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Insectivorous bird communities of diverse agro-ecosystems in the Bengaluru region, India

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Abstract
A majority of bird species are insectivorous that check the buildup of insect pest species in agro-ecosystems. A study on insectivorous bird communities was conducted at selected ten major agro-ecosystems in the Bengaluru region. Thirty eight species of insectivorous birds belonging to 17 families under 26 genera were recorded. The number of insectivorous bird species was highest in Chandapura, Hesaraghatta and Thippagondanahalli and lowest at Sarjapura regions. The percentage of population density of insectivorous birds was highest in Hesaraghatta (14.23) and lowest at Somanahalli (6.99). The relative percent abundance of *Apus affinis* was highest (8.36) and it was recorded lowest (0.01) for *Parus nuchalis*. Muscicapidae was the most abundant family. Maximum insectivorous bird species belonged to Motacillidae and Muscicapidae (six each). The variation in abundance of different species of insectivorous birds was found to be dependent on the availability of variety of crops, number of nesting sites and density of perching trees in the vicinity of agro-ecosystems. The current study will be helpful for preparing and implementing the explicit conservation plans for insectivorous avifauna in different agro-ecosystems.

Keywords: Biological control, family abundance and richness, insect predation, insectivorous birds, species diversity and richness.

1. Introduction
Agro-ecosystems are the habitats where native animals can find food and shelter, and reproduce successfully. Agricultural habitat is the main factor determining which animal species - insect, reptile, bird and mammal - an area can support, and the population sizes that can be maintained. Birds constitute an important component in agro-ecosystems and are gaining more and more attention [1]. The role of birds in agriculture is well known as agricultural ecosystem provides a concentrated and highly predictable source of food to many birds. Birds that feed on harmful insects and other pests in agro-ecosystems are beneficial to agriculturists [2].

Agricultural production is highly dependent on ecosystem services such as pest control, pollination and soil fertility [3]. Both ‘‘planned’’ and ‘‘associated’’ biodiversity in farming systems and agricultural landscapes provide important ecosystem services. A one-hectare cereal field hosts several 100,000 individuals and several 100’s of species of predators (beetles, spiders, flies) [4]. The pollinators are required for reproduction of almost 90% of angiosperms and consequently are a limiting factor of most plant communities and vegetation types. Further, pollinators improve production of 70% of the globally most important crop species and influence 35% of global human food supply [5].

Many people appreciate the biodiversity in agricultural landscapes allowing bird watching and any other wildlife protection. This interest is also reflected in large numbers of publications dealing with the current decline of common farmland birds that is perceived as a severe problem in parts of continents [6].

In agricultural ecosystems, natural habitat and habitat heterogeneity are known to increase natural enemy density and diversity to decrease crop pests [7]. The ecological restoration aims to recover the characteristics of an ecosystem, its biodiversity and functions, which have been degraded or destroyed, generally as a result of human activities. Restoration actions are increasingly being implemented in response to the global biodiversity crisis, and are supported by global agreements such as the Convention for Biological Diversity (CBD) [8].

Numerous taxa including species of birds, insects and plants, some of them endangered, depend on low-intensity agricultural practices for their survival [9]. Conservation of existing

biodiversity in agricultural landscapes and the adoption of biodiversity-based practices have been proposed as ways of improving the sustainability of agricultural production through greater reliance on ecological goods and services, having less damaging effects on environmental quality and biodiversity [10-11]. The benefits of organic farming which utilizes fertilizers, herbicides and pesticides which cause lesser contamination to the environment [12], enhancement of natural pest control [13], and conservation of the genetic diversity of local varieties of domestic plants and animals has resulted in increase in agro-biodiversity [14].

In the Indian context, a large number of birds are mainly insectivorous and they help to diminish large numbers of the pest species in agricultural ecosystems. They are the potential natural enemies of a variety of insect pests and helps in the integrated pest management of several insects of important crops. Several bird species play a useful role in agriculture by having a check on insects [15] and rodent pests [16]. Insectivorous birds act as important biological control agents of insect pests in agriculture, floriculture, horticulture and forests [17-20].

As birds are good bio-indicators in the agro-ecosystems, their communities in the Bengaluru region should be protected to conserve the agro-biodiversity and environment. This region attracts a large number of bird species, which include many types of birds, and thus, these are ideal locations for undertaking avifaunal studies [21]. Although insectivorous bird species in some locations of Karnataka have been recorded [17, 19, 22-26], their composition, abundance and diversity have not been thoroughly studied in the major agro-ecosystems. The requirement of scientific information on insectivorous bird communities in different agro-ecosystems of Bengaluru region has led us to take up the present study.

2. Material and Methods

2.1 Description of study areas

Bengaluru is the capital of Karnataka state located in the heart of South Deccan of Peninsular India (Figure 1). Bengaluru region lies between latitudinal parallels 12º 39' -13º 18' N and longitudinal parallels 77º22'-77º52' E at an elevation range 839-962 metres above sea level (masl) [27]. It covers an area of 2191 km^2 [28] and has a population of about 9 million [29]. In Bengaluru region, the average maximum and minimum temperature is 36 and 14 ºC respectively, and humidity ranges between 35 and 80%. Three main seasons are winter (December to February), summer (March to May) and the monsoon (June to November, with rainfall an average of 800 mm).

Ten different agro-ecosystems of Bengaluru region were chosen, based on existence of birds and each ecosystem is comprised of different agricultural crops. Different study sites and their distance from the Central railway station have been presented in Table1 and Figure 1. The distribution of rainfall in different agro-ecosystems of the Bengaluru region is given in the Figure 2. The variety of agricultural crops grown in different agro-ecosystems in the Bengaluru region is given in Table1 and Figure 3.

