Study of the Bird Community in Agasthyamalai hills, Western Ghats, Kerala, India

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In

ZOOLOGY

(Interdisciplinary-Environmental Science)

By

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CERTIFICATE

This is to certify that the thesis, entitled **"Study of the Bird Community in Agasthyamalai hills, Western Ghats, Kerala, India"** submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the **Degree of Doctor of Philosophy in Zoology (Interdisciplinary-Environmental Science)** is a record of original work done by **Ms. Madhumita Panigrahi** during the period of September 2012–August 2018 of her research in the Department of Conservation Ecology at **Sálim Ali Centre for Ornithology and Natural History (SACON)** under my supervision and guidance. I further certify that this research work has not previously formed the basis for the award of any other Degree /Diploma /Associateship /Fellowship or other similar title to any candidate in any University.

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If I have seen further it is by standing on the shoulders of giants.

- Sir Issac Newton

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CHAPTER- 1

Introduction

1.1 Introduction:

Community ecology revolves around the study of biotic assemblages, their interactions, patterns of occurrence or distribution and generality of the pattern (Weins 1989, Vellend 2010). A community is structured by wide array of factors, competition, niche availability, spatial heterogeneity, predation, climatic stability, productivity, dispersal, speciation and many more (Hutchinson 1959, Pianka 1966, Vellend 2010). On the other hand, distribution of species may be influenced by species composition, abundance, behaviour, morphology and their association with the environment (Weins 1989). Owing to the complexity of the systems and interactions among them, the study of community ecology is rightly stated by Schoener (1986) as the 'most tumultuous and alluring of ecology's subdisciplines'. Studies on avifauna have been playing a pivotal role in addressing intricate questions and testing varied hypotheses relating to community ecology. As widely noted, methodological advances, well-studied taxonomy and natural history, mostly diurnal behaviour and conspicuousness make birds an easy species to study (Weins 1989, Bibby et al. 1998).

Community ecology is addressed according to the field of study, where population ecologist deals with the number of individuals, community ecologist deals with distribution of species in space and time, and biogeographer focuses on distribution on spatial scales (Kaspari 2013). For decades, these disciplines have been trying to come up with a single unifying factor that drives the species richness pattern. Many of the pioneering studies have stated that avifaunal assemblages are primarily influenced by vegetation structure rather than composition (MacArthur and MacArthur 1961, MacArthur et al. 1962). Some consider factors associated with spatial and temporal dynamics involving microclimatic conditions like temperature and moisture may be more important in influencing species abundance, richness, composition and turnover. These microclimatic conditions may indirectly affect thermoregulatory activities of birds or influence distribution of food resources (Karr and Freemark 1983). With the advance in genetics studies, a combination of historical biogeography and phylogenetics (Wiens 2012) is now increasingly being used to understand global patterns of species richness.

Vegetation and bird community: Many studies have shown a positive correlation between vegetation and bird richness and diversity (Weins 1989). Species diversity, abundance and guild structure are some of the properties that emerge as a result of interactions with habitat constituted of various biotic and abiotic factors. Vegetative parameters factors such as foliage height diversity, canopy cover, and plant diversity have been found to determine the bird community pattern (Willson 1974, Beedy 1981, Rotenberry 1985). Vegetation structure and floristics may influence the resource segregation, giving rise to different guild classes that provide insight into bird community organisation (Holmes and Recher 1986). Root (1967) defined 'Guild' as a group of species that exploit the same class of environmental resources in a similar way. As the food availability in tropics is varied supporting coexistence of a diverse array of species, it is observed that many species are not specialist and instead exploit more than two resources, and hence forming an overlap in niches in tropical forests (Karr 1990). Guild classification of birds helps in assessing the availability of resources in the forest, its ability to support diverse species and improve our understanding of the local factors driving distribution patterns.

Distribution patterns and underlying mechanisms: Diversity patterns traditionally have been explored on species-area, local and regional level species richness, diversity-productivity and lastly diversity at latitudinal gradient, one of the widely studied gradients (Pianka 1966, Willig et al. 2003). Declines in species richness with elevation have been reported for many taxa and it is considered as a general, widely seen, pattern (Rohde 1992, Stevens 1992). The pattern is as common and conspicuous as the latitudinal pattern. As the number of species decreases from hotter tropics to cooler poles, it decreases from hotter lowlands to cooler mountaintops, although, the underlying process shaping the distribution pattern varies when tested at different scales. For example, a monotonic decline in species richness pattern is common at smaller spatial scales while the hump-shaped pattern is prominent at larger scales (Rahbek 2005). While general is the declining pattern, many studies have shown a peak in richness at intermediate elevations (Rahbek 2005). Temperature and other associated variables decrease whereas precipitation and moisture availability increase when ascending a mountain, this results in an increase of species richness at intermediate elevation as that provide the most suitable environment (Brown and Lomolino 1998). The underlying processes have been tested based on theories like historical perturbation, productivity, harshness, climatic stability, habitat heterogeneity and interspecific interaction (Brown and Lomolino 1998). Blackburn and Gaston (2002) observed that the factors affecting the avian richness pattern differ with the scale of analysis, where patterns of energy availability and topography derive the pattern at large scales and set a tone for local scale species distribution with climate and habitat heterogeneity (Būhning 1997).

Despite numerous studies on distribution patterns of species, the underlying reason for these patterns, continue to be a challenge and so far, have failed to bring out a unifying factor; but more often, it has been found that a combination of multiple factors drives the distribution pattern (Brown and Lomolino 1998, Gaston 2000).

Altitude for latitude: Tropical forest owing to their elaborate mosaics of micro and macro habitats, historical and climatic stability supports highly diverse biota including avifauna (Orians 1969, Karr 1990). In the case of montane tropics, being a wet forest, dry season and especially temperature is the primary limiting factor. Both temperature and rainfall are high in these parts and mostly stable throughout the year. These tropical forests coupled with rugged mountains terrains provide an excellent opportunity for allopatric speciation with a high level of endemism. Altitudinal belts in the tropical mountains represent small-scale replicates of latitudinal vegetational zonation as both temperature and precipitation vary systematically along an altitudinal gradient. Studies relating to elevational gradient are as old as those on latitudinal gradient. Seminal works were carried out by some of the widely known biogeographers like Von Humboldt's in the Ecuadorian Andes (1849), Wallace in Indonesia (1876), Darwin in Chilean Andes (1939) and many others (Lomolino 2001 and references therein). It is a well-known fact that mountains serve as a cradle for species since many relicts, endemics and montane species survives at the mountaintop (Fjeldså et al. 2012). Hence, altitudinal gradient provides an excellent prospect to infer the pattern of distribution and subsequent test for the effect of contemporary climate, geographical history and stochastic factors as they vary along the altitudinal gradient (Rahbek 2005). The pattern of distribution is the result of the extent of range sizes of species determined by various biotic and abiotic factors.

Range Sizes: Janzen (1967) observes that tropical species have evolved under stable climatic conditions and hence have narrow habitat tolerances and sensitive to geographical barriers compared to temperate species. Distribution or geographical range of species depends on the availability of its niche or suitable habitat, and hence the geographic range limits are a reflection of **ecological niche** in space (Sexton et al. 2009). The population of the species within its range is subjected to various environmental stresses, which affects the growth and survival of the species. To understand these spatial variations in species composition and richness needs a thorough understanding of the factors that restrict the distribution along a gradient. One of the widely documented patterns about range sizes is that, in a terrestrial environment where the range sizes of species tend to decrease with decreasing latitude. Better known as **Rapoport's Latitudinal Rule** it assumes that species in higher latitudes are able to withstand greater temporal variability in climatic conditions and as a result of which it has wider rage sizes or latitudinal extents compared to lower latitudinal species (Stevens 1989). When tested across altitudes (Stevens 1992) this rule known as **Rapoport's Elevational rule**, assumes that species at higher altitude have wider altitudinal range sizes compared to species in lower altitude, nevertheless, this generalisation has been challenged in the case of tropical conditions (Rohde 1996).

Null Model: Colwell and Hurtt (1994) taking Rapoport's rule further has developed null models, which assume that if the geographic ranges are randomly placed in a gradient, then the species richness will be high in the middle of the gradient in the absence of any environmental factors. They also pointed out that Rapoport's rule along altitude might be result of sampling bias. This null model also predicts species richness to be higher in the middle, and it is popularly called as Mid-Domain Model (MDE). Despite being heavily criticised and debated upon owing to its incapability of predicting species richness for small-ranged species as well as the inherent quality of this null model, it is still widely considered as one of the underlying patterns (Zapata et al. 2005 and references therein).

Turnover or Beta diversity: A landscape is considered to harbour higher diversity if the species assemblages have least or no overlap compared to a landscape having a high number of shared species. The measure of this change in community composition or species replacement along a gradient is termed as beta diversity or turnover (Whittaker 1972, Magurran 2004). Turnover pattern along gradients assists in identifying specific transition zone in a community and that reflects the specialisation of species to a specific habitat. High species turnover in consecutive zones or within a regional pool means unique species surviving within close distances, usually highly adapted to local conditions, and so would be highly susceptible to any habitat alteration (Castilheiro et al. 2017). Identifying these transition zones and areas supporting unique species assemblages helps in prioritising areas for conservation management at a landscape level (Adolfo 1992, Poynton 1996, Castilheiroet al. 2017).

Conservation status: Tropical forest structure is more complex than other forest types and the structural complexity aids in higher bird species diversity (MacArthur 1965, 1969). Detailed information on distribution of endemic and montane species is essential in planning conservation actions, as these are centres of radiation vital for contemporary evolution in maintaining species diversity (Erwin 1991). Small geographic ranges of restricted range species, the degree of overlap in the distribution of such species and their vulnerability to habitat destruction makes these species a useful criterion in assessing conservation priorities (Renjifo et al. 1997). Assessing the abundance and distribution of bird species in an area is essential to discern the conservation importance of a study area and to find how much population of certain species that area may support, and such information is crucial in designing conservation reserves (Brown et al. 1995). In the case of Tropics, bird species abundance is lower than their temperate counterparts (Karr 1977). As the number of species is high, the abundance of each species decreases giving rise to higher number of rare species or specialist species than common or generalist species. Identifying niche boundaries of the rare species is essential in demarking extent of an area for species conservation (Thiollay 1994).

The Western Ghats being a biodiversity hotspot is well known for rich avifauna harbouring many endemic and disjunct species (Myers et al. 2000). Though birds of the Western Ghats are well-studied in general, there are a few landscapes including Agasthyamalai, that remain under-documented. Agasthyamalai Hills situated at the southern extent of Western Ghats provides an apt study system in this long chain of the mountain range. Considered to be one of few remaining intact wet evergreen patches of forest in the Western Ghats (Henry et al.1984), it is well known for its rich biodiversity, especially of plants. Past decade has also generated much interest in herpetofaunal aspect (Jins 2017). However, studies in avifauna have been restricted to few checklists and anecdotal reporting. Much of the mention about these parts of the hills can be found in ‘Birds of Kerala' by Salim Ali giving an account of bird species under the name ‘Ashambu hills’ which includes other nearby areas as well. On the contrary, the eastern slope of the hills having Kalakkad Mundanthurai Tiger Reserve (KMTR) is quite well studied in terms of avifauna (Raman et al. 2005). The current work is the only intensive study of avifauna in the western slope of the mountain covering the complete elevational gradient as of June 2018 as per published literature (online bibliography was searched, Pittie 2018). In addition to the rich biodiversity, these hills also harbour deep-rooted spiritual beliefs for people of both Kerala and Tamil Nadu that shares boundaries in either of the slopes. This intense pilgrimage is slowly driving this unique ecosystem into jeopardy with ever-increasing population and associated impacts on the habitats. Apart from testing a couple of general theories in community ecology, the study provides an account of avifaunal status in the hills and provides the base over which further focused research can be carried out in future.

1.2. Objectives of the study:

(1) Explore the influence of vegetation structure and composition on bird assemblages,

(2) Investigate patterns of bird species distribution, turnover along an elevational gradient and underlying factors determining the pattern, and

(3) Explore population and conservation status of bird species of Agasthyamalai Hills.

1.3. Organisation of the thesis:

The thesis is organised into six chapters, and each chapter has its own introduction section while the method section would be overlapping with the subsequent chapter.

The first chapter is the introduction to the whole work discussing the bird community studies in general and possible factors driving the distribution of species.

The second chapter introduces the study site, emphasizing the importance of the site regarding biodiversity and in the context of local people's beliefs.

The third chapter explores the association between the bird species assemblages and community and vegetation composition and structure. Sampling procedures and efforts at each elevation are also described in detail and that forms the basis for analysis of the data for the next two chapters, fourth and fifth.

The fourth chapter deals with patterns of distribution of bird community along elevation and tests various hypotheses which may govern the patterns of distribution.

The fifth chapter discusses the status of bird species of the Agasthyamalai hills in general. Notes on the threatened and disjunct species of Western Ghats are also given. Briefly the methodological issues in estimating density are also discussed.

The sixth chapter is the summary of significant findings, followed by conclusions and highlights of the conservation implications for Agasthyamalai Hills.

CHAPTER- 2

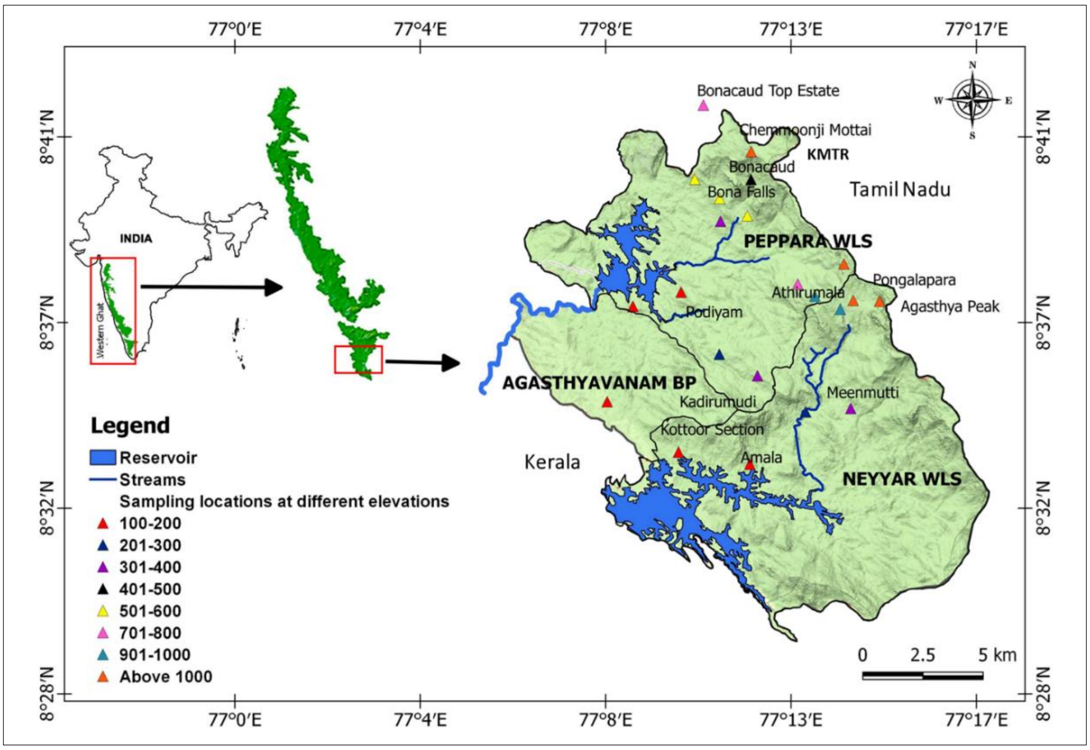
Study Area

Agasthyamalai hills is the southern-most part of the 1600-kilometre-long Western Ghats that runs parallel to the west coast of India. Lying in the southern Western Ghats, the intensive study area falls on the windward side of the western slopes of the Ghats in the state of Kerala. It covers Neyyar Wildlife Sanctuary (NWLS) and Peppara Wildlife Sanctuary (PWLS), and Agasthyavanam Biological Park (ABP). All these three are parts of the Agasthyamalai Biosphere reserve (ABR) (Fig.2.1). In the present study, these three are referred together as Agasthyamalai hills as they form a continuous system of the mountain range in the western slope towards Kerala.

2.1. Western Ghats: The Western Ghats starts from the Tapti river mouth at the base of Gujarat state and runs through Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The Western Ghats is globally recognised as one among the 200 most important ecoregions (Olson and Dinerstein 1988), a global biodiversity hotspot, a designated UNESCO World Heritage Site (Myers et al. 2000) and an Endemic Bird Area (Stattersfield et al. 1998). In the Western Ghats, 508 species of birds, 218 of fishes, 157 of reptiles, 137 of mammals and 126 of amphibians occur. Of this, 78 % of amphibian, 62 % of reptiles, 53 % of fishes, 12 % of mammals and 4 % of birds are endemic to the Ghats (Bawa et al. 2007).

The topography and orography had created variation in climate and rainfall throughout the Ghats that varies latitudinally as well as altitudinally. Along with precipitation and other climatic features, long isolation after breaking away from Gondwana and various other biogeographic episodes has given rise to many endemics and disjunct species. Indian landmass in general shows Gondwana relationship and the southern tip of India shows similarities with the vertebrate fauna of Madagascar (Briggs 2003). It also harbours relict species having association with the Himalayas and Srilanka, which further underscore the importance of these Ghats (Ali 1935, Ripley 1949, Dilger 1952). Vegetation characteristics in the Western Ghats are influenced more by rainfall than the atmospheric temperature (Subramanyam and Nayar 1974). They also form major catchment area for many perennial streams and rivers, significant rivers among them are Cauvery, Krishna and Godavari, which flows towards the East.

(a)



(b)

Figure 2.1: *(a) Map showing the intensive study area and (b) the image of the Agasthyamalai peak from the foothills of the mountain.*

The Western Ghats are majorly classified into three regions: Northern Western Ghats, Central Western Ghats, and Southern Western Ghats (SWG). This otherwise continuous chain of mountains has three gaps; Goa Gap, Palghat gap and Shencottah gap. Of these, the Palghat gap is the widest, up to 30 km (average width 13 km - Subramanian and Muraleedharan 1985), and act as a barrier (separating the part of the Ghats south of the gap from the rest) aiding formation of different clades and species (Ali and Ripley 2001, Joshi and Karanth 2013, Robin et al. 2010).

2.2. Southern Western Ghats: The Southern Western Ghats starts from south of Canara where Netravati Valley forms a broad embayment into the Ghats (Nair 1991). South of Palghat gap the Western Ghats attains the maximum height at Anaimudi (2695 m), the highest peak in South India. Further down south, the Ghats forms an elevated high plateau in Elamalai or Cardamom hills. These hills incline towards Periyar plateau where Devarmalai (1922m) is the highest peak. Further down south of Devarmalai the Ghats has a narrow pass called Ariankavu pass. After the pass, the Ghats attains the roughest terrain with narrow ridge and steep slopes both along the western and eastern side of the Ghats (Ramesh et al. 2003). In the southernmost tip of the Ghats, the highest is Agasthyamalai (1869 m) in Kerala (where the current study is carried out) and Mahendragiri (1654 m) in Tamil Nadu. Among the various sections of the Ghats, the SWGs have the highest mountain ranges, rugged terrains, high rainfall and diverse climate, and are known to harbour high diversity and endemism (Pascal 1988, Pascal et al. 2004). Joshi and Karanth (2013) found that SWGs act as refugia for several wet evergreen species from where invasion has taken place to the rest of the Western Ghats. Owing to the orographic effect, the windward or the western side of the Ghats receives maximum rainfall. The leeward side, i.e., the eastern slope towards the state of Tamil Nadu receives low rainfall. Up to 900 m altitude, the mean temperature of the coldest month remains higher than 20^0C and from 1450 m onwards it is below 15^0C. At the crest of the mountain, the mean temperature in the coldest month may be as low as 7-8^0C (Pascal 1988). High rainfall and a brief dry season have given rise to highly diverse wet evergreen forest, rich in floral diversity and endemism (Pascal et al. 2004).

2.3. Agasthyamalai Biosphere Reserve: In 2016, Agasthyamalai Biosphere Reserve (ABR) was included in UNESCO's World Network of Biosphere Reserves making it the 10^{th} Biosphere Reserve, of the 18 from India. The biosphere reserve is spread across the states of Kerala and Tamil Nadu with a total area of 3500 km^2. The Biosphere Reserve has

1135 km^2 of core area, 1445 km^2 of buffer area and 920 km^2 of transition area. In Kerala, it covers an area of 1828 km^2 having three wildlife sanctuaries (Neyyar, Peppara, Shendurney), territorial divisions of Achencoil, Thenmala, Konni and Punalur, and Agasthyavanam Biological Park (ABP) range. In Tamil Nadu, it covers an area of 1672 km^2 that includes part of Kalakkad Mundanthurai Tiger (KMTR) reserve and parts of Kanyakumari and Tirunelveli districts. These hills harbour one of the last remaining continuous tracts of wet evergreen forest in the Western Ghats with around 150 species of plants endemic to this region (Henry et al.1984). Apart from the floral aspect, these regions are rich in herpetofauna (Bawa et al. 2007). These forests are known for a good population of endangered mammals like Lion-tailed Macaque *Macaca silenus,* Nilgiri Langoor *Trachypithecus johnii,* Indian Elephant *Elephas maximus indicus,* Tiger *Panthera tigris* and Indian Leopard *Panthera pardus fusca* and Nilgiri tahr *Nilgiritragus hylocrius*. The area receives rainfall both during southwest monsoon (maximum rainfall) and from northeast monsoon. Compared to the nearest Cardamom hill, receiving maximum rainfall in the region, Agasthyamalai hills receives low rainfall; but have only two to three dry months in a year (Nair 1991). These mountains serve as the catchment area for rivers like Neyyar, Karamanayar, Thamirabarani and Kodayar.

2.3.1. Peppara wildlife sanctuary: The sanctuary falls between 8^{0}34' and 8^{0}41'N latitude and 77^{0}6' and 77^{0}14'E longitude with total area of 53 Km^2. Neyyar WLS falls in the southeast of the Peppara WLS, in its west is Agasthyavanam Biological Park range, in the north-west is Paruthippally range and in the north is Bonaccord tea estate and Palode range. KMTR fall on the eastern side of the sanctuary. In the eastern part of the sanctuary an area of 30 km^2 comprising hills like Chemmunjimotta, Pandipath, Koviltherimala, Athirumala, Nachiyar-motta, Kannan Kunnu and Kadirumudimala constitutes the 'core zone'. In the western part with an area of 23 km^2 is the buffer zone. The tourism zone of the sanctuary is not well demarcated. Peppara WLS is part of Periyar Elephant Reserve. Areas like Chemmunjii-Panipath having grasslands and montane forest harbours rich endemic flora and fauna in the sanctuary. The main peaks of this highly undulating terrain are Chemmunjimotta (third highest peak in Kerala, 1717 m), Athirumala (1594 m), Arumukhamkunnu (1457 m), Koviltherimala (1313 m) and Nachiyadikunnu (957 m). Along with minor watersheds, Karamana river or Karamanayar, the major river originating from Chemmunjimotta, is the main source of water for Peppara Dam (Management Plan Peppara Wildlife Sanctuary 2011). The adjoining Bonacaud Estate is more than 100 years old and is spread across 1500 acres growing mostly tea, rubber and spices. Most of the tea estate is not actively managed and hence are in different phases of regeneration. Much of the endemic fauna can be sighted here. Due to the adjoining forest areas, the unmanaged parts of the estate have high species richness.

2.3.2. Neyyar Wildlife Sanctuary: The sanctuary lies between 8^{0}17’ and 8^{0}53’N Latitude and 76^{0}40’ and 77^{0}17’E longitude with a total area of 128 km^2. On the north of the sanctuary are Peppara WLS and ABP. Private owned lands skirt the south and west and KMTR falls towards the eastern part of the sanctuary. With an area of 68 km^2 towards the east and northeastern parts with areas like Ananirathi, Venkulamedu, Pulivizhunthanchuna, Varayattumudi, Meenmutty, Theerthakkara, Kaduvappara, Athirumala constitutes the ‘core zone’. Agasthyarkoodam (1868 m), Athirumala (1594 m) and Varayattumudi (1420 m) are prominent peaks of this region. The western part of the sanctuary with an area of 40 km^2 is the buffer zone. Neyyar WLS, like Peppara WLS, also falls under Periyar Elephant Reserve. The Neyyar river, which is the main source of water for Neyyar Dam, originates from Agasthyarkoodam mountains located in the sanctuary (Management Plan Neyyar Wildlife Sanctuary 2011).

2.3.3. Agasthyavanam Biological Park (ABP): ABP is situated between 8^{0}33’ and 8^{0}37’N latitudes and 77^{0} 5’ and 77^{0} 11’ E longitude. This 31 km^2 range is sandwiched between Neyyar in south-west and Peppara in north-east. It forms a part of Kottoor Reserve forest and Paruthypally range. This park was primarily declared with an objective of afforestation, eco-restoration and conservation of wildlife and ecotourism. Apart from Peppara and Neyyar reservoirs, the major sources of water in this area are Anchunazhikathodu, Kottoor thodu and Perumbankadu thodu. The forest range under ABP is mostly degraded moist deciduous forest. This area has plantations in Paruthipally range of Eucalyptus, Albesia, Teak and especially Acacia which is harvested by the Kerala forest department. *Acacia auriculiformis* trees are harvested for pulp wood with patch rotation in 7-8 years. Some of the park fringe area also has privately owned rubber plantation. ABP also has a facility for rehabilitating Elephants. The Elephant Rehabilitation Centre under forest department is used for treating aged and rescued elephants.

2.4. Climate, Rainfall and Temperature: The three intensive study sites (Peppara, Neyyar and ABP) share more or less similar environmental conditions that vary drastically with altitude. The climate in the plains like Kottor range is mostly hot and humid. The higher elevation like Agasthyakodum (area near to peak) and Pandipath is wet and misty with clear skies during the dry months. The higher altitude of the regions receives high rainfall up to 2000-5000 mm with just 2-3 months of dry season (Ramesh et al. 1997). The area receives rainfall during both southwest and northeast monsoons. Heavy windy condition prevails during the Northeast monsoon. In the plains, the maximum mean daily temperature in the hottest month (March) is 35^0C and in the coldest month (January), it is 21^0C. In the higher altitudes, mean daily temperature in hottest month (March) is 32^0C and in the coldest month, it is 17^0C (Management Plan Neyyar Wildlife Sanctuary, 2011).

2.5. Vegetation: Floral aspect has been well studied in these hills. Of the 301 endemic species found in peninsular India, about 45 species are endemic to this locality and a few species have their type locality in Agasthyamalai (Kunhi and Sankar 2002). Broadly, the study area has the following vegetation types (Plate 2.1) according to Champion and Seth (1968), Henry et al. (1984), Varghese and Menon (1999), Varghese and Balasubramanyan (1999), and Menon and Varghese (2000).

2.5.1. Southern Moist mixed Deciduous forest: It is the predominant forest type in the study area. The lower reaches of the study area have degraded forest and prone to fire. However, few good patches of the forest type could be seen from an altitude of 50 m up to 500 m after which semi-evergreen forest type takes over. Few of the common species seen here are *Terminalia paniculata*, *Pterocarpus marsupium*, *Dalbergia latifolia*, *Dillenia pentagyna*, *Careya arborea*, *Butea parviflora*, and *Ipomea campanulata*. Plants such as *Strobilanthes* spp., *Ochlandra* spp., *Bambusa* spp also occurs in some parts.

2.5.2. West Coast Semi-evergreen Forest: This vegetation type occurs at 500 to 800 m of altitude. In a few undisturbed sites in lower altitudes also this type of vegetation occurs. Some of the representative species of this forest types are *Hopea parviflora, Macaranga peltata, Pterocarpus marsupium, Artocarpus hirsutus, Elaeocarpus tuberculatus, Vateria indica, Olea dioica,* and *Xanthophyllum arnottianum.* In some parts, especially near human settlements, species such as *Strobilanthes* spp., *Ochlandra* spp., and *Bambusa* spp also occurs.

2.5.3. West Coast Tropical Evergreen Forest: These are the dominant forest types at altitude of 800 m until 1100m. It occurs at lower elevation at deep pockets in the

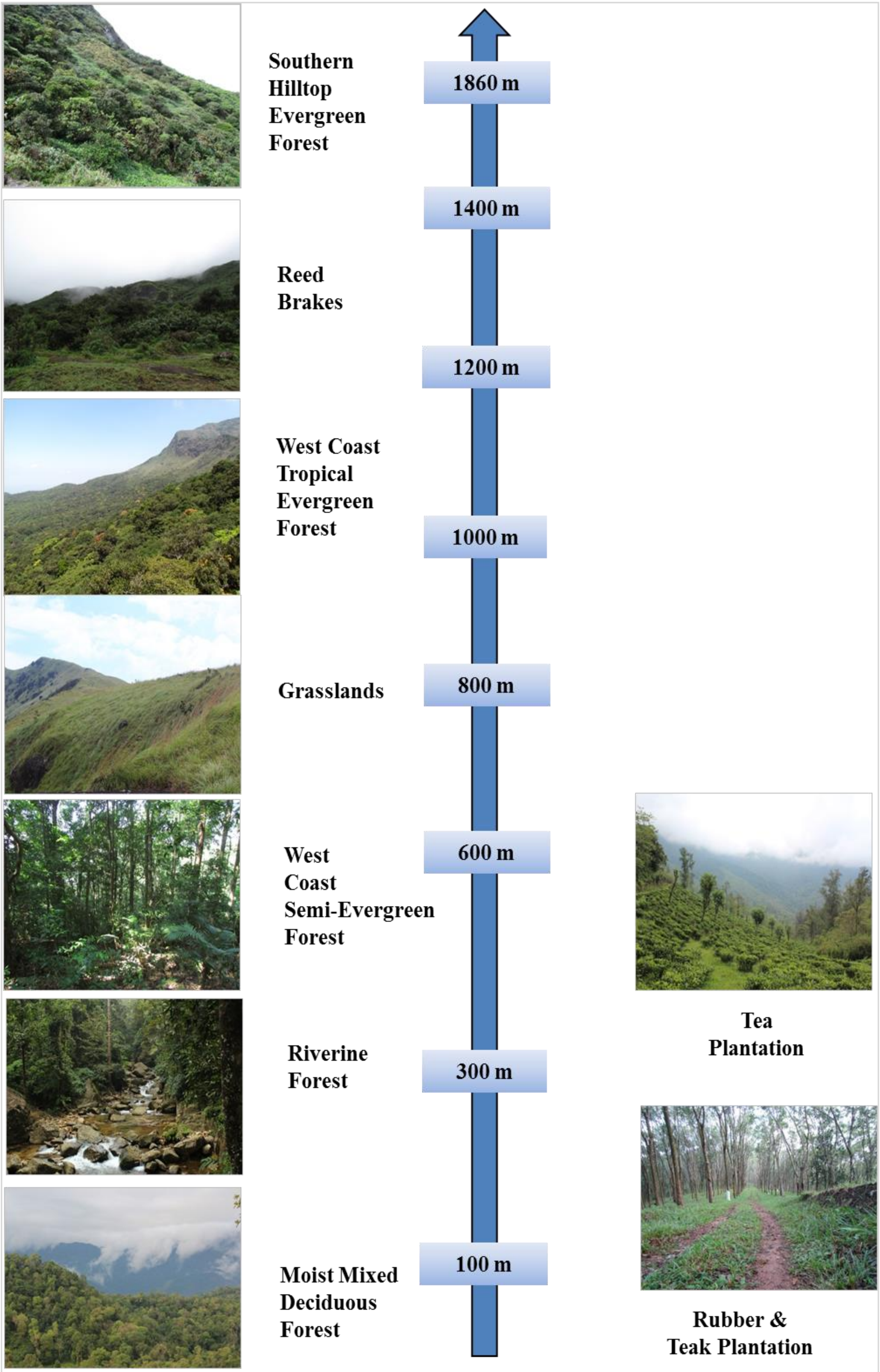


Plate 2.1: *Forest types along the elevation gradient in Agasthyamalai Hills. The elevation given is only for indication purpose. Moist mixed deciduous, riverine and semi-evergreen Forest types extend up to mid-elevation.*

mountain along the slopes of the mountain, intermittently interspersed by patches of grasslands. The common species in these forest types are *Cullenia exarilata*, *Mesua Calophyllum*, *Palaquium ellipticum*, *Elaeocarpus tuberculatus, Poeciloneuron indicum, Artocarpus hirsutus*, *Myristica malabarica*, *Dipterocarpus indicus, Holigarna arnottiana, Pavetta* spp. and *Calamus* spp.

2.5.4. Southern Hilltop Evergreen forest: It occurs from around 1200 m altitude to the top of the hill. The forest is characterised by stunted growth of trees with a maximum height of 10 m, having moss covered bark with tress tightly packed together creating a dense cover. This forest type is exposed to strong winds and hence is stunted, and has lower temperature with heavy mist in most of the months. Plants found commonly here are *Gluta travancorica, Elaeocarpus tuberculatus, Cullenia exarilata, Smilax zeylanica, Calophyllum apetalum, Jasminum* spp, *Impatiens spp, Syzygium* spp*, etc.*

Other vegetation types like reed brakes of *Ochlandra* spp. mostly occurs in higher slopes as well as in the lower altitudes along the streams. Savannah grasslands with species like *Careya arobrea* and *Emblica officinalis* are present at lower as well as medium altitudes. Myristica swamps can also be found in patches here, but not as developed as the ones found in Kulathupuzha in Kerala. Apart from the natural vegetation, lower elevations have rubber, Acacia, Teak and Eucalyptus plantations. Around mid-elevation tea, rubber and other spices are grown.

2.6. Ethnic group: ‘Kani' or ‘Kanikkar' is the major indigenous tribe living in these hills. Their settlements are situated inside the forest as well at the forest fringes. Their settlements are called as ‘Kaanikkudi', their headman is called ‘Moottukani', and their indigenous medicine man is known as ‘Plathi'. Compared to the past, in these days with weakening of traditional social systems, the headman has less influence on the community. These tribes are famous for their traditional knowledge of medicine (Ayyanar and Ignacimuthu 2011, Prakash et al. 2008). This tribe came into limelight for an ayurvedic medicine ‘Jeevani’ the main constituent being the herb ‘Arogyapacha’ *Trichopus zeylanicus ssp. Travancoricus*. The tribe has traditionally used the herb known for anti-fatigue and other properties for centuries. The medicine was developed with the help of Jawaharlal Nehru Tropical Botanical Garden and Research Institute (JNTBGRI) scientists (Anilkumar et al. 2002). Traditionally these tribes are hunter-gathers and depend on forest resources (Anuradha 1998). Forest, wildlife and deity Rishi Agasthya are of high

Bentinckia condapanna (VU), Endemic to Southern Western Ghats

Paphiopedilum druryi Lady's slipper orchid (CR), Endemic to Southern Western Ghats

'Kani' tribe offering prayers to Rishi Agasthya

Plate 2.2

influence in their day-to-day chores, and faith. Nonetheless, in recent times, their customary social organisations have eroded; population and lifestyle have changed which as a concomitant consequence is putting additional pressure on these forests.

2.7. Mythology: According to Hindu mythology, stories abound that during the marriage ceremony of the one of the Trinity God 'Shiva' with Parvati, many devotees and sages gathered in Mount Kailash to attend the occasion thereby tilting the earth to a side for their weight. To restore balance Rishi Agasthya, a greatly revered Vedic sage, was requested to go the southern tip of India. There are several legends about the rishi travelling from mount Kailash to the Vindhyan and finally to the southern tip of the Western Ghats. In Tamil Nadu, Rishi Agasthya is renowned as the proponent of Tamil language whereas in Kerala he is known more for Siddha system of indigenous medicine. The mountain itself is an abode of several medicinal plants, widely used in Ayurveda. In Tamil Nadu, the mountain is known as 'Pothagai' while in Kerala it is known as 'Agathyamalai' or 'Agasthyakoodum'.

Even the nearby mountains are abounded with myths and sanctities and are worshipped by a large number of pilgrims from the neighbouring states. The face of the mountain towards Kerala has a natural impression on the rock that resembles standing Rishi Agasthya. Additionally, a strange resemblance of this mountain to Mount Kailash, another sacred mount, with unique near-conical shape makes it stand out among the chain of mountains (Lockwood 2011). A statute of Rishi Agasthya is placed just at the top of the mountain in the heart of the core region of the sanctuary. Pilgrims from both the states flock to the site especially during February and March with permission from Kerala Forest department. Although there are paths to the site from both Tamil Nadu and Kerala, mostly the path from the Kerala side is used.

With such a rich spiritual value, myths, traditional culture and biodiversity abounding it, this mountain is of utmost importance to people of Kerala and Tamil Nadu. Hence, it attracts numerous pilgrims from both the states, and the number of visitors has been increasing in recent years. Apart from the pilgrims with permits, there is unchecked visitation as diverse routes are there to reach the base of the mountain. The increased visitation has already started taking a toll on these montane forests posing threat to this culturally and biologically highly diverse and endemic region of Western Ghats. The present study is undertaken in the area to unravel further the ecological uniqueness and value of the hills focussing on the avifauna abundant in the area.

