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Diversity of Insectivorous Avian Species and their Foraging Activities at Ponds in Agricultural Habitats in Punjab, India

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Authors' Contribution
TKK planned this research and designed the experiment. SKS, GSS and SK performed the field survey, identified the birds and population census. SKS and GSS wrote research paper with the help of TKK. AKC helped in the identification of insects.

Key words
Biocontrol, Crop fields, Insectivorous birds, Insects, Village ponds

ABSTRACT

Ponds constitute biodiversity hotspots within a region or landscape. The objective of this investigation was to assess the diversity of avian species of insectivorous feeding guild and their foraging activities at ponds surrounded by wheat and rice crop fields. Three ponds were selected and surveyed during April 2020 to March 2021 in village Mukrabpur, district Rupnagar (pond I), village Gopalpur, district Ludhiana (pond II) and in Punjab Agricultural University (PAU) campus (pond III), district Ludhiana. Out of 67 bird species recorded 44, 47 and 46 were observed at pond I, pond II and pond III respectively. Seventeen species of purely insectivorous and 19 species of partially insectivorous bird species were recorded. In total, 19 insect species of nine orders were recorded, out of which five lepidoptera species had the insect pest status. Statistical comparison of population of purely insectivorous birds in *Kharif* crop (rice) showed significant difference as compared to *Rabi* crop wheat. Daily foraging frequency of each individual bird species has signified their year round ecological services as biocontrol agents corresponding to *Rabi* and *Kharif* crops. Results have shown that foraging frequency of black drongo (*Dicrurus macrocercus*) was the highest followed by green bee-eater (*Merops orientalis*), wire-tailed swallow (*Hirundo smithii*), common swallow (*Hirundo rustica*) and house swift (*Apus affinis*). Study results have highlighted the biocontrol potential of insectivore avian species along with relevance of ponds in agricultural habitats.

INTRODUCTION

Significant role of ponds has been emphasized by many workers both for rural community and for farming in agricultural landscapes of different regions worldwide (Khan, 2002; Miracle *et al*., 2010; Toor *et al*., 2011). Ponds have been mentioned as a common feature of urban and rural areas but varying in their origin and biodiversity values. Review of publications on biodiversity aspects of ponds has shown higher species richness in rural ponds as compared to urban ponds; however, threatened species were found in rural ponds (Oertli and Parris, 2019). Toor *et al*. (2011) have highlighted the multipurpose utilization of ponds for drinking, bathing of domestic animals and for irrigation; and also their ecological role for groundwater recharge. Ponds like other freshwater bodies provide ecological services (sustaining aquatic organisms as well as terrestrial organisms) thereby increasing biodiversity value of different ecosystems. Their direct and indirect roles in regulating temperature and humidity conditions at local scale have been explored by Downing (2010). Ponds are important components sustaining regional freshwater diversity and terrestrial diversity in both urban and rural settlements; their indirect benefit as habitats preferred by diverse types of animals like bats and reptiles cannot be overlooked (Sirami *et al*., 2013; Oertli, 2018; Williams *et al*., 2020). Khan (2002) stated that the freshwater bodies like ponds and lakes are home to large number of species of insects and invertebrates. Two important aspects of pond characteristics i.e., their small size and high potential as biodiversity sites have significance for location specific conservation efforts specifically for species with low dispersal rates in areas under intensive agriculture (Casas *et al*., 2012).

Different studies have been conducted on the ponds as favourable habitats for flora elements like aquatic plants and

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fauna elements like invertebrates and vertebrate species; and also endangered species of animals (Biggs *et al*., 1994; Oertli *et al*., 2002). Majority of workers have emphasized on the aquatic biodiversity of pond ecosystems thereby giving less attention to high productivity value of ponds as compared to terrestrial and to the interactions existing at the aquatic-terrestrial interface (Baxter *et al*., 2005). Ponds in farmlands have suitable habitat niches for a wide variety of animal groups like insects, annelids, mollusks, amphibians, reptiles and birds (Huang, 2012). de Marco *et al*. (2013) have stated that there is ecological similarity between artificial man-made ponds and natural ponds; however, less information is available on the ecological succession in artificial ponds considering its biotic and abiotic components in relation to habitat restoration and landscape preservation. Farm ponds have numerous services like presence of sub habitat for beneficial animal species like insects and birds in addition to their recycling of soil nutrients in agriculture (Rana *et al*., 2019).

