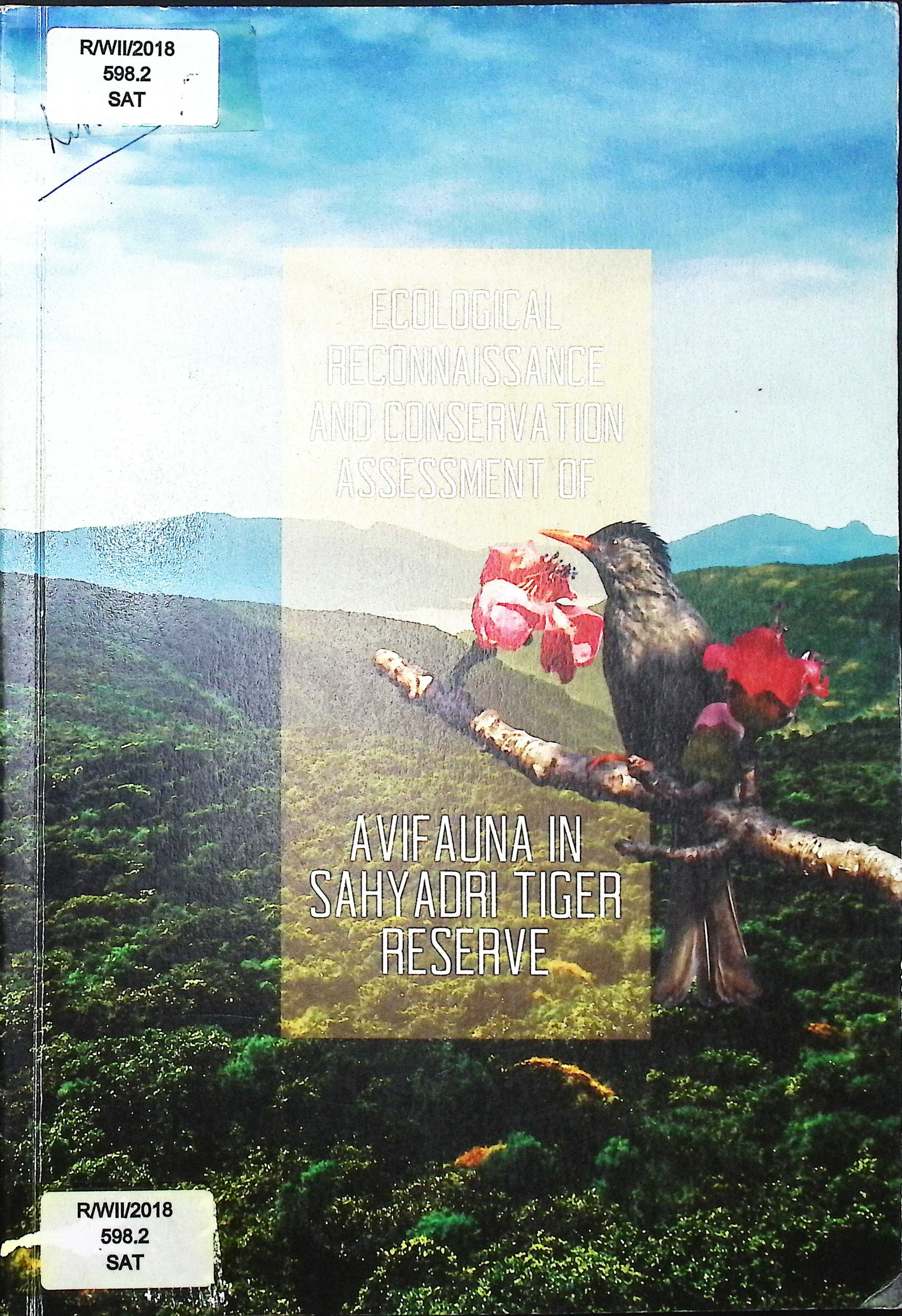

ECOLOGICAL RECONNAISSANCE AND CONSERVATION ASSESSMENT OF AVIFAUNA IN SAHYADRI TIGER RESERVE

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ACKNOWLEDGMENTS

We would like to sincerely thank the following individuals and organizations for their advice, necessary permission, logistic support and assistance for conducting this study.

Dr. Vinita Vyas
(DCF & Deputy Director, Sahyadri Tiger Reserve)

Wildlife Institute of India
Dr. V. B. Mathur (Director),
Dr. G. S. Rawat (Dean),
Dr. V.P. Uniyal (NOCP),
Dr. K. Ramesh (Scientist-E),
Dr. Sutirtha Dutta (Scientist-D),
Dr. Tapojit Dutta (RA),
Mr. Avinash Gaikwad (Researcher),
Mr. Shah Nawaz Jalil (Researcher),
Mr. Suresh Rana (Researcher)

ACF and RFO,
Sahyadri Tiger Reserve
Mr. Tanaji Gaikwad (ACF),
Mr. Prajyot Palvey (RFO),
Mr. Rajendra Patil (RFO),
Mr. K.S. Kamble (RFO),
Mr. Ashok Rangappa (RFO)

Co-ordinators,
Sahyadri Tiger Reserve
Mr. Azim Mujawar,
Mr. Rahul Kale

Forester and Forest guards,
Sahyadri Tiger Reserve
Mr. A.B. Mane,
Ms. D.A. Tashildar,
Ms. R.M. Mulla,
Mr. S.A. Kamble,
Mr. R.P. Pernole,
Mr. G.R. Chougule,
Mr. A.Y. Gurav,
Mr. A.D. Hoval,
Mr. A.R. Dalvi,
Mr. A.I. Khan,
Mr. Yogesh Punaji Gavit,
Mr. Prakash Devaji Shinde,
Mr. B. K. Bhosale,
Mr. Devkar,
Mr. Vitthal Sahdev Gole,
Mr. P. N Rathore,
Mr. A. M. Mulla,
Mr. P. J. Shewale,
Mr. Prakash Maruti Shinde,
Mr. P. K. Shevate,
Mr. M. S. Sonawale,
Ms. Pooja Manik Parule,
Mr. Abhijeet Kumbhar,
Mr. S. R. Mahale,
Mr. R.V. Kakade.

Forest Watchers,
Sahyadri Tiger Reserve
Mr. Ashok Dattu Mane,
Mr. Sankar Bhau Dhadave,
Mr. Ramchandra Ganpati Chaugule,
Mr. Balu Bandu Agre,
Mr. S. K. Maskar,
Mr. L. B. Desai,
Mr. Prakash Dondiba Jhadhav,
Mr. Kondiba Annaji Jhadhav,
Mr. Rajendra Ramchandra Dhebe,
Mr. Shailesh Ramdas Tambe,
Mr. Krishna Shankar Jangam,
Mr. Tanaji Krishna Sedar,
Mr. Suresh Narayan Bhosle ,
Mr. Pandurang Laxman Shinde.

Field Assistants
V. K. Gaikwad,
Mr. S.D. Jende.
Mr. V. B. Nangare,
Mr. A.S. Mule,

PROJECT COMPLETION REPORT

Title of the project
Ecological Reconnaissance and Conservation Assessment of Avifauna in Sahyadri Tiger Reserve

Principal investigators
Dr. Gopi G.V.
Dr. V. Clement Ben

Researchers
Surabhi Sati
Anurag Vishwakarma
Ashutosh Singh

Implementing institution(s) and other collaborators
Wildlife Institute of India, Dehradun
Sahyadri Tiger Reserve, Maharashtra

Month and year of commencement
September 2016

Month and year of completion
February 2018

September 2018

Wildlife Institute of India , Post Box # 18,
Dehradun-248001 Uttarakhand, India
Tel: +91-135-2646100; 2640114-115;
Fax: +91-135-2640117,
Email: gopigv@wii.gov.in

Citation:

Surabhi Sati, Anurag Vishwakarma, Ashutosh Singh, Clement Ben and Gopi G.V. (2018) Ecological Reconnaissance And Conservation Assessment of Avifauna in Sahyadri Tiger Reserve. Technical Report, Wildlife Institute of India, Dehradun, India. TR No. 2018/45. Pp. 76

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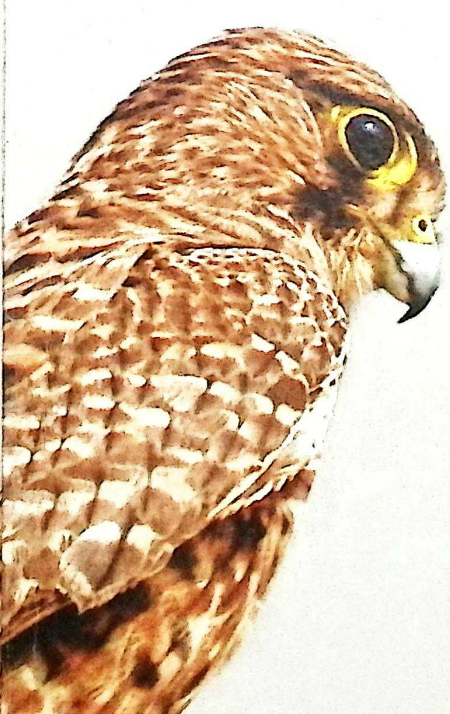


SUMMARY

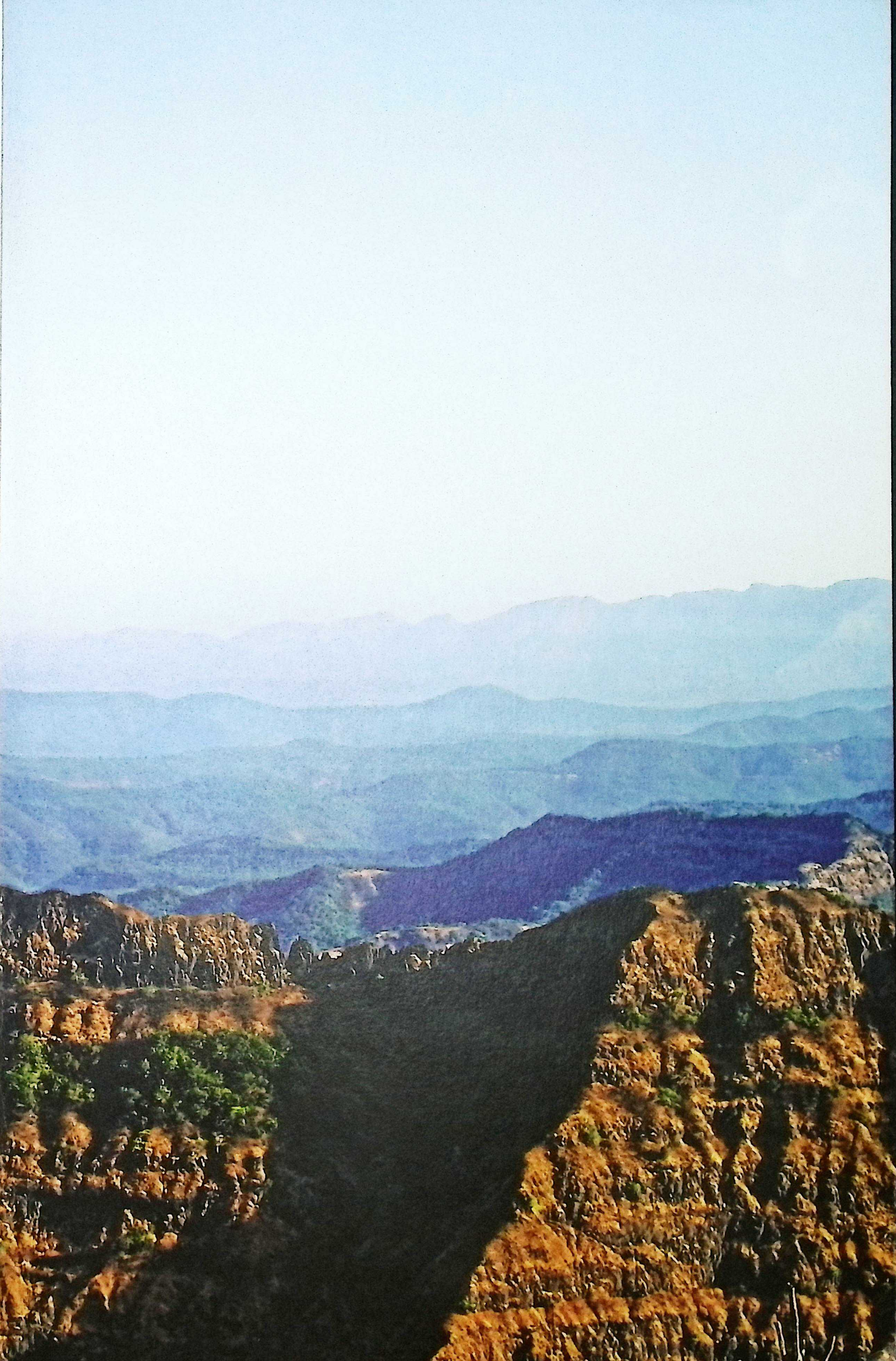
The Western Ghats have been designated a World Heritage Site by UNESCO because of their Outstanding Universal Values (OUVs), and they support several threatened plant and animal species. The birds of the Western Ghats have received a great deal of academic and conservation attention because of their endemism and the conservation threats they face. However, there is only limited empirical ecological information on the avifauna of Sahyadri Tiger Reserve (STR). Hence, a systematic study of the avifauna was required to fill the existing knowledge gap and for long-term conservation. This study was initiated in collaboration with STR, Maharashtra and Wildlife Institute of India. The study was conducted between October 2016 and February 2018. The area was divided into four major habitat types, namely agriculture land, grassland, shrubland and forest. The aim of the study was to assess the conservation importance of STR with respect to the avifauna by, understanding the diversity, abundance and habitat utilization in relation to the anthropogenic pressure in different seasons (autumn, winter, summer).

Systematic field data were collected using the point count method to determine the distribution and abundance of species. The bird species, number of individuals (male, female and juvenile), habitat variables, vegetation characteristics and disturbance variables were recorded and quantified. The bird abundances and diversities of the different habitat types were compared and related to habitat features. Bird densities were estimated using the distance sampling method. The Shannon-Wiener diversity index (H') was used to determine the species diversity. The Spearman correlation coefficient was used to determine the relationship between the bird abundance and the habitat features within habitat types.

A total of 218 species of bird belonging to 66 families were recorded during the study. Seven of these are threatened species. The highest number of recorded species (30) was in the family Accipitridae. Seven endemic birds of the Western Ghats were also recorded. We found that there is a significant relation between the bird density and diversity within a habitat type across the three sampling seasons. In autumn, the density ranged from 733.75 ± 63.14 to 485.91 ± 46.01 per Km^2. The highest density was recorded in agriculture land and the lowest in forest. In winter the density ranged from 1673.3 ± 90.27 to 519.83 ± 31.43, the highest being in agriculture land and the lowest in forest. In summer the density ranged from 900.59 ± 68.58 to 403.00 ± 39.97, the highest being in shrubland and the lowest in grassland. The study found higher bird densities in autumn and winter in areas with highly intenseagriculture activities as human-disturbed areas such as agriculture areas provide heterogeneous habitats that attract human-tolerant bird species. It was also observed that during summer, shrubland had the highest density of birds whereas the lowest density was in grassland and agriculture land. In summer the grasslands and agriculture lands were usually dry. Farmers burn field residues, and hence shrubland provided a more open habitat that supports shrubs that provide food and canopy cover for different bird species. Unlike the bird density, the diversity of the avifauna was high in forest in all three seasons. In autumn, the diversity index values ranged from 3.867 to 3.533, and in winter the diversity index values ranged from 3.895 to 3.551. In summer the diversity index values ranged from 3.941 to 3.258. The diversity was highest in forest and lowest in grassland in all three seasons.

We observed unusual flowering of the Dhak, Butea monosperma (Lam.) Taub. (Fabaceae). The flowering time of the species is March–April though sometimes it also flowers in late February and the flowering lasts till early May. Notably, during our of the field surveys, we observed 10 fully grown individuals of B. monosperma in full bloom from mid-November to late December in Chandoli National Park and Koyna Wildlife Sanctuary. Through continuous monitoring of these individuals in the tiger reserve we confirmed unusual phenological events that have not been reported earlier for this species. The change in phenological events of this species could be attributed to climatic change, irregular drought patterns or genetic factors, albeit further research is needed.

The study reveals the relationship between avifauna species richness and habitat patterns and addresses the effects of anthropogenic pressure on avian species richness and its distribution patterns. Also, this study provides evidence that settlement areas can serve as refuges for birds. Therefore, conservation efforts should be directed towards making communities view human-occupied areas as habitats for birds and not as lost habitats. Hence, scientific understanding backed by empirical evidence about the process and patterns of avifaunal assemblages in STR can be used to formulate a robust conservation plan for the birds of the reserve.



