	2.143	2.537	83.74	0.167	0.444
Aeromachus pygmaeus	2.112	2.5	86.24	0.5	0
Papilio polytes	1.715	2.03	88.27	0	0.556
Danaus genutia	1.597	1.89	90.16	0	0.556
Telicota colon	1.472	1.743	91.91	0.333	0
Mycalesis perseus	1.37	1.622	93.53	0.167	0.222
Euploea core	1.326	1.57	95.1	0	0.556
Delias eucharis	1.236	1.463	96.56	0.167	0.222
Appias albina	1.046	1.239	97.8	0	0.444

Butterfly Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean Abundance	
				Non-organic	Organic
Jamides celeno	1.041	1.232	99.03	0.167	0.111
Zizula hylax	0.295	0.3492	99.38	0	0.111
Junonia atlites	0.295	0.3492	99.73	0	0.111
Catopsilia pyranthe	0.2281	0.2701	100	0	0.111
PS 4 - Overall average dissimilarity - 72.11%					
Ampittia dioscorides	26.21	34.25	34.25	6.17	0.889
Borbo cinnara	8.92	11.65	45.9	3	0.889
Mycalesis perseus	6.353	8.3	54.2	0.667	1.44
Melanitis leda	5.802	7.581	61.78	1.67	1.22
Ariadne merione	3.759	4.911	66.7	0.833	0.333
Pelopidas mathias	3.178	4.153	70.85	0.667	0
Junonia almana	2.864	3.742	74.59	0.667	0
Euchrysops cnejus	2.433	3.178	77.77	0.667	0
Parnara sp.	2.366	3.091	80.86	0.5	0
Telicota colon	1.871	2.445	83.3	0.333	0.222
Atrophaneura aristolochiae	1.834	2.396	85.7	0.333	0.111
Danaus chrysippus	1.747	2.282	87.98	0.333	0.222
Papilio polytes	1.681	2.196	90.18	0.333	0.222
Eurema hecabe	1.055	1.379	91.56	0.333	0
Telicota ancilla	0.7503	0.9802	92.54	0.167	0.111
Atrophaneura hector	0.6814	0.8903	93.43	0	0.222
Everes lacturnus	0.5615	0.7336	94.16	0.167	0
Melanitis phedima	0.5615	0.7336	94.9	0.167	0
Hypolimnas misippus	0.5615	0.7336	95.63	0.167	0

Butterfly Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean Abundance	
				Non-organic	Organic
Danaus genutia	0.5615	0.7336	96.36	0.167	0
Acraea violae	0.5004	0.6537	97.02	0	0.111
Pseudozizeeria maha	0.4937	0.6451	97.66	0.167	0
Delias eucharis	0.4937	0.6451	98.31	0.167	0
Jamides celeno	0.4777	0.6241	98.93	0	0.111
Colotis danae	0.4777	0.6241	99.55	0	0.111
Catopsilia pomona	0.3407	0.4452	100	0	0.111
PS 5 - Overall average dissimilarity - 67.2%					
Mycalesis perseus	9.137	13.6	13.6	5	2
Eurema hecabe	7.662	11.4	25	0.6	3
Ampittia dioscorides	7.643	11.37	36.37	2.8	1.4
Euchrysops cnejus	6.386	9.503	45.88	2	0
Ariadne ariadne	5.684	8.458	54.33	0.2	2
Melanitis leda	4.893	7.282	61.62	2	1.6
Borbo cinnara	3.847	5.724	67.34	1	0.8
Junonia almana	3.778	5.623	72.96	1.4	0.2
Delias eucharis	2.337	3.478	76.44	0.6	0.8
Everes lacturnus	1.982	2.949	79.39	0.6	0
Papilio polytes	1.935	2.88	82.27	0	0.6
Catopsilia pomona	1.895	2.819	85.09	0.6	0
Ariadne merione	1.307	1.945	87.03	0	0.4
Telicota colon	1.265	1.883	88.92	0	0.4
Acraea violae	1.199	1.785	90.7	0	0.4
Danaus chrysippus	1.151	1.713	92.41	0.4	0

Butterfly Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean Abundance	
				Non-organic	Organic
Pelopidas mathias	0.7249	1.079	93.49	0	0.2
Atrophaneura hector	0.7249	1.079	94.57	0	0.2
Zizina otis	0.6834	1.017	95.59	0.2	0
Pseudozizeeria maha	0.6534	0.9724	96.56	0	0.2
Appias albina	0.6326	0.9414	97.5	0	0.2
Catochrysops strabo	0.5775	0.8594	98.36	0	0.2
Atrophaneura aristolochiae	0.5505	0.8193	99.18	0.2	0
Junonia atlites	0.5505	0.8193	100	0.2	0
PS 6 - Overall average dissimilarity - 75.61%					
Eurema hecabe	12.43	16.44	16.44	0	5.25
Ampittia dioscorides	9.73	12.87	29.3	5	1
Junonia almana	8.64	11.43	40.73	4.17	0.5
Euchrysops cnejus	6.487	8.58	49.31	1.83	3.13
Mycalesis perseus	6.015	7.955	57.27	2.33	1.75
Melanitis leda	5.225	6.911	64.18	2.67	0.875
Zizula hylax	2.526	3.341	67.52	1	0
Atrophaneura aristolochiae	2.478	3.277	70.79	0.167	1.13
Catopsilia pomona	2.404	3.179	73.97	1	0.375
Borbo cinnara	2.152	2.846	76.82	1	0.125
Danaus chrysippus	1.901	2.514	79.33	0.833	0.25
Delias eucharis	1.706	2.257	81.59	0.333	0.625
Atrophaneura hector	1.648	2.179	83.77	0.5	0.375
Junonia atlites	1.584	2.095	85.86	0.667	0.125
Papilio demoleus	1.546	2.045	87.91	0.667	0

Butterfly Species	Average dissimilarity	Contribution in %	Cumulative contribution in %	Mean Abundance	
				Non-organic	Organic
Ariadne ariadne	1.351	1.786	89.69	0	0.625
Acraea violae	1.068	1.412	91.11	0.5	0
Danaus genutia	0.994	1.315	92.42	0.5	0
Appias albina	0.7362	0.9737	93.39	0.333	0
Telicota ancilla	0.718	0.9496	94.34	0.167	0.25
Zizina otis	0.6768	0.8951	95.24	0.167	0.125
Tirumala limniace	0.4901	0.6482	95.89	0.167	0
Everes lacturnus	0.4622	0.6113	96.5	0.167	0
Taractrocera maevius	0.3685	0.4873	96.99	0.167	0
Pareronia valeria	0.3685	0.4873	97.47	0.167	0
Junonia lemonias	0.3685	0.4873	97.96	0.167	0
Freyeria trochylus	0.3448	0.4561	98.42	0	0.125
Ariadne merione	0.3313	0.4382	98.85	0.167	0
Aeromachus pygmaeus	0.3313	0.4382	99.29	0.167	0
Pseudozizeeria maha	0.2816	0.3725	99.67	0	0.125
Castalius rosimon	0.2528	0.3344	100	0	0.125