CHAPTER-3

Vegetation and Bird Species Assemblages

3.1 Introduction:

The importance of habitat selection by birds on a vegetation gradient has long been recognised and tested for (Wiens 1989). Much of the work on this aspect comes from the temperate forests, but the complex vegetation structure and highly diverse tropical forests are interesting study systems to decipher the within (alpha diversity) and between (beta diversity) community patterns of bird assemblages. Community pattern within and between habitats may differ according to the influencing variables, such as within habitat diversity of birds could be attributed to the spatial heterogeneity of vegetation and bird adaptation to the vegetation (MacArthur and MacArthur 1961). The complex structure of tropical forest may indicate the type and richness of bird fauna as the complexity of structure may influence the birds' nesting, perching, feeding, singing and other life history traits (Halle 1990). MacArthur (1965, 1969) has argued that the number of vertical strata or vegetation layers in the tropical forest is partly responsible for high bird species diversity. Many studies have emphasised the importance of vegetation structure (physiognomy) in determining the bird species diversity (MacArthur and MacArthur 1961, Karr and Roth 1971, Rotenberry and Wiens 1980). The importance of vegetation composition (floristics) has also been equally emphasised for bird species diversity (Wiens and Rotenberry 1981, Rice et al. 1983, 1984, Fleishman et al. 2003). Some of the studies have shown that both vegetation structure and composition are important determinants for bird species diversity (Arnold 1988, MacNally 1990). However, the patterns may differ with the spatial extent. Structural features may be more significant at a biogeographical scale and floristics at a regional or local scale (Rotenberry 1985, Wiens et al.1987). In an assemblage, species, composition and density may be influenced by different factors. As observed by Cody (1981) vegetation structure, influence species numbers, whereas productivity and resource density may influence species composition.

Differential habitat selection by closely associated species in limited resources helps species to coexist (Rosenzweig 1981). The major factor behind the increase in diversity of bird species in tropics is due to increase in the similarity of coexisting species thereby reducing the niche sizes of species thereby causing higher overlap in niches, and hence tightly packed community (Klopfer and MacArthur 1961). Overlap in niches may indicate that bird species could be utilising more than one food resource (Karr 1990) and thus giving rise to mixed feeding guilds especially in structurally and compositionally diverse tropical forests. Species diversity and abundance are masked with species-specific details and hence, to understand the community pattern concerning resources, feeding guild act as a bridge between diversity and abundance (Wiens 1989).

As numbers of species occurring in an assemblage are essential in understanding the pattern of species distribution and habitat use, the difference in abundance of each species is also as vital as diversity. Abundance patterns give a picture of rarity and commonness in the community. Mostly it has been found that in a stable community there will be many species with low abundances and fewer species with high abundance. Thus, in general, terms, such a community will be dominated by a few species occurring in large numbers and many rare species occurring in low numbers, and hence the community as a whole could be more diverse. Such relation of species abundance has been explored mainly under four mathematical models, which could garner biological explanations for the patterns relatively well. These models are (1) Log-series, (2) Log-normal, (3) Broken Stick and (4) Geometric. Of these, the last one is the least popular models of all. In general, a community fits log-series model when there are high number of rare species and low number of abundant species and it probably would be a community governed by fewer factors (Fisher et al. 1943, Magurran 2004). If the community fits the log-normal model, it suggests that the community is in equilibrium (Preston 1948, Ugland and Gray 1982). While that being the most common model seen across taxa, the biological reason behind the fit is debatable (Sugihara 1980, Magurran 2004). The community if fits into a broken stick model (MacArthur 1957) then it is assumed that species abundances are relatively even with very few dominant species. Although this model has been renounced, it is still widely tested (Wiens 1989). Lastly, the geometric series model fits community which has low diversity or in an early stage of succession (Magurran 2004). Although these models suffer from various statistical issues of poor sampling efforts, and robust biological theorizations, these models are widely applied to represent the pattern of abundance in a community.

This chapter primarily explores the role of vegetation attributes over bird species assemblages and the structure of bird community as regards to species abundances. The association between the vegetation structure and vegetation composition and the bird species composition have also been tested. The influence of habitat variables on feeding guilds and feeding strata in different forest types has also been examined. An overview of the bird communities regarding structure and assemblages among the forest types is also presented.

3.2 Methods:

3.2.1. Bird Sampling: Sampling was carried out from October 2012 to December 2014. A variable circular plot method was adopted to estimate bird abundance in all locations. Primarily, sampling plots were placed based on elevation and accessibility at each 100 m elevation, except in the case of the elevation classes 600-700m and 800-900m owing to inaccessibility. Transects of one km length were laid in each elevation band on an already existing path or animal trails (Fig 3.1). Sampling was done in the first 3 hours of the day after sunrise, preferably in clear weather conditions and the duration spent on each point count was 10 minutes (Ralph et al. 1995, Raman and Sukumar 2002, Raman 2003). For a multispecies survey, a longer time period is advisable which can be later truncated to different time slots in the case where overestimation of species may create biases in density estimation (Bibby et al. 1998, Lee and Marsden 2008). In each sampling plot, the observer takes note of individuals encountered along with its distance from the centre of the plot (Bibby et al. 1998, Reynolds et al.1980). Birds seen, heard and flying up to a distance of 50 m were recorded. Radial distance and perching height were recorded using a Nikon Forestry Pro laser range finder.

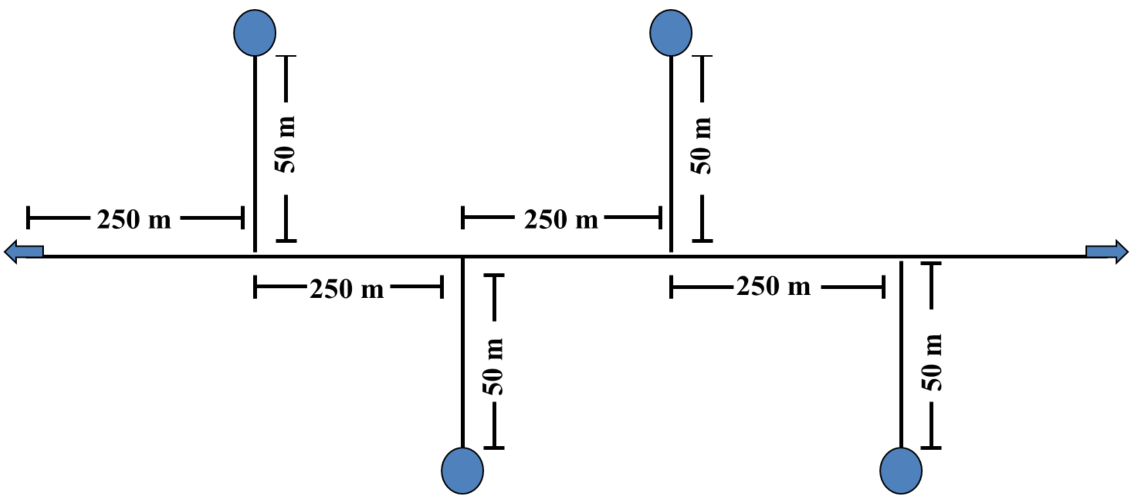


Figure 3.1: *Diagrammatic representation of sampling locations along a transect; the circles indicate the bird and vegetation sampling points.*

Other attributes like group sizes, sex and type of detection (sight / call) were also recorded. Permanent sampling plots were placed at each 250 m, perpendicular to either side of the transect at a distance of 50 meters to avoid habitat edges following Jones et al. (1995). Sampling points were colour marked using paint, and GPS coordinates of locations were noted. In total, 120-point count stations were thus laid representing all habitats types and elevation ranges. Bird counts in each point were repeated with the number of replications varying between 2-16 depending on accessibility and logistics and that resulted in 746-point count efforts in total. Table 3.1 and 3.2. shows the details on the plots and sampling effort at each forest type and elevation classes. Sampling was also governed by the area available at each elevation class (Fig 4.2, chapter 4). Birdlife International (2017) version 9.1 was followed for taxonomic classification and nomenclature, and Rasmussen and Anderton (2012) was followed for subspecies identification (Appendix I).

3.2.2. Vegetation Sampling: To measure vegetation variables, quadrat method was used (Mishra and Jeeva 2012). Only one-time vegetation data collection was done for each plot. For trees, plants with height ≥ 3 m were listed in a quadrat size 10×10 m. For Shrub species, plants with height < 3 m were enumerated in 5×5m quadrat inside the larger tree quadrat of 10×10 m. Attributes such as canopy cover (using Spherical Crown Concave densiometer), percentage herb cover, leaf litter, rock and boulder cover, exposed soil (recorded visually) were recorded in 1×1m quadrat at the four corners of the larger quadrat. To estimate the height of trees, rangefinder was used with visual estimation wherever possible. In the case of trees with multiple trunks, each one was measured separately. For buttressed trees, GBH was measured above the buttress as far as possible. Vegetation plots were laid primarily taking the bird sampling point at the centre, and wherever steep terrain did not permit us to collect data, plots were laid close to the bird sampling point. The Plant list (2013) and Sasidharan (2013) were followed for plant taxonomy.

3.3 Data analysis: Bird and vegetation attributes collected from 120 plots were pooled together for analysis. In total, 223 species of trees (Appendix III) and 158 species of shrubs, belonging to 303 genera, were recorded. For vegetation classification, the forest types were identified using Champion and Seth (1968) and other studies that had been earlier carried out in the study area such as Varghese and Menon (1999), Varghese and Balasubramanyan (1999), and Menon and Varghese (2000).

Table 3.1: *Number of point count stations, total efforts including replicates and bird species recorded in each forest type.*

Major types of forest	Number of Point Count Stations	Total number of efforts with replicates	Total number of bird species recorded in the sample
Hill Top Evergreen	20	84	26
Moist mixed Deciduous	57	434	84
Reed Breaks	2	9	8
Tree Savannah	4	22	27
West Coast Evergreen	28	142	44
West Coast Semi - evergreen	9	55	35
Grand Total	**120**	**746**	**---**

Table 3.2: *Number of point count stations, total efforts including replicates and bird species recorded in each elevation class.*

Elevation Classes (m)	Number of Point Count Stations	Total number of efforts with replications	Total number of species observed in the sample
100-200	33	276	75
200-300	8	47	39
300-400	13	77	56
400-500	3	22	23
500-600	12	90	41
700-800	11	50	37
900-1000	7	24	27
1000-1100	8	52	25
1100-1200	3	15	17
1200-1300	9	39	20
1300-1400	2	10	9
1400-1500	6	27	11
1500-1600	2	6	6
1600-1700	1	5	6
1700-1800	1	3	1
1800-1900	1	3	2
Grand Total	**120**	**746**	**---**

In the case of birds, repeated sampling efforts in each plot have been taken for analysis. From all the plots together, 100 species of birds have been recorded. Further, the bird data have been categorized into 8 feeding guilds on the basis of preferred food, namely (1) frugivore, (2) frugivore and insectivore, (3) frugivore, nectarivore and insectivore, (4) granivore and frugivore, (5) granivore and insectivore, (6) insectivore, (7) insectivore and nectarivore and lastly (8) omnivore. In addition, bird species were categorized, based on perching and feeding height, into different categories as follows: (1) aerial feeder, (2) all canopy levels, (3) bark feeder, (4) ground feeder, (5) lower canopy, (6) Middle canopy, (7) Top canopy and (8) understory. The classification was based on the dietary and feeding height information given by Ali and Ripley (2001) and supplemented by our field observations. The classification of the birds recorded in the sample into different feeding guilds and vertical categories is given in Appendix II. Only one species of granivore and insectivore (i.e. Paddyfield Pipit *Anthus rufulus*) and one species of aerial feeder (i.e. Crested treeswift *Hemiprocne coronata*) was recorded in point counts and therefore it was removed for analysis and data for 7 feeding guild and 7 vertical strata has been analysed except in Fig.3.4 and 3.5 where it is shown for representational purpose.

3.3.1. Diversity indices and species richness estimation: For calculating diversity indices, PAST version 3.20 software was used. For estimating species richness, ESTIMATE S version 9.1.0 (Colwell 2013) was used. Various estimators were compared and selected on the basis of lower standard deviation.

3.3.2. Species abundance distribution: PAST version 3.20 software (Hammer et al. 2001) was used to test different models. For fitting log-normal model, the software runs on an algorithm from Kerbs (1989). The data were binned into different octaves where each octave represents $\log_2$ of the base value. If the value of p is < 0.05, then the distributions are taken as significantly different at the 5 % level. For the analysis, the elevation classes were classified into three different classes of lower, middle and high to test the abundance model.

3.3.4. Vegetation habitat attributes: As the parameter relating to **vegetation composition (floristics),** relative abundance of tree species at each plot was taken. Wherever tree species could not be identified to species level, a unique code was given to such species for the purpose of analysis. As the parameters relating to **vegetation structure (physiognomy)**, plant genus diversity, tree diversity, shrub diversity, tree height diversity, mean of GBH, canopy cover, leaf litter cover, exposed ground, rock and boulder cover and exposed roots in each plot were considered for analysis. For tree height categories, tree heights (m) were classified into 7 categories, namely (0-5), (5.1-10), (10.1-15), (15.1-20), (20.1-25), (25.1-30), (30.1-35).

3.3.5. Step-wise multiple regression: To test for the role of vegetation structure and composition over bird species richness, diversity, feeding guild and feeding stratum, multiple linear regressions (Mac Nally 2000) with weighted least squares was done using SPSS version 20.1 (IBM 2012). As the study area is dominated by hilly terrain, elevation was found to be significantly correlated with bird species compared to other habitat variables. To develop a model in the absence of elevation as predictor variable, weighted least square method has been used.

3.3.6. Test for the influence of vegetation over bird species: To determine if any significant association between bird species composition, tree species composition and vegetation structure, Mantel's test was performed in 'PAST software version 3.20. Mantel's test (Mantel 1967, Mantel and Valand 1970) calculates the degree of association between two variables, which are distance or dissimilarity matrices summarising pairwise similarities among the sampling plots (Urban 2003). Since the test incorporates the species composition into the analysis through the use of similarity indices, it is much easier to infer the correlations between the variables (Shahabuddin and Kumar 2006). The strength of the correlation is often rather low even when it is highly significant statistically (Dutilleul et al. 2000). Different matrices were constructed taking relative abundance of bird species, tree species composition and attributes of vegetation structure (plant genus diversity, tree diversity, shrub diversity, tree height diversity, mean GBH, canopy cover, leaf litter cover, exposed ground, rock and boulders and exposed roots) at each sampling plot. These matrices were then grouped into three matrix types to identify each set. Three similarity indices were chosen: for bird species composition - Simpson index; tree species composition - Bray-Curtis index, and for vegetation structure - Gower index. To examine the relative influence of tree species composition and vegetation structure on bird composition, Partial Mantel test was performed (Rotenberry 1985). In Partial Mantel test, two variables can be compared while controlling for the effect of the third one. Since both tree composition and vegetation structure were significantly correlated with the bird composition, the effect of each variable on bird composition was tested individually, while controlling for the other. The significance levels for both the tests were tested by permutations with 9999 iterations (Hammer et al. 2001). Hierarchical cluster analysis using UPGMA linkage with the Morisita-Horn similarity index was used to analyse the similarity between forest types in regard to bird composition.

3.4. Results:

A total of 3201 individuals belonging to 100 species (78 residents and 21 winter visitors) were recorded from the study area during sampling and 97 species were recorded opportunistically. Thus, in total 197 bird species from 20 orders and 60 families were observed during the study (Appendix I). Species belonging to family Accipitridae was the highest in number (20) followed by Muscicapidae (16 species), Picidae (10 species) and Cuculidae (8 species).

3.4.1. Species richness Estimator: Jackknife 2 (JK 2) was preferred over other estimators because of low standard deviation compared to other estimators and the estimators value were closer to the actual number of species observed (including observational data outside the regular sampling) (Magurran 2004). For rest of the analysis in all other chapters Jackknife 2 estimator has been taken for analysis for bird estimated species richness. Jackknife 1 and 2 are preferred estimators when more singletons and doubletons are in the sample (Magurran 2004, Colwell 2013).

3.4.2. Bird species Abundance Distribution: The model fit for overall study area and elevation category is shown in Table 3.3. For the overall study (χ^2 = 5.979, p = 0.426) and lower elevation (χ^2 = 6.997, p = 0.321), the abundance distribution followed the truncated log-normal model. Middle elevation also followed the log-normal distribution except for the high elevations which closely followed the log-series model with α = 7.687, χ^2 = 18.82, and p = 0.2783.

Table 3.3: *Log-normal fit for various elevation categories.*

	Overall	Lower (100-700) m	Middle (701-1200) m	High (1201-1900) m
Mean (μ)	1.022	0.9668	0.5804	0.2984
Variance (σ^2)	0.4737	0.4436	0.4141	0.5543
Chi^2 (χ^2)	5.979	6.997	2.536	1.014
P value	0.4256	0.3211	0.6382	0.7979

Species abundance distribution models for the overall study area and three elevational categories have been shown in Fig.3.2. For the overall study area (Fig.3.2 (a)), the most abundant class with 8-15 individuals (22 species) which included species like Malabar Barbet *Psilopogon malabaricus* and Nilgiri Woodpegion *Columba elphinstonii*. The next abundant class with 16-31 individuals (21 species) included species like Grey-headed Bulbul *Brachypodius priocephalus*, Dark-fronted Babbler *Rhopocichla atriceps* and Indian Scimitar-babbler *Pomatorhinus horsfieldii*. Nine species had abundance of more than 100 individuals which included species like Crimson-backed Sunbird *Leptocoma minima*, Greenish Warbler *Phylloscopus trochiloides*, Greater Racquet-tailed Drongo *Dicrurus paradiseus*, Southern Hill Myna *Gracula indica*, Nilgiri Flowerpecker *Dicaeum concolor*, Scarlet Minivet *Pericrocotus flammeus*, Square-tailed Bulbul *Hypsipetes ganeesa*, White-cheeked Barbet *Psilopogon viridis*, Yellow-browed Bulbul *Acritillas indica*. Of the total species having 1-3 individuals, 8 species were winter visitors. The partially revealing curve beyond the veil line for overall study area as well as for lower elevation shows the sample has captured rare species.

In the case of lower elevation (Fig.3.2 (b)), the most abundant class with 8-15 individuals had 21 species. Of the total species, 19 species had 1-3 individuals only and that included generalist species like Oriental Magpie-robin *Copsychus saularis*, White-breasted Kingfisher *Halcyon smyrnensis* and endemics like White-bellied Blue-flycatcher *Cyornis pallidipes*.

In the middle elevation (Fig 3.2 (c)) 22 species were observed in abundance class of 1-3 individuals. Only one species i.e., Greater Racquet-tailed Drongo was observed in abundance class of 32-63 individuals. Only 3 (Southern Hill Myna, Square-tailed Bulbul, Yellow-browed Bulbul) species were seen in abundance class of 64-125 individuals.

For the higher elevation (Fig.3.2 (d)), 15 species like Crimson-backed Sunbird, Dark-fronted Babbler, Malabar Whistling-thrush *Myophonus horsfieldii* and Grey Junglefowl *Gallus sonneratii* occurred with 1-3 individuals and only 1 species i.e., Square-tailed Bulbul occurred in abundance class of 64-125 individuals. Only one species i.e., Travancore Laughingthrush *Trochalopteron meridionale* (endemic to southern Western Ghats) was observed in abundance class of 32-63 individuals.

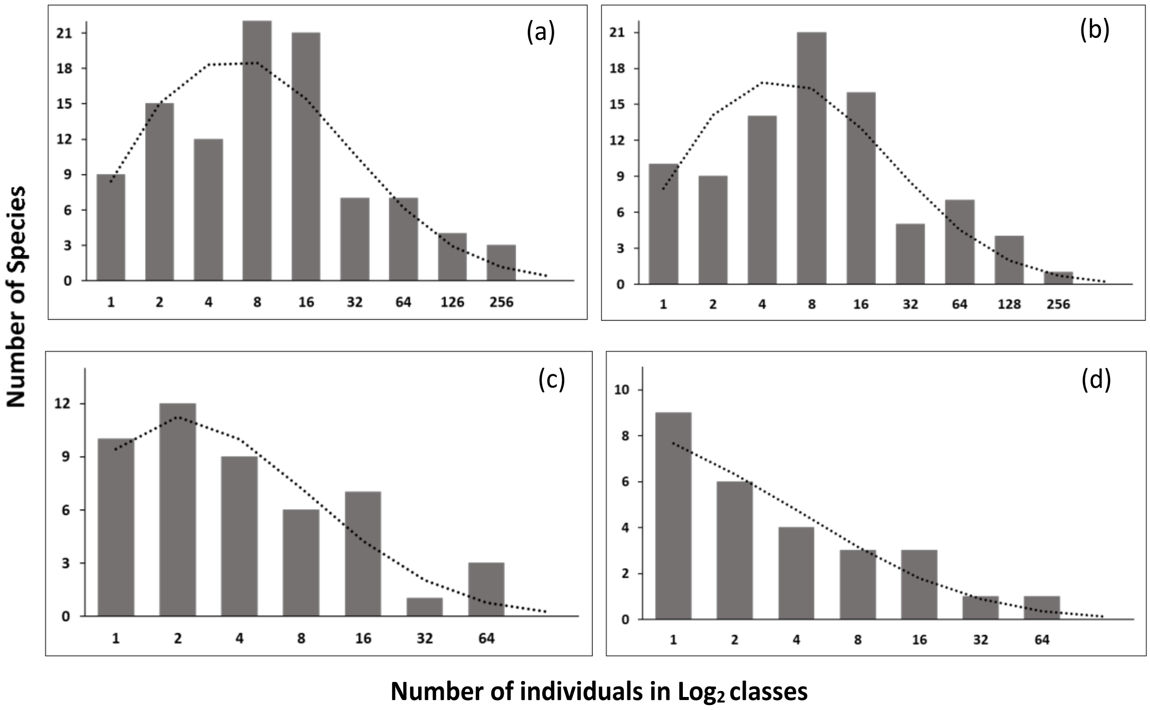


Figure 3.2: *Species abundance distribution on a truncated log-normal scale; (a) Overall (b) Lower elevation (0-700m); (c) Middle elevation (701-1200m); (d) High elevation (1201-1900m). The bar denotes the observed number of species and dotted line corresponding best-fit model values.*

3.4.3. Bird feeding guilds and vertical strata diversity: Bird species composition and abundance in different feeding guilds and vertical strata were analysed. The insectivore guild had the highest diversity (Fisher's α = 10.77 with 48 species), followed by frugivores + nectarivores + insectivore (Fisher's α =2.72 with 15 species), the mixed guild of frugivores + insectivores **(**Fisher's α =35.17 with 10 species), and omnivores (Fisher's α =1.7 with 7 species). In the case of relative abundance, insectivores were the highest (36%) followed by the mixed guild of frugivores + insectivores (20%) (Fig 3.3).

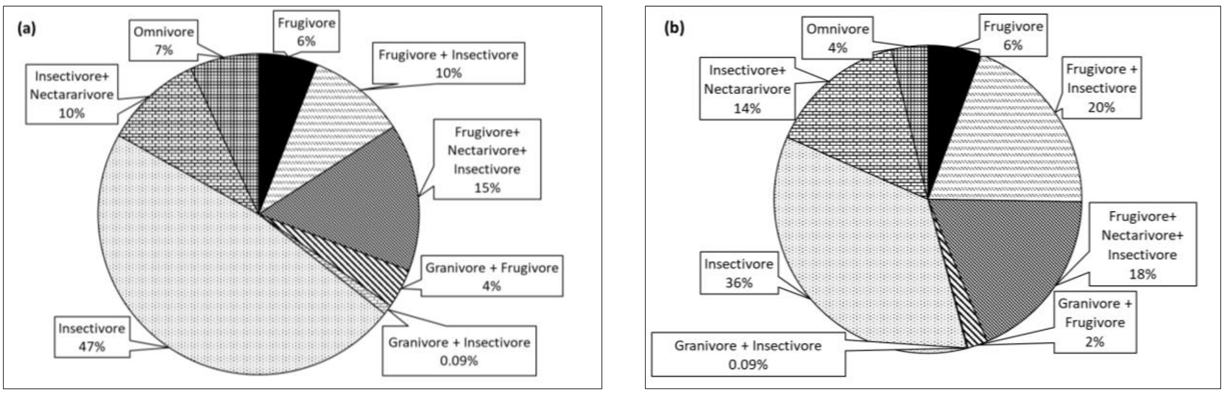


Figure 3.3: *Feeding guilds of the species encountered in the sample (n=100). (a) Species in each guild in percentage of the total number of species; (b) individuals in percentage of the total individuals of all species in each guild.*

Across the vertical feeding strata (Fig.3.4 (a)), the diversity was almost similar for majority of classes. The highest species diversity was of 'ground feeder' (Fisher's α = 3.77 with 15 species), closely followed by 'understorey' (Fisher's α = 3.73 with 14 species), Middle canopy (Fisher's α = 3.32 with 17 species), top canopy (Fisher's α = 2.95 with 17 species), lower canopy (Fisher's α = 2.57 with 15 species) and all canopy feeder (Fisher's α = 2.38 with 12 species). The relative abudance was higher for top canopy cataegory (31%) followed by the lower canopy (27%), middle canopy (17%) and all canopy levels (11%) (Fig.3.4 (b)).

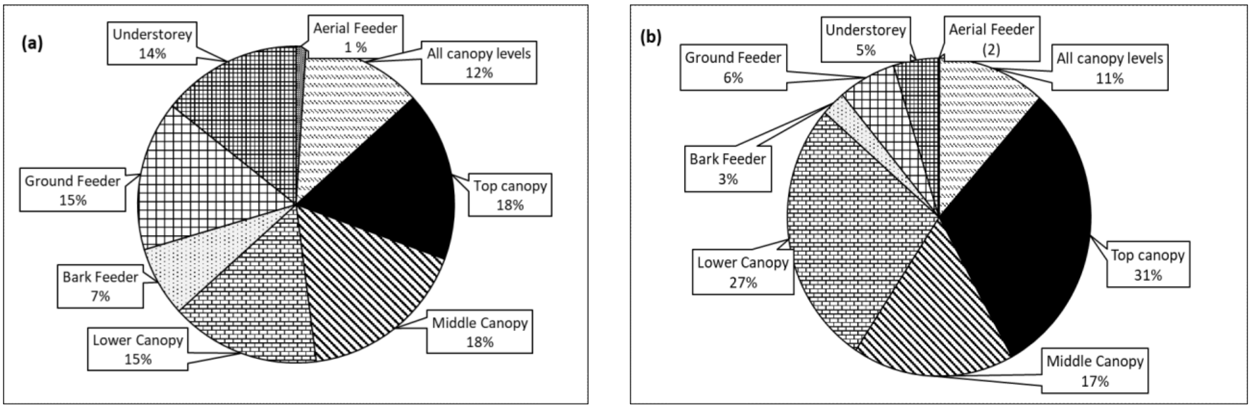


Figure 3.4: *Vertical stratification of species encountered in the sample (n=100), (a) Species in each class in percentage of the total number of species and (b) the number of individuals in percentage of the total individuals of all species in each class.*

The number of guilds and number of individuals present at each feeding stratum were analysed (Fig 3.5). Among the vertical feeding strata, middle canopy showed the highest diversity (Fisher's α = 0.945 with 6 feeding guilds) followed by the ground feeder (Fisher's α = 0.711 with 4 feeding guilds) and top canopy (Fisher's α = 0.6891 with 5 feeding guilds). In **ground feeder** the highest relative abundance of feeding guild was of frugivores + insectivores (0.33) followed by insectivore (0.32). In **understory**, only three guilds were observed with insectivores being the most abundant (0.93). **Bark feeder** consisted of only one feeding guild, i.e., insectivore. In **lower canopy**, the highest relative abundance was of the mixed guild of Frugivores +Insectivores (0.41).

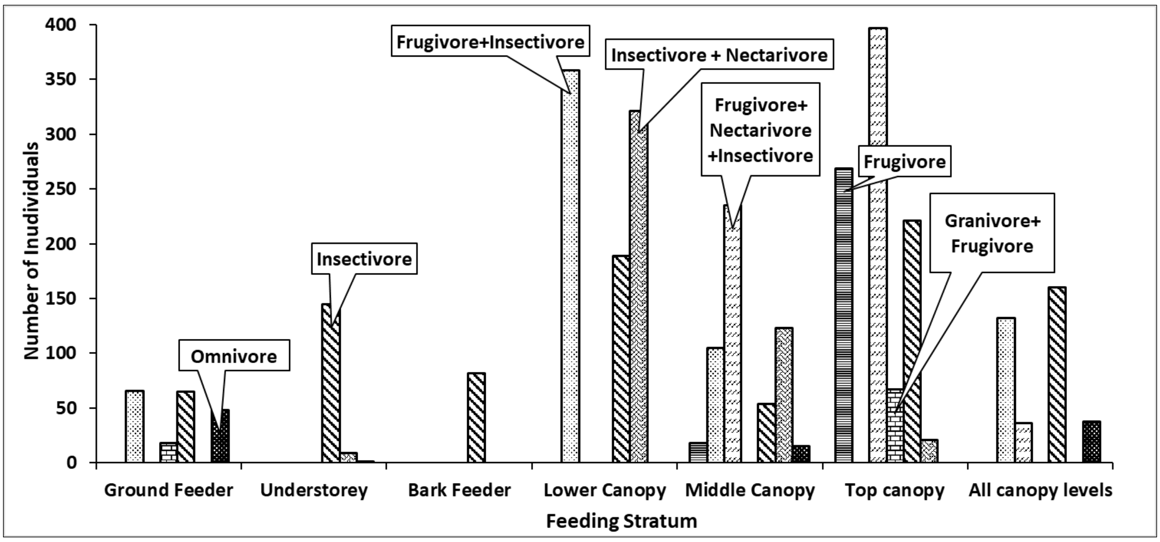


Figure 3.5: *Number of individuals in each feeding guild along the vertical feeding strata. Data callouts are given in box to each category instead of legend.*

Middle canopy with the highest diversity of feeding guilds had the highest relative abundance of frugivores + nectarivores + insectivores (0.43) and then insectivores + nectarivores (0.22) among the guilds in the stratum. **Top canopy**, also had the highest relative abundance of frugivores + nectarivores + insectivores (0.40), followed by frugivores (0.27). In **all canopy levels,** insectivores had the highest relative abundance (0.43) followed by frugivores + insectivores (0.36).

Frugivores were found in both middle and top canopy while their relative abundance was highest in the top canopy (0.94). Mixed guild class of **frugivores + insectivores** were observed in lower (0.54) and middle canopy (0.15). Mixed guild class of **frugivores + nectarivores + insectivores** were observed in the middle (0.35), top (0.59) and all canopy (0.05) strata. Mixed guild class of **granivores + frugivores** were observed in the ground feeder (0.21) and top canopy (0.78). **Insectivores** were found in all feeding strata with the highest relative abundance being in the top canopy (0.24) and then lower canopy (0.20). Mixed guild of **insectivores + nectarivores** were observed in four strata with highest relative abundance in lower canopy (0.67) followed by the middle canopy (0.25). **Omnivores** were found in four feeding strata with the highest relative abundance being in ground feeder stratum (0.48) followed by all canopy level (0.37).

Forest types: Bird species composition along 120 plots were analysed against forest types. The Moist mixed deciduous forest (MMDF) showed the highest diversity (Shannon Weiner H′= 3.621) followed by West coast evergreen forest (WCEG, H′ = 3.005) and

Tree Savannah (SAVN, H ′= 2.91). The lowest diversity was observed in reed brakes (REBK, H′ = 1.55). Feeding guild and vertical strata showed almost similar diversity values among the forest types. The highest diversity of feeding guild was observed in MMDF (H′ = 1.735) followed by WCEG (H′ = 1.666) and West Coast Semi-Evergreen Forest (WCSE, H′ = 1.589). For vertical feeding strata, the highest diversity was observed in MMDF (H′ = 1.661) closely followed by SAVN (H′ = 1.65) and Hilltop Evergreen forest (HTEG, H′ = 1.601). The diversity of bird species, feeding guild and vertical strata were lowest for REBK compared to other forest types. However, the dominance values were higher for REBK than other forest types for all the three categories (Table 3.4).

Table 3.4: *Diversity indices for bird species, feeding guild and vertical strata, in each forest type [Moist mixed Deciduous forest (MMDF), West Coast Semi-Evergreen (WCSE), West Coast Evergreen (WCEG), Tree Savannah (SAVN), Reed Brakes (REBK), Hilltop Evergreen (HTEG)].*

	Bird species		Feeding guild		Vertical stratum	
	H′	D	H′	D	H′	D
MMDF	3.621	0.04133	1.735	0.1983	1.661	0.2187
WCSE	2.586	0.1476	1.589	0.2363	1.47	0.2859
WCEG	3.005	0.07702	1.666	0.2072	1.594	0.2455
SAVN	2.91	0.07727	1.408	0.2788	1.65	0.2199
REBK	1.557	0.3065	0.9529	0.4414	1.195	0.3988
HTEG	2.461	0.137	1.319	0.2965	1.601	0.2404

(H′ denotes Shannon Weiner index of diversity and D denotes dominance index).

Bird composition between forest types: Of the forest types, HTEG shared an equal number of species with MMDF and WCEG, but in terms of bird species composition, it was closer to REBK (0.636). MMDF showed greater similarity with all other forest types except HTEG (0.28) and REBK (0.25) (Table 3.5). Similarly, cluster analysis using species composition in different forest types showed two major clusters (Fig. 3.6(a)). HTEG and REBK ($r = 0.675$, $p < 0.01$) formed one cluster and rest of the forest type formed another. WCEG and WCSE shared greater similarity ($r = 0.858$, $p < 0.01$) compared with other forest types. MMDF shared greater similarity with WCEG (r =

0.746, $p < 0.01$) then WCSE ($r = 0.644$, $p < 0.01$). SAVN showed greater similarity with MMDF ($r = 0.626$, $p < 0.01$) compared to other forest types. Cluster analysis using Morisita-Horn similarity index showed clear zonation of forest types along the altitudinal gradient. The bird composition was also similar, changing along the altitudinal gradient.

Table 3.5: *Morisita-Horn similarity index among forest types in terms of bird species composition. Bird species abundance was used to calculate the similarity index between the forest types. Numbers without decimals given below the diagonal depicts the number of shared species and numbers with decimal above the diagonal depicts similarity indices.*

	HTEG	MMDF	REBK	SAVN	WCEG	WCSE
HTEG	-	0.28	0.636	0.152	0.446	0.466
MMDF	17	-	0.25	0.626	0.747	0.648
REBK	7	6	-	0.118	0.42	0.469
SAVN	8	27	5	-	0.506	0.289
WCEG	17	36	7	16	-	0.872
WCSE	10	34	6	18	26	-

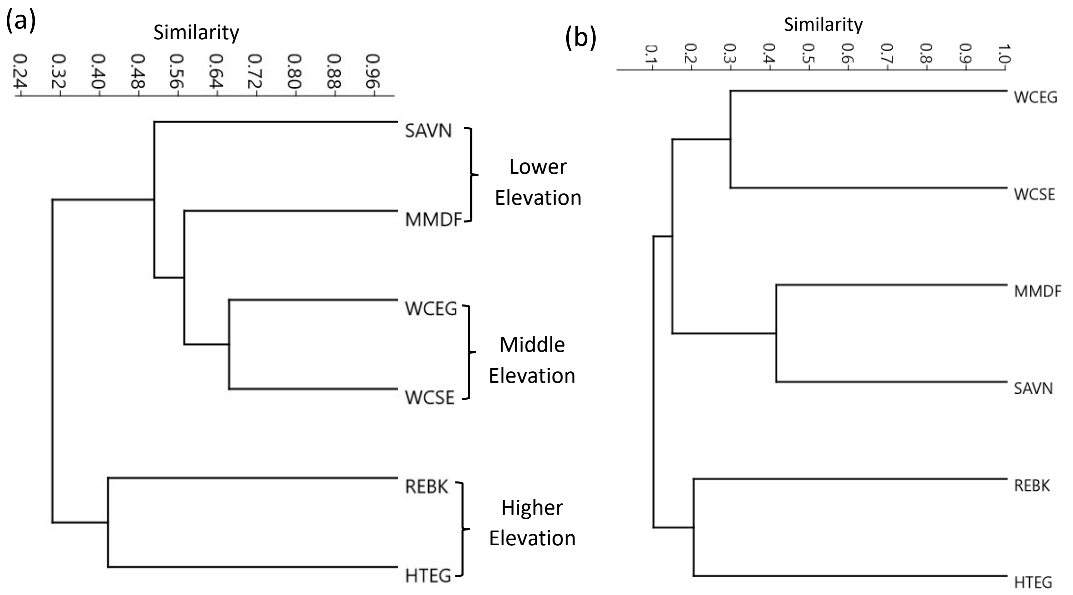


Figure 3.6: *Dendrogram showing clustering of forest types using Morisita-Horn similarity index among the forest type with respect to (a) bird species and (b) tree species composition.*

Tree species composition between forest types: Tree species among forest types were analysed by cluster analysis using Morisita-Horn similarity index (Fig.3.6 (b)). Almost a similar pattern of clustering was observed for tree species as well as bird species. The west coast evergreen and semi evergreen formed one cluster with close proximity to moist mixed deciduous and tree savannah. The hilltop evergreen forest and reed breaks made a separate cluster. The highest tree species diversity was observed in WCEG (H ′= 3.879), followed by HTEG (H′ =3.657), WCSE (H′=3.637), MMDF (H′ =3.55), REBK (H′=2.64) and SAVN (H′=1.92).