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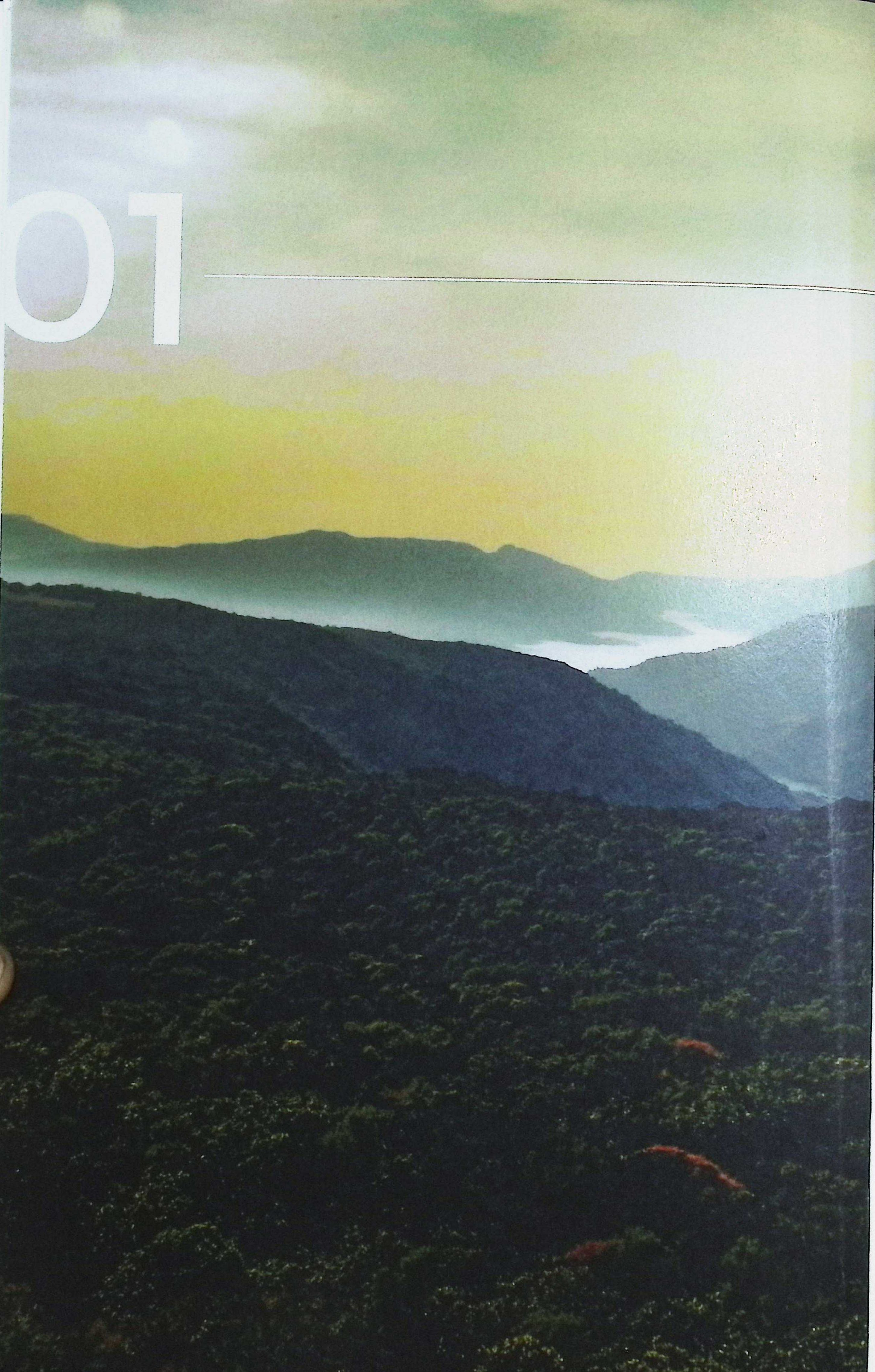


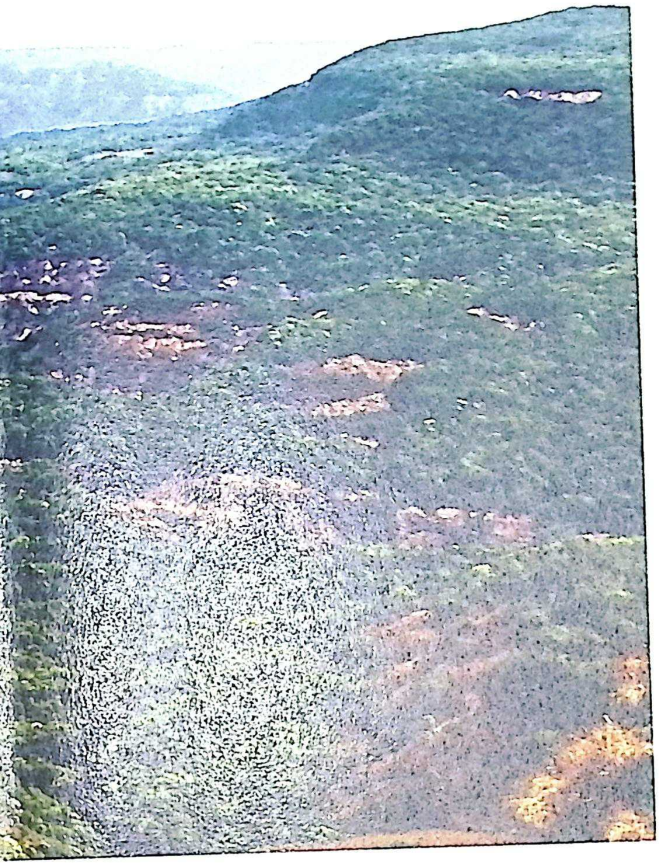
ECOLOGICAL RECONNAISSANCE AND CONSERVATION ASSESSMENT OF AVIFAUNA IN SAHYADRI TIGER RESERVE

INTRODUCTION

The Western Ghats, a biodiversity hotspot, are characterized by a high level of endemicity. They start near the border between Gujarat and Maharashtra, south of the Tapti River and run approximately 1600 km long along the western coast of the Indian peninsula (Myers et al., 2000). The Western Ghats have been designated a World Heritage Site due to their Outstanding Universal Values, and there are several national parks, wildlife sanctuaries, and reserve forests in them. There are 58 protected areas, of which 34 are in Maharashtra (National Wildlife Database Cell, 2011). The evergreen forests of this region have 528 bird species and 16 bird species endemic to this region. Hence, the region is categorized as an Endemic Bird Area (EBA) (Birdlife International, 2016). Out of the 16 endemic bird species of the Western Ghats, eight species are found all along the northern Western Ghats, while the remaining eight species are confined to the southern Western Ghats (Mehta and Kulkarni, 2012). The avifaunal diversity of most of the areas of the Western Ghats is well documented. However, the present study describes the forest community of the central Western Ghats in Sahyadri Tiger Reserve (hereinafter, STR), which has received very limited scientific attention. No systematic study of the avifauna had been carried hitherto (Birdlife International, 2016).

Birds are highly mobile endothermic vertebrates that are highly susceptible to changes in habitat caused by human use and modification (Raman et al., 1998; Thiollay, 1999; Lohr et al., 2002). Birds are considered indicators of biological richness and the health of our environment. They provide a means of improving our scientific knowledge and promoting conservation and environmental awareness. STR is one of the important tiger reserve of Maharashtra. This area is home to many endangered birds such as the Oriental White-backed Vulture (*Gyps bengalensis*) and Long-billed Vulture (*Gyps indicus*), vulnerable birds such as the Nilgiri Wood Pigeon (*Columba elphinstonii*) and endemic birds such as the Malabar Grey Hornbill (*Ocyceros griseus*), Nilgiri Wood Pigeon (*Columba elphinstonii*), Black-and-Rufous Flycatcher (*Ficedula nigrorufa*), Nilgiri Pipit (*Anthus nilghiriensis*), Malabar Lark (*Galerida malabarica*), Malabar Parakeet (*Psittacula columboides*), White-cheeked Barbet (*Psilopogon viridis*) and Crimson-backed sunbird (*Leptocoma minima*).

A vast number of studies have sought to establish relationships between bird species diversity and habitat attributes such as vegetation structure and heterogeneity (MacArthur and MacArthur, 1961; Wilson, 1974; Roth 1976; James and Wamer, 1982; Mills et al., 1991; Gillings and Fuller, 1998; Haney and Lydic, 1999). Birds are considered good predictors of habitat quality as they relate to changes in their associated habitats in numerous ways (Raman et al., 1998; Chettri et al., 2001; Raman, 2001), because they respond to habitat structure (MacArthur and MacArthur, 1961) and represent several trophic levels and guilds (Steele et al., 1984). The distribution of many bird communities is affected by habitat fragmentation or other habitat parameters that reflect the inter-specific dynamics and population trends associated with the habitat (O'Connell et al., 2000). This sensitivity suggests that bird communities have a high potential to act as a surrogate for their habitats at structural, regional and landscape-level management (Canterbury et al., 2000; Lindenmayer et al., 2000; O'Connell et al., 2000). For example, nectarivorous bird species pollinate plant species that are dependent on them, contributing to the exchange of unrelated genetic material between areas. Frugivorous bird species consume and disperse seeds, improve their germination and are responsible for genetic exchange between areas. Moreover, they can contribute to the recolonization and restoration of disturbed ecosystems. Insectivorous bird species control insect populations and can serve as an alternative to pesticides as they reduce plant damage, a fact that has great economic importance (Sekercioglu et al., 2004). A global analysis of avian ecological data conducted by Sekercioglu (2012) revealed that the conversion of forest land to agricultural land causes a shift to less specialized bird communities that are mainly composed of common and widespread species. This also leads to modified proportions of functional groups and can reduce the ecosystem functions and services provided by birds in agricultural landscapes (Sekercioglu, 2012). This classification of bird feeding guilds becomes even more significant when finer functional differences (e.g., size and type of food) within broad categories are also considered (Petchey and Gaston, 2006). A study by Flynn et al. (2009) has shown that functionally distinct species (specialists) are much more vulnerable to extinction through agricultural intensification than are functionally redundant species (generalists) that share similar ecological functions.



This study was designed to address the objectives by investigating avian assemblages of STR. A systematic survey provides data on the distribution of key species, the richness of sites or habitat variation and assesses the sensitivity of birds threatened by loss or degradation of their microhabitat. The understory insectivore is a highly sensitive guild that declines significantly due to disturbance-mediated change in the vegetation and habitat properties. In the study area there is grazing pressure in the buffer zone of the reserve forest, as a result of which there is reduced availability of food resources, especially ground-dwelling insects. Fodder collection or lopping of fruiting trees is also expected to reduce the overall abundance of fruits and flowers in the areas adjoining the reserve forests. This study aims to understand the diversity and abundance of the avifauna in relation to habitat association and the anthropogenic pressure in STR. A management action plan to work on conservation of avian species in the tiger reserve is recommended.

Nevertheless, a decrease in species richness is not always accompanied by a loss of functional diversity (e.g., generalized bird species could fulfill all functions that extinct specialized bird species no longer provide in agricultural landscapes), and so the species richness is not necessarily a good indicator of functional diversity (Flynn et al., 2009). It is becoming increasingly important for ecologists and evolutionary biologists to study animal–plant interactions to understand ecological communities and to improve their management and conservation (Vázquez et al., 2009). An ecological community is composed of many different populations that form a multi-layered entity and interact with each other in several ways (e.g., predation, seed dispersal, pollination, competition, parasitism). This complex system can be visualized and analyzed by creating an ecological network in which relationships and energy fluxes between certain species are linked (Carnicer et al., 2009). Food networks can show a large number of coexisting species in specific consumer–resource interactions (Allesina and Pascual, 2007), and they can be further described by computing a variety of indices (Dormann et al., 2009).

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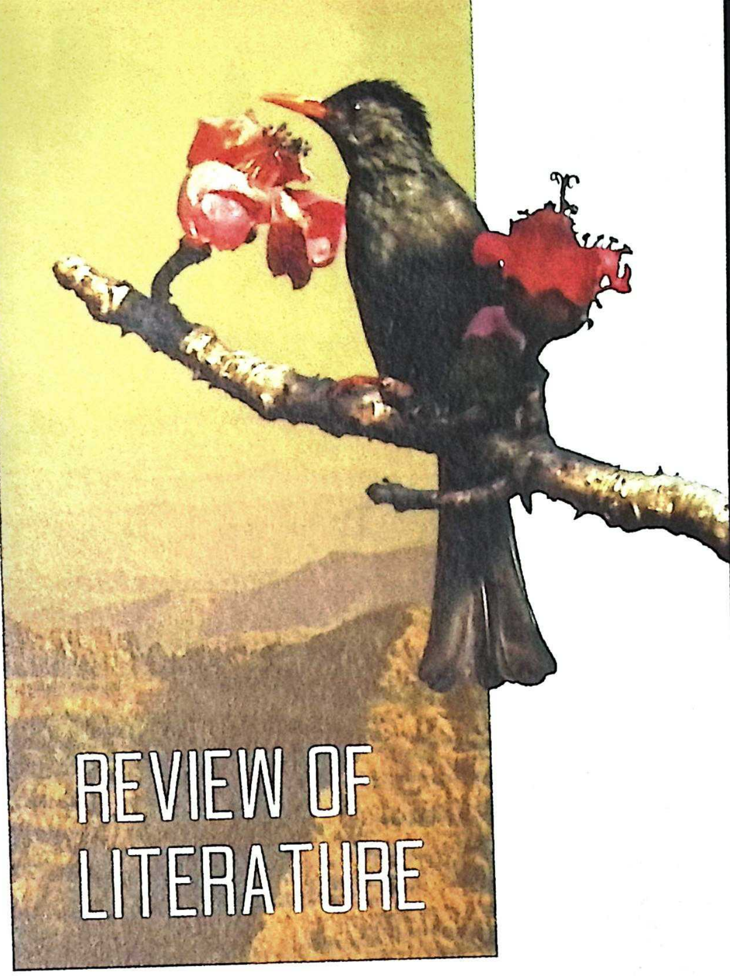

REVIEW OF LITERATURE

Birdlife International categorized the Western Ghats as an Endemic Bird Area (EBA). Local avian assemblages have been a major area of research in community ecology from both theoretical and empirical perspectives since the pioneering works of Robert H. MacArthur in the 1960s. Till the early 1990s, the focus was mainly on local patterns and processes, and there were only a few notable regional studies (e.g., Williams 1964; MacArthur, 1972). Rev. S.B. Fairbank (1876) had published a list of birds in Stray Feathers, recording birds found in the vicinity of Khandala and Mahabaleshwar. This list mentions that species such as the Red Spurfowl, Red-whiskered Bulbul, Blackbird, Malabar Whistling Thrush and Wren-babbler were common in Khandala and Mahableshwar. E.A. Butler, in 1881, published "Tentative Catalogue of Birds of Deccan and South Maratha Country" in Stray Feathers in 1881, and in his work he provides a list of birds occurring in the Sahyadri Range from Goa to Khandala. In the Book of Indian Hill Birds, Dr. Salim Ali, in 1949, mentions a checklist of 104 bird species of the Sahyadri Range. A short account of the avifauna of Maharashtra compiled by V.C. Ambedkar (1969) appears in the fauna volume of the Gazetteer of Maharashtra, in which he presents a brief family-wise account of birds occurring in Maharashtra. In a checklist of the birds of Maharashtra Humayun Abdulali (1981) mentions that 540 species of bird occur in this state. According to him, 442 birds on his checklist are found in Bombay and neighboring areas of the Konkan, including the Western Ghats. The most comprehensive work has been done by Gole from 1994 to 1996. This covers the Sahyadri landscape, and 205 bird species were encountered. The protected areas and reserve forests of the Sahyadri Range were surveyed by Mehta and Kulkarni in 2012. They report a total of 224 bird species belongs to 48 families. They also surveyed the protected areas of North Maharashtra, including the undisturbed area and mature forest of Chandoli. Phansad has the highest richness of birds, followed by Sanjay Gandhi National Park (SGNP), Bhimashankar and Koyana Wildlife Sanctuary, while Harischandragad-Kalsubai Wildlife Sanctuary (HKWS) has the lowest richness. They also studied birds in the reserve forests of Sawantwadi, Lonavala and Amba. They found that Sawantwadi, Lonavala and Amba had the highest richness of birds. Chandgad, Sinhagad and Mulshi have intermediate richness. The high-altitude plateaus of Mahabaleshwar and Raireshwar have a low richness of birds. Small sites such as Durgmanwadi (DMW) and Kasarsada (KSD) have very low richness. Birds select habitats that fit their requirements for successful reproduction and survival, though some generalist species may utilize several habitats (Rodríguez-Estrella, 2007). Differences in requirement among bird species have caused specificity of habitat requirements (Buckley and Freckleton, 2010). In most habitats, plant communities determine the physical structure of the environment and, therefore, have a considerable influence on the distribution, abundance and diversity of birds and on the interactions of other animal species. For example, Tews et al. (2004) provided evidence to show that the physical structure of a plant community, i.e., how the foliage is distributed vertically, may be more important than the actual composition of plant species for bird species diversity in forests. Ranganathan et al. (2007) found that agriculture land also has been an important habitat for birds and that due to land use changes it is difficult to find forest habitats covering large areas. Studies of bird species diversity, distribution and abundance are important not only for knowledge but also for conservation purposes as birds have been used as ecological indicators (Rittiboon and Karntanut, 2011). Habitat destruction, fragmentation and loss have been observed due to the increase in the human population (Manhães and Loures-Ribeir, 2005). Forests have been converted to urban settlements, agricultural fields and pasture land, sometimes open land. These human activities have an impact on bird species abundance, distribution and diversity through isolation and fragmentation (Westphal et al., 2006). Declines in abundance and loss of species due to human interference have been observed in the tropics (Cordeiro, 2005). Shankar Raman (2006) analyzed the effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats. He found that plantations and fragments that adjoined undisturbed tropical rainforests had greater tree canopy connectivity and had a greater diversity of rainforest bird species and fewer open forest bird species, while those plantation lacking such connectivity had fewer rainforest bird species and more open forest bird species. Vijayan and Gokula (2006) studied bird communities along a disturbance gradient in five major habitats in the Western Ghats. They described the status of disturbance of two endemic birds in different habitats: the Nilgiri Laughing Thrush in shola forest and the Nilgiri Pipit in grassland. They found that both birds continuously decline with increase in disturbance in the habitat.

In the last many years, avian diversity and avian distribution across varying habitats have emerged as important areas of research. Studies have been carried out to understand the avian diversity and distribution pattern of the Western Ghats. STR, located in the northern Western Ghats, with a mosaic of habitats, provides an excellent location for such studies.

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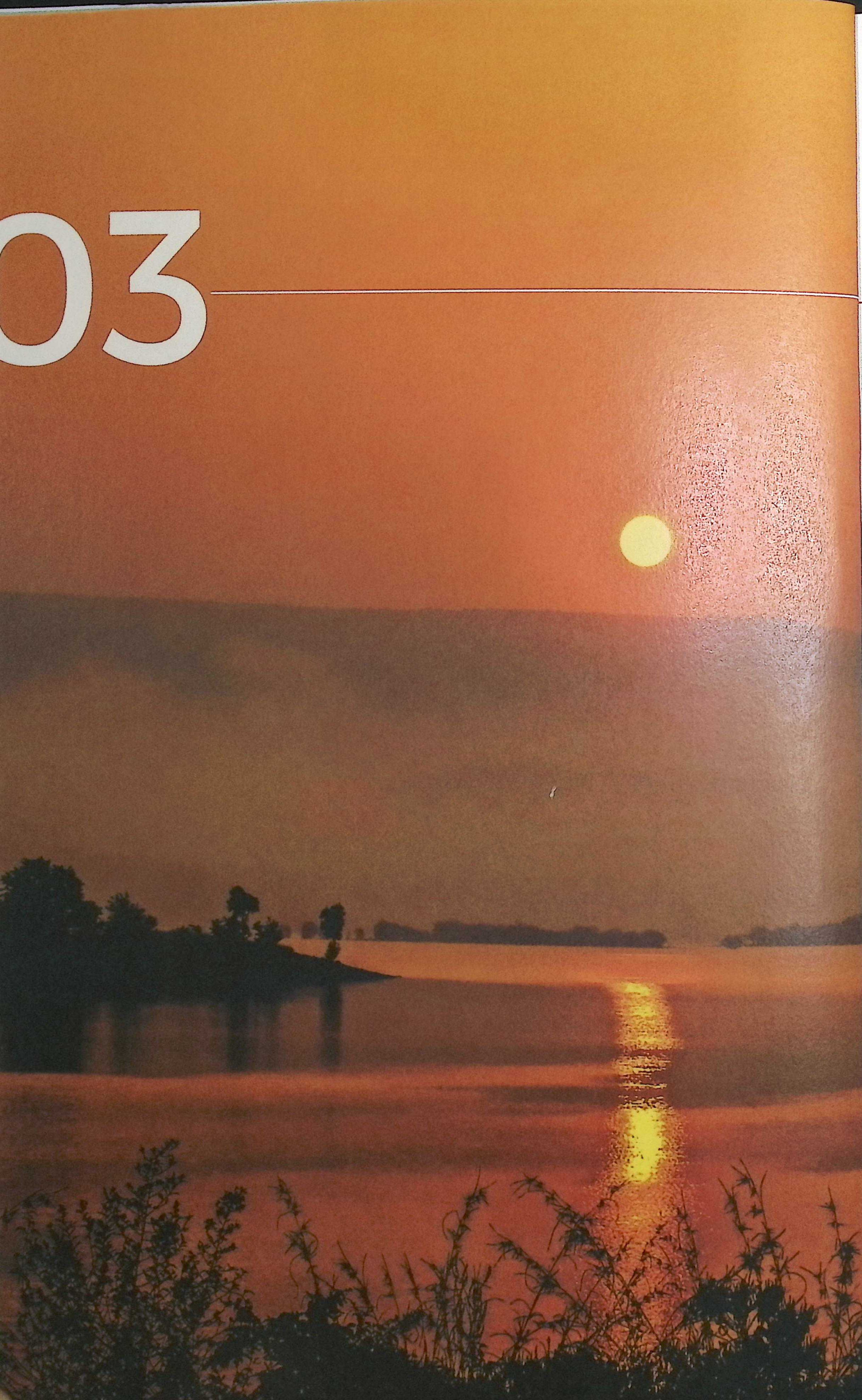