APPENDIX 5

Records of select indicator taxa from paddy fields of India

Records of Odonata from rice fields of India

SL No	Species	Common Name	Recorded by
Sub-order Anisoptera			
Family Aeshnidae			
1	*Hemianax ephippiger*	Vagrant Emperor	Arulprakash and Gunathilagaraj, 2010
2	*Anax guttatus*	Blue-tailed Green Darner	Authors unpublished data, Coimbatore; Kandibane *et al*, 2003 and 2005;
3	*Anax immaculifrons*	Blue Darner	Authors unpublished data, Coimbatore
4	*Gynacantha bayadera* Selys, 1891	Parakeet darner	Talmale and Kulkarni, 2003
	Family Gomphidae		
5	*Ictinogomphus rapax*	Common Clubtail	Authors unpublished data, Coimbatore
Family Libellulidae			
6	*Acisoma panorpoides*	Trumpet Tail	Mathew *et al*, 2014; Suhirtha Muhil, 2017 ; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Majumdar *et al*, 2014
7	*Brachythemis contaminata*	Ditch Jewel	Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Palot *et al*, 2005; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003

SL No	Species	Common Name	Recorded by
8	*Bradinopyga geminata*	Granite Ghost	Mathew *et al*, 2014
9	*Crocothemis servilia*	Ruddy marsh skimmer	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Gunathilagaraj *et al*, 1999; Ragnekar *et al*, 2010; Kandibane *et al*, 2003; Kandibane *et al*, 2005; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Majumdar *et al*, 2014; Nair ,2014; Subramanian, 2009; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003
10	*Diplacodes nebulosa*	Black-tipped Ground Skimmer	Saikia *et al*, 2016
11	*Diplacodes trivialis*	Ground skimmer	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Ragnekar *et al*, 2010; Kandibane *et al*, 2003 and 2005; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi amd Manickavasagam, 2002; Majumdar *et al*, 2014; Palot *et al*, 2005; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003
12	*Neurothemis fulvia*	Fulvous forest skimmer	Mathew *et al*, 2014Ragnekar *et al*, 2010 Majumdar *et al*, 2014 Saikia *et al*, 2016
13	*Neurothemis tullia*	Pied Paddy skimmer	Mathew *et al*, 2014Authors unpublished data, Coimbatore; Gunathilagaraj *et al*, 1999Kandibane *et al*, 2005Majumdar *et al*, 2014 Nair ,2014Emiliyamma *et al*, 2005 Subramanian, 2009
14	*Neurothemis intermedia*	Paddyfield Parasol	Palot *et al*, 2005; Talmale and Kulkarni, 2003
15	*Orthetrum chrysis*	Brown-backed Marsh Hawk	Mathew *et al*, 2014; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Arulprakash and Gunathilagaraj, 2010

SL No	Species	Common Name	Recorded by
16	*Orthetrum glaucum*	Blue marsh hawk	Mathew *et al*, 2014; Ragnekar *et al*, 2010
17	*Orthetrum luzonicum*	Tri- coloured Marsh Hawk	Mathew *et al*, 2014; Majumdar *et al*, 2014; Subramanian, 2009; Rohmare *et al*, 2016
18	*Orthetrum pruinosum*	Crimson tailed marsh hawk	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Emiliyamma *et al*, 2005
19	*Orthetrum sabina*	Green marsh hawk	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Ragnekar *et al*, 2010; Kandibane *et al*, 2003 and 2005; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi amd Manickavasagam, 2002; Majumdar *et al*, 2014; Nair ,2014; Palot *et al*, 2005; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003
20	*Palpopleura sexmaculata*	Blue-tailed yellow skimmer	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Majumdar *et al*, 2014
21	*Pantala flavescens*	Wandering glider	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Ragnekar *et al*, 2010; Kandibane *et al*, 2003 and 2005; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi and Manickavasagam, 2002; Majumdar *et al*, 2014; Subramanian, 2009; Palot *et al*, 2005; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003
22	*Potamarcha congener*	Yellow- tailed ashy skimmer	Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Arulprakash *et al*, 2017; Majumdar *et al*, 2014; Palot *et al*, 2005; Talmale and Kulkarni, 2003
23	*Rhyothemis plutonia*	Greater Blue Wing	Mitra, 2006

SL No	Species	Common Name	Recorded by
24	*Rhyothemis variegata*	Common picturewing	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Kandibane *et al*, 2003 and 2005; Arulprakash *et al*, 2017; Majumdar *et al*, 2014; Subramanian, 2009; Palot *et al*, 2005; Rohmare *et al*, 2016
25	*Tholymis tillarga*	Coral-tailed cloud wing	Mathew *et al*, 2014; Suhirtha Muhil, 2017; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Mitra, 2006; Palot *et al*, 2005; Talmale and Kulkarni, 2003
26	*Tramea basilaris*	Red Marsh Trotter	Authors unpublished data, Coimbatore; Gunathilagaraj *et al*, 1999; Arulprakash *et al*, 2017; Talmale and Kulkarni, 2003
27	*Tramea limbata*	Black marsh trotter	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Kandibane *et al*, 2003 and 2005; Arulprakash *et al*, 2017; Palot *et al*, 2005
28	*Trithemis aurora*	Crimson marsh glider	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Arulprakash and Gunathilagaraj, 2010; Majumdar *et al*, 2014; Palot *et al*, 2005; Talmale and Kulkarni, 2003
29	*Trithemis festiva*	Black Stream Glider	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Talmale and Kulkarni, 2003
30	*Trithemis pallidinervis*	Long legged marsh glider	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Ragnekar *et al*, 2010; Arulprakash *et al*, 2017; Palot *et al*, 2005; Rohmare *et al*, 2016
31	*Urothemis signata*	Greater Crimson Glider	Suhirtha Muhil, 2017; Arulprakash and Gunathilagaraj, 2010; Majumdar *et al*, 2014; Nair ,2014; Subramanian, 2009
32	*Zyxomma petiolatum* Rambur, 1842	Brown Dusk hawk	Talmale and Kulkarni, 2003