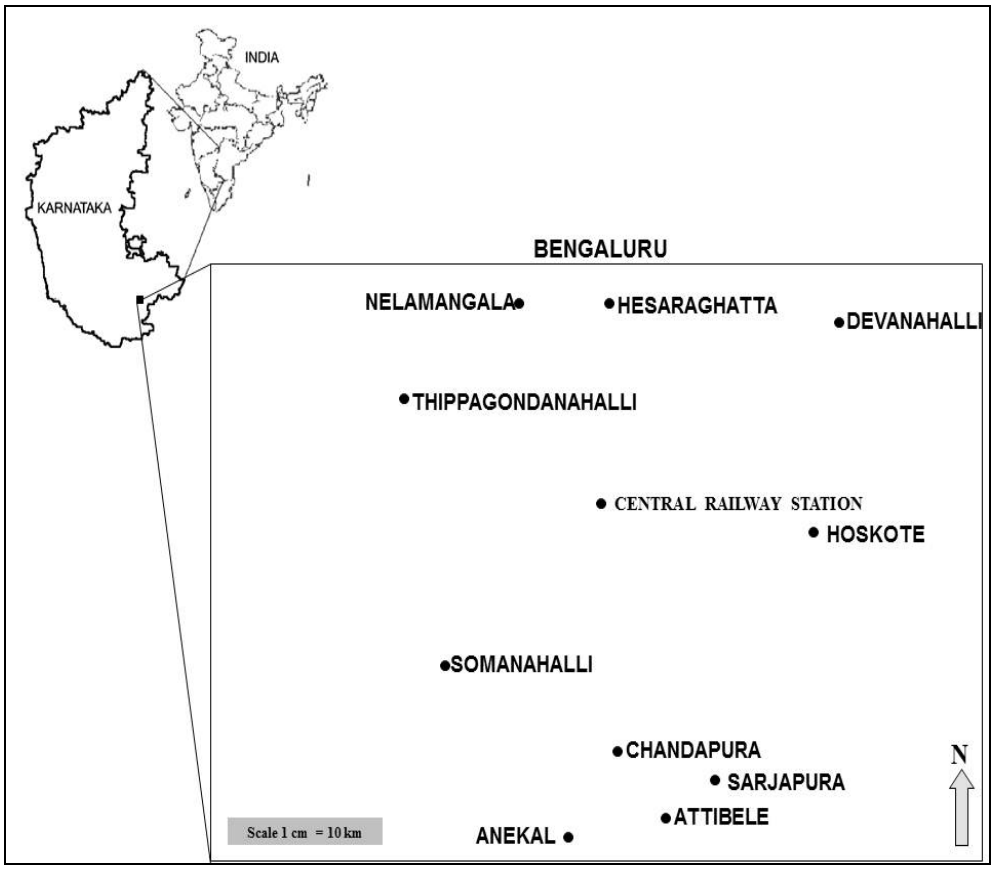

Fig 1: Location of different agro-ecosystems in the Bengaluru region (2008-2010).

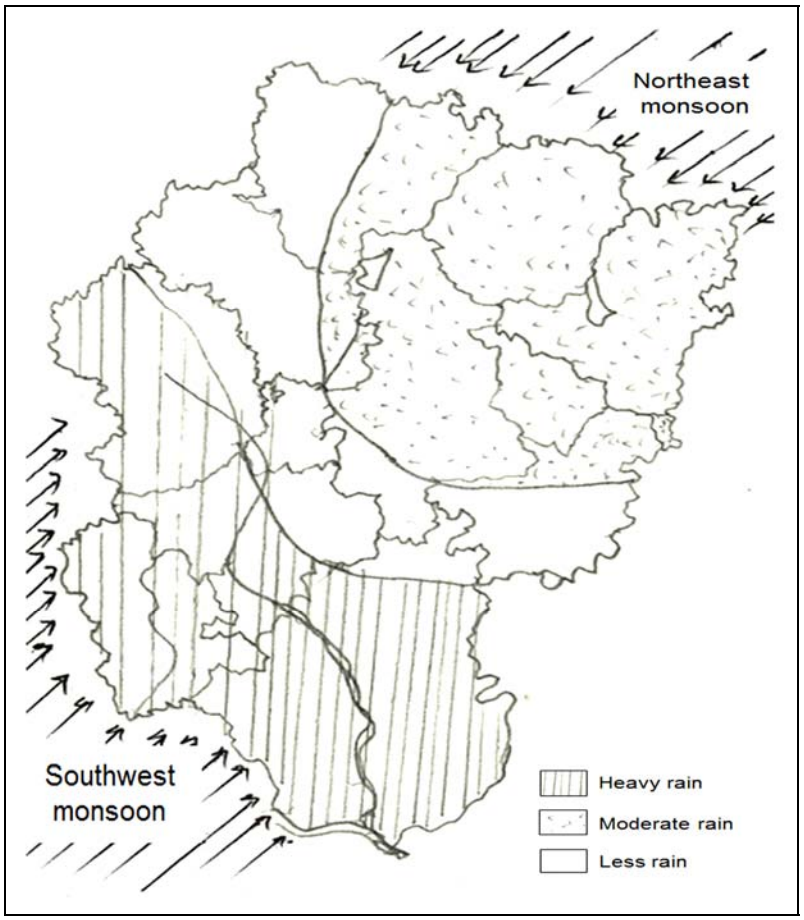

Fig 2: Distribution of rainfall in different agro-ecosystems of the Bengaluru region (2008-2010).

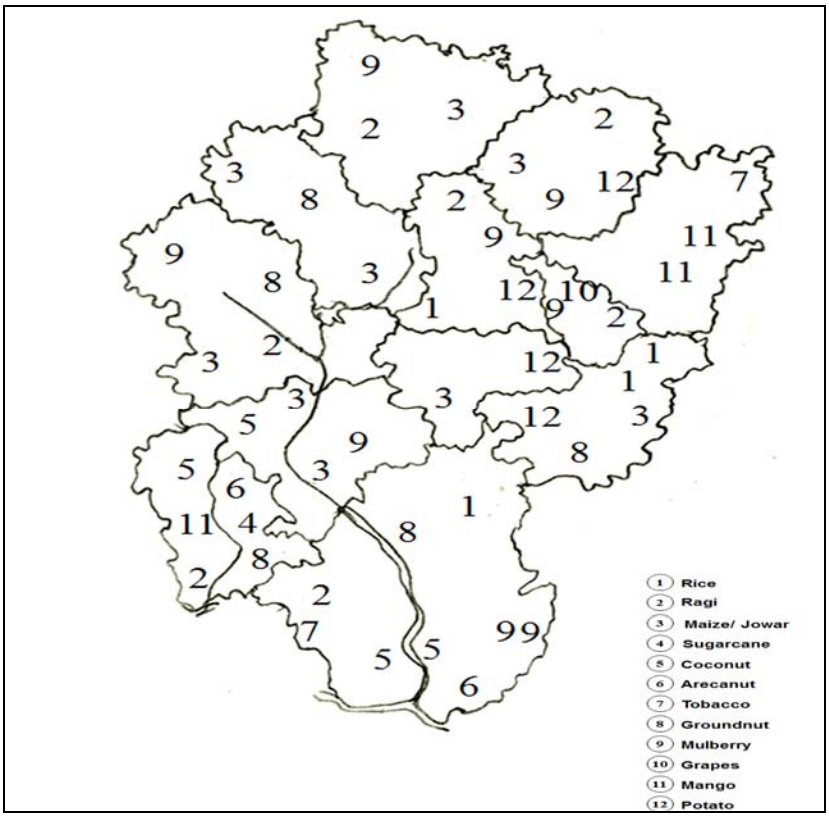

Fig 3: Agricultural crops of different agro-ecosystems of the Bengaluru region (2008-2010).