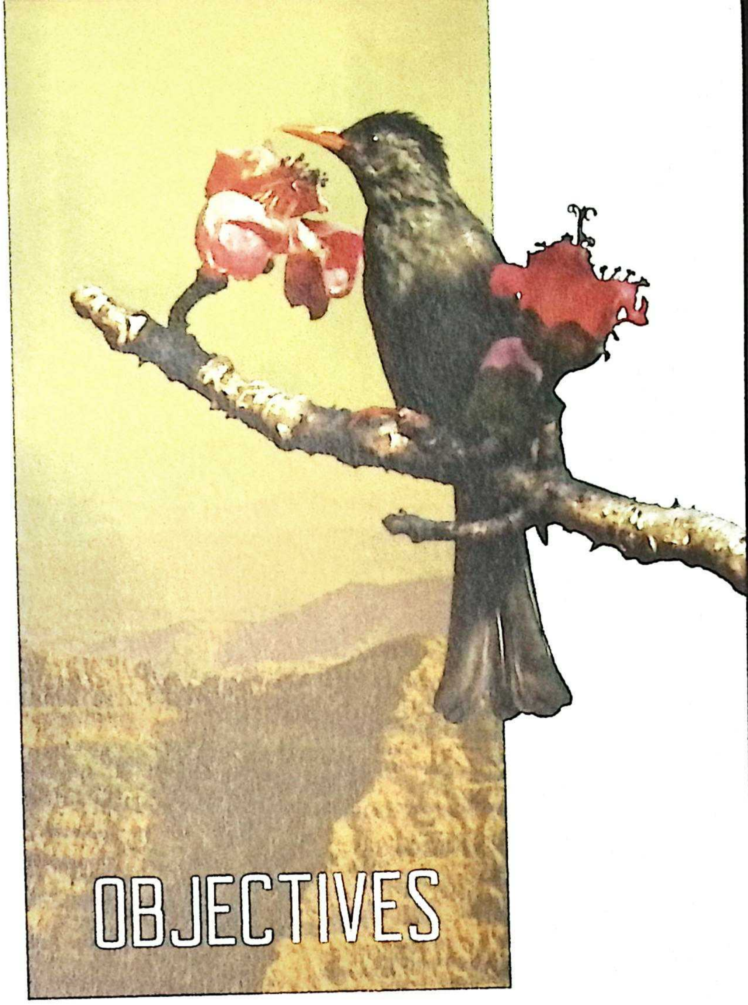

OBJECTIVES

In a developing country like India, the available natural habitats are under human pressure. As a result, different types of habitats are vanishing or shrinking. Hence, it a major challenge to conserve birds within the natural habitats available. This study was carried out to assess the conservation importance of STR in respect of the avifauna.

The underlying objectives of this study are the following:

1

To determine the avian species diversity patterns in STR

2

To identify the determinants of bird species richness in STR

3

To determine the pattern of habitat utilization by birds and determine the influence of habitat variables on the diversity and composition in STR

4

To determine the effect of anthropogenic pressure on the avian species richness in STR

5

To prepare a conservation plan for the avifauna of STR from the information generated.

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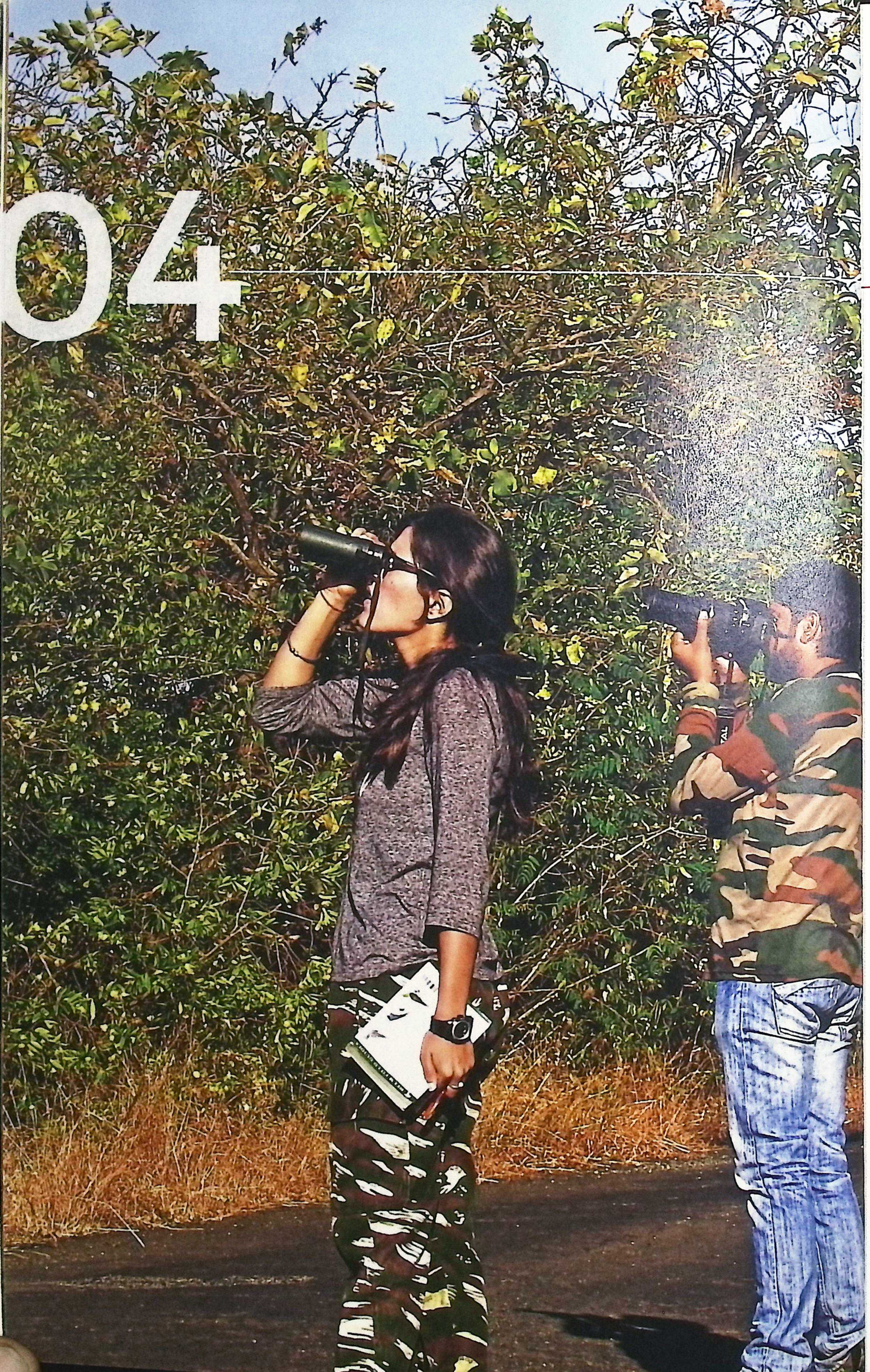
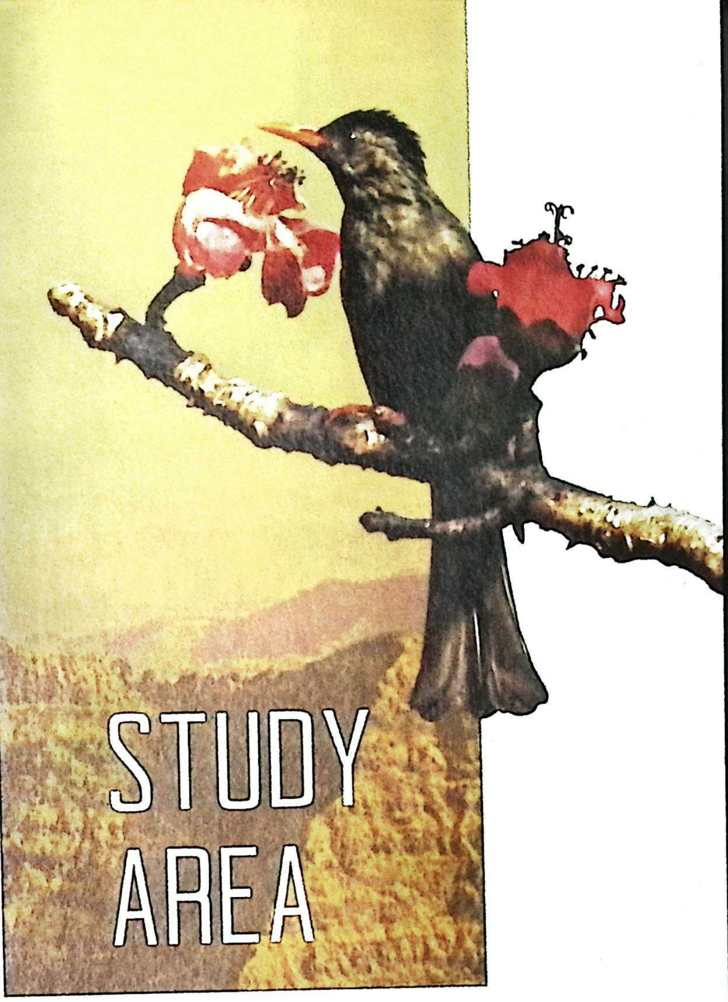




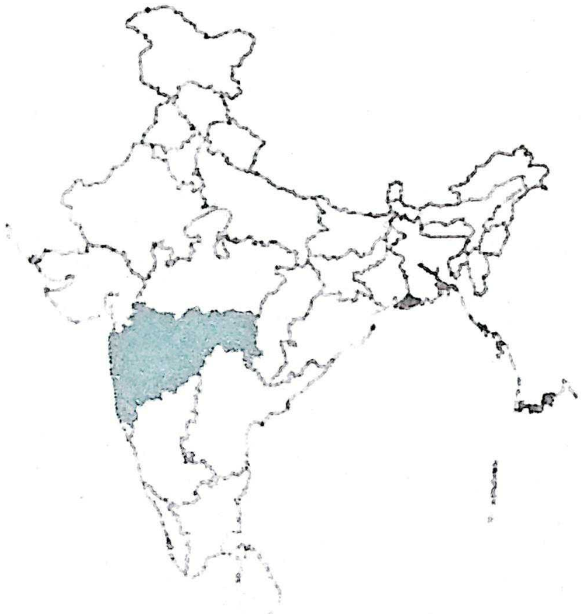
STUDY AREA

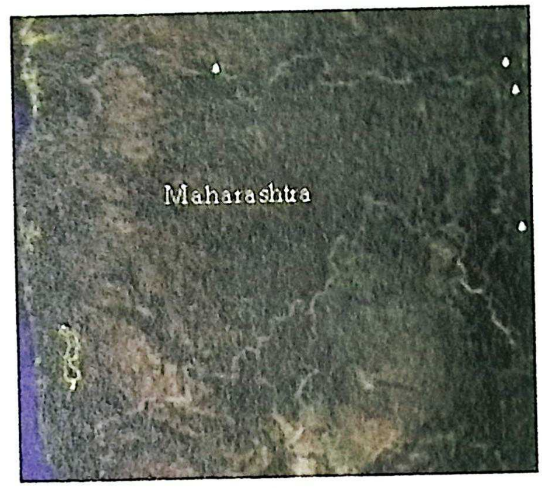
The Western Ghats are one of the global hotspots of biodiversity in India and an Endemic Bird Area (Stattersfield et al., 1998). The Western Ghats (10°10'N, 77°04'E) run approximately 1600 km parallel to the west coast of the peninsular part of India. They occupy an area of 1,60,000 km^2 in the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil-Nadu. The Western Ghats end at Kanyakumari, at the southern tip of India. An extent of 37,554 km^2 of the Western Ghats lies in Maharashtra. This zone is further divided into two biotic provinces, the Malabar plains and the Western Ghats mountains. The Malabar plains lies mainly between the Arabian Sea coast and the Western Ghats mountain province–this part of Maharashtra is also known as 'Konkan'. The province covers six coastal districts (Thane, Mumbai City, Mumbai Suburban, Raigad, Ratnagiri and Sindhudurg). The Western Ghats mountains province extends from Nanddurbar District of Uttar Maharashtra and Dang District of Gujarat in the north to Terekhol Creek of Goa in the south. This part of the Western Ghats of Maharashtra is also called 'Sahyadri' and is located at the rising border with the Deccan Plateau.

Figure 3. View of Koyna Wildlife Sanctuary landscape

Figure 4. View of Chandoli National Park landscape

The study was conducted in STR (area 1166 km^2), which is the most recently constituted tiger reserve in the Western Ghats in Maharashtra. The reserve is spread across four districts, viz. Ratnagiri, Kolhapur, Satara and Sangli, and comprises two major protected areas, viz. Koyna Wildlife Sanctuary in the north, with an area of 423.55 km^2, and Chandoli National Park in the south, with an area of 317.67 km^2. The extent of the adjoining areas of the STR landscape is 424.34 km^2. The core and buffer areas of the tiger reserve have myriads of habitats, from pristine forests to anthropogenically modified habitats.





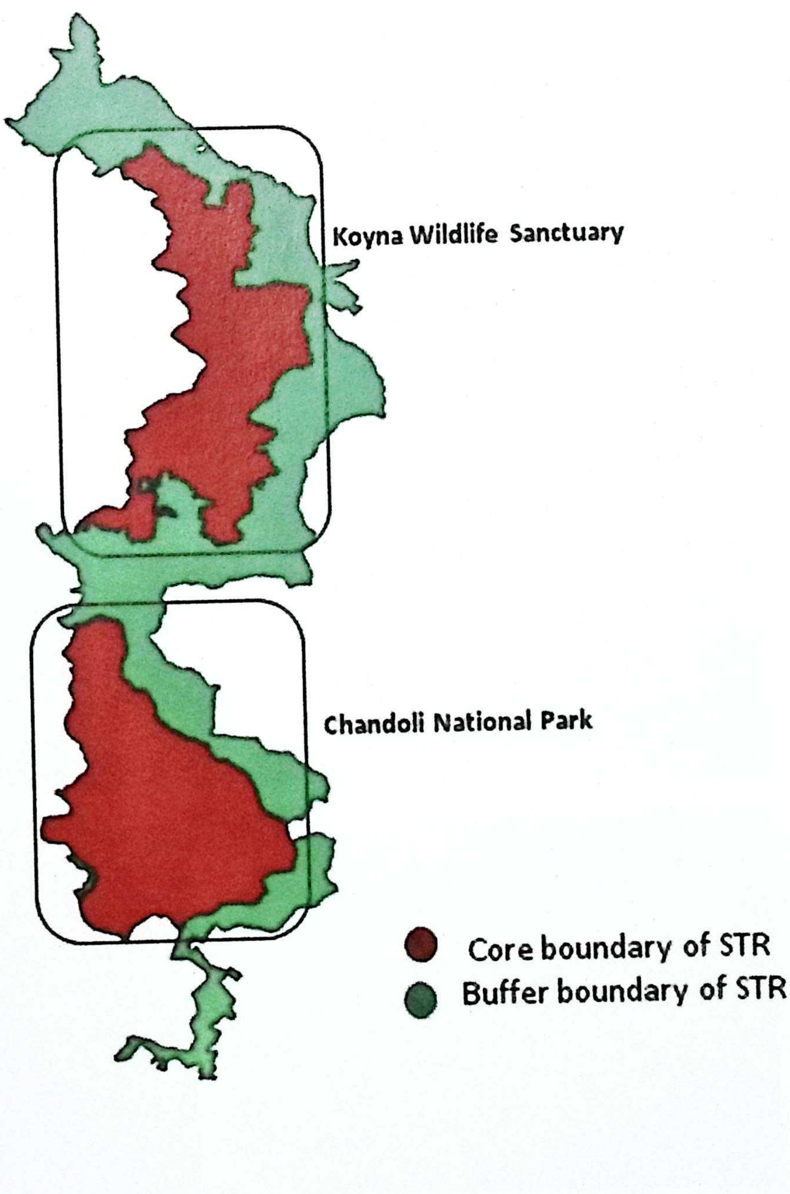


Figure 5. Map of study area

4.1

FLORA

STR has a rich floral biodiversity due to its abundant rainfall and favorable conditions. Ingalhalikar (2001) has given information about and photographs of 500 species of flowering plant of Sahyadri. The sanctuary hosts a threatened tree species called Narkya (Mappia foetida). The Umb (*Euphorbia longana*) and Kasa (*Elaeocoarpus tectorius*) are other uncommon species. Giant trees such as Harpuli (*Harpullia arborea*) and Amli (*Turpunia malabarica*), endemic to the Western Ghats, are commonly found in this area. Koyna Wildlife Sanctuary is known for semi-evergreen, mixed semi-moist deciduous and dry and mixed deciduous hill forests, while Chandoli National Park has sub-tropical hill forest and semi-evergreen and southern moist mixed-deciduous forests.

Figure 6. Some dominant plant species of STR

Terminalia paniculata

Dendrophthoe falcata

Memecylon umbellatum

Terminalia paniculata

The floristic composition of STR is representative of the following forest types:

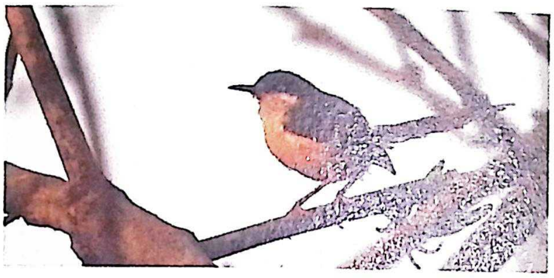
West Coast Semi-evergreen Forests

Western (Montane) Subtropical Hill Forests

Southern Moist Mixed Deciduous Forests

4.2 FAUNA AND CONSERVATION IMPORTANCE

The topographic division and the high productivity of the landscape have resulted in a rich array of animals. The protected area has global significance as it is one of the habitats of the Royal Bengal Tiger (*Panthera tigris tigris*) and Leopard (*Panthera pardus*). The other mammals include ungulate species, namely the Sambar (*Rusa unicolor*), Barking Deer (*Muntiacus muntjak*) and Gaur (*Bos gaurus*). Thirty-four species of mammal have been found in Chandoli National Park, of which the Indian Wild Dog (*Cuon alpinus*), Sloth Bear (*Melursus ursinus*), Indian Giant Squirrel (*Ratufa indica*), Gaur (*Bos gaurus*) and Four-horned Antelope (*Tetracerus quadricornis*) are vulnerable. The bird diversity is very high in this region. with a total number of 275 species, which includes eight endemic species (Mehta and Kulkarni, 2012). The area supports a good population of important species such as the Great Pied Hornbill (*Buceros bicornis*), Malabar Pied Hornbill (*Anthracoceros coronatus*), Yellow-browed Bulbul (*Acritillas indica*), Painted Bush-quail (*Perdicula erythrorhyncha*), Malabar Trogon (*Harpactes fasciatus*), Malabar Whistling-thrush (*Myophonus horsfieldii*) and White-browed Bulbul (*Pycnonotus luteolus*) (Gole 1998; Islam and Rahmani, 2004).