According to Wood *et al*. (2003) freshwater bodies like ponds are disappearing rapidly due to anthropogenic activities which has led to habitat fragmentation and habitat loss. In the Indian context, majority of bird species are insectivorous and they forage upon insects thereby helping in insect pest control in crop fields (Rajashekara and Venkatesha, 2014). Detailed studies on ponds are scarce and there is need to have assessment of pond ecosystems in view of vulnerability and disappearance of ponds due to less attention and inadequate legislation protection (Miracle *et al*., 2010). There are well recognized factors like vegetation structure, species–area relationships and other anthropogenic features in the vicinity which influence the animal diversity in ponds at local scale (Cereghino *et al*., 2014). Therefore, a survey was carried out for two consequent days on monthly basis from April 2020 to March 2021, to assess the insectivorous bird species inhabiting ponds and their foraging behaviour in surrounding crop fields (wheat in Rabi season and rice in Kharif season) in Punjab State, India.

MATERIALS AND METHODS

Study area

Three ponds were selected as follows: pond I in village Mukrabpur of district Rupnagar (latitude 30° 58'30.9"N and longitude 76° 31' 38.3"E), pond II in village Gopalpur of district Ludhiana (latitude 30° 43' 37.2"N and longitude 75° 51' 01.7"E) and pond III (latitude 30° 54' 22.3"N and longitude 75° 48' 36.1"E) in Punjab Agricultural University (PAU) campus of district Ludhiana. Pond I (area 4 acre) and pond II (area 2 acre) were situated on village outskirts in close proximity to crop fields. Ponds I and II received wastewater from village households, pond III (4 acre) was receiving wastewater from sewage treatment unit surrounded by agricultural fields.

Methodology insects and bird diversity analysis

The survey was conducted on diversity of avian species of different feeding guilds inhabiting ponds from April 2020 to March 2021. Data on insect diversity were also recorded at these ponds surrounded by crops namely wheat (Rabi cropping season) and rice (Kharif cropping season). Rabi cropping season corresponds to winter months and extends from mid-October to March while Kharif cropping season corresponds to both summer and rainy seasons from June to first fortnight of October. Summer extending from April to September, is characterized by sweltering hot and dry conditions from March through June and is followed by monsoon season having hot and humid conditions from July to September months. Data on insectivorous avian species, their foraging activities and insect diversity composition were collected in the morning between 5.00-8.00 am and in the evening between 5.00-6.30 pm for two consequent days every month (Asokan and Ali, 2010). Survey was conducted by walking on existing trails and track using the knowledge of standard field guides (Grimmett *et al*., 2011). Bird population was estimated employing Point Count Protocol (Verner, 1985), using Nikon action 16x50x4.1 zooming binoculars. Photographic documentation was also made. A checklist of species was prepared following the nomenclature of Parveen *et al*. (2016). Net sweeping was carried out to record insect diversity by selecting ten quadrats of 1m x 1m each around ponds. The insects were collected in polythene bags and preserved in 70% alcohol for identification. Net sweeps were made in the mornings and evenings twice in a month (Dalal and Gupta, 2016). Two hours in the morning and 1½ h in the evening were observed as the peak feeding hours of birds, and accordingly, bird foraging frequency was calculated for per hour and on daily basis. Calculated values were extrapolated to know annual foraging frequency of purely insectivorous bird species.

RESULTS AND DISCUSSION

Bird species related to different feeding guilds were recorded at all three ponds under study. In total of 44 bird species including 18 insectivorous species having a relative abundance 23.79% were observed at pond I. Species belonging to other feeding guilds were carnivores (14), omnivores (4), granivores (3), frugivores (4) and only one nectarivore species. The relative abundance of granivorous bird species was the highest (35.25%), followed by

omnivorous (25.28%), insectivorous (23.79%) and nectarivorous (0.63%) bird species (Table I). Nectarivorous bird species were not observed at pond II and pond III. At Pond II, the species richness and relative abundance of insectivorous species were as the highest (19 and 36.81%, respectively) as compared to other feeding guilds. Species richness of birds belonging to other feeding guilds was 6 omnivorous (24.86%), 4 granivorous (20.63%), 17 carnivorous (17.37%) and one frugivorous (0.47%). The maximum value of avian species richness, i.e., 47 was recorded at Pond II. At pond III, insectivores recorded the maximum species richness (18) followed by carnivores (15), omnivores (6), frugivores (4) and granivores (3) species. Relative abundance was the highest in the insectivorous feeding guild (37.49%) followed by omnivorous (28.00%) and carnivorous (24.47%), frugivorous 7.48% and granivorous 1.54% species (Table I). Seventeen species of purely insectivorous and 19 species of partially insectivorous bird species were recorded during the study period.