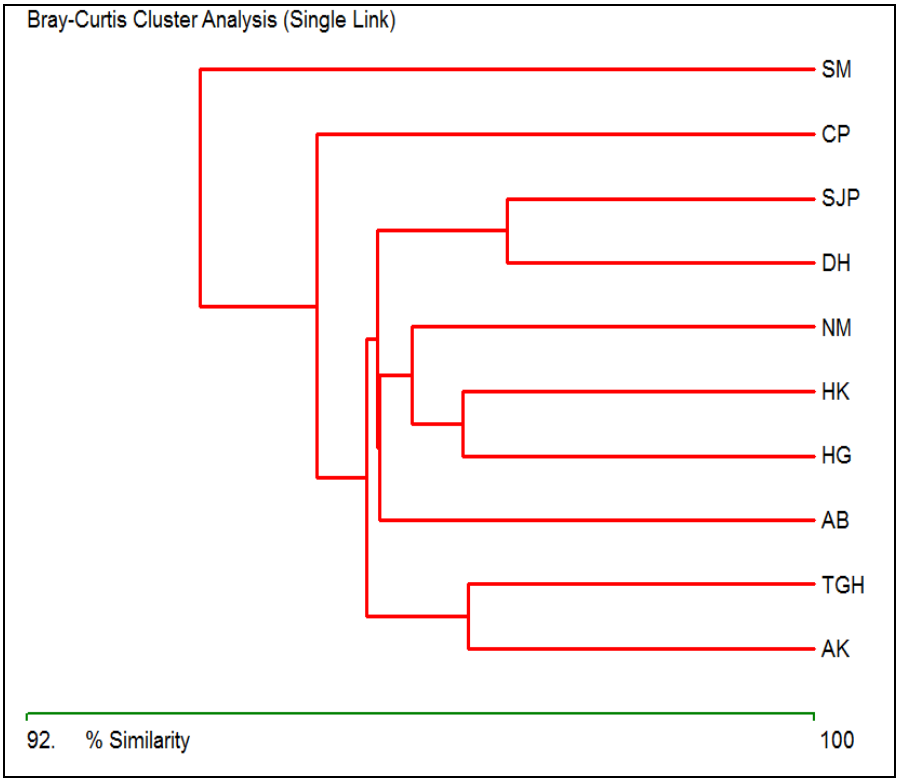

Fig 4: Single linkage clustering of mean population abundances of insectivorous bird communities across different agro-ecosystems using Bray-Curtis Cluster Analysis of Similarity (for acronym of agro-ecosystems, see Table 1).

2.2 Sampling

Our sampling methods aimed to capitalize on completeness and, more outstandingly, ensure that the level of completeness is equivalent across all ecosystems being sampled [30]. Ten observation locations were selected in each of the agro-ecosystem, easily covered by one person walking as followed by Bibby *et al.* [31]. Each spot was located in relation to roads along agricultural lands, incorporating trees corridors, hedgerows and vegetation patches. At each spot point count of birds was made for six to ten minutes within the visible radius as followed by several workers [32-34]. In addition to point counts, line transects were also used to estimate bird diversity and density in order to achieve the complete surveys. The 100 m transects extended 10 m into the crop on each side of the agricultural boundary. An agricultural field margin was defined as 'any feature which divided an area of land into two fields; it could range from a bare or grassy strip to a complex of trees, hedges, watercourse, bank and track'. The dominant features were a bank, a small managed hedge or a tall unmanaged hedge. The same bird survey methods were carried out at both sites. Firstly, the field margins and crop strips were scanned with binoculars to note the birds present. Transects was then slowly walked along (over about 10 min) and any birds that were seen or heard were noted for their location [35]. Based on the field conditions, the growth stages of agricultural crops was divided into ploughing and transplantation (P&T), tillering (T), booting (B) and harvesting (H).

Investigations were conducted once a fortnight in the identified agro-ecosystems from February 2008 to January 2010. Surveys were carried out once in a day (morning 08.00-11.00h and evening 15.00-18.00 h) irrespective of agricultural practices such as sowing and cultivation months of many agricultural crops and each transect was visited an equal number of times [35]. Birds were counted at their point of first detection and care was taken to ensure that individual birds were not counted twice. Birds were recorded only if they perched or actively foraged in the study sites. Overpasses except for habitually aerial species as swallows and swifts were not scored as followed by Trager and Mistry [36]. Call notes of birds were also used for locating the birds [37]. The survey methods used fixed time-spans for all samples (e.g. 30-40 min transect count), thereby using 'standardized search' sampling effort across all agro-ecosystems [33].

Recordings were not made at the time of drizzling/raining or wind exceeded a gentle breeze. In addition, regular field observations were also made on the nests, nesting sites, feeding habitat, vegetation and food sources. Observations were also made on the natural predation of birds. The number of birds of various species was recorded in a data sheet at each sampling site on each census day. The data recorded in each survey from the different agro-ecosystems were analyzed separately for assessing relative abundance (encounter rates) during two years. The check list of species was prepared based on Grimmett and Inskipp [21] and Ali [37]. Nomenclature and taxonomy of insectivorous birds was assigned according to BirdLife International [38]. The data generated at each study site on avifauna were converted to estimate the biodiversity indices. A list of insectivore bird species encountered in each different agro-ecosystem with irrespective of crops during both visits was compiled. Habitat variables were collected from surveyed agricultural fields [35].