3.4.4. Bird species attributes and habitat variables:

Correlation between bird species and habitat variable is shown in (Table 3.6). Most of the variables are highly correlated with elevation. All the bird attributes showed significant negative correlation with elevation. Tree diversity showed significant positive correlation with elevation and significant negative correlation with bird species attributes. Bird diversity and estimated species richness also showed negative correlation with canopy cover.

Table 3.6: *The r values and associated P-values for bird species attributes with elevation and habitat variables.*

	Bird Diversity	Bird estimate species Richness	Guild Diversity	Bird Vertical stratification	Elevation
Elevation	-0.643**	-0.570**	-0.573**	-0.415**	1
Plant Genus Diversity	-0.089	-0.079	-0.086	-0.091	0.081
Tree Diversity	-0.401**	-0.383**	-0.170	-0.275**	0.408**
Shrub Diversity	-0.217*	-0.154	-0.201*	-0.159	0.235**
Tree height Diversity	0.118	0.114	0.171	0.145	0.045
GBH mean	0.096	0.087	0.094	0.102	-0.070
Canopy Cover	-0.274**	-0.274**	-0.161	-0.175	0.303**
Herb Cover	0.183*	0.156	0.075	0.116	-0.208*
Ground Cover	0.166	0.152	0.217*	0.116	-0.321**
Rock and boulder	-0.129	-0.083	-0.134	-0.042	0.223*
Litter Cover	-0.111	-0.149	-0.086	-0.096	0.179*

**(2-tailed). Correlation is significant at the 0.01 level *Correlation is significant at the 0.05 level.

Stepwise multiple linear regression was performed taking bird diversity (H′), birds estimated species richness (JK2), guild diversity (H′), and bird vertical stratification (H′), as dependent variables against 10 habitat variables: plant genus diversity, tree diversity, tree height diversity, shrub diversity, mean GBH, canopy cover, leaf litter cover, exposed ground, rock and boulders and exposed roots (Table 3.7). Elevation was found to have a significant correlation with bird species compared to all other habitat variables. To develop a model in the absence of elevation as predictor variable, weighted least square method has been used. Hence elevation has been weighed against the habitat variable in all cases.

When bird species diversity was regressed against all habitat variables, the most suitable model was combination of tree diversity, shrub diversity and tree height diversity. 26.5% is the variability accounted by this model. Variability explained by each variable is 6.15% by shrub diversity, 9.85% by tree diversity and 6.76 % by tree height diversity.

Bird Diversity = (-0.20*Shrub diversity) + (-0.389*Tree diversity) + 0.328*Tree height diversity + 2.175

Birds estimated species richness and habitat variables

The total variability explained by this model was 16.1%. Individual contribution by vegetation variables were 11.08% by tree height diversity, 4.49% by tree diversity and 3.27% by ground cover.

Birds Estimated Richness = 6.107*Tree height diversity + (-4.329*Tree Diversity) + 0.130*Ground cover + 14.451

Bird guild diversity and habitat variables

Overall model variability explained is 23.6 %. Each explanatory variable’s contribution is 20.88% by tree height diversity and 8.94 % by ground cover.

Bird Guild Diversity = 0.350*Tree height diversity + 0.009*Ground cover + 0.595

Bird Vertical Stratification and habitat variables

Total model variability explained is 24.5%. Individual contribution by vegetation variables are 5.24% by shrub diversity, 11.22% by tree diversity and 5.56% by tree height diversity.

Bird Vertical Stratification = (-0.118*Shrub diversity) + (-0.259*Tree diversity) + 0.186* Tree height diversity + 1.542

Table 3.7: *Result of stepwise multiple regression analysis, on bird species diversity, estimated richness, guild diversity and vertical stratification diversity against 10 vegetation variables (plant genus diversity, tree diversity, tree height diversity, shrub diversity, mean GBH, canopy cover, leaf litter cover, exposed ground, rock and boulders and exposed roots).*

Dependent Variable	Model Selected	F	P	Adjusted R^2 ±SE	Durbin-Watson
Bird Diversity	Shrub Diversity Tree diversity & Tree height Diversity	15.573	0.000	0.265±12.36	1.388
Birds Estimated Richness	Tree height Diversity Tree diversity & Ground cover	8.747	0.000	0.161±205.3	1.352
Bird Feeding Guild Diversity	Tree height Diversity & Ground cover	19.642	0.000	0.236± 8.25	1.801
Bird Vertical Stratification	Shrub Diversity Tree Diversity & Tree Height Diversity	14.088	0.000	0.245±7.796	1.775

3.4.5. Role of vegetation structure and composition on bird species composition:

Mantel test was done on bird species composition with tree species composition and vegetation structure. All forest types except reed brakes were considered for analysis, as samplings were very low for the later. Vegetation structure and tree composition in each plot was significantly correlated (r = 0.236, p = 0.0001). Bird composition was also found positively correlated with both tree composition (r = 0.211, p = 0.001) and vegetation structure (r = 0.141, p = 0.0008). Partial Mantel test showed that correlation between bird species composition and tree species composition were significant (r = 0.239, p = 0.0001) even when controlled for the effects of vegetation structure. In contrast, bird species composition did not show any significant correlation with vegetation structure (r = 0.084, p = 0.025) when the effect of tree composition was controlled (Fig 3.7).

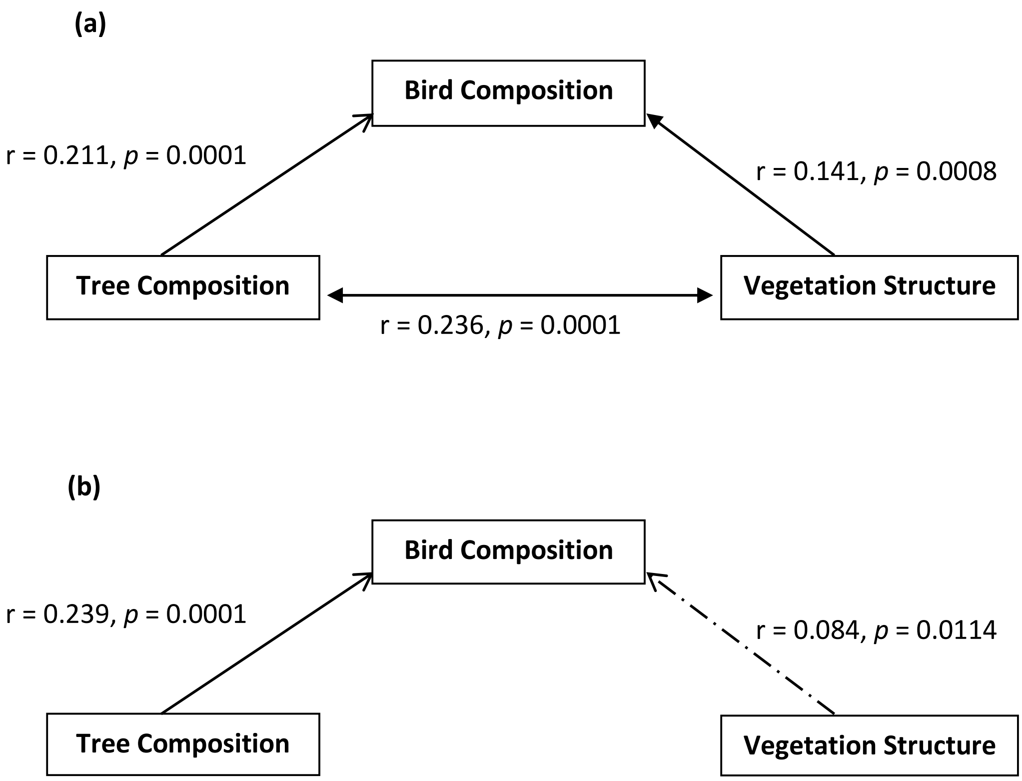


Figure 3.7: *Role of tree composition and vegetation structure over bird species composition among sampling plots. (a) Mantel correlation and significance value with habitat attributes and bird composition. (b) Partial Mantel Test where the correlation between tree composition and vegetation structure has been partialled out. (Dark line shows significant correlation and dashed line weak or no correlation.*

Role of vegetation structure and composition over feeding guilds: Partial Mantel test was performed to analyse the association between the feeding guilds with vegetation structure and composition. When all the guild classes were analysed together, no significant correlation with either vegetation composition (r = 0.049, p=0.023) or structure (r = -0.003, p = 0.522) was observed after the effect of either of the variable was partialled out. When the guilds were analysed separately, frugivore + insectivore (r = 0.116, p = 0.001), granivore + frugivore (r = 0.106, p = 0.0003) and insectivore + nectarivore (r = 0.216, p = 0.0001) guilds showed significant correlation with tree composition when effect of vegetation structure was partialled out. Further, none of these guilds showed any correlation with vegetation structure.

3.5 Discussion:

Species abundance models: Overall bird community of Agasthyamalai hills followed a log-normal distribution. Log-normal curves indicate that more bird species are of intermediate abundance with only a few rare species. Same was the case for lower elevation, which could be indicative of well-developed habitats and availability of resources. However, in the middle elevation and especially for high elevation the bird community is showed higher preference towards log-series model. This indicates the majority of species in higher elevation are present in lower abundance and very few species are present with intermediate abundance.

There are some traits of community that makes it good fit for the model. These traits are (1) large number of species, (2) distribution of niche sizes among species should be normal thereby the community having more of moderately abundant species and few rare species, (3) community is undisturbed and hence in equilibrium, and (4) adequacy of sampling (Wiens 1989, Hill and Hamer 1998, Magurran 2004). For the current study, the model fit suggests that overall sampling of the study area is sufficient as the left side of the veil line is also being revealed (Preston 1948). The lower elevation also shows the same pattern as the overall community. Although, the middle elevation deviates from the log-normal fit, but yet it is better fit than the log-series model. Interestingly the higher elevation shows a better fit to the log-series model. It is considered that log-normal will fit to those communities governed by multiple variables and log series will be fitting the communities with lesser number (one or two) of variables influencing the patterns in the community (consequence to the central limit theorem) (Magurran 2004 and references therein). If this holds true then in the current study area, the lower and middle elevation has a greater number of forest types that includes, moist mixed deciduous forest, low elevation semi-evergreen, riverine forest, tree savannah, reed brakes. Apart from the varied forest types, the temperature and precipitation also vary in the study area. It is possible that multiple factors govern the abundances in lower elevation forest due to availability of varied habitats; but as the elevation increases the variability in habitat decreases. As in the case of higher elevation, the hilltop evergreen forest is the dominant forest type with patches of reed brakes. In addition, throughout the year, the higher elevation has lower temperature and higher precipitation with only two to three dry months. The bird diversity has shown a significant negative correlation with precipitation ($r = -0.754$, $p < 0.05$) and significant positive correlation with minimum temperature ($r = 0.771$, $p < 0.01$). Hence, with a lesser number of factors influencing bird abundance at the higher elevation, the log-series model apparently is a better fit.

Ugland and Gray (1982) and Hill and Hamer (1998), have also demonstrated the usefulness of these models as an indicator of the disturbance. An undisturbed community will follow log-normal and a disturbed community the log-series model. Although at higher elevation temperature is almost constantly lower throughout the year, disturbance by intense precipitation may prevent the community from achieving a theoretical equilibrium (Buzas 1972). For the current study majority of the sampling points were in relatively lesser-disturbed forests. In the study area, lower elevation forests are naturally more disturbed from anthropogenic pressure compared to other elevation belts; nevertheless, it showed log-normal distribution. The high elevation forests in the area is also under anthropogenic pressure due to pilgrimage; however, that has been not quantified, and hence it is difficult to tease apart whether the pattern is due to disturbance, biotic and abiotic variables or simply an artefact due the sampling strategy. The use of these models as indicators of disturbance is however debatable (Nummelin 1998, Watt 1998) and requires furthermore intensive and extensive investigations for clarity.

Even though the biological explanation behind the fit of the log-normal and log-series model is logical, mathematical issues behind the fit cannot be ruled out. The fitness of the log-normal model specific to the local situation is debatable in terms of its ecological / biological rationale because large population may tend to fall into a log-normal distribution owing to central limit theorem (Magurran 2004 and references therein). In the current study, more sampling effort is put in the moist mixed deciduous forest at lower elevation, and that might be the reason that in the overall landscape as well as in the lower elevation the community, having a greater number of species as well as individuals, fits the log-normal distribution. On the other hand, the higher elevation areas have relatively lesser number of sampling efforts, and was seen to have lesser number of species (hilltop evergreen forest inherently have lower species diversity than other forest types) showing better fit to the log-series model. Thus, it is difficult to explicate the models based on their biological and mathematical reasoning in the current study as of now.

Bird community assemblage: Insectivores were the most abundant among the guilds which is a common phenomenon in forested habitats (Jayson and Mathew 2003, Das 2008). Insectivores were also the only guild spread across all the feeding strata thereby indicating the presence of varied vegetation structure and composition available for the species. In general, it was observed that relative abundance of guilds like insectivore, frugivore, and nectarivore constituted about 94 % of the total guild class indicative of the rich food resources and intact forest. Frugivores are also important element of tropical communities because of their role in seed dispersal (Loiselle and Blake 1991). Insectivore and frugivores in general are observed to decline in disturbed areas whereas granivores increases (Gray et al. 2007). Relative abundance of guilds like granivore + frugivore and omnivore were less compared to other guilds. This can be attributed to the fact, species in these guilds need more of open country habitat which is hardly available except the tree savannah in the current study. Omnivores had species like Large-billed Crow *Corvus macrorhynchos*, Rufous Treepie *Dendrocitta vagabunda* and Southern Coucal *Centropus sinensis* which are open country and generalist species. Other omnivore species having affinity to forest included Grey Junglefowl *Gallus sonneratii*, Red Spurfowl *Galloperdix spadicea* and White-bellied Treepie *Dendrocitta leucogastra* among others which occurred in higher abundance compared to the generalist species.

Among the forest types the bird species composition almost showed the same trend as tree species composition. The bird composition among the forest types differed and showed clear clustering with increasing elevation. The lower elevations are dominated by moist mixed deciduous forest which showed the highest bird diversity. The tree savannah mostly occurs in small patches especially close to moist mixed deciduous forest and hence shared more common species. The hilltop evergreen forest and reed brakes showed highest similarity with each other. Both the forest types occur in conjugation in higher elevations and the tree species composition when analysed across different forest habitats formed almost same type of clusters as bird composition among different forests. Raman and Sukumar (2002) observed that sites with similar tree composition had more similar bird communities. However, the tree species diversity was higher for evergreen and hilltop forests compared to moist mixed deciduous forest. The low bird species diversity in hilltop evergreen forest and reed brakes could be due to reduced canopy height and structural complexity compared to other forest types (MacArthur and MacArthur 1961).

The bird species diversity among the vertical strata was almost similar. Of the 98 species (two species deleted for reasons mentioned earlier), only 12 species were recorded at all canopy levels. The middle canopy had maximum number of guilds followed by top canopy; however, the relative abundance of individuals was higher for top canopy than all the other canopy levels. Jayson and Mathew (2003), in their study of evergreen and moist deciduous forests in Silent valley, reported higher utilization of middle canopy compared to bottom or top canopy. Ramachandran and Ganesh (2012) in their study incorporating both traditional as well as canopy sampling found canopies to be species rich compared to mid-storey and understorey in primary forest, especially presence of guilds like frugivores and nectarivores in the canopy. The current study also observed similar patterns, the highest relative abundance of insectivore and frugivores were observed in the top canopy.

Role of vegetation structure and composition on bird species composition: In the current study, bird species composition was found to be significantly related to vegetation composition then vegetation structure across different habitats. This finding is consistent with studies such as Jayson and Mathew (2002) in Silent valley that found high density of birds being related to high vegetation diversity. Raman et al. (2005) found bird community composition as significantly correlated with elevation and tree composition along the altitudinal gradient in KMTR. Raman and Sukumar (2002) in their study of abandoned plantations and logged forest in the Western Ghats also found significant relationship between bird species composition and vegetation composition and no relation to vegetation structure. Ramachandran and Ganesh (2012) in KMTR in a comparative study between disturbed and primary forest found that along a successional gradient, both habitat structure and tree species composition influence bird community structure. Contrary to this, Daniels et al. (1992) found an inverse relation between bird diversity and plant species diversity and structural attributes of vegetation. On a similar line, Johnsingh and Joshua (1994) in the study carried out in dry deciduous and riverine forest in

Mundathurai plateau did not find any significant relation between bird species composition with either tree species or foliage diversity. Jayson and Mathew (2003) reported significant positive correlation with foliage abundance and bird diversity in their study in Silent Valley. In central Indian highlands, Jayapal et al. (2009) found bird species composition to be significantly related to forest structure across habitats and vegetation compositions within the moist deciduous forest. Teak and Sal trees dominate the forest type in this study. In the Western Himalayas, Joshi and Bhatt (2015) found a weak correlation between bird composition and tree diversity and density; instead, they found a significant correlation with shrub diversity and density. Acharya et al. (2017) in Eastern Himalayas, found a significant positive relation between foliage abundance and species richness, abundance and diversity of birds. From the above-mentioned studies, in the forest types known for high plant species diversity significant positive relation with bird species composition was seen unlike the relatively less diverse forest types as well as those with no contiguous forest patches that are structurally diverse like that by Daniels et al. (1992), Jayapal et al. (2009) and Joshi and Bhatt (2015). The present study is carried out along 6 habitat types that included moist mixed deciduous forest, west coast evergreen and Semi-evergreen forest, and Hilltop evergreen forest known for high tree species diversity and this may be the reason that tree species diversity overrides the influence of vegetation structure over bird species composition, contrary to the earlier studies. Though it is not necessary that this relation will be apparent in species rich habitat as some of the studies with structurally simple forest has also shown similar relation (e.g. Tomoff 1974 in desert scrub, Wiens and Rotenberry 1981, Rotenberry 1985 in shrub steppe, Fleishman et al. 2003 in desert watershed). In the present study, that also considered the role of vegetation structure and composition on birds with respect to feeding guild and foraging strata, the guilds taken together did not show any significant correlation with either vegetation composition or structure.

Insectivorous birds are known to use the vertical stratification of forest (Holmes et al. 1979) as they use different foraging techniques to procure food, while frugivores are associated with vegetation composition because of their dependency on fruits and phonological seasonality. Interestingly, in the current study neither insectivores nor frugivores showed any correlation with the tree species composition. For frugivores, it could be due to the local movement among different habitats and altitude (Loiselle and Blake 1991) and availability of variety of fruiting trees in the nearby locations, while, insectivores occupied all the strata with high relative abundance in top canopy. Contrary to this, the mixed guild of frugivore + Insectivore, granivore + frugivore and insectivore + nectarivore showed significant, but weak, correlation with tree composition that explains their dependence upon the tree diversity. Feeding guilds are known to be governed by the distribution of food plants (Rice et al. 1983). Cueto and Casenave (2000) also observed plant species composition influenced frugivore-insectivore guild. The feasibility of prey capture and abundance of prey varies among different tree species and associated foliage density (Holmes and Robinson 1981). Whelan (2001) observed that for insectivores, different trees species provides distinct foraging environment and microhabitat. In the present study, the insectivore feeding guild had the highest diversity, and relative density, which is found to be common in other studies also (Vijayakumar 2015). The dominance of insectivores in understory and mixed guild across the canopy may reflect the relative availability of different food resources (Thiollay 1994).

The study area is predominately a hilly terrain, and forest types are quite distinct with increasing altitude with a smooth transition. Bird species diversity and richness were significantly correlated with elevation that could be confounding the effect of vegetation attributes (Lescourret and Genard 1994). When effect of elevation was weighted against other habitat variables, then a combination of habitat variables explained for bird diversity and other habitat attributes. A point to be noted here is that tree height diversity was corelated with tree diversity ($r = 0.228$, $p < 0.05$); nevertheless, the variable was maintained in analysis for its importance in bird community structure. The percentage contribution of each model was generally low in explaining various bird species attributes indicating role of other explanatory variables in shaping the community structure. Vegetation itself showed cleared demarcation with increasing altitude. Many studies have shown the change in results with different spatial extents. Estades (1997) in his study found mixed relationships according to the scale of analysis where foliage height diversity explained the variation in bird richness and density on a vegetation gradient; but within sites some bird species showed affinity to particular plant species. Cueto and Casenave (1999) found vegetation structure to be determinant to bird species richness at three spatial scales but also found the complexity of other factors including climatic influencing bird species richness. Rotenberry and Wiens (1980) suggested the possible role of other environmental variables influencing the bird species composition than only the vegetation attributes.

3.6. Conclusion:

Bird community of Agasthyamalai hills, with many species having intermediate abundance and few rare species with lower abundance, showed a log-normal distribution. However, when tested for higher elevations it seemed to closely follow log-series model indicating more of rare species with low abundance and a few species with intermediate abundance. Although, the higher elevation having montane habitat are inherently species poor, low sampling at higher elevation could be an additional reason for log-series model.

In general, the higher diversity and abundance of insectivores and frugivores, and mixed guild of these are indicative of the intact forest habitats of the study area. Compared to the earlier mentioned guild, omnivores and granivores were low in terms of both species diversity and relative abundance, indicative of lesser availability of open habitat specialists. As echoed in other studies in the Western Ghats, current study also showed highest diversity and relative abundance of feeding guilds in middle canopy followed by top canopy.

Bird diversity was higher in moist mixed deciduous forest compared to other forest types. However, the similarity of bird species composition was not much different among forest types except the hilltop forest and associated reed beds. Tree species diversity increased with increasing elevation, while bird species diversity decreased. This could be due to the harsh climate in high elevation areas that supports only certain species. Though vegetation structure (combining various variables of vegetation structural attributes) did not show any correlation with bird species richness in the absence of vegetation composition, the importance of vegetation structure cannot be ruled out entirely. In the present study, all forest types were analysed together, and hence leaving the possibility of the factor of heterogeneity among habitats influencing the analysis. If each forest type is analysed separately, then perhaps it could reveal within-habitat pattern of bird species diversity. Although, the bird species composition differed along the forest types, the guild diversity and vertical strata did not show much difference between each in diversity and dominance indices. When forest types were analysed based on bird species composition and tree species composition, it showed clusters that were distinct with altitudinal classes. This could be due to the confounding effect of elevation over bird and tree species diversity.

CHAPTER-4

Bird Species Richness Pattern along Altitudinal Gradient

4.1 Introduction:

The most alluring fact about species richness patterns is that it, varies depending upon a gradient and differs when analysed at different spatial scales. This pattern has long been tested over latitudes, which shows that species richness increases from higher to lower latitude. Elevational gradients, where a substantial change in community composition and abiotic factors are observed at short distances (Terborgh 1971), are potential surrogates of latitude easier to quantify, and hence have given rise to a number of studies in recent decade (Sanders and Rahbek 2012, Grytnes and McCain 2007). Rahbek (1995) observed three kinds of species distribution patterns along the elevational gradient: mid-elevation peak, monotonic decline, and increase with elevation. A mid-elevation (unimodal) peak is reported to be the most common pattern of species richness in most of the taxa especially birds (Rahbek 2005). Shiu and Lee (2003) found that resident species showed a hump-shaped pattern while migratory birds showed a negative exponential pattern in diversity. Hawkins (1999) observed decline in species richness with increase in altitude until 1300 m after which it remained constant or declined slightly.

Studies along the elevational gradient have additionally concentrated on three major features; change in species richness, species turnover patterns, and range sizes of species (Raman et al. 2005). Bird species richness in a gradient is determined by the bird composition that structures the community. The change in species assemblages along a slope can be quantified in terms of species turnover; higher turnover rate signifies a higher replacement of species or set of different assemblage (Whittaker 1972). Turnover of species may be due to change in temperature, rainfall, humidity, vegetation, productivity, ecotone and area availability (Terborgh 1971, 1977; Rahbek 1995, 1997; McCain 2005, 2006). Information regarding the range sizes of bird species especially of threatened and endemic species is helpful in locating hotspots of diversity in a landscape. Rapoport’s elevational rule, states a positive relationship of species range sizes with increasing elevation (Stevens1992). However, the generality of Rapoport’s rule is also debatable (Gaston and Chown 1999, McCain and Knight 2013).

Factors influencing species' distribution and turnover pattern have long been of interest in ecology and biogeography alike. Studies to understand the factors governing distribution patterns have led to more than 100 plausible theories which have been proposed and tested over different taxa (Gaston 2000). How various factors influence diversity in one region and taxa depends upon the scale, extent and resolution of analysis (Blackburn and Gaston 2002, Willig et al. 2003). The underlying mechanisms have been broadly classified under five different hypotheses: (a) species-area (Connor and McCoy 1979), (b) species-productivity or habitat heterogeneity (Mittelbach et al. 2001) (c) species-energy or climatic factors (Hawkins et al. 2003) (d) phylogenetic niche conservatism (Khaliq et al. 2015) and (e) geometric constraints or the mid-domain effect (Colwell and Hurtt 1994).

Of the above hypotheses, the most debated one is the Mid-domain effect (MDE) Null model, which assumes that species distribution is the result of geographical hard boundaries. When species range sizes are randomly placed, in the absence of any environmental gradient within a bounded domain, then a mid-domain peak is observed in the middle of the domain (Colwell and Hurtt 1994, Colwell and Lees 2000). Jetz and Rahbek (2001) in a study in African birds found MDE as a good predictor for birds with wide ranges but not for those with small ranges. Pan et al. (2016) observed MDE as a significant variable for shaping richness pattern of large ranged species in central Himalayas of China. On the contrary, Cavarzere and Silveira (2012) and Diniz-Filho et al. (2002) in South American birds found least support for MDE from bird species diversity. MDE is highly debatable, but is still tested for across taxa. Though contentious based on theoretical and empirical opinions, it can be applied for detecting areas that deviate from observed species richness pattern and patterns produced as a result of random process seeking biological explanation for it (Zapata et al. 2003).

For understanding the factors contributing to the distribution pattern of species, in addition to the vegetation or biotic variables, climatic and energy variables are being widely explored primarily for studies done in large spatial scales (Continental and latitudinal) (Hawkins et al. 2003, Currie et al. 2004). Due to the easy availability, at a finer scale with free access, currently climatic and energy variables are being widely used to explore the association of species diversity and richness at local and regional scales. Hawkins et al. (2003) had reviewed the importance of water-energy variables in explaining the species richness and distribution pattern and the importance of these variables in determining species richness and distribution. Variables like Potential Evapotranspiration (PET - a measure of ambient or atmospheric energy closely related to solar energy and mean annual temperature), Actual Evapotranspiration (AET - measure of water-energy balance closely associated with plant productivity), and Normalized Difference Vegetation Index (NDVI - a measure of primary productivity), are some of the variables widely being tested. These energy related variables may have indirect effect on physiology of species or direct effect on its food resources (Currie et al. 2004), thus, determining the extent of their distribution.

In recent years, a steady increase in studies related to species distribution pattern in various taxa with respect to elevational gradient has been seen. In the case of birds in the western Ghats, Raman et al.(2005) in Kalakad-Mundanthurai Tiger Reserve (KMTR), reported no significant change in resident bird species richness with elevation. Das (2008) in Silent Valley National Park reported a negative correlation of bird species richness with elevation. In Eastern Himalayas, Acharya et al. (2011b) reported bird species richness to be highest at intermediate elevation. In Western Himalayas studies like (Raza 2006, Joshi and Bhatt 2015) also recorded distinct hump-shaped pattern. Price et al. (2011) in a latitudinal study along the western Himalayas in its southeast also reported a peak in mid-elevation of the latitudinal gradient. In the case of other taxa like reptiles a decrease in species richness with elevation was seen in Agasthyamalai hills (Jins 2017), but anurans in KMTR showed different patterns at alpha and gamma level (Naniwadekar and Vasudevan 2007). In Eastern Himalayas, species richness in reptiles (Chettri et al. 2010), butterfly (Acharya and Vijayan 2015) and fish (Bhatt et al. 2012) declined with increasing elevation; but butterfly richness showed a hump at 1000 m heights. In the case of vegetation, Acharya et al. (2011a) observed tree species richness showing a unimodal pattern in the Eastern Himalayas, whereas in Western Himalayas, plant species richness pattern was reported to differ based on the scale of analysis (Oommen and Shanker 2005).

The Western Ghats is one among the global biodiversity hotspots (Myers et al. 2000) and it is also an area of high endemism in birds (Stattersfield et al. 1998). Agasthyamalai Hills at the southernmost tip of the Western Ghats lower areas having hot and humid environment and changing vegetation and higher altitudes having colder conditions, is rich in biodiversity and endemism. This geographical and ecological setup makes the area an ideal place to test different hypotheses relating to species distribution. Thus, in the current study, in Agasthyamalai Hills, we tried to explore species richness, turnover and range sizes of birds along the elevations ranging from 100-1860 m, and the role of biotic and abiotic factors in explaining the pattern of distribution in the hills.

4.2 Methods:

4.2.1. Bird sampling: Variable width point count method (Bibby et al. 1998) was used, and the sampling was carried out during October 2012 to December 2014. At each 100m elevation interval were sampled depending on accessibility, except between 600-700 and 800-900m due to inaccessibility. A total of 120 such point count stations were laid representing all possible habitat types and elevation ranges and that in total resulted in 746-point count effort (including replication) (Refer chapter 3 for details). Fig.4.1 shows only a few representative sampling locations along the elevational gradeint.

4.2.2. Vegetation sampling: In total, 120 vegetation sampling plots were laid starting from the centre of the birds' point count station. Only one-time vegetation sampling was done. Quadrat method was used to measure vegetation attributes (Mishra and Jeeva 2012). Variables like tree species and height, shrub species and height, the percentage of leaf litter cover, herb cover, rock and boulder cover, exposed soil and canopy cover were recorded (Refer to Chapter 3 for details).

4.2.3. Other variables: ASTER DEM Global Digital Elevation Model (GDEM) was used to find area availability in each altitudinal category in the intensive study area. Elevation for each sampling point was determined using an altimeter. Abiotic variables like temperature, precipitation and other 19 bioclimatic variables were downloaded from the Worldclim database (Hijmans et al.2005). For Potential Evapotranspiration (PET), monthly data were downloaded from the Global Aridity index (Trabucco and Zomer 2009).

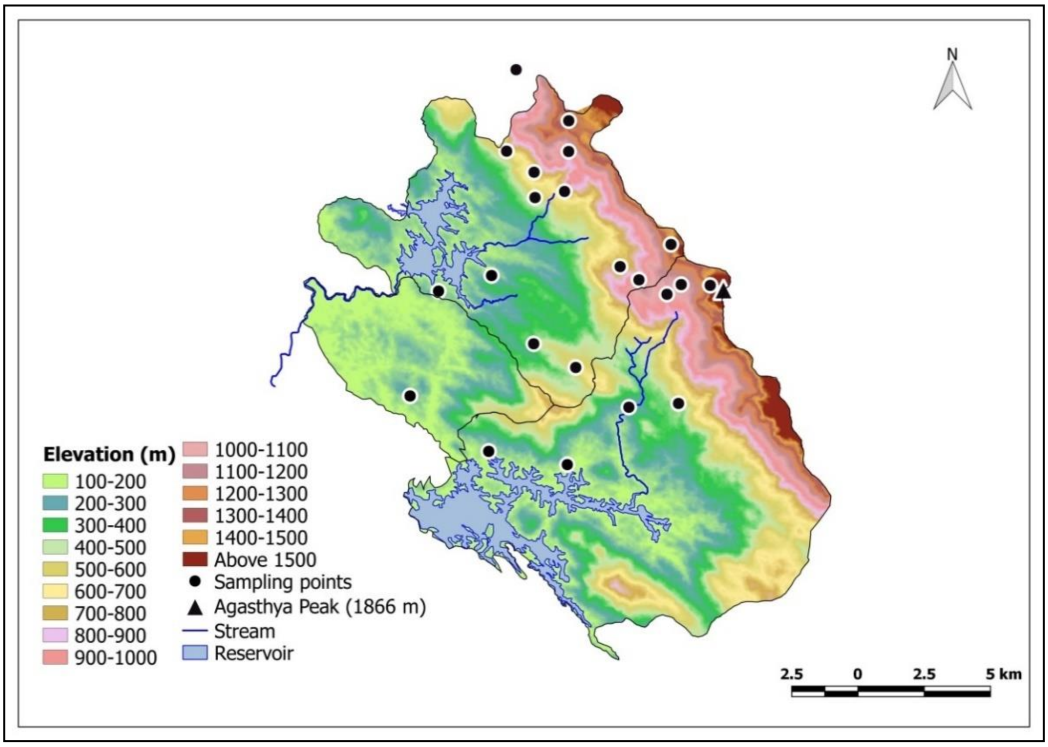


Figure 4.1: *Digital Elevation Map, showing select sampling locations at different elevation bands in intensive study area in Neyyar WLS, Peppara WLS and Agasthyavanam Biological Park, Kerala.*

For NDVI, fortnightly data for the year 2012 and 2013 were downloaded from Bhuvan database[1]. All the above variables were available at a resolution of 1×1-kilometer grid size. QGIS.2.12.3 version was used for extracting the above-mentioned environmental variables from different layers.

4.3 Data analysis:

4.3.1. Richness and turnover: Bird species recorded in sample, i.e. 100 species, were considered to calculate species richness estimates. For data analysis, samplings have been pooled beyond 1400 m as the area availability and sampling points were low in higher altitudes. Beyond 1400m only one forest type was present i.e., southern hilltop forest hence controlling for habitat heterogeneity. Species richness and turnover both were computed using Estimate S software version 9.1.0 (Colwell 2013).

For species richness non-parametric estimator Chao and Jackknife, are considered as suitable estimators when communities have more singletons and doubletons (Gotelli and

[1] http://bhuvan.nrsc.gov.in/data/download/index.php

Colwell 2011). For the analysis, only Jackknife-2 estimator was used as it had relatively lower standard deviations.

For species turnover or beta diversity, first alpha diversity (Sørenson's similarity index) at each elevation belt (as noted above points above 1400m were pooled together) was calculated using species abundance data at that elevation. For calculating beta diversity or dissimilarity of species between two consecutive altitudinal zones, the index of similarity was then subtracted from 1 (Magurran 2004, Chao et al. 2005).

Turnover $\boldsymbol{\beta}$ = 1- $\boldsymbol{c_N}$ (Sørenson's similarity index)

4.3.2. Mid-Domain Effect Null Model: It predicts a hump-shaped pattern of species richness better known as the Mid-Domain effect (MDE) towards the centre of domain due to spatial constraints, in the absence of abiotic and biotic factors (Colwell and Lees 2000). To study the effect of MDE, the observed pattern in species richness was compared with null model predictions generated by a Monte Carlo simulation procedure (McCain 2004). Prediction curves (95%) based on 5000 simulations without replacement from empirical range sizes were used to assess the impact of geometric constraints on bird distribution. Regression analysis was performed to examine the fitness between estimated species richness and simulated curve. The domain limit was set to 18 representing all elevation categories between 100-1900 m. The upper and lower recorded range limits of each bird species were considered for analysis. The difference between the upper and lower range limits defined the **range size** of each species, considered to be continuous, even if the species have not been recorded from the intermediate zone.

4.3.3. Rapoport's rule: Rapoport's elevational rule was also tested which predicts a positive correlation between range size and altitude. Rapoport's rule can be tested in two ways: (1) Stevens method (Stevens 1989, 1992) and (2) Mid-point method (Rohde et al. 1993). The former method, test the strength of correlation between elevations and mean elevational range of all species occurring at the same elevation using Spearman rank correlation. However, this method is debated to be statistically non-independent and hence the second method (Mid-point method) has been used as a test for Rapoport's rule in the current study. Mid-point method uses individual species as data points, which makes it statistically independent, and regresses elevational range sizes with the midpoint of elevational range sizes of individual species.

4.3.4. Step-wise multiple regression: Multivariate analysis is used when more than one factor influences the study system, and the relationship between the factors makes it necessary to be tested simultaneously. To test for significant explanatory variables predicting estimated bird species richness along elevation, step-wise multiple linear regressions was carried out. At each successive step, variable that was selected by the previous model was dropped out from the subsequent model. In the case where more than one variable was picked up by the model, the variable having the highest part-correlation was removed for testing the influence of other explanatory variables. An explanatory variable showing significant Pearson's correlation was chosen for regression analysis. Explanatory variables were classified into two: habitat variables [Girth at breast height coefficient of variation (GBH_CV), NDVI, Tree Density, Litter cover] and environmental factors (Temperature, precipitation, PET, Area, MDE predicted richness).

