Insectivorous bird communities of monoculture plantations in Konkan region, Maharashtra

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CERTIFICATE

This is to certify that **Mr. Shardul Joshi** of Sálim Ali Centre for Ornithology and Natural History (SACON) has carried out an original research work titled, '***Insectivorous bird communities of monoculture plantations in Konkan region, Maharashtra***' in partial fulfilment of the M.Sc. (Ornithology & Conservation Biology) degree of Saurashtra University, Rajkot. This investigation was carried out under my supervision from December 2019 to August 2020. I also certify that this research work has not been submitted for any other degree to any university.

Date: 24 August, 2020
Place: Coimbatore

(**Dr. Rajah Jayapal**)
Senior Principal Scientist

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SUMMARY

Tropical forests worldwide are increasingly fragmented and converted into human-modified landscapes owing to the mounting anthropogenic pressures. The forest fragments remain as habitat islands situated amidst a matrix of human-modified land uses. Though such landscapes of multiple land use are known to negatively impact wild biodiversity, some human-modified land uses are known to act as secondary habitats for select taxa. One such land use type is agricultural plantations. Large amounts of forests around the world have been converted into commercial plantations of cash crops and the role of such plantations in sustaining local biodiversity is of key conservation interest.

The present study seeks to investigate the role of mango and cashew plantations in rescuing the insectivore bird communities in a multiple use landscape in Dapoli Taluk of Ratnagiri district in the Konkan region of Maharashtra. The forests in Dapoli comprise sacred groves that represent primary forests, and private forests, which are patches of secondary forests overgrown in long-abandoned private lands. Such private forests have been extensively converted into commercial plantations of mango and cashew during recent times.

The objectives of the study were to determine the differences in community composition and structure of insectivorous birds between forests and plantations, and to ascertain the habitat covariates influencing it. Investigations were also carried out to determine whether the insectivore bird communities of plantations and their sub-guilds were a subset of the forest bird assemblages to deduce the role of plantations as secondary habitats for insectivorous birds.

Insectivorous birds were classified into sub-guilds based on types of foraging strata, foraging behaviour and habitat specialization, and Pearson's chi square test was done to compare the proportions of each sub-guild among the four land cover types. Spearman's correlation coefficient was calculated to identify habitat variables that influence community composition and structure of insectivorous birds. Further, nestedness analysis was carried out to know if there was any nestedness in the insectivorous bird communities and their sub-guilds along the gradient of plantations to forests.

The chi-square analysis revealed that forest specialist species were less represented in the plantations that were dominated by open-habitat species. Particularly, the ground and

understorey foragers were completely absent in the plantations, possibly owing to a paucity of leaf litter and understorey in the plantations.

The mean relative frequency of foraging strata sub-guilds was the same between cashew plantations and forested habitats. The high tree density and profuse branching pattern in the cashew plantations may provide a diversity of vertical strata for foraging. In contrast, mango plantations showed significant similarity with regard to sub-guilds of foraging behaviour.

Significant positive correlations were found between insectivore richness and diversity with variables, known to represent the vegetation structural complexity. This is because the structural complexity increases the availability of specialized niches that insects occupy. The vegetation diversity and litter arthropod richness was also correlated with the insectivore diversity and richness. On the other hand, grass cover and distance from the forest negatively influenced the insectivore bird community. Regular removal of leaf litter in intensively managed plantations gives rise to grass growth that negatively affects the litter-probing insectivores.

A moderate yet statistically significant degree of nestedness was observed, implying that cashew and mango plantations seemed to harbour a significant part of insectivorous assemblages and their sub-guilds in the region. It, then, follows that there is a great potential for cashew and mango plantations to serve as an optimal secondary habitat in the landscape. Further study on improving structural complexity and habitat quality of the plantations with no corresponding cost to their productivity would fetch a win-win solution for sustaining the insectivorous bird diversity of the region.

1. INTRODUCTION

1.1. BACKGROUND

Conservation is a profound term with diverse perspectives and ideologies, some of which are contrasting, each with a vast body of literature that supports their views. One such dichotomy is about creating inviolate spaces for biodiversity versus involving communities in the conservation programme.

The basic premise behind creating inviolate spaces for wildlife is that, when the communities are relocated from the forest, activities such as logging, grazing, fire kindling are curtailed allowing wildlife populations to recover. Although this is expected, there are only anecdotal records of such recoveries happening (Karanth, 2006; MoEF, 2006) and there exist few long-term studies as to the response of wildlife to human interference.

Advocates of the community-conservation paradigm state that management of forests by communities is more sustainable and effective due to their efficiency in doing collective actions (Agrawal & Gibson, 1999), clarity over property rights, strictness regarding harvesting rules (Rao *et al.*, 2016) and strong leadership (Sudtongkong & Webb, 2008). On the other hand, there are many studies where community-conserved areas are found to be degraded and depauperate owing to unsustainable management practices, change in the belief system and increased human and cattle population (Kothari, 2006; Rao *et al.*, 2016). In a global review (Shahabuddin & Rao, 2010), which looked at the effectiveness of community-conserved areas (CCA) in conserving biodiversity, it was found that the strictly protected areas were more effective than the CCAs, but CCAs were significantly more effective than open-access areas and had the potential to protect a significant proportion of regional flora and fauna.

Presently there are 2,55,665 Protected Areas (PAs) in the world comprising 15 % of the earth's surface. In India, there are 903 PAs covering 5% of the area [Source: *WII Envis Centre on Wildlife & Protected Areas*, as on December 2019]. As these protected spaces cover only a minuscule area of the earth's surface, the presence of community-conserved areas along with PAs is an added advantage. Furthermore, many of the community conserved areas are pretty small in size and somewhat isolated. Not all the biodiversity-significant areas can be brought under PA network owing to severe paucity of resources and other socio-economic limitations,

and often a prioritization exercise is undertaken to optimize site selection process. During the prioritization process, such small areas have a relatively lower probability of coming under the PA network. Hence, such community-managed areas, although not as good as the PAs, can be assets for conservation.

Sacred groves are forest patches adjoining a village or group of villages and are preserved by the local communities for their spiritual and religious significance. The local communities believe that such forests are an abode to various deities that protect the village and its people, and their destruction or degradation shall bring misfortune to the communities. Sacred groves act as refuges for the conservation of local biodiversity and consist of a wide variety of local, endemic and endangered species (Debal *et al.*, 1997).

Along with such community-protected primary forests, in the Western Ghats, there still are some patches of overgrown secondary forests that are privately owned. These patches were once under cultivation but now have been left unattended for many years due to several reasons like land disputes over ancestral property, lack of labour to cultivate, and owners' migration towards cities (Kulkarni & Mehta, 2013). About 74% of the forests in the Western Ghats are outside the protected areas (Blicharska *et al.*, 2013) and detailed studies on biodiversity in such forests are few and far between.

Tropical forests worldwide have been prone to fragmentation and conversion into human-modified landscapes. Since 1990, about 178 million ha of forests are lost worldwide (FAO, 2020) at alarming rates each year. One of the major altered land-use types in the world is the agricultural plantations with cash crops. Plantations are mostly monocultures as they provide higher yields, improved stem quality and facilitate management interventions (Kelty, 2006). They, however, lead to habitat degradation, loss of biodiversity, a shift in soil quality and increase in greenhouse gas emissions (Foley *et al.*, 2011).

Considering this context, the present study is broadly aimed at studying the variation in the insectivore bird communities in monoculture crop plantations of mango and cashew, as compared to primary forests in sacred groves and secondary forests in private lands in the Konkan region of Maharashtra and assessing the factors influencing the insectivore bird community structure and composition.

1.2. OBJECTIVES

1) To study how monoculture plantations, serve as secondary habitats for sustaining the insectivorous bird communities of surrounding forests.
2) To identify the determinants of community structure and composition of insectivorous birds in a mixed landscape.

Research Questions

1) How do the composition and structure of insectivorous bird communities differ across primary forests, secondary forests and monoculture plantation crops?
    a) How similar is the composition of insectivorous birds across land-use types?
    b) How does the diversity of various insectivorous guilds vary between plantations and forest patches?
2) Which are the key habitat parameters that determine the structure and composition of insectivorous birds across a land-use gradient from forests to plantation crops?
3) How insect diversity and biomass affect the spatial organization of insectivorous bird communities across the land-use gradient?

1.3. LITERATURE REVIEW

1.3.1. Community Ecology: Patterns and Processes

Community ecology is a study of patterns of natural assemblages of species and finding out the processes that underly the observed patterns. Palmer (1994) has enlisted 120 hypotheses explaining the patterns of variation in species richness. The main four processes, however, operating in a community can be classified into four broad categories: selection, speciation, drift and dispersal (Vellend, 2010). Predictions of such processes are important and also has implications for conservation.

1.3.2. Choice of Taxa

In ecological studies, indicator taxa are used as representatives to explain processes underlying the observed patterns. Although birds are not the best indicator taxa, they are favoured due to easy detection and identification (Carignan & Villard, 2001). Birds are also

said to respond to environmental changes over many spatial scales (Carignan and Villard, 2001). Even among birds, the most abundant guild present in the tropical forests is of insectivorous birds as insects predominate the world's biodiversity.

1.3.3. Birds in sacred groves

The sacred groves represent a relict and climax vegetation community prominently distinct from that of the surrounding regions (Gadgil & Vartak, 1976) and are also described as bird refuges (Debal *et al.*, 1997).

A comparative study between sacred groves, young secondary forest, annual cultures and woodland savannah conducted in the Eastern Guinea-Bissau riparian forest found that the wooded savannas and annual cultures had greater species richness than the secondary forests and the sacred groves. However, the sacred groves were characterized by a high proportion of forest specialists and insectivorous birds (Kühnert *et al.*, 2019). A similar study carried out in the Abiriw Sacred Grove in East Ghana also showed that forest specialists were more abundant in the sacred groves (Kangah-Kesse *et al.*, 2007).

The sacred forests of northwest Yunnan China had a distinct avifaunal community composition than the surrounding matrix and had higher species richness at plot, patch and landscape scales. Habitat covariates characterizing old-growth such as 'plots with largest diameter trees' and 'native bamboo groves' influenced the bird community composition. Furthermore, there was significant growth in the use of the sacred groves during a drought year as compared to the preceding years (Brandt *et al.*, 2013). This study highlights the importance of sacred groves as refuges and emphasizes the need to protect forests with old-growth characteristics.

Birds in sacred groves in India are relatively less studied and documented. Most of the available literature are in the form of simple checklists or descriptive statistics (Debal *et al.*, 1997; Kushalappa & Bhagwat, 2001; Chandrashekara, 2011; Bhakat, 2015; Katuwal *et al.*, 2016).

Patil *et al.* (2015) conducted a study considering birds, butterflies and spiders as indicator taxa and recorded the diagnostic species of each of the taxa in select sacred groves in south-western Maharashtra. Diversity indices for the taxa and threat index were estimated for each

of the selected sacred groves. In a study involving 15 sacred groves in Kerala, canopy insectivore guild (23%) was the predominant group followed by frugivores (21%); tree density and altitude were found to be positively correlated with forest bird abundance (Mandan & Nameer, 2015). Joshi and Sarnaik (2014) documented 101 species from 19 sacred groves in the Sangameshwar Taluk in Maharashtra; insectivorous (40.59%) and middle-canopy nesters (31.68%) were the predominant guilds observed in their study.

1.3.4. Bird communities of secondary forests

There have been very few studies on the avifauna of the secondary forests. In a review of 18 studies (Barlow *et al.*, 2007), it was found that only 11 studies had primary forests as control sites. Most of the studies, which compared primary and secondary forests, found no significant difference in bird species richness (Andrade &Rubio-Torgler, 1994, Lawton *et al.*, 1998; Borges, 2007; Schulze *et al.*, 2004; Waltert *et al.*, 2004; Sodhi *et al.*, 2005), and a few recorded lower species richness in the secondary forests (Terborgh & Weske, 1969; Bowman *et al.*, 1990; Raman *et al.*, 1998; Barlow *et al.*, 2007). Interestingly, some studies documented lower species richness in primary forests than secondary vegetation (Johns, 1991; Blake & Loiselle, 2001). In all the studies, the older secondary forests were more similar in species composition to the primary forests. In another study in the *jhum* cultivations of Mizoram in north-east India, bird species diversity, richness and abundance recovered in parallel with vegetation recovery. The bird community composition of the primary forest was similar to the *jhum* cultivations having a large fallow period (Raman *et al.*, 1998).

A meta-analysis (Dunn, 2004) showed that a fallow period of 20-40 years is required for animal taxa in secondary forests to recover to a species richness similar to that of the primary forest. The recovery of original species composition, however, requires a substantially longer period.

1.3.5. Bird Communities of Plantations

Plantations over the world cover about 131 million ha, which is 3% of the global forest area and 45% of the total area of planted forests. South America, particularly the area comprising Brazil, Uruguay, Chile and Argentina has the largest area under plantations, and Europe has the lowest (FAO, 2020). Some of the major large-scale plantations around the world include

the Oil Palm plantations mainly in Indonesia (Austin *et al.* 2019) and Malaysia (FAO, 2020), Rubber and Cocoa in Africa, and Pine and Eucalyptus in Brazil, Argentina, Chile, Ecuador and Uruguay. The history of forest conversion to plantations in the Western Ghats dates back to early 19th Century when large tracts of forests were converted into plantations of teak, tea, coffee, eucalyptus and wattle. In the northern Western Ghats, since the 1990s, large areas were brought under mango and cashew cultivation owing to the various schemes of the government.

Coffee plantations have been extensively studied especially in neotropics with respect to their role in sustaining biodiversity. The intensity of management in the plantations determines their effectiveness in conservation. It is widely established that the traditional shade-coffee plantations with native tree cover hold higher avifaunal diversity than the open- canopy sun coffee plantations (Moguel & Toledo, 1999; Komar, 2006; Philpott *et al.*, 2008). A review of the studies in coffee plantations in the Neotropics showed that shade coffee plantations supported higher number of IUCN's threatened taxa and CITES-listed species than the intensively managed sun coffee plantations (Dietsch, 2000). Ranganathan *et al.* (2010) compared the avifauna of the areca and coffee plantations in the Western Ghats and found that the areca plantations were better in retaining the bird species composition of the regional forests than the coffee plantations.

A comparison between rubber tree plantations, oil palm plantations and open areas in Peninsular Malaysia, revealed that the avifaunal richness and abundance were more in rubber plantations and open habitats (Peh *et al.*, 2006). Sheldon *et al.* (2010) conducted a spatio-temporal study in Borneo comparing bird richness between various exotic plantations and a logged native forest between a time interval of 23 years. They found that bird species richness did not change significantly between years in all the land use types; *Albizzia* plantations were the most species-rich followed by *Acacia mangium,* and Oil Palm plantations recorded the lowest species richness.