2.3 Data analyses

Incidence (encounter rate) is the number of times a species was encountered, that is, the number of intervals in which it was recorded divided by the total number of sampling intervals [39]. The number of species observed on each surveyed farm was used directly as the measure of species richness

(equivalent to the species density of Gotelli and Colwell [40]). These variables were those that have been shown to influence avian species richness and population size for a variety of species, i.e. the proportion of the field boundaries that was vegetated with hedges (as opposed to unvegetated fences and walls), the number of trees present, the number of grazing animals etc. [35].

Insectivorous bird species which were observed in the field considered only for inventorying purposes and not for statistical analysis of data. The diversity of insectivorous birds is analyzed using the different indices as given below paragraphs (PAST version 1.60 software by Hammer *et al*. [41]) and statistical tests as Magurran [42].

1. Individuals (N) are the total number of individuals of all species recorded in a trail and it is presented in mean ± standard error.
2. Furthermore, based on these individuals, relative abundance of species is measured by the following formula of Singh and Rai [43]: A = a/N X 100. Where, A = Relative abundance; a = Total population of a particular species/ taxon and N = Total population of all the species/ taxon. It measures the percentage of individuals over all the species.
3. Number of species (S) is the total number of species recorded.
4. Shannon-Wiener's diversity index (H') is estimated using the following formula $H' = \sum P_i \ln P_i$, where P_i is the proportion of total individuals belong to the *i*th species in the sample (Shannon and Wiener [44]).
5. Fisher's alpha diversity is defined using the formula $S = a * \ln(1 + n/a)$, where S = is the number of taxa, n = is the number of individuals and a = is the Fisher's alpha (Fisher *et al*. [45]).
6. Sheldon's index of evenness (E2) is estimated using the formula $E2 = e^H / S$; $(0 < E < 1)$, where, e = is the natural logarithm base, H' = Shannon-Wiener's diversity index and S = Number of species (Buzas and Gibson [46]; Sheldon [47]).
7. Margalef's richness index (R1) is assessed using the formula R1 = (S-1) / ln N, where S = is the number of species in a community and N = is the total number of individuals observed in that particular community [48].
8. Berger-Parker index is estimated using the formula Dominance = Nmax / N
9. Goodness of fit (G) is estimated using the formula $G = 2 \sum Ob \times \ln(Ob/Ex)$, where Ob is the observed/recorded number of individuals and Ex is the expected number of individuals (Chi-square test [49]).
10. Bray-Curtis Cluster Analysis was carried out to create a dendrogram to assess the similarity in the populations of insectivorous birds among the study agro-ecosystems using Biodiversity Professional Version 2.0 software [49].
11. Family abundance is calculated similar to that of relative abundance of species B = b/P X 100, where, B = Relative abundance of a family, b = Total population of a Particular family and P = Total Population of all the species in that particular family (Singh and Rai [43]). It measures the percentage of populations over all the species in a family.
12. Family richness was estimated using the following formula R1 = (S-1) / ln N, where S = is the number of species in a family and n = is the total number of individuals observed in that particular family [48]. The number of species in a family or in an observation represents family richness, which is the simplest and most useful measure to know the difference among the families. The simplest form of richness is the Hill's number 0 (N_0) which is the total number of species (S) in a given habitat.

3. Results

The different agro-ecosystems of the Bengaluru region are commonly endowed with agricultural and horticultural crops i.e. ragi, rice, groundnut, sugarcane, castor, grapes, mulberry, etc. (Table 1).

The occurrence of different species of bird communities recorded at selected ten major different agro-ecosystems in the Bengaluru region is given in Table 2. Thirty eight bird species belonging to 17 families under 26 genera were recorded during the study period. Of the recorded bird species, the relative abundance of *Apus affinis* was highest (8.36%), whereas it was 0.01% for *Parus nuchalis* (Table 2).The goodness of fit test showed a significant difference in the abundance of individual insectivorous bird species in the diverse agro-ecosystems of the Bengaluru region (Table 3). The highest number of insectivorous birds (22) was residents followed by resident migrants (12) and migrants (4) (Table 2). *Parus nuchalis* was the only vulnerable insectivorous bird species and remaining 37 species were of least concern (Table 2).

The number of insectivorous bird species was highest in Chandapura, Hesaraghatta and Thippagondanahalli (36 each) and lowest at Sarjapura (32). The percentage of population density of insectivorous birds was highest in Hesaraghatta (14.23 and 503.79 ± 120.16), and lowest at Somanahalli (6.99 and 247.42 ± 26.28). The highest diversity (3.44) of birds was observed at Chandapura and Thippagondanahalli and least (3.12) in Hesaraghatta. The Fisher's alpha diversity (4.60) of birds was highest at Chandapura and least (4.01) in Sarjapura. The Margalef's species richness was highest in Chandapura (3.74) and lowest in Sarjapura (3.31). The species evenness index was highest in Sarjapura (0.90) and least in Hesaraghatta (0.63). The Berger-Parker index of insectivorous birds was highest in Hesaraghatta (0.25) and was lowest at Attibele, Devanahalli and Thippagondanahalli (0.05 each) (Table 4).

On the whole, the present sampling success of insectivorous bird communities in an agro-ecosystems distributed across the Bengaluru region showed a significant bias towards different species of birds (Goodness of fit $\chi^2 = 24742.043$, df = 9, $p < 0.00$; Table 5).

Of the 17 families, Muscicapidae was the most abundant (17.33%) and dominant family, whereas Motacillidae was the richest family (0.52). Motacillidae and Muscicapidae were represented by maximum number of insectivorous bird species (six species each). The highest number (five) of genera was recorded from Muscicapidae (Table 6).

Dendrogram showing similarity in the population density of insectivorous birds of different agro-ecosystems with three major clusters represented significant positive affinities. Sub-cluster 1 with Nelamangala, Hoskote and Hesaraghatta, and sub-cluster 2 with Thippagondanahalli and Anekal (14.23 to 10.08%) accounted for greater population density of insectivorous birds, whereas Attibele, Devanahalli and Sarjapura (8.58 to 9.41%) formed the second cluster representing a moderate population density of insectivorous birds. While the rest of the two separate clusters from Chandapura (8.54%) and Somanahalli (6.99%) accounted for a minimum population density of insectivorous birds (Fig. 4).

The natural control of insect predation by insectivorous birds is listed in the Table 7.

Table 1: Various crops of different agro-ecosystems of insectivorous avifaunal communities of the Bengaluru region (2008-2010).