4.3 ANTHROPOGENIC PRESSURE

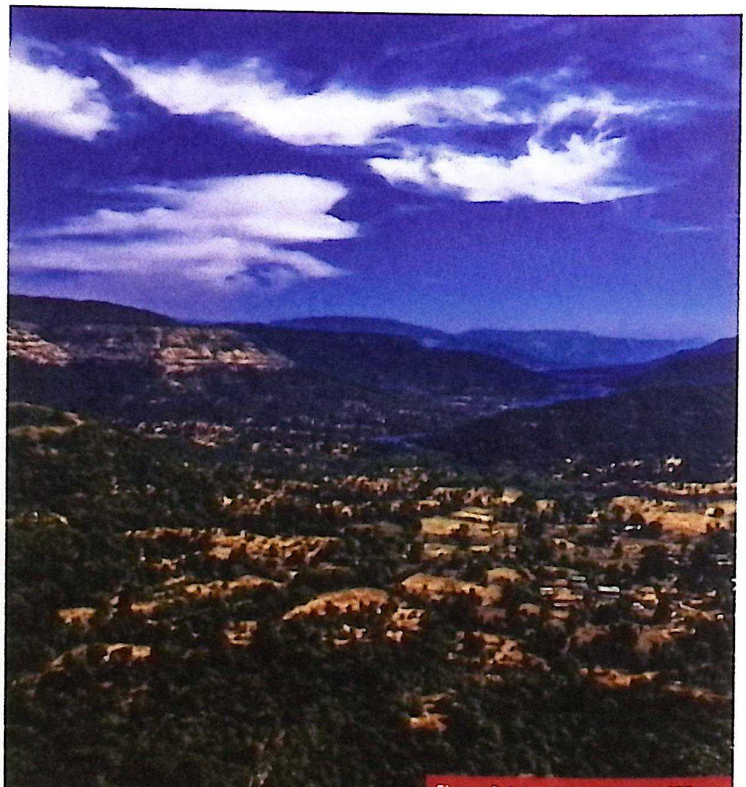
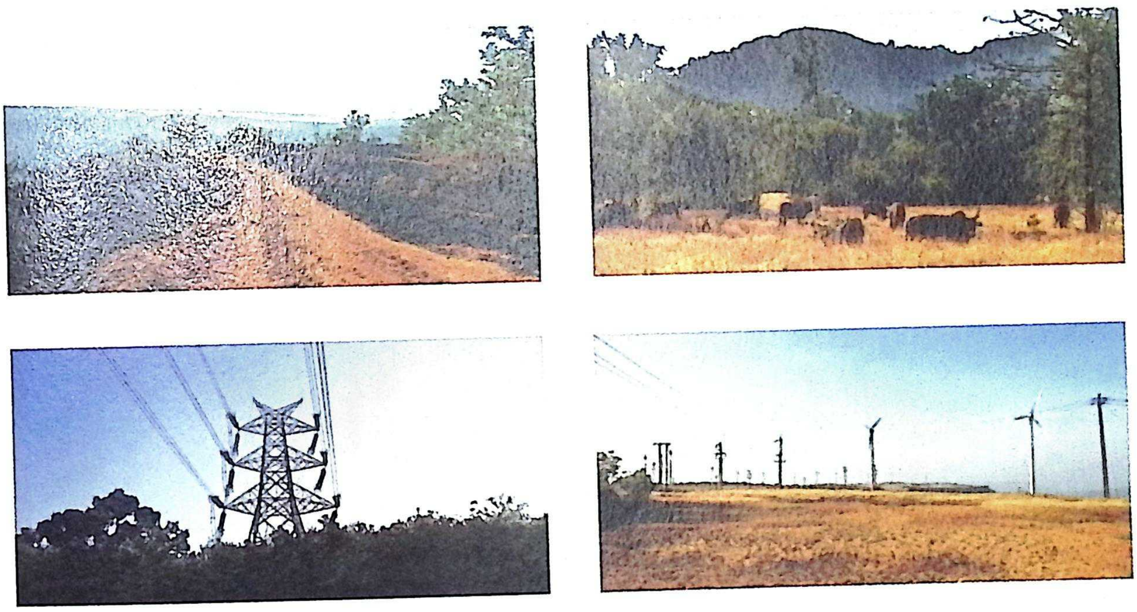


Figure 9. View of a village in STR

The forest in the Sahyadri has a long history of human use. Two major reasons for forest degradation in the study area are human settlement inside the forest and villages along the periphery. Peoples rely heavily on the forest resources, like fodder for their livestock, which supports their dairy product-based economy. The dependence of the people on the forest resources in all possible ways is the main reason for the anthropogenic pressure. In the villages of STR, the people mostly practice agriculture in and around the forest land.

There were 134 villages in STR before it was declared a tiger reserve. After the declaration, the government has relocated 55 villages from the core zone and buffer zone of STR. Now there are 79 villages remaining in the five ranges of STR. Of these, 18 villages are in core zone and 61 villages are in the buffer zone of STR. The total village population is 39,731, out of which 9506 people are living in the core zone of STR and 30,225 people are living in the buffer zone. The total number of households in the five ranges in STR is 3601. These villages are inhabited by members of the Hindu Maratha community, nomadic tribes, the Bodh community and the Muslim community. Inside these villages, people living in wadis (colonies) on the basis of their communities.

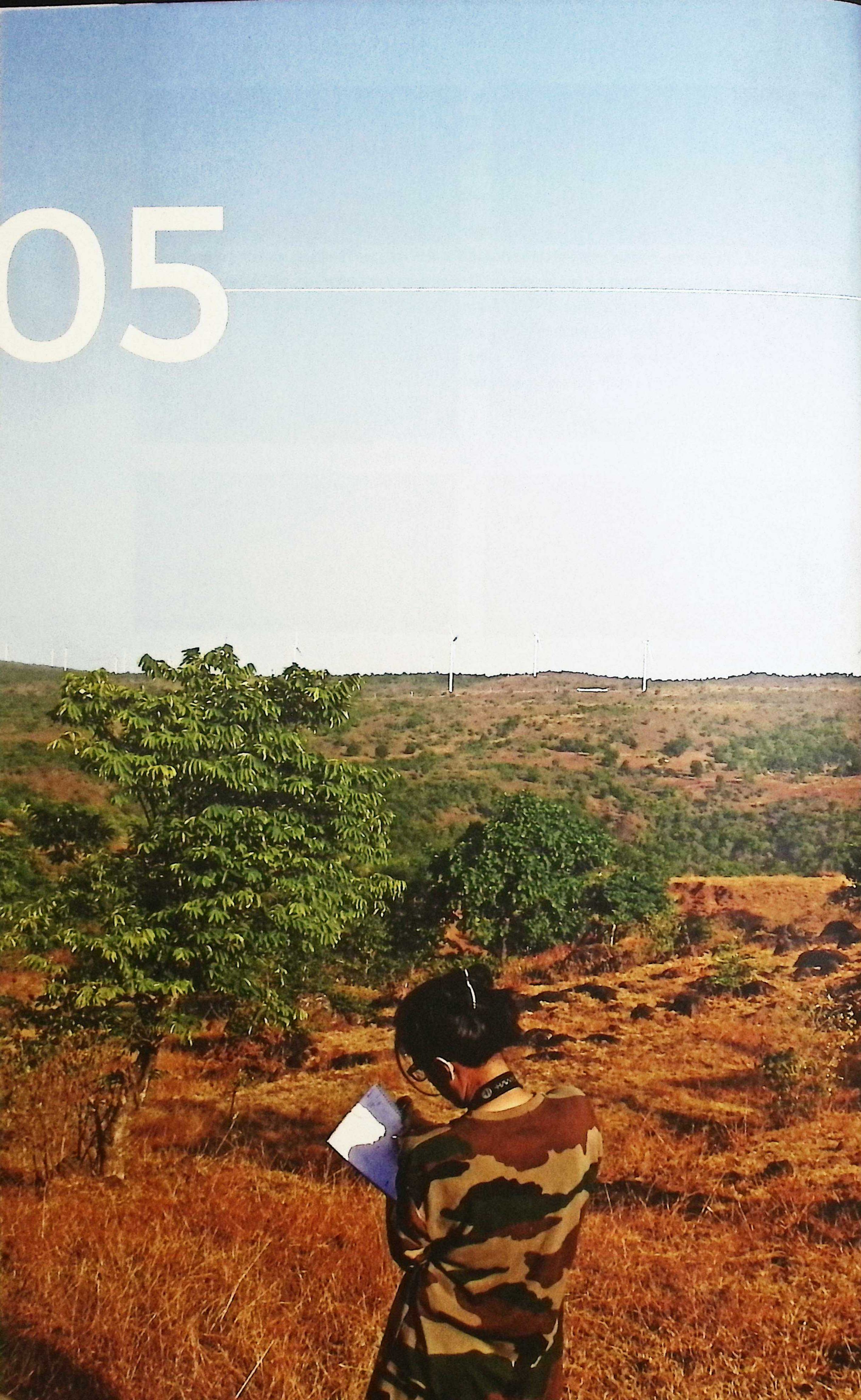
Figure 10. Some major disturbances to the forest



4.4 CLIMATE

The study area lies in the subtropical zone and receives heavy rainfall during JuneSeptember, after which there are long dry spells in April and May. There are three prominent seasons: winter (from the middle of November to March), the hot season (from April to the middle of June) and the season of heavy rains (from June to September). The mean annual precipitation in the area ranges between 4000 mm and >6000 mm. The rainfall decreases rapidly towards the east of the Sahyadri Range, and the climate shows greater variations in the minimum and maximum temperatures. The mean temperature in winter is 12°C, and the mean temperature in summer is 28°C.

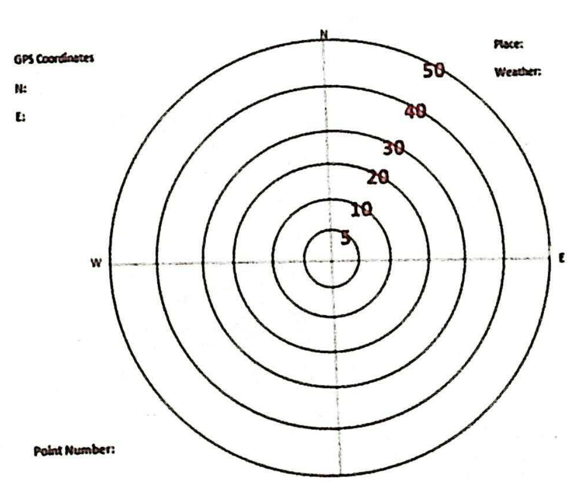
05

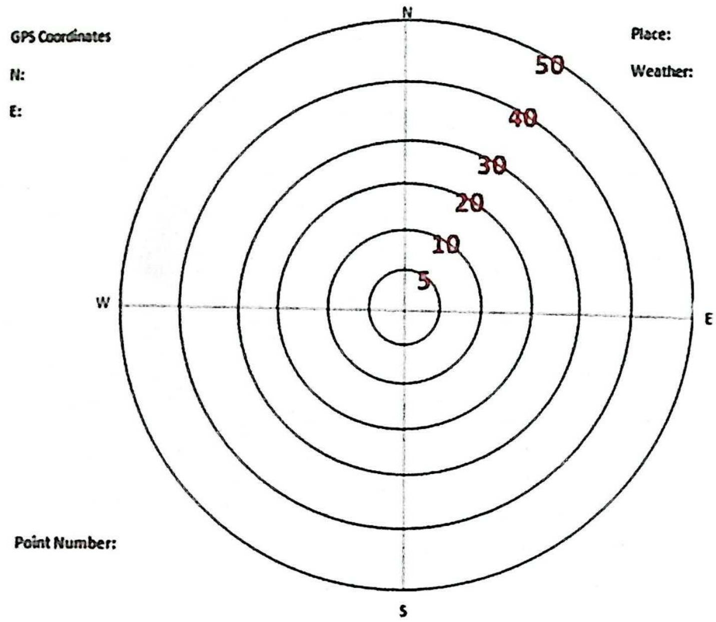


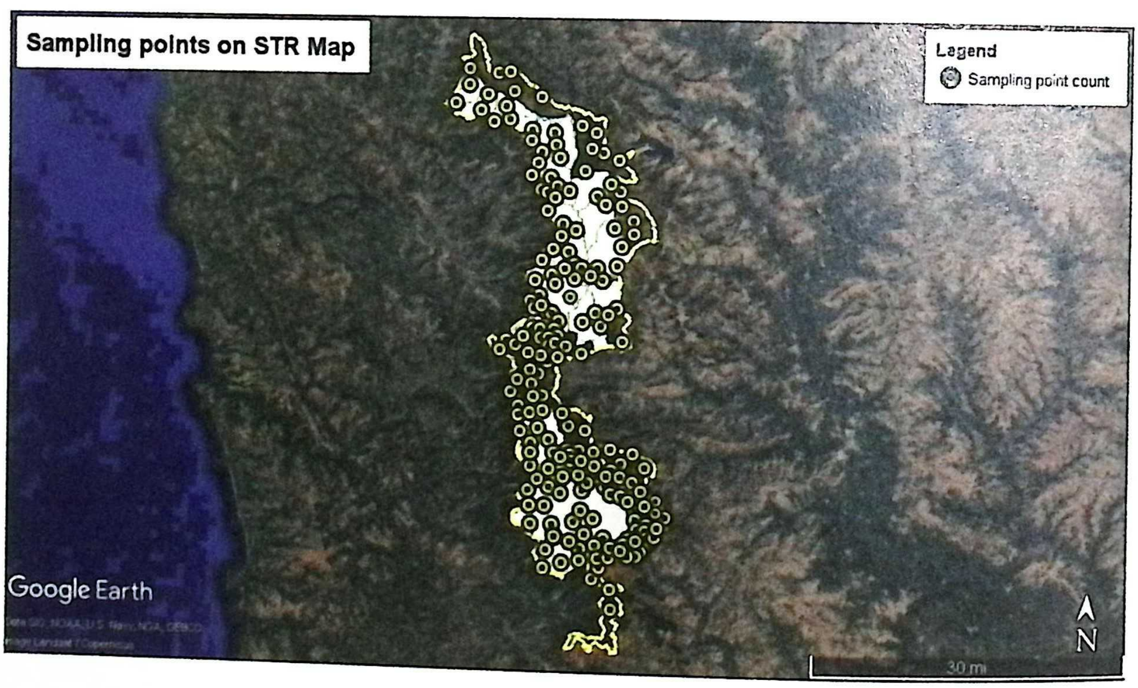
FIELD METHODS

5.1 POINT COUNT

This is the simplest method used for enumeration of birds. Observations are taken from visual encounters and from bird calls, which are recorded from a point count station for a pre-defined time. Counting and observing birds on roads and off-road counts (Ralph et al., 1992) were also done. The sampling time at each point was 20 minutes, which was preceded by 5 minutes' stationary time to ensure there was no disturbance to the birds because of the observer's movements. Birds perching or flying under the canopy or heard were recorded at each point. The two sampling points were 1 km away from each other. On each day, four to six points were surveyed, depending on the accessibility of the points and weather conditions since the visibility or detection of a species varies with time of year and day (Best 1981; Robbins 1981; Lynch, 1995; Buskirk and McDonald, 1995). The survey was not conducted in rainy or foggy weather. All the birds were identified using a standard field guide (Grimmett et al., 1999).







Before systematic data collection in the study area, we familiarized ourselves with the birds and their calls through regular bird watching sessions. Whenever birds could not be identified to the species level because there were only aural cues (e.g., drumming in the case of woodpeckers), because of the small size of the bird or because of a great distance from the observer (e.g., leaf warblers) only generic-level information about the birds was recorded. Only the birds using the area during the count were recorded. Birds were observed every day only during the early morning hours, when bird activity is the highest (Raman et al., 1998), and in the evening 3 hours before sunset. The activity period differed with season. In summer, the counts ended before 3 hours from sunrise, while in winter the bird activity started a little late and continued till 3 hours from sunrise. To capture the maximum species variation within a season, all the points were replicated thrice in the different seasons (autumn, winter, summer).

5.2

HABITAT QUANTIFICATION

The point count stations were located at the centers of the same circular plots that were used for collecting data on the vegetation. Variables such as tree cover percentage, shrub cover percentage, grass density (bundle), shrub density and tree density were measured. Grass cover, tree cover and shrub crown cover are known to vary seasonally, and therefore information on these variables was collected during the breeding and non-breeding times of the birds. Habitat features such as floristic complexity, cover and density of vegetation are the important factors in bird habitat selection. When these features are correlated, a positive correlation is found since they provide food, nesting material and cover for predators (Marone, 1991; Whittingham and Evans, 2004). The heterogeneity of the habitat features can play a significant role in determining the species abundance and occurrence within a habitat type (Pennington and Blair, 2011). Removal or reduction of vegetation reduces the total area of the contiguous habitat available to birds and increases the isolation of the habitat, which results in fragmentation. In fragmented habitats, various predators can successfully prey on eggs, young birds and even adults, which impacts bird populations (Schlossberg and King, 2008).

5.3

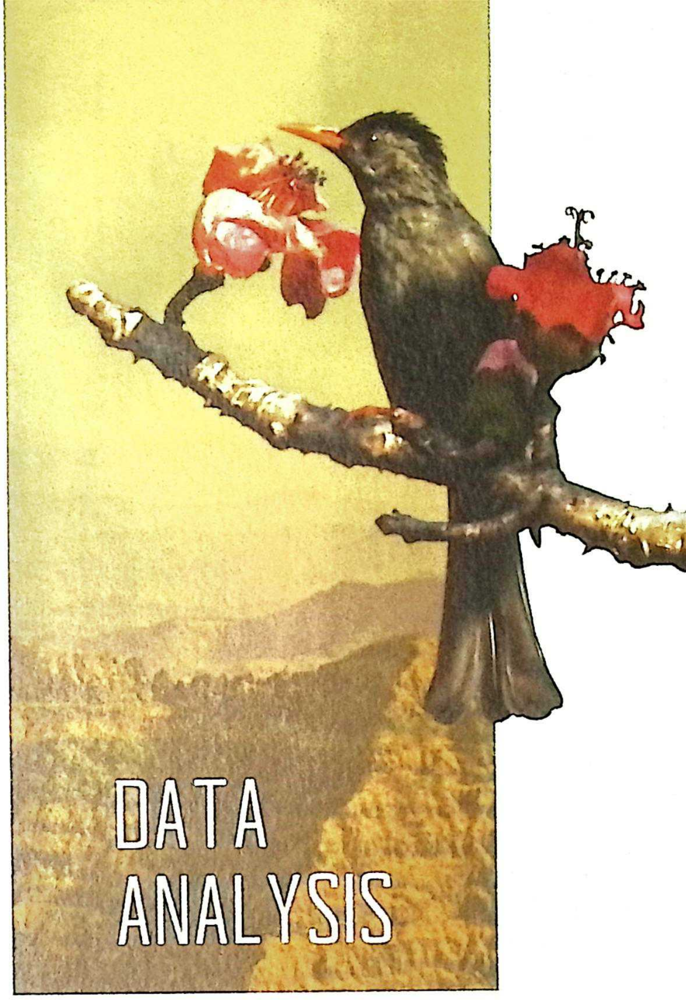
DISTURBANCE QUANTIFICATION

Disturbance quantification was carried out at the same circular plots used for sampling birds. To reduce observer bias, the assessments were done by a single observer.