4.4. Results:

4.4.1. Area and richness: Area availability in the intensive study area is shown in Fig. 4.2. Area decreased monotonically with increasing elevation. Areas beyond 1400 m till 1868 m (the top of the mountain) were clubbed together for the purpose of analysis and hence more area is shown in this category compared to 1300 m. For the more or less conical shape of the mountain, the area decreases gradually as the altitude increases. Bird species richness also showed a significant positive correlation with the area and ($r = 0.81$ $p = 0.001$).

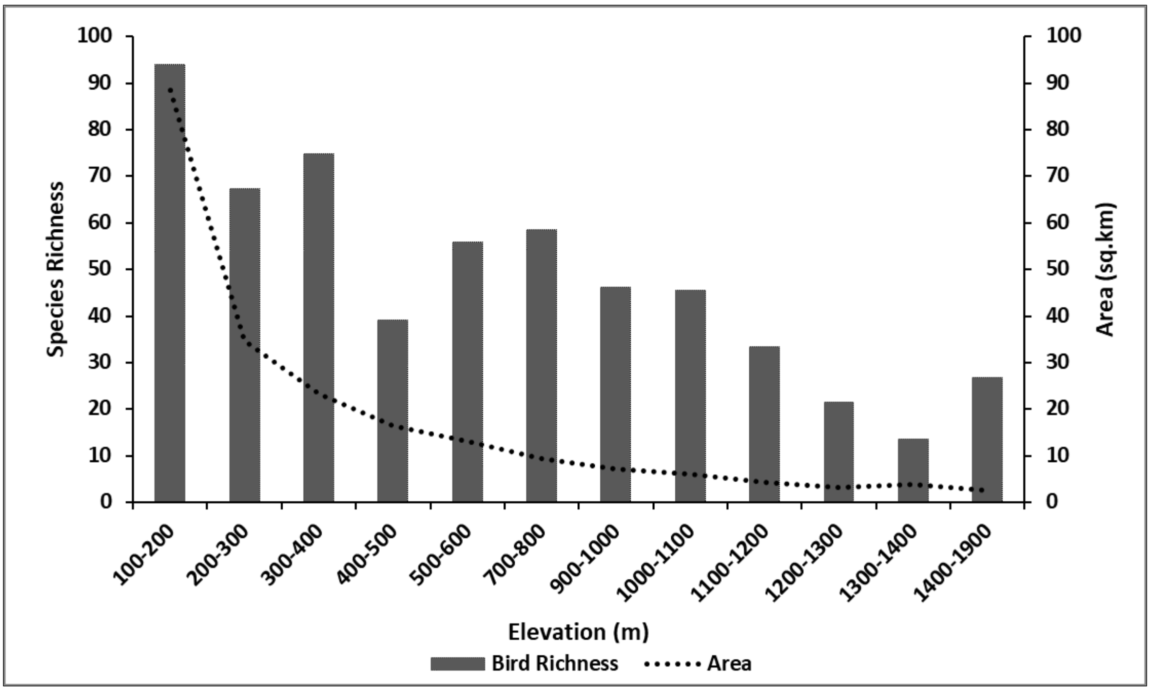
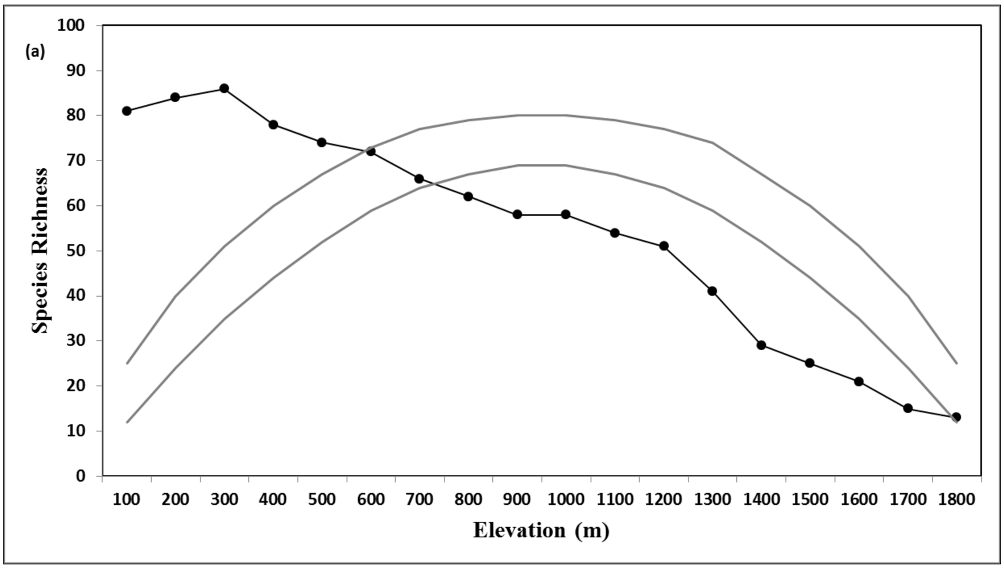


Figure 4.2*:Total area and estimated bird species (Jackknife-2 estimator) richness at each elevation.*

4.4.2. MDE and bird species richness- The data were analysed (1) for all species (n=100), and (2) only endemics (n=12)

All species - In the case of all the birds, a decreasing trend in species richness was seen with increasing elevation (Fig. 4.3 a). As only 3 out of 18 points (16%) were found within the 95 % confidence interval curve, the present dataset showed least support for MDE. Estimated species richness showed significant negative correlation with MDE predicted richness (r = -0.64, p = 0.02). The empirical richness deviated from the MDE predicted richness in both lower (100 – 500 m) and higher (800 – 1700 m) elevations with comparatively higher value in lower elevation. The correlation between empirical species richness and MDE predicted richness was found insignificant (r = - 0.37, p = 0.23).

Only Endemics- Whereas for endemic bird species (Fig. 4.3 b), a total of 16 out of 18 data points (89%) occurred within the 95 % confidence interval curve showing support for mid-domain effect. Empirical species richness showed significant correlation with MDE predicted richness (r = 0.62, p = 0.03). The empirical richness deviated from the MDE predicted richness at 100m at the lower elevation and a sudden drop at 900 m that can be ascribed to a localised habitat effect.



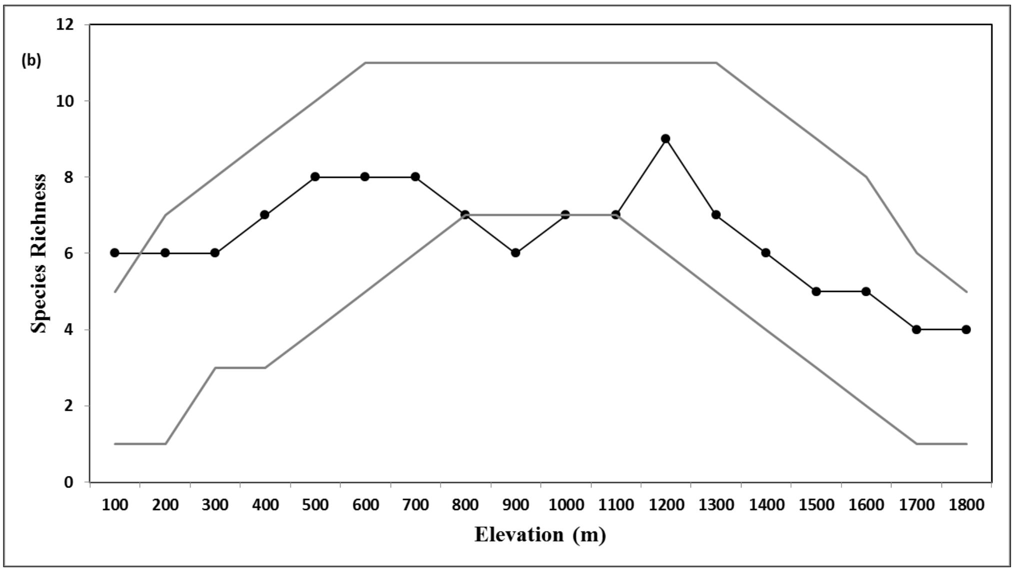


Figure 4.3: *Distribution of interpolated species richness (line with data points-dark dots) along elevation with 95% simulation curves (smooth lines) using empirical range sizes without replacement (5,000 simulations) in Mid-Domain Null model programme (McCain 2004). (a) All birds (n=100) and (b) Endemic species (n=12)*

4.4.3. Elevational range profile: Most of the species showed a narrow elevational range size. Of the 100 species, 27 species were restricted below 600 m, 32 species occurred below 1200 m, only five species were using the complete elevational range (Fig. 4.4 a). For all species, only the upper limit was significantly correlated with altitudinal range size (r =0.84, p= 0.00), whereas for endemics (Fig. 4.4 b), lower limit was significantly negatively correlated with altitudinal range size (r = -0.59, p = 0.04).

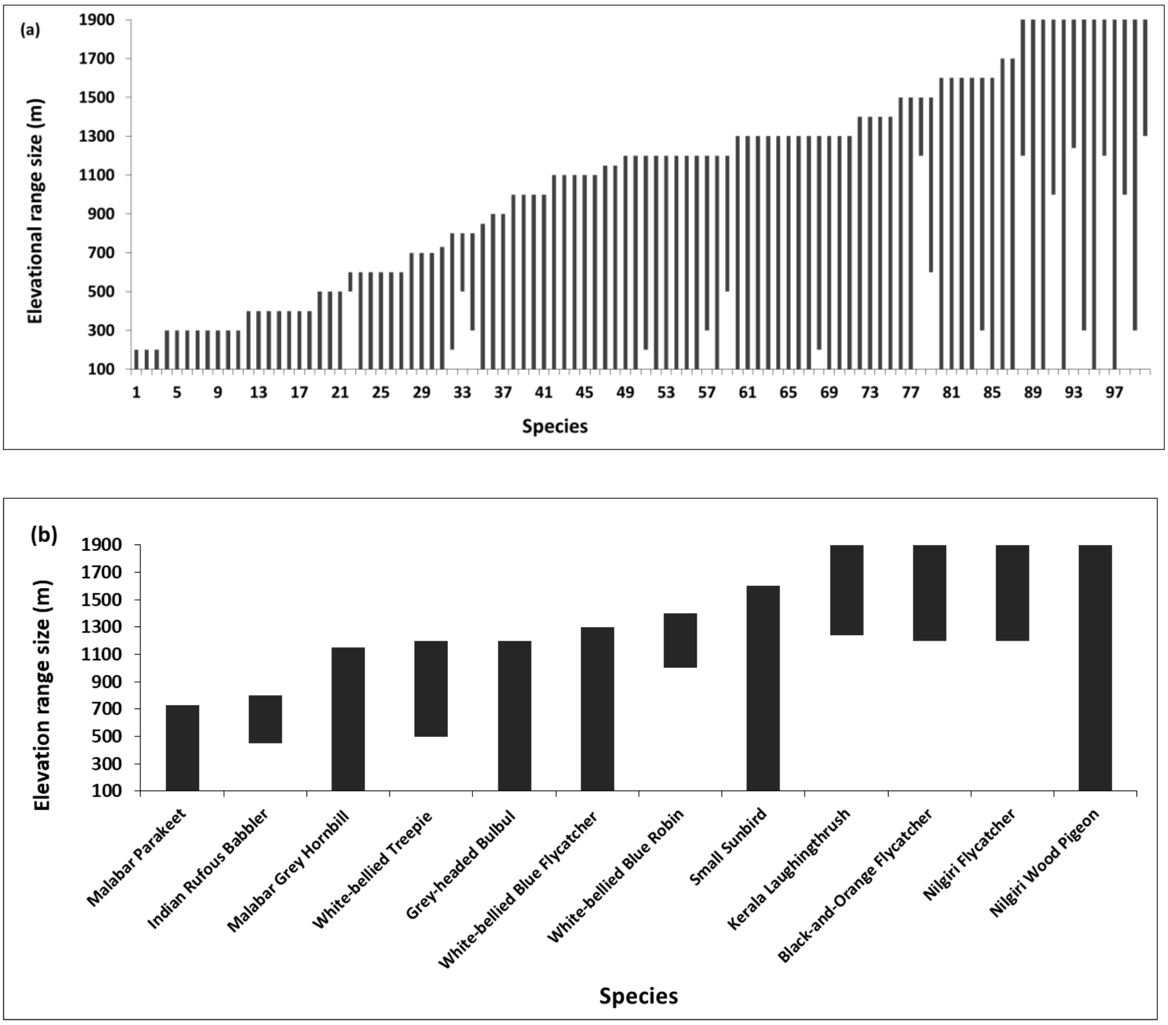


Figure 4.4: *Elevation range profiles of (a) All bird species, and (b) Endemic birds. The bars show the upper and lower limit of each bird species' range. The range sizes are arranged in ascending order of upper range limit of species.*

Among endemics, Nilgiri Wood Pigeon *Columba elphinstonii* occurred in the widest elevation range (100 – 1800 m), followed by Small Sunbird *Leptocoma minima* that occurred at a range of 100 – 1600 m. It was observed that low elevation endemic species like Malabar Parakeet *Psittacula columboides*, Malabar Grey Hornbill *Ocyceros griseus* and Grey-headed bulbul *Pycnonotus priocephalus* were restricted below 1200 m. The high elevation endemic species like Black-and-Orange Flycatcher *Ficedula nigrorufa*, Travancore Laughingthrush *Trochalopteron meridionale* and Nilgiri Flycatcher *Eumyias albicaudatus* were restricted to the area above 1200m. Species like White-bellied Blue Robin *Sholicola ashambuensis* and Indian Rufous Babbler *Turdoides subrufa* had narrow range compared to other endemics.

4.4.4. Rapoport's elevational rule: When elevational range sizes were plotted against the range mid-points, a clear mid-elevation peak, after 1000 m, was seen (Fig.4.5). Elevational range size and range midpoints had significant positive correlation (r^2 = 0.33, p = 0.0001) and showed a quadratic relation (y = 163.15x^2 + 0.77x + 0.0002, r^2 =0.36); but the fit of the equation was very low. This shows that bird distribution pattern to an extent follows Rapoport's elevational rule. Of all the bird species, thirty-two species showed elevational range size between 1201-1900 m while the remaining sixty-two species had elevational range sizes from 100 to below 1200 m. Of these sixty-two species, five were exclusively found only above 1200 m and are montane species having restricted distribution in and above that altitude. When altitudinal range size was regressed with upper and lower limit for all species (Fig.4.5 a), only the upper limit showed significant relation with altitudinal range size (r^2 = 0.70, p < 0.001).

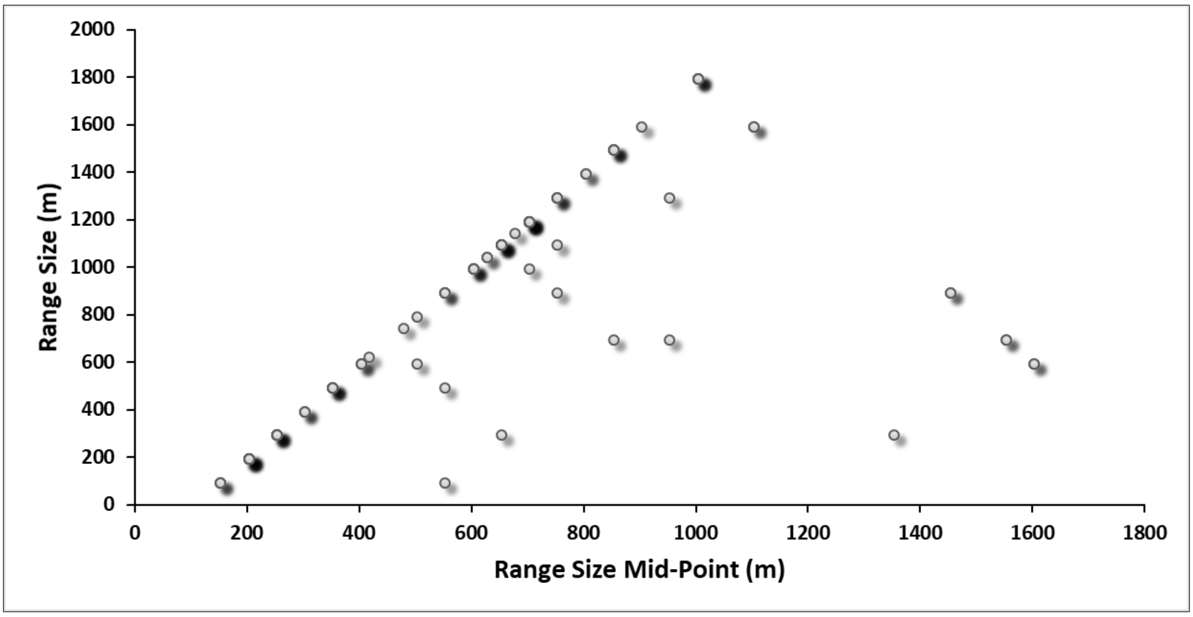


Figure 4.5: *Mid-point method used to test for Rapoport's rule in bird species. Each specie's range midpoints have been plotted against specie's elevational range sizes (n= 100 species occurring in the sample plots). Each circle represents one species, and the darker shadow below the circles denote other species having the same range sizes.*

4.4.5. Species Turnover: Gradual change in species turnover can be seen along the different altitudinal gradient (Table 4.1). Above 1100 m, bird community is shown to have a significant amount of turnover compared to the lower elevation. Below 1100 m, communities did not show turnover of more than 64%. The highest bird species turnover (0.875) was seen between 200 m and 1400 m. While the maximum number of species shares the altitude between 100-400 m, only minimum number shared the area between 200-1400 m. Neighbouring altitudinal zones showed low species turnover compared to the disjunct zones. Turnover median of each altitude showed significant negative correlation with GBH_CV (r = -0.892, p = 0.0001); tree diversity (r = -0.621, p = 0.03); NDVI November (r = -0.788, p= 0.002) and NDVI December (r = 0.634, p= 0.03). In general, turnover values were high at higher altitudinal bands. Bird communities were different at broader landscape (altitudinal) level, i.e. low (<900m) and high (>1100 m) levels. Of all variables regressed regressed against the turnover (median) of bird species along different elevational gradient, only GBH_CV explained around 79% of the turnover (F = 38.83, p= 0.00).

Table 4.1: *Bird species turnover (based on Sorensen's dissimilarity Index) between pairs of altitudinal categories in Agasthyamalai Hills. The coloured boxes show the turnover rate in relation to elevation band. Values closer to one signifies a high rate of species turnover (Darker colour signifies a high rate of turnover). The number given in the uncoloured cells are number of shared species in each elevational belt.*

Elevation (in meters)	100-200	200-300	300-400	400-500	500-600	700-800	900-1000	1000-1100	1100-1200	1200-1300	1300-1400	>1401
100-200	0	0.404	0.206	0.571	0.397	0.482	0.549	0.64	0.761	0.787	0.857	0.802
200-300	34	0	0.368	0.516	0.475	0.5	0.515	0.625	0.786	0.759	0.875	0.855
300-400	52	30	0	0.418	0.258	0.29	0.422	0.506	0.671	0.707	0.815	0.75
400-500	21	15	23	0	0.406	0.367	0.32	0.375	0.55	0.667	0.75	0.692
500-600	35	21	36	19	0	0.308	0.382	0.394	0.552	0.667	0.8	0.719
700-800	29	19	33	19	27	0	0.281	0.387	0.593	0.714	0.826	0.774
900-1000	23	16	24	17	21	23	0	0.308	0.5	0.696	0.778	0.674
1000-1100	18	12	20	15	20	19	18	0	0.238	0.591	0.647	0.561
1100-1200	11	6	12	9	13	11	11	16	0	0.5	0.538	0.455
1200-1300	10	7	11	7	10	8	7	9	9	0	0.5	0.486
1300-1400	6	3	6	4	5	4	4	6	6	7	0	0.36
>1401	9	4	9	6	8	6	7	9	9	9	8	0

4.4.6. Testing for habitat and environmental factors: The r values and associated p values of the significantly correlated explanatory variables with estimated bird species richness and empirical endemic species richness is given below (Table 4.2). Mean Annual Temperature, Area, GBH_CV were positively correlated, whereas MDE predicted richness, precipitation, tree density, NDVI February, NDVI July, NDVI December were negatively correlated with estimated bird species richness. NDVI mean and NDVI_CV were not correlated with bird species richness but mean NDVI of February, July and December month showed significant correlation.

Among the environmental variables temperature, precipitation and PET were highly correlated with each other. In habitat variables, GBH_CV & tree density and GBH_CV & December NDVI were highly correlated.

Table 4.2: *The r values and associated p-values for total species as well as endemic species with twelve habitat and environmental explanatory variables.*

Variables	**All Species r**	**All Species p**	**Endemics r**	**Endemics p**
Temperature Mean	0.896	0.00**	-0.197	0.54
Precipitation	-0.869	0.00**	0.249	0.434
PET	0.869	0.00**	-0.131	0.685
Area	0.808	0.001**	-0.322	0.308
GBH_CV	0.727	0.007**	0.165	0.609
NDVI December	-0.678	0.015*	0.067	0.835
NDVI July	-0.669	0.017*	0.359	0.256
MDE richness	-0.645	0.023*	0.617	0.033*
Tree density	-0.624	0.030*	-0.388	0.212
NDVI February	-0.600	0.039*	0.417	0.178
Litter cover	-----	----	-0.442	0.151

**Correlation is significant at 0.01 level (2-tailed). *. Correlation is significant at 0.05 level (2-tailed).

4.4.6.1. Explanatory model for all Species: In the first model, annual mean temperature alone explained 78.4 % of variation in bird species richness (Table 4.4). After removing temperature, 81.8 % was explained by precipitation and area together. GBH_CV and MDE explained 82.5%. December and February mean NDVI values together explained 79.1%. In the last models, NDVI July and tree density explained 39.2% and 38.9% respectively.

Table 4.3: *Multiple stepwise regressions with bird estimated richness as dependent variable and temperature, precipitation, area, GBH_CV, MDE predicted richness, NDVI February, July, December and tree density as independent variables. In the first step, all the independent variables were included. Then, each independent variable selected in each model is excluded in the subsequent steps, one by one.*

Step number/ Model	Variables selected in Model	Part Correlation	Adjusted R^2 ±SE	F	p
1.	Temperature	0.896	0.784±10.86	40.94	0.000
2.	Precipitation Area	-0.446 0.310	0.818±9.8	25.73	0.000
3.	Area GBH_CV	0.594 0.479	0.855±8.89	33.51	0.000
4.	GBH_CV MDE	0.663 -0.573	0.825±9.78	26.88	0.000
5.	NDVI_ December NDVI_ February	-0.685 -0.608	0.791±10.68	21.82	0.000
6.	NDVI_ July	-0.669	0.392±18.23	8.08	0.017
7.	MDE Tree Density	-0.557 -0.532	0.633±14.17	10.46	0.004
8.	Tree Density	-0.624	0.328±19.16	6.36	0.030
9.	NDVI_ February	-0.600	0.296±19.61	5.62	0.039

The variable selected in the first model were removed in the subsequent step, one at a time.

4.4.6.2. Explanatory model for endemics: In the case of endemics, only MDE predicted richness showed significant correlation with interpolated endemic empirical species richness (r = 0.62, p =0.03). Here endemic empirical species richness (interpolated data) was taken as the dependent variable rather than estimated species richness. When all habitat and environmental variable were pooled in, MDE predicted richness, mean litter cover and area was selected by the model that explained 89.9 % of the variation in endemic richness pattern (Table 4.5). For the second model, when MDE predicted richness was removed, none of the variables was selected by the model. In the third model, only in the absence of litter cover, MDE predicted richness was picked up and it explained about 32% of the variation in endemic species richness.

Table 4.4: *Multiple stepwise regressions with endemic empirical species richness as dependent variable and temperature, precipitation, area, GBH mean and CV, MDE predicted richness, NDVI (mean, CV and monthly means), litter cover, tree density, tree diversity, shrub diversity, and canopy cover as independent variables.*

Step number / Model	Variables selected in Model	Part Correlation	Adjusted R^2 ±SE	F	p
1.	MDE	0.735	0.899±0.35	33.74	0.000
	Litter cover mean	-0.705			
	Area	0.248			
2.	---	---	---	---	---
*3.	MDE	0.617	0.319±0.926	6.152	0.033

The variable selected in the first model were removed in the subsequent step one at a time.
*After removing only litter cover mean only MDE was selected by the model.

4.5. Discussion:

Distribution pattern: In the present study, bird species richness and area decreased with increasing elevation. A monotonic decline in species richness has been detected in earlier studies also (Patterson et al. 1998, Blake and Loiselle 2000). Rahbek (2005) reported that a monotonic decrease in species richness is the most dominant shape where altitudinal gradient is ≤ 1000 m. Raman et al. (2005) reported no significant change in resident bird species richness with elevation in Kalakad-Mundanthurai Tiger Reserve (KMTR), an area very close to the present study area. This would be due to low variability in altitude (500-1400 m). Das (2008) reported a negative correlation of bird species richness with elevation in Silent Valley National Park (800-2200 m) also in the Western Ghats. On the contrary, Acharya et al. (2011b) reported bird species richness to be highest at intermediate elevation in the Eastern Himalayas (300-4700m). Other studies in Western Himalayas, also recorded a distinct hump-shaped pattern (Raza 2006, Joshi and Bhatt 2015). Compared to Western Ghats, Himalayas has a wider elevational range with more area available at the intermediate elevations and that may support more species in middle elevation, while that is not the case in Western Ghats. While the area availability decreases with increasing altitude, altitudinal decrease in temperature and increase in precipitation supports a unique forest which mostly supports montane species. Among recent studies, McCain (2009) reported bird diversity on humid mountains either decreased or showed a low-elevation plateau in diversity. However, endemic species richness did not show a declining trend. Endemics seem to peak after 1100 m. Generally, with increasing elevation endemism is said to increase as a result of increasing isolation and decreasing surface area of montane zones, which together give rise to small, fragmented species populations much amenable to speciation processes (Graves 1985). Such differences in patterns in total species richness and endemic species richness are most likely commonplace along elevational gradients, particularly for a highly diverse group (Grytnes and McCain 2007).

Range sizes: Majority of the bird species showed narrow elevational range sizes. Same results of bird species having narrow range sizes are reported from the tropics. Rhode (1996) states that Rapoport's rule is a local phenomenon valid in northern latitudes, in Palaearctic and Nearctic areas that had undergone greatest temperature fluctuation in the past, and Rapoport's rule does not apply to tropics, that for long have been under stable climatic conditions. Likewise, Raman et al. (2005) in KMTR did not find any support and

Acharya et al. (2011b) in the Eastern Himalayas found weak support for Rapoport's elevational rule in bird distribution. Contrary to this, two studies along the latitudinal extent of the Western Ghats found significant support for Rapoport's rule in the case of birds (Vijayakumar 2015) and trees (Page 2015). The current study also found significant support for Rapoport's elevational rule despite most of the species being distributed up to 1100m after which the composition changes and species richness decreases. Birds having large elevational range size and also occurring in high altitude mostly consisted of generalist species including many latitudinal migrants, and also high altitude had montane species that are range-restricted. The combined effect of some large ranged species occurring in elevational mid-point and low species richness at higher altitude would have given support for Rapoport's elevational rule in the present case. Despite species richness decreasing along increasing altitude, a clear mid-elevation peak is seen in the mid-point graph, possibly a result of spurious effect (the tendency of the range sizes to fall in the middle of the elevational gradient) (Colwell and Hurtt 1994). Mid-point method also suffers from analytical complications as each species though act as independent data points are associated by phylogenetic relatedness and that does not make them really independent data points (Gaston et al. 1998) and restrictive in sub-sampling having few species (McCain and Knight 2013). Significant support for Rapoport's elevational rule in such a small spatial scale in an altitudinal gradient remains a dubious pattern that requires further studies considering past climatic factors (Price et al. 1997) as well or competition hypothesis (Terborgh and Weske 1975) to clarify that the agreement with the Rapoport's rule in the present case is not because of spurious effect.

Turnover Pattern: Turnover median of each altitude showed significant correlation with GBH_CV, tree diversity, NDVI November and NDVI December. This shows that turnover pattern or the species composition in different elevation is influenced more by vegetation characteristics and productivity compared to environmental variables. In the present study, above 1100 m altitude the forest type changes drastically; from evergreen forest, the habitat changes abruptly to southern hilltop forest. Species richness decreased along the elevation, but because of addition of new species (montane species), a significant turnover rate was observed. As more species occur together along a gradient, competition among species tends to narrow their distribution, and because of the narrow distribution, the extent of change in species composition increases along the gradient (Whittaker 1972). Local beta diversity and geographic differentiation were higher in tropical bird communities compared to temperate communities (MacArthur 1965, 1969). Apart from historical events and geographic phenomena, species diversity may depend upon local level ecosystem process (Brown et al. 2001). In addition, the transition or change of species composition may be marked by ecotones (Patterson et al.1998). Raman et al. (2005) also observed a significant change in bird community composition in KMTR along elevation and found elevation and tree species richness as deterministic factors in structuring the bird community.

Mid-domain Effect Null Model: Bird species richness (including both residents and migrants) showed least support for MDE null model. The biological explanation and fit of the mid-domain null model have been questioned frequently. Dunn et al. (2006) highlighted that the predictions of the mid-domain model are reliable only when range sizes and scale of analysis are large. Many studies have shown a weak relation between MDE predicted richness and observed species richness in birds (Hawkins and Diniz-Filho 2002, Herzog et al. 2005, McCain 2009, Cavarzere and Silveira 2012). Since the spatial extent of the current study site is very small, this might be the reason that MDE did not emerge as a significant factor for determining species richness. Also compared to other mountains like Himalayas the range size of the species here is smaller, thereby showing least support for MDE. McCain (2009) also observed that in wet mountains where humidity is high the bird diversity either decline with increasing elevation or is relatively constant over low elevations, which is also echoed in the current study. On the contrary, empirical endemic bird species richness showed significant correlation with MDE predicted richness. Even though the empirical richness deviated from the MDE predicted richness at 100 m and there was a sudden drop in it at 900 m. This sudden drop might have occurred because of the presence of grassland in this elevation zone where bird species richness decreased as well as the sampling site was less. To test the mid-domain effect in a broader analysis of climatic, ecological and evolutionary hypotheses for diversity gradient, it is important to analyse data separately for endemics and non-endemics (Hawkins and Diniz-Filho 2002). In the present study, the endemics occurred more or less uniformly in both lower and higher elevations, a finding that echoes the patterns observed in nearby KMTR as well (Raman et al. 2005). MDE model predictions depend on the frequency distribution of range size, as small–ranged species can be freely located nearly anywhere within the domain in contrast to species with larger ranges, which are forced to be closer to the centre of the elevation range (Colwell and Hurtt 1994, Aliabadian et al. 2008). Since the majority of the endemics covered the complete elevational gradient, it resulted in a significant correlation with MDE predicted richness. Storch et al. (2006) in a global analysis of birds found that MDE is only a good predictor of global richness patterns if tested over traditional biogeographic realms compared to factors such as Actual Evapotranspiration (AET). In either of the regression analysis separately for all species and endemics, MDE was always picked in conjugation with other habitat variables. In the case of endemics, MDE alone explained only 32% variation in species richness. These results clearly show a strong association between MDE and habitat variables and the inability of MDE to come out as a single most influential variable. Currie and Kerr (2008), in their review also put emphasis on this collinearity of MDE with other climatic and habitat variables. Aliabadian et al. (2008), Hawkins and Diniz-Filho (2002) found least support for MDE in endemic species richness. A combination of variables shows that endemic species richness in Agasthyamalai hills might be more influenced by historical and evolutionary trends rather than geographical hard boundaries. Western Ghats are older mountain ranges that for long been experiencing somewhat stable climatic condition, isolation from similar forest patches in other mountain ranges including Himalayas and a consistent birds species richness (Ripley 1949, Daniels et al. 1990) that has resulted in higher endemism and narrow range sizes of species (Fjeldså et al. 2012).

Underlying Mechanisms: In the present study, temperature alone explained 78.4% variation in species richness along elevation. This is consistent with the findings of McCain (2009) in which temperature rather than area was said to drive the pattern globally in birds. Jayson and Mathew (2000) in Silent valley reported negative relationship between rainfall and bird diversity while temperature was significantly correlated with bird community attributes in evergreen forest. In the present study, higher altitudes receive highest amount of rain up to 5000 mm annually. Besides the rainfall, these high-altitude areas face dense mist, high wind velocities and low temperatures for most of the year. This, in turn, may affect the productivity (resources available) of the montane forest in addition to being limited in area, thereby reducing the number of species and increase in endemics (Orians 1969). In the current study, mean NDVI values were not significantly different along elevation and in fact were higher in higher altitudes where species richness is less. Many studies have found negative correlation or hump-shaped correlation of species richness with increase in diversity (Rosenzweig 1992, Waide et al. 1999).

Climatic variables like temperature, rainfall, and productivity are probably the most commonly cited causes for broad-scale patterns in species richness (Grytnes and McCain 2007). Rabinovich and Rapoport (1975) found species richness to be strongly correlated to temperature and weakly correlated to altitude and precipitation in case of Argentine passerine birds. They also emphasised that both biotic and abiotic factors may affect species differently at local scales. Rahbek and Graves (2001) found different variables influencing the distribution pattern depending on the scale of analysis. Climate was the significant predictor of species richness at local and regional scales. Topography was a better predictor at coarser spatial scales ($\geq 4^0$) whereas precipitation was significant predictor at a finer scale. They further suggested that at the coarser spatial scale the interaction between climate and topography influence the species pool and that in turn influences the local species composition.

In the second model, after removing temperature, 81.8 % variation in species richness was explained by precipitation and area together. Both temperature and precipitation tend to vary systematically with both elevation and latitude (Brown and Lomolino, 1998). Similar kind of results of combined influence of temperature and water exists globally for most animal groups and plants (Hawkins et al. 2003, Oommen and Shanker 2005). Szewczyk and McCain (2016) in their study on ants conclude that taxon's ecology and natural history may be critical in influencing broad scale patterns. Several studies show that vegetation structure and composition governs bird species richness and assemblages (Cueto and De Casenave 1999, Ramachandran and Ganesh 2012). Normalized difference vegetation index (NDVI) has been taken as a surrogate for the primary productivity in many studies (Lee et al. 2004, Wu et al. 2014). Although temperature came up as the most significant variable, the model also picked other factors like GBH_CV and MDE together and NDVI of December and November. This influence of vegetation heterogeneity and productivity is reflected in the bird species composition (turnover pattern). Additionally, significant correlation with NDVI of November and December most probably will be because of the influx of migratory birds during the winters. In contrast, Acharya et al. (2011b) found AET and various habitat variables accounted the most for bird species distribution in eastern Himalayas. Currie (1991) and Kerr (1999) found PET to be better correlated with bird species richness. Vijayakumar (2015) reported NDVI, precipitation and elevation to be important predictors for overall bird species richness along latitude in the Western Ghats.

For endemics species, however, MDE, litter cover mean and area explained about 89 % of the variability in species distribution. The pattern of endemics in the current study may indicate that the role of regional biogeographical history (past climatic events) and other biotic factors (niche preference, vegetation, food availability and phylogeny) would give better answers to the question of endemics species distribution compared to the current climatic regime. Oswald et al. (2016) found both geological barriers (Andes mountain) and historical climatic regime as likely responsible factors for high endemism and distributions of dry forest bird community in north-western Peru.
The area availability certainly plays an important role in bird species richness pattern as seen in stepwise multiple regression models. In addition, sampling effort and species richness were significantly correlated and proportional to the decreasing area, and increasing altitude. Availability of area especially is important in case of mountain ecosystem that supports higher heterogeneity in habitat. Mountain shape determines the area availability that, in this case, has a larger base, gradually tapering in a conical shape towards the top thereby resulting in a continuous decrease in area with increasing elevation. Elsen and Tingley (2015) in their global analysis of mountain shape also reported pyramidal shaped mountains in Southern Western Ghats.

4.6. Conclusion:

A decline in species richness along rising elevation was observed in the case of bird species in Agasthyamalai Hills. However exclusively in the case of endemics, the species showed wider distribution across various elevational categories gradient with only a few endemics inhabiting the whole range of elevations. Most of the avian endemics are either restricted to low and mid-elevation forest, while the group consisting of montane species are restricted to the higher altitude. White and Bennett (2015) highlighted the importance of elevational patterns in determining extinction risk for species, but very so often overlooked in many of the conservation prioritisation schemes. Species with narrow ranges tend to have less climatic tolerance and are vulnerable to extinction due to global climate changes. In the current study, most of the species showed narrow elevational range sizes. Elevational range size and range midpoints showed significant positive correlation. As the elevation increased, the range size of species also increased until 1100 m after which it decreased drastically. Birds' distribution pattern in Agasthyamalai hill supported Rapoport's elevational rule although the relevance of it is debatable. This is probably due to the presence of certain montane species that are restricted to the higher elevation as well as the resident species that are widespread along the complete elevation gradient.