Agro-ecosystems (with acronym)	Area (in km^2)	Distance from City Railway Station (in km)	Detailed list of agricultural crops grown
Anekal (AK)	6.00	40	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, *Amaranthus*), Tubers (Potato, Sweet Potato, Colocasia, Tapioca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, *Sapota*, Gooseberry, Wood apple, Custard apple, Jamun, Pine apple, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, *Barleria*, *Dahlia*, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Ashwagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Sugarcane, Mushroom and Mulberry
Attibele (AB)	2.50	35	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Mustard, Oil palm), Jute (Cotton), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Colacasia, Tapioca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Pine apple, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Neem, Eucalyptus), Medicinal plants (Glory lily, Ashwagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Mushroom and Mulberry
Chandapura (CP)	3.00	30	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Colacasia, Tapioca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Ashwagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Sugarcane, and Mulberry
Devanahalli (DH)	5.00	39	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Colacasia, Tapioaca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Pine apple, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Ashwagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Sugarcane and Mulberry
Hesaraghatta (HG)	7.00	28	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Colacasia, Tapioaca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Pine apple, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily,

			Ashwagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Mushroom and Mulberry
Hoskote (HK)	4.00	27	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Colacasia, Tapioaca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Aswagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Sugarcane and Mulberry
Nelamangala (NM)	5.00	28	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Colacasia, Tapioaca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Pine apple, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Aswagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), and Mulberry
Sarjapura (SJP)	4.00	40	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Sunflower, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf), Tubers (Potato, Sweet Potato, Colacasia, Tapioaca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Grapevine, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Pine apple, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Aswagandha, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), Sugarcane, Mushroom and Mulberry
Somanahalli (SM)	2.00	28	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Mustard, Oil palm), Jute (Cotton, Jute), Masticatories (Tobacco, Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf, Amaranthus), Tubers (Potato, Sweet Potato, Tapioaca, Yams), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Papaya, Tamarind), Spices (Turmeric, Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Barleria, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Eucalyptus, Neem), Medicinal plants (Glory lily, Solanum, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), and Mulberry
Thippagondanahalli (TGH)	7.00	40	Rice, Millets (Sorghum, Ragi), Pulses (Lab niger, Toor dal, Bengal gram, Black gram, Green gram), Oil seeds (Castor, Coconut, Gingelly, Groundnut, Mustard, Oil palm), Jute (Cotton), Masticatories (Arecanut), Vegetables (Brinjal, Tomato, Bhendi, Cucurbits, Cluster bean, Cowpea, Drumstick, Curry leaf), Tubers (Potato, Sweet Potato, Colacasia, Tapioca), Fruits (Mango, Citrus, Cashew, Guava, Banana, Fig, Pomegranate, Ber, Jack, Sapota, Gooseberry, Wood apple, Custard apple, Jamun, Papaya, Tamarind), Spices (Ginger, Chillies, Onion, Garlic, Mint, Poppy seeds, Coriander and Cumin), Ornamentals (Rose, Jasmine, Lily, Crotons, Oleander, Chrysanthemum, Dahlia, Tulip, Gerbera, Bird of Paradise, Gloriosa, Sweetpea, Balsam, Hollyhock), Forest trees (Teak, Bamboo, Casuarina, Sandal wood, Neem, Eucalyptus), Medicinal plants (Glory lily, Solanum, *Solanum* spp., Vasaka), Cosmetics (Soapnut, Osilam), and Mulberry

Tables 2: Encounter rate (%), occurrence and residential status of insectivorous bird communities in different agro-ecosystems of the Bengaluru region (2008-2010).

Sl. No.	Bird families	Common names	Scientific names of insectivorous birds	% abundance	Residential status♦
1	Accipitridae	Oriental Honey-buzzard	*Pernis ptilorhyncus*	0.28	Resident migrant
2	Aegithinidae	Common Iora	*Aegithina tiphia*	1.37	Resident
3	Apodidae	Little Swift	*Apus affinis*	8.36	Resident migrant
4		Asian Palm-swift	*Cypsiurus balasiensis*	0.84	Resident
5	Campephagidae	Common Woodshrike	*Tephrodornis pondicerianus*	0.76	Resident
6	Cisticolidae	Ashy Prinia	*Prinia socialis*	4.65	Resident
7		Tawny-flanked Prinia	*Prinia subflava*	4.82	Resident
8	Hirundinidae	Barn Swallow	*Hirundo rustica*	4.21	Resident migrant
9		Wire-tailed Swallow	*Hirundo smithii*	1.75	Resident
10		Red-rumped Swallow	*Hirundo daurica*	3.93	Resident migrant
11	Laniidae	Great Grey Shrike	*Lanius excubitor*	0.57	Resident migrant
12	Meropidae	Little Green Bee-eater	*Merops orientalis*	2.31	Resident
13	Monarchidae	Asian Paradise-flycatcher	*Terpsiphone paradisi*	1.11	Resident migrant
14	Motacillidae	Paddyfield Pipit	*Anthus rufulus*	1.70	Resident
15		Red-throated Pipit	*Anthus cervinus*	1.51	Resident
16		Forest Wagtail	*Dendronanthus indicus*	0.40	Resident migrant
17		Grey Wagtail	*Motacilla cinerea*	2.20	Migrant
18		White Wagtail	*Motacilla alba*	2.77	Resident migrant
19		White-browed Wagtail	*Motacilla maderaspatensis*	2.57	Resident
20	Muscicapidae	Asian Brown Flycatcher	*Muscicapa dauurica*	3.71	Resident migrant
21		Blue-throated Flycatcher	*Cyornis rubeculoides*	2.67	Resident
22		Tickell's Blue-flycatcher	*Cyornis tickelliae*	3.62	Resident
23		Verditer Flycatcher	*Eumyias thalassinus*	0.80	Resident
24		Oriental Magpie-robin	*Copsychus saularis*	2.83	Resident
25		Pied Bushchat	*Saxicola caprata*	3.70	Resident
26	Paridae	Great Tit	*Parus major*	3.00	Resident
27		White-naped Tit	*Parus nuchalis*	0.01	Resident
28	Picidae	Rufous Woodpecker	*Celeus brachyurus*	2.73	Resident
29		Black-rumped Flameback	*Dinopium benghalense*	1.56	Resident
30	Rhipiduridae	White-bellied Fantail	*Rhipidura euryura*	3.10	Resident
31		White-browed Fantail	*Rhipidura aureola*	4.16	Resident
32		White-throated Fantail	*Rhipidura albicollis*	4.85	Resident
33	Sylviidae	Thick-billed Warbler	*Acrocephalus aedon*	0.90	Migrant
34		Paddyfield Warbler	*Acrocephalus agricola*	3.91	Resident migrant
35		Large-billed Leaf-warbler	*Phylloscopus magnirostris*	3.82	Migrant
36		Greenish Warbler	*Phylloscopus trochiloides*	5.25	Migrant
37	Turdidae	Eurasian Blackbird	*Turdus merula*	2.13	Resident migrant
38	Upupidae	Eurasian Hoopoe	*Upupa epops*	1.14	Resident migrant
			Total	100.00	

♦Ali [37].