Table 1. Variables used to quantify disturbances with their respective factors

Disturbance factor	Variable quantified
Lopping	Number of lopped trees
Livestock grazing	Number of dung pats
Browsing signs	
Human usage	Number of trails
Trail width	
Firewood collection	Number of cut trees (>20 cm GBH)
Timber extraction	Number of cut trees (<20 cm GBH)
Fire	Signs of fire (0/1)

06



6.1 ESTIMATING BIRD DENSITY WITHIN HABITATS IN THE THREE SEASONS

Bird densities were estimated from the point count data for each point within a 1 km^2 grid for all three seasons (autumn, winter and summer). Since the density estimated from raw counts may be highly biased due to differential detectability of species, we corrected the detection bias in the density calculation by fitting a detection function in the program DISTANCE (Thomas et al., 2010).

6.2 ESTIMATION OF BIRD DIVERSITY AND ITS DISTRIBUTION PATTERN WITHIN A HABITAT IN THE THREE SEASONS

Species diversity was determined using the Shannon-Weiner diversity index in the Paleontological Statistics (PAST) program. The Shannon-Weiner diversity index takes into account the species richness as well as the evenness.

$$H = -\sum_{i=1}^{S} (p_i \ln p_i)$$

Where:

H = Shannon diversity index

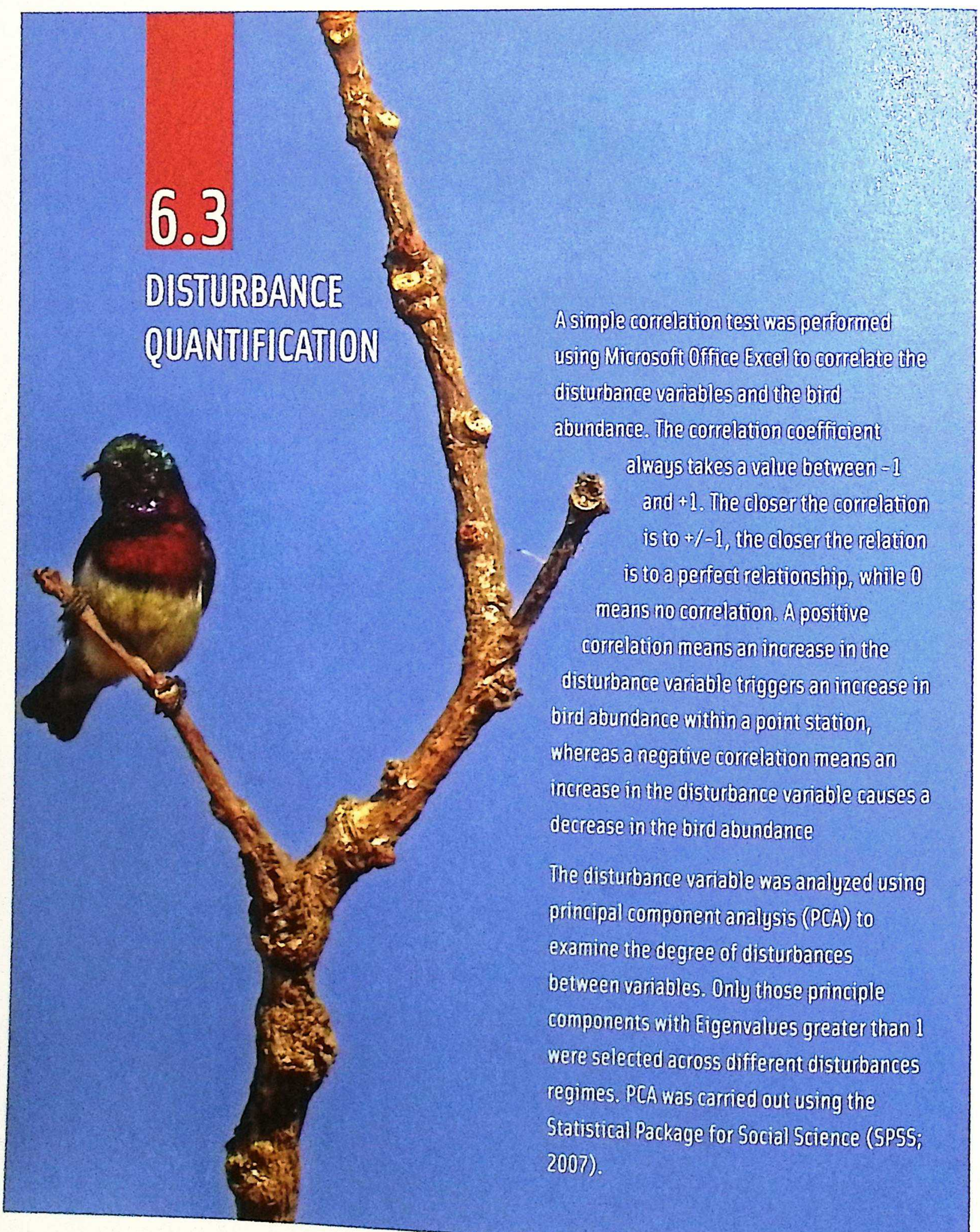
Pi = fraction of the entire population made up of species i

S = numbers of species encountered

$\sum$ = sum from species 1 to species S

The value of the index ranges from 1.5 (low species richness and evenness) to 5.0 (high species evenness and richness). The index of dominance was also measured to find the probability of taking randomly two individuals belonging to different species. The dominance measures the proportionof common species in the habitat, and its value ranges from 0 to 1. Moreover, the Sørensen similarity index (S) was used to measure the species similarities of different habitat types. This index is designed to have a value equal to 1 in case there is complete similarity between two habitats and 0 if the species of the two habitat types are dissimilar (Krebs and Lewis, 1999 in Azeria, 2007; Magurran, 1988).

The measurement of beta diversity has become a fundamental topic in connecting the spatial structure of species assemblages to ecological processes such as species coexistence or environmental control (Anderson et al., 2006; Tuomisto, 2010). Whittaker (1960) proposed that given a set of N plots, the beta diversity could be determined as the ratio of two inventory diversities measured at different scales (i.e., local scale diversity or alpha diversity and regional diversity or gamma diversity); $\beta = \gamma/\alpha$, where α is the average diversity of the N plots and γ is the total diversity of the pooled set of plots.



6.3 DISTURBANCE QUANTIFICATION

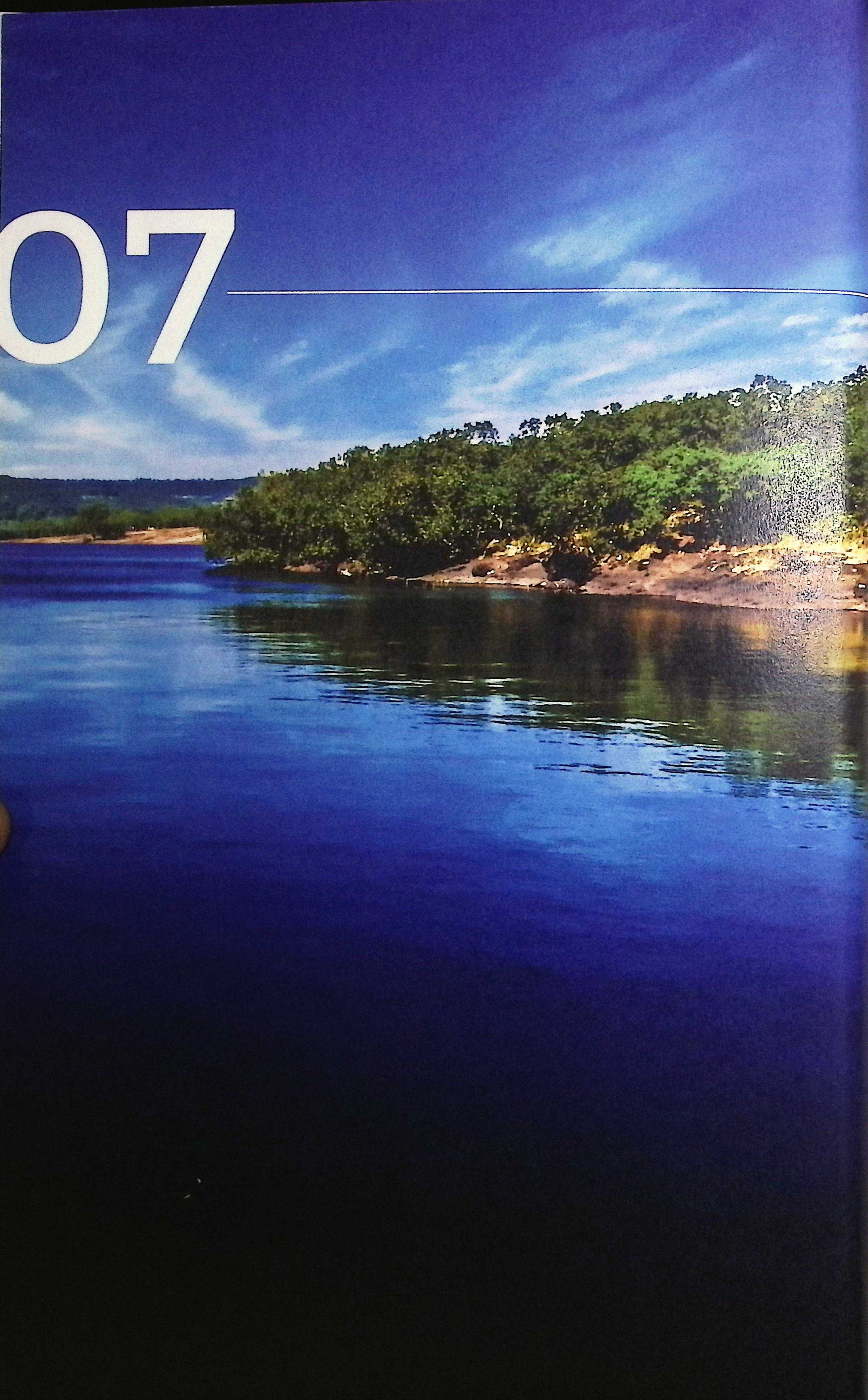
A simple correlation test was performed using Microsoft Office Excel to correlate the disturbance variables and the bird abundance. The correlation coefficient always takes a value between -1 and +1. The closer the correlation is to +/-1, the closer the relation is to a perfect relationship, while 0 means no correlation. A positive correlation means an increase in the disturbance variable triggers an increase in bird abundance within a point station, whereas a negative correlation means an increase in the disturbance variable causes a decrease in the bird abundance

The disturbance variable was analyzed using principal component analysis (PCA) to examine the degree of disturbances between variables. Only those principle components with Eigenvalues greater than 1 were selected across different disturbances regimes. PCA was carried out using the Statistical Package for Social Science (SPSS; 2007).

6.4 CORRELATION OF HABITAT FEATURES WITH BIRD ABUNDANCE

A simple correlation test (Spearman correlation coefficient test) available in SPSS was used to correlate the habitat features and bird abundance. The correlation coefficient always takes a value between -1 and +1. The closer the correlation is to +/-1, the closer the relation is to a perfect relationship, while 0 means no correlation. A positive correlation means an increase in the habitat variable triggers an increase in the bird abundance within the habitat type, whereas a negative correlation means an increase in the habitat variable causes a decrease in the bird abundance.

07

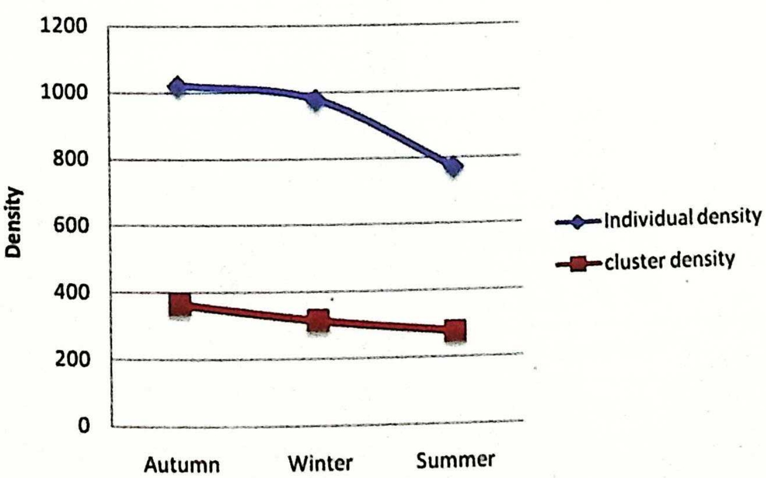


7.1 DENSITY OF AVIFAUNA IN THREE SAMPLING SEASONS

7.1.1 DENSITY OF AVIFAUNA IN THREE SAMPLING SEASONS

	Density/km^2 (±SE)	DS (Cluster Density)
Autumn	1020.3 ± 39.89	364.94 ± 12.75
Winter	976.84 ± 36.54	313.99 ± 10.39
Summer	770.87 ± 36.50	276.49 ± 6.99

Table 2. Bird density in three seasons



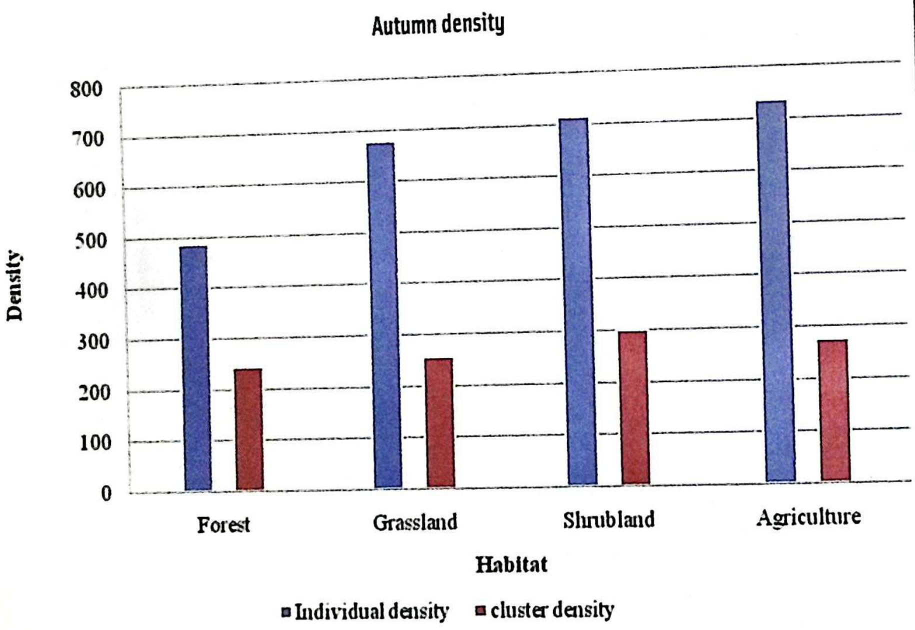
Graph 1. Individual density and cluster density of birds in different seasons

7.1.2

DENSITIES OF AVIFAUNA IN DIFFERENT HABITAT TYPES IN THREE SEASONS (AUTUMN, WINTER, SUMMER)

	Density/km²	DS (Cluster Density)
Forest	485.91 ± 46.01	242.64 ± 21.77
Grassland	676.85 ± 54.55	254.54 ± 18.61
Shrubland	711.03 ± 59.24	298.97 ± 21.08
Agriculture	733.75 ± 63.14	274.48 ± 21.70

Table 3. Densities of avifauna in different habitat types in autumn



Graph 2. Densities of avifauna in different habitat types in autumn

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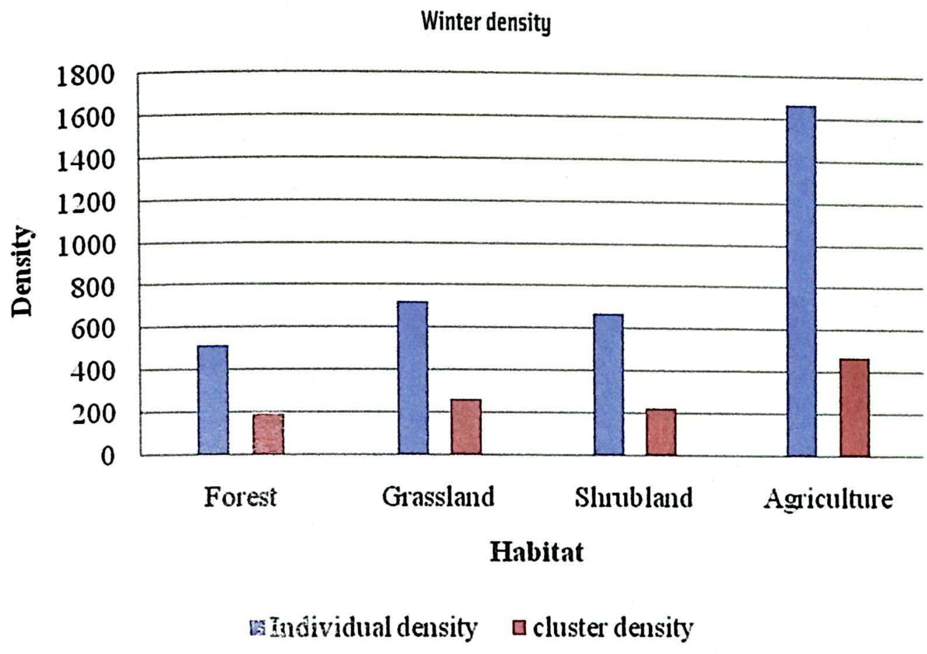
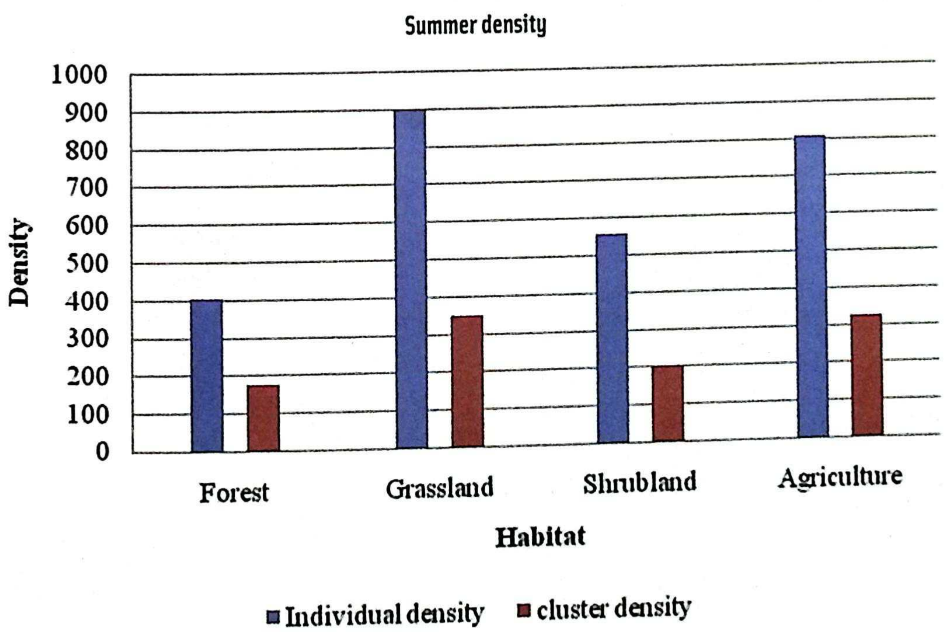
Table 4. Density of avifauna in different habitat types in winter