SL No	Species	Common Name	Recorded by
Sub-order Zygoptera			
Family Calopterigidae			
33	*Vestalis gracilis* Rambur, 1842	Clear-winged Forest glory	Mathew *et al*, 2014; Palot *et al*, 2005
Family Coenagrionidae			
34	*Aciogrion occidentale* Laidlaw, 1919	Green-striped Slender Dartlet	Palot *et al*, 2005
35	*Agriocnemis femina* Brauer, 1868	Pinhead wisp	Kandibane *et al*, 2003 and 2005
36	*Agriocnemis lacteola* Selys 1877	Milky dartlet	Majumdar *et al*, 2014
37	*Agriocnemis pieris* Laidlaw,1919	White dartlet	Saikia *et al*, 2016; Talmale and Kulkarni, 2003
38	*Agriocnemis pygmaea* Rambur, 1842	Pygmy dartlet	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Kandibane *et al*, 2003 and 2005; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi amd Manickavasagam, 2002; Nair ,2014; Mitra, 2006; Palot *et al*, 2005; Saikia *et al*, 2016
39	*Agriocnemis rubescens* Selys 1877	Variable Sprite	Gunathilagaraj *et al*, 1999; Asaithambi amd Manickavasagam, 2002
40	*Ceriagrion cerinorubellum* Brauer, 1865	Orange-tailed Marsh Dart	Mathew *et al*, 2014; Gunathilagaraj *et al*, 1999

SL No	Species	Common Name	Recorded by
41	*Ceriagrion coromandelianum* Fabricius,1798	Coromandel Marsh Dart	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi amd Manickavasagam, 2002; Majumdar *et al*, 2014; Nair ,2014; Subramanian, 2009; Palot *et al*, 2005; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003
42	*Ceriagrion olivaceum*Laidlaw, 1914	Rusty marsh dart (W G race)	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Saikia *et al*, 2016
43	*Ceriagrion rubiae* Laidlaw, 1916	Orange Marsh Dart	Mathew *et al*, 2014
44	*Enallagma cyathigerum* Charpentier,1840	Common Blue Damselfly	Rohmare *et al*, 2016
45	*Ischnura aurora* Brauer,1865	Golden dartlet	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Kandibane *et al*, 2003; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi amd Manickavasagam, 2002; Majumdar *et al*, 2014; Palot *et al*, 2005; Rohmare *et al*, 2016; Saikia *et al*, 2016; Talmale and Kulkarni, 2003
46	*Ischnura elegans*	Blue-tailed damselfly	Rohmare *et al*, 2016
47	*Ischnura senegalensis*	Senegal Golden Dartlet	Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Gunathilagaraj *et al*, 1999; Kandibane *et al*, 2003; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Asaithambi amd Manickavasagam, 2002; Rohmare *et al*, 2016

SL No	Species	Common Name	Recorded by
48	*Pseudagrion decorum*	Three-lined Dart	Suhirtha Muhil, 2017; Arulprakash *et al*, 2017
49	*Pseudagrion microcephalum*	Blue grass dartlet	Mathew *et al*, 2014; Suhirtha Muhil, 2017; Arulprakash *et al*, 2017; Palot *et al*, 2005; Rohmare *et al*, 2016
50	*Pseudagrion rubriceps*	Saffron faced blue dart	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Palot *et al*, 2005
51	*Pseudogrion decorum*	Elegant sprite	Mathew *et al*, 2014; Arulprakash *et al*, 2017
52	*Pseudogrion indicum*	Yellow striped blue dart	Mathew *et al*, 2014
Family Lestidae			
53	*Lestes elatus* Hagen in Selys,1862	Emerald spreadwing	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Suhirtha Muhil, 2017; Arulprakash *et al*, 2017; Arulprakash and Gunathilagaraj, 2010; Mitra, 2006; Palot *et al*, 2005
54	*Lestes praemorsus* Hagen in Selys,1862	Sapphire-eyed Spreadwing	Mathew *et al*, 2014; Authors unpublished data, Coimbatore
55	*Lestes viridulus* Rambur, 1842	Emerals-striped Spreadwing	Gunathilagaraj *et al*, 1999; Talmale and Kulkarni, 2003
56	*Lestes malabaricus* Fraser	Malabar Spreadwing	Palot *et al*, 2005
57	*Lestes Umbrinus*	Brown spreadwing	Talmale and Kulkarni, 2003
Family Platycnemididae			
58	*Copera marginipes*	Yellow bush dart	Mathew *et al*, 2014; Authors unpublished data, Coimbatore; Palot *et al*, 2005; Talmale and Kulkarni, 2003

Butterflies recorded from paddy fields in India

Sl No	Species	Common Name	Recorded by
Family Hesperiidae			
1	*Aeromachus pygmaeus* (Fabricius)	Pygmy Scrub Hopper	Mathew *et al*, 2014
2	*Ampittia dioscorides* (Fabricius)	Bush Hopper	Soniya and Palot, 2002; Mathew *et al*, 2014
3	*Badamia exclamationis* (Fabricius)	Brown awl	Ganvir and Khaparde, 2018; Mathew *et al*, 2014
4	*Borbo cinnara* (Wallace)	Rice Swift	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Dwari and Mondal, 2015; Mathew *et al*, 2014
5	*Caltoris kumara* (Moore)	Blank Swift	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
6	*Pelopidas conjuncta* (Herrich- Schaffer)	Conjoined Swift	Ganvir and Khaparde, 2018
7	*Pelopidas mathias* (Fabricius)	Small Branded Swift	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018
8	*Pelopidas subochracea* (Moore)	Large Branded Swift	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
9	*Spialis galba* (Fabricius)	Indian Skipper	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
10	*Suastus greminus* (Fabricius)	The Indian Palm Bob	Soniya and Palot, 2002
11	*Telicota ancilla* (Herrich-Schaffer)	Dark Palm Dart	Mathew *et al*, 2014
12	*Terectrocera ceramas* (Hewitson)	Tawny Spotted Grass Dart	Mathew *et al*, 2014
13	*Terectrocera maevius* (Fabricius)	Common Grass Dart	Ganvir *et al*, 2017; Mathew *et al*, 2014
Family Lycaenidae			
14	*Amblypodia anita* (Hewitson)	Purple Leaf Blue	Ganvir and Khaparde, 2018
15	*Castalius rosimon* (Fabricius)	Common Pierrot	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014