1.3.6. Structure of Bird Communities in Forests vs Plantations

It has been widely documented that plantations hold less avifaunal richness than the natural forests (Carlson, 1986; Beehler *et al.*, 1987; Kunte *et al.*, 1999; Petit *et al.*, 1999). However, in some cases, species richness is also observed to be similar to natural forests (Durran & Kattan,

2005; Soh *et al.*, 2006). Widespread and generalist species predominate the bird communities of the plantations while the forest specialist species are under-represented (Danielsen &Heegaard, 1995; Peh *et al.*, 2006, Sheldon *et al.*, 2010; Azhar *et al.*, 2011).

With regard to the guild composition of species, the insectivorous guild is more sensitive to human disturbances than any other guild (Shahabuddin & Kumar, 2006; Najera & Simonetti, 2010). The species richness of insectivorous birds in Amazonia was found to decrease with an increasing gradient of human impact unlike that of frugivorous and omnivorous birds (Canaday, 1996). Studies comparing bird communities in natural forests and plantations like shade coffee (Tejeda-Cruz & Sutherland, 2004), oil palm, and rubber (Aratrakorn *et al.*, 2006) show that the insectivorous bird species are less represented in plantations than in the natural forests.

Three hypotheses have been proposed to explain this pattern. Firstly, forest conversion creates open spaces with less moisture leading to a reduction in insect abundance and diversity. This reduction creates a food scarcity for the insectivorous birds, thereby reducing their numbers. Secondly, insectivorous species have evolved highly specialized structural and functional niches owing to high selection pressures for efficient detection and foraging of insect prey. Lastly, due to the altered habitat conditions, the activity patterns of mixed-species insectivorous bird flocks in tropical forests undergo drastic changes often resulting in disintegration of their group structure (Canaday, 1996).

With respect to foraging strata, undergrowth foragers are less represented in shade coffee plantations than natural forests because the undergrowth is completely transformed, and overstorey foragers are relatively less affected as there is native canopy cover available (Terborgh & Weske 1969; Roberts *et al.*, 2000; Strong, 2000).

1.3.7. Habitat Use in bird communities

Bird-habitat association studies form an important component in community ecology and can be used to determine the responses of birds to habitat alteration (MacNally & Bennet, 1997). Bird communities are majorly influenced by three types of variables-geographical, structural and floristic. Lee and Marsden (2008) tested the significance of these categories in determining the bird community distributions. It was established that geographical variables

were the most powerful among these three factors, followed by floristic and structural. However, it has been demonstrated that on a regional scale, the bird communities are influenced by forest structure and on a local scale by floristics (Wiens & Rotenberry, 1981; Jayapal *et al.*, 2009). In a mosaic of land uses including shade-coffee, cardamom plantations and tropical rainforest fragments in the Valparai plateau, it was found that vegetation structure had the strongest influence on bird species richness and density, while the bird community composition was influenced by floristics (Raman, 2006).

Within vegetation structure, Percent tree cover and tree species richness were found to positively affect the bird species richness in different agroforestry systems in Karnataka (Karanth *et al.*, 2016).

Understorey vegetation is also important in determining the bird community composition particularly of insectivorous birds (Aratrakorn *et al.*, 2006). In an experimental study, which involved the removal of understorey vegetation in oil palm plantations in Eastern Guatemala, bird richness and abundance were found to be much less in the plots where the understorey was removed (Najera and Simonetti 2010). The understorey weeding regime was found to affect the community composition of birds in shaded cash crops and exotic tree plantations in southwest Ghana; with long periods between understorey weeding being the most suitable for forest specialists (Holbech, 2009).

Similar studies in the Western Ghats have also highlighted the importance of vegetation structure in determining the avifaunal composition (Ranganathan *et al.*, 2008; Sidhu *et al.*, 2010). Besides, other parameters like plantation age, arthropod abundance and proximity to the forest also affect the avifaunal composition (Mitra & Sheldon, 1993, Zhang *et al.*, 2017).

The choice of metrics used in comparing bird communities of different land-use types seems to be important as statistical properties of each index are known to influence the observed patterns. In a study conducted across different land cover types in the Western Ghats, although the bird species diversity was found to be greater in human-modified vegetation types than the natural forests, there was a gradual displacement of bird species composition from typical forest species to urban and ruderal habitat taxa (Daniels *et al.*, 1990). Hence, bird species composition rather than plain diversity indices of no dimensions is perhaps the best descriptor of a community.

Such comparison studies in India are mostly restricted to the southern Western Ghats where comparisons are made between the natural forests and plantations like shade-coffee, Acacia, Eucalyptus, Tea, Teak, Arecanut, cardamom, etc. The northern part of the Western Ghats is relatively less explored in this context (Bhuvad *et al.*, 2011; Patil, 2016).

2. STUDY AREA

2.1. KONKAN LANDSCAPE

The northern part of the Western Ghats along with the adjacent coastal plains in the state of Maharashtra constitutes the Konkan region. It covers a total geographical area of 30,728 sq. km. comprising Palghar, Thane, Mumbai, Navi Mumbai, Raigad, Ratnagiri, and Sindhudurg districts. The altitude ranges from mean sea level to about 1200 m. This region is generally divided into north and south Konkan. The south Konkan contains the districts of Ratnagiri and Sindhudurg. According to the physiography, south Konkan can be broadly divided into three regions- The Sahyadri ranges, the low-level lateritic plateaux, and the coastal plains (Kale *et al.*, 2016). Rivers like Savitri, Vashishti, Amba, Jagbudi, Shastri, Ratnagiri, Jaitapur, Muchkundi, Vaghotan, Devgad, Karli, Tillari, Terekhol, and Jog originate in the Sahyadri mountains and debouch into the Arabian Sea.

This area is characterized by a typically tropical climate with mild winters and humid summers and a temperature range between 7 and 38^{o}C. The rainfall is very heavy (exceeding 4000 mm in some places) and is received mostly through the south-west monsoon during the months of June to September.

2.2. LAND USE PATTERN

The land use in this region is a mosaic of forests, agricultural land, crop plantations, private forests, sacred groves, and mangroves. The major forest types in this region according to the Champion and Seth classification (1968) are Southern Tropical Semi-Evergreen Forests, Southern Tropical Moist Deciduous Forests, Southern Tropical Dry Deciduous Forests, and Littoral and Swamps. These forest types are highly fragmented and are present in patches in the form of sacred groves, reserve forests and private forests. Private forests are overgrown secondary forests on private land. The private forests were acquired by the Forest Department under the Maharashtra Private Forest Acquisition Act, 1975. This act was later amended in 1978 whereby areas above 12 ha were retained by the Forest Department and rest were returned to the owners. There are nine Protected Areas in the Konkan region constituting a very minor proportion of the total area. Maharashtra has about 2800 sacred groves and most of them are present in the Konkan region (Datar, 2014). Sindhudurg district

has the greatest number of sacred groves followed by Ratnagiri. Agriculture is the main occupation of the people in south Konkan, comprising 43.05 % of the working population. Rice and finger millet are the two main agricultural crops grown extensively in the Konkan region. The crop plantations of mango and cashew have replaced the natural forests and grasslands on plateaus over the last three decades (Patil, 2016). Coconut and areca nut plantations are found extensively near the coastal areas. Fishing is the major livelihood for people living along the Konkan coast.

2.3. HISTORY OF LAND USE CHANGES

The history of forest conversion in the northern Western Ghats is fairly recent in comparison to the southern Western Ghats. Several policies of the government, however, accelerated the process of cultivation during the end of the 20th Century. Mango and Cashew are the major plantation crops grown in the Konkan region, along with coconut and areca nut.

It is widely believed that mango originated in the South Asian region, though exact place of origin is still being debated. Mango is known to have been cultivated in India even around 2000 BC and is therefore deeply embedded in the Indian culture; references for mango and its cultivation can be found in the Ain-i-Akbari written in the 16th century (Mukherjee, 1953). The total area under mango cultivation in India is 22,93,000 ha (DES, 2019) and Maharashtra ranks 4th in the total area under mango cultivation in India, covering an area of 1,66,760 ha (7%). In Maharashtra, the Ratnagiri district has the highest area under mango cultivation (60,050 ha). Also known as the 'King of Fruits', a wide number of varieties have been introduced among which the Alphonso variety is quite famous in the Konkan region.

Cashew, which is a tree native to Brazil, was first introduced in India in the 16th century by the Portuguese sailors who arrived at the Malabar Coast. From the Malabar coast, it spread to the entire country (Agnolioni and Guilians, 1977). Presently, an area of 11,05,370 ha is under cashew cultivation in India, out of which 1,91,450 ha (17.32%) is present in Maharashtra, which is next only to Odisha that has 18.58% area under cashew plantation.

In Maharashtra, Ratnagiri and Sindhudurg are the leading districts in cashew production. During the early 1960s, the Department of Soil and Water Conservation, Maharashtra,

promoted cashew plantation for the conservation of soil on hill slopes by distributing seedlings and providing subsidies to the planters. Subsequently, the soil and water conservation department along with the Department of Agriculture, proposed a joint scheme for the development of horticulture along with soil conservation further increasing the area under cashew plantations. In 1990-91, the government of Maharashtra formulated the Employment Generation Scheme (EGS), which was linked with the horticulture development programme, in which small and marginal farmers were encouraged to grow fruit orchards by providing free inputs and a remuneration to cover the labour costs (Patil *et al*., 2016). As a result of this scheme, a large area was brought under mango and cashew cultivation in the Konkan region of Maharashtra.

2.4. INTENSIVE STUDY AREA: DAPOLI TALUK

The study was conducted in Dapoli (17°34' to 17°56'; 73°03' to73°20'), a coastal taluk in the Ratnagiri district of Konkan region (Fig 1). The geographical area of the taluk is 846 km^2 comprising a population of 1.9 lakh people residing in 176 villages (2001 Census). Each village is further divided into many hamlets locally known as *wadis.*

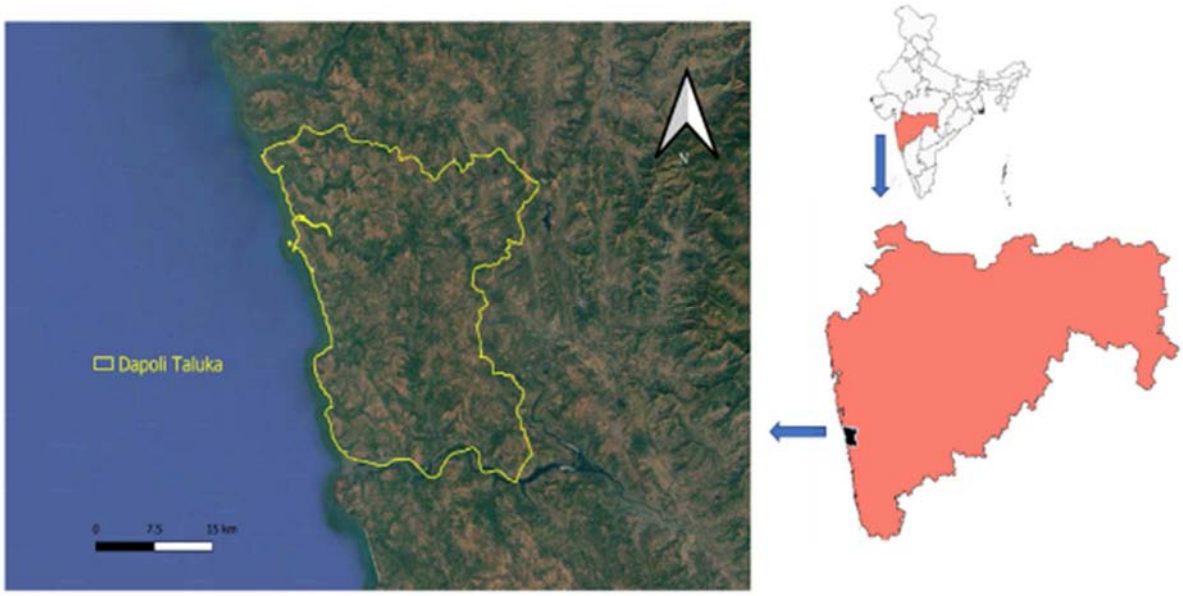


Figure 1: Map of the Study Area, showing the location of Dapoli Taluk.

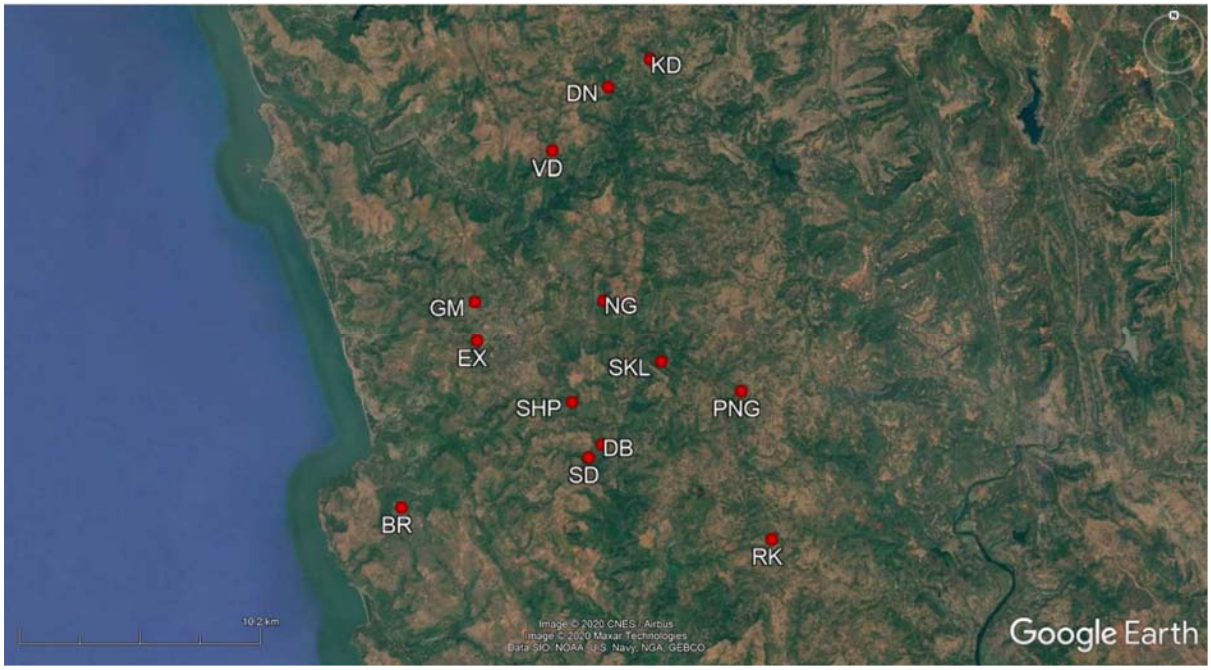


Figure 2: Locations of all the sampling sites in Dapoli Taluk. Mango Plantations (GM-Gimhavane, Ex- Mango Excellence Centre, BR- Burondi, PNG- Pangari); Cashew (RK- Rukhi, VD- Vaidya, Sakurde Village, DB- Dabre, Shirde Village); Sacred Groves (DN- Dhankoli, KD- Kudawale, SD- Sadavali); Private Forests (SKL- Sakhloli, SHP- Shirde, NG- Nargoli).