Graph 3. Densities of avifauna in different habitat types in winter

Table 5. Densities of avifauna in different habitat types in summer

	Density/km²	DS (Cluster Density)
Forest	808.66 ± 88.08	323.21 ± 34.09
Grassland	403.00 ± 39.97	172.84 ± 15.39
Shrubland	900.59 ± 68.58	346.81 ± 23.24
Agriculture	556.21 ± 47.51	199.41 ± 14.11

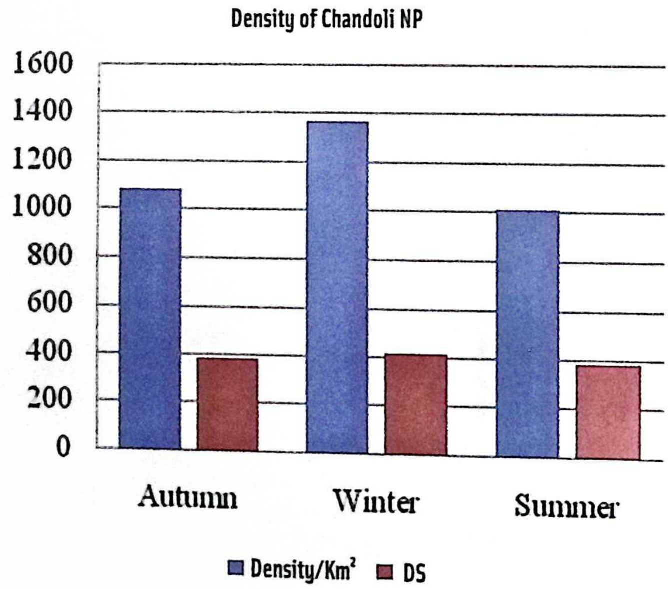


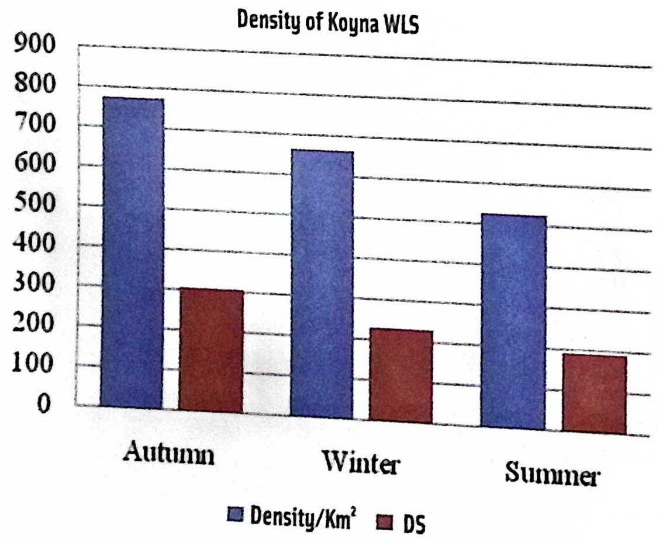
Graph 4. Densities of avifauna in different habitat types in summer

7.1.3 BIRD DENSITIES OF TWO PROTECTED AREAS

Table 6. Total bird densities of two protected areas in three seasons

Range	Season	Density/km²	DS (Cluster Density)
Chandoli National Park	Autumn	1078.1 ± 87.78	381.75
	Winter	1364.6 ± 88.57	410.04
	Summer	1012.2 ± 55.59	383.02
Koyna Wildlife Sanctuary	Autumn	773.60 ± 35.12	306.63
	Winter	661.26 ± 29.85	231.21
	Summer	526.73 ± 24.61	193.86





Graph 5. Densities of avifauna of Chandoli National Park and Koyna Wildlife Sanctuary in three seasons

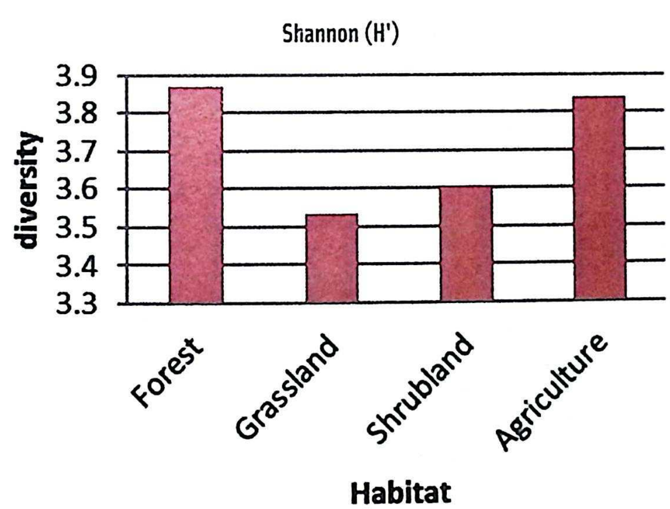
7.2 DENSITY OF AVIFAUNA IN THREE SAMPLING SEASONS

7.2.1 DIVERSITY OF AVIFAUNA OF DIFFERENT HABITATS (FOREST, GRASSLAND, SHRUBLAND AND AGRICULTURE) IN THREE SEASONS (AUTUMN, WINTER, SUMMER)

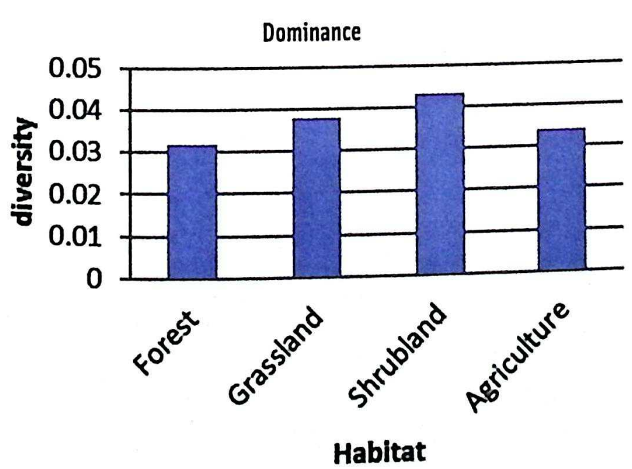
Table 7. Shannon diversity (H'), dominance (D) and evenness of different habitats in autumn

Autumn

	Shannon (H')	Evenness (e^ H/S)	Dominance
Forest	3.867	0.330	0.032
Grassland	3.533	0.467	0.038
Shrubland	3.605	0.477	0.043
Agriculture	3.841	0.438	0.034



Graph 6. Shannon diversity (H'), dominance (D) and evenness (e^ H/S) of different habitats in autumn



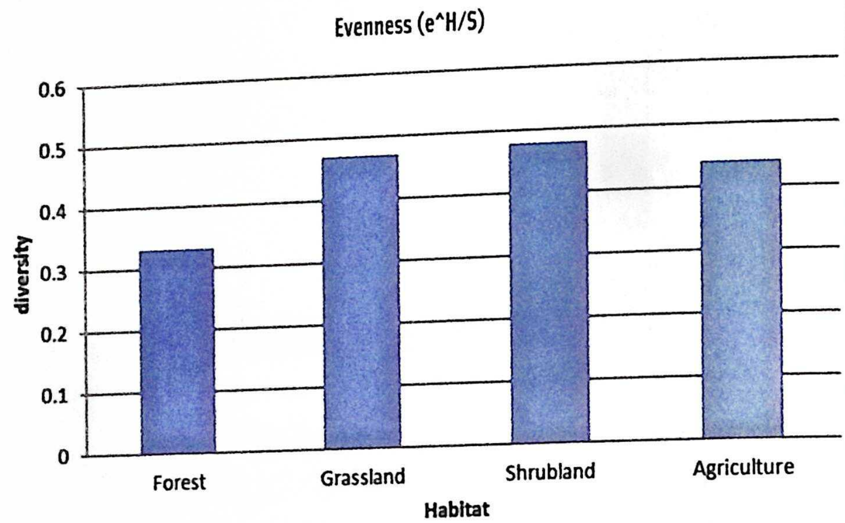
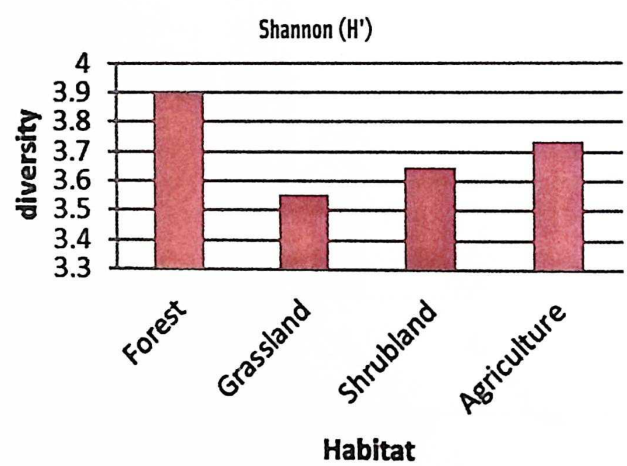
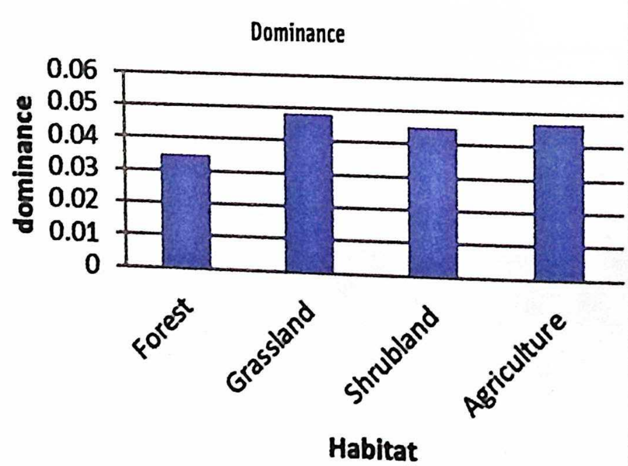


Table 8. Shannon diversity (H'), dominance (D) and evenness within habitats in winter

Winter	Shannon (H')	Evenness (e^ H/S)	Dominance
Forest	3.895	0.459	0.035
Grassland	3.551	0.535	0.048
Shrubland	3.644	0.477	0.045
Agriculture	3.736	0.460	0.047



Graph 7. Shannon diversity (H'), dominance (D) and evenness of different habitats in winter



Evenness (e^H/S)

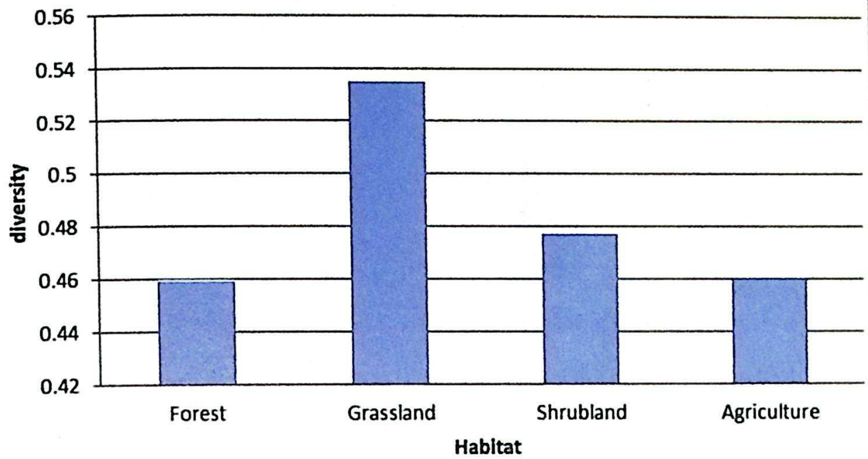
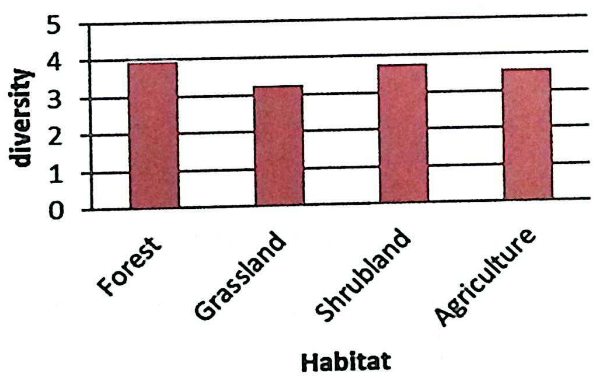


Table 9. Shannon diversity (H'), dominance (D) and evenness of different habitats in summer

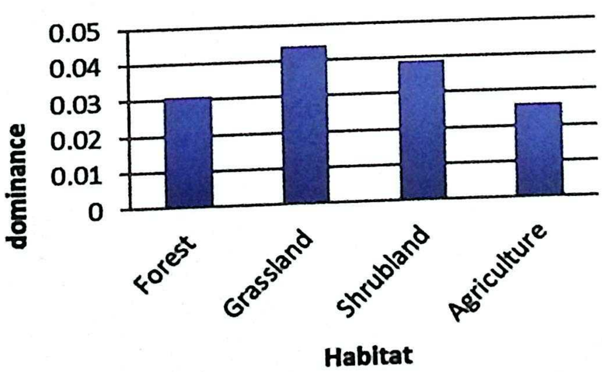
Summer	Shannon (H')	Evenness (e^ H/S)	Dominance
Forest	3.941	0.425	0.031
Grassland	3.258	0.564	0.044
Shrubland	3.765	0.570	0.039
Agriculture	3.558	0.518	0.026

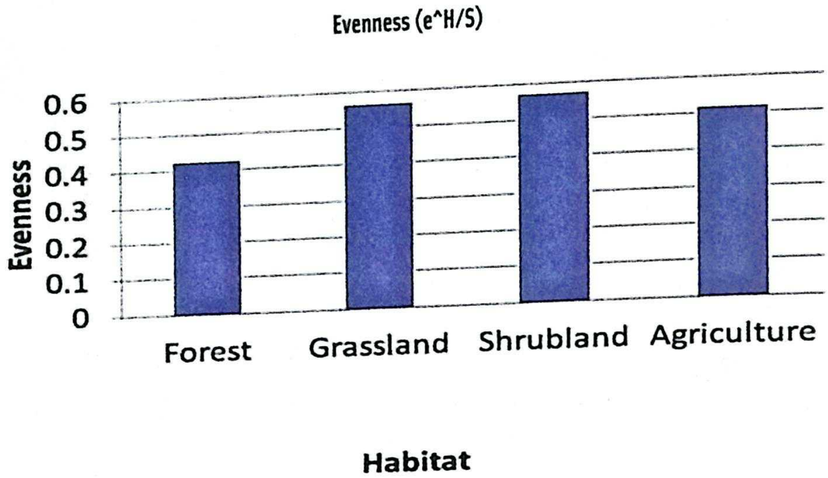
Shannon (H')



Graph 8. Graphs represents Shannon diversity (H'), dominance (D) and evenness of different habitats in summer

Dominance





7.2.2 ENDEMIC BIRD DIVERSITY IN SAHYADRI TIGER RESERVE

Table 10. Shannon diversity (H') of endemic birds of different habitats in three seasons

	Forest	Grassland	Shrubland	Agriculture
Autumn	1.43	0.68	1.10	1.30
Winter	1.05	1.04	0.71	1.03
Summer	1.14	0.93	1.01	0.38

7.2.3 BETA DIVERSITY

Table 11. Beta diversity of avifauna of different habitat types in three seasons

AUTUMN

	Forest	Grassland	Shrubland	Agriculture
Forest	0	0.37	0.36	0.29
Grassland	0.37	0	0.34	0.43
Shrubland	0.36	0.34	0	0.38
Agriculture	0.29	0.43	0.38	0

WINTER				
	Forest	Grassland	Shrubland	Agriculture
Forest	0	0.22	0.26	0.31
Grassland	0.22	0	0.27	0.33
Shrubland	0.26	0.27	0	0.42
Agriculture	0.31	0.33	0.42	0
SUMMER				
	Forest	Grassland	Shrubland	Agriculture
Forest	0	0.29	0.28	0.28
Grassland	0.29	0	0.29	0.21
Shrubland	0.28	0.29	0	0.36
Agriculture	0.28	0.21	0.36	0

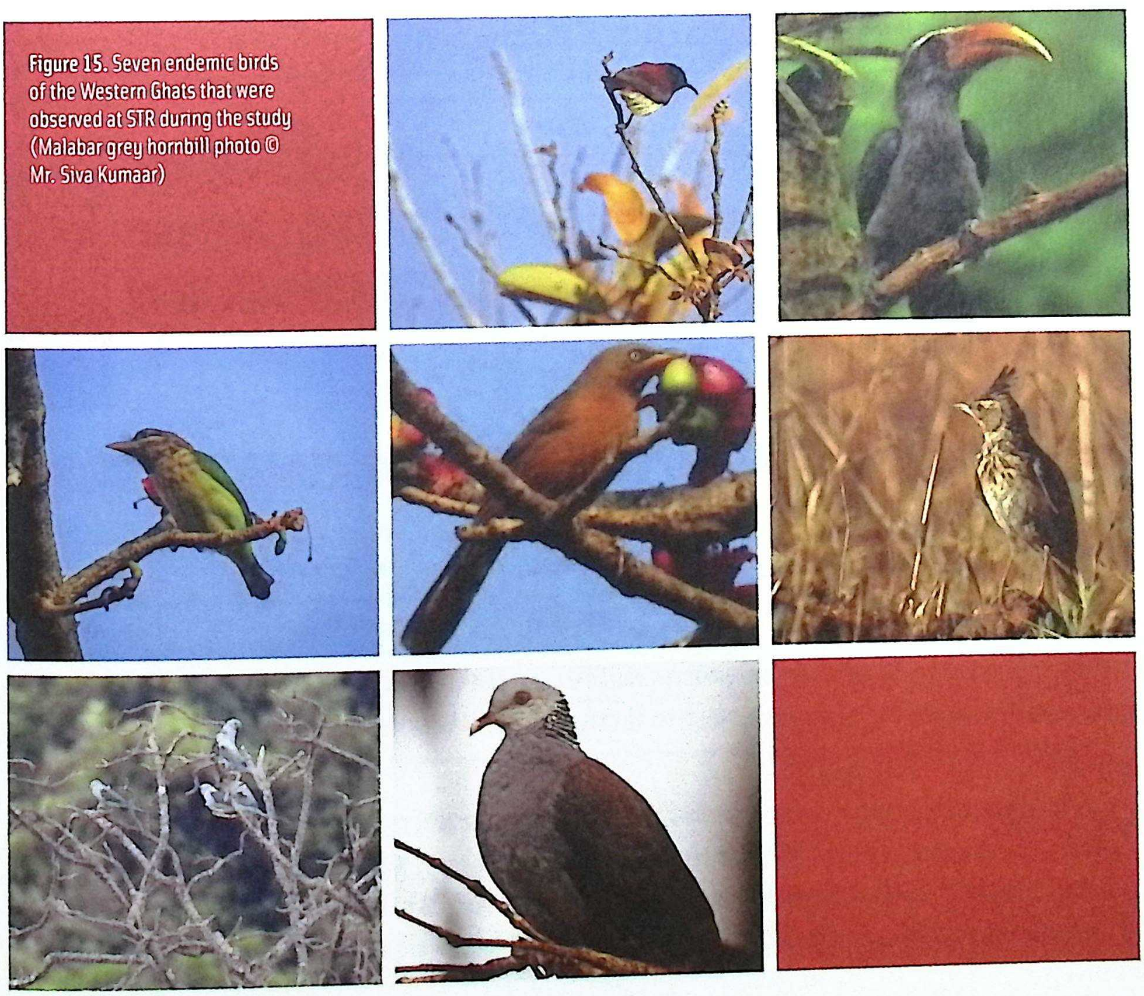


Figure 15. Seven endemic birds of the Western Ghats that were observed at STR during the study (Malabar grey hornbill photo © Mr. Siva Kumaar)

DISTURBANCE QUANTIFICATIONS

7.3

7.3.1 CORRELATION BETWEEN BIRD ABUNDANCE AND DISTURBANCE VARIABLES

In autumn, the number of trails, dung and litter showed a positive correlation with bird abundance, whereas the numbers of cut trees, cut stumps and predators showed a negative correlation with bird abundance. In winter season, the number of trails showed a positive correlation with the bird abundance, whereas the number of cut trees and the number of predators showed a negative correlation with the bird abundance. In summer, the number of dung pats showed a high positive correlation with the bird abundance, whereas the number of cut trees and litter showed a negative correlation with the bird abundance.