Sl No	Species	Common Name	Recorded by
16	*Catochrysops strabo* (Fabricius)	Forget me-not	Ganvir *et al*, 2017
17	*Euchrysops cnejus* (Fabricius)	Gram Blue	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Dwari and Mondal, 2015
18	*Everes lacturnus* (Godart)	Indian Cupid	Soniya and Palot, 2002; Mathew *et al*, 2014
19	*Freyeria trochylus* (Freyer)	Grass Jewel	Soniya and Palot, 2002; Kunte *et al*, 1999; Mathew *et al*, 2014
20	*Jamides celeno* (Cramer)	Common Cerulean	Soniya and Palot, 2002; Kunte *et al*, 1999; Ganvir and Khaparde 2018; Mathew *et al*, 2014
21	*Leptotes plinius*	Zebra Blue	Mathew *et al*, 2014
22	*Pseudozizeeria maha* (Kollar)	Pale Grass Blue	Ganvir *et al*, 2017; Soniya and Palot, 2002
23	*Rathinda amor* (Fabricius)	Monkey Puzzle	Soniya and Palot, 2002
24	*Spindasis vulcanus* (Fabricius)	Common Silverline	Ganvir and Khaparde, 2018; Mathew *et al*, 2014
25	*Talycada nyseus* (Fabricius)	Red Pierrot	Mathew *et al*, 2014
26	*Tarucus Ananda* (de Nicéville)	Dark Pierrot	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
27	*Tarucus extricates* (Butler)	Rounded Pierrot	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
28	*Tarucus nara* (Kollar)	Striped Pierrot	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
29	*Zizina otis* (Fabricius)	Lesser Grass Blue	Ganvir *et al*, 2017
30	*Zizula hylax* (Fabricius)	Tiny Grass Blue	Ganvir *et al*, 2017; Kunte *et al*, 1999; Mathew *et al*, 2014
Family Nymphalidae			
31	*Acraea violae* (Fabricius)	Tawny Coster	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
32	*Ariadne ariadne* (Linnaeus)	Angled Castor	Mathew *et al*, 2014

Sl No	Species	Common Name	Recorded by
33	*Ariadne merione* (Cramer)	Common Castor	Soniya and Palot, 2002; Mathew *et al*, 2014
34	*Byblia ilithyia* (Drury)	Joker	Mathew *et al*, 2014
35	*Charaxes bernardus* (Fabricius)	Tawny Rajah	Mathew *et al*, 2014
36	*Cirrochroa aoris* (Doubleday)	Large Yeoman	Mathew *et al*, 2014
37	*Cupha erymanthis* (Drury)	Rustic	Mathew *et al*, 2014
38	*Danaus chrysippus* (Linnaeus)	Plain Tiger	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
39	*Danaus genutia* (Cramer)	Striped Tiger	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
40	*Elymnias hypermnestra* (Linnaeus)	Common Palmfly	Mathew *et al*, 2014
41	*Euploea core* (Cramer)	Common Crow	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Mathew *et al*, 2014
42	*Euthalia aconthea* (Cramer)	Common baron	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
43	*Euthalia nais* (Forster)	Baronet	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
44	*Hypolimnas bolina* (Linnnaeus)	Great Eggfly	Ganvir *et al*, 2017; Kunte *et al*, 1999; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
45	*Hypolimnas misippus* (Linnaeus)	Danaid Eggfly	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
46	*Junonia almana* (Linnaeus)	Peacock Pansy	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Ganvir and Khaparde,2018; Dwari and Mondal, 2015; Mathew *et al*, 2014
47	*Junonia atlites* (Linaeus)	Grey Pansy	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Ganvir and Khaparde. 2018; Mathew *et al*, 2014

Sl No	Species	Common Name	Recorded by
48	*Junonia hierta* (Fabricius)	Yellow Pansy	Kunte *et al*, 1999; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
49	*Junonia iphita* (Cramer)	Chocolate Pansy	Soniya and Palot, 2002; Gavir and Khaparde, 2018; Mathew *et al*, 2014
50	*Junonia lemonias* (Linnaeus)	Lemon Pansy	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
51	*Junonia orithiya* (Linnaeus)	Blue Pansy	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
52	*Melanitis leda* (Linnaeus)	Common Evening Brown	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Dwari and Mondal, 2015; Mathew *et al*, 2014
53	*Moduza procris* (Cramer)	Commander	Ganvir and Khaparde, 2018
54	*Mycalesis patnia* (Moore)	Gladeye Bushbrown	Mathew *et al*, 2014
55	*Mycalesis perseus* (Fabricius)	Common Bushbrown	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Dwari and Mondal, 2015; Mathew *et al*, 2014
56	*Mycalesis visala* (Moore)	Long Brand Bushbrown	Ganvir *et al*, 2017
57	*Mycalesis mineus* (Cramer)	Dark-brand Bushbrown	Soniya and Palot, 2002; Mathew *et al*, 2014
58	*Neptis hylas* (Linnaeus)	Common Sailor	Kunte *et al*, 1999; Mathew *et al*, 2014
59	*Orsotrioena medus* (Moore)	Nigger	Soniya and Palot, 2002; Mathew *et al*, 2014
60	*Parantica aglea* (Stoll)	Glassy Tiger	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
61	*Phalanta phalanta (Drury)*	Common Leopard	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Ganvir and Khaparde. 2018; Mathew *et al*, 2014

Sl No	Species	Common Name	Recorded by
62	*Polyura arthamas (Drury)*	Common Nawab	Ganvir and Khaparde, 2018; Mathew *et al*, 2014
63	*Tanaecia lepidea (Butler)*	Grey Count	Mathew *et al*, 2014
64	*Tirumala limniace (Cramer)*	Blue Tiger	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Mathew *et al*, 2014
65	*Ypthima baldus* (Fabricius)	Common fivering	Mathew *et al*, 2014
66	*Ypthima ceylonica* (Hewitson)	White Fourring	Mathew *et al*, 2014
67	*Ypthima hubneri* (Kirby)	Common fourring	Mathew *et al*, 2014
Family Papilionidae			
68	*Atrophaneura aristolochiae* (Fabricius)	Common Rose	Ganvir *et al*, 2017; Soniya and Palot, 2002; Kunte *et al*, 1999; Ganvir and Khaparde. 2018; Mathew *et al*, 2014
69	*Atrophaneura hector* (Linnaeus)	Crimson Rose	Soniya and Palot, 2002; Kunte *et al*, 1999; Mathew *et al*, 2014
70	*Chylasa clytia* (Linnaeus)	Common mime	Mathew *et al*, 2014
71	*Graphium agamemnon* (Felder & Felder)	Tailed Jay	Soniya and Palot, 2002; Gavir and Khaparde, 2018; Mathew *et al*, 2014
72	*Graphium sarpedon* (Linnaeus)	Common Bluebottle	Soniya and Palot, 2002; Kunte *et al*, 1999; Mathew *et al*, 2014
73	*Pachliopta polymnestor* (Cramer)	Blue Mormon	Soniya and Palot, 2002; Kunte *et al*, 1999; Mathew *et al*, 2014
74	*Papilio demoleus* (Linnaeus)	Lime Butterfly	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
75	*Papilio Helenus* (Linnaeus)	Red Helen	Mathew *et al*, 2014