A total of 18 species of insects belonging to eight different orders and 17 families was recorded during the study period. Species richness of different insect orders was as follows: Lepidoptera (5), Odonata (3), Coleoptera (3), Orthoptera (2), Dictyoptera (2), Isoptera (1), Dermaptera (1) and Hymenoptera (1) were recorded at selected locations. During summer a total of 14 species of insectivorous guild consisting of 7 purely insectivores and 7 partially insectivores had subsisted on 11 insect species at pond I. A total of 15 insect species was noted during summer followed by 14 during the monsoon season at all study locations. As many as 13 insect species were recorded at pond II, followed by 11 species at both pond I and III during summer season. Twelve species were recorded at pond II followed by 11 at pond I and 10 at pond III during monsoon season. In winter season, out of eight observed species, seven were recorded at pond II while ponds I and pond III recorded four and three species, respectively.

Insects belonging to order orthoptera order were recorded consistently at all three ponds during summer and monsoon except winter months. Order Dictyoptera consisting american cockroach and isoptera consisting of termite were observed in all three seasons at pond I whereas these were not observed during winter season at pond II and pond III. Insect species namely fruit sucking moth (pest of citrus), anar butterfly (pest of pomegranate) and rice leaf folder (pest of paddy) from order Lepidoptera have been mentioned as agricultural pests in agritech portal (https://agritech.tnau.ac.in/). Cabbage butterfly and lime butterfly are known pests for brassica plants and citrus plant species, respectively. During present study, these five insect pest species were observed to be preyed upon by insectivore bird species. Common swallow, wire-tailed swallow, black drongo, house swift and green bee eater were noted foraging on the mentioned insect pest species and thereby showing their biocontrol potential. Indian robin and Oriental magpie robin were noted feeding on the larvae of moths and butterflies.

Nonparametric data analysis using Kruskal-Wallis H test revealed a significant difference in population of purely insectivorous birds (P= 0.000), partially insectivorous birds (P= 0.031) and insect (P= 0.038) at all three selected ponds during Kharif season. The nonparametric Mann-Whitney U test revealed that between pond I and II the population of both purely and partially insectivorous birds differed significantly (P= 0.004 and P= 0.012, respectively) during Kharif season. However, this difference was significant for only purely insectivorous birds during Rabi season. Comparison of pond II and III also showed a significant difference in purely insectivorous birds (P= 0.000) and insect population (P= 0.015) during Kharif season and also during Rabi season for purely insectivore birds (P= 0.032). Significant difference in purely insectivore bird population (P= 0.027) was found between pond I and III during Kharif season. Standing irrigation water in rice crop (Kharif season) seemed to provide favourable habitat for insect populations directly and for insectivore birds indirectly.

Table I. Abundance according to feeding guilds in studied locations.

Feeding guild	District Rupnagar		District Ludhiana			
	Pond I Mukrabpur		Pond II Gopalpur		Pond III PAU, Ludhiana	
	Number of species	Relative abundance (%)	Number of species	Relative abundance (%)	Number of species	Relative abundance (%)
Insectivore	18	23.79	19	36.81	18	37.49
Carnivore	14	10.98	17	17.37	15	24.47
Granivore	3	35.25	4	20.63	3	1.54
Frugivore	4	3.88	1	0.47	4	7.48
Nectarivore	1	0.63	-	-	-	-
Omnivore	4	25.28	6	24.86	6	28.00
Total	44		47		46	

Table II. Foraging behaviour of purely insectivore bird species.