Table 12. Correlation coefficient (r) between bird abundance and disturbance variables in the three seasons

Disturbance variable	Autumn	Winter	Summer
Dung	0.10	0.001	0.21**
Predator	-0.16	-0.13*	0.05
Trails	0.21**	0.18*	0.06
Cut trees	-0.20**	-0.17*	-0.24**
Cut stumps	-0.10	0.11	0.07
Litter	0.02	0.004	-0.12*

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

7.3.2 COMPARISON OF DISTURBANCE REGIMES

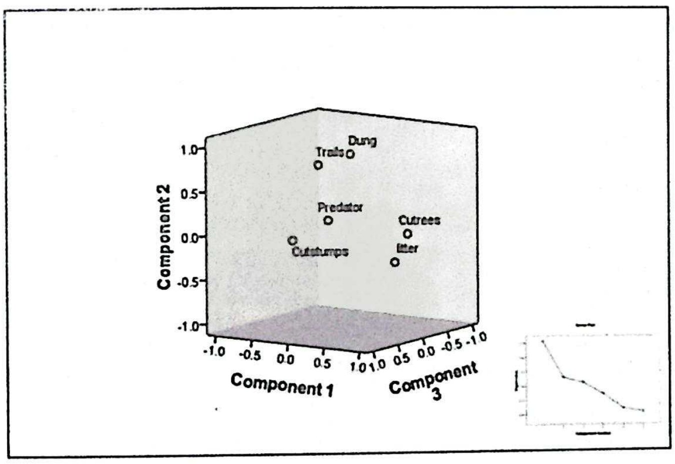
PCA carried out on six standardized disturbances variables resulted in the extraction of three principal components (eigenvalues greater than 1) that collectively explained 67% of the total variation in the disturbance variables.

Dung is a constituent of principal component 1, and it accounted for 30% of the total variance, whereas the second component related to predators and accounted for 19% of the total variance. The third component related to trails, and it accounted for 17% of the total variance. There was segregation of disturbance variables on the principal component axis scores. PC1 was negatively related with the number of predators and number of cut stumps, while it was positively related with cut trees. PC2 was positively related to dung pats and number of trails and was negatively related to litter. PC3 was positively related to the number of cut stumps and number of trails and negatively related to dung pats and cut trees.

Table 13. Principal component matrix

Parameter	Component 1	Component 2	Component 3
Dung	-0.95	0.823	-0.289
Predators	-5.36	0.010	-0.470
Trails	-1.03	0.791	0.341
Cut trees	0.794	0.018	-0.162
Cut stamps	-0.121	0.003	0.831
Litter	0.722	-0.291	-0.007

Component Plot in Rotated Space



Graph 9. All six variables showing the relationships with each other

7.4 CORRELATION OF HABITAT FEATURES WITH BIRD ABUNDANCE

Table 14. Spearman correlation coefficient (r) between bird abundances of different habitat types and habitat features in the non-breeding period

Habitat feature	Agriculture	Grassland	ShrublandForest
Grass cover (%)	0.344**	0.220**	0.077-0.171*
Shrub cover (%)	-0.435**	-0.340**	0.153*0.241**
Tree cover (%)	0.520**	0.056	-0.084-0.071
Grass density (bundles)	-0.094	-0.220**	-0.0770.171*
Shrub density	-0.093	-0.340**	0.0790.185*
Tree density	0.520**	0.056	-0.084-0.061

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

In the non-breeding period, none of the habitat features showed a strong correlation with the bird abundance in all the habitats although a few habitat features showed a significant correlation with the bird abundance. The tree percentage cover and tree density had a positive correlation with the bird abundance in the agriculture habitat type, in contrast to shrub density, which had a negative correlation in the same habitat. The grass cover percentage had a positive correlation with bird abundance in grassland and the agriculture habitat type, while it had a negative correlation with the bird abundance in the forest habitat type.

Habitat feature	Agriculture	Grassland	Shrubland	Forest
Grass cover (%)	0.147*	0.292**	0.536**	-0.296**
Shrub cover (%)	-0.787**	-0.472**	-0.223**	0.365**
Tree cover (%)	0.755**	0.062	-0.218**	-0.118
Grass density (bundles)	-0.149*	-0.292**	-0.536**	0.296**
Shrub density	-0.149*	-0.472**	-0.427**	0.273**
Tree density	0.755**	0.062	-0.218**	-0.118

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

Table 15. Spearman correlation coefficient (r) between bird abundances in different habitat types and habitat features in the breeding period

In the breeding period, the bird abundance was found to be correlated with habitat features. Strongly negative correlation features were observed between the bird abundance and shrub percentage cover in agricultural land during the breeding period. Likewise, a strong positive correlation was observed between the bird abundance and tree percentage cover as well as tree density in agricultural land during the same period. However, the bird abundances in agricultural land and grassland had significant relations with all the habitat features.

This study found that associations tend to increase towards disturbed areas such as agricultural land, grassland and shrubland and to decrease towards less disturbed areas such as forests.

7.5 NEW OBSERVATIONS

7.5.1 UNUSUAL FLOWERING OF BUTEA MONOSPERMA (LAM.) TAUB. (FABACEAE) IN NORTHERN WESTERN GHATS

During our habitat quantification, we observed 10 fully grown individuals of B. monosperma in full bloom from mid-November to late December in Chandoli National Park (17.17995°N, 73.87060°E to 17.18280°N, 73.84756°E). During the same period, we recorded around 50 fully grown B. monosperma trees bloom in Koyna Wildlife Sanctuary (17.74552°N, 73.66013°E to 17.75797°N, 73.66660°E). After continuous monitoring, we confirmed the unusual phenological event, which has not been reported previously in this species.

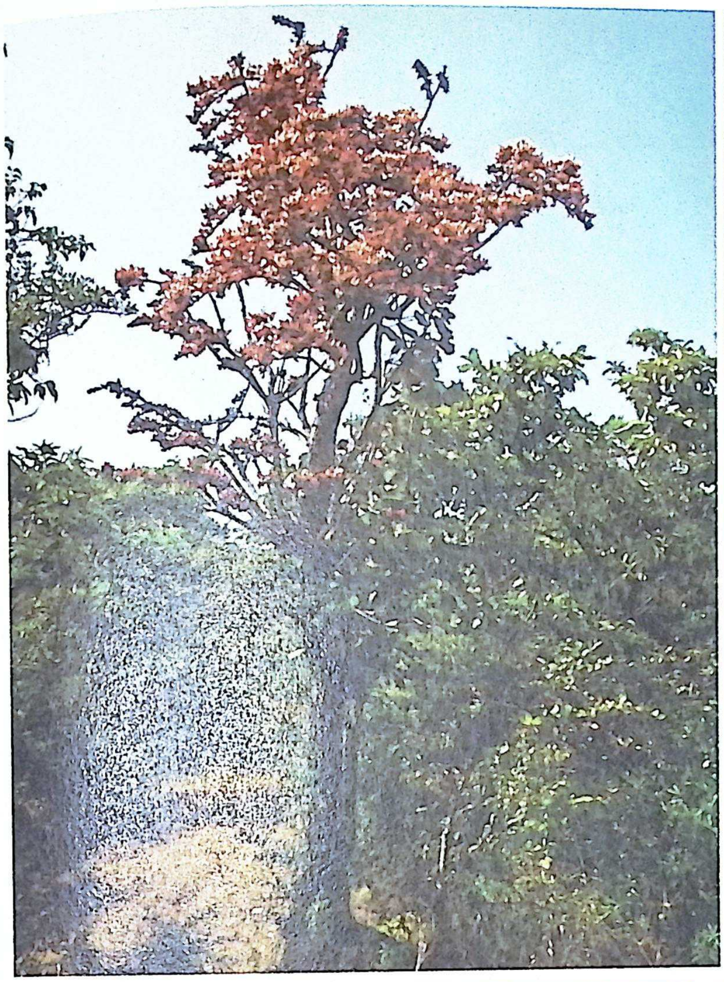


Figure 16. *Butea monosperma*:
(a) habit;
(b) leaves;
(c) flower

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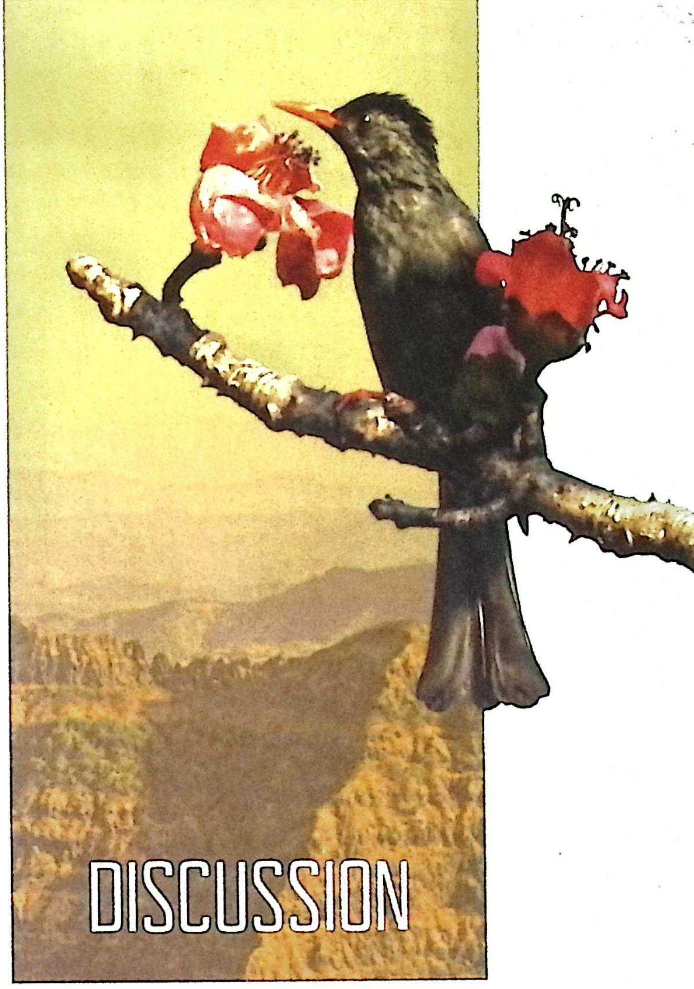

DISCUSSION

It is evident from the results that in autumn and winter there is higher bird diversity and abundance in all areas. The results of this study concurs with the findings of Elsen et al. (2017), who concluded that the primary forest harbors many Himalayan birds during the breeding period, but agricultural intensification, especially increased grazing, has resulted in the loss of primary forest, and so large numbers of birds use agricultural land during winter. The Western Ghats are also a breeding ground of winter migratory birds, but agricultural intensification may also attract birds towards agricultural land. Clergeau et al. (1998), Chace and Walsh (2006) and Sandstrom et al. (2006) also concluded that a human-disturbed area like agricultural land provides heterogeneous habitats, which attract human-tolerant bird species.

Other studies conducted elsewhere in human-disturbed areas (Pennington and Brail, 2011; Shochat et al., 2010) have also found similar results. Their conclusion is that higher abundance in the agricultural lands was triggered by habitat heterogeneity (trees and crops) created by man.

It was observed that during summer, shrubland had a higher density of birds whereas there was a lower density in grassland and agricultural land because grasslands usually remain dried in this season and farmer burn crop residues. So shrubland provides greater openness in the habitat, which supports shrubs that provide food and cover for different bird species (Askins et al., 2012; Shochat et al., 2010).

Unlike the bird density, the diversity of the avifauna is the highest in forest in all three seasons. The bird species diversity was found to increase towards areas with less human activity with more vegetation cover. The lower bird species diversity observed in agricultural land could be caused by continued clearing of natural vegetation for human settlements as was observed during the fieldwork. The finding supports that of many other studies (Clergeau et al., 1998; Chace and Walsh, 2006; Sandstrom et al., 2006) that greater vegetation cover values support a higher diversity of birds. It is likely that the highest diversity was found in the forest because there was sufficient vegetation cover there whereas grassland and agricultural land had been affected by land use changes. The high species diversity indicates a complex community in which there is a high degree of species interactions, possibly in contrast to the greater dominance observed in agricultural land, grassland and shrubland, which implies that a few species dominate the habitats. That is why the density was highest in this area. Though agricultural land showed less diversity, the higher dominance was due to the presence of native and generalist species like the Cattle Egret

(*Bubulcus ibis*) (Chace and Walsh, 2006; Pennington and Blair, 2011).

Our study also signifies that bird diversity is impacted by weather condition (precipitation and temperature) (Waterhouse and Trapani, 2002). According to Parmesan (2005), weather conditions determine bird diversity by the spatial-temporal shift of the species from one habitat to the other, seeking favorable conditions. The highest diversity is in the forest due to the availability of food, water, breeding sites, breeding material and cover from predators (Hobson et al., 2003; Waterhouse and Trapani, 2002). Interestingly, in autumn, the higher dominance in shrubland was contributed by swifts that were feeding on insects influenced by higher rainfall before this season in the Western Ghats (Busch et al., 2011; Soini, 2006). In general, the forest habitat had a higher diversity when the sampling periods were pooled together. This result is in agreement with many studies that conclude that the forest is the main habitat that supports a great bird species diversity (Askins et al., 2012; Azeria et al., 2007; Burgess et al., 2002; Buckley and Bhatia, 1998). Therefore, forest bird species may disappear if degradation continues to modify the habitat.

According to Storch et al. (2003) and Buckley and Freckleton (2010), the distribution patterns of bird species normally follow the spatial structure of the environment and habitat requirements of the bird species. This corresponds with the results of this study, wherein habitat specificity and generalization were observed. For example, the Brown-headed Barbet (*Psilopogon zeylanicus*) and Red-vented Bulbul (*Pycnonotus cafer*) were recorded in all habitat types. In contrast, the Pied Bushchat (*Saxicola caprata*), Indian Peafowl (*Pavo cristatus*) and Yellow-eyed Babbler (*Chrysomma sinense*) were recorded only in agricultural land. However, human-disturbed areas had mixtures of built habitats and green patches where bird species have managed to exist and thrive in a complex habitat (Sandstrom et al., 2006).

Seasonal changes in the avifauna of temperate forests are more extreme than changes in the avifauna of tropical forests (Karr, 1976). In our study, various disturbances were positively and negatively related to one another. This is in agreement with the findings of other studies on small-scale extractive disturbances. Such correlation among variables justified the use of PCA for summarizing the disturbance variables (Martorell and Peters, 2005; Karanth et al., 2006). Human proximity and degree of protection influenced the disturbance intensities to some extent. Although the village densities explained lopping and grazing disturbance, they barely explained firewood and timber extraction. Moist forest faced a much higher intensity of firewood and timber extraction compared with other forest types. Disturbances in the forest were mostly caused by people who live in the STR villages. Moreover, a moderate level of disturbance also led to density enhancement among all forests of the Sahyadri across the seasons. The abundance of resources is in terms of food (Mills et al., 1991), nesting sites (Grewal et al., 1987; Newton, 1994) and perch sites (Dickson et al., 1983; Preston, 1990), which have been shown to be some of the most important predictors of bird density. In this study, moderate levels of firewood collection and timber extraction resulted in increased overall bird densities. Various studies have shown that low levels of extraction of vegetation often result in canopy opening in an otherwise closed forest (Chettri et al., 2002; Shahabuddin and Kumar., 2006). Also, moderately disturbed areas are characterized by higher levels of primary productivity, and consequently vegetative structural complexity increased insect-visibility and fleshy fruit-production (Blake and Hoppes, 1986; Levey, 1988). Such areas may attract breeding birds by providing a better foraging and nesting habitat (Blake and Hoppes, 1986; Noss, 1991) and may be especially important for fledglings from adjacent mature-forest habitats (Anders et al., 1998).

Bird abundance was found to be influenced by the habitat features of the studied area as was reported by Pearman (2002). In our study, we looked at two different seasons (breeding and non-breeding seasons) of birds. During the non-breeding period, bird abundance had a strong positive correlation with tree cover and tree density in the agricultural land. Shochat et al. (2010) argued that trees contribute to the complexity of the habitat, which enables a bird's survival. The negative association shown by bird abundance with tree cover and tree density in the shrubland was due to the seasonal occurrence of insects that birds feed on, causing them to concentrate in a small area with sufficient shrub density as was observed by Askin et al. (2012). Their study concluded that the openness of the habitat favors less availability of food, cover, nesting material and sites compared with other habitats. Grass percentage cover showed a positive correlation with bird abundance in agricultural land, shrubland and grassland, indicating that large areas of grassland support relatively large numbers of some grassland bird species in the habitats. The finding concurs with those of Murray et al. (2008), who found that the number of grassland birds tends to increase with extent of grass cover. The negative association observed between bird abundance and tree percentage cover as well as tree density in the forest was expected because bird abundance tends to decrease with tree canopy closure in a well-developed forest (McWethy et al. 2009). However, the strong negative association between bird abundance and shrub percentage cover in the agricultural land was due to the decrease in shrub cover, which may provide refuge for human-tolerant bird species. On the other hand, the positive association shown by bird abundance toward shrub percentage cover and shrub density in the forest and shrubland supports the argument of Chapman and Reich (2007) that bird abundance increases with shrub cover and density in forest and shrubland. Bird abundance is associated with increased ground cover and an understory layer in which both birds and their nests are concealed. It underscores the fact that any human activity that causes changes in habitat structure tends to impact micro-ecological patterns, thus affecting the species abundance, diversity and distribution (Gaston, 2004). During the breeding period, none of the habitat types showed a strong association between bird abundance and habitat features, probably because there were dramatic increases in the bird abundance during the breeding season. The negative correlation observed between bird abundance and percentage cover of shrubs and the density of shrubs in the agricultural land, grassland and shrubland might have had been caused by the presence of a large number of insectivorous birds such as swifts. Swifts are usually specialized and become more sensitive to prey abundance (Sekercioglu et al., 2002).