Environmental factors were seen to be good predictors of bird species richness than the mid-domain predicted richness along altitudinal bands in Agasthyamalai hills. Temperature largely seems to govern the species richness or distribution in most cases. The lower elevation areas with a higher number of species and higher elevations with unique species, emphasise the need for conservation efforts encompassing the whole of elevational range. The areas above 1200 m ASL in these hills consists of hilltop forests resembling sholas, which are preferred by the Western Ghats endemics. Study of the distribution pattern of birds, especially of endemics, is not only important from a theoretical perspective but also is highly significant for conservation as endemic taxa, owing to their restricted range, are very vulnerable to changes in habitats.

CHAPTER-5

Population and Conservation Status of Avifauna in Agasthyamalai Hills

5.1. Introduction:

Birds are one among the many bioindicators of an ecosystem (Koskimies 1989). Regional assessment of the population status of any taxa is crucial for conservation planning of species and landscapes (Vetaas and Grytnes 2002). Enumerating the number of species and population helps in assessing the condition of an area thereby highlighting the importance of the study site in species conservation (Brown et al. 1995). Status assessment of disjunct and endemic species of an area adds up to the conservation value of a threatened and ecological sensitive landscape like the Western Ghats. Species that earlier had widespread distribution, but currently are absent from intervening areas surviving only either in small pockets of habitat segregated by geographical barriers or past climatic events are called 'Disjunct species' (Brown and Lomolino 1998). The Western Ghats supports many relict and disjunct species having association with Himalayas and Srilanka (Ali and Whistler 1935, Dilger 1952). Varied taxa including aves, survives in the wet evergreen forest of Western Ghats (Ripley 1949, Zacharias and Gaston 1999). Palghat gap, the widest gap in the mountain range, acts as a geographical barrier leading to distinctive species with its nominate race in the north of the gap and subspecies in its south (Ali 1953), an example for which is the Dark-fronted Babbler *Rhopocichla atriceps* and Rufous Babbler *Argya subrufa*.

Compared to temperate regions, tropical species shows more rarity although overall species richness will be higher in the tropics (Orians 1969). This makes absolute density estimates of many species a difficult task and hence calls for more than one census techniques to be incorporated during such surveys. Most of the studies do not include more than one technique especially in the case of tropical forest where bird detections are difficult and mostly based on calls. Wildlife biologists adopts various methods for counting terrestrial birds, and that help in analysing the variations in the population, bird movements, habitat relationships, distribution and change in detectability of birds depending upon the prevailing environmental conditions (Mehlman 1997). Primarily, bird species richness indices or relative abundances are used as tools to assess the population of groups or a single species. Rosenstock et al. (2002) had emphasised the need for empirical modelling for direct estimates of densities over the traditional index counts. Density estimates using distance sampling is relatively better, reliable and usable than other techniques even in tropical bird communities where species detections are difficult (Gale et al. 2009). Norvell et al. (2003) compared population trend between traditional relative abundance indices with that from distance sampling and found the later to perform well even in large scale and multispecies surveys. There are many studies in which distance sampling has given satisfactory results over other methods (Jones et al. 1995, Marsden, 1999, Rosenstock et al. 2002, Jones et al. 2000, Marques et al. 2007). However, Johnson (2008) had argued against the use of distance sampling, as many of the assumptions are hard to satisfy in point counts especially in a multispecies survey. Despite this, for many taxa distance sampling is used to estimate density.

In distance sampling, distance from the observer to each detected bird is recorded from the point or line of observation. It is similar to the traditional point count method, additionally incorporating a distance factor. This method is termed as Variable Circular Plot (VCP) method. The absolute density is calculated as the number of individuals in the area covered. Distance sampling rely primarily on three assumptions: (1) all the objects directly on the line, or point is always detected, i.e. g (0) =1; (2) objects are detected prior to any of their movement from their initial location, and (3) all distances are measured accurately (Thomas et al. 2002). The Formula used for estimating density in point count is:

$$\widehat{D} = \frac{n}{k\pi w^2 \hat{P}a}$$

Where, $\widehat{D}$ = estimate of density, n = number of observed objects (single or cluster), k= point transect effort, π = 3.14, w = radius of the point transects, $\hat{P}a$ = probability of observing an object in the defined area ‘a’.

Avifauna of Southern-western Ghats: Of the 504 species of birds occurring in southwestern India, 360 species are terrestrial (Daniels 1997). Of this, 16 species are endemic and restricted to the Western Ghats (Stattersfield et al. 1998). Palghat gap, a 30 km wide low-elevation mountain pass at 10.08N latitude between Nilgiris in the north and Anaimalai Range in the south, influence the range boundaries of many bird species. The moist forests, mainly tropical montane evergreen rainforests, in the southern Western

Ghats is a major habitat for over 100 species of birds, including 14 endemics (Mudappa and Raman 2008). In Kerala alone, 500 species of birds, belonging to 88 families and 22 orders, have been recorded, out of which 17 are endemic to this region (Praveen 2015). In the light of latest taxonomic revisions, 26 species are considered to be endemic to the Western Ghats (Rasmussen and Anderton 2012, Rahmani et al. 2016). Neyyar and Peppara wildlife sanctuaries in the area qualifies as Important Bird Areas (IBAs) (Birdlife international 2015, Rahmani and Zafar-Ul Islam 2004) based on three criteria, namely A1 (Threatened species), A2 (Endemic Bird area) and A3 (Biome 10: Indian Peninsula Tropical Moist Forest) (Rahmani et al. 2016) thereby underscoring the importance of area in terms of endemism. Nair (1993) has recorded 172 bird species belonging to 39 families from Neyyar Wildlife Sanctuary (NWS) alone. A concise checklist by Sashikumar et al. (2011) enlists a total of 221 and 215 birds from Neyyar and Peppara respectively making a total list of 227 birds in this area.

There are some studies conducted on the eastern slope of the mountain range, i.e., mostly covering Kalakad-Mundanthurai Tiger Reserve (Johnsingh and Joshua 1994, Venkatraman 2011, Ramachandran and Ganesh 2013, Raman et al. 2005). However, no long-term studies on the forest bird community are available from the western slopes of southern part of the Western Ghats, except for a couple of checklists. In the light of the information gap on the area, this chapter discusses the status of forest birds in the Western slope of Agasthyamalai Hills of Kerala.

5.2. Data Collection: Variable Circular Plot (VCP) method was adopted for sampling the birds. All observations, including visual and aural, were included in the analysis. In total, 120-point count stations were laid representing all major habitat types and elevational ranges. Bird counts at each point were repeated (2-16 repeats) depending on the accessibility of the point count stations and logistics. This resulted in 746-point count efforts in total. For each observation in a sampling session, the following information was recorded: species name, number of individuals, observer-animal distance (r) using Nikon Forestry Pro range finder and perch height. In case of occurrence of birds in a cluster, the centre of the cluster was considered to estimate the observer-animal distance (See chapter three for details). For taxonomic classification and nomenclature, Birdlife International (2017) version 9.1 and for subspecies identification, Rasmussen and Anderton (2012) were followed. Recent taxonomic changes for Travancore Laughingthrush

Trochalopteron meridionale (Ashambu Chilappan *Montecincla meridionale*) and White-bellied Blue Robin *Myiomela albiventris* (Ashambu Sholakili *Sholicola ashambuensis*) have also been considered (Robin et al. 2017) although the old commona and scientifc names have been maintained in the text as per birdlife international checklist (2017) version 9.1.

5.3. Data analysis: For assessing the status of birds, in addition to systematic sampling, opportunistic sightings of species were also included and presented as categorical status. At the local level, bird species were assigned to a frequency category based on the likelihood of their detection in 10 random visits in the right season. The six status categories were 'abundant' (9–10 numbers), 'common' (7–8 numbers), 'fairly common' (5–6 numbers), 'uncommon' (3–4 numbers), 'locally common' (3–4 numbers in suitable habitats), and 'rare' (1–2 numbers). Criteria as per IUCN (2016) were used to assign conservation status of each species at a global level.

Distance 6.2 Release 1 (Buckland et al. 2001), for estimating the overall bird population density for Agasthyamalai Hills and also for the density of 18 species of birds for which an adequate number of detections could be made, i.e. >28 in number except Malabar Grey Hornbill which showed detection less than 28. A priori estimator models with key functions like uniform, half-normal, hazard-rate along with adjustments terms (series expansions) cosine adjustments, simple polynomial, and Hermite polynomial were used. Detection distances were not grouped into different categories; instead exact detection distance without rounding off was used for density estimate. Depending on the outliers, the detection distances for each species were truncated to achieve the best-fit model. Cut points for distance classes were set according to the χ^2 goodness of fit test. To improve the model fit of selected species (Table 5.3) the detections of the species was pooled along altitudinal and vegetational gradients. However, select point count stations were included with suitable habitats based on prior knowledge of species biology. The best-fit model was examined using Akaike Information Criterion (AIC) value and goodness of fit tests (Thomas et al. 2010, Buckland et al. 2001).

Relative densities were calculated to evaluate the most dominant species in the landscape and different elevational zones. Since a sufficient number of detections for some species in all elevational zones were not available, instead of calculating absolute density, relative abundance was calculated as the number of individuals (as proportion) in the total number of individuals of all species as shown below.

$$\text{Relative abundance of species A} = \frac{\text{Number of individuals of species A}}{\text{Total number of individuals of all species}}$$

5.4. Results: The present study reports 197 bird species (belonging to 20 orders and 60 families) in total from Neyyar Wildlife Sanctuary, Peppara Wildlife Sanctuary and Agasthyavanam Biological Park (Appendix 1). This list does not include waterbirds, as the study focused on forest habitats. Table 5.1 lists includes the 23 Western Ghats endemic, based on current study and secondary literature. For the table the distribution records of the Western Ghats endemic species given in, Rasmussen and Anderton 2012 was referred.

According to the IUCN criteria, **eight** of the total reported species in the current study are under **'Near Threatened'** category and that includes Black-and-orange Flycatcher *Ficedula nigrorufa*, Great Hornbill *Buceros bicornis*, Grey- headed Bulbul *Brachypodius priocephalus*, Grey-headed Fish Eagle *Icthyophaga ichthyaetus,* Nilgiri Flycatcher *Eumyias albicaudatus,* Lesser Fish Eagle *Icthyophaga humilis,* Oriental Darter *Anhinga melanogaster* and River Tern *Sterna aurantia*. The study recorded three **'Vulnerable'** species, i.e., Asian Woollyneck *Ciconia episcopus*, Nilgiri Woodpigeon *Columba elphinstonii* and Travancore Laughingthrush *Trochalopteron meridionale* and an **'Endangered'** species, i.e. White-bellied Blue Robin *Myiomela albiventris.* Some of the bird species which were recorded in the current study, but were either not recorded from the region or were previously reported as unconfirmed sighting records are Jungle Bush-quail *Perdicula asiatica*, Indian Peafowl *Pavo cristatus*, White-eyed Buzzard *Butastur teesa*, Legge's Hawk-eagle *Nisaetus kelaarti*, Mountain Hawk Eagle *Nisaetus nipalensis*, Pied Harrier *Circus melanoleucos*, Brown Wood-Owl *Strix leptogrammica*, Brown-headed Barbet *Psilopogon zeylanicus*, Chestnut-winged Cuckoo *Clamator coromandus*, Orange-headed Thrush *Geokichla citrina*, Nilgiri Thrush *Zoothera neilgherriensis*, Tawny-bellied Babbler *Dumetia hyperythra*, Grasshopper-warbler *Locustella naevia* and

Booted Warbler *Iduna caligata*. Most of the birds mentioned above occurs in other close by forested areas and must have missed in previous surveys. Birds like Indian Peafowl were seen closer to human habitation and hence were seen in forest edges. In places like Bonacaud Tea estate, the population of Peafowl is reported to have increased in the past decade as observed by the residents working in tea estate. However, the statement is not quantified in the current study. Black Kites *Milvus migrans* that were often observed in the periphery of forest in Neyyar WLS were not recorded from the interior forests. Lesser Fish-eagle was sighted only once in flight in Neyyar WLS, while the Grey-headed Fish-eagle is quite a common sight in Kaviyar river, Peppera WLS. A single individual of Pied Harrier was sighted at an elevation of 1300 m in the grassland and southern hilltop forest. Brown Wood-Owl can be regularly heard in Athirumala base camp. Brown-headed Barbet has often been sighted from Peppara WLS (Panigrahi and Jins 2018).

5.4.1. Status of bird species: Frequency analysis (Fig. 5.1) revealed that 9.64 % (n=19) of bird species fell into the category ‘abundant’, 13.19 % (n= 26) were ‘common’, 35.02% (n = 69) appeared to be ‘fairly common’, followed by 22.84 % (n = 45) which were ‘uncommon’ in the study area. 10.65% (n = 21) species that were ‘locally common’ includes most of the endemic and threatened species, which are restricted to specific habitats. Such species were Nilgiri Woodpigeon, Grey-headed Bulbul, Travancore Laughingthrush, Black-and-orange Flycatcher, Nilgiri Flycatcher, Rufous Babbler, White-bellied Treepie and Wynaad Laughingthrush. Lastly, 8.62% (n = 17) were rare including some vagrant species like Asian Woollyneck and Large Hawk-cuckoo *Hierococcyx sparverioides*.

Three species, i.e., Red-vented Bulbul *Pycnonotus cafer,* India Peafowl *Pavo cristatus* and House Crow *Corvus splendens*, which are otherwise abundant elsewhere, fell into the category ‘rare’ in the region because the study area is dominated by moist-deciduous and evergreen forests largely avoided by these open-habitat specialists. Other species that are in the ‘rare’ category although common in other areas are rare here because of their limited sighting records (Appendix 1).

***Table 5. 1:** Western Ghats endemic birds seen in Agasthyamalai Hills (IUCN status in Parenthesis).*

Sl. No.	English Name	Scientific Name
1	Nilgiri Woodpigeon (VU)	*Columba elphinstonii*
2	Grey-fronted Green-pigeon	*Treron affinis*
3	Malabar Parakeet	*Psittacula columboides*
4	Malabar Grey Hornbill	*Ocyceros griseus*
5	Malabar Barbet	*Psilopogon malabaricus*
6	Malabar Flameback[$]	*Chrysocolaptes socialis*
7	Nilgiri Pipit[#] (VU)	*Anthus nilghiriensis*
8	Malabar Woodshrike	*Tephrodornis sylvicola*
9	Grey-headed Bulbul (NT)	*Pycnonotus priocephalus*
10	Flame-throated Bulbul	*Pycnonotus gularis*
11	Nilgiri Thrush[$]	*Zoothera neilgherriensis*
12	Black-and-orange Flycatcher (NT)	*Ficedula nigrorufa*
13	Nilgiri Flycatcher (NT)	*Eumyias albicaudatus*
14	White-bellied Blue Flycatcher	*Cyornis pallidipes*
15	White-bellied Blue Robin[*] (EN)	*Myiomela albiventris*
16	Wynaad Laughingthrush	*Garrulax delesserti*
17	Travancore Laughingthrush[*] (VU)	*Trochalopteron meridionale*
18	Rufous Babbler	*Argya subrufa*
19	Broad-tailed Grassbird[#] (VU)	*Schoenicola platyurus*
20	Nilgiri Flowerpecker	*Dicaeum concolor*
21	Crimson-backed Sunbird	*Leptocoma minima*
22	Malabar Starling [$]	*Sturnus blythii*
23	White-bellied Treepie	*Dendrocitta leucogastra*

[#] Doubtful records from Agasthyamalai Hills in the past
[*] Restricted to the southern Western Ghats south of Palghat Gap
[$] According to Rasmussen and Anderton (2012). Not recognized as species by birdlife International (2017)

5.4.2. Density Estimates: In total, 2137 detections were made from 746-point count efforts in the overall Agasthyamalai range (Table 5.2). Total survey efforts at lower elevation (100-700 m) was 515, in the medium elevation (700-1200 m) it was 141, and lastly at high elevation (>1200m) it was 93. To estimate the overall density of birds in the

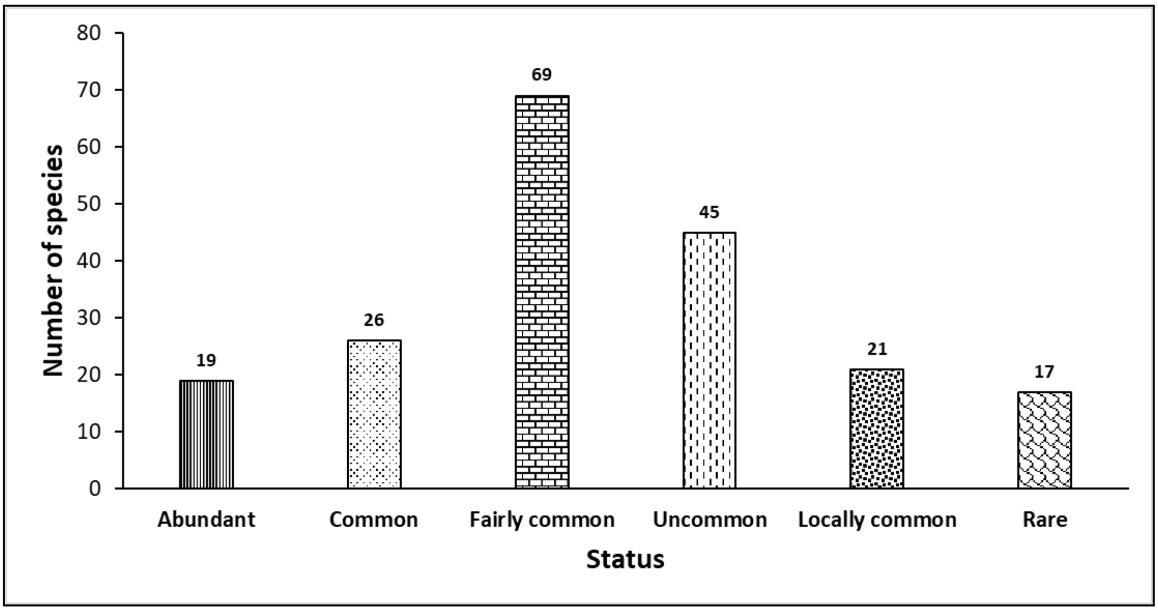


***Figure 5.1**: Number of species (n=197) in each status category is shown in the graph. It is based on the likelihood of their detection in 10 random visits in the right season. Abundant (9–10 in number), Common (7–8 in number), Fairly common (5–6 in number), Uncommon (3–4 in number), Locally common (3–4 in number, in suitable habitats), and Rare (1–2 in number). Above-mentioned criteria are based on field observation.*

study area, 'Uniform key' function was selected as the best fit model since its AIC value was the lowest. The cluster density was estimated to be 55.16 clusters/ha with a mean cluster size of 1.03 clusters/ha. The estimated density of individuals was 58.28 individuals/ha with a coefficient of variation of 6.15%. For the overall bird community in the study area, the highest bird density was recorded at high elevations (101.05 individuals/ha) followed by low elevations (45.71 individuals/ha) and lowest was in the middle elevation (23.32 individuals/ha).

Density was estimated for 18 species that had, the minimum required detections for a robust estimate using Distance program (Table 5.3). The highest cluster density was of Crimson-backed Sunbird *Leptocoma minima* (5.39 clusters/ha) followed by Yellow-browed Bulbul *Acritillas indica* (5.02 clusters/ha) and Nilgiri Flowerpecker *Dicaeum concolor* (5.01clusters/ha). The highest density was of Yellow-browed Bulbul (11.25 individuals/ha) followed by Square-tailed Bulbul *Hypsipetes ganeesa* (9.58 individuals/ha) and Crimson-backed Sunbird (8.09 individuals/ha). The details of detection functions and density estimates for all the 18 species are provided in Table 5.3.

***Table 5.2**: Estimate of density for bird species along the different elevational range in Agasthyamalai hills. All point count data has been used to estimate the density. To estimate density in each of the different elevation classes, the bird detections were pooled for each elevational class.*

			Detection Functions				Density Estimate			
Elevation	**n**	**ER**	**EDR (m)**	**Selected Model**	**Min. AIC**	**DS (ha)**	$\boldsymbol{MCS}$	$\hat{D}$ **(ha)**	**% CV ($\hat{D}$)**	**95% CI**
Overall	2054	2.75	12.61	Uniform	6264.48	55.16	1.03	58.28	6.15	51.67- 65.75
Low (100-700m)	1560	3.05	15.01	Half-normal	3391.4	43.11	1.06	45.71	6.42	40.29- 51.86
Medium (701-1200 m)	321	2.26	17.92	Uniform	900.12	22.40	1.04	23.32	10.46	18.91- 28.76
High (>1200) m	175	1.88	7.80	Half-normal	433.06	98.37	1.02	101.05	15.47	74.41- 137.23

n : No. of Detections; **ER** $(\mathbf{n/k})$: Encounter rate; **EDR**: Effective Detection Radius; **AIC** : Akaike's Information Criterion; $\boldsymbol{DS}$: Estimate density of cluster; $\boldsymbol{MCS}$: Mean Cluster size; $\hat{\boldsymbol{D}}$**:** Density of individuals; **%CV**: Percent coefficient of variation; **95%CI** : 95% confidence interval.

***Table 5.3**: Estimate of density for 18 bird species that had minimum required detections for density estimates. The bird detections were pooled for all elevationl classes, and density estimate in their suitable habitats has been considered.*

Species	n	Detection Functions				Density Estimate					
		(ER)	EDR (m)	Selected Model	Min. AIC	DS (ha)	MCS	E(S)	$\hat{D}$ (ha)	% CV ($\hat{D}$)	95% CI
YBBB	155	0.23	12.17	Uniform	706.86	5.02	2.04	2.24	11.25	14.30	8.50 – 14.89
SQBB	119	0.32	10.20	Half-normal	431.37	4.59	2.39	2.08	9.58	18.82	6.63 – 13.85
CBSB	67	0.09	7.26	Half-normal	328.83	5.39	1.51	1.49	8.09	18.08	5.66 – 11.55
NLFP	106	0.14	9.49	Half-normal	465.98	5.01	1.11	1.11	5.58	17.03	3.99 – 7.81
SCMV	72	0.11	10.69	Half-normal	312.73	2.88	1.93	1.9	5.45	18.95	3.73 – 7.88
GNWR	131	0.17	9.37	Half-normal	473.74	3.28	1.32	1.35	4.43	14.88	3.31 – 5.94
SHMN	40	0.06	16.45	Uniform	178.03	0.69	4.15	4.77	3.33	25.12	2.03 – 5.45
BTBF	55	0.09	12.32	Hazard Rate	201.30	1.82	1.16	1.28	2.34	19.29	1.59 – 3.43
LSHT	38	0.05	9.31	Half-normal	171.71	1.87	1.05	1.13	2.11	24.21	1.29 – 3.41
GRTD	125	0.16	13.64	Half-normal	374.05	1.25	1.83	1.66	2.09	17.98	1.47 – 2.97
MGHB	23	0.03	12.34	Half-normal	136.72	0.87	1.87	2.37	2.06	37.03	0.99 – 4.29
WCBR	95	0.14	14.67	Half-normal	283.64	1.06	1.22	1.22	1.30	16.64	0.94 – 1.80
BNMR	39	0.05	11.44	Half-normal	98.15	0.76	1.28	1.22	0.93	26.71	0.55 – 1.57
LBLW	64	0.09	19.41	Hazard Rate	246.86	0.75	1.08	1.09	0.82	12.59	0.64 – 1.05
FTBB	30	0.05	18.75	Hazard Rate	124.99	0.43	1.33	1.53	0.66	23.61	0.40 – 1.06
AFBB	61	0.08	24.11	Hazard rate	186.59	0.45	1.29	1.36	0.61	15.56	0.45 – 0.83
MWTH	31	0.08	21.65	Half-normal	126.74	0.54	1.03	0.97	0.52	21.86	0.33 – 0.81
MLTR	30	0.04	12.46	Uniform	104.91	0.32		1	0.32	22.41	0.21 – 0.51

n: No. of Detections; **ER: (n/k)**Encounter rate; **EDR**: Effective Detection Radius; DS : Density of cluster; **AIC** : Akaike's Information Criterion; **MCS**: Mean Cluster size; **E(S):** Estimate of expected value of cluster size; $\hat{D}$**:** Density of individuals; **%CV**: Percent coefficient of variation; 95**%CI**: 95% confidence interval.
YBBB :Yellow-browed Bulbul; **SQBB:** Square-tailed Black Bulbul; **CBSB**: Crimson-backed Sunbird; **NLFP**: Nilgiri Flowerpecker**; SCMV:** Scarlet Minivet; **GNWR**: Greenish Warbler; **SHMN**- Southern Hill Myna; **BTBF**: Blue-throated Blue-flycatcher; **LSHT**: Little Spiderhunter; **GRTD**: Greater Racket-tailed Drongo; **MGHB**: Malabar Grey Hornbill; **WCBR**: White-cheeked Barbet; **BNMR**: Black-naped Monarch; **LBLW**: Large-billed Leaf Warbler; **FTBB**: Flame-throated Bulbul; **AFBB**: Asian Fairy-bluebird; **MWTH**: Malabar Whistling-thrush; **MLTR**: Malabar Trogon.

5.4.3. Relative abundance: The highest relative abundance along all elevational bands was seen for Yellow-browed Bulbul (0.08) followed by Greenish Warbler *Phylloscopus trochiloides* (0.066), Greater Racket-tailed Drongo *Dicrurus paradiseus* and Square-tailed Bulbul both had a relative abundance of 0.06. In the case of the three different elevation classes, in lower elevation (100–700 m) Yellow-browed Bulbul had the highest relative abundance (0.08), followed by Greater Racket-tailed Drongo (0.068) and Greenish Warbler (0.065). In the middle elevation (701–1,200 m), the highest relative abundance was in the case of Square-tailed Bulbul (0.123), followed by Yellow-browed Bulbul (0.12) and then White-cheeked Barbet *Psilopogon viridis* is (0.06). In higher elevation (above 1201m), Square-tailed Bulbul again dominated with a relative abundance of 0.18 followed by Travancore Laughingthrush (0.16) and Greenish Warbler (0.1).

5.5. Discussion:

In the tropical forest, bird species richness is high but abundance per species will be lower compared to the temperate forest (Orians 1969, Karr 1977). The categorical status based on field observation revealed that most of the species frequencies of sighting were low in number. Only 22 % of the species were found to be in the 'abundant' and 'common' category. Though higher elevation had few species (27) compared to medium (47) and lower elevations (87), it showed the highest density of 101.05 individuals/ha. This higher density of birds at higher elevations may be due to several reasons. Firstly, the number of detections was less compared to other elevations with 15.47 % CV with a high 95 % CI (74.41-137.23). More detection would have improved the density estimates as lower detection probabilities produce high-density estimates (Gale et al. 2009). The geographic area at higher elevations is significantly lesser (9.71 km^2) compared to medium (35.51km^2) and lower altitudes (206.95 km^2) and that augment the density estimate in a smaller area. Besides, several Western Ghats endemics like Travancore Laughingthrush, Black-and-orange Flycatcher, and Nilgiri Flycatcher are only found in higher elevations. Square-tailed Bulbul having 9.58 individuals/ha were mostly recorded in large groups at the higher elevation. Blackburn and Gaston (1999) observed a significant negative relationship between the abundance and area, and argued that density estimates will be higher if the sampling area is small and lower if sampling area is large. Nee and Cotgreave (2002) also found that larger area will have a lower density of individuals of species owing to the habitat heterogeneity which will support more species at lower densities to accommodate different species and it is termed as density-area relationship.

In the current study, only VCP method has been used to estimate density which is said to overestimate the abundance in general (Raman 2003, Buckland 2006) despite being advantageous over other methods in undulating terrains (Reynolds et al. 1980). Many reasons could be attributed for a biased estimate in the case of point counts. In distance sampling, three primary assumptions, as mentioned earlier, need to be fulfilled. In tropical conditions, these assumptions are difficult to be fully satisfies as bird detections are affected by thick forest, less vocal and cryptic behaviour of some species in addition to other local environmental factors (Gale et al. 2009). Furthermore, while the investigator approaches the point during the count that may cause evasive movement or the calling behaviour of the bird. To reduce bias due to such evasive movement of the observed, 10 minutes was consistently maintained for each point count and the detections were noted immediately after reaching point count stations with no settling down period (SDP) as that would lead to underestimating the density (Lee and Marsden, 2008). Most of the bird detections were by calls and that might also influence the density estimates (Alldredge et al. 2007). Hence, absolute density measures should be used carefully in the case of terrestrial birds to improve density estimates of especially rare or cryptic species. Additionally, multiple methods can be applied for detecting rare and cryptic species that would have missed out in point counts.

In terms of both relative abundance and absolute density, Yellow-browed Bulbul was the most abundant followed by Square-tailed Bulbul for the entire study area. When only relative abundance measure was considered then Greenish Warbler and Greater Racket-tailed Drongo had same abundance values as Square-tailed Bulbul. In terms of absolute density estimates, the third highest density was Crimson-backed Sunbird. This difference in estimation might be because for absolute density measures only those point counts stations were considered that was having suitable habitats for the species. The density estimation that considers the habitat preference of each species for estimating density is called as 'Ecological densities' and the estimation without consideration of species habitat predicted density for the whole study site is known as 'Crude densities'. Ecological densities are much better parameters as they predict the population taking account of habitat preference of an individual species (Gaston et al. 1999).

The absolute density estimates that were calculated for selected species from the study were part of a multispecies survey. Although 100 species of birds were detected in the point counts, appropriate density estimates only for a few species were possible. Most of the endemic and threatened species though detected in the point counts had altogether very low detections. The present study reported 1643.6 birds/km^2 compared to 1122 birds/km^2 in the Silent Valley in Nilgiris (Jayson and Mathew 2000). Mudappa and Raman (2008) have reported White-cheeked Barbet and Crimson-backed Sunbird to be widely distributed in a study conducted in the selective places in the Western Ghats from Goa to Tamil Nadu. Vijayakumar (2015) in a study carried out in the whole of Western Ghats found Yellow-browed Bulbul and White-cheeked Barbet to be most abundant. Jayson and Mathew (2002) in their study conducted in Silent Valley National Park in Kerala reported Yellow-browed Bulbul to be the most common and dominant species and White-Cheeked Barbet the second common and sixth in dominance index. In the current study, Yellow-browed Bulbul, Crimson-backed Sunbird, and White-cheeked Barbet were found to be widely distributed in Agasthyamalai landscape.

5.5.1. Species account in Agasthyamalai Hills: Brief descriptions are given below about a few ‘threatened’, ‘endemic’ and ‘disjunct’ species found in Agasthyamalai hills. Zacharias and Gaston (1999) was followed for disjunct species and following abbreviations were followed for the species account given below; Western Ghats Endemic (WGE) species endemic to western Ghats; Isolated Disjunct (ID) - those species which have isolated population without any intermediate population between the Western Ghats and Himalayas; Quasi-disjunct (QD) - comprises species connected via pockets in the Eastern Ghats and Satpura hills in Madhya Pradesh; Resident (R) in the Western Ghats; IUCN Category: Near Threatened (NT), Vulnerable (VU).

Nilgiri Woodpigeon *Columba elphinstonii*: R, VU, WGE. This species has a broader distribution across the elevations compared to other endemic bird species in the area. It was sighted in almost all forest types, except grasslands and fire-prone areas. In particular, it was seen in higher numbers in high-elevations starting from 1200m to the hilltop where many nests were also seen. Eggs were observed in March and hatchlings in April. Ali (1953) recorded nesting season principally from April to June. A few sightings were recorded from rubber plantations and adjoining highly disturbed forest patches in lower elevations (50 m). Overall detections in counts were less rendering an encounter rate of 0.01 (Detections/survey effort).

Malay Night-heron *Gorsachius melanolophus*: R, ID. Only sighted twice around the elevation of 1000-1050 m near to stream in the evergreen forest. May be underreported due to their sulking and nocturnal behaviour.

Great Hornbill *Buceros bicornis*: R, NT, ID. The species was mostly recorded in and around evergreen patches at 500–1,000 m elevation ranges. Seasonal movements were observed which could be influenced by the availability of fruits. Though nesting activity was not recorded during the current study, mating calls were heard, and sub-adults were seen in the evergreen to semi-evergreen forest. Found to be Uncommon.

Malabar Grey Hornbill *Ocyceros griseus*: R, WGE. Among the two-hornbill species recorded from the study area, this species was the most abundant with a density of 2.06 individuals/ ha. It was found in almost all habitat type as reported in other studies from the Western Ghats (Balasubramanian et al. 2004, Mudapppa and Raman 2008) from 100 to 1050 m elevations. Fledglings were seen during March in moist-deciduous forest.
Two juveniles were kept as pet birds in one of the ‘kani’ settlement. Both were not caged and roamed around freely around the house. This practise of keeping pet birds is uncommon in the area.

Malabar Pied Hornbill *Anthracoceros coronatus*: R. This species has not been recorded in the present study. Balasubramanian et al. (2004), however, have reported its rare presence from Neyyar Wildlife Sanctuary and Thenmala Reserve Forest in Agasthyamalai Hills, considered as the southernmost distribution range for this species. The absence of this ‘Near Threatened’ species in Neyyar during the present study is of great concern.

Oriental Dwarf-kingfisher *Ceyx erithaca:* R, ID. Sighted twice around the same point near to a stream in April. Recorded to be rare in the study area.

Malabar Barbet *Psilopogon malabaricus*: R, WGE. This species was fairly common in comparison to Coppersmith Barbet (uncommon). It was observed to be widespread from lower elevational forest up to 1000m.

White-cheeked Barbet ***Psilopogon viridis****:* R, WGE. One among the most abundant and common birds encountered at elevations from 100m to 1300m. In higher areas, the species was recorded near to evergreen forest and hill top forest transition zone. Nest excavation activity was seen in November in the moist deciduous forest. With an encounter rate of 0.14 the density was estimated to be 1.30 individuals/ha (Table 5.3).

Speckled Piculet ***Picumnus innominatus:*** R, QD. Found to be fairly common, mostly encountered around 400 m elevation where moist deciduous forest and semi-evergreen are in close proximity. Recorded from Moist-Deciduous forest from 200 m to 1300 m in Hill top evergreen forest, and possibly distributed above 1300 m also.

Heart-spotted Woodpecker ***Hemicircus canente:*** R, QD. Fairly common with most of the sightings in the moist deciduous forest from 100-600 m, however, most probably present up to 1000m.

White-Bellied Woodpecker ***Dryocopus javensis:*** R, QD. Only sighted from the evergreen patches around 900-1100 m. Very few sight records hence an uncommon species.

Malabar Parakeet ***Psittacula columboides***: R, WGE. One of the common endemics of the lower reaches of Western Ghats rarely observed in the present study. A few records were made from semi-evergreen and moist-deciduous forests near Bonacaud tea estate at an elevation of 700–750 m.

White-bellied Treepie ***Dendrocitta leucogastra***: R, WGE. Observed mostly near semi-evergreen and evergreen forests at 500–1,100 m. Mostly recorded from evergreen forest. This species appeared to be locally common in suitable habitats.

Square-tailed Bulbul ***Hypsipetes ganeesa****:* R, ID. With a density of 9.58 individuals/ha, this species dominated mid as well as higher elevations. Invariably present throughout the year in higher elevation where nesting was also recorded in March. Shows altitudinal migration, groups sometimes numbering in hundreds can be seen from October onwards until first few weeks in December and again in February in mid-elevations (500-600 m) in Semi-evergreen patches near to Bonacaud forest rest house. December onwards the number reduces in mid-elevation. The species has been recorded at elevations as low as 300-400 meters in November near the edges to semi-evergreen patches, but only in points having forest connectivity. Species were not recorded from the point stations at the same elevation that had degraded mixed deciduous forest and closer to settlements. The altitudinal movements in October have also been reported from Kalakad-Mundanthurai Tiger reserve (Raman, 1999).

Flame-throated Bulbul *Pycnonotus gularis:* R, ID. Found to be fairly common from lower elevation to 1000 m almost in all forest types. Nesting was recorded in February from disturbed moist deciduous forest along the periphery of path in a small bush. Two eggs were observed that fledged within 12 days of observation. Density was estimated to be 0.66 individuals/ha (Table 5.3).

Grey-headed Bulbul *Brachypodius priocephalus*: R, WGE, NT. Locally common, encountered from low elevation up to 1,000m. Encountered during point counts mostly in low elevational forest, not far from tribal settlements, and disturbed forests; however, sighted mostly in patches dominated by reed bamboo (*Ochlandra* sp.) in lower elevation to middle elevation.

Dark-fronted Babbler *Rhopocichla atriceps:* R. Disjunct population within the Western Ghats. Race *bourdilloni* found in the south of the Palghat gap (Ali 1953). Found to be common, sighted mostly in edges of forests preferring thick bushes and reeds, although mostly sighted from the evergreen forest. Distribution is from 100-1500 m, most probably present up to the top of the mountain, as habitat is the same.

Puff-throated Babbler *Pellorneum ruficeps:* R, QD. Common species recorded from 100-1400m mostly preferring moist deciduous, semi and evergreen forest. Nesting recorded from 100m in February as well as in March in evergreen forest.