Sl No	Species	Common Name	Recorded by
76	*Papilio polytes* (Linnaeus)	Common Mormon	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Dwari and Mondal, 2015; Mathew *et al*, 2014
77	*Troides minos* (Cramer)	Southern Birdwing	Soniya and Palot, 2002
Family Pieridae			
78	*Anaphaeis aurota* (Fabricius)	Pioneer	Ganvir and Khaparde, 2018
79	*Appias albina* (Boisduval)	Common Albatross	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
80	*Appias libythea* (Fabricius)	Striped Albatross	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
81	*Catopsilia pomona* (Fabricius)	Common Emigrant	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
82	*Catopsilia pyranthe* (Fabricius)	Mottled Emigrant	Soniya and Palot, 2002; Kunte *et al*, 1999; Ganvir and Khaparde 2018
83	*Cepora nerissa* (Fabricius)	Common Gull	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
84	*Colotis danae* (Fabricius)	Crimson Tip	Mathew *et al*, 2014
85	*Delias eucharis* (Drury)	Common Jezebel	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Mathew *et al*, 2014
86	*Eurema andersoni* (Moore)	One-spot Grass Yellow	Ganvir and Khaparde, 2018; Mathew *et al*, 2014
87	*Eurema blanda* (Boisduval)	Three-spot Grass Yellow	Soniya and Palot, 2002; Gavir and Khaparde, 2018; Mathew *et al*, 2014
88	*Eurema hecabe* (Linnaeus)	Common Grass Yellow	Ganvir *et al*, 2017; Soniya and Palot, 2002; Ganvir and Khaparde, 2018; Dwari and Mondal, 2015; Mathew *et al*, 2014

Sl No	Species	Common Name	Recorded by
89	*Eurema laeta* (Boisduval)	Spotless Grass Yellow	Ganvir and Khaparde, 2018
90	*Hebomoia glaucippe* (Linnaeus)	Great Orange-tip	Mathew *et al*, 2014
91	*Ixias Marianne* (Cramer)	White Orange-tip	Mathew *et al*, 2014
92	*Ixias pyrene* (Linnaeus)	Yellow Orange-tip	Mathew *et al*, 2014
93	*Leptosia nina* (Fabricius)	Psyche	Soniya and Palot, 2002; Mathew *et al*, 2014
94	*Loxura atymnus* (Stoll)	Yamfly	Mathew *et al*, 2014
95	*Pareronia valeria* (Cramer)	Common Wanderer	Soniya and Palot, 2002; Mathew *et al*, 2014
96	*Parthens sylvia* (Cramer)	Clipper	Kunte *et al*, 1999
97	*Pieris canidia* (Linnaeus)	Indian Cabbage White	Ganvir and Khaparde, 2018
98	*Prioneris sita* (Felder & Felder)	Painted Sawtooth	Ganvir *et al*, 2017; Ganvir and Khaparde, 2018
99	*Vanessa Cardui* (Linnaeus)	Painted Lady	Kunte *et al*, 1999
Family Riodinidae			
100	*Abisara echerius* (Stoll)	Plum Judy	Mathew *et al*, 2014

APPENDIX 6

Checklist of select indicator taxa in the two cultivation regimes and paddy growth stages

List of birds in the two cultivation regimes and paddy growth stages. 'p' indicates presence and '-' indicates absence

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
I	**Order Galliformes**										
	Family Phasianidae										
1	*Francolinus pondicerianus*	Grey Francolin	p	p	p	p	p	p	-	p	-
2	*Pavo cristatus*	Indian Peafowl	-	p	-	-	-	-	-	p	-
II	**Order Columbiformes**										
	Family Columbidae										
3	*Columba livia*	Rock Pigeon	p	-	p	p	p	p	p	p	p
4	*Streptopelia decaocto*	Eurasian Collared Dove	p	p	-	-	p	p	p	p	p
5	*Streptopelia senegalensis*	Laughing Dove	p	p	p	p	p	-	p	p	p
6	*Streptopelia chinensis*	Spotted Dove	p	p	p	p	p	p	p	p	p
III	**Order Cuculiformes**										
	Family Cuculidae										
7	*Eudynamys scolopaceus*	Asian Koel	p	p	p	p	p	p	p	p	p
8	*Hierococcyx varius*	Common Hawk Cuckoo	p	p	-	p	-	p	-	-	p
9	*Centropus sinensis*	Greater Coucal	p	p	-	-	p	p	p	-	-
10	*Clamator jacobinus*	Pied Cuckoo	p	p	p	-	p	p	-	p	p

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
IV	**Order Gruiformes**										
	Family Rallidae										
11	*Gallinula chloropus*	Common Moorhen	p	p	-	-	-	p	p	p	-
12	*Zapornia fusca*	Ruddy-breasted Crake	p	p	p	p	-	p	p	p	-
13	*Amaurornis phoenicurus*	White-breasted Waterhen	p	p	p	p	p	p	p	p	p
V	**Order Pelecaniformes**										
	Family Ciconiidae										
14	*Anastomus oscitans*	Asian Openbill	p	p	p	p	p	p	p	p	p
	Family Ardeidae										
15	*Ixobrychus flavicollis*	Black Bittern	p	p	-	-	-	p	-	p	p
16	*Bubulcus ibis*	Cattle Egret	p	p	-	p	p	-	-	-	-
17	*Ixobrychus cinnamomeus*	Cinnamon Bittern	-	p	p	-	-	p	-	p	-
18	*Ardea intermedia*	Intermediate Egret	p	p	p	p	p	p	p	p	p
19	*Ardeola grayii*	Indian Pond Heron	p	p	p	p	p	p	p	p	p
20	*Ixobrychus minutus*	Little Bittern	p	p	-	-	p	p	p	-	-
21	*Egretta garzetta*	Little Egret	p	p	p	p	p	p	p	p	-
22	*Ardea purpurea*	Purple Heron	p	p	p	p	-	p	p	-	p
	Family Threskiornithidae										
23	*Platalea leucorodia*	Eurasian Spoonbill	p	-	-	p	-	-	-	-	-