Every plant has a definite period of flowering and fruiting albeit strongly controlled by climatic factors and evolutionary processes (Silva et al., 2011). These phenological events ultimately determine the reproductive success of plants (Carvalho and Sartori, 2015). Although some plants such as the *Corypha palm*, bamboos, *Strobilanthes callosa* and *Strobilanthes kunthiana* have exceptional phenological events with respect to their life span (Kulkarni and Mulani, 2004), it becomes interesting when these phenological events get changed. Butea monosperma (Lam.) Taub. (Fabaceae), a legume tree of tropical and sub-tropical climates, is found throughout the drier parts of India, in open grasslands and in wastelands. Commonly known as the Flame of the Forest, Dhak and Palas, it is native to the country. This medium-sized tree is a characteristic species of the plains, often forming pure patches in grazing grounds and other open places. This deciduous tree is drought resistant and frost hardy, although the leaves turn white and fall off. Generally, *B. monosperma* flowers regularly once in a year, but all trees do not flower every year. Peak flowering occurs during March–April and sometimes begins in late February and lasts up to early May (Tandon et al., 2003). A study by Tandon et al. (2003) revealed that in consecutive years, peak flowering was during the first week of April and that trees remained in bloom for 8 weeks. Fruiting commenced from the last week of March and the first week of April, and the fruits reached maturity by the end of May and were dispersed in mid-June. Seeds were not liberated from the fruits. Leaf primordia appeared in April–May, and leaves attained their maximum size by May–June. Notably, during one of the field surveys in STR, we observed 10 fully grown individuals of B. monosperma in full bloom from mid-November to late December in Chandoli National Park and Koyna Wildlife Sanctuary. Through continuous monitoring of these individuals in the northern Western Ghats, the authors confirmed the unusual phenological event, which has not been reported previously in this species. The change in the phenological event could be attributed to climatic climate or irregular droughts or genetic factors, albeit further research is needed.

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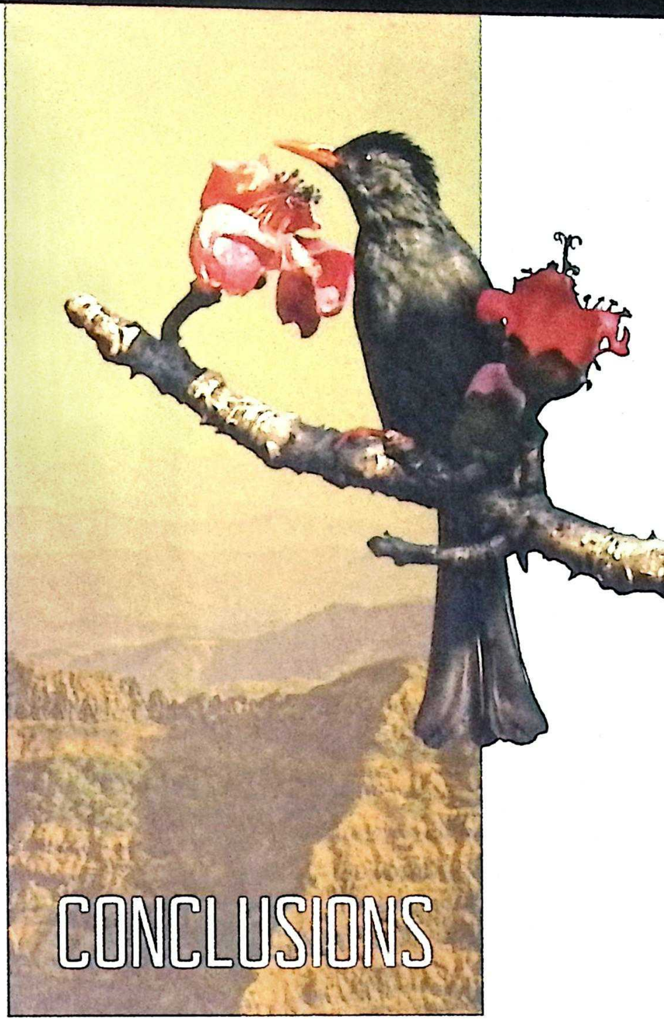

CONCLUSIONS

Our study concludes that highly disturbed areas are indicated by generalist bird species, whereas the specialist birds indicate less disturbed habitats. The generalist birds prefer unstable heterogeneous habitats and often specialize in utilizing diverse resources and perform well in an unstable environment. The generalist bird species utilize limited resources well and are therefore favored by a stable or homogeneous environment.

The study also concludes that human activity that changes the habitat structure is impacting the bird abundance, diversity and distribution.

The bird density was higher in areas with more human activities such as agricultural land. As due to increasing in agriculture intensification many agriculture habitat specific bird species attract toward agriculture land. So the findings of this study provide evidence that agricultural areas can serve as refuges for birds. Therefore, conservation efforts should be directed towards making communities view human-occupied areas as habitats for birds and not as lost habitats.

The bird species diversity was higher in areas with less human activities, i.e. forests and shrubland with more vegetation cover compared with agricultural land. The higher diversity suggests higher ecological stability compared with human-disturbed habitats, where few habitat specific species occur. The forest is the main habitat that harbors a large forest-specific bird diversity. So, the forest bird species may disappear if degradation continues to modify the habitat.

Differences between habitats in the availability of resources such as breeding sites, nesting material, cover, food and water restrict some species to certain habitat types while allowing others to be widely distributed. Our study confirms the utility of birds as indicators of disturbances in habitats. Disturbances could influence the bird community directly or indirectly by modifying the vegetation and habitat characteristics such as canopy cover and availability of resources. Therefore our study investigates the role of disturbance and vegetation attributes in determining bird abundance. Disturbances such as lopping and extraction of timber are negatively related to those breeding birds that are dependent on tree cavities during the breeding season. Such breeding birds are usually restricted to large-sized trees and emerged as excellent indicators of the disturbance.

The study was brief work with some basic goals only to assess the bird diversity with its habitat utilization pattern along with anthropogenic pressure. An intense study is needed to assess other important factors associated with bird diversity. The findings stress the need for more such studies from different forest types and biogeographic regions to draw general conclusions about forest effects. Further, with increasing human density and consequently increasing pressure on the forest for biomass, it becomes important to estimate the permissible limits of biomass extraction to identify and promote new livelihood options for the forest-dependent communities.

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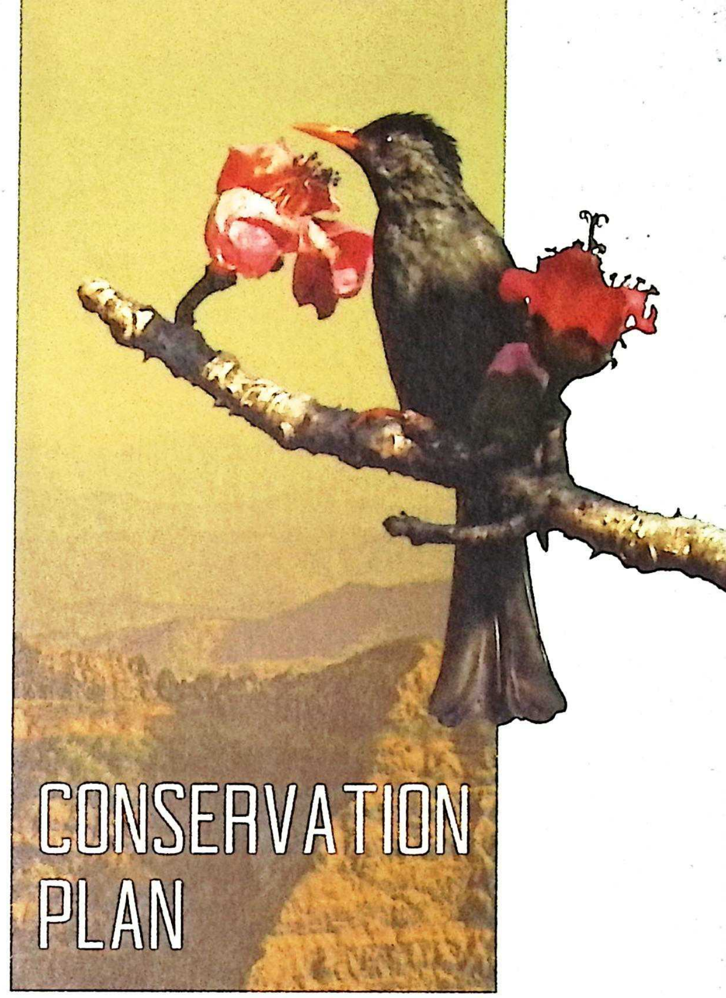


CONSERVATION PLAN

Bird conservation is one of the important tasks for any conservationist as birds are very sensitive indicators of disturbance. Using the outputs from the study we can manage the landscape for conservation. The biggest threat is habitat loss. Other threats include overhunting, accidental mortality due to collisions with structures, pollution, competition and predation by pets. STR, with its biological diversity and inherent values, represents a bio-reserve with dynamic interrelations. In the broader interests of society, preservation of this natural heritage—along with its characteristic representation values—is the ultimate goal of the management. The various biological, ecological and evolutionary processes, interacting over a period, require a long span of time to produce a resultant goal. And hence it is important that continuity is maintained in management practices and measures to achieve the management goals. On the basis of our objectives and conclusion, we generate a conservation plan for the avifauna with a few recommendations.

Figure 17.
STR core zone

PLAN OBJECTIVES

Generating a management action plan along with a few recommendations in respect of the avifauna is one of the important objectives of our study. The overall mission of the plan is to protect and conserve STR. Hence the objectives of this management plan are the following:

1) To manage and improve the bird habitat in the forest by improving the vegetation cover and the water availability
2) To encourage community participation in the management of the tiger reserve through eco-development and conservation awareness program activities to reduce the existing competition for the resources between the forest dweller user group and the fauna in the tiger reserve
3) To provide ecological research and niche-based development ground studies to generate supportive managerial information
4) To reintroduce and rehabilitate rare and endangered bird species.

To manage and improve the habitat of the avifauna of the forest by improving the vegetation cover and availability of water

Problems

- Problems related to habitat shrinkage such as shortages of fodder and water, soil erosion and heavy encroachment
- Competition between wildlife and human beings for space
- Setting forest fires for religious beliefs, through carelessness and for clearing the land for cultivation.

Strategy

- Habitat management through improvement and extension of water regimes
- Protection of niches and home ranges of birds and wild animals
- Intensive fire management
- Trees need to be planted around agricultural fields.

Proposed action

- Plantation of fruit and fodder species in the form of groves
- Grassland development in open areas
- Construction of artificial water bodies such as check dams, forest ponds, water holes and guzzlers
- Pre-consented re-location of people
- Awareness programs
- Involvement of people in fire management
- Fire prevention measures
- Setting up fire control team
- Infrastructure development with quick communication and transport systems.

Figure 18. Habitat for birds

Figure 19. Agriculture habitat of birds

Using habitat suitability mapping, habitats that are potentially suitable for the avifauna have been identified within STR. The potentially suitable habitats need better protection and conservation efforts to sustain viable bird populations. Some parameters were used to identify unique habitats, namely habitat type, bird density and diversity, availability of water and distance from anthropogenic disturbances.

Habitats may be clearly defined or may have transitional zones where different types of habitats merge, such as woodland edges, which are transitions between forests and grasslands. The type of habitat with the most diverse avifauna is tropical forest, but multiple bird species and good birding can be found in every habitat.

The types of habitat that birds requires for survival and growth depend on the species. While an individual bird may have a relatively small range, many species require large habitats for a healthy population so that competition for food sources and nesting grounds is minimized. At the same time, many species may occupy the same range because their food, shelter and nesting needs do not overlap, and they do not compete individually. Instead, they share resources and use specific environmental niches that make the habitat more diverse.

In our study, we divided the point counts among the four major habitats of STR (forest, grassland, shrubland and agriculture land) and described the role of each habitat with respect to the avifauna. We found that many species were restricted to specific habitats, whereas a few species were common to all the habitat types. So it is important to prevent the loss of bird habitats in STR.

It is also important that the focus for conservation of birds should be on agricultural land. So trees need to be planted in and around agriculture land so that farmers can utilize them for their domestic requirements. Hence, the dependence on forests will decrease.

To encourage community participation in tiger reserve management through eco-development and conservation awareness programme activities to reduce the existing competition for resources between the forest dweller user group and the fauna in the tiger reserve

Problems

- The ever-increasing human and livestock populations and a lack of development activities inside the tiger reserve in comparison with the outside world leads to an antagonistic attitude among local inhabitants toward the tiger reserve.
- Poverty and dependence on forest resources
- Lack of skills to adopt alternative livelihoods
- Illiteracy and lack of awareness and trust
- Poverty overrides the concept of nature education.

Strategy

- Intensive livelihood development activities in the villages and awareness programmes
- Nature education, intensive agriculture, medical camps and cattle camps to help the rural poor
- To impart knowledge and develop awareness regarding nature, endangered species and biodiversity.

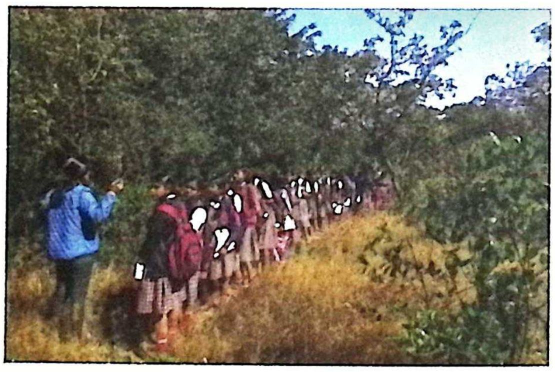
Proposed actions

- Carrying out a baseline survey using rural appraisal techniques
- Planning need-based development activities in each village
- Providing alternatives for fuelwood and promoting stall feeding of cattle
- Providing nature education to the young minds of the tiger reserve
- Providing high-yielding varieties of seed and essential field knowledge through farmer's camps
- Medical and child health camps and animal husbandry camps in remote areas of the tiger reserve.

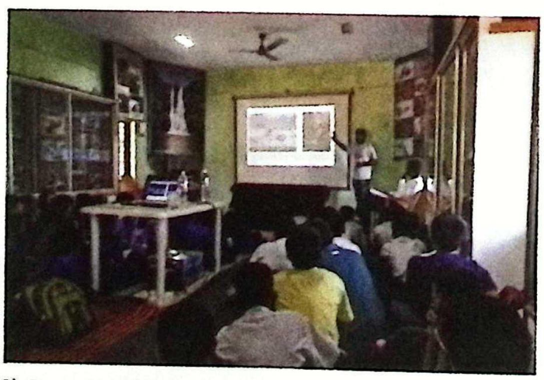
During our study, we found an antagonistic attitude among the village people toward the conservation of the tiger reserve. This may be due to illiteracy and a lack of awareness and trust. During our study, we tried to create awareness among the local people of the tiger reserve and encouraged them to participate in conservation awareness activities. We also involved local people and school students in birdwatching

Figure 20. Glimpses of bird conservation awareness programmes conducted at STR during our study period

1) Celebration of GBBC event STR Team



2) Avifauna awareness program for School



3) Conservation lectures given to stusents

4) Celebration of World Wildlife Day in STR

sessions, which we conducted from time to time during our study sessions. The main objectives of conducting such events in the tiger reserve were to impart knowledge about the rare, endemic and endangered species of bird and to develop awareness regarding the environmental, aesthetic, recreational and sustenance values of the tiger reserve.

To provide ecological research on avifauna and niche-based development ground studies to generate supportive managerial information

Problems

- Inadequate knowledge and poor skills among the staff of STR related to wildlife management
- Lack of social and scientific information about the tiger reserve.

Strategy

- Development of scientific reports and database
- A proper record should be maintained of the bird populations in the protected areas and used for subsequent monitoring of their populations.
- Ecological studies of bird populations, distribution and status: Species-specific studies of hornbills, thrushes and endemics birds of STR and their specific habitats

Proposed actions

- Identification of relevant aspects of intensive research
- Collaboration with research organizations
- Conducting regular monitoring activities in collaboration with resource persons and scientists
- Providing logistic support to researchers

To reintroduce and rehabilitate rare and endangered bird species

Problems

- Lack of sufficient research backup
- Lack of knowledge about rare and endangered bird species such as vultures

Strategy

- To conserve the gene pool of rare, endangered and threatenedbird species
- Captive breeding programme of vultures in tiger reserve
- Artificial nesting
- Plantation of some important trees on which birds depend.

- Conducting survey of rare and endangered bird species in the tiger reserve and providing protection to the existing species
- Encouraging more research activities in association with scientific organizations
- Training programmes for forest staff
- Plantation in the form of groves with adequate protection.

PROPOSED ACTION

As STR is a plateau with good forests and grassland it has the preferred habitat of vultures. Prakash Gole (1998) reported vultures species from the Sahyadri region, but in the present study no species of vultures was found in STR. So it is important to conduct a survey and research study on vultures in the tiger reserve. If any species of vulture is found to occur in the Sahyadri region, then restoration of this population in the tiger reserve be carried out according to the guidelines of the captive breeding programme of vultures. The same types of efforts are being made in Haryana by the forest department and Bombay Natural History Society.

RECOMMENDATIONS

1) Develop migratory corridors by planting suitable tree species/shrubs in the buffer and core zones of the tiger reserve.

2) Manage and improve the bird habitat in the forest by improving the vegetation cover and availability of water.

3) A proper record should be maintained with respect to the bird populations in the protected areas and used for subsequent monitoring of their populations.

4) Controlled fire lines. Controlled burning (forest fires) has a positive approach to the forest and grassland bird abundance and distribution and hence needs to be practiced.

5) To improve the bird diversity in human-occupied environments, gardening and tree planting should be encouraged. These will enhance the bird species diversity such that human settlements and farmlands will no longer be viewed as habitats lost for wildlife but rather habitats that, with proper management, have the potential to support diverse bird communities.

6) Artificial nesting. While artificial nesting structures cannot replace natural nesting habitats, they can increase the number of nesting sites available in an area. Artificial bird nests are created to increase wild bird populations, to study bird reproduction and behaviour and to exterminate pests (Lee et al., 2002). Many types of bird use artificial nesting structures, including songbirds, woodpeckers, waterfowl and raptors. While these structures are generally designed to meet the nesting requirements of certain species, and provide roosting and winter cover for a variety of birds.

7) The local communities lack awareness about birds being an important part of the ecosystem as environmental health indicators, pollinators and pest controllers. So the Department of Natural Resources, Land and Environment in the municipality has to provide conservation education to the communities so that the contribution of birds in the ecosystem is appreciated. This should be the mandate of the wildlife policy of Maharashtra.

8) The presence of environmental committees in the villages offers an opportunity to improve the conservation of birds and their habitats. The committee should limit the forest conversion and fragmentation by adopting bylaws that prevent land degradation.

9) Prohibition of hunting & poaching. Hunting and poaching should be strictly banned as these were the major threats in Bamnoli Range, Koyna Wildlife Sanctuary.

10) Cooperation among different stakeholders, i.e. ecologists, land surveyors, municipal council members, social scientists, environmentalists, communities and birdwatcher groups, is required to ensure that birds are conserved. A conservation group of Sahyadri should initiate the cooperation.

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Appendix 1. Checklist of bird species reported from STR

Family	Common name	Scientific name
Cisticolidae	Grey-breasted Prinia	*Prinia hodgsonii*
	Jungle Prinia	*Prinia sylvatica*
	Ashy Prinia	*Prinia socialis*
	Plain Prinia	*Prinia inornata*
	Common Tailorbird	*Orthotomus sutorius*
	Zitting Cisticola	*Cisticola juncidis*
Muscicapidae	Indian Robin	*Saxicoloides fulicatus*
	Oriental Magpie-robin	*Copsychus saularis*
	Blue-throated Blue Flycatcher	*Cyornis rubeculoides*
	Tickell's Blue Flycatcher	*Cyornis tickelliae*
	Verditer Flycatcher	*Eumyias thalassinus*
	Indian Blue Robin	*Larvivora brunnea*
	Malabar Whistling-thrush	*Myophonus horsfieldii*
	