Rufous Babbler *Argya subrufa*: R, WGE. Mostly encountered in area intermixed with grasses along the forest edges and abandoned tea plantations above 400m were nesting was recorded in May. The race *hyperythrus* is found here having distribution south of Palghat gap.

Wayanad Laughingthrush *Garrulax delesserti*: R, WGE. Flocks were recorded near the forest edges, and tea plantation prefers semi-evergreen forest. Found to be locally common.

Travancore Laughingthrush *Trochalopteron meridionale*: R, WGE, VU. Locally common, restricted to an altitude above 1,100m in high elevation evergreen forest.

Majority of the detections were made at 1200 m and above. It was one of the most common birds encountered at higher altitude. Often found feeding on the offerings left behind by visitors and on *Maesa indica* fruits. A nest with two eggs was photographed in February. The eggs were pale blue with uneven brownish blotches. Adult carrying nesting material was seen in April as well. One record of Black Eagle preying on Travancore Laughing thrush nestlings was also recorded at 1500 m elevation. The species found here is having a very restricted distribution and reported to be sensitive to habitat alterations (Praveen and Nameer 2012). Though having limited sightings in the current study, the species encounter rate (ER) were 0.36 (22.43 individuals/ha; 12.69-39.67 CI).

Southern Hill Myna *Gracula indica:* R, QD. Among the common birds recorded from lower altitude up to 1200 m after which the hilltop forest dominates the area. Mostly sighted in Semi-evergreen patches. Sometimes occur in large groups with Square-tailed Bulbul in 500-600 m altitude during February. Nesting activity in a tree whole was recorded in lower elevation moist deciduous forest in March. Density estimate was 3.33 individuals/ ha. One sub adult kept as pet bird with one of the tribal family. Although the practise is not common in the area, the species is kept as a pet because of its capability to mimic. In the cases of keeping birds as pets (e.g. Malabar Grey Hornbill, Southern Hill Myna and another case of Crested Serpent Eagle), the birds were hand reared from nestling stage and were not caged.

Nilgiri Thrush *Zoothera dauma neilgherriensis*: R, ID, WGE. Found in the areas having some undergrowth and good litter cover mostly in the semi to evergreen forest. It has been recorded from 500 m up to the top of the hill up to 1860 m. This species could be under-reported due to its sulking behaviour hence found to be uncommon.

Indian Blackbird *Turdus simillimus*: R, ID. The race *bourdilloni* is one of the common birds sighted in hilltop evergreen forest throughout the year, starting from 1200 m to the top of the mountain. Occasionally may descend down to the periphery of hilltop forest. Encounter rate was 0.09 in high altitude forest. Mud collection by an individual for nesting was recorded in January from a tree hole at 1250 m elevation in evergreen hilltop forest. Fledglings were seen in March at the top of the mountain at 1860m. Ali (1953) recorded nesting season from March to June in Kerala. Like Travancore Laughingthrush, this species was observed to feed on fruits of *Maesa indica.* The other race *nigropileus* is a winter visitor and is recorded from low elevation forests to 1000m with more sightings in plantations.

Broad-tailed Grassbird *Schoenicola platyurus*: R, WGE, VU. Though said to be breeding in areas of Pandipath and Ponmudi by local bird watchers, this generally rare species was not recorded in the present study.

Nilgiri Flycatcher *Eumyias albicaudatus*: R, WGE. Restricted to the hilltop evergreen patches between 1100–1860 m. Encountered commonly in undisturbed habitats mostly hilltop evergreen patches intermixed with grasslands and reeds than the same kind of habitat in disturbed areas. In the recent assessment of Birdlife international (2017), the species has been downlisted from 'Near Threatened' to 'Least Concern'.

White-bellied Blue Flycatcher *Cyornis pallidipes*: R, WGE. It was widely distributed from the lower elevation to 1,200m and prefers well-wooded areas. Found to be fairly common in this region.

White-bellied Blue Robin *Myiomela albiventris*: R, WGE. Rarely seen and restricted to above 1,000m and evergreen biotope. Sightings were only four times that also not in point counts.

Black-and-orange Flycatcher *Ficedula nigrorufa*: R, WGE. Restricted to hilltop evergreen patches and mostly sighted in the elevation belt of 1100–1860 m. This species shared the same habitat as Nilgiri Flycatcher, but was always observed in low abundance. This species also appears to avoid the disturbed areas. In the recent assessment of Birdlife international (2017), the species has been downlisted from 'Near Threatened' to 'Least Concern'.

Asian Fairy-bluebird *Irena puella:* R, ID. Common species sighted in all types of forest from 100-1600 m, probably till the top of the mountain, as habitat is same. Density was estimated to be 0.61 individuals/ha.

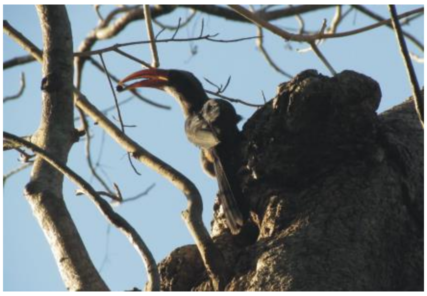
Nilgiri Flowerpecker *Dicaeum concolor*: Among the abundant species found in the study area. Noted from 100-1600 m but possibly up to top as the same habitat occurs as in 1600m. Nesting was recorded from 400 m elevation savanna type forest (Trees intermixed with grassland) in January. Ali (1953) has recorded nesting season chiefly from February to May in Kerala. Density estimate showed 5.58 individuals/ha.

Little Spiderhunter *Arachnothera longirostra:* R, QD. Fairly common. Spread across from lower elevation to 1300m in all forest types. Nest was observed at 1000m elevation in the evergreen forest during March under the leaf of *Ochlandra sps*.

Crimson-backed Sunbird *Leptocoma minima*: R, WGE. A widely distributed endemic species and has been recorded from the lower elevation to 1,600m most probably till the top of the hill as habitat is same as in 1600m. A density of 8.09 individuals/ha was recorded for the species (Table 5.3). Found in almost all forest types and among the most abundant species in the study area. An active nest was seen in March at 1000 m elevation, constructed underside of *Calamus* sps leaves.

5.6. Conclusion: Most of the species occurred in lower abundance and only a few species dominated the bird community. Lower elevation had more species and more sampling effort compared to middle and the higher elevations; however, highest density estimates for bird species were recorded at the higher elevation. This may be a sampling artefact and density-area effect. Species such as Yellow-browed Bulbul, Square-tailed Bulbul, and Crimson-backed Sunbird were the most abundant in Agasthyamalai hills respectively. Of the groups of birds in terms of their abundance, only 19 species were found to be abundant, 26 were common, 69 were fairly common, 45 were uncommon, 21 locally common and 17 were found to be rare. Although the study is a multispecies survey, for many bird species detections were low to calculate absolute density. In general, it was observed that most of the species occurred in low numbers owing to their low detection during the counts. For many endemics and endangered species, density estimates were not possible. Hence, it is recommended that in addition to point counts for all species separate counts should be carried out for site-specific important species to design better conservation practices. It is advisable to carry out modified point counts or transects for species, which are difficult to detect otherwise.

Nilgiri Woodpigeon



Malabar Grey Hornbill

Malabar Barbet

Flame-throated Bulbul

Grey-headed Bulbul

Rufous Babbler

Wynaad Laughingthrush

Travancore Laughingthrush

Nilgiri Thrush

Nilgiri Flycatcher

White-bellied Blue-flycatcher

Black-and-orange Flycatcher

Plate 5.1: *Few of the Western Ghats endemic species of birds found in Agasthyamalai Hills.*


Yellow-browed Bulbul


Square-tailed Bulbul


Crimson-backed Sunbird


Nilgiri Flowerpecker


Scarlet Minivet


Green Warbler


Southern Hill Myna


White-cheeked Barbet

Plate 5.2*:Some of the common species of birds found in Agasthyamalai hills.*

CHAPTER-6

Summary and Conclusion

Mountain ecosystem provides highly varied gradients at a smaller spatial extent compared to latitudes and hence are one of the exceptional study systems for testing various hypotheses in community ecology. Birds, being widely explored taxa with rich historic studies, are an ideal model to test various principles under the discipline of community ecology. The present work explores the bird community pattern along the elevational gradient in Agasthyamalai hills which is one of the under-documented areas in terms of bird community in otherwise well studied Western Ghats. The work explores the association between bird assemblages with respect to vegetation and elevation, and the influencing factors governing bird species distribution in the mountain.

The study result shows remarkable difference in bird community at higher elevation which is a general phenomenon in mountain ecosystems. Although in contrast with studies carried out in mountains, the current study covers relatively a lower elevation range. Even along the chain of the Western Ghats, the highest peak of which is Anaimudi (2695m), Agasthyamalai rank only 27th (1869m) at the southernmost tip of the Ghats. However, compared to the other mountains in the Western Ghats this is probably among the most rugged mountain receiving intense precipitation (only 2-3 dry months) and experiencing high wind speed almost throughout the year especially at higher elevations. This has given rise to a unique forest type called southern hilltop evergreen forest at higher elevation which is highly diverse in terms of vegetation, have lower structural complexity because of stunted growth of trees and have thick foliage that act as wind breaks. Altogether because of drastic change in biotic and abiotic conditions above 1200 m the bird species composition also changes and this change is strongly reflected in the datasets analysed in each chapter of the thesis, and is given in brief below.

6.1. Vegetation and bird assemblages:

- Overall bird community in Agasthyamalai hills reflects a community in equilibrium with many species having intermediate abundance and few rare species with lower abundance (log-normal model). However, when tested along different elevations zones difference in species abundance patterns was observed.

In lower (100-700m) and middle (701-1200m) elevations the pattern was almost similar to that of overall study area. At higher (1200-1868m) elevation the species abundance pattern was significantly different; many species with lower abundance and a few species with intermediate abundance (log-series) were observed. The biotic and abiotic conditions at the higher elevation are remarkably different to those at middle and lower elevations. The communities at higher elevation are subject to harsh climatic conditions, intense rain and winds, compared to communities at other elevation areas. With lower species richness in montane habitats (inherently species poor) (and also lower sampling effort) could be main reasons that that bird community there are not showing any inclination towards reaching a theoretical equilibrium and hence followed a log-series model.

- Insectivore guild was the most diverse and abundant feeding guild in the study area, followed by a mixed guild of frugivore + nectarivore + insectivore. In general, the insectivores, frugivores and their mixed guilds were the dominant ones, indicating intact forest and availability of food resources. Guilds such as omnivores and granivores were low in both species diversity and relative abundance, possibly due to low availability of open habitat. Among the vertical feeding strata, the highest species diversity seen was of ground feeder followed by understorey feeders. This could be due to sampling bias of terrestrial point counts where sampling in canopy was limited. In terms of diversity and relative abundance of guilds along the vertical strata, the middle canopy showed the highest diversity and relative abundance of feeding guilds followed by the top canopy.
- Among the forest types, bird diversity was highest in moist mixed deciduous forest. However, the bird species composition in the case of moist mixed deciduous forest was almost similar with the rest of forest types except the hilltop forest and associated reed beds. In contrast to bird diversity, the feeding guild diversity and vertical feeding strata showed almost equal diversity and dominance values among different forest types. Cluster analysis of bird species composition among the forest types resulted in two clusters, the first one of mixed moist deciduous, evergreen and semi-evergreen forest, and the second cluster of hilltop evergreen and reed beds. Same kinds of clusters were observed when tree species composition was analysed along forest types. Distinct clusters were formed with

respect to different elevational classes, which shows the overriding influence of elevation on both tree and bird species compositions. When elevation was weighted against habitat variables in regression analysis, the habitat variables explained significant variability for the bird species attributes (bird diversity, estimated species richness, guild diversity and vertical feeding stratum). Unlike bird species diversity, tree species diversity increased along increasing elevation.

- Vegetation composition was significantly correlated with bird species composition even when the effect of vegetation structure was controlled. On the other hand, vegetation structure did not show any correlation when effect of tree composition was controlled. Among the feeding guilds, mixed guild of 'frugivore + insectivore', 'granivore + frugivore' and 'insectivore + nectarivore' showed significant, but weak, correlation with tree composition. However, the importance of vegetation structure cannot be ruled out as it showed strong correlation with vegetation composition. Altogether the bird species composition showed a significant correlation to tree species composition as evident from the analysis in this chapter; but influence of elevation is also a predominant factor in structuring the bird species assemblages.

6.2. Bird species richness along elevation:

- Bird species richness showed a declining trend along increasing elevation. Exclusively endemics did not show any particular pattern. Only a few endemics were found to inhabit across the whole range of elevations while many were seen only in middle and lower elevations. Avian groups consisting of montane species are restricted to the higher altitude.
- Birds' distribution pattern roughly agrees with Rapoport's elevational rule although its relevance is debatable. It could be due to the presence of certain montane species restricted to the higher elevation and the resident species that are widespread along the complete elevation categories.
- In general, species showed narrow elevation ranges. As the elevation increased the range size of species increased until 1100 m, after which it decreased drastically.
- Gradual change in species turnover can be seen along the different altitudinal gradient. Above 1100 m, bird community is seen to have higher level of turnover compared to that in the lower elevations. Below 1100 m, communities did not

show more than 64% turnover. Vegetation characteristics and productivity were observed to influence the turnover pattern along the elevation.

- Environmental factors were seen to be good predictors of bird species richness along the altitudinal bands. Temperature largely seems to govern the species richness or distribution. Apart from temperature, precipitation and area also were good predicators of bird species richness. Bird species richness showed least support for MDE null model. However, the endemic species richness showed a weak correlation with MDE. This could be due to the presence of endemics in the full range of elevations. The pattern of endemics in the current study possibly indicates that regional biogeographical history (past climatic events) and other biotic factors (niche preference, vegetation, food availability and phylogeny) may give better answers to the question of endemics species distribution than the current climatic regime.

6.3. Conservation status of birds:

- In total 197 (100 in sample plots and 97 opportunistic observation) bird species were reported in the current study. According to IUCN criteria, of this eight bird species were 'Near threatened', three were 'Vulnerable' and one species was under 'Endangered' category. Yellow-browed Bulbul, Square-tailed Bulbul, and Crimson-backed Sunbird were the first, second and third in terms of abundance in Agasthyamalai hills. Most of other species were seen in intermediate abundance. Of the groups of birds in terms of their abundance, only 19 species were found to be abundant, 26 were common, 69 were fairly common, 45 were uncommon, 21 locally common and 17 were found to be rare.
- Most of the species occurred in low numbers, possibly for their low detectability during counts. Of the 100 birds seen in the sampling plots, density estimates of only 18 species could be calculated. Of that 15species were resident (including four Western Ghats endemics) and three species were winter visitors. For many endemics and endangered species, seen during the study, density estimates were not possible.
- Bird density was observed to be higher at high elevation followed by lower elevation and then middle elevation, despite higher sampling efforts in lower and middle elevation. The higher density at high elevations could be due to lesser area at that elevation, which increases the density estimates with a higher confidence

interval. The biological explanation for the same could be density-area effect, which predicts that larger area will support more species at lower densities to accommodate different species owing to the habitat heterogeneity.

***Future directions**:* The study on the bird community pattern essentially is baseline information for the western slope of the Agasthyamalai hills. So far there is no long-term study on the bird community in the western aspect of the hills while the eastern slope is relatively better-studied. The results of the current study almost resonate with other studies carried out in the Western Ghats. The bird community shows a stable community pattern influenced by vegetation composition. Of the abiotic factors, temperature seems to influence the bird richness along the elevation. The future work to be done on bird community in this area can concentrate on a larger study area of the mountain range encompassing the whole Agasthyamalai range. The range sizes in this study are from the primary observation since there is no such information of range sizes in this slope as such. Field sampling methods and observational data at times won’t be sufficient for revealing the distribution patterns of all species and that demands for other sampling methods such as mist-netting that could help in recording sulking species which escapes direct diurnal observation. Another aspect that needs to be further investigated is the pilgrimage pressure in these mountains, possibly the biggest threat, slowly but steadily growing. Field observations around higher elevations showed low abundance of endemic species like Nilgiri Flycatcher and Black-orange-Flycatcher compared to undisturbed areas. Future studies should cover the disturbance aspect in this area, one of the strongholds of several endemic species, both flora and fauna, in the Western Ghats.

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Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
		GALLIFORMES		
		Phasianidae : Pheasants, partridges, turkeys, grouse		
1	Red Spurfowl	*Galloperdix spadicea*	LC	Fairly Common
2	Indian Peafowl	*Pavo cristatus*	LC	Uncommon
3	Jungle Bush-quail	*Perdicula asiatica*	LC	Rare
4	Grey Junglefowl	*Gallus sonneratii*	LC	Abundant
		COLUMBIFORMES		
		Columbidae: Pigeons, doves		
5	Rock Dove	*Columba livia*	LC	Uncommon
6	Nilgiri Woodpigeon	*Columba elphinstonii*	VU	Locally Common
7	Eastern Spotted Dove	*Spilopelia chinensis*	LC	Fairly Common
8	Grey-capped Emerald Dove	*Chalcophaps indica*	LC	Abundant
9	Grey-fronted Green-pigeon	*Treron affinis*	NT	Fairly Common
10	Mountain Imperial-pigeon	*Ducula badia*	LC	Common
		CAPRIMULGIFORMES		
		Caprimulgidae: Nightjars		
11	Jerdon's Nightjar	*Caprimulgus atripennis*	LC	Fairly Common
		Hemiprocnidae: Treeswifts		
12	Crested Treeswift	*Hemiprocne coronata*	LC	Fairly Common
		Apodidae: Swifts		
13	White-rumped Spinetail	*Zoonavena sylvatica*	LC	Fairly Common
14	Brown-backed Needletail	*Hirundapus giganteus*	LC	Uncommon
15	Indian Swiftlet	*Aerodramus unicolor*	LC	Fairly Common
16	Asian Palm-swift	*Cypsiurus balasiensis*	LC	Uncommon
17	Alpine Swift	*Tachymarptis melba*	LC	Fairly Common
18	Little Swift	*Apus affinis*	LC	Fairly Common
		CUCULIFORMES		
		Cuculidae: Cuckoos		
19	Greater Coucal	*Centropus sinensis*	LC	Fairly Common
20	Lesser Coucal	*Centropus bengalensis*	LC	Rare
21	Chestnut-winged Cuckoo	*Clamator coromandus*	LC	Rare
22	Western Koel	*Eudynamys scolopaceus*	LC	Fairly Common
23	Fork-tailed Drongo-cuckoo	*Surniculus dicruroides*	LC	Fairly Common
24	Large Hawk-cuckoo	*Hierococcyx sparverioides*	LC	Rare
25	Common Hawk-cuckoo	*Hierococcyx varius*	LC	Fairly Common
26	Indian Cuckoo	*Cuculus micropterus*	LC	Fairly Common
		GRUIFORMES		
		Rallidae: Rails, gallinules, coots		
27	White-breasted Waterhen	*Amaurornis phoenicurus*	LC	Fairly Common
		CICONIIFORMES		
		Ciconiidae: Storks		

- Frequency category based on the likelihood of their detection in 10 random visits in the right season: Abundant (9–10), Common (7–8), Fairly common (5–6), Uncommon (3–4), Locally common (3–4 in suitable habitats), and Rare (1–2).
- Species without serial number are doubtful records.

Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
28	Asian Woollyneck	*Ciconia episcopus*	VU	Rare
		PELECANIFORMES		
		Ardeidae: Herons		
29	Cinnamon Bittern	*Ixobrychus cinnamomeus*	LC	Uncommon
30	Malay Night-heron	*Gorsachius melanolophus*	LC	Rare
31	Green-backed Heron	*Butorides striata*	LC	Fairly Common
32	Indian Pond-heron	*Ardeola grayii*	LC	Abundant
33	Cattle Egret	*Bubulcus ibis*	LC	Common
34	Little Egret	*Egretta garzetta*	LC	Common
		SULIFORMES		
		Phalacrocoracidae: Cormorants		
35	Little Cormorant	*Microcarbo niger*	LC	Common
		Anhingidae: Darters		
36	Oriental Darter	*Anhinga melanogaster*	NT	Locally Common
		CHARADRIIFORMES		
		Charadriidae: Plovers		
37	Red-wattled Lapwing	*Vanellus indicus*	LC	Fairly Common
		Scolopacidae: Sandpipers, snipes, phalaropes		
	Pintail Snipe?	*Gallinago stenura*	LC	Uncommon
		Laridae: Gulls, terns, skimmers		
38	River Tern	*Sterna aurantia*	NT	Uncommon
		STRIGIFORMES		
		Tytonidae: Barn-owls		
39	Common Barn-owl	*Tyto alba*	LC	Uncommon
		Strigidae: Typical owls		
40	Brown Boobook	*Ninox scutulata*	LC	Fairly Common
41	Jungle Owlet	*Glaucidium radiatum*	LC	Abundant
42	Indian Scops-owl	*Otus bakkamoena*	LC	Fairly Common
43	Brown Wood-owl	*Strix leptogrammica*	LC	Uncommon
44	Spot-bellied Eagle-owl	*Bubo nipalensis*	LC	Rare
45	Brown Fish-owl	*Ketupa zeylonensis*	LC	Uncommon
		ACCIPITRIFORMES		
		Accipitridae: Hawks, eagles		
46	Black-winged Kite	*Elanus caeruleus*	LC	Fairly Common
47	Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	Fairly Common
48	Black Baza	*Aviceda leuphotes*	LC	Rare
49	Crested Serpent-eagle	*Spilornis cheela*	LC	Abundant
50	Mountain Hawk-eagle / Legge's Hawk -eagle	*Nisaetus nipalensis*	LC	Uncommon
51	Changeable Hawk-eagle/ Crested Hawk-eagle	*Nisaetus cirrhatus*	LC	Fairly Common
52	Rufous-bellied Eagle	*Lophotriorchis kienerii*	LC	Uncommon
53	Black Eagle	*Ictinaetus malaiensis*	LC	Fairly Common

- Frequency category based on the likelihood of their detection in 10 random visits in the right season: Abundant (9–10), Common (7–8), Fairly common (5–6), Uncommon (3–4), Locally common (3–4 in suitable habitats), and Rare (1–2).
- Species without serial number are doubtful records.

Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
54	Bonelli's Eagle	*Aquila fasciata*	LC	Uncommon
55	Booted Eagle	*Hieraaetus pennatus*	LC	Uncommon
56	Pied Harrier	*Circus melanoleucos*	LC	Rare
57	Shikra	*Accipiter badius*	LC	Abundant
58	Crested Goshawk	*Accipiter trivirgatus*	LC	Fairly Common
	Lesser Fish-eagle ?	*Icthyophaga humilis*	NT	Rare
59	Grey-headed Fish-eagle	*Icthyophaga ichthyaetus*	NT	Uncommon
60	Brahminy Kite	*Haliastur indus*	LC	Locally Common
61	Black Kite	*Milvus migrans*	LC	Uncommon
62	White-eyed Buzzard	*Butastur teesa*	LC	Uncommon
63	Eurasian Buzzard	*Buteo buteo*	LC	Locally Common
	Long-legged Buzzard ?	*Buteo rufinus*	LC	Rare
		TROGONIFORMES		
		Trogonidae: Trogons		
64	Malabar Trogon	*Harpactes fasciatus*	LC	Fairly Common
		BUCEROTIFORMES		
		Bucerotidae: Hornbills		
65	Great Hornbill	*Buceros bicornis*	NT	Uncommon
66	Malabar Grey Hornbill	*Ocyceros griseus*	LC	Fairly Common
		BUCEROTIFORMES		
		Upupidae: Hoopoes		
67	Common Hoopoe	*Upupa epops*	LC	Uncommon
		CORACIIFORMES		
		Meropidae: Bee-eaters		
68	Blue-bearded Bee-eater	*Nyctyornis athertoni*	LC	Rare
69	Asian Green Bee-eater	*Merops orientalis*	LC	Common
70	Chestnut-headed Bee-eater	*Merops leschenaulti*	LC	Fairly Common
		Coraciidae: Rollers		
71	Indian Roller	*Coracias benghalensis*	LC	Uncommon
		Alcedinidae: Kingfishers		
72	Oriental Dwarf-kingfisher	*Ceyx erithaca*	LC	Rare
73	Common Kingfisher	*Alcedo atthis*	LC	Fairly Common
74	Pied Kingfisher	*Ceryle rudis*	LC	Fairly Common
75	White-breasted Kingfisher	*Halcyon smyrnensis*	LC	Common
76	Black-capped Kingfisher	*Halcyon pileata*	LC	Uncommon
		PICIFORMES		
		Megalaimidae: Asian barbets		
77	Coppersmith Barbet	*Psilopogon haemacephalus*	LC	Uncommon
78	Malabar Barbet	*Psilopogon malabaricus*	LC	Fairly Common
79	Brown-headed Barbet	*Psilopogon zeylanicus*	LC	Uncommon
80	White-cheeked Barbet	*Psilopogon viridis*	LC	Abundant
		PICIFORMES		

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- Species without serial number are doubtful records.

Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
		Picidae: Woodpeckers		
81	Speckled Piculet	*Picumnus innominatus*	LC	Fairly Common
82	Heart-spotted Woodpecker	*Hemicircus canente*	LC	Fairly Common
83	Greater Flameback	*Chrysocolaptes guttacristatus*	LC	Fairly Common
84	Common Flameback	*Dinopium javanense*	LC	Fairly Common
85	Black-rumped Flameback	*Dinopium benghalense*	LC	Abundant
86	Rufous Woodpecker	*Micropternus brachyurus*	LC	Rare
87	Lesser Yellownape	*Picus chlorolophus*	LC	Fairly Common
88	Streak-throated Woodpecker	*Picus xanthopygaeus*	LC	Fairly Common
89	White-bellied Woodpecker	*Dryocopus javensis*	LC	Uncommon
90	Indian Pygmy Woodpecker	*Picoides nanus*	LC	Fairly Common
		FALCONIFORMES		
		Falconidae: Falcons, caracaras		
91	Common Kestrel	*Falco tinnunculus*	LC	Fairly Common
92	Peregrine Falcon	*Falco peregrinus*	LC	Uncommon
	Shaaheen Falcon*	*Falco peregrinus peregrinator*	LC	Uncommon
		PSITTACIFORMES		
		Psittacidae: Parrots		
93	Vernal Hanging-parrot	*Loriculus vernalis*	LC	Abundant
94	Plum-headed Parakeet	*Psittacula cyanocephala*	LC	Abundant
95	Malabar Parakeet	*Psittacula columboides*	LC	Uncommon
		PASSERIFORMES		
		Pittidae: Pittas		
96	Indian Pitta	*Pitta brachyura*	LC	Common
		Oriolidae: Old World orioles		
97	Black-hooded Oriole	*Oriolus xanthornus*	LC	Fairly Common
98	Indian Golden Oriole	*Oriolus kundoo*	LC	Fairly Common
99	Black-naped Oriole	*Oriolus chinensis*	LC	Fairly Common
		Campephagidae: Cuckoo-shrikes		
100	Small Minivet	*Pericrocotus cinnamomeus*	LC	Fairly Common
101	Scarlet Minivet	*Pericrocotus flammeus*	LC	Abundant
102	Indian Cuckoo-shrike	*Coracina macei*	LC	Fairly Common
		Artamidae: Woodswallows and butcherbirds		
103	Ashy Woodswallow	*Artamus fuscus*	LC	Fairly Common
		Vangidae: Vangas and allies		
104	Bar-winged Flycatcher-shrike	*Hemipus picatus*	LC	Fairly Common
105	Malabar Wood-shrike	*Tephrodornis sylvicola*	LC	Fairly Common
106	Common Wood-shrike	*Tephrodornis pondicerianus*	LC	Fairly Common
		Aegithinidae: Ioras		
107	Common Iora	*Aegithina tiphia*	LC	Fairly Common

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- Species without serial number are doubtful records.

Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
		Dicruridae: Drongos		
108	Black Drongo	*Dicrurus macrocercus*	LC	Uncommon
109	Ashy Drongo	*Dicrurus leucophaeus*	LC	Common
110	Bronzed Drongo	*Dicrurus aeneus*	LC	Common
111	Hair-crested Drongo	*Dicrurus hottentottus*	LC	Rare
112	Greater Racquet-tailed Drongo	*Dicrurus paradiseus*	LC	Abundant
		Monarchidae: Monarch-flycatchers		
113	Black-naped Monarch	*Hypothymis azurea*	LC	Common
114	Indian Paradise-flycatcher	*Terpsiphone paradisi*	LC	Fairly Common
		Laniidae: Shrikes		
115	Brown Shrike	*Lanius cristatus*	LC	Common
		Corvidae: Crows and jays		
116	Rufous Treepie	*Dendrocitta vagabunda*	LC	Fairly Common
117	White-bellied Treepie	*Dendrocitta leucogastra*	LC	Locally common
118	House Crow	*Corvus splendens*	LC	Uncommon
119	Large-billed Crow	*Corvus macrorhynchos*	LC	Fairly Common
		Stenostiridae: Fairy Flycatcher and allies		
120	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	LC	Locally common
		Paridae: Tits and chickadees		
121	Great Tit	*Parus major*	LC	Fairly Common
122	Black-lored Tit	*Machlolophus xanthogenys*	LC	Locally common
		Cisticolidae: Cisticolas and allies		
123	Grey-breasted Prinia	*Prinia hodgsonii*	LC	Fairly Common
124	Jungle Prinia	*Prinia sylvatica*	LC	Uncommon
125	Ashy Prinia	*Prinia socialis*		Uncommon
		Acrocephalidae: Reed-warblers		
126	Booted Warbler	*Iduna caligata*	LC	Fairly Common
127	Sykes's Warbler	*Iduna rama*	LC	Rare
128	Blyth's Reed-warbler	*Acrocephalus dumetorum*	LC	Common
129	Paddyfield Warbler	*Acrocephalus agricola*	LC	Rare
		Locustellidae: Grasshopper-warblers and grassbirds		
130	Common Grasshopper-warbler	*Locustella naevia*	LC	Locally common
		Hirundinidae: Swallows and martins		
131	Red-rumped Swallow	*Cecropis daurica*	LC	Uncommon
132	House Swallow	*Hirundo javanica*	LC	Locally common
133	Barn Swallow	*Hirundo rustica*	LC	Uncommon
134	Dusky Crag Martin	*Ptyonoprogne concolor*	LC	Uncommon
		Pycnonotidae: Bulbuls		
135	Square-tailed Bulbul	*Hypsipetes ganeesa*	LC	Locally common
136	Flame-throated Bulbul	*Pycnonotus gularis*	LC	Fairly Common

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- Species without serial number are doubtful records.

Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
137	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	Fairly Common
138	Red-vented Bulbul	*Pycnonotus cafer*	LC	Rare
139	Grey-headed Bulbul	*Brachypodius priocephalus*	NT	Locally common
140	Yellow-browed Bulbul	*Acritillas indica*	LC	Abundant
		Phylloscopidae: Leaf-warblers		
141	Tickell's Leaf-warbler	*Phylloscopus affinis*	LC	Locally common
142	Green Warbler	*Phylloscopus nitidus*	LC	Common
143	Greenish Warbler	*Phylloscopus trochiloides*	LC	Abundant
144	Large-billed Leaf-warbler	*Phylloscopus magnirostris*	LC	Common
145	Western Crowned Leaf-warbler	*Phylloscopus occipitalis*	LC	Uncommon
		Sylviidae: Old World warblers and parrotbills		
146	Lesser Whitethroat	*Sylvia curruca*	LC	Fairly Common
		Zosteropidae: White-eyes and yuhinas		
147	Oriental White-eye	*Zosterops palpebrosus*	LC	Locally common
		Timaliidae: Scimitar-babblers and allies		
148	Indian Scimitar-babbler	*Pomatorhinus horsfieldii*	LC	Common
149	Tawny-bellied Babbler	*Dumetia hyperythra*	LC	Uncommon
150	Dark-fronted Babbler	*Rhopocichla atriceps*	LC	Common
		Pellorneidae: Ground babblers		
151	Puff-throated Babbler	*Pellorneum ruficeps*	LC	Common
		Leiotrichidae: Laughingthrushes and allies		
152	Brown-cheeked Fulvetta	*Alcippe poioicephala*	LC	Abundant
153	Rufous Babbler	*Argya subrufa*	LC	Locally common
154	Jungle Babbler	*Turdoides striata*	LC	Uncommon
155	Yellow-billed Babbler	*Turdoides affinis*	LC	Uncommon
156	Wynaad Laughingthrush	*Garrulax delesserti*	LC	Locally common
157	Travancore Laughingthrush	*Trochalopteron meridionale*	VU	Locally common
		Sittidae: Nuthatches		
158	Velvet-fronted Nuthatch	*Sitta frontalis*	LC	Common
		Sturnidae: Starlings		
159	Chestnut-tailed Starling	*Sturnia malabarica*	LC	Uncommon
	Malabar White-headed starling	*Sturnia blythii*	LC	Uncommon
160	Common Myna	*Acridotheres tristis*	LC	Uncommon
161	Southern Hill Myna	*Gracula indica*	LC	Abundant
		Turdidae: Thrushes		
162	Scaly Thrush/ Nilgiri Thrush	*Zoothera neilgherriensis dauma*	LC	Uncommon
163	Orange-headed Thrush	*Geokichla citrina*	LC	Fairly common
164	Indian Blackbird	*Turdus simillimus*	LC	Uncommon
	Bourdillon's Blackbird*	*Turdus merula bourdilloni*	LC	Locally common
		Muscicapidae: Old World flycatchers and chats		

- Frequency category based on the likelihood of their detection in 10 random visits in the right season: Abundant (9–10), Common (7–8), Fairly common (5–6), Uncommon (3–4), Locally common (3–4 in suitable habitats), and Rare (1–2).
- Species without serial number are doubtful records.

Sl. No.	Common name	Scientific name	2016 IUCN Red List category	Field Observation
165	Oriental Magpie-robin	*Copsychus saularis*	LC	Uncommon
166	White-rumped Shama	*Kittacincla malabarica*	LC	Fairly common
167	Brown-breasted Flycatcher	*Muscicapa muttui*	LC	Fairly common
168	Asian Brown Flycatcher	*Muscicapa dauurica*	LC	Common
169	Nilgiri Flycatcher	*Eumyias albicaudatus*	NT	Locally common
170	Verditer Flycatcher	*Eumyias thalassinus*	LC	Uncommon
171	White-bellied Blue-flycatcher	*Cyornis pallidipes*	LC	Fairly common
172	Tickell's Blue-flycatcher	*Cyornis tickelliae*	LC	Locally common
173	Blue-throated Blue-flycatcher	*Cyornis rubeculoides*	LC	Common
174	Indian Blue Robin	*Larvivora brunnea*	LC	Common
175	White-bellied Blue Robin	*Myiomela albiventris*	EN	Rare
176	Malabar Whistling-thrush	*Myophonus horsfieldii*	LC	Fairly common
177	Rusty-tailed Flycatcher	*Ficedula ruficauda*	LC	Fairly common
178	Black-and-orange Flycatcher	*Ficedula nigrorufa*	NT	Locally common
179	Blue-capped Rock-thrush	*Monticola cinclorhyncha*	LC	Locally common
180	Blue Rock-thrush	*Monticola solitarius*	LC	Uncommon
		Irenidae: Fairy-bluebirds		
181	Asian Fairy-bluebird	*Irena puella*	LC	Common
		Chloropseidae: Leafbirds		
182	Golden-fronted Leafbird	*Chloropsis aurifrons*	LC	Common
183	Jerdon's Leafbird	*Chloropsis jerdoni*	LC	Fairly common
		Dicaeidae: Flowerpeckers		
184	Thick-billed Flowerpecker	*Dicaeum agile*	LC	Uncommon
185	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	LC	Common
186	Nilgiri Flowerpecker	*Dicaeum concolor*	LC	Abundant
		Nectariniidae: Sunbirds		
187	Little Spiderhunter	*Arachnothera longirostra*	LC	Fairly common
188	Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	Fairly common
189	Crimson-backed Sunbird	*Leptocoma minima*	LC	Abundant
190	Purple Sunbird	*Cinnyris asiaticus*	LC	Fairly common
191	Loten's Sunbird	*Cinnyris lotenius*	LC	Common
		Estrildidae: Waxbills		
192	Black-throated Munia	*Lonchura kelaarti*	LC	Uncommon
		Motacillidae: Pipits and wagtails		
193	Forest Wagtail	*Dendronanthus indicus*	LC	Fairly common
194	Paddyfield Pipit	*Anthus rufulus*	LC	Fairly common
195	Long-billed Pipit	*Anthus similis*	LC	Locally common
196	Grey Wagtail	*Motacilla cinerea*	LC	Abundant
197	White-browed Wagtail	*Motacilla maderaspatensis*	LC	Common

- Frequency category based on the likelihood of their detection in 10 random visits in the right season: Abundant (9–10), Common (7–8), Fairly common (5–6), Uncommon (3–4), Locally common (3–4 in suitable habitats), and Rare (1–2).
- Species without serial number are doubtful records.