Table 3: Goodness of fit test for insectivorous bird species in different agro-ecosystems of the Bengaluru region.

Insectivorous bird species	Variance	Mean	Chi-square Values (G)	Degree of freedom	Probability	Aggregation
Oriental Honey-buzzard	1007.11	38.00	238.53	9	0.00	Aggregated
Common Iora	1654571.63	1124.60	13241.28	9	0.00	Aggregated
Little Swift	23296.71	113.60	1845.69	9	0.00	Aggregated
Asian Palm-swift	5485.73	310.20	159.16	9	0.00	Aggregated
Common Woodshrike	1059.73	152.80	62.42	9	0.00	Aggregated
Ashy Prinia	6989.38	367.40	171.22	9	0.00	Aggregated
Tawny-flanked Prinia	2824.93	209.40	121.42	9	0.00	Aggregated
Barn Swallow	97099.55	566.00	1543.99	9	0.00	Aggregated
Wire-tailed Swallow	5699.73	234.80	218.47	9	0.00	Aggregated
Red-rumped Swallow	10204.84	528.20	173.88	9	0.00	Aggregated
Great Grey Shrike	5849.07	77.20	681.89	9	0.00	Aggregated
Little Green Bee-eater	7801.60	101.60	691.09	9	0.00	Aggregated
Asian Paradise-flycatcher	3465.96	184.80	168.80	9	0.00	Aggregated
Paddyfield Pipit	4313.11	499.00	77.79	9	0.00	Aggregated
Red-throated Pipit	2586.71	417.40	55.77	9	0.00	Aggregated
Forest Wagtail	3759.82	359.60	94.10	9	0.00	Aggregated
Grey Wagtail	20820.49	487.40	384.46	9	0.00	Aggregated
White Wagtail	3578.49	107.60	299.32	9	0.00	Aggregated
White-browed Wagtail	11038.04	560.40	177.27	9	0.00	Aggregated

Asian Brown Flycatcher	9991.12	652.30	137.85	9	0.00	Aggregated
Blue-throated Flycatcher	1512.00	150.00	90.72	9	0.00	Aggregated
Tickell's Blue-flycatcher	14941.56	625.00	215.16	9	0.00	Aggregated
Verditer Flycatcher	12319.51	648.20	171.05	9	0.00	Aggregated
Oriental Magpie-robin	7808.71	121.60	577.95	9	0.00	Aggregated
Pied Bushchat	15470.93	526.40	264.51	9	0.00	Aggregated
Great Tit	10793.29	514.20	188.91	9	0.00	Aggregated
White-naped Tit	14188.44	706.00	180.87	9	0.00	Aggregated
Rufous Woodpecker	5824.71	380.40	137.81	9	0.00	Aggregated
Black-rumped Flameback	5334.04	498.40	96.32	9	0.00	Aggregated
White-bellied Fantail	11549.38	286.60	362.68	9	0.00	Aggregated
White-browed Fantail	8194.18	403.80	182.63	9	0.00	Aggregated
White-throated Fantail	14.40	1.20	108.00	9	0.00	Aggregated
Thick-billed Warbler	5745.96	229.20	225.63	9	0.00	Aggregated
Paddyfield Warbler	9621.51	202.80	426.99	9	0.00	Aggregated
Large-billed Leaf-warbler	3958.22	54.00	659.70	9	0.00	Aggregated
Greenish Warbler	2152.40	296.20	65.40	9	0.00	Aggregated
Eurasian Blackbird	6582.44	373.00	158.83	9	0.00	Aggregated
Eurasian Hoopoe	3246.62	345.80	84.50	9	0.00	Aggregated

Table 4: Density and diversity of insectivorous bird communities in different agro-ecosystems of the Bengaluru region (2008-2010).

Agro-ecosystems	Mean ± Standard Error	% population density	No. of Insectivorous birds (S)	Shannon-Weiner's Diversity (H')	Sheldon's evenness index (E2)	Margalef's species Richness	Fisher's alpha Diversity	Berger-Parker's Index
AK	453.05 ± 49.14	12.80	35	3.40	0.86	3.49	4.21	0.08
AB	303.84 ± 31.54	8.58	33	3.38	0.89	3.42	4.16	0.05
CP	302.37 ± 29.40	8.54	36	3.44	0.86	3.74	4.60	0.06
DH	333.05 ± 35.25	9.41	33	3.38	0.89	3.39	4.11	0.05
HG	503.79 ± 120.16	14.23	36	3.12	0.63	3.55	4.28	0.25
HK	358.79 ± 35.14	10.13	35	3.42	0.88	3.57	4.35	0.06
NM	356.90 ± 41.74	10.08	35	3.38	0.84	3.57	4.35	0.09
SJP	309.53 ± 32.92	8.74	32	3.36	0.90	3.31	4.01	0.06
SM	247.42 ± 26.28	6.99	34	3.37	0.86	3.61	4.44	0.06
TGH	372.08 ± 35.56	10.51	36	3.44	0.87	3.66	4.47	0.05

For acronym of agro-ecosystems, see Table 1.

Table 5: Goodness of fit test for insectivorous bird communities in different agro-ecosystems of the Bengaluru region.

Chi - Square	Value	Degree of freedom	Probability (G)	Dispersion
Total	24742.04	380	0.000	Aggregated
Pooled	5533.823	9	0.000	Aggregated
Heterogeneity	19208.22	371	0.000	Discordant

Table 6: Encounter rates of insectivorous bird family and richness in different agro-ecosystems of the Bengaluru region (2008-2010).