Apart from agriculture and fisheries, tourism is fast emerging as alternate economic activity in Dapoli, as the taluk is well endowed with numerous beaches, historic temples, caves and a pleasant climate. Dr Balasaheb Sawant Konkan Krishi Vidyapeeth (DBSKKV), an agricultural university is situated in Dapoli and covers an extensive area of cultivation of field crops and plantations. Some of the plantations of the university were sampled in this study. The landscape of Dapoli consists of forests, laterite plateaus, plantations and agricultural patches.

For the present study, the following four land-use types were sampled:

Sacred Groves

Ratnagiri stands second in the number of sacred groves in Maharashtra after the Sindhudurg district with more than 800 sacred groves. A detailed inventory of sacred groves in Dapoli taluk conducted by Patil (2016), documented 102 of them. Gawade *et al.* (2018) mapped 11 sacred groves in Dapoli taluk to study the change in areas of the groves over years and found

that most of the sacred groves had retained their forest cover but the quality of the forests had since been significantly degraded. The most common and predominant threat to the sacred groves is erosion of traditional values and belief system among the local communities followed by the removal of biomass and modernization (Patil 2016).

Three sacred groves were selected for the present study namely- Dhankoli, Kudawale and Sadavali with areas of 9.4 ha, 40.4 ha and 14.3 ha respectively. All the sacred groves had perennial water streams within the forest or in the vicinity. Kudawale had a direct tar road access, whereas Dhankoli and Burondi were slightly isolated. The main festivals celebrated by the villagers include Holi (*shimga),* Navratri, Diwali and an annual fare (*jatra).* During such festivals, the villages gather near the forest and perform religious rites including animal sacrifice, and a range of local cultural. Grazing, logging, firewood and litter collection is prohibited in these sacred groves. However, collection of plants for medicinal purposes and for offerings to the temple deity is allowed (Ghalame, 2012).

Private Forests

Ratnagiri district has the highest area under private forests in Maharashtra. Such forests are generally found on the hill slopes and are prone to erosion (Burondkar *et al.,* 2018). They are under the threat of conversion into resorts, farmhouses, and plantations like coconut, rubber, and banana. There is no formal documentation of the biodiversity of these forests.

Three Private forest patches were selected for sampling found in the villages of Sakhloli, Nargoli and Shirde. Sakhloli is a large contiguous patch of forest (56.4 ha) between the state highway 104 joining the Khed and Dapoli taluks and an inner access road to the Sakhloli village. The patch contains numerous plant nurseries in between and very little settlements. Deforestation was prevalent in the patch during the study period. The patch has a sloping topography, with a hill on one side showing evidences of terrace farming. Shirde private forest is a rectangular patch of 15.4 ha area adjoining a small road, with very less traffic. This patch is surrounded by plantations of mango and cashew. Evidences of previous plantations of mango and cashew were visible in this forest indicating that this private forest is relatively of recent origin. Exotic trees like *Acacia auriculiformis* were also observed. The topography is slightly slopy, with evidences of terrace farming on the slopes. Nargoli is a large (87.3 ha), completely isolated patch of forest lying in the slopes and valley of two hills. The plateau part

on one of the hills has two operating laterite quarrying mines. The access to the patch is by a mud road created by the mine workers. The sloping part of the hills show evidences of terrace farming prevalent earlier in the area. A seasonal stream flows in the valley throughout the length of the patch.

Mango Plantations

Konkan region provides optimum conditions for the growth of the 'Alphonso' variety of mango, which fetches high price in international market and is largely exported overseas. As a result, many private forests have since been converted into mango orchards in the last few decades. These plantations which are raised from grafts are intensively managed.

Four mango plantations were selected for the present study namely- Burondi, Pangari, Gimhavane and Mango Excellence Centre. Burondi is a privately-owned orchard located on a flat laterite plateau. It is an even-aged plantation with trees show stunted growth due to the absence of deep soil. Pangari is a plantation managed by DBSKKV having an area of 97.6 ha. It is an uneven-aged plantation with wide variations in growth patterns observed in the trees. Gimhavane and Mango Excellence Centre (MEC) are two small plantations 5 ha and 8.5 ha respectively managed by the university. Gimhavane is an even-aged plantations whereas MEC is an uneven aged plantation. Both the plantations are in the vicinity of the town and are surrounded by settlements and built-up areas. All the plantations are very intensively managed and yield large amounts of produce.

Cashew Plantations

It is estimated that the Konkan region of Maharashtra exports about 15% of India's cashew export worth Rs 370 crores annually. These plantations are also raised from grafts and are characterized by a relatively open canopy, profuse branching, low tree height, heavy and slowly decomposing leaf litter, and very sparse undergrowth.

Three cashew plantations were selected for the purpose of this study present in the villages of Shirde, Rukhi and Sakurde. The plantation in Shirde village covers an area of 12 ha and is present on a hill slope. The plantation is very compactly spaced and contains patches of similar ages. It is surrounded by other plantations and private forests. Sakurde is a privately-owned small cashew plantation of 3 ha area located on a steep hill slope. It is relatively less

intensively managed and also contains some undergrowth. Rukhi is a large plantation (34 ha) intensively managed by the university and is surrounded by other plantations.

(a)

(b)

(c)

(d)

Plate 1: Sacred Groves In Dapoli Taluk. (a), (b) An old *Somaya* Temple at Dhankoli Sacred Grove; (c) Land cleared near the new renovated temple; (d) Interiors of the new temple.

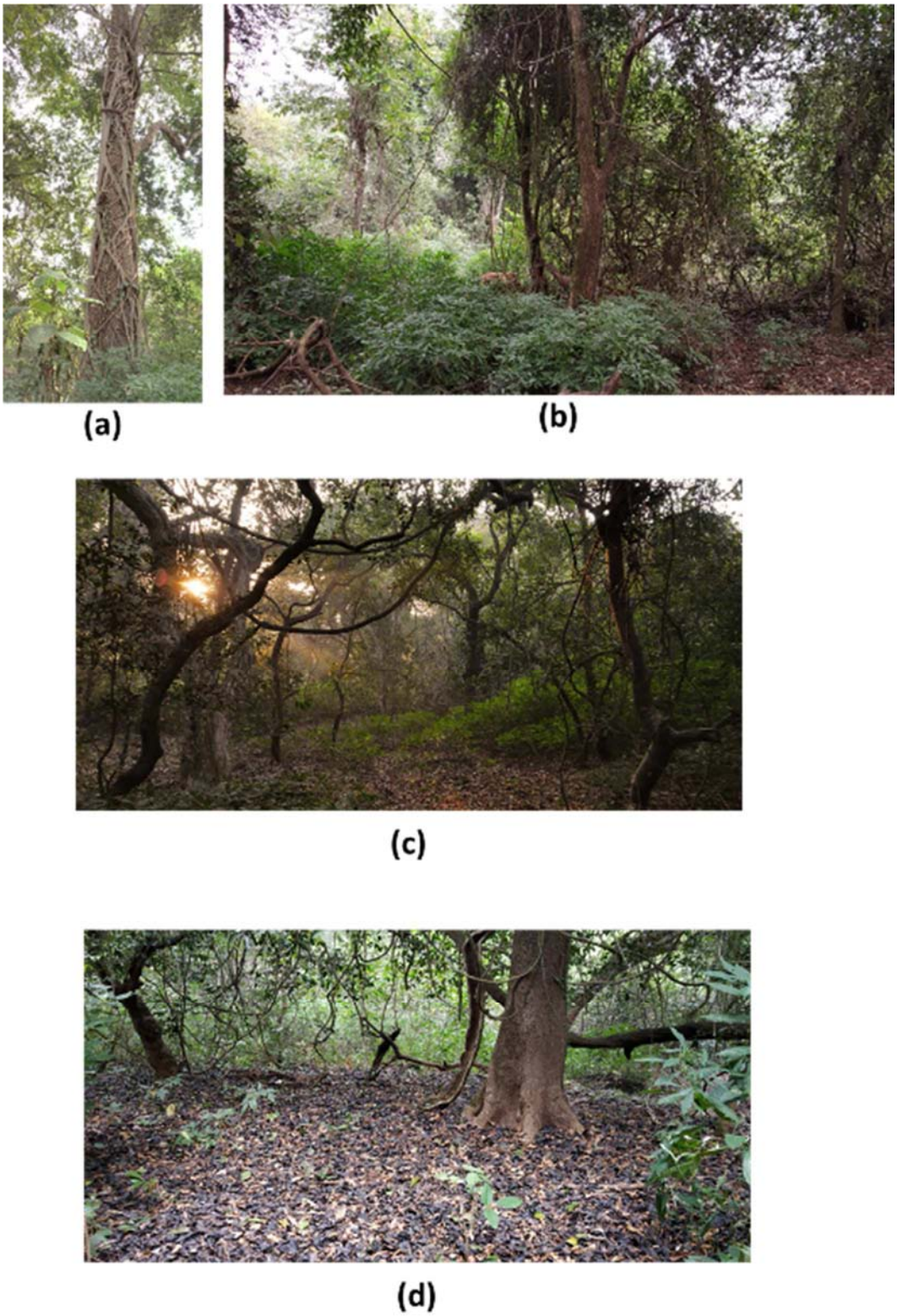


Plate 2: Vegetation characteristics of Sacred Groves in Dapoli Taluk (a) Tall trees; (b) Dense undergrowth, (c) High structural complexity, (d) Heavy leaf litter.

(a)

(b)

Plate 3: Vegetation characteristics of Cashew Plantations in Dapoli Taluk (a) less amount of leaf litter, (b) High Density of plantatio

(a)

(b)

Plate 4: Private Forests in Dapoli Taluk. (a) A typical scenario in the Konkan region, where only a small proportion of land owned is actually cultivated and the remaining area is an overgrown forest. (b) Complex vegetation structure in a Private Forest.

(a)

(b)

Plate 5- Mango Plantations in Dapoli Taluk. (a) Pangari mango plantation covering an extensive area. (b) Wide spacing between trees.

3. METHODS

3.1. STUDY DESIGN

Sampling for birds, vegetation and arthropods was done in each of the four land-use patterns viz: sacred groves, private forests, mango plantations and cashew plantations. In total, 13 sites were chosen for the study and among them, mango plantations were represented by four sites and other land use types by three each. A total of 60 sampling points were selected in these 13 sites with each site represented by 3 to 7 points. A distance of at least 200m was maintained between two points to avoid double counting of birds. Each point was replicated at least twice and some were replicated thrice for bird sampling, while vegetation and arthropod sampling was done only once. The area of each plot was estimated along with the distance from the nearest forest area.

3.2. BIRDS

Birds were surveyed using variable-width point count method as the sampling sites were not large enough for line transect surveys. Besides, point counts are preferred over line transects in fine-grained habitats and also in studies where identification of habitat determinants of bird communities is the primary objective (Bibby *et al.* 2000). Sampling was done in the mornings during 6:30-9:30 hours and the duration of each point count was set to 15 minutes. Bird sightings as well as calls were recorded and identified up to species level using standard field guides (Grimmett *et al.*, 2014). The approximate distance of birds from the centre of the point was estimated and noted for each record. Birds in flight above the canopy layer were not included in the analysis.

3.3. VEGETATION

The vegetation sampling protocol is shown in Figure 3. Around each point count, a 10m radius vegetation plot for quantification of trees and 5 m radius plot within the larger plot for shrub density estimation were laid. Five 1x1 m quadrats were laid for ground cover estimation at four ends and centre of the 5m radius plots. The following vegetation parameters were measured:

- Tree abundance & density: Total number of trees was counted in each vegetation plot and their density estimated. Any woody plant with a height of >2m and a girth of >30cm at breast height was considered a tree in the study.
- GBH: Girth at breast height was measured for each tree as defined above. In case of multiple branching at a lower level, an average was computed.
- Height of tree canopy: The height of the top canopy was estimated in an ocular manner.
- Canopy cover: Canopy cover was estimated at five points using a spherical densiometer and expressed as mean percentage.
- Litter depth: Litter depth was measured by using a calibrated probe in five random points within each plot.
- Shrub density: Plants with a height between 0.5 m to 2m were considered as shrubs and their abundance and density were quantified. In addition, the average height of each shrub species was also measured.
- Ground cover: The ground cover was estimated in five 1x1 m quadrats and the percentage of each element (herb, grass, litter, bare soil, rock) was noted through visual estimation.

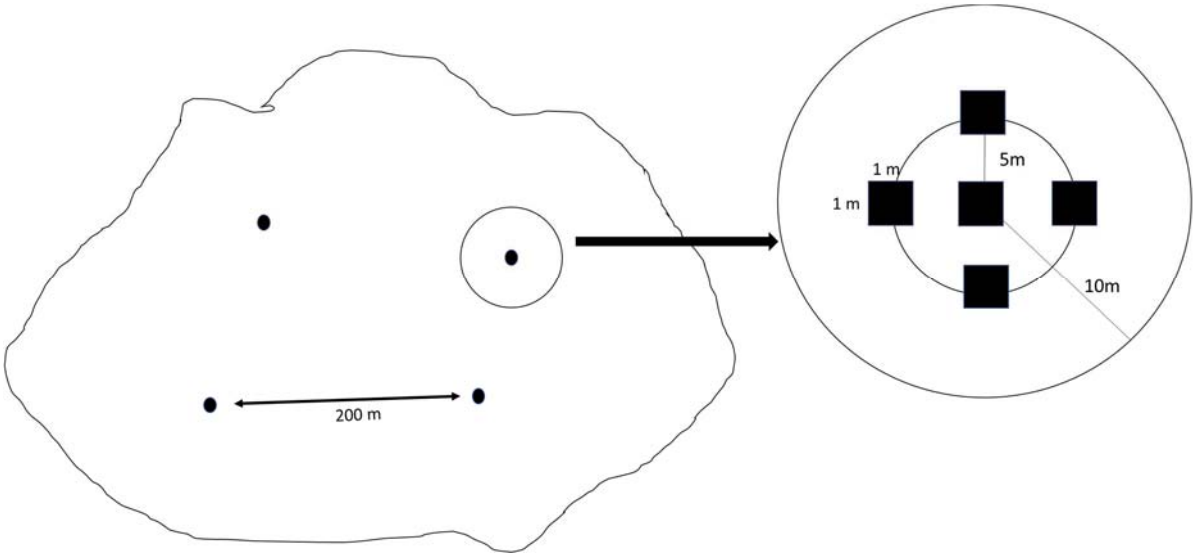


Fig 3 Diagram showing the vegetation sampling protocol as adopted in the present study.