Bird species	Flock type	Foraging frequency		Perch types	Foraging substrate	Foraging method	Insect species preyed upon	Insect order
		@ per individual bird per day	@ per individual bird per year					
Common swallow (*Hirundo rustica)*	Flock (7-10)	24	8760	EW	Air	Aerial feeding	dung beetles, rice leaf folder, dragonflies	Lepidoptera, Odonata, Coleoptera,
Wire-tailed swallow (*Hirundo smithii)*	Flock (10-15)	25.6	9344	EW	Air	Aerial feeding	dung beetles, rice leaf folder, dragonflies, wasps	Lepidoptera, Odonata, Coleoptera, Hymenoptera
Indian robin (*Saxicoloides fulicatus*)	Single, Pair	24	8760	S, G	Ground	Gleaning and ground feeding	beetles and bugs	Coleoptera
Brown rock chat (*Oenanthe fusca*)	Single	14.4	5256	S, G	Ground	Gleaning and ground feeding	termite, beetles, bugs, cricket	Isoptera, Coleoptera, Orthoptera
Black redstart (*Phoenicurus ochruros*)	Single	11.2	4088	S, G	Plant (Shrub vegetation) Ground	Gleaning and ground feeding	grasshopper, beetles	Orthoptera, Coleoptera
Oriental magpie robin (*Copsychus saularis*)	Single	16	5840	T, S, G	Plant, Ground	Aerial feeding, gleaning, ground feeding	larve of butterflies and moth species, termite, earwig, beetles	Isoptera, Lepidoptera, Dermaptera, Coleoptera
Paddyfield pipit (*Anthus rufulus*)	Single	11.2	4088	S, G	Air, Plants, Ground	Ground feeding	beetles, bugs, termites	Coleoptera, Isoptera
Black drongo (*Dicrurus macrocercus*)	Flock (4-6)	33.6	12264	T, EW	Air, Plants, Ground	Aerial feeding, gleaning, ground feeding	grasshopper, cricket, termite, wasps, moths, beetles, dragonflies	Orthoptera, Isoptera, Hymenoptera, Lepidoptera, Odonata, Coleoptera
Common tailorbird (*Orthotomus sutorius*)	Single	14.4	5256	T, S	Plants, Ground	Gleaning, ground feeding	wasps, bugs, beetles, grasshoppers, termite	Coleoptera, Orthoptera, Isoptera, Hymenoptera
Ashy prinia (*Prinia socialis*)	Single	16	5840	T, S,	Plants	Gleaning, ground feeding	bugs, termite, beetles	Coleoptera, Isoptera
Plain prinia (*Prinia inornata*)	Single	12.8	4672	T, S, G	Plants	Gleaning, ground feeding	bugs, termite, beetles	Coleoptera, Isoptera
House swift (*Apus affinis*)	Flock (7-8)	24	8760	EW	Air	Aerial feeding	dragonflies, grasshopper, moths, butterflies, cricket	Odonata, Orthoptera, Lepidoptera, Orthoptera
White-browed fantail (*Rhipidura aureola*)	Single	9.6	3504	T, G	Air, plants	Aerial feeding, Gleaning	wasps, crickets	Orthoptera, Hymenoptera
Black-winged stilt (*Himantopus himantopus*)	Flock (10-15)	16	5840	G	Ground	Ground feeding	beetles, bugs	Coleoptera
Common hoopoe (*Upupa epops*)	Single	23.2	8468	G, T	Trees, ground	Gleaning, ground feeding	Crickets, beetles, earwig, bugs	Orthoptera, Coleoptera, Dermaptera,
Common golden-backed woodpecker (*Dinopium javanense*)	Single	14.4	5256	T	Trees	Gleaning	Beetles, termites, crickets	Orthoptera, Isoptera, Coleoptera
Green bee-eater (*Merops orientalis*)	Flock (8-10)	30.4	11096	EW, T	Air, trees, plants, ground	Aerial feeding, gleaning, ground feeding	wasps, beetles, bees, butterflies, cricket, dragonflies, moth, termites	Hymenoptera, Coleoptera, Lepidoptera, Orthoptera, Odonata, Isoptera

EW, Electric wires; T, trees; G, ground; S, Shrub.

Species specific avian preferences for insects depending on their size and abundance were found. Purely insectivorous black drongo was observed feeding on different insect species *viz*. grasshopper, termites, wasps, beetles and dragonflies during evening observations at selected ponds. Black drongo was found utilizing foraging substrates like air, plants and ground during feeding endeavours. Brown rock chat foraged on insects in wild vegetation at periphery of pond II and III. Arial feeding behaviour of wire-tailed swallow had shown it capturing rice leaf folder, beetles and bugs at pond I and II. Purely insectivores like ashy prinia and plain prinia had dietary component including small insects, spiders and flies; they were found more active during morning and evening observations at pond I and pond III, respectively. Oriental magpie robin was observed mostly close to the ground, hopping along branches or foraging in leaf-litter on the ground to find insects and leeches at pond II. Common golden-backed woodpecker was noted on the pond banks surrounding trees like peepal (*Ficus religiosa*), neem (*Azadirachta indica*), lassura (*Cordia myxa*) and feeding on termites, spiders and other insects at pond III. Black redstart was observed feeding in air on flies during winter evenings at pond III. Green bee- eater was observed during summer and monsoon mornings feeding on wasps and flies at pond I and III. Partially insectivore cattle egret and red-wattled lapwing preferred to feed on insects and small invertebrates namely frogs and lizards at pond I (Table II).