Sl. No.	Bird Family	No. of species	No. of genera	Margalef's family richness	Relative family abundance (%)
1	Accipitridae	1	1	0.00	0.28
2	Aegithinidae	1	1	0.00	1.37
3	Apodidae	2	2	0.11	9.20
4	Campephagidae	1	1	0.00	0.76
5	Cisticolidae	2	1	0.11	9.46
6	Hirundinidae	3	1	0.21	9.88
7	Laniidae	1	1	0.00	0.57
8	Meropidae	1	1	0.00	2.31
9	Monarchidae	1	1	0.00	1.11
10	Motacillidae	6	3	0.52	11.16
11	Muscicapidae	6	5	0.50	17.33
12	Paridae	2	1	0.12	3.01
13	Picidae	2	2	0.12	4.29
14	Rhipiduridae	3	1	0.21	12.12
15	Sylviidae	4	2	0.31	13.88
16	Turdidae	1	1	0.00	2.13
17	Upupidae	1	1	0.00	1.14
	Total	38	26		100.00

Tables 7: Natural predation /biological control of insects by insectivorous bird communities in different agro-ecosystems of the Bengaluru region (2008-2010).

Sl. No.	Insectivorous bird species		Harmful Insects in various agricultural crops*		
	Common names	Scientific names	Family: Scientific name	Common name	Crops
1	Oriental Honey-buzzard	*Pernis ptilorhyncus*	Hymenoptera: Vespidae eating *Polistes* spp.	Paper wasps larvae	
2	Common Iora	*Aegithina tiphia*	Eat insects and spiders, but tend to hunt in pairs for caterpillars, moths, and spiders		
3	Little Swift	*Apus affinis*	Coleoptera, Hemiptera, Diptera, Hymenoptera and Homoptera [66]	Aerial insectivore	
4	Asian Palm-swift	*Cypsiurus balasiensis*	Preys insects on flight	Aerial insectivore	
5	Common Woodshrike	*Tephrodornis pondicerianus*	Insects		
6	Ashy Prinia	*Prinia socialis*	Hemiptera: Aphididae *Aphis gossypii*; Hymenoptera and Hemiptera	Pea Aphid	Guava; Cotton
7	Tawny-flanked Prinia	*Prinia subflava*	Hymenoptera and Hemiptera	Aerial insectivore	
8	Barn Swallow	*Hirundo rustica*	Different species of flies including horn flies, face flies, horse flies, flying around livestock, beetles, leafhoppers, wasps, ants, moths, grasshoppers, and crickets		
9	Wire-tailed Swallow	*Hirundo smithii*	Different species of flies including horn flies, face flies, horse flies, flying around livestock, beetles, leafhoppers, wasps, ants, moths, grasshoppers, and crickets		
10	Red-rumped Swallow	*Hirundo daurica*	Different species of Coleopterans, Heteropterans, Hymenopterans, Homopterans, and Dipterans		
11	Great Grey Shrike	*Lanius excubitor*	Different species of Orthopterans, Coleoptera, Heteroptera, Hymenoptera and Lepidoptera		
12	Little Green Bee-eater	*Merops orientalis*	Hemiptera: Aphididae *Aphis craccivora* Lepidoptera: Pieridae *Pieris brassicaae* Hymenoptera: Apidae *Apis mellifera, A. cerana, A. dorsata, A. florea* [67-68]	Pea Aphid Cabbage aphid Cabbage white (cabbage butterfly) European honey bee, Asiatic Honeybees, giant honey bee, red dwarf honey bee	Pea; Guava; Cotton Cucurbits
13	Asian Paradise-flycatcher	*Terpsiphone paradisi*	Different species of insects		
14	Paddyfield Pipit	*Anthus rufulus*	Different species of insects		
15	Red-throated Pipit	*Anthus cervinus*	Different species of insects		
16	Forest Wagtail	*Dendronanthus indicus*	Different species of insects		
17	Grey Wagtail	*Motacilla cinerea*	Hemiptera: Aphididae *Aphis craccivora Brevicoryne brassicae* Lepidoptera: Plutellidae *Plutella maculipennis*	Pea Aphid Cabbage aphid (cabbage aphis) Diamondback moth (Cabbage moth)	Field bean; Pea; Guava; Cotton Cabbage
18	White Wagtail	*Motacilla alba*	Hemiptera: Aphididae *Aphis craccivora Brevicoryne brassicae* Lepidoptera: Plutellidae *Plutella maculipennis*	Pea Aphid Cabbage aphid (cabbage aphis) Diamondback moth (Cabbage moth)	Field bean; Pea; Guava; Cotton Cabbage
19	White-browed Wagtail	*Motacilla madaraspatensis*	Hemiptera: Aphididae *Aphis craccivora Brevicoryne brassicae* Lepidoptera: Plutellidae *Plutella maculipennis*	Pea Aphid Cabbage aphid (cabbage aphis) Diamondback moth (Cabbage moth)	Field bean; Pea; Guava; Cotton Cabbage
20	Asian Brown Flycatcher	*Muscicapa dauurica*	Different species of insects		
21	Blue-throated Flycatcher	*Cyornis rubeculoides*	Different species of insects		
22	Tickell's Blue-flycatcher	*Cyornis tickelliae*	Different species of insects		
23	Verditer Flycatcher	*Eumyias thalassinus*	Different species of insects		
24	Oriental Magpie-robin	*Copsychus saularis*	Lepidoptera: Noctuidae *Helicoverpa armigera* [58]	American Bollworm/ Pod Borer	Cotton, Sorghum, Pulses, Groundnut, Tomato