3.4. ARTHROPODS

This being a correlational study, the sole purpose of arthropod sampling was to get an overall indication of the arthropod biomass available in the given habitat irrespective of their actual status as prey to insectivorous birds and to identify whether there is any relation between

the arthropod biomass and community composition of insectivorous birds. Accordingly, arthropod sampling was carried out using two methods- vegetation beating and litter sorting at each point (Leather, 2008). In the vegetation beating method, an inverted umbrella was kept under the branches which were tapped vigorously with a uniform stick. The dislodged arthropods, were collected in vials. In the litter sorting method, the leaf litter including dead leaves, soil, humus and debris was hand collected and kept on a white sheet. This collected litter was then searched for arthropods which were collected in vials. Both the sampling methods were time-constrained with 10 minutes spent for each method in each vegetation plot. The biomass of insects was measured in the field with a portable weighing balance (accuracy- 0.001g).

3.5. DATA ANALYSIS

3.5.1. Guild Classification

The birds were categorized into foraging guilds as insectivores, omnivores, nectarivores, carnivores, frugivores and granivores based on the predominance of food types consumed. The insectivorous birds were further classified into two sub-guilds based on foraging substrate and foraging behavior for the guild composition analysis in the following manner:

Table 1: Description of different categories of insectivore sub-guild based on foraging substrate in Dapoli, Maharashtra.

Foraging Strata	Description	Examples
Ground	Ground Foraging (both in open and on forest floor)	Black Redstart and Puff-throated Babbler
Understorey	Primary confined to undergrowth and shrub layer	Common Tailorbird and White-rumped Shama
Middle Canopy	Foraging on the lower branches and short-heighted trees.	Black-naped Monarch and Tickell's Blue Flycatcher
Canopy	Foraging on the top canopy	Ashy Drongo and Common Iora
Trunk	Feeding on arthropods on or inside the tree trunk	Rufous Woodpecker, and Black-rumped Flameback
All Storey	Foraging in all the strata	Blyth's Reed Warbler and Grey-headed Canary Flycatcher.

Table 2: Description of different categories of insectivore sub-guild based on foraging behaviour in Dapoli, Maharashtra.

Foraging Behaviour	Description	Examples
Gleaning	Actively searching and picking arthropods from the vegetation	Brown-cheeked Fulvetta and Common Woodshrike
Air Sallying	Catching prey in the air and returning to a perch for feeding	Green Bee-eater and Indian Paradise Flycatcher
Ground Sallying	Making swift flights to catch prey on the ground and returning to a perch for feeding	Malabar Whistling Thrush and Black Redstart
Litter Probing	Actively probing the litter for arthropods.	Indian Blackbird and Indian Scimitar Babbler
Pecking	Creating a crevice in the trunk and foraging for arthropods within.	Rufous Woodpecker, and Black-rumped Flameback

3.5.2. Diversity Descriptors

If relative abundance is dominated by a few species in a community, then there is a possibility that the richness is underestimated. Also, due to variation in detectability of different species, rare species are usually missed which may generate error. In less species rich habitats such as temperate regions, it may be possible to record the absolute species richness. But in the case of birds in the tropical region, recording absolute richness is difficult (Magurran, 2013). Hence, species richness estimators are used in ecological studies. Accordingly, the Chao-1 (Colwell & Coddington, 1994) estimator was used in this study. It is calculated as follows:

$S_{chao\ 1} = S_{obs} + (F_1^2 / 2F_2^2)$

Where S_{obs} = the number of species in the sample; F_1 = number of singletons; and F_2 = number of doubletons. Chao-1 estimator is basically, a function of the ratio of singletons to doubletons and generally exceeds the observed species richness. It requires abundance rather than occurrence data for calculation, and hence was used in this study.

An ideal diversity index is the one which is easy to compute and interpret, tolerates extreme values, is interoperable and takes in to account both commonness and rarity. The Simpson's Index fulfils most of these criteria. It is the most meaningful and robust diversity measure (Magurran, 2013). Simpson's D is the probability that two randomly drawn individuals from an infinitely large community are of the same species (Simpson, 1949). It is calculated as:

Simpson Index (D)= $\sum \left(\frac{n_i[n_i-1]}{N[N-1]}\right)$

Where n_i= number of individuals of the *i*th species and N= total number of individuals.

The greater the value of D, the greater is the dominance. It is usually expressed Simpson's (1-D) for species diversity measure. A greater value of the complement index (1-D) implies greater evenness in the assemblage.

In the present study, Simpson's (1-D) index (Magurran, 2013) was calculated for estimating the diversity of birds in each land use type. Chao-1 estimator (Colwell & Coddington, 1994) was used to estimate the bird species richness for each point.

3.5.3. Comparison of insectivorous birds between forests and plantations

Pearson's chi-square test was used to compare the proportions of different insectivorous sub-guilds (based on foraging substrate and foraging behaviour) among the four land cover types. The proportions were transformed to mean relative frequency values for the chi-square analysis (Sokal & Rohlf, 1995).

3.5.4. Nestedness of insectivorous bird assemblages along a land use gradient

Nestedness analysis using NODF measure (Nestedness based on Overlap & Decreasing Fills) (Almeida-Neto *et al.* 2008) was done to test if the insectivore bird communities of the plantations were a subset of the forest bird assemblages. The NODF measure was used as it is found superior to all other measures of nestedness, and it is more apt to test if depauperate assemblages constitute subsets of progressively richer ones along an ecological gradient (Urlich *et al.*, 2009). The statistical significance of NODF is determined by comparing the observed matrix with given number of null models. Though the algorithm with both row and column Marginal Totals fixed in null matrices is theoretically the most robust (Ulrich *et al.* 2009), this is found to be inappropriate for matrices with significant zero cells (see Matthews *et al.* 2015). Therefore, the 'Equiprobable Row and Fixed Column' algorithm was applied in the null models as habitats ("columns") in the study area are not homogeneous and their carrying capacity ('composition function') is limited by their productivity; on the other hand, species numbers ("rows") and their occurrence in sites ('incidence function') are limited more by habitat quality and productivity and much less by any intrinsic demographic factor.

First, all the insectivorous birds were included in the nestedness analysis with respect to a gradient of land use from cashew and mango plantations to private forests and sacred groves. Further, it was tested if niche differentiation was preserved across land use types by independently examining the nestedness of two subguilds of insectivorous birds, viz., one based on their foraging strata and another on their foraging behaviour. All the nestedness analyses and null models were done in R statistical environment using the R Package RInSp (Zaccarelli, 2013).

3.5.5. Correlations of Structure and Composition of Insectivorous Birds

Normality of the data was tested using one-sample Kolmogorov-Smirnov Test. As all the variables did not show a normal distribution, Spearman's rank correlation coefficients were estimated to examine the correlation of the insectivore species richness and diversity with the habitat variables at each sampling point. Correlation analysis was also done between raw species richness, estimated species richness, bird abundance, species diversity and the area of each site to know if there is any relationship between site area and bird diversity.

All the univariate and multivariate analysis was done in PAST (v4.03) (Hammer et. al, 2001) and IBM-SPSS Statistics v.26 (George & Mallary, 2019).

4. RESULTS

4.1. BIRD COMPOSITION AND DIVERSITY

A total of 74 bird species comprising 1561 individuals were recorded during sampling, and among the bird species, 67 were resident and 8 were winter migrants. Blyth's Reed Warbler (*Acrocephalus dumetorum*) was the most abundant bird with 143 individuals, while 11 species including Black Redstart (*Phoenicurus ochruros*), Crested Hawk Eagle (*Nisaetus cirrhatus*), and Malabar Pied Hornbill (*Anthracoceros coronatus*) were represented by just single observations. The observed species richness of birds in sacred groves, private forests, mango plantations and cashew plantations were 51, 51, 42, 32 respectively (Fig 4).

Table 3: Summary of the biological attributes of avifauna in different land cover types in Dapoli, Maharashtra.

Attribute	Cashew Plantations	Mango Plantations	Private Forests	Sacred Groves
Species Richness (Obs)	32	42	51	51
Species Richness (Est)	35.75	53	53.8	70.5
Species Diversity (Simpson 1-D)	0.9391	0.9352	0.9495	0.9547

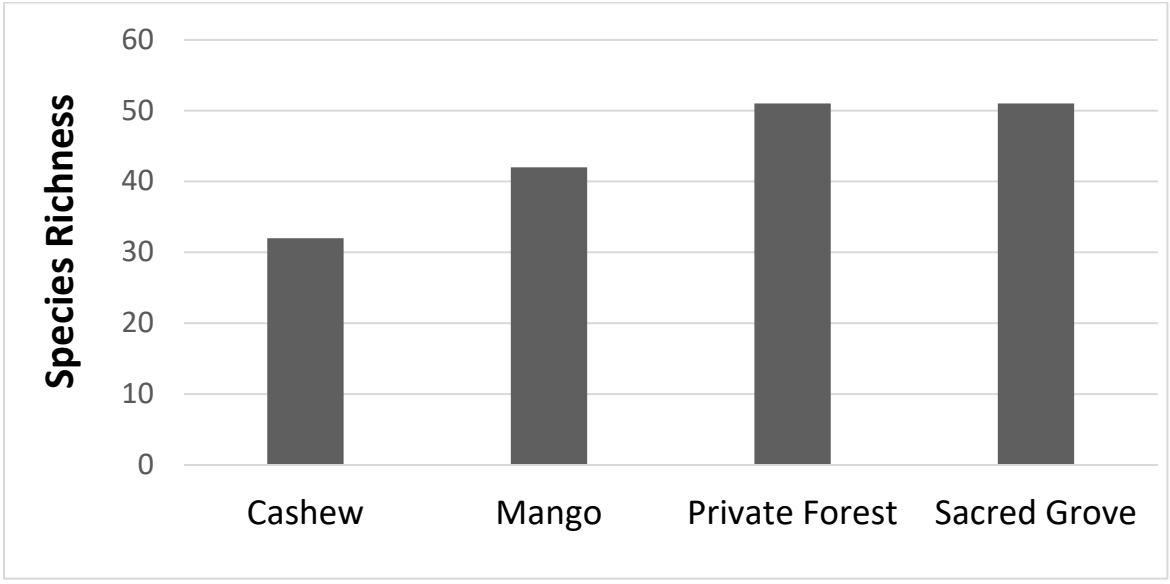


Fig 4: Bar graph representing the observed bird species richness across a range of four land cover patterns (Mango, Cashew Plantations, Private Forests and Sacred Groves) in Dapoli, Maharashtra.

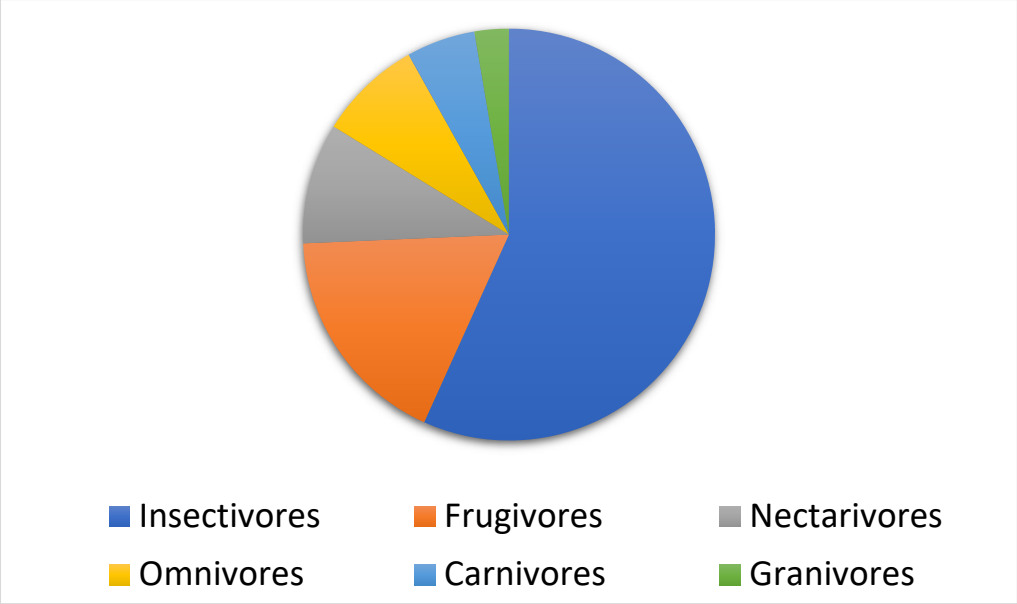


Fig 5: Proportion of foraging guilds of birds in a multi-use landscape in Dapoli, Maharashtra.

Insectivores were the predominant guild with 42 species followed by frugivorous (13), nectarivorous (7), omnivorous (6), carnivorous (4), and granivorous (2) guilds. Figure 5 gives a representation of the proportion of guilds as observed among the birds of the landscape. The species diversity of birds in each guild in all the land cover types is shown in Figure 6.

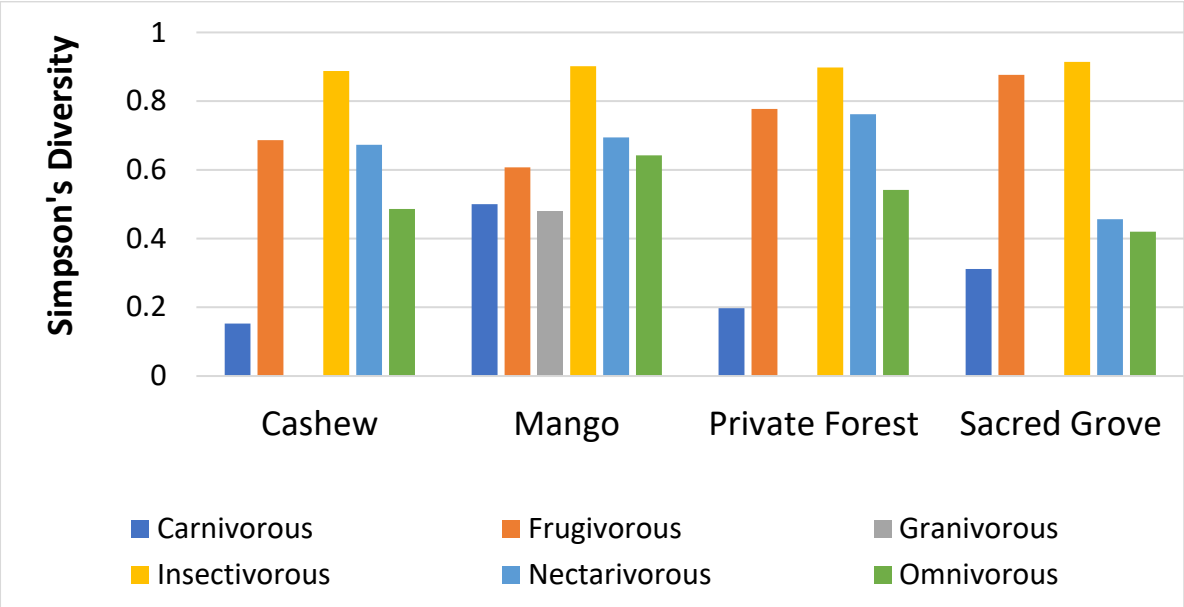


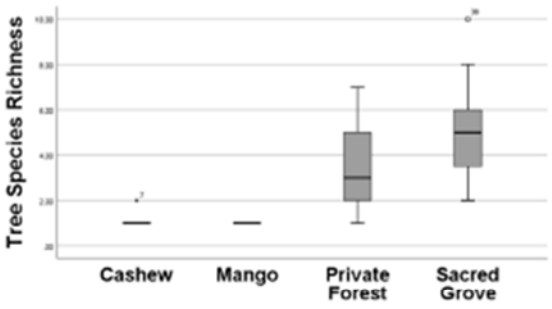
Fig 6: Diversity of birds of different foraging guilds in the four land cover types found in Dapoli, Maharashtra.