Sl. No.	Species Name	Feeding guild	Vertical stratum
1	Ashy Drongo	Insectivore + Nectarivore	Top canopy
2	Asian Brown Flycatcher	Insectivore	Lower Canopy
3	Asian Fairy-bluebird	Frugivore +Nectarivore Insectivore	Middle Canopy
4	Indian Paradise-flycatcher	Insectivore	Lower Canopy
5	Bar-winged Flycatcher-shrike	Insectivore	Middle Canopy
6	Black Drongo	Insectivore + Nectarivore	Middle Canopy
7	Black-and-orange Flycatcher	Insectivore	Understorey
8	Black-hooded Oriole	Frugivore +Nectarivore Insectivore	Top canopy
9	Black-naped Monarch	Insectivore	Lower Canopy
10	Black-naped Oriole	Frugivore +Nectarivore Insectivore	Top canopy
11	Blue-capped Rock-thrush	Insectivore	Ground Feeder
12	Blue-throated Blue-flycatcher	Insectivore	Lower Canopy
13	Blyth's Reed-warbler	Insectivore	Understorey
14	Blyth’s Starling	Frugivore +Nectarivore Insectivore	Top canopy
15	Booted Warbler	Insectivore	Understorey
16	Bronzed Drongo	Insectivore + Nectarivore	Middle Canopy
17	Brown Shrike	Insectivore	Understorey
18	Brown-breasted Flycatcher	Insectivore	Lower Canopy
19	Brown-cheeked Fulvetta	Insectivore	Understorey
20	Brown-headed Barbet	Frugivore +Nectarivore Insectivore	Top canopy
21	Chestnut-tailed Starling	Frugivore +Nectarivore Insectivore	Middle Canopy
22	Common Flameback	Insectivore	Bark Feeder
23	Common Iora	Insectivore	Lower Canopy
24	Crested TreeSwift	Insectivore	Aerial Feeder
25	Crimson-backed Sunbird	Insectivore + Nectarivore	Middle Canopy
26	Dark-fronted Babbler	Insectivore	Understorey
27	Grey-capped Emerald Dove	Granivore + Frugivore	Ground Feeder
28	Flame-throated Bulbul	Frugivore + Insectivore	Middle Canopy
29	Forest Wagtail	Insectivore	Ground Feeder
30	Golden-fronted Leafbird	Frugivore +Nectarivore Insectivore	All canopy levels
31	Common Grasshopper-warbler	Insectivore	Understorey
32	Great Tit	Insectivore	All canopy levels
33	Greater Flameback	Insectivore	Bark Feeder
34	Greater Racquet-tailed Drongo	Insectivore + Nectarivore	Lower Canopy
35	Greenish Warbler	Insectivore	All canopy levels
36	Grey-fronted Green-pigeon	Frugivore	Top canopy
37	Grey Junglefowl	Omnivore	Ground Feeder
38	Grey Wagtail	Insectivore	Ground Feeder
39	Grey-breasted Prinia	Insectivore	Understorey
40	Grey-headed Bulbul	Frugivore	Middle Canopy
41	Grey-headed Canary-flycatcher	Insectivore	Lower Canopy

Sl. No.	Species Name	Feeding guild	Vertical stratum
42	Heart-spotted Woodpecker	Insectivore	Bark Feeder
43	Indian Blackbird	Frugivore + Insectivore	Ground Feeder
44	Indian Blue Robin	Insectivore	Understorey
45	Indian Golden Oriole	Frugivore +Nectarivore Insectivore	Top canopy
46	Large-billed Crow	Omnivore	All canopy levels
47	Indian Pitta	Insectivore	Ground Feeder
48	Indian Scimitar-babbler	Insectivore	Understorey
49	Jerdon's Leafbird	Frugivore +Nectarivore Insectivore	All canopy levels
50	Jungle Babbler	Insectivore	Ground Feeder
51	Travancore Laughingthrush	Frugivore + Insectivore	Ground Feeder
52	Indian Cuckoo-shrike	Frugivore + Insectivore	Top canopy
53	Large-billed Leaf-warbler	Insectivore	Middle Canopy
54	Lesser Coucal	Omnivore	Understorey
55	Black-rumped Flameback	Insectivore	Bark Feeder
56	Southern Hill Myna	Frugivore	Top canopy
57	Lesser Yellownape	Insectivore	Bark Feeder
58	Little Spiderhunter	Insectivore + Nectarivore	Lower Canopy
59	Loten's Sunbird	Insectivore + Nectarivore	Middle Canopy
60	Malabar Barbet	Frugivore +Nectarivore Insectivore	Top canopy
61	Malabar Grey Hornbill	Frugivore + Insectivore	Middle Canopy
62	Malabar Parakeet	Granivore + Frugivore	Top canopy
63	Malabar Trogon	Insectivore	Middle Canopy
64	Malabar Whistling-thrush	Insectivore	Ground Feeder
65	Malabar Wood-shrike	Insectivore	Middle Canopy
66	Mountain Imperial-pigeon	Frugivore	Top canopy
67	Nilgiri Flowerpecker	Frugivore + Insectivore	All canopy levels
68	Nilgiri Flycatcher	Insectivore	Middle Canopy
69	Nilgiri Woodpigeon	Frugivore	Top canopy
70	Scarlet Minivet	Insectivore	Top canopy
71	Orange-headed Thrush	Frugivore + Insectivore	Ground Feeder
72	Oriental Magpie-robin	Insectivore	Understorey
73	Oriental White-eye	Frugivore +Nectarivore Insectivore	Middle Canopy
74	Paddyfield Pipit	Granivore + Insectivore	Ground Feeder
75	Pale-billed Flowerpecker	Frugivore + Insectivore	All canopy levels
76	Plum-headed Parakeet	Granivore + Frugivore	Top canopy
77	Puff-throated Babbler	Insectivore	Ground Feeder
78	Purple Sunbird	Insectivore + Nectarivore	Middle Canopy
79	Purple-rumped Sunbird	Insectivore + Nectarivore	Middle Canopy
80	Red Spurfowl	Omnivore	Ground Feeder
81	Red-vented Bulbul	Frugivore +Nectarivore Insectivore	All canopy levels
82	Red-whiskered Bulbul	Frugivore +Nectarivore Insectivore	All canopy levels

Sl. No.	Species Name	Feeding guild	Vertical stratum
83	Rufous Babbler	Insectivore + Nectarivore	Understorey
84	Rufous Treepie	Omnivore	All canopy levels
85	Rusty-tailed Flycatcher	Insectivore	Lower Canopy
86	Small Minivet	Insectivore	All canopy levels
87	Southern Coucal	Omnivore	Ground Feeder
88	Speckled Piculet	Insectivore	Bark Feeder
89	Square-tailed Bulbul	Frugivore +Nectarivore Insectivore	Top canopy
90	Thick-billed Flowerpecker	Frugivore + Insectivore	All canopy levels
91	Tickell's Blue-flycatcher	Insectivore	Lower Canopy
92	Tickell's Leaf-warbler	Insectivore	Understorey
93	Velvet-fronted Nuthatch	Insectivore	Bark Feeder
94	Vernal Hanging-parrot	Frugivore	Top canopy
95	White-bellied Blue-flycatcher	Insectivore	Understorey
96	White-bellied Treepie	Omnivore	Middle Canopy
97	White-cheeked Barbet	Frugivore +Nectarivore Insectivore	Middle Canopy
98	White-rumped Shama	Insectivore	Lower Canopy
99	White-breasted Kingfisher	Insectivore	Lower Canopy
100	Yellow-browed Bulbul	Frugivore + Insectivore	Lower Canopy

Sl.No.	Species	Sl.no	Species
1	*Actinodaphne lawsonii*	39	*Camellia sinensis*
2	*Agasthiyamalai pauciflorum*	40	*Canthium dicoccum*
3	*Aglaia anamallayana*	41	*Careya arborea*
4	*Aglaia bourdillonii*	42	*Casearia ceylanicus*
5	*Aglaia elaeagnoidea*	43	*Catunaregam spinosa*
6	*Agrostistachys meeboldii*	44	*Celastrus paniculatus*
7	*Ailanthus triphysa*	45	*Chionanthus courtallensis*
8	*Albizia amara*	46	*Chionanthus malabaricus*
9	*Alstonia scholaris*	47	*Chionanthus ramiflorus*
10	*Alstonia venenata*	48	*Chionanthus sp*
11	*Ancistrocladus heyneanus*	49	*Chrysophyllum lanceolatum*
12	*Annonaceae sp1*	50	*Cinnamomum malabatrum*
13	*Annonaceae sp2*	51	*Cinnamomum sulphuratum*
14	*Antidesma menasu*	52	*Clerodendrum infortunatum*
15	*Antidesma sp 1*	53	*Connarus wightii*
16	*Aphanamixis polystachya*	54	*Croton zeylanicus*
17	*Apollonias arnottii*	55	*Cryptocarya bourdillonii*
18	*Aporosa lindleyana*	56	*Cullenia exarillata*
19	*Aporosa sp*	57	*Dalbergia latifolia*
20	*Aporosa sp1*	58	*Dillenia pentagyna*
21	*Archidendron monadelphum*	59	*Dimocarpus longan*
22	*Artocarpus fraxinifolius*	60	*Diospyros bourdillonii*
23	*Artocarpus gomezianus*	61	*Diospyros buxifolia*
24	*Artocarpus heterophyllus*	62	*Diospyros candolleana*
25	*Artocarpus hirsutus*	63	*Diospyros elata*
26	*Arundinella densiflora*	64	*Diospyros oocarpa*
27	*Asteraceaes sp1*	65	*Diospyros sp*
28	*Baccaurea courtallensis*	66	*Diospyros sulcataa*
29	*Bambusa bambos*	67	*Diospyros sylvatica*
30	*Benkara malabarica*	68	*Drypetes malabarica*
31	*Bombax ceiba*	69	*Dysoxylum malabaricum*
32	*Briedelia retusa*	70	*Elaeagnus kologa*
33	*Butea parviflora*	71	*Elaeocarpus glandulosus*
34	*Byrosphyllum tetrandrum*	72	*Elaeocarpus munroii*
35	*Calamus sp*	73	*Elaeocarpus munronii*
36	*Calophyllum elatum*	74	*Elaeocarpus tuberculatus*
37	*Calophyllum polyanthum*	75	*Elatostema sp*
38	*Calycopteris floribunda*	76	*Euodia lunu-ankenda*

Sl.No.	**Species**	**Sl.no**	**Species**
77	*Eupatorium sulphuratum*	115	*Ligustrum perrottetii*
78	*Euphorbiaceae sp*	116	*Litsea floribunda*
79	*Eurya japonica*	117	*Litsea ghatica*
80	*Eurya nitida*	118	*Litsea insignis*
81	*Fagrea ceilanica*	119	*Litsea laevigata*
82	*Ficus sp*	120	*Litsea mysorensis*
83	*Flacourtia sp*	121	*Litsea sp*
84	*Garcinia gummi-gutta*	122	*Litsea stocksii*
85	*Glochidion arboreum*	123	*Litsea wightiana*
86	*Glochidion sp1*	124	*Lophopetalum wightianum*
87	*Glochidion sp2*	125	*Macaranga peltata*
88	*Glochidion zeylanicum*	126	*Maesa indica*
89	*Gluta travancorica*	127	*Mallotus philippensis*
90	*Gomphandra pentandra*	128	*Mangifera indica*
91	*Gomphandra tetrandra*	129	*Mappia foetida*
92	*Goniothalamus cardiopetalus*	130	*Mastixia arborea*
93	*Gordonia obtusa*	131	*Melicope lunu-ankenda*
94	*Grewia tiliifolia*	132	*Meliosma simplicifolia*
95	*Helicteres isora*	133	*Memecylon sp*
96	*Heritiera papilio*	134	*Memecylon umbellatum*
97	*Holigarna arnottiana*	135	*Mesua ferrea*
98	*Holigarna beddomei*	136	*Microtropis ramiflora*
99	*Hopea parviflora*	137	*Miliusa montana*
100	*Hopea racophloea*	138	*Miliusa montana*
101	*Humboldtia bourdillonii*	139	*Mitragyna parvifolia*
102	*Hydnocarpus pentandrus*	140	*Murraya paniculata*
103	*Hydnocarpus sp*	141	*Myristica dactyloides*
104	*Ilex walkeri*	142	*Naringi crenulata*
105	*Isonandra sp*	143	*Neolamarckia cadamba*
106	*Ixora arborea*	144	*Neolitsea scrobiculata*
107	*Ixora brachiata*	145	*Neolitsea zeylanica*
108	*Ixora lawsonii*	146	*Ochlandra travancorica*
109	*Kingiodendron pinnatum*	147	*Olea dioica*
110	*Knema attenuata*	148	*Olea paniculata*
111	*Lagerstroemia sp*	149	*Palaquium ellipticum*
112	*Lasianthus parvifolius*	150	*Paramignya sp1*
113	*Leea indica*	151	*Pavetta indica*
114	*Lepisanthes sp*	152	*Pavetta travancorica*

Sl.No.	Species	Sl.no	Species
153	*Persea macrantha*	191	*Symplocos cochinchinensis*
154	*Phyllanthus emblica*	192	*Symplocos racemosa*
155	*Pithecellobium dulce*	193	*Syzygium lanceolatum*
156	*Pittosporum tetraspermum*	194	*Syzygium mundagam*
157	*Pogostemon travancoricus*	195	*Syzygium munronii*
158	*Polygonum plebeium*	196	*Syzygium sp1*
159	*Prunus ceylanica*	197	*Syzygium sp2*
160	*Psychotria beddomei*	198	*Syzygium sp3*
161	*Psychotria nigra*	199	*Syzygium sp4*
162	*Psychotria sp1*	200	*Syzygium sp5*
163	*Psychotria sp2*	201	*Syzygium arnottianum*
164	*Psychotria sp3*	202	*Syzygium calophyllifolium*
165	*Pterocarpus marsupium*	203	*Syzygium caryophyllatum*
166	*Rutaceae sp*	204	*Syzygium densiflorum*
167	*Sapotaceae sp*	205	*Syzygium gardneri*
168	*Saprosma fragrans*	206	*Syzygium hemisphericum*
169	*Schefflera sp1*	207	*Syzygium laetum*
170	*Schefflera sp2*	208	*Tabernaemontana alternifolia*
171	*Schleichera oleosa*	209	*Tabernaemontana ceylanica*
172	*Scolopia crenata*	210	*Terminalia alata*
173	*Semecarpus anacardium*	211	*Terminalia paniculata*
174*	*spA*	212	*Thottea siliquosa*
175*	*spD*	213	*Tricalysia apiocarpa*
176*	*spH*	214	*Tricalysia arnottianum*
177*	*spI*	215	*Trichilia connaroides*
178*	*spJ*	216	*Vaccinium leschenaultii*
179*	*spK*	217	*Vateria indica*
180*	*spL*	218	*Vernonia arborea*
181*	*spM*	219	*Vitex altissima*
182*	*spN*	220	*Wrightia tinctoria*
183	*Spondias pinnata*	221	*Xanthophyllum arnottianum*
184*	*spQ*	222	*Xanthophyllum sp*
185*	*spR*	223	*Ziziphus rugose*
186	*Sterculia guttata*		
187	*Stereospermum chelonoides*		
188	*Strobilanthes wightiana*		
189	*Strobilanthus homotropus*		
190	*Swietenia mahagoni*		

*unidentified species

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Status of birds in Agasthyamalai Hills, Western Ghats, Kerala, India

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Abstract: The present study focused on the status of birds in two wildlife sanctuaries, Neyyar and Peppara, located in Agasthyamalai Biosphere Reserve, Kerala State, India. A total of 197 bird species representing 16 orders and 57 families are reported from the study area. According to the IUCN Red List, one Endangered, two Vulnerable, and nine Near Threatened bird species occur in the landscape. Black Bulbul was the most abundant species with highest density, followed by Yellow-browed Bulbul and Crimson-backed Sunbird. Despite many bird species being broadly distributed across elevations, most endemic species occur or breed at elevations above 1,200m, dominated by southern hilltop evergreen forest. This highlights the prominence of these high altitude species and their habitats. A customized conservation plan is needed for the whole elevation gradient with greater emphasis on high elevation forest.

Keywords: Bird community, density estimates, elevation, endemism, Neyyar, Peppara.

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Author details: Madhumita Panigrahi - PhD scholar with interest in bird communities, ecology and species distribution patterns. V.J. Jins - PhD scholar, interested in community ecology, herpetology and landscape level patterns in biodiversity.

Author Contribution: MP carried out field sampling, compiled data, analyzed and wrote the manuscript. JVJ assisted in fieldwork and helped in revising the manuscript.

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INTRODUCTION

Regional assessment of population status of any taxa is crucial for conservation planning of species and landscapes (Vetaas & Grytnes 2002). The mountain ranges of Western Ghats, are ranked high among the global biodiversity hotspots (Myers et al. 2000; Mittermeier et al. 2004). It is one of the 200 most important global ecoregions (Olson & Dinerstein 1998), and endemic bird areas of the world (Stattersfield et al. 1998). The Western Ghats form one of the 10 biogeographic zones of India (Rodgers et al. 2002) and are known to harbour more than 500 species of birds (Ali & Ripley 1996).

Of the 504 species of birds occurring in southwestern India, 360 species are terrestrial (Daniels 1997). A total of 16 species are endemic and restricted to the Western Ghats (Sattersfield et al. 1998, 2005). The range boundaries of many of the bird species is largely influenced by the Palghat Gap, a 30km wide low-elevation mountain pass at 10.0833^{0}N latitude between Nilgiris in the north and Anaimalai Range in the south. Notably, the moist forests, particularly tropical montane evergreen rainforest in the southern Western Ghats, is a major habitat for over 100 species of birds, including 14 endemics (Mudappa & Raman 2008). In Kerala alone, 500 species of birds have been recorded belonging to 88 families and 22 orders, out of which 17 species are endemic to this region (Praveen 2015). In the light of new taxonomic revisions, 24 species are considered to be endemic to the Western Ghats (Rasmussen & Anderton 2012).

The present study was carried out in Agasthyamalai Biosphere Reserve (ABR), particularly in two wildlife sanctuaries namely, Neyyar and Peppara in Kerala State which have been listed among the Important Bird Areas (Birdlife international 2015; Rahmani & Zafar-Ul Islam 2004). Nair (1993) has recorded 172 bird species belonging to 39 families from Neyyar Wildlife Sanctuary (NWS) alone. A concise checklist by Sashikumar et al. (2011) has enlisted a total of 221 and 215 birds from Neyyar and Peppara respectively making a total list of 227 birds in this area. There are many studies conducted in the eastern slope of the mountain range, i.e., mostly covering Kalakad-Mundanthurai Tiger Reserve (Johnsingh & Joshua 1994; Venkatraman 2011; Ramachandran & Ganesh 2013). However, no long-term studies on forest bird community are available from the western slopes apart from a few checklists. In light of the above-mentioned gap in information, the present study highlights the status of forest birds in the western slope of Agasthyamalai Hills of Kerala.

MATERIALS AND METHODS

Study area

The intensive study area (250km^2) is along the western slope of Agasthyamalai Hills in Kerala 8.55N-77.10E & 8.7166N-77.250E, and includes the areas of Neyyar and Peppara wildlife sanctuaries and the Agasthyavanam Biological Park (ABP) (Fig. 1). The area has an elevation range between 100–1,866 m above mean sea level. The forest types of this region include southern hilltop evergreen forest, west coast tropical evergreen forest, west coast semi-evergreen forest, southern secondary moist mixed deciduous forest and reed brakes (Champion & Seth 1968). The lower elevations (<600m) are dominated by mixed deciduous and semi-evergreen forests, and the zone 600–1,200 m is characterized by tropical evergreen forest. Southern hilltop evergreen forests and reed brakes occur near and above 1,200m (Varghese & Balasubramanyan 1999; Kunhi & Sankar 2000). Higher elevations are marked by steep undulating terrains and the area receives 2,000–5,000 mm annual rainfall with only two-three dry months in a year. The mean temperature of the coldest month ranges from 13.5^{0}C to above 23^{0}C (Pascal 1982). Besides the natural vegetation, these hill ranges also have vast stretches of tea, cardamom and rubber plantations. In 2016, ABR was included in UNESCO's World Network of Biosphere Reserves making it 10th Biosphere Reserve in the list, out of 18 from India. It falls within the Indo-Malayan realm and the Western Ghats biogeographic zone. This region is the traditional stronghold of 'Kanis', one of the oldest tribal groups living in the southern Western Ghats. This mountain peak is also of paramount spiritual and cultural significance for people in the states of both Tamil Nadu and Kerala and is an important pilgrim center.

Data collection

Sampling was carried out from October 2012 to December 2014. Variable circular-plot method was used to survey bird populations at each sampling plot (Reynolds et al. 1980; Bibby et al. 1998). Point count survey was carried out for a duration of 10 minutes on a clear day in the first three hours after sunrise (Ralph et al. 1995; Raman & Sukumar 2002; Raman 2003). Birds seen and heard up to a distance of 50m were recorded. Radial distance and perching height were recorded by the help of Nikon Forestry Pro laser range finder. Other parameters like group sizes, sex, and type of contact

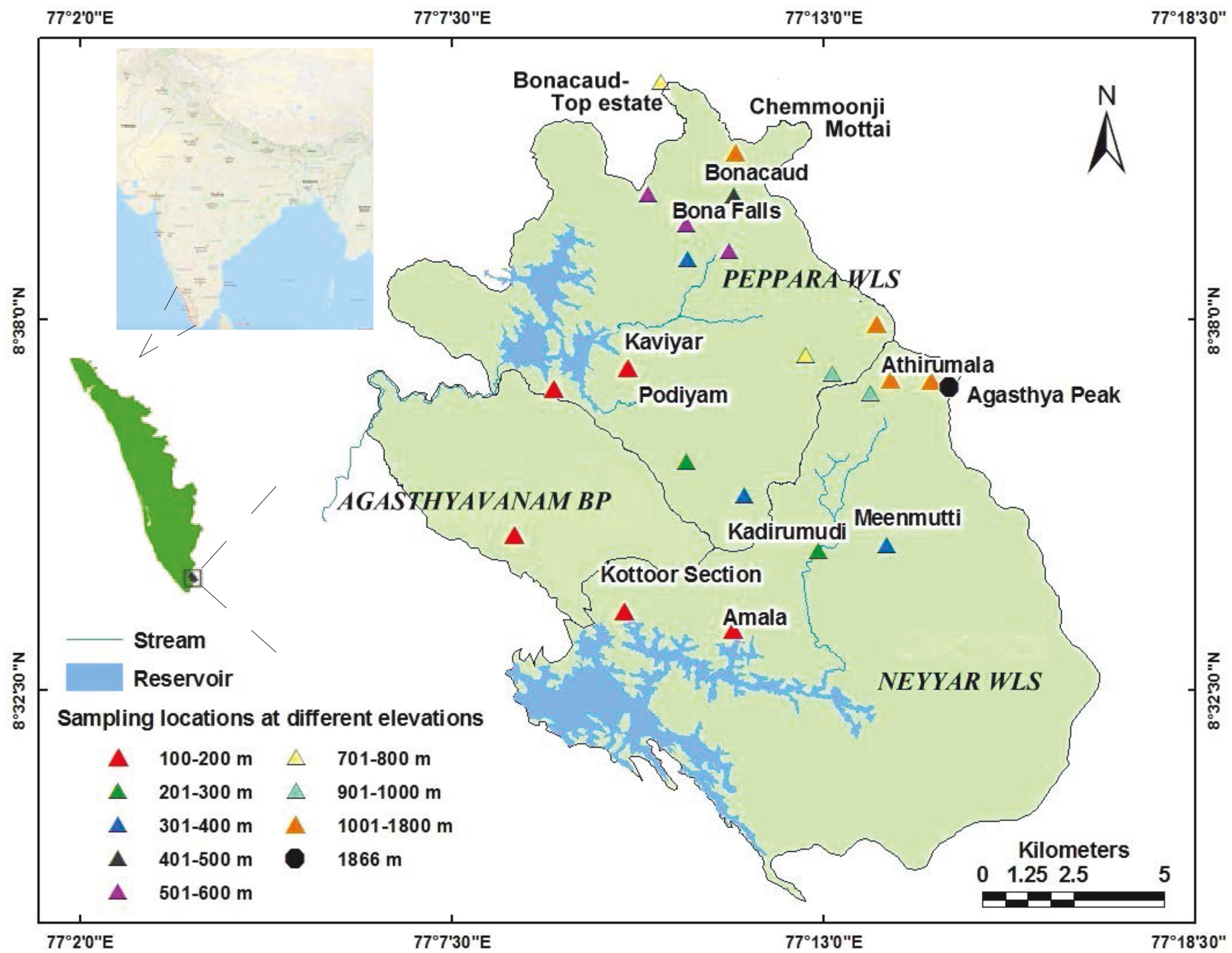

Figure 1. Location of sampling points in Neyyar and Peppara wildlife sanctuaries, and Agasthyavanam Biological Park

were also recorded. Primarily, sampling plots were placed on the basis of elevation and accessibility at each 100m elevation, except the elevation classes between 600–700 and 800–900 meters due to unapproachability. Transects of one kilometer length were laid in each elevation band mostly along the existing paths or animal trails. The transect was divided into each 250m and the permanent sampling point were taken perpendicular to the transect line at a distance of 50m on either side of transect to avoid habitat edges (Jones et al. 1995). A total of 122 point count stations were laid representing all possible habitat types and elevational ranges in the study area. Bird counts in each point were repeated with number of replications varying between 2–16 depending on accessibility and logistic support which resulted in 746 point count efforts in total. Sampling points were marked using colour paint and GPS coordinates were noted. We followed Praveen et al. (2016) for taxonomic classification and nomenclature. For subspecies identification we followed Rasmussen & Anderton (2012). Recent taxonomic changes for Kerala Laughingthrush *Trochalopteron fairbanki meridionale* (Ashambu Chilappan *Montecincla meridionale*) and white-bellied Shortwing *Brachypteryx major* (Ashambu Sholakili, *Sholicola ashambuensis*) have also been considered (Robin et al. 2017) although the old names have been maninated in the text.

Data analysis

For assessing the status of birds; in addition to our systematic sampling, opportunistic sightings of species were also included. IUCN criteria (IUCN 2015) were used to assign conservation status at a global level.

Density estimates were calculated using Distance 6.2 Release 1, for the overall bird population density for Agasthyamalai Hills and also density of 18 species of birds for which we had adequate number of detections, i.e. >28. For density estimates of specific species, select point count stations were included with suitable habitats based on prior knowledge of species biology. The best-fit model was examined using Akaike's Information Criterion (AIC) value and goodness of fit tests (Thomas et al. 2010; Buckland et al. 2001). The best possible model with lowest AIC values was then selected. Variables like encounter rate, average probability of detection, cluster density were computed on the basis of priori estimator models namely uniform, half-normal, hazard-rate and negative exponential along with cosine adjustments. Depending on the outliers, the detection distances for each species were truncated to achieve the best-fitted model.

Relative density was calculated to evaluate the most dominant species in the landscape and in different elevational zones. Since sufficient numbers of detections for certain species in all elevational zones was not available for calculating absolute density, relative abundance was calculated as the number of individuals in proportion of the total number of individual of all species.

RESULTS

The present study reports 197 bird species from 16 orders and 57 families from both Neyyar and Peppara Wildlife Sanctuaries (Appendix 1; Images 1–101). This list does not include many species of waterbirds, as the study focused on forest habitats. According to the IUCN criteria 5% (n = 9) species are under Near Threatened category including Black-and-orange Flycatcher *Ficedula nigrorufa*, Great Hornbill *Buceros bicornis*, Grey-headed Bulbul *Brachypodius priocephalus*, Grey-headed Fish Eagle *Icthyophaga ichthyaetus*, Kerala Laughingthrush *Montecincla meridionale*, Lesser Fish Eagle *Icthyophaga humilis*, Nilgiri Flycatcher *Eumyias albicaudatus*, Oriental Darter *Anhinga melanogaster*, and River Tern *Sterna aurantia*. The study recorded two Vulnerable species, i.e., Woolly-necked Stork *Ciconia episcopus* and Nilgiri Woodpigeon *Columba elphinstonii*, and one Endangered species i.e. White-bellied Shortwing (Ashambu Sholakili) *Sholicola ashambuensis*.

Other species though common in other areas are categorized as rare because of their limited sight records. Some interesting sightings from the study area where of: *Milvus migrans* Black Kite which have been observed in periphery of forest in Neyyar WLS but not recorded from interior forest. Lesser Fish-eagle *Icthyophaga humilis* was sighted only once in flight in Neyyar WLS, while the Grey-headed Fish-eagle *Icthyophaga ichthyaetus* is quite common site in Kaviyar river, Peppera WLS. A single individual of Pied Harrier *Circus melanoleucos* was sighted at an elevation of 1300 m among grassland and southern hilltop forest. Brown-headed Barbet *Psilopogon zeylanicus* has been often sighted from Peppara WLS.

Density Estimates: A total of 3151 individuals of birds were recorded in 1997 detections in overall Agasthyamalai range (Table 1). To estimate the density of birds 'Half normal key' function was selected as the best fit model based on its lowest AIC value. The cluster density was estimated to be 1137.9 clusters/km^2 with a mean cluster size of 1.59 clusters/km^2. The estimated density of individuals was 1643.6 individuals/km^2 with a coefficient of variation of 10.97%, which accounts for a population range size from 334,030–412,530 birds in the entire region (intensive study area). The highest bird density was recorded at high elevations (2988.7 individuals/km^2) followed by low elevations (1833.8

Table 1. Estimate of density for bird species along different elevational range of Agasthyamalai Hills

			Detection Functions				Density Estimate					
Elevation	n	ER	*P*	EDR (m)	Selected Model	Min. AIC	DS (km^2)	*MCS*	E (S)	*D* (km^2)	% CV (*D*)	95% CI
Overall	1997	0.60	0.13	12.95	Half-normal	7812.03	1137.9	1.59	1.44	1643.6	10.79	1330.8-2029.8
Low (100–700 m)	1510	0.57	0.11	11.83	Uniform	5563.73	1315	1.50	1.39	1833.8	12.99	1422.7-2363.7
Medium (701–1,200 m)	312	0.68	0.25	17.67	Half-normal	1058.32	695.77	1.65	1.69	1176.5	18.11	825.48-1676.7
High (>1,200) m	172	0.65	0.12	9.86	Half-normal	544.89	2148.3	1.43	1.39	2988.7	20.14	2017.4-4427.7

n - No. of Detections; ER(n/k) - Encounter rate; *P* - average detection probability between the point count and truncation distance; EDR - Effective Detection Radius; *DS* - Estimate density of cluster; *AIC* - Akaike's Information Criterion; *MCS* - Mean Cluster size; E(S) - Estimate of expected value of cluster size; *D* - Density of individuals; %CV - Percent coefficient of variation; 95%CI - 95% confidence interval.

individuals/km^2) and least in the middle elevation (1176.5 individuals/km^2).

Density estimates of 18 species, which provided minimum possible detections to run the Distance program (Table 2), were calculated. The highest cluster density was of Black Bulbul *Hypsipetes leucocephalus ganeesa* (459.63 clusters/km^2), followed by Plain Flowerpecker *Dicaeum concolor* (370.97 clusters/km^2) and Crimson-backed Sunbird *Leptocoma minima* (358.72 clusters/km^2). The highest density of 958.57 individuals/km^2 was of Black Bulbul, followed by Yellow-browed Bulbul *Acritillas indica* 722.12 individuals/km^2 and Crimson-backed Sunbird 506.74 (individuals/km^2). The details of detection functions and density estimates for all 18 species are provided in Table 2.

Relative abundance: The highest relative abundance along all elevational bands was for Yellow-browed Bulbul (0.08), followed by Greenish Leaf warbler *Seicercus trochiloides* (0.066), and 0.06 each for Greater Racket-tailed Drongo *Dicrurus paradiseus* and Black Bulbul. In case of three different elevation classes, in lower elevation (100–700 m) Yellow-browed Bulbul had the highest relative abundance (0.08); Greater Racket-tailed Drongo (0.068) and Greenish Leaf Warbler is 0.065. In the middle elevation (701–1,200 m), the highest relative density was of Black Bulbul (0.123), Yellow-browed Bulbul (0.12); White-cheeked Barbet *Psilopogon viridis* is (0.06). In higher elevation (Above 1201m), Black Bulbul again dominated with a relative density of 0.18; Kerala Laughingthrush *Montecincla meridionale* (0.16) and Greenish Leaf Warbler (0.1).

Species account of threatened and endemic species in Agasthyamalai Hills are given below:

Great Hornbill: The species was mostly recorded in and around evergreen patches at 500–1,000 m elevation ranges. Seasonal movements were observed which could be influenced by the availability of fruits. Though we did not record its nesting during our study, but mating calls and sub-adult were seen in suitable localities.

Malabar Grey Hornbill *Ocyceros griseus*: Among the two hornbill species recorded from Neyyar and Peppara, this species was the most abundant. It was found in almost all habitat type, in accordance with other studies from the Western Ghats (Balasubramanian et al. 2004; Mudapppa & Raman 2008).

Malabar Pied Hornbill *Anthracoceros coronatus*: This species has not been recorded in the present study. Balasubramanian et al. (2004), however, have reported its rare presence from NWS and Thenmala Reserve Forest in Agasthyamalai Hills, which are considered as the southernmost distribution record for this species. Absence of this species in Neyyar during our study is of great concern as the species is Near Threatened under IUCN Red List of Threatened Species.

Nilgiri Wood Pigeon *Columba elphinstonii*: This species had a wider distribution across the elevation compared to other endemic bird species in the area. It has been sighted in almost all forest types except grasslands and fire prone areas. In particular, it was seen in higher numbers in high-elevation preferring hilltop forests where nesting has also been recorded. Few sightings were recorded from rubber plantations and adjoining highly disturbed forest patches in lower elevations.

Malabar Barbet *Psilopogon malabaricus*: This species was fairly common in comparison to Coppersmith Barbet. It was observed to be widespread from low elevational forest up to 1000m.

White-bellied Treepie *Dendrocitta leucogastra*: Observed mostly near semi-evergreen and evergreen forests from 500–1,100 m. Appeared to be locally common in suitable habitats.

White-bellied Blue Flycatcher *Cyornis pallidipes*: It was widely distributed from lower elevation to 1,200m and prefers well-wooded areas. Found to be fairly common in this region.

Nilgiri Flycatcher *Eumyias albicaudatus*: Restricted to the of hilltop evergreen patches between 1,100–1,860 m. Encountered commonly in undisturbed habitats mostly hilltop evergreen patches intermixed with grasslands and reeds compared to same kind of habitat in disturbed area.

Black-and-orange Flycatcher *Ficedula nigrorufa*: Restricted to hilltop evergreen patches and mostly sighted in the elevation belt of 1,100–1,860 m. This species shares same habitat as Nilgiri Flycatcher, but was always observed in lower abundance. This also appears to avoid disturbed areas.

Crimson-backed Sunbird *Leptocoma minima*: A widely distributed endemic species and has been recorded from lower elevation to 1,600m. We recorded a density of 506.74 individuals/km^2 (Table 2). Found in almost all forest types and among the most abundant species in the study area.

Malabar Parakeet *Psittacula columboides*: Though one of the common endemics of the lower reaches of Western Ghats, was rarely observed in present study. A few records were made from semi-evergreen and moist-deciduous forests near Bonacaud tea estate at an elevation of 700–750 m.

Grey-headed Bulbul *Brachypodius priocephalus*:

Table 2. Estimate of density for 18 bird species in their suitable habitats.