Small insects constituted the diet of Scaly-breasted munia recorded at pond I and II. Common myna and Asian pied starling foraged near the banks of ponds and were generally observed along with Indian robin, brown rock chat and cattle egret at all study locations. Rufous-fronted warbler and jungle babbler at pond II were observed gleaning wild grass and weed vegetation for insect food along the banks. Common sandpiper foraged on insects and small invertebrates while probing mud along the banks or in the shallow waters at pond II. Indian tree pie and Asian koel were noted foraging on fig fruit of goolar tree (*Ficus racemosa*) in the morning and were noted hopping to capture insects from the bark and branches of peepal, neem, goolar and lassura at pond I and III. Specialized insect feeder like hoopoe was recorded feeding on house cricket, European earwig and beetles at pond II and III. warblers and babblers were present at all study locations. According to present work specialized insect feeders are of three types' *viz.,* gleaners, ground and arial feeders, which have demonstrated the presence of specialized foraging behaviour of insectivorous birds. These included three species of arial feeders, 4 voracious feeders (arial, gleaning, ground), eight of gleaning and ground feeders while one species each of ground feeder and gleaner.

Maximum foraging frequency at selected ponds was recorded for black drongo with 33.6 times/day and 12264 times annually and the least was recorded for white-browed fantail with 9.6 times/ day and 3504 times annually. Few other species namely green bee eater, wire-tailed swallow, common swallow and house swift were recorded with 30.4, 25.6, 24 and 24 times per day respectively (Table II). The actual population numbers of individual insectivorous species were considered along with their foraging frequencies can provide estimate of species wise biocontrol potential values and the impact of ecological services provided by insectivorous birds in agricultural landscapes.

Village ponds are the life line of the people in Punjab (Toor *et al*., 2011). Traditional settlements and their farmyards offer a range of microhabitats for farmland biodiversity for their breeding and foraging activities (Donald *et al*., 2001; Hiron *et al*., 2013). Ponds play an important role in maintaining avian diversity and abundance (Kaur *et al*., 2018). Insectivorous and carnivorous species are considered to be useful since they keep a very potent check on populations of insects and rodents in the ecosystem (Dhindsa and Saini, 1994). Most bird species are insectivorous that depend for the most part on insects as prey (Losey and Vaughan, 2006; Şekercioğlu, 2006). Insectivorous birds are known to be sensitive to changes in habitat structure due to their specialized foraging behaviour (Castano-Ville *et al*., 2019). Graber and Graber (1983) stated that lepidopteran larvae amounted to 75% diet of warbler species. Rajashekara and Venkatesha (2014) studied insectivorous bird communities at selected major agro ecosystems in the Bengaluru region. Thirty-eight species of insectivorous birds belonging to 6 orders and 17 families under 26 genera were recorded. Foraging niche of small green bee-eater, Indian roller, common myna and black drongo were studied in and around agricultural landscapes of Nalgonda District of Telangana, India (Narayana *et al*., 2016). Kumar and Cheema (2020) recorded visits of seven insectivorous bird species with t perches in fodder crop.

Kaur and Kler (2018) inferred that black drongo spent maximum time in foraging activities. Bilal *et al*. (2020) mentioned that arial feeding mode had been preferred over plant or tree gleaning and ground feeding by black drongo. They further mentioned solitary foraging behaviour during morning and in cluster with others during evening. Vyas and Upadhyay (2015) reported that both adults of ashy prinia fed the chicks continuously with various types of small insects, caterpillars, and spiders. Wasnik *et al*. (2014) noted that the little green bee-eater takes rapid flight after an insect, seizing its prey and returning to the perch, where it strikes the insect to kill it before devouring it. Zhu and

Zou (2001) studied that cattle egret preferred to forage on insects and other arthropods. Machovsky-Capuska *et al.* (2016) reported the behavioural observations of Common Myna that they consumed more than 40% of insects in their diet. Studies of Mansor *et al.* (2019) indicated that leaf litter could serve as a vital foraging resource for gleaning babblers.

CONCLUSIONS

A large number of avian species of insectivorous guild inhabit village ponds which are potential biocontrol agents that suppress the agricultural insect pest species. Previous studies of authors along with their unpublished data have found declining population trends in birds of insectivorous feeding guild in agricultural habitats of Punjab State, India. The results of this study results are applicable via two pronged approaches: Preservation of pond habitat is required along with conservation interventions for sustenance of insectivorous species which might lead to insect pest reduction to some extent in agricultural areas. Stake-holders like ornithologists, agronomists and policy makers should formulate agricultural policies by integrating conservation of wild bird population along with rejuvenation of village ponds in sustainable agricultural models.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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