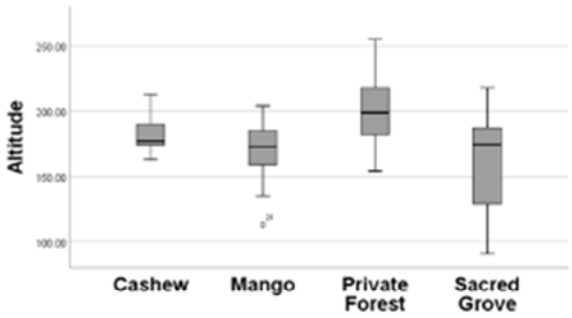
4.2. VEGETATION STRUCTURE & COMPOSITION

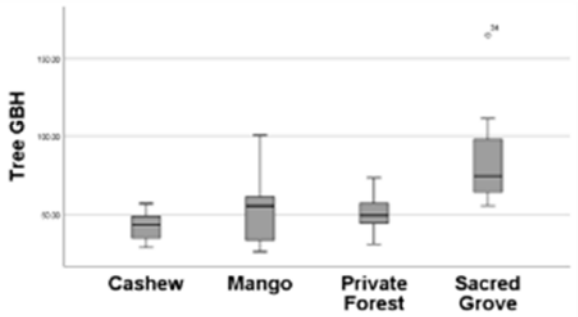
A total of 49 species of trees were recorded from the study area and these include Western Ghats endemics like *Ixora brachiata* and *Terminalia paniculata* and threatened species like *Hydnocarpus pentandrus, Garcinia indica, Calophyllum inophyllum* and *Saraca asoca*. The mango and cashew plantations were entirely monocultures with very little or no understorey vegetation, whereas private forests and sacred groves exhibited prominent vertical stratification. Table 4 summarizes various habitat attributes and their values averaged over each land cover type (also see Figure 7).

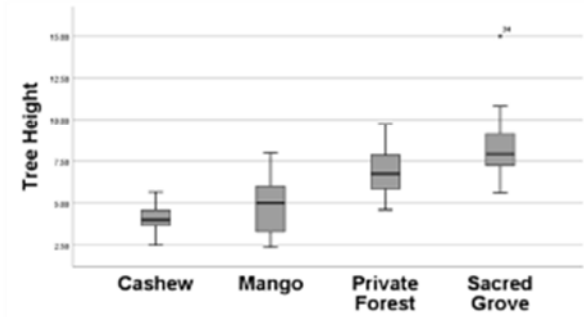
Table 4: List of habitat attributes and their measurements (Mean ± SD) across the four land cover types in Dapoli, Maharashtra.

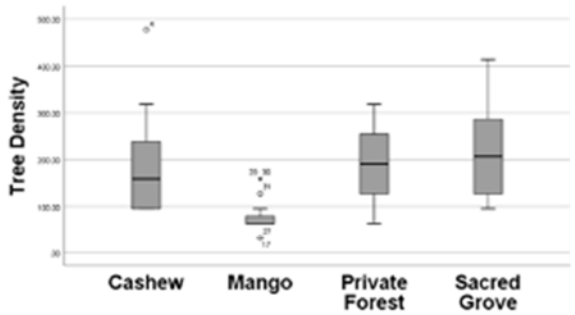
Habitat Attributes	Cashew	Mango	Sacred Grove	Private Forest
Tree Species Richness	1.08 ± 0.29	1	5.08± 2.23	3.53± 2.03
Tree GBH (cm)	52.58± 25.40	52.92± 20.27	85.29± 30.76	49.95±10.95
Tree Height (m)	4.06±0.82	4.68±1.57	8.58±2.41	6.97±1.56
Tree Density (no./ha)	188.42±118.74	77.1±35.71	214.37±104.41	196.7±73.17
Canopy Cover (%)	58.18±28.28	48.59±26.94	93.04±2.98	86.93±6.50
Grass Cover (%)	36±31.80	48.05±27.07	0	0.23±0.97
Herb Cover (%)	3.23±2.45	8.65±12.28	1.63±1.90	7.18±7.64
Soil Cover (%)	6.7±7.54	8.78±8.20	15.8±18.59	14.12±13.82
Rock Cover (%)	30.18±35.26	10.63±15.59	9.92±15.26	17.21±14.70
Litter Cover (%)	23.88± 23.59	23.88±18.22	72.65±19.69	61.23±15.76
Litter Depth (cm)	2.37±0.81	2.46±1.17	4.4±1.67	3.82±1.45
Shrub Species Richness	0.58± 1.16	0.53±0.77	2.75±1.96	3.82±1.81
Shrub Height (m)	0.37±0.57	0.59±0.77	1.39±0.55	1.43±0.42
Shrub Density (no./ha)	106.15±194.59	254.78±470.93	1231.42±733.47	1495.69±610.16

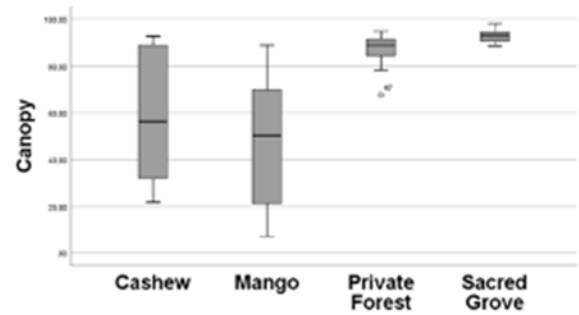

Tree Species Richness
Cashew
Mango
Private Forest
Sacred Grove

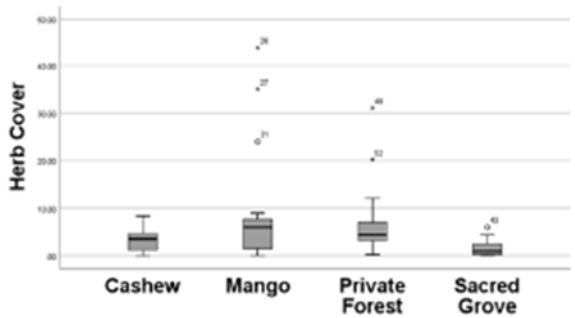

Altitude
Cashew
Mango
Private Forest
Sacred Grove

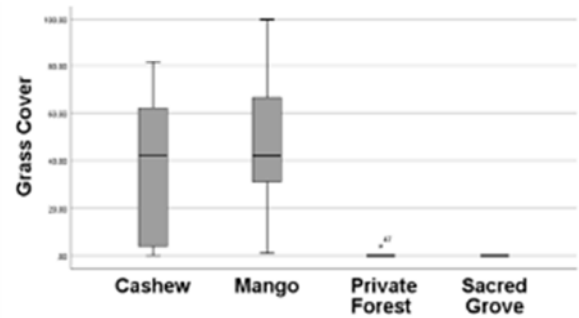

Tree GBH
Cashew
Mango
Private Forest
Sacred Grove


Tree Height
Cashew
Mango
Private Forest
Sacred Grove


Tree Density
Cashew
Mango
Private Forest
Sacred Grove


Canopy
Cashew
Mango
Private Forest
Sacred Grove


Herb Cover
Cashew
Mango
Private Forest
Sacred Grove


Grass Cover
Cashew
Mango
Private Forest
Sacred Grove

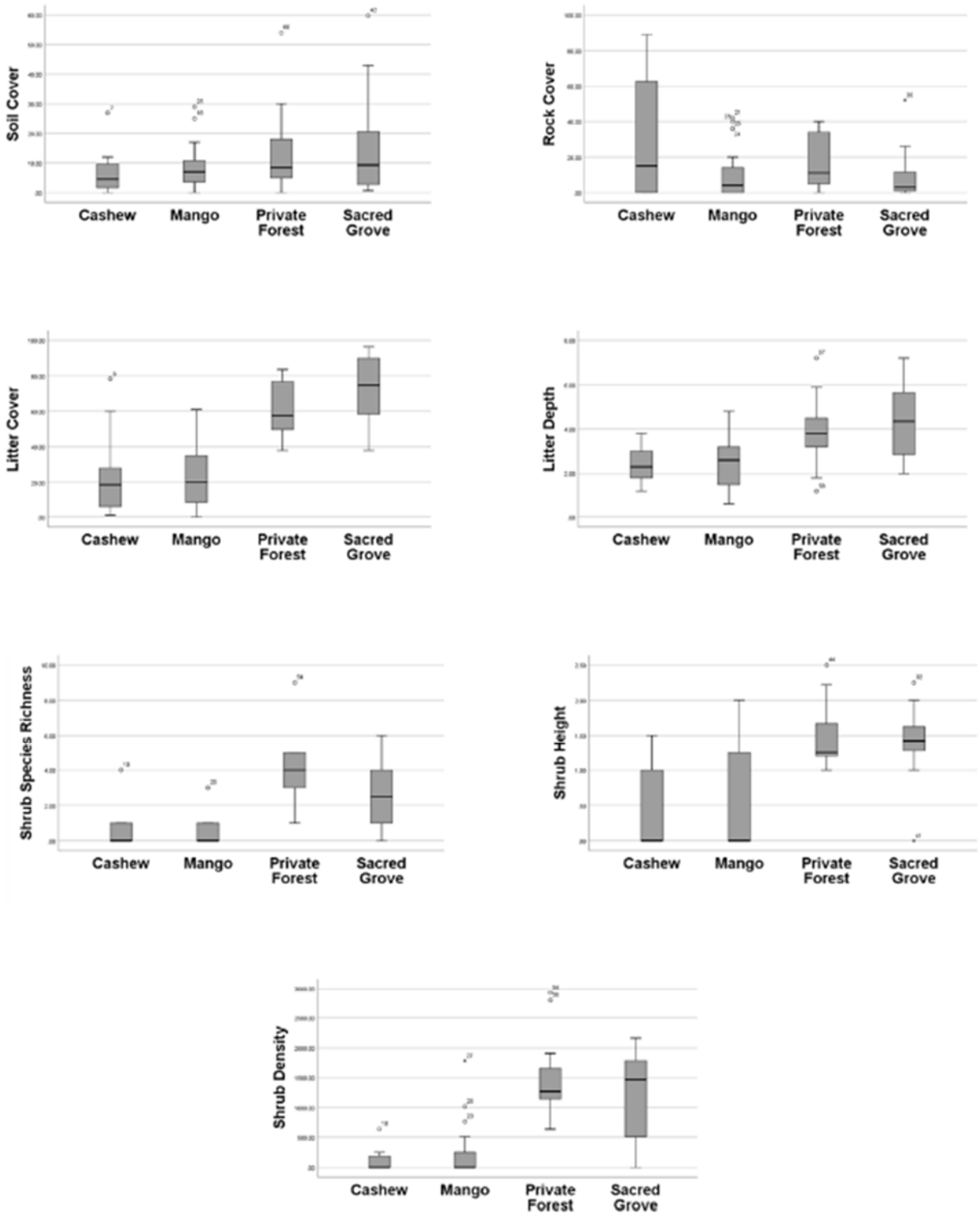


Fig 7: Box and whisker plots showing the variation in vegetation variables across land cover types in Dapoli, Maharashtra.

4.3. ARTHROPOD ABUNDANCE AND BIOMASS

The arthropods were identified up to the order level and a total of 17 orders were recorded from the entire study area. The beating method yielded 16 orders, whereas the litter method yielded 11 arthropod orders. Spiders (Order-Araneae) was the most abundant order recorded by both methods. The arthropod sampling could not be carried out in 9 sites.

Table 5: Biological attributes of arthropods sampled by vegetation beating method in the four land covers in Dapoli, Maharashtra.

Attribute	Cashew Plantations	Mango Plantations	Private Forests	Sacred Groves
No. of Orders	10	9	12	11
Arthropod Abundance	55	175	200	147
Arthropod Biomass (g)	0.769	3.142	0.9619	2.014

Table 6: Biological attributes of arthropods sampled by litter sorting method in the four land covers in Dapoli, Maharashtra.

Attribute	Cashew Plantations	Mango Plantations	Private Forests	Sacred Groves
No. of Orders	6	8	10	9
Arthropod Abundance	32	86	93	93
Arthropod Biomass (g)	0.457	6.931	0.325	1.304

4.4. COMPOSITION AND DIVERSITY OF INSECTIVOROUS BIRDS

A total of 42 insectivorous bird species were recorded in the entire study area. The species richness of insectivores was highest in private forests (28) followed by sacred groves (27), mango plantations (24) and cashew plantations (19). The species richness of sub-guilds of insectivores in each land cover type is shown in Figures 8 and 9. The ground sallying and pecking insectivores were not represented in the cashew plantations. With regard to the habitat specialization sub-guild, 29 were forest specialists and 13were open habitat species.

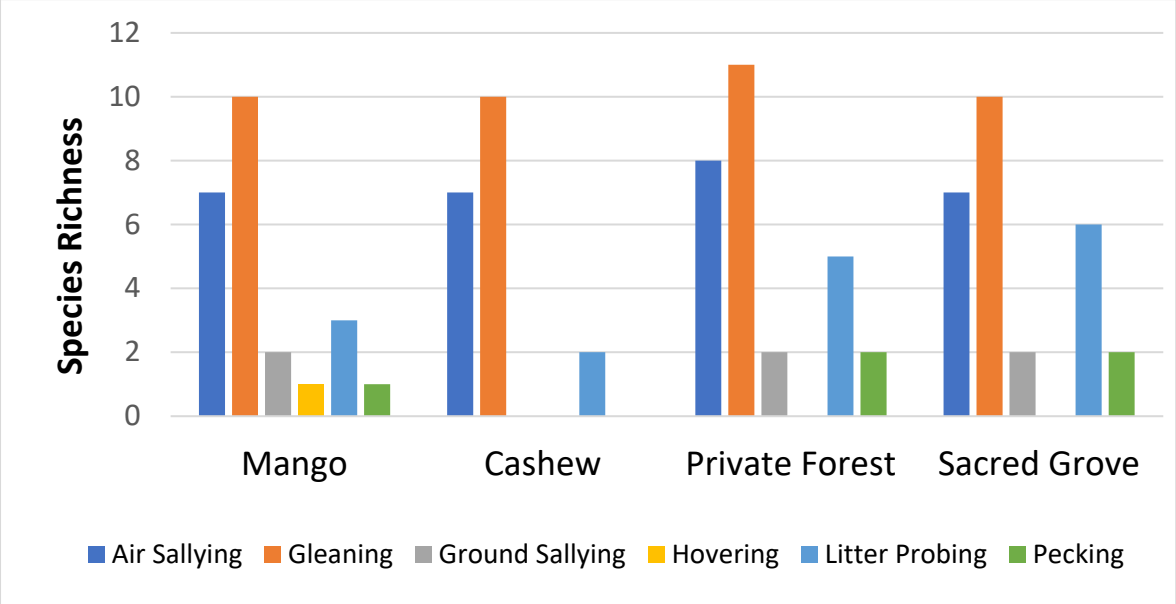


Fig 8: Cluster bar graph depicting the proportion of sub- guilds (based on foraging behaviour) of insectivorous birds across land cover types in Dapoli, Maharashtra.