			And many other insects		
25	Pied Bushchat	*Saxicola caprata*	Lepidoptera: Noctuidae *Helicoverpa armigera* [58] And many other insects	American Bollworm/ Pod Borer	Cotton, Sorghum, Pulses, Groundnut, Tomato
26	Great Tit	*Parus major*	Lepidoptera: Noctuidae *Helicoverpa armigera* [58] Also, Lepidoptera larvae and adults, Symphita larvae, Orthoptera, Coleoptera, Arachnida, Chrysalis, Tipulae, Homoptera, Phasmida, Neuroptera, Formicidae, Mantidae, Heteroptera, Myriapoda, Gasteropoda forms major diet	American Bollworm/ Pod Borer	Cotton, Sorghum, Pulses, Groundnut, Tomato
27	White-naped Tit	*Parus nuchalis*	Lepidoptera: Noctuidae *Helicoverpa armigera* [58]	American Bollworm/ Pod Borer	Cotton, Sorghum, Pulses, Groundnut
28	Rufous Woodpecker	*Celeus brachyurus*	Different species of insects		
29	Black-rumped Flameback	*Dinopium benghalense*	Different species of insects		
30	White-bellied Fantail	*Rhipidura euryura*	Different species of insects		
31	White-browed Fantail	*Rhipidura aureola*	Different species of insects		
32	White-throated Fantail	*Rhipidura albicollis*	Different species of insects		
33	Thick-billed Warbler	*Acrocephalus aedon*	Different species of insects		
34	Paddyfield Warbler	*Acrocephalus agricola*	Different species of insects		
35	Large-billed Leaf-warbler	*Phylloscopus magnirostris*	Different species of insects		
36	Greenish Warbler	*Phylloscopus trochiloides*	Different species of insects		
37	Eurasian Blackbird	*Turdus merula*	Different species of insects		
38	Eurasian Hoopoe	*Upupa epops*	Lepidoptera: Arctiidae *Spilosoma obliqua*; Lepidoptera: Thaumetopoeidae *Thaumetopoea pityocampa* [69]	Jute Hairy Caterpillar or Bihar Hairy Caterpillar Pine Processionary	

*Richards and Davies [65].

4. Discussion

Subramanya and Veeresh [24] recorded 81 species of birds in the rice fields of north Bengaluru. As well, Sundar and Subramanya [50] reviewed the role of birds in rice fields in the Indian subcontinent and have listed 351 species (27% of species of the subcontinent), which included the present 38 species. About 30% of the avifauna in the agricultural fields is reported in the Bangladesh region [51].

Residential status of individual bird species in the different agro-ecosystems of the Bengaluru region is similar to avian fauna present in the rice fields of north Bengaluru [17, 24].

The fluctuations in diversity, richness, number of species and percentage of population density showed an increase during the migratory season of insectivorous birds. This indicates that fluctuations in the population sizes of individual species may have been mediated by the availability of suitable field conditions. Thus, the field conditions may have been suitable for only a few species that show high abundances [24]. Jones *et al*. [52] reported that bird species richness and abundance differs with agro-ecosystems. The highest bird abundances were associated with mixed crop plantings, field borders, and adjacent matrix composed of forest and hedge; and abundances of ten species identified as functional insectivores were primarily influenced by crop type as mixed crops attracted significantly more insect foragers into fields than monocrops [52].

The highest evenness index of insectivorous bird species at Sarjapura may be because of widely cultivated variety of crops grown in the field that provided insect food sources especially caterpillars in the field for nestlings and suitable nesting spaces. Standing crops provide shelter to a variety of resident birds and also attract the migratory species [53]. The presence of a large number of rare or irregular species may have contributed to the erratic fluctuations in evenness. As a result, diversity shows a high dependence on the richness component alone. Human activities and their direct interference strongly disturb the avifauna [54-55]. This suggests that the primary requirements such as food, shelter, resting, roosting and nesting sites for insectivorous bird communities are not equally available in the various agro-ecosystems.

Tscharntke *et al*. [56] reported that agricultural bird species have greater habitat and diet breadth than forest species. The community similarity is greater among agricultural systems than in natural habitats and more in simple than in complex landscapes for birds and insects, so natural communities, low-intensity agriculture and heterogeneous landscapes appear to be critical in the preservation of beta diversity [56].

The variation in abundance of different species of

insectivorous bird communities in these agro-ecosystems is depending on the availability of variety of crops, number of nesting sites, and density of perching trees. The natural control of insect predation by insectivorous birds was similar to earlier findings by Verghese and Sriharan [17], Keshavan and Malavannan [19], Chakravarthy [22-23], Subramanya and Veeresh [24], Chakravarthy *et al*. [26], Dhindsa and Saini [57], Mehta *et al*. [58]. Insects comprised the main part of the diet in the agro-ecosystems and were the only invertebrates form the important diet for insectivorous birds. In addition to agro-ecosystems, adjacent deciduous forests provide good cover and nesting sites as well as foraging for insectivorous birds in different parts of the Bengaluru region.

Some measures to protect birds dwelling in agro-ecosystems include (i) Farming using organic pesticides and fertilizers, (ii) Protecting and providing the nesting and roosting sites in agro-ecosystems, (iii) Erecting bird perches and thus helps for foraging, (iv) Planting hedges and shrubbery around fields as shelter and nesting sites, (v) Maintaining local water bodies to encourage wetland birds and (vi) Maintain forest cover and scrub jungles near villages [59]. Additional to these, some more recommendations and suggestions are (i) Use of multi-cropping or mixed cropping favors bird predators, (iv) Electric poles and wires in a non-grain ecosystems are again useful in attracting birds, (v) Providing of water-troughs attract ground insectivorous birds such as wagtails [17].

Diversified habitats that include trees and tall shrubs can contribute to the conservation of insectivorous bird diversity, by avoiding breeding habitats for pest birds in agro-ecosystems [1, 60]. In addition, insectivorous birds are important bio-control agent of insect pests of agro-ecosystems [20]. House sparrow [1, 42, 61-62], Black drongo [63] and common myna [64] help in the control of harmful insects in agricultural fields [19]. Some species of waterbirds i.e. Rosy pelican, Painted stork, Grey heron and Little egrets feed on the food sources in nearby tanks, ponds and rice fields which act as feeding grounds in agro-ecosystems [50].

A greater variety of agro-ecosystem plants will support a greater diversity of insects, because many insects need specific plants for food and habitat. A diverse array of predatory insects and spiders, in turn, feed on insects. All these invertebrates are important food sources for passerines, whistlers, honeyeaters, cuckoo-shrikes and hornbills.

5. Conclusion

Findings of this study indicates that the availability of a variety of food sources for both adults and nestlings, safe habitat for nesting/roosting in and around the agro-ecosystems are important for the occurrence and abundance of insectivorous bird populations. Follow up monitoring studies in the same agro-ecosystems for a longer period are necessary to determine the species specific conservation measures for insectivorous birds. Eco-friendly management of agricultural landscape is essential for bird conservation. The current study will be helpful for preparing and implementing the explicit conservation plans for insectivorous avifauna in different agro-ecosystems for reducing the incidence of insect pests.

6. References

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