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
24	*Plegadis falcinellus*	Glossy Ibis	p	p	-	-	p	p	-	-	-
25	*Threskiornis melanocephalus*	Black-headed Ibis	p	p	p	p	-	p	p	p	p
	Family Phalocrocaracidae										
26	*Microcarbo niger*	Little Cormorant	p	p	p	p	p	p	p	-	p
VI	**Order Charadriiformes**										
	Family Recurvirostridae										
27	*Himantopus himantopus*	Black- winged Stilt	p	-	p	p	p	-	-	-	-
	Family Charadriidae										
28	*Charadrius dubius*	Little Ringed Plover	p	p	p	p	-	-	-	-	-
29	*Vanellus indicus*	Red-wattled Lapwing	p	p	p	p	p	p	p	p	p
	Family Rostratulidae										
30	*Rostratula benghalensis*	Greater Painted Snipe	p	-	p	-	-	-	-	-	-
	Family Scolopacidae										
31		Sandpiper spp.	p	p	p	p	p	p	p	p	p
32	*Gallinago gallinago*	Common Snipe	p	p	-	p	p	p	p	p	p
	Family Laridae										
33	*Chlidonias hybrida*	Whiskered Tern	p	-	-	p	-	-	-	-	-

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
VII	**Order Accipitriformes**										
	Family Accipitridae										
34	*Milvus migrans*	Black Kite	p	p	p	p	p	p	p	p	p
35	*Haliastur indus*	Brahminy Kite	p	p	p	p	p	p	p	p	p
36	*Elanus caeruleus*	Black-winged Kite	p	p	p	p	p	p	p	p	p
37	*Accipiter badius*	Shikra	p	-	-	-	-	p	p	p	p
38	*Butastur teesa*	White- eyed Buzzard	-	p	-	p	-	-	-	-	-
VIII	**Order Strigiformes**										
	Family Strigidae										
39	*Athene brama*	Spotted Owlet	p	-	p	p	p	p	p	p	p
IX	**Order Piciformes**										
	Family Picidae										
40	*Dinopium benghalense*	Lesser Golden-backed Woodpecker	p	p	-	-	p	p	p	p	p
	Family Ramphastidae										
41	*Psilopogon haemacephalus*	Coppersmith Barbet	p	p	-	-	p	p	p	p	-
X	**Order Coraciiformes**										
	Family Meropidae										
42	*Merops philippinus*	Blue-tailed Bee -eater	-	p	-	-	-	-	-	-	p
43	*Merops orientalis*	Green Bee-eater	p	p	p	p	p	p	p	p	p

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
	Family Coraciidae										
44	*Coracias benghalensis*	Indian Roller			p	p	-	-	p	p	p
	Family Alcedinidae										
45	*Ceryle rudis*	Pied Kingfisher	p	p	p	p	p	p	p	p	p
46	*Alcedo atthis*	Common Kingfisher	p	p	-	p	p	p	p	-	-
47	*Halcyon smyrnensis*	White-throated Kingfisher	p	p	p	p	p	p	p	p	p
XI	**Order Falconiformes**										
	Family Falconidae										
48	*Falco chicquera*	Red-necked Falcon	p	p	-	-	p	-	p	-	-
XII	**Order Psittaciformes**										
	Family Psittaculidae										
49	*Psittacula krameri*	Rose-ringed Parakeet	p	p	p	p	p	p	p	p	p
XIII	**Order Passeriformes**										
	Family Oriolidae										
50	*Oriolus oriolus*	Eurasian Golden Oriole	p	p	p	p	p	p	p	p	p
	Family Artamidae										
51	*Artamus fuscus*	Ashy Woodswallow	p	p	p	p	p	p	-	p	p
	Family Dicruridae										
52	*Dicrurus macrocercus*	Black Drongo	p	p	p	p	p	p	p	p	p

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
	Family Laniidae										
53	*Lanius cristatus*	Brown Shrike	p	p	-	-	p	p	-	p	-
	Family Corvidae										
54	*Corvus splendens*	House Crow	p	p	p	p	p	p	p	p	p
55	*Dendrocitta vagabunda*	Rufous Treepie	p	p	p	p	p	p	p	p	p
56	*Corvus macrorhynchos*	Large-billed Crow	p	p	p	p	p	p	p	p	p
	Family Monarchidae										
57	*Terpsiphone paradisi*	Asian Paradise Flycatcher	p	-	-	-	p	-	-	-	-
	Family Nectariniidae										
58	*Leptocoma zeylonica*	Purple-rumped Sunbird	p	-	-	-	-	p	-	-	-
	Family Ploceidae										
59	*Ploceus philippinus*	Baya Weaver	p	p	p	p	p	p	p	p	p
	Family Estrildidae										
60	*Lonchura malacca*	Black-headed Munia	p	p	p	p	p	p	p	p	p
61	*Euodice malabarica*	Indian Silverbill	p	-	-	-	-	p	-	-	-
62	*Amandava amandava*	Red Munia	p	-	-	-	p	p	-	p	-
63	*Lochura punctulata*	Scaly-breasted Munia	p	p	-	-	p	-	p	p	p
64	*Lonchura striata*	White-rumped Munia	p	p	p	p	p	p	p	p	-

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
	Family Passeridae										
65	*Gymnoris xanthocollis*	Yellow-throated Sparrow	p	-	-	-	-	-	-	p	p
	Family Motacillidae										
66	*Motacilla cinerea*	Grey Wagtail	p	-	-	-	-	-	-	p	-
67	*Anthus rufulus*	Paddyfield Pipit	p	p	-	p	p	p	p	p	p
68	*Motacilla maderaspatensis*	White-browed Wagtail	p	p	p	p	p	-	-	-	-
	Family Alaudidae										
69	*Mirafra affinis*	Jerdon'sBushlark	p	p	p	-	p	p	p	p	p
	Family Cisticolidae										
70	*Prinia socialis*	Ashy Prinia	p	p	p	p	p	p	p	p	p
71	*Orthotomus sutorius*	Common Tailorbird	p	p	-	-	-	p	-	-	p
72	*Prinia hodgsonii*	Grey-breasted Prinia	p	-	p	-	-	-	-	-	-
73	*Prinia inornata*	Plain Prinia	p	p	p	p	p	p	p	p	p
74	*Cisticola juncidis*	Zitting Cisticola	p	p	p	p	p	p	p	p	p
	Family Acrocephalidae										
75	*Acrocephalus dumetorum*	Blyth's reed Warbler	p	p	p	p	p	p	p	p	p
76	*Iduna rama*	Syke's Warbler	p	-	-	-	-	-	-	p	-
77	*Acrocephalus agricola*	Paddyfield Warbler	p	p	-	p	p	p	p	p	p