For the representation of the bird community structure of the foraging strata sub-guild (Fig 9), the representation by Aerts *et al.* (2008) was followed. The figure shows the distribution of the foraging sub-guilds across the different land cover types and also depicts their proportion in different combinations of land uses. Out of the 42 insectivorous species recorded in this study, only 14 (33.33%) were restricted to the forests and just one species (4.16%) was exclusively found in the plantations. Both mango and cashew plantations had 3 species in common with the forests. Interestingly, 7 species were exclusively restricted to the mango plantations, but no such restricted species were observed in the cashew plantations.

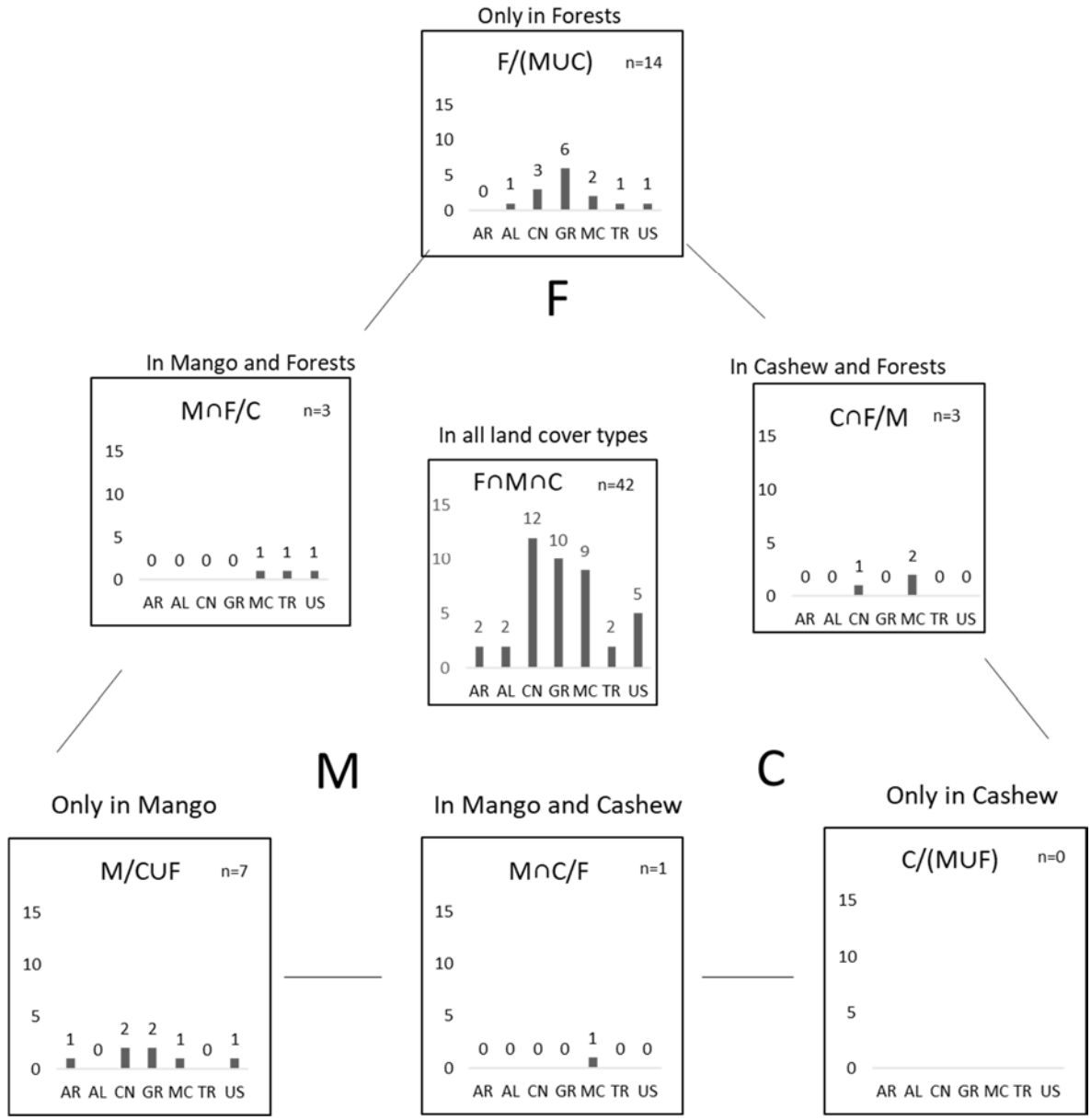


Fig 9: Differences in the community structures of insectivorous sub-guilds (based on foraging strata) between Forests (F), Mango Plantations (M) and Cashew Plantations (C) in Dapoli, Maharashtra. AR: Aerial feeders, AL: All storey foragers, CN: Canopy Foragers, GR: Ground Foragers, MC: Mid-Canopy Foragers, TR: Trunk Foragers, US: Understorey Foragers. (adopted after Aerts *et al*., 2008).

4.5. COMPARISON OF INSECTIVOROUS BIRDS BETWEEN FORESTS AND PLANTATIONS

A comparison of the proportion of insectivores in the habitat specialization sub-guild (forest vs open-habitat birds) across land use types revealed that both cashew and mango plantations were significantly different from forested habitats in terms of mean relative frequency; in other words, open-habitat specialists are represented more in plantations. Interestingly, mean relative frequency of foraging strata sub-guilds was the same between

cashew plantations and forested habitats; in contrast, mango plantations showed significant similarity with regard to sub-guilds of foraging behaviour (Table 7).

Table 7. Comparison of relative mean frequencies of two insectivorous sub-guilds between agricultural plantations (cashew & mango) and forest habitats (private forests and sacred groves) in Dapoli, Maharashtra.

Insectivorous sub-guild	Contingency table	df	Chi-square	P-value
Habitat specialists	Cashew plantation - Forest sites (*PF U SG*)	1	9.742	<0.01
Habitat specialists	Mango plantation - Forest sites (*PF U SG*)	1	12.653	<0.01
Foraging strata	Cashew plantation - Forest sites (*PF U SG*)	6	15.589	>0.01
Foraging strata	Mango plantation - Forest sites (*PF U SG*)	6	52.986	<0.01
Foraging behaviour	Cashew plantation - Forest sites (*PF U SG*)	4	21.434	<0.01
Foraging behaviour	Mango plantation - Forest sites (*PF U SG*)	4	6.357	>0.01

4.6. EFFECT OF AREA ON BIRD SPECIES DIVERSITY

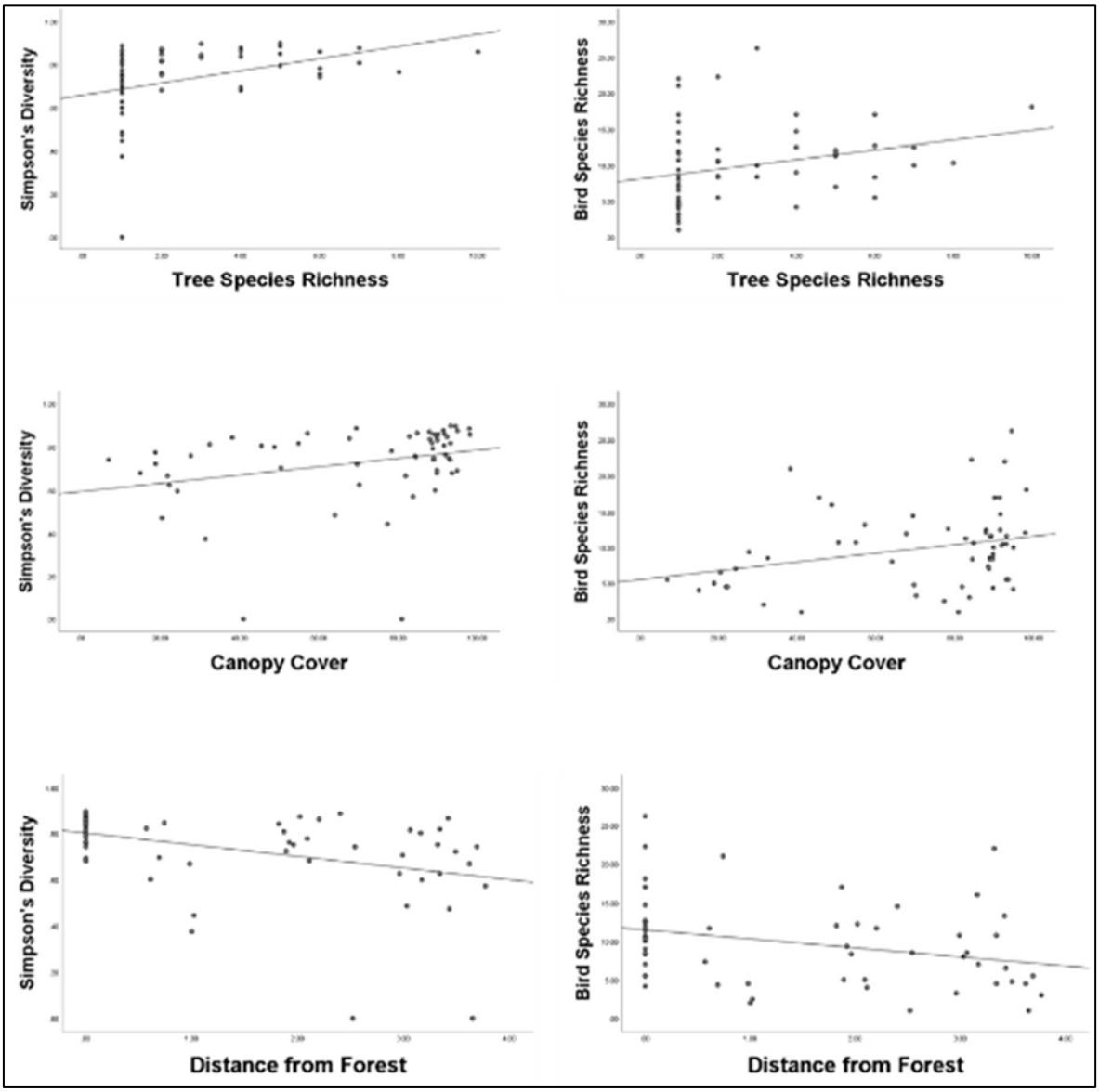
The area of sampling sites was significantly correlated with the abundance of insectivores ($r=0.721$, $p<0.05$) but bird diversity and richness were found to be uninfluenced by area.

4.7. CORRELATES OF STRUCTURE AND COMPOSITION OF INSECTIVOROUS BIRDS

The correlation analysis showed significant relationships between insectivore richness and diversity with covariates like tree species richness, tree height, tree abundance, tree density, canopy cover, litter cover, litter depth, shrub species richness, shrub abundance, shrub density, richness of litter arthropods and distance from the nearby forest (see Table 8). Grass cover was negatively correlated with the insectivore richness and diversity. Tree GBH was correlated with only insectivore species richness, while shrub height was only correlated with insect diversity. Figure 10 shows the scatterplots of some significant associations.

Table 8: Spearman's correlation coefficients between insectivore species richness, diversity and habitat attributes in a multi-use landscape in Dapoli, Maharashtra.

Covariates	**Estimated Species Richness of Insectivores (Chao-1 Estimator)**	**Insectivore Species Diversity (Simpson 1-D)**
Tree Species Richness	.469	.491
Tree GBH (cm)	.303	-
Tree Height (m)	.389	.398
Tree Density (no/ha)	.364	.306
Canopy Cover (%)	.484	.432
Grass Cover (%)	-.410	-.477
Litter Cover (%)	.305	.360
Litter Depth (%)	.297	.355
Shrub Species Richness (%)	.322*	.392
Shrub Height	-	.369
Shrub Density	.329	.435
Arthropod Richness (Litter Method)	.376	.334
Distance from nearest forest	-.456	-.475


Simpson's Diversity
Tree Species Richness
Bird Species Richness
Tree Species Richness
Simpson's Diversity
Canopy Cover
Bird Species Richness
Canopy Cover
Simpson's Diversity
Distance from Forest
Bird Species Richness
Distance from Forest

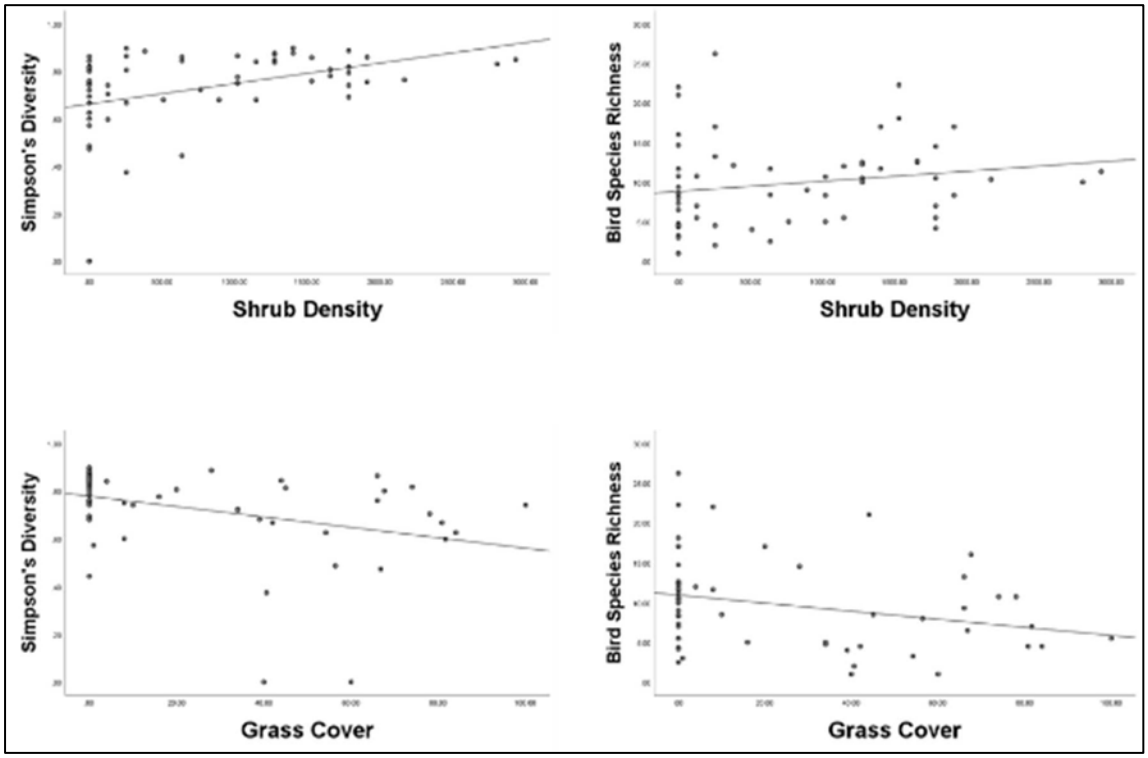


Fig 10: Scatter plots depicting significant relationships between insectivore birds and select habitat variables in a mosaic of land cover types in Dapoli, Maharashtra.