			Detection Functions				Density Estimate					
Species	n	(ER)	*P*	EDR (m)	Selected Model	Min. AIC	*D* (km^2)	MCS	E(S)	*D* (km^2)	% CV (*D*)	95% CI
AFBB	61	0.08	0.47	24.1	Hazard rate	223.13	44.66	1.29	1.34	60.25	20.19	40.62–89.36
BNMR	37	0.05	0.31	14.1	Uniform	138.96	79.3	1.27	1.23	98.26	21.98	64.00–150.88
CBSB	67	0.09	0.06	8.9	Uniform	270.29	358.72	1.50	1.41	506.74	25.92	306.34–838.22
BCBB	30	0.04	0.33	18.43	Uniform	120.84	44.59	1.33	1.72	76.7	20.62	51.23–114.83
GRTD	123	0.16	0.25	20.26	Half-normal	514.89	128.92	1.82	1.66	214.02	18.18	150.06–305.24
HLMN	47	0.07	0.30	19.19	Uniform	184.04	64.16	4.21	4.24	272.49	25.53	165.78–447.90
LSHT	39	0.05	0.10	9.75	Half-normal	120.71	174.28	1.05	1.12	195.77	32.57	104.50–366.76
PLFP	106	0.14	0.12	11.02	Uniform	417.13	370.97	1.11	1.11	412.03	18.02	289.70–586.02
SCMV	72	0.10	0.11	11.9	Half-normal	249.89	246.36	1.93	1.9	470.36	21.52	309.05–715.87
BKBB	119	0.32	0.21	14.98	Half-normal	431.37	459.63	2.39	2.08	958.57	18.82	663.31–1385.3
WCBR	87	0.13	0.23	14.65	Negative Expo	334.94	197.45	1.22	1.14	225.56	25.49	137.35–370.41
YBBB	160	0.24	0.30	15.41	Uniform	532.9	323.49	2.00	2.23	722.12	10.82	583.69–893.39
GNWR	135	0.18	0.21	13.88	Half-normal	487.97	297.73	1.32	1.34	399.49	14.51	300.66–530.81
MLTR	30	0.04	0.23	19.32	Half-normal	102.68	39.04		1	39.04	29.29	29.29–69.03
MGHB	23	0.03	0.14	10.89	Half-normal	93.69	94.75	1.86	2.3	224.33	39.11	104.98–479.35
LBLW	67	0.09	0.37	21.44	Hazard Rate	246.86	64.59	1.07	1.08	70.308	19.95	47.61–103.82
BTBF	56	0.08	0.17	16.72	Half-normal	192.9	100.73	1.16	1.27	128.54	20.37	86.28–191.49
MWTH	31	0.02	0.23	21.89	Half-normal	128.33	57.99	1.03	0.96	56.19	27.99	32.52–97.08

AFBB: Asian Fairy-bluebird; BNMR: Black-naped Monarch; CBSB: Crimson-backed Sunbird; BCBB: Black-crested Bulbul GRTD: Greater Racket-tailed Drongo; HLMN-Hill Myna; LSHT- Little Spiderhunter; PLFP: Plain Flowerpecker; SCMV: Scarlet Minivet; BKBB:Black Bulbul ; WCBR: White-cheeked Barbet; YBBB :Yellow-browed Bulbul; GNWR: Greenish Leaf Warbler; MLTR: Malabar Trogon; MGHB: Malabar Grey Hornbill; LBLW: Large-billed Leaf Warbler; BTBF: Blue-throated Flycatcher; MWTH: Malabar Whistling Thrush.
n - No. of Detections; ER(n/k) - Encounter rate; *P* - average detection probability between the point count and truncation distance; EDR - Effective Detection Radius; *DS* - Estimate density of cluster; *AIC* - Akaike's Information Criterion; *MCS* - Mean Cluster size; E(S) - Estimate of expected value of cluster size; *D* - Density of individuals; %CV - Percent coefficient of variation; 95%CI - 95% confidence interval.

Locally common, encountered from low elevation up to 1,000m preferably in patches dominated by reed bamboo (*Ochlandra* sp.).

White-bellied Shortwing *Sholicola ashambuensis*: Rarely seen and restricted to above 1,000m and evergreen biotope.

Broad-tailed Grassbird *Schoenicola platyurus*: Though said to be breeding in areas of Pandipath and Ponmudi by local bird watchers; we did not record this generally rare species in the present study.

Kerala Laughingthrush *Montecincla meridionale*: Locally common, restricted to altitude above 1,100m in high elevation evergreen forest. It was one of the most common birds encountered at higher altitude. Often found feeding on the offerings left behind by visitors. The subspecies found here is having a very restricted distribution and reported to be sensitive to habitat alterations (Praveen & Nameer 2012).

Wayanad Laughingthrush *Garrulax delesserti*: Flocks were recorded near the forest edges and tea plantation prefers semi-evergreen forest. Found to be locally common.

Rufous Babbler *Argya subrufa*: Mostly encountered in area intermixed with grasses along the forest edges and abandoned tea plantations above 400m.

Nilgiri Thrush *Zoothera dauma neilgherriensis*: A sulking species, found in the areas having some undergrowth and good litter cover. It has been recorded from 500m up to the top of the hill. May be under-reported due to its sulking behaviour.

DISCUSSION

Despite the fact that many bird species are broadly distributed, most of the endemic species occur or breed only in restricted elevation ranges, i.e., above 1,200m dominated by southern hilltop evergreen forest. Though higher elevation had few species (27) compared to medium (47) and lower elevation (87), it showed highest density of 2988.7 individuals/km^2. This higher density of birds at higher elevations may be due to several reasons. Firstly number of detections is less compared to other elevations with 20.14% CV with a very high % CI (2017.4–4427.7). More detection might have improved the density estimates. The geographic area at higher elevations is significantly less (9.71km^2) compared to medium (35.51km^2) and lower altitudes (206.95km^2) thereby augmenting the density in a smaller area. Besides, several Western Ghats endemics like Kerala Laughingthrush, Black-and-orange Flycatcher, and Nilgiri Flycatcher are only found in higher elevations and other species that have widest elevational amplitude further augment the density. Black Bulbul having the highest density (958.57 individuals/km^2) among all the bird species was mostly recorded in large groups at higher elevation. These may be some of the reasons for the inflation in density at higher elevation. Since much of the bird detection where through calls, calculating absolute density may not give very good results. Density estimates of 18 species in table 2, shows that despite having low CV in 11 species, a higher value of 95% CI was obtained. Hence absolute density measures should be used carefully.

Present study reported 1643.6 birds/km^2 compared to 1122 birds/km^2 in the Silent Valley in Nilgiris (Jayson & Mathew 2000). Mudappa & Raman (2008) have reported White-cheeked Barbet and Crimson-backed Sunbird to be widely distributed in a study conducted in the selective places in Western Ghats from Goa to Tamil Nadu. In the current study, Yellow-browed Bulbul, Crimson-backed Sunbird and White-cheeked Barbet were found to be widely distributed in Agasthyamalai landscape.

In a hill range, species are often restricted or distributed across particular elevation bands, as their distribution may be governed by bioclimatic or vegetation attributes; since these environmental parameters are vulnerable to climate change and habitat alteration, montane species are at greater risk of extinction in the long run (White & Bennett 2015). Apart from this, the number of endemics found in specific habitats has to be taken as important criterion for landscape level conservation actions (Aliabadian et al. 2008). Impacts of human factors on the montane ecosystem with respect to the distribution and population status of endemic species are well documented (Vijayan & Balakrishnan 2005; Vijayan et al. 2005). Agasthyamalai and specifically Agasthyarkoodam attract a lot of pilgrims from both Tamil Nadu and Kerala and the trend is increasing every year especially during January to April. The visitation has increased from 5,490 visitors in 2007 to 7,055 visitors in 2011. (Management Plan 2012–2013 to 2021–2022). Increased and unchecked pilgrimage activity may have a detrimental effect not only on the endemic birds but on other fauna as well. Generally, it was observed that areas with least disturbance hold a good number of endemic species compared to same kind of forest type in areas frequented by visitors. Among the six forest types, the southern hilltop evergreen forest appears to the most important habitat for the endemic birds (Robin & Nandini 2012) which are currently under pilgrimage pressure in the Agasthyamalai Hills. An urgent management intervention is needed to regulate the flow of the tourist and pilgrims in this area before it severely affects these biodiversity rich high altitude forests.

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Image 1. *Columba elphinstonii* Nilgiri Wood Pigeon


Image 2. *Treron pompadora* Pompadour Green Pigeon


Image 3. *Chalcophaps indica* Emerald Dove


Image 4. *Ducula badia* Mountain Imperial Pigeon


Image 5. *Hemiprocne coronata* Crested Treeswift


Image 6. *Tachymarptis melba* Alpine Swift


Image 7. *Eudynamys scolopaceus* Asian Koel


Image 8. *Surniculus lugubris* Drongo Cuckoo


Image 9. *Hierococcyx sparverioides* Large Hawk Cuckoo


Image 10. *Hierococcyx varius* Common Hawk Cuckoo


Image 11. *Ardeola grayii* Indian Pond Heron


Image 12. *Butorides striata* Striated Heron


Image 13. *Anhinga melanogaster* Oriental Darter


Image 14. *Elanus caeruleus* Black-winged Kite

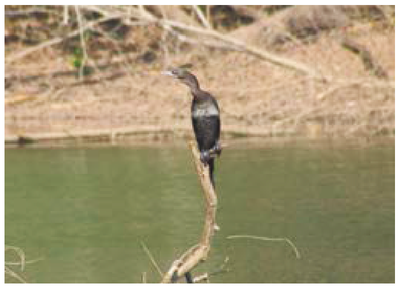
Image 15. *Microcarbo niger* Little Cormorant

Image 16. *Glaucidium radiatum* Jungle Owlet

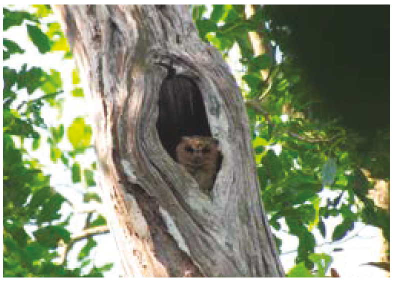

Image 17. *Otus bakkamoena* Collared Scops Owl

Image 18. *Buteo buteo* Common Buzzard

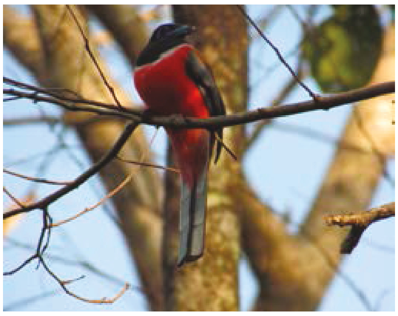

Image 19. *Harpactes fasciatus* Malabar Trogon

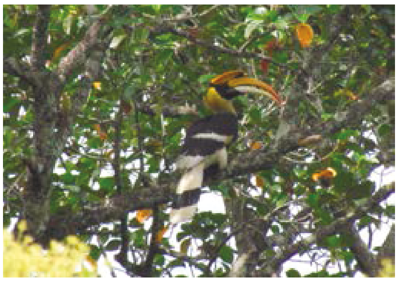

Image 20. *Buceros bicornis* Great Hornbill

Image 21. *Ocyceros griseus* Malabar Grey Hornbill

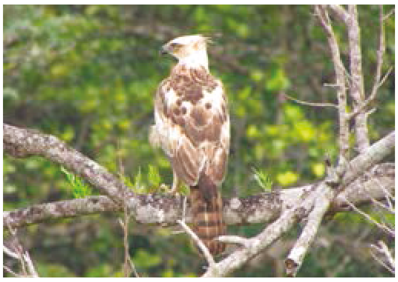

Image 22. *Nisaetus cirrhatus* Changeable Hawk Eagle

Image 23. *Ictinaetus malaiensis* Black Eagle

Image 24. *Spilornis cheela* Crested Serpent Eagle

Image 25. *Hieraaetus pennatus* Booted Eagle

Image 26. *Accipiter badius* Shikra

Image 27. *Accipiter trivirgatus* Crested Goshawk

Image 28. Fish Eagle species

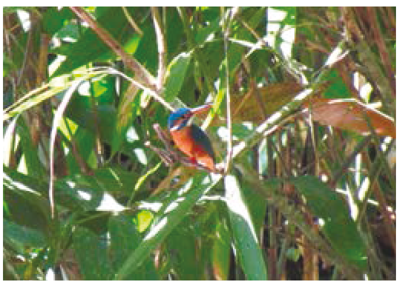

Image 29. *Alcedo atthis* Common Kingfisher

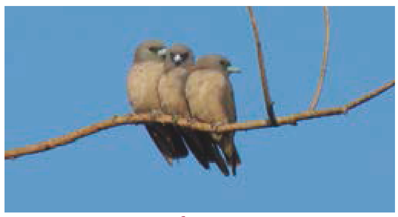

Image 30. *Artamus fuscus* Ashy Woodswallow

Image 31. *Picus chlorolophus*
Lesser Yellow-naped Woodpecker

Image 32. *Picus xanthopygaeus*
Streak-throated Woodpecker

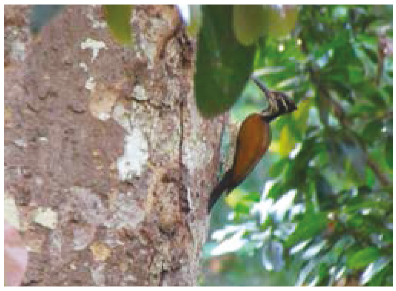

Image 33. *Chrysocolaptes lucidus*
Greater Golden-backed Woodpecker

Image 34. *Psilopogon viridis*
White-cheeked Barbet

Image 35. *Psilopogon malabaricus*
Malabar Barbet

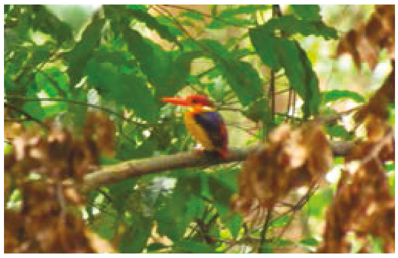

Image 36. *Ceyx erithaca*
Oriental Dwarf Kingfisher

Image 37. *Merops leschenaulti*
Chestnut-headed Bee-eater

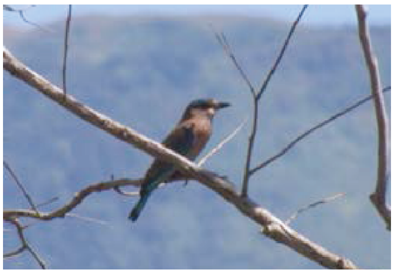

Image 38. *Coracias benghalensis*
Indian Roller

Image 39. *Falco tinnunculus*
Common Kestrel

Image 40. *Falco peregrinus* Shaheen Falcon

Image 41. *Psittacula cyanocephala* Plum-headed Parakeet

Image 42. *Pericrocotus flammeus*
Scarlet Minivet

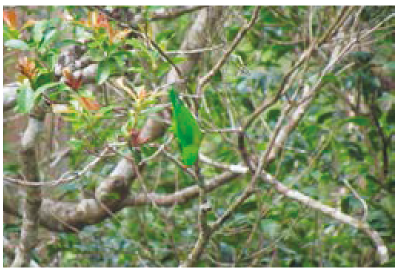

Image 43. *Loriculus vernalis*
Vernal Hanging Parrot

Image 44. *Pitta brachyura* Indian Pitta

Image 45. *Pericrocotus cinnamomeus*
Small Minivet


Image 46. *Dicrurus leucophaeus* Ashy Drongo


Image 47. *Dicrurus aeneus* Bronzed Drongo


Image 48. *Dicrurus paradiseus* Greater Racket-tailed Drongo


Image 49. *Corvus macrorhynchos* Large-billed Crow

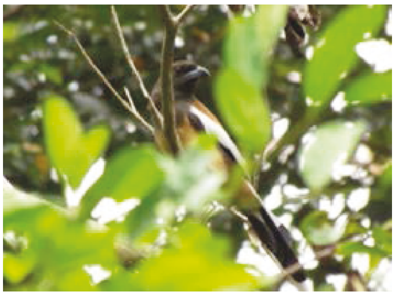
Image 50. *Dendrocitta vagabunda* Rufous Treepie


Image 51. *Dendrocitta leucogastra* White-bellied Treepie


Image 52. *Leptocoma minima* Crimson-backed Sunbird


Image 53. *Hypothymis azurea* Black-naped Blue Monarch


Image 54. *Terpsiphone paradisi* Indian Paradise-flycatcher


Image 55. *Cinnyris lotenius* Loten's Sunbird


Image 56. *Oriolus xanthornus* Black-hooded Oriole


Image 57. *Dicaeum concolor* Plain Flowerpecker


Image 58. *Arundinax aedon* Thick-billed Warbler


Image 59. *Anthus similis* Long-billed Pipit


Image 60. *Locustella naevia* Grasshopper Warbler

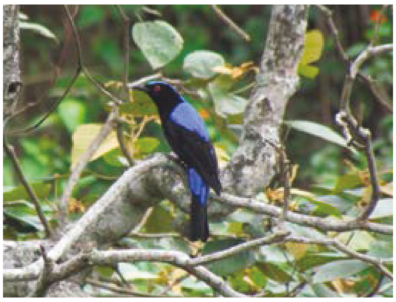

Image 61. ***Irena puella*** **Asian Fairy-bluebird**

Image 62. ***Chloropsis aurifrons*** **Golden-fronted Leafbird**

Image 63. ***Hypsipetes leucocephalus*** **Black Bulbul**

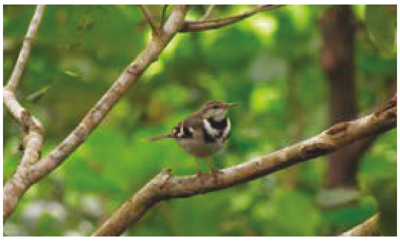

Image 64. ***Dendronanthus indicus*** **Forest Wagtail**

Image 65. ***Anthus rufulus*** **Paddyfield Pipit**

Image 66. ***Brachypodius priocephalus*** **Grey-headed Bulbul**

Image 67. ***Motacilla cinerea*** **Grey Wagtail**

Image 68. ***Culicicapa ceylonensis*** **Grey-headed Canary-flycatcher**

Image 69. ***Aegithina tiphia*** **Common Iora**

Image 70. ***Hemipus picatus*** **Bar-winged Flycatcher-shrike**

Image 71. ***Tephrodornis virgatus*** **Large Woodshrike**

Image 72. ***Pycnonotus melanicterus*** **Black-crested Bulbul**

Image 73. ***Zosterops palpebrosus*** **Oriental White-eye**

Image 74. ***Pomatorhinus horsfieldii*** **Indian Scimitar Babbler**

Image 75. ***Acritillas indica*** **Yellow-browed Bulbul**

Image 76. *Phylloscopus affinis*
Tickell's Leaf Warbler

Image 77. *Rhopocichla atriceps*
Dark-fronted Babbler

Image 78. *Pellorneum ruficeps*
Puff-throated Babbler

Image 79. *Alcippe poioicephala*
Quaker Tit Babbler

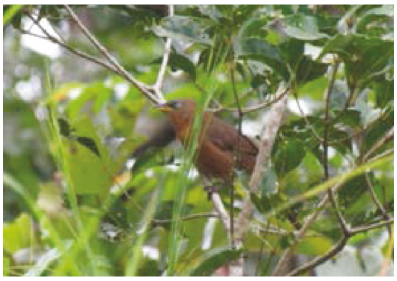

Image 80. *Argya subrufa* Rufous Babbler

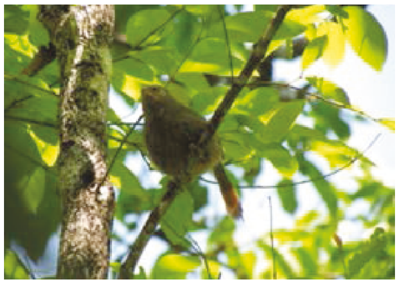

Image 81. *Turdoides striata* Jungle Babbler

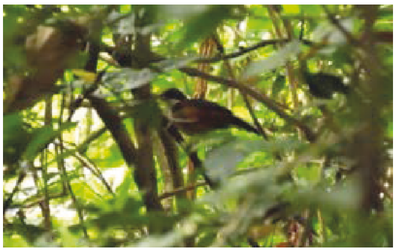

Image 82. *Garrulax delesserti*
Wynaad Laughingthrush

Image 83. *Montecincla meridionale*
Ashambu Chilappan

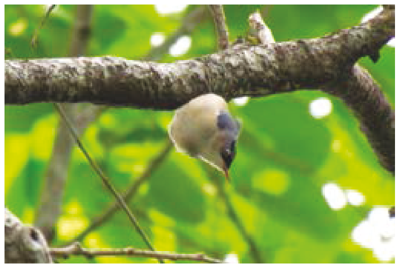

Image 84. *Sitta frontalis*
Velvet-fronted Nuthatch

Image 85. *Sturnia malabarica*
Chestnut-tailed Starling

Image 86. *Sturnia blythii*
Malabar White-headed starling

Image 87. *Gracula religiosa indica*
Hill Myna

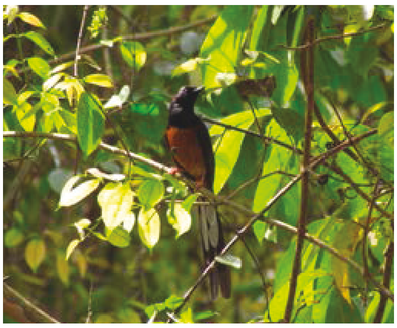

Image 88. *Kittacincla malabarica*
White-rumped Shama

Image 89. *Muscicapa dauurica*
Asian Brown Flycatcher

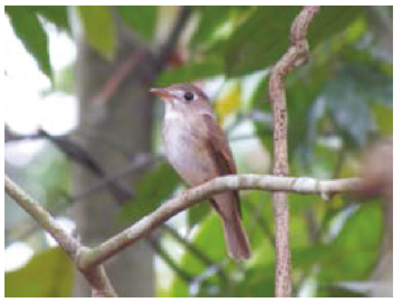

Image 90. *Muscicapa muttui*
Brown-breasted Flycatcher


Image 91. *Turdus simillimus*
Indian Blackbird


Image 92. *Cyornis pallidipes*
White-bellied Blue Flycatcher


Image 93. *Eumyias albicaudatus*
Nilgiri Flycatcher


Image 94. *Zoothera dauma* Scaly Thrush


Image 95. *Eumyias thalassinus*
Verditer Flycatcher


Image 96. *Ficedula nigrorufa*
Black-and-orange Flycatcher


Image 97. *Larvivora brunnea*
Indian Blue Robin


Image 98. *Seicercus nitidus*
Green Leaf Warbler


Image 99. *Geokichla citrina*
Orange-headed Thrush


Image 100. *Monticola cinclorhyncha*
Blue-capped Rock Thrush


Image 101. *Seicercus magnirostris*
Large-billed Leaf Warbler

Appendix I. A checklist of birds observed from Agasthyamalai Hills.

	Order/ Family	English name	Scientific name
	GALLIFORMES		
1	Phasianidae (partridges, pheasants & grouse)	Indian Peafowl	*Pavo cristatus*
2		Jungle Bush Quail	*Perdicula asiatica*
3		Grey Junglefowl	*Gallus sonneratii*
4		Red Spurfowl	*Galloperdix spadicea*
	COLUMBIFORMES		
5	Columbidae (pigeons)	Rock Pigeon	*Columba livia*
6		Nilgiri Wood Pigeon# (VU)	*Columba elphinstonii*
7		Spotted Dove	*Streptopelia chinensis*
8		Pompadour Green Pigeon/ Grey-fronted Green-pigeon#	*Treron pompadora*
9		Emerald Dove	*Chalcophaps indica*
10		Mountain Imperial Pigeon	*Ducula badia*
	CAPRIMULGIFORMES		
11	Caprimulgidae (nightjars)	Jerdon's Nightjar	*Caprimulgus atripennis*
12	Apodidae (swifts)	Crested Treeswift	*Hemiprocne coronata*
13		White-rumped Spinetail	*Zoonavena sylvatica*
14		Brown-backed Needletail	*Hirundapus giganteus*
15		Indian Swiftlet	*Aerodramus unicolor*
16		Asian Palm-swift	*Cypsiurus balasiensis*
17		Alpine Swift	*Tachymarptis melba*
18		Indian House Swift	*Apus affinis*
	CUCULIFORMES		
19	Cuculidae (cuckoos)	Greater Coucal	*Centropus sinensis*
20		Lesser Coucal	*Centropus bengalensis*
21		Chestnut-winged Cuckoo	*Clamator coromandus*
22		Asian Koel	*Eudynamys scolopaceus*
23		Drongo Cuckoo	*Surniculus lugubris*
24		Large Hawk Cuckoo	*Hierococcyx sparverioides*
25		Common Hawk Cuckoo	*Hierococcyx varius*
26		Indian Cuckoo	*Cuculus micropterus*
	GRUIFORMES		
27	Rallidae (rails & coots)	White-breasted Waterhen	*Amaurornis phoenicurus*
	PELECANIFORMES		
28	Ciconiidae (Storks)	Woolly-necked Stork (VU)	*Ciconia episcopus*
28	Ardeidae (Herons & Egrets)	Cinnamon Bittern	*Ixobrychus cinnamomeus*
29		Malayan Night Heron	*Gorsachius melanolophus*
30		Striated Heron	*Butorides striata*
31		Indian Pond Heron	*Ardeola grayii*
32		Cattle Egret	*Bubulcus ibis*
33		Little Egret	*Egretta garzetta*
34	Phalacrocoracidae (cormorants)	Little Cormorant	*Microcarbo niger*
35	Anhingidae (darters)	Oriental Darter (NT)	*Anhinga melanogaster*
	CHARADRIIFORMES		
36	Charadriidae (Plovers & lapwings)	Red-wattled Lapwing	*Vanellus indicus*
37	Scolopacidae (Sandpipers)	Snipe species	*Gallinago sp.*
38	Laridae (gulls & terns)	River Tern (NT)	*Sterna aurantia*
	ACCIPITRIFORMES		
39	Accipitridae (kites, hawks & eagles)	Black-winged Kite	*Elanus caeruleus*
40		Oriental Honey-buzzard	*Pernis ptilorhynchus*
41		Black Baza	*Aviceda leuphotes*
42		Crested Serpent Eagle	*Spilornis cheela*
43		Mountain Hawk Eagle/ Legge's Hawk Eagle	*Nisaetus nipalensis*
44		Changeable Hawk Eagle / Crested Hawk Eagle	*Nisaetus cirrhatus*
45		Rufous-bellied Eagle	*Lophotriorchis kienerii*
46		Black Eagle	*Ictinaetus malaiensis*
47		Bonelli's Eagle	*Aquila fasciata*
48		Booted Eagle	*Hieraaetus pennatus*
49		Pied Harrier	*Circus melanoleucos*
50		Shikra	*Accipiter badius*
51		Crested Goshawk	Accipiter trivirgatus
		Lesser Fish Eagle ? (NT)	*Icthyophaga humilis*
52		Grey-headed Fish Eagle (NT)	*Icthyophaga ichthyaetus*
53		Brahminy Kite	*Haliastur indus*
54		Black Kite	*Milvus migrans*
55		White-eyed Buzzard	*Butastur teesa*
56		Common Buzzard	*Buteo buteo*
	STRIGIFORMES		
57	Tytonidae (barn owls)	Common Barn Owl	*Tyto alba*

58	Strigidae (owls)	Brown Hawk Owl	*Ninox scutulata*
59		Jungle Owlet	*Glaucidium radiatum*
60		Collared Scops Owl	*Otus bakkamoena*
61		Brown Wood Owl	*Strix leptogrammica*
62		Spot-bellied Eagle Owl	*Bubo nipalensis*
63		Brown Fish Owl	*Ketupa zeylonensis*
	TROGONIFORMES		
64	Trogonidae (trogons)	Malabar Trogon	*Harpactes fasciatus*
	BUCEROTIFORMES		
65	Bucerotidae (hornbills)	Great Hornbill (NT)	*Buceros bicornis*
66		Malabar Grey Hornbill#	*Ocyceros griseus*
67	Upupidae (hoopoes)	Common Hoopoe	*Upupa epops*
	PICIFORMES		
68	Picidae (woodpeckers)	Speckled Piculet	*Picumnus innominatus*
69		Heart-spotted Woodpecker	*Hemicircus canente*
70		Common Golden-backed Woodpecker	*Dinopium javanense*
71		Lesser Golden-backed Woodpecker	*Dinopium benghalense*
72		Rufous Woodpecker	*Micropternus brachyurus*
73		Lesser Yellow-naped Woodpecker	*Picus chlorolophus*
		Streak-throated Woodpecker	*Picus xanthopygaeus*
74		White-bellied Woodpecker	*Dryocopus javensis*
75		Greater Golden-backed Woodpecker	*Chrysocolaptes lucidus*
76		Brown-capped Pygmy Woodpecker	*Dendrocopos moluccensis*
77	Ramphastidae (toucans & barbets)	Brown-headed Barbet	*Psilopogon zeylanicus*
78		White-cheeked Barbet	*Psilopogon viridis*
79		Malabar Barbet#	*Psilopogon malabaricus*
80		Coppersmith Barbet	*Psilopogon haemacephalus*
	CORACIIFORMES		
81	Meropidae (bee-eaters)	Blue-bearded Bee-eater	*Nyctyornis athertoni*
82		Green Bee-eater	*Merops orientalis*
83		Chestnut-headed Bee-eater	*Merops leschenaulti*
84	Coraciidae (rollers)	Indian Roller	*Coracias benghalensis*

85	Alcedinidae (kingfishers)	Oriental Dwarf Kingfisher	*Ceyx erithaca*
86		Common Kingfisher	*Alcedo atthis*
87		Pied Kingfisher	*Ceryle rudis*
88		White-throated Kingfisher	*Halcyon smyrnensis*
89		Black-capped Kingfisher	*Halcyon pileata*
	FALCONIFORMES		
90	Falconidae (falcons & caracaras)	Common Kestrel	*Falco tinnunculus*
91		Peregrine Falcon / Shaheen Falcon*	*Falco peregrinus*
	PSITTACIFORMES		
92	Psittaculidae (Old World parrots)	Plum-headed Parakeet	*Psittacula cyanocephala*
93		Malabar Parakeet#	*Psittacula columboides*
94		Vernal Hanging Parrot	*Loriculus vernalis*
	PASSERIFORMES		
95	Pittidae (pittas)	Indian Pitta	*Pitta brachyura*
96	Campephagidae (minivets & cuckooshrikes)	Small Minivet	*Pericrocotus cinnamomeus*
97		Scarlet Minivet	*Pericrocotus flammeus*
98		Large Cuckooshrike	*Coracina javensis*
99	Oriolidae (orioles, figbirds & allies)	Black-hooded Oriole	*Oriolus xanthornus*
100		Indian Golden Oriole	*Oriolus kundoo*
101		Black-naped Oriole	*Oriolus chinensis*
102	Artamidae (woodswallows, Australian magpies and allies)	Ashy Woodswallow	*Artamus fuscus*
103	Vangidae (vangas & helmet-shrikes)	Bar-winged Flycatcher-shrike	*Hemipus picatus*
104		Large Woodshrike/ Malabar Woodshrike #	*Tephrodornis virgatus*
105		Common Woodshrike	*Tephrodornis pondicerianus*
106	Aegithinidae (ioras)	Common Iora	*Aegithina tiphia*
107	Dicruridae (drongos)	Black Drongo	*Dicrurus macrocercus*
108		Ashy Drongo	*Dicrurus leucophaeus*
109		Bronzed Drongo	*Dicrurus aeneus*
110		Hair-crested Drongo	*Dicrurus hottentottus*
111		Greater Racket-tailed Drongo	*Dicrurus paradiseus*
112	Laniidae (shrikes)	Brown Shrike	*Lanius cristatus*

113	Corvidae (Crows & jays)	Rufous Treepie	*Dendrocitta vagabunda*
114		White-bellied Treepie#	*Dendrocitta leucogastra*
115		House Crow	*Corvus splendens*
116		Large-billed Crow	*Corvus macrorhynchos*
117	Monarchidae (monarchs & paradise-flycatchers)	Black-naped Monarch	*Hypothymis azurea*
118		Indian Paradise-flycatcher	*Terpsiphone paradisi*
119	Dicaeidae (flowerpeckers)	Thick-billed Flowerpecker	*Dicaeum agile*
120		Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*
121		Plain Flowerpecker/ Nilgiri Flowerpecker#	*Dicaeum concolor*
122	Nectariniidae (sunbirds)	Little Spiderhunter	*Arachnothera longirostra*
123		Purple-rumped Sunbird	*Leptocoma zeylonica*
124		Crimson-backed Sunbird#	*Leptocoma minima*
125		Purple Sunbird	*Cinnyris asiaticus*
126		Loten's Sunbird	*Cinnyris lotenius*
127	Irenidae (fairy-bluebirds & leafbirds)	Asian Fairy-bluebird	*Irena puella*
128		Golden-fronted Leafbird	*Chloropsis aurifrons*
129		Jerdon's Leafbird	*Chloropsis jerdoni*
130	Estrildidae (waxbills)	Black-throated Munia	*Lonchura kelaarti*
131	Motacillidae (wagtails & pipits)	Forest Wagtail	*Dendronanthus indicus*
132		Paddyfield Pipit	*Anthus rufulus*
133		Long-billed Pipit	*Anthus similis*
134		Grey Wagtail	*Motacilla cinerea*
135		White-browed Wagtail	*Motacilla maderaspatensis*
136	Stenostiridae (fairy-flycatchers & crested-flycatchers)	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*
137	Paridae (tits, chickadees)	Cinereous Tit	*Parus cinereus*
138		Black-lored Tit	*Machlolophus xanthogenys*
139	Cisticolidae (cisticolas)	Grey-breasted Prinia	*Prinia hodgsonii*
140		Jungle Prinia	*Prinia sylvatica*
141		Ashy Prinia	*Prinia socialis*
142	Locustellidae (bush warblers)	Grasshopper Warbler	*Locustella naevia*
143	Acerocephalidae (brush, reed & swamp warblers)	Thick-billed Warbler	*Arundinax aedon*
144		Booted Warbler	*Iduna caligata*
		Sykes's Warbler ?	*Iduna rama*
145		Blyth's Reed-warbler	*Acrocephalus dumetorum*
146		Paddyfield Warbler	*Acrocephalus agricola*
147	Hirundinidae (swallows)	Red-rumped Swallow	*Cecropis daurica*
148		Pacific Swallow	*Hirundo tahitica*
149		Barn Swallow	*Hirundo rustica*
150		Dusky Crag Martin	*Ptyonoprogne concolor*
151	Pycnonotidae (bulbuls)	Black Bulbul/ Square-tailed Bulbul #	*Hypsipetes leucocephalus*
152		Black-crested Bulbul/ Flame-throated Bulbul*#	*Pycnonotus melanicterus*
153		Red-whiskered Bulbul	*Pycnonotus jocosus*
154		Red-vented Bulbul	*Pycnonotus cafer*
155		Grey-headed Bulbul# (NT)	*Brachypodius priocephalus*
156		Yellow-browed Bulbul	*Acritillas indica*
157	Phylloscopidae (Old World leaf warblers)	Tickell's Leaf Warbler	*Phylloscopus affinis*
158		Green Leaf Warbler	*Seicercus nitidus*
159		Greenish Leaf Warbler	*Seicercus trochiloides*
160		Large-billed Leaf Warbler	*Seicercus magnirostris*
161		Western Crowned Warbler	*Seicercus occipitalis*
162	Sylviidae (sylvia warblers, parrotbills & allies)	Lesser Whitethroat	*Curruca curruca*
163	Zosteropidae (white-eyes & yuhinas)	Oriental White-eye	*Zosterops palpebrosus*
164	Timaliidae (scimitar babblers and allies)	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*
165		Tawny-bellied Babbler	*Dumetia hyperythra*
166		Dark-fronted Babbler	*Rhopocichla atriceps*
167	Pellorneidae (smaller babblers)	Puff-throated Babbler	*Pellorneum ruficeps*
168	Leiothrichidae (babblers, laughingthrushes & allies)	Quaker Tit Babbler	*Alcippe poioicephala*
169		Rufous Babbler#	*Argya subrufa*
170		Jungle Babbler	*Turdoides striata*
171		Yellow-billed Babbler	*Turdoides affinis*
172		Wynaad Laughingthrush#	*Garrulax delesserti*
173		Kerala Laughingthrush#/ Ashambu Chilappan (NT)	*Trochalopteron meridionale/ Montecincla meridionale*
174	Sittidae (nuthatches, spotted creepers & wallcreeper)	Velvet-fronted Nuthatch	*Sitta frontalis*
175	Sturnidae (starlings)	Chestnut-tailed Starling	*Sturnia malabarica*
176		Malabar White-headed starling*#	*Sturnia blythii*
177		Common Myna	*Acridotheres tristis*
178		Hill Myna / Southern Hill Myna*	*Gracula religiosa*

179	Muscicapidae (Chats & flycatchers)	Oriental Magpie Robin	*Copsychus saularis*
180		White-rumped Shama	*Kittacincla malabarica*
181		Asian Brown Flycatcher	*Muscicapa dauurica*
182		Brown-breasted Flycatcher	*Muscicapa muttui*
183		Rusty-tailed Flycatcher	*Muscicapa ruficauda*
184		White-bellied Blue Flycatcher #	*Cyornis pallidipes*
185		Tickell's Blue-flycatcher	*Cyornis tickelliae*
186		Blue-throated Flycatcher	*Cyornis rubeculoides*
187		Verditer Flycatcher	*Eumyias thalassinus*
188		Nilgiri Flycatcher# (NT)	*Eumyias albicaudatus*
189		White-bellied Shortwing#/ Ashambu Sholakili (EN)	*Brachypteryx major / Sholicola ashambuensis*
190		Indian Blue Robin	*Larvivora brunnea*
191		Malabar Whistling Thrush	*Myophonus horsfieldii*
192		Black-and-orange Flycatcher# (NT)	*Ficedula nigrorufa*
193		Blue-capped Rock Thrush	*Monticola cinclorhyncha*
194		Blue Rock-thrush	*Monticola solitarius*
195	Turdidae (thrushes)	Scaly Thrush / Nilgiri Thrush*#	*Zoothera dauma*
196		Orange-headed Thrush	*Geokichla citrina*
197		Indian Blackbird	*Turdus simillimus*

Note: 1) *Not recognized as a species by Birdlife international 2015 list, but are recognized as subspecies under nominate race
2) # Endemic to Western Ghats
3) ? Species for which sight record is not confirmed. Serial number has not been given for the species with unconfirmed sightings

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Notes

Miscellaneous