SL No.	Scientific Name	Common Name	Organic regime	Non-organic regime	PS1	PS2	PS3	PS4	PS5	PS6	PS7
	Family Hirundinidae										
78	*Hirundo rustica*	Barn Swallow	p	p	p	p	p	p	p	p	p
79	*Cecropis daurica*	Red-rumped Swallow	p	p	-	-	-	p	p	p	p
	Family Pycnonotidae										
80	*Pycnonotus cafer*	Red-vented Bulbul	p	p	p	p	p	p	p	p	p
	Family Leiothrichidae										
81	*Turdoides affinis*	Yellow-billed Babbler	p	p	p	p	p	p	p	p	p
	Family Sturnidae										
82	*Sturnia pagodarum*	Brahminy Starling	p	p	p	p	p	p	p	p	p
83	*Acridotheres tristis*	Common Myna	p	p	p	p	p	p	p	p	p
	Family Muscicapidae										
84	*Luscinia svecica*	Bluethroat	p	-	-	-	-	-	-	p	-
85	*Saxicola maurus*	Siberian Stonechat	p	-	-	-	-	-	p	-	-
86	*Copsychus saularis*	Oriental Magpie Robin	-	p	-	-	-	p	-	-	-
87	*Saxicola caprata*	Pied Bushchat	p	-	p	-	p	-	-	-	-

List of odonates in the two cultivation regimes, paddy growth stages and Habitat. 'p' indicates presence and '-' indicates absence

Sl No.	Odonate Species	Scientific Name	Cultivation regime		Paddy Growth Stages							Habitat		
			Organic	Non-organic	PS1	PS2	PS3	PS4	PS5	PS6	PS7	Dry	Wet	Wetland
Sub-order Zygoptera or Damselflies														
Family Lestidae														
1	Emerald Spreadwing	*Lestes elatus*	p	p	p	-	p	-	-	-	-	-	-	p
Family Coenagrionidae														
2	Blue Grass Dartlet	*Pseudagrion microcephalum*	p	p	p	p	p	-	-	-	-	-	p	p
3	Coromandel Marsh Dart	*Ceriagrion coromandelianum*	p	p	p	p	p	p	p	p	p	p	p	p
4	Golden Dartlet	*Ischnura aurora*	p	p	p	p	p	p	p	p	p	p	p	p
5	Green-striped Slender Dartlet	*Aciogrion occidentale*	-	p	-	-	-	-	-	p	-	-	-	p
6	Pigmy Dartlet	*Agriocnemis pygmaea*	p	p	p	p	p	p	p	p	p	p	p	p
7	Saffron-faced Blue Dart	*Pseudagrion rubriceps*	-	p	-	-	-	-	-	p	-	-	-	p
8	Senegal Golden Dartlet	*Ischnura senegalensis*	p	p	p	p	p	p	-	-	-	p	p	p
9	Three-lined Dart	*Pseudagrion decorum*	-	p	-	p	-	-	-	-	-	-	p	-
Sub-order Anisoptera or Dragonflies														
Family Gomphidae														
10	Common Hooktail	*Paragomphus lineatus*	p	p	p	-	-	p	-	-	-	-	p	p

Sl No.	Odonate Species	Scientific Name	Cultivation regime		Paddy Growth Stages							Habitat		
			Organic	Non-organic	PS1	PS2	PS3	PS4	PS5	PS6	PS7	Dry	Wet	Wetland
Family Aeshnidae														
11	Blue-tailed Green Darner	*Anax guttatus*	p	p	-	p	-	p	-	-	-	-	-	p
Family Libellulidae														
12	Common Picturewing	*Rhyothemis variegata*	p	p	p	-	p	-	-	p	-	-	p	p
13	Coral-tailed Cloudwing	*Tholymis tillarga*	p	p	-	p	p	p	-	-	-	-	p	p
14	Ditch Jewel	*Brachythemis contaminata*	p	p	p	p	p	p	p	p	p	p	p	p
15	Greater Crimson Glider	*Urothemis signata*	p	-	p	-	-	-	-	-	-	-	-	p
16	Green Marsh Hawk	*Orthetrum sabina*	p	p	p	p	p	p	p	p	p	p	p	p
17	Ground Skimmer	*Diplacodes trivialis*	p	p	p	p	p	p	p	p	p	p	p	p
18	Long-legged Marsh Glider	*Trithemis pallidinervis*	p	p	p	p	p	-	-	-	-	p	-	p
19	Red Marsh Trotter	*Tramea basilaris*	p	p	p	p	p	p	-	-	-	-	p	p
20	Ruddy Marsh Skimmer	*Crocothemis servilia*	p	p	p	p	p	p	p	p	p	p	p	p
21	Trumpet Tail	*Acisoma panorpoides*	p	-	-	-	-	-	p	-	-	-	p	-
22	Wandering Glider	*Pantala flavescens*	p	p	p	p	p	p	p	p	p	p	p	p
23	Yellow-tailed Ashy Skimmer	*Potamarcha congener*	-	p	p	p	-	-	-	-	-	-	p	p

List of butterflies in the two cultivation regimes and paddy growth stages. 'p' indicates presence and '-' indicates absence