4.8. NESTEDNESS OF INSECTIVOROUS BIRD ASSEMBLAGES ALONG A LANDUSE GRADIENT

The results of the nestedness analysis showed that all the land use types from plantations to forests show a moderate yet statistically significant nestedness with respect to insectivorous birds (Table 9). In other words, cashew and mango plantations seem to harbour a significant part of insectivorous assemblages in the region (See Figure 11 for packed species incidence matrices). This persistence of insectivorous communities across a gradient of land use types is also evident from a stronger nestedness of both the insectivorous subguilds – of foraging strata and behaviour between plantations and forests.

Table 9. Results of nestedness analysis of insectivorous bird assemblages across four major habitats ranging from plantations to private forests in Dapoli, Maharashtra. For each run, 999 null matrices were generated with equiprobable row total and fixed column total.

Data Matrix	Matrix Size	FILL Score	$NODF_r$	Z Score	P Value
ALL Insectivorous Birds x ALL Sampling points	42x60	0.16	28.852	16.399	<0.001
Insectivorous Guilds of Foraging Strata x ALL Sampling Points	07x60	0.569	77.450	5.157	<0.001
Insectivorous Guilds of Foraging Behaviour x ALL Sampling Points	06x60	0.442	74.958	9.759	<0.001

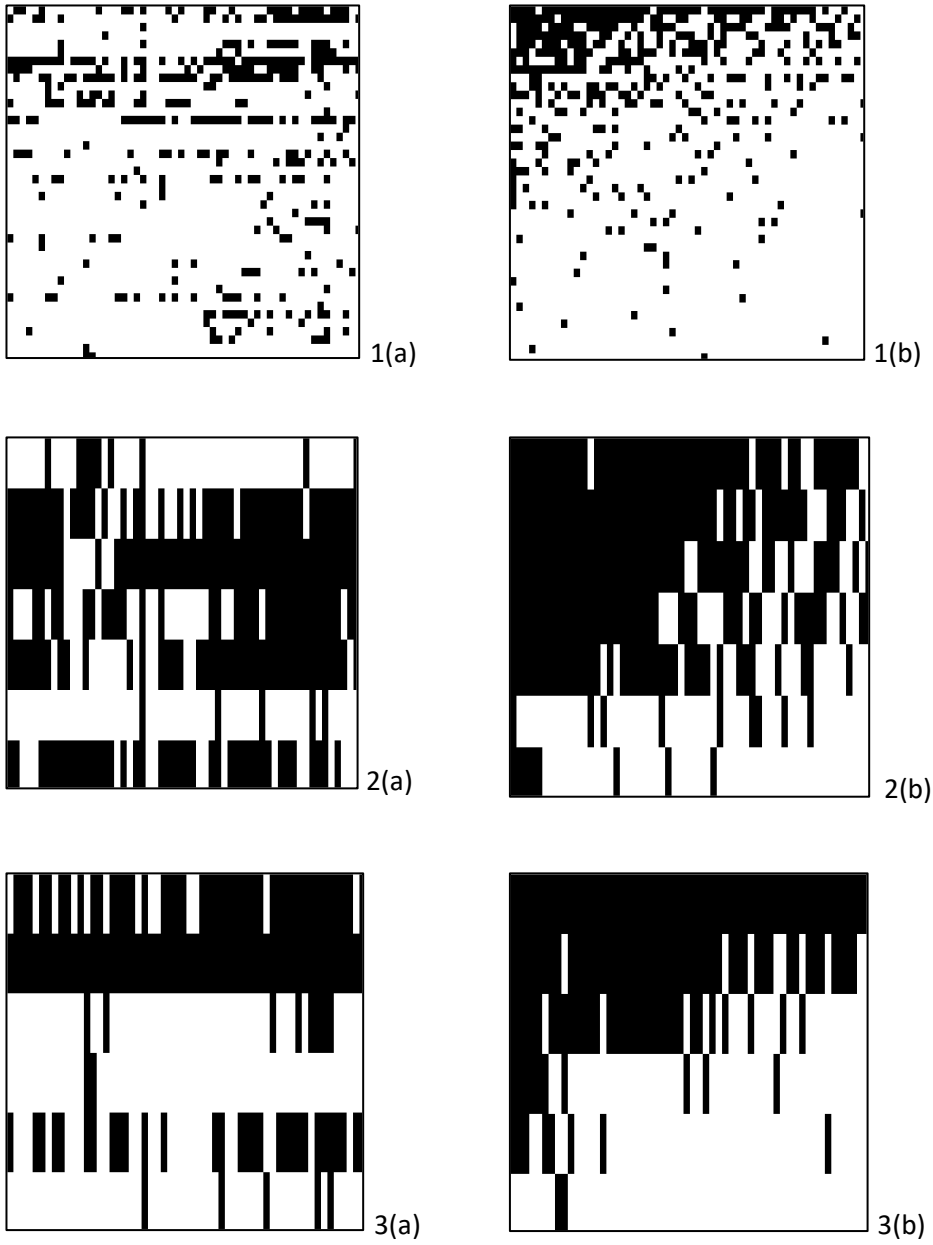


Fig. 11. Observed (a) and packed (b) matrices of 1) insectivorous birds, 2) insectivorous sub-guilds of different foraging strata and 3) insectivorous sub-guilds of foraging behaviour in a mosaic of natural forests and mango and cashew plantations in Dapoli, Maharashtra. [Species are arranged along rows and habitats along columns in the matrices].

5. DISCUSSION

5.1. INSECTIVOROUS BIRD ASSEMBLAGES OF PLANTATIONS VERSUS FORESTS

The present study in a multiple landuse landscape of western India found that the plantations were dominated by open habitat insectivores and contained a smaller number of forest specialist species. This pattern is consistent with many studies elsewhere too (Danielsen & Heegaard, 1995; Peh *et al*., 2006, Sheldon *et al*., 2010; Azhar *et al*., 2011). Forest specialist species like Indian Blackbird, Indian Scimitar Babbler, Malabar Whistling Thrush, Orange-headed Thrush, Puff-throated Babbler, Tawny-bellied Babbler and White-rumped Shama were completely absent in the plantations. A common feature among these birds is that all these are ground or understorey foragers. Hence, the paucity of leaf litter and understorey in plantations may be an important factor for the rarity of forest specialists in plantations.

Interestingly, relative mean frequency of foraging strata sub-guilds was similar between cashew plantations and forested habitats; on the other hand, mango plantations showed significant similarity with regard to sub-guilds of foraging behaviour.

Unlike the monocultural timber plantations which are characterized by straight growing branchless trees, the mango and cashew plantations have irregular growth and profuse branching. As a result, these plantations resemble a forest with varying strata. Besides, the tree density of cashew plantations is much higher than that of mango plantations. Hence such a structural resemblance may give rise to similar patterns of space use for foraging.

Mango and forested habitat were similar in terms of the proportion of foraging behaviour. This is also evident from the fact that pecking and ground sallying insectivores are absent in the cashew plantations. The ground sallying birds in mango plantations are represented by only two species having a single occurrence each. Also, there is only one occurrence of pecking insectivore (Black-rumped Flameback) in a mango plantation. Hence, this pattern may have arisen due to inadequate sampling.

5.2. HABITAT CORRELATES OF INSECTIVOROUS BIRD COMMUNITIES

The habitat attributes like tree height, tree abundance, canopy cover, litter cover, litter depth and shrub density were positively correlated with insectivore species richness and diversity. All these habitat covariates add to the structural complexity of vegetation. Similar studies

have shown that structural complexity of vegetation positively influences the structure and composition of bird communities (Mitra & Sheldon, 1993; Aratrakorn *et al*., 2006; Holbech, 2009; Najera & Simonetti, 2010). With increasing complexity of horizontal and vertical vegetation structure, diversity of microhabitats and niches are expected to increase, supporting a high diversity of birds. Most insectivores are said to be habitat specialists and some even have very specific microhabitat requirements. And a structurally complex habitat is more likely to increase availability of such specialized niches.

Species richness of trees and shrubs was found to be positively associated with insectivore diversity in this study. This is in conformity with Karanth *et al*. (2016), who found tree species richness influenced bird species richness in various agroforestry systems in the Western Ghats. This may be because insectivores get more foraging opportunities with more diverse vegetation. Also, canopy development is known to buffer the arboreal microclimate like temperature and humidity, resulting in high arthropod diversity (Wong, 1985). It is also found in the study that insectivore bird diversity was positively related to species richness of litter arthropods.

Intriguingly, grass cover was found negatively correlated with insectivore richness and diversity. This is because grass cover was predominantly present in the plantations and was almost absent in the forests. Regular removal of leaf litter in intensively managed plantations give rise to grass growth in plantations where litter-probing insectivorous birds are naturally low in numbers.

The insectivore diversity and richness were negatively correlated with distance from the forest. This means that greater the isolation of a plantation from a forest, the lesser bird diversity it has. This 'distance effect' is well documented in ecological literature (e.g., Mitra & Sheldon, 1993, Zhang et al., 2017). Fragments of forests are known to act as source populations in human-dominated landscapes (Raman, 2006). Anand et al. (2010) in their review mention the 'halo effect' that the remnant forest fragments in the Western Ghats produce. The halo effect is essentially the influence of patch attributes on the differential use of matrix adjacent to native patches (Tuberalis et al., 2004). In the current case, the presence of fragmented forest patches such as sacred groves and private forests create the halo effect which influences the insectivore bird communities in the adjacent human-dominated landscape matrix.

Area effect, as a primary determinant of size of avian assemblages, is often touted as a sampling effect (see Tjørve 2003 for a review). Loyn *et al*. (1987) studied the effect of patch area on the diversity and abundance of birds in fragmented Victorian forests and found positive relationships with patch area and bird abundance as well as diversity. Here, I found that area of sampling site was significantly correlated with the abundance of insectivores but not their diversity and richness. This also means that we could rule out the role of area (as a sampling effect) in the observed relationships between habitat variables and insectivorous bird diversity.

5.3. RESCUE EFFECT OF PLANTATIONS FOR INSECTIVORE BIRD COMMUNITIES

Results of the nestedness analysis show that all the land use types from plantations to forests show a moderate yet statistically significant nestedness with respect to insectivorous birds.

In a review by Wright *et al*. (1998), statistically significant nestedness was commonly observed in a large number of studies on assemblages of vertebrates, arthropods, molluscs, plants, and other taxa. In a more recent review (Watling & Donnelly, 2006), nearly 94% of the studies on species assemblages showed significant nestedness. Several other studies have also shown a nested pattern of bird communities in fragmented habitats and plantations (Wright & Reeves, 1992; Fischer & Lindenmayer, 2005; Jacoboski *et al*., 2016; Wang *et al.*, 2013). However, Mathews *et al.* (2015) argue that the occurrence of significant nested patterns is rare and commonness in nested patterns observed previously is due to the limitations of the methodology adopted. Hence, it is extremely important not to assume nestedness a priori in making management decisions. Nestedness pattern was also found to be seasonal as an increase in the movement of birds during the non-breeding season reduces the nestedness (Murgui, 2010).

In the case of fragmented landscapes, nestedness occurs because of ordered extinction sequences. Smaller habitat fragments selectively lose habitat specialist species which are already low in abundance (Patterson & Atmar, 2000). It can result from drivers of habitat degradation like forest fragmentation and overexploitation. In that sense, nestedness is a sign of decomposition of community integrity so long as the forests do not undergo conversion. But when an extensive and continuous primary forest gradually transforms into parcels of

multiple land use (like plantations), the same nestedness may indicate a 'rescue effect' in the sense that the new modified habitats still hold a significant proportion of the source biota. Higher the degree of nestedness, better is their potential to buffer the forces of local extinction as forest fragments are getting increasingly isolated and converted. The prevalence of such a rescue effect could not be ascertained in the present study as the nestedness may also be an artefact of the shared generalist species between plantations and forests. Further analysis is needed to tease such effects apart.

5.4. CONCLUSION

Apart from a minuscule proportion of area legally protected and some forest fragments conserved by the community, the entire Konkan region is under tremendous pressure for conversion into various human-modified land uses like plantations. Many studies have looked at the comparisons between natural forests and plantations in the southern Western Ghats. Such studies were lacking in the northern Western Ghats. This study also aims to fill the gaps in the published literature in the northern Western Ghats in this context.

In the Konkan landscape, once extensive primary forests now remain only as patches of sacred groves and as private forests (mediated through secondary forest growth in old abandoned clearings). The remaining land area is now under extensive cultivation, predominantly of mango and cashew plantations.

The results indicate that the plantations hold an impoverished subset predominantly consisting of the open habitat species. However, the moderate degree of nestedness of overall insectivorous birds implies that there is a great potential for cashew and mango plantations to serve as an optimal secondary habitat in the landscape. Further study on improving structural complexity and habitat quality of the plantations with no corresponding cost to their productivity would fetch a win-win solution for sustaining the insectivorous bird diversity of the region.

There is a heavy usage of pesticides in such plantations which has not been quantified in this study. The pesticide use may affect the arthropod numbers which in turn may influence the insectivorous bird communities inhabiting the plantations. In addition, the season of sampling

coincided with the season where maximum management practices are carried out in the plantations. The results may differ if studies are carried out comparing different seasons.

Although sacred groves are considered as primary undisturbed forests in this study, they are under immense pressure. Activities such as renovation of temples, dumping of excessive soil dug out from an adjacent pond, grazing, land clearing for making paths were observed during sampling. Detailed documentation of the entire biodiversity spectrum of such sacred groves is needed in the wake of such developments, and this study, with a focus on insectivorous bird communities, is a small step in this direction.

Given the similarity of avifauna of the private forests to that of the sacred groves, it is important that such private secondary forests need to be conserved. This is a first documentation on the biodiversity of the private forests in the Konkan region. More such studies carried out over a wide variety of taxa are needed in conserving such forests. The private forests are under the threat of conversion into plantations, resorts and real estate projects. There are a few examples of ecotourism in such private forests prevalent in the region. Such projects aim at utilizing the fund obtained from the tourism activities towards protecting and maintaining the forests. Projects like these are very few in this region and can be promoted in the future in order to conserve such forests.