Butterfly Species	Common Name	Paddy Growth Stages							Cultivation regime	
		PS1	PS2	PS3	PS4	PS5	PS6	PS7	Organic	Non-organic
Family Hesperiidae										
Ampittia dioscorides (Fabricius)	Bush Hopper	p	p	p	p	p	p	p	p	p
Taractrocera maevius (Fabricius)	Common Grass Dart	-	-	-	-	-	p	-	-	p
Telicota ancilla (Herrich-Schaffer)	Dark Palm Dart	p	-	-	p	-	p	-	p	p
Telicota colon (Fabricius)	Pale Palm Dart	-	-	p	p	p	-	-	p	p
Aeromachus pygmaeus (Fabricius)	Pygmy Scrub Hopper	-	-	p	-	-	p	-	-	p
Borbo cinnara (Wallace)	Rice Swift	p	p	p	p	p	p	p	p	p
Pelopidas mathias (Fabricius)	Small Branded Swift	-	p	-	p	p	-	-	p	p
Parnara sp.	Straight Swift	-	-	-	p	-	-	-	-	p
Family Lycaenidae										
Jamides celeno (Cramer)	Common Cerulean	p	p	p	p	-	-	-	p	p
Castalius rosimon (Fabricius)	Common Pierrot	-	-	-	-	-	p	-	p	-
Catochrysops strabo (Fabricius)	Forget me-not	-	-	-	-	p	-	-	p	-
Euchrysops cnejus (Fabricius)	Gram Blue	p	-	-	p	p	p	p	p	p
Freyeria trochylus (Freyer)	Grass Jewel	-	-	-	-	-	p	-	p	-
Everes lacturnus (Godart)	Indian Cupid	p	-	-	p	p	p	-	-	p
Zizina otis (Fabricius)	Lesser Grass Blue	-	-	-	-	p	p	p	p	p

Butterfly Species	Common Name	Paddy Growth Stages							Cultivation regime	
		PS1	PS2	PS3	PS4	PS5	PS6	PS7	Organic	Non-organic
Pseudozizeeria maha (Kollar)	Pale Grass Blue	-	-	-	p	p	p	-	p	p
Curetis thetis (Drury)	Indian Sunbeam	-	p	-	-	-	-	-	-	p
Zizula hylax (Fabricius)	Tiny Grass Blue	p	p	p	-	-	p	p	p	p
Family Nymphalidae										
Ariadne ariadne (Linnaeus)	Angled Castor	-	-	-	-	p	p	p	p	p
Junonia orithiya (Linnaeus)	Blue Pansy	p	-	-	-	-	-	p	p	p
Tirumala limniace (Cramer)	Blue Tiger	p	p	p	-	-	p	-	p	p
Melanitis leda (Linnaeus)	Common Evening Brown	p	p	p	p	p	p	p	p	p
Junonia atlites (Cramer)	Chocolate Pansy	-	-	p	-	p	p	-	p	p
Mycalesis perseus (Fabricius)	Common Bushbrown	p	p	p	p	p	p	p	p	p
Ariadne merione (Cramer)	Common Castor	-	p	p	p	p	p	p	p	p
Euploea core (Cramer)	Common Crow	p	p	p	-	-	-	-	p	p
Hypolimnas misippus (Linnaeus)	Danaid Eggfly	p	p	p	p	-	-	-	p	p
Melanitis phedima (Cramer)	Dark Evening Brown	-	-	-	p	-	-	-	-	p
Byblia ilithyia (Drury)	Joker	p	p	-	-	-	-	-	p	p
Junonia lemonias (Linnaeus)	Lemon Pansy	-	p	-	-	-	p	-	-	p
Junonia almana (Linnaeus)	Peacock Pansy	p	p	p	p	p	p	p	p	p
Danaus chrysippus (Linnaeus)	Plain Tiger	p	p	p	p	p	p	p	p	p

Butterfly Species	Common Name	Paddy Growth Stages							Cultivation regime	
		PS1	PS2	PS3	PS4	PS5	PS6	PS7	Organic	Non-organic
Danaus genutia (Cramer)	Striped Tiger	p	p	p	p	-	p	-	p	p
Acraea violae (Fabricius)	Tawny Coster	p	p	p	p	p	p	p	p	p
Family Papilionidae										
Graphium sarpedon (Linnaeus)	Common Bluebottle	p	p	-	-	-	-	-	p	-
Graphium doson (C. and R. Felder)	Common Jay	p	-	-	-	-	-	-	p	-
Papilio polytes (Linnaeus)	Common Mormon	p	p	p	p	p	-	p	p	p
Atrophaneura aristolochiae (Fabricius)	Common Rose	p	p	p	p	p	p	p	p	p
Atrophaneura hector (Linnaeus)	Crimson Rose	p	p	p	p	p	p	p	p	p
Papilio demoleus (Linnaeus)	Lime Butterfly	p	p	p	-	-	p	p	p	p
Family Pieridae										
Eurema hecabe (Linnaeus)	Common Grass Yellow	p	p	p	p	p	p	p	p	p
Appias albina (Boisduval)	Common Albatross	p	p	p	-	p	p	-	p	p
Catopsilia pomona (Fabricius)	Common Emigrant	p	p	p	p	p	p	-	p	p
Cepora nerissa (Fabricius)	Common Gull	p	-	-	-	-	-	p	p	p
Delias eucharis (Drury)	Common Jezebel	p	p	p	p	p	p	p	p	p
Pareronia valeria (Cramer)	Common Wanderer	-	-	-	-	-	p	p	p	p
Colotis danae (Fabricius)	Crimson Tip	-	-	-	p	-	-	-	p	-
Catopsilia pyranthe (Fabricius)	Mottled Emigrant	p	p	p	-	-	-	-	p	p

APPENDIX 7

Environmental and Habitat variables recorded from the field during the study

Environmental Variables	
Weather	Sunny, Cloudy, Misty, Drizzly, Rainy
Habitat	Wetland, Wet, Dry
Field Condition	Paddy growth stages
Measured Variables	
Water level	Using measuring scale
Water pH	Using Eutech Multi-purpose meter
Total Dissolved Salts in water	
Water Temperature	

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COMMUNICATION

Diversity and temporal variation of the bird community in paddy fields of Kadhiramangalam, Tamil Nadu, India

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Abstract: Paddy, a major food crop of India, provides a variety of habitats in a short period of time and supports diverse organisms. Paddy fields also harbour many birds with varying species composition across the different cultivation phases of paddy. This study, conducted in the paddy fields of Kadhiramangalam, Tamil Nadu, India, recorded the bird community composition there during the various cultivation phases of paddy. The bird community data was analysed and a total of 87 bird species were recorded from the study area belonging to 41 families and 13 orders. The growth phase (PS 3) is the most diverse phase. The bird composition showed a significant variation across the paddy cultivation phases with overall average dissimilarity of 71.41%. The patterns shown by graphs of bird species composition across the paddy cultivation phases is based on guild, habitat usage and order overlap and elucidates that the change in bird community composition temporally can be attributed to the niche variability across the paddy cultivation phases. The major species contributing to these changes observed are Black-headed Munia, Baya Weaver, Common Sandpiper, Barn Swallow, Common Myna, and Black Drongo in this region.

Keywords: Agro-ecosystems, aves, habitat usage, paddy cultivation phases, rice fields.

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