There are two lines of thought regarding conservation in human-modified landscapes: land sparing and land sharing. The former approach advocates certain areas to be kept as biodiversity offsets, while the latter approach proposes modifications in the present habitats to make it more biodiversity-friendly. In the present study, the sacred groves and the private forests act as spared lands and the plantations are shared lands. By conserving the spared lands and modifying the shared lands, the biodiversity of the Konkan landscape can be effectively conserved.

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Appendix 1. List of birds observed in Dapoli Taluk, Maharashtra, along with their foraging guilds and migratory status.

SN	English Name	Scientific Name	Foraging Guild	Migratory Status
1	Ashy Drongo	*Dicrurus leucophaeus*	Insectivorous	Winter migrant
2	Brown-cheeked Fulvetta	*Alcippe poioicephala*	Insectivorous	Resident
3	Brown-headed Barbet	*Psilopogon zeylanicus*	Frugivorous	Resident
4	Black-hooded Oriole	*Oriolus xanthornus*	Frugivorous	Resident
5	Black Drongo	*Dicrurus macrocercus*	Insectivorous	Resident
6	Black Redstart	*Phoenicurus ochruros*	Insectivorous	Winter migrant
7	Black-naped Monarch	*Hypothymis azurea*	Insectivorous	Resident
8	Bronzed Drongo	*Dicrurus aeneus*	Insectivorous	Resident
9	Blyth's Reed Warbler	*Acrocephalus dumetorum*	Insectivorous	Winter migrant
10	Crimson-backed Sunbird	*Leptocoma minima*	Nectarivorous	Resident
11	Crested Hawk Eagle	*Nisaetus cirrhatus*	Carnivorous	Resident
12	Coppersmith Barbet	*Psilopogon haemacephalus*	Frugivorous	Resident
13	Common Iora	*Aegithina tiphia*	Insectivorous	Resident
14	Common Tailorbird	*Orthotomus sutorius*	Insectivorous	Resident
15	Common Woodshrike	*Tephrodornis pondicerianus*	Insectivorous	Resident
16	Crested Serpent Eagle	*Spilornis cheela*	Carnivorous	Resident
17	Green Bee-eater	*Merops orientalis*	Insectivorous	Resident
18	Grey-breasted Prinia	*Prinia hodgsonii*	Insectivorous	Resident
19	Grey-fronted Green Pigeon	*Treron affinis*	Frugivorous	Resident
20	Golden-fronted Leafbird	*Chloropsis aurifrons*	Nectarivorous	Resident
21	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	Insectivorous	Winter migrant
22	Greater Coucal	*Centropus sinensis*	Carnivorous	Resident
23	Grey Junglefowl	*Gallus sonneratii*	Omnivorous	Resident
24	Green Warbler	*Phylloscopus nitidus*	Insectivorous	Winter migrant
25	Hume's Warbler	*Phylloscopus humei*	Insectivorous	Winter migrant
26	Indian Golden Oriole	*Oriolus kundoo*	Frugivorous	Resident
27	Indian Blackbird	*Turdus simillimus*	Insectivorous	Resident
28	Indian Peafowl	*Pavo cristatus*	Omnivorous	Resident
29	Indian Robin	*Copsychus fulicatus*	Insectivorous	Resident
30	Indian Paradise-flycatcher	*Terpsiphone paradisi*	Insectivorous	Resident
31	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	Insectivorous	Resident
32	Indian Yellow Tit	*Machlolophus aplonotus*	Insectivorous	Resident
33	Jerdon's Leafbird	*Chloropsis jerdoni*	Nectarivorous	Resident
34	Jungle Babbler	*Turdoides striata*	Insectivorous	Resident
35	Jungle Myna	*Acridotheres fuscus*	Omnivorous	Resident
36	Jungle Prinia	*Prinia sylvatica*	Insectivorous	Resident
37	Large Cuckooshrike	*Coracina macei*	Insectivorous	Resident

SN	English Name	Scientific Name	Foraging Guild	Migratory Status
38	Large-billed Crow	*Corvus macrorhynchos*	Omnivorous	Resident
39	Black-rumped Flameback	*Dinopium benghalense*	Insectivorous	Resident
40	Long-tailed Shrike	*Lanius schach*	Insectivorous	Resident
41	Malabar Pied Hornbill	*Anthracoceros coronatus*	Frugivorous	Resident
42	Malabar Whistling Thrush	*Myophonus horsfieldii*	Insectivorous	Resident
43	Nilgiri Flowerpecker	*Dicaeum concolor*	Nectarivorous	Resident
44	Orange-headed Thrush	*Geokichla citrina*	Insectivorous	Resident
45	Oriental Magpie Robin	*Copsychus saularis*	Insectivorous	Resident
46	Orange Minivet	*Pericrocotus flammeus*	Insectivorous	Resident
47	Oriental White-eye	*Zosterops palpebrosus*	Insectivorous	Resident
48	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	Nectarivorous	Resident
49	Plum-headed Parakeet	*Psittacula cyanocephala*	Frugivorous	Resident
50	Plain Prinia	*Prinia inornata*	Insectivorous	Resident
51	Purple-rumped Sunbird	*Leptocoma zeylonica*	Nectarivorous	Resident
52	Puff-throated Babbler	*Pellorneum ruficeps*	Insectivorous	Resident
53	Purple Sunbird	*Cinnyris asiaticus*	Nectarivorous	Resident
54	Red-breasted Flycatcher	*Ficedula parva*	Insectivorous	Winter migrant
55	Rose-ringed Parakeet	*Psittacula krameri*	Frugivorous	Resident
56	Rufous Treepie	*Dendrocitta vagabunda*	Omnivorous	Resident
57	Rufous Woodpecker	*Micropternus brachyurus*	Insectivorous	Resident
58	Red-vented Bulbul	*Pycnonotus cafer*	Frugivorous	Resident
59	Red-whiskered Bulbul	*Pycnonotus jocosus*	Frugivorous	Resident
60	Shikra	*Accipiter badius*	Carnivorous	Resident
61	Small Minivet	*Pericrocotus cinnamomeus*	Insectivorous	Resident
62	Spotted Dove	*Streptopelia chinensis*	Granivorous	Resident
63	Tawny-bellied Babbler	*Dumetia hyperythra*	Insectivorous	Resident
64	Tickell's Blue Flycatcher	*Cyornis tickelliae*	Insectivorous	Resident
65	Vigor's Sunbird	*Aethopyga vigorsii*	Nectarivorous	Resident
66	White-browed Bulbul	*Pycnonotus luteolus*	Frugivorous	Resident
67	White-bellied Drongo	*Dicrurus caerulescens*	Insectivorous	Resident
68	White-cheeked Barbet	*Psilopogon viridis*	Frugivorous	Resident
69	Western Crowned Warbler	*Phylloscopus occipitalis*	Insectivorous	Winter migrant
70	White-rumped Shama	*Copsychus malabaricus*	Insectivorous	Resident
71	White-throated Kingfisher	*Halcyon smyrnensis*	Insectivorous	Resident
72	Wire-tailed Swallow	*Hirundo smithii*	Insectivorous	Resident
73	Yellow-footed Green Pigeon	*Treron phoenicopterus*	Frugivorous	Resident
74	Yellow-throated Sparrow	*Gymnoris xanthocollis*	Granivorous	Resident

Appendix 2. List of insectivorous birds and their sub-guilds recorded in Dapoli Taluk, Maharashtra.

S N	English Name	Scientific Name	Habitat	Foraging Behaviour	Foraging Strata
1	Ashy Drongo	*Dicrurus leucophaeus*	Forest	Air Sallying	Upper-canopy
2	Brown-cheeked Fulvetta	*Alcippe poioicephala*	Forest	Gleaning	Mid-canopy
3	Black Drongo	*Dicrurus macrocercus*	Open habitat	Air Sallying	Upper-canopy
4	Black Redstart	*Phoenicurus ochruros*	Open habitat	Ground Sallying	Ground
5	Black-naped Monarch	*Hypothymis azurea*	Forest	Air Sallying	Mid-canopy
6	Bronzed Drongo	*Dicrurus aeneus*	Forest	Air Sallying	Upper-canopy
7	Blyth's Reed Warbler	*Acrocephalus dumetorum*	Open habitat	Gleaning	All storeys
8	Common Iora	*Aegithina tiphia*	Open habitat	Gleaning	Mid-canopy
9	Common Tailorbird	*Orthotomus sutorius*	Open habitat	Gleaning	Understorey
10	Common Woodshrike	*Tephrodornis pondicerianus*	Forest	Gleaning	Mid-canopy
11	Green Bee-eater	*Merops orientalis*	Open habitat	Air Sallying	Aerial
12	Grey-breasted Prinia	*Prinia hodgsonii*	Open habitat	Gleaning	Understorey
13	Grey-headed Canary-Flycatcher	*Culicicapa ceylonensis*	Forest	Air Sallying	All storeys
14	Green Warbler	*Phylloscopus nitidus*	Forest	Gleaning	Upper-canopy
15	Hume's Warbler	*Phylloscopus humei*	Forest	Gleaning	Upper-canopy
16	Indian Blackbird	*Turdus simillimus*	Forest	Litter Probing	Ground
17	Indian Robin	*Copsychus fulicatus*	Open habitat	Litter Probing	Ground
18	Indian Paradise-flycatcher	*Terpsiphone paradisi*	Forest	Air Sallying	Mid-canopy
19	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	Forest	Litter Probing	Ground
20	Indian Yellow Tit	*Machlolophus aplonotus*	Forest	Gleaning	Upper-canopy
21	Jungle Babbler	*Turdoides striata*	Open habitat	Litter Probing	Ground
22	Jungle Prinia	*Prinia sylvatica*	Forest	Gleaning	Understorey
23	Large Cuckooshrike	*Coracina macei*	Forest	Air Sallying	Upper-canopy

S N	English Name	Scientific Name	Habitat	Foraging Behaviour	Foraging Strata
24	Black-rumped Flameback	*Dinopium benghalense*	Forest	Pecking	Trunk
25	Long-tailed Shrike	*Lanius schach*	Forest	Ground Sallying	Mid-canopy
26	Malabar Whistling Thrush	*Myophonus horsfieldii*	Forest	Ground Sallying	Ground
27	Orange-headed Thrush	*Geokichla citrina*	Forest	Litter Probing	Ground
28	Oriental Magpie Robin	*Copsychus saularis*	Open habitat	Litter Probing	Ground
29	Orange Minivet	*Pericrocotus flammeus*	Forest	Gleaning	Upper-canopy
30	Oriental White-eye	*Zosterops palpebrosus*	Forest	Gleaning	Upper-canopy
31	Plain Prinia	*Prinia inornata*	Open habitat	Gleaning	Understorey
32	Puff-throated Babbler	*Pellorneum ruficeps*	Forest	Litter Probing	Ground
33	Red-breasted Flycatcher	*Ficedula parva*	Forest	Air Sallying	Mid-canopy
34	Rufous Woodpecker	*Micropternus brachyurus*	Forest	Pecking	Trunk
35	Small Minivet	*Pericrocotus cinnamomeus*	Open habitat	Gleaning	Upper-canopy
36	Tawny-bellied Babbler	*Dumetia hyperythra*	Forest	Litter Probing	Ground
37	Tickell's Blue Flycatcher	*Cyornis tickelliae*	Forest	Air Sallying	Mid-canopy
38	White-bellied Drongo	*Dicrurus caerulescens*	Forest	Air Sallying	Upper-canopy
39	Western Crowned Warbler	*Phylloscopus occipitalis*	Forest	Gleaning	Mid-canopy
40	White-rumped Shama	*Copsychus malabaricus*	Forest	Gleaning	Understorey
41	White-throated Kingfisher	*Halcyon smyrnensis*	Open habitat	Ground Sallying	Mid-canopy
42	Wire-tailed Swallow	*Hirundo smithii*	Open habitat	Air Sallying	Aerial

Appendix 3. Details of the sampling sites along with their areas and the number of point counts in Dapoli Taluk, Maharashtra.

Land Cover	Site Name	Area (ha)	No. of point counts
Sacred Grove	Sadavali	14.3	4
Sacred Grove	Kudawale	40.4	5
Sacred Grove	Dhankoli	9.4	3
Private Forest	Sakhloli	56.4	7
Private Forest	Nargoli	87.3	6
Private Forest	Shirde	15.4	4
Mango Plantation	Pangari	97.6	8
Mango Plantation	Excellence	8.49	3
Mango Plantation	Gimhavane	4.69	3
Mango Plantation	Burondi	27	5
Cashew Plantation	Dabre	12	4
Cashew Plantation	Vaidya	3	3
Cashew Plantation	Rukhi	34	5

Appendix 4. Bird-Incidence Matrix of insectivorous birds in the four land cover types in Dapoli Taluk, Maharashtra. Species are arranged in decreasing fill format (as used in nestedness analysis)

Insectivorous Bird Species	Private Forest	Sacred Grove	Mango Plantation	Cashew Plantation
Ashy Drongo	1	1	1	1
Brown-cheeked Fulvetta	1	1	1	1
Black-naped Monarch	1	1	1	1
Blyth's Reed Warbler	1	1	1	1
Common Iora	1	1	1	1
Common Tailorbird	1	1	1	1
Green Bee-eater	1	1	1	1
Green Warbler	1	1	1	1
Indian Paradise Flycatcher	1	1	1	1
Jungle Babbler	1	1	1	1
Black-rumped Flameback	1	1	1	0
Bronzed Drongo	1	1	0	1
Common Woodshrike	1	1	0	1
Western-crowned Warbler	1	1	0	1
Indian Scimitar Babbler	1	1	0	0
Malabar Whistling Thrush	1	1	0	0
Orange-headed Thrush	1	1	0	0
Puff-throated Babbler	1	1	0	0
Rufous Woodpecker	1	1	0	0
Tickell's Blue Flycatcher	1	1	0	0
White-rumped Shama	1	1	0	0
Grey-breasted Prinia	1	0	1	1
Large Cuckooshrike	1	0	1	1
Oriental Magpie Robin	1	0	1	1
Small Minivet	1	0	1	1
Long-tailed Shrike	1	0	0	0
Oriental White-eye	1	0	0	0
White-bellied Drongo	1	0	0	0
Plain Prinia	0	1	1	0
White-throated Kingfisher	0	1	1	0
Grey-headed Canary Flycatcher	0	1	0	0
Hume's Warbler	0	1	0	0
Indian Blackbird	0	1	0	0
Tawny-bellied Babbler	0	1	0	0
Red-breasted Flycatcher	0	0	1	1
Black Drongo	0	0	1	0
Black Redstart	0	0	1	0
Indian Robin	0	0	1	0
Indian Yellow Tit	0	0	1	0
Jungle Prinia	0	0	1	0
Wire-tailed Swallow	0	0	1	0
Orange Minivet	0	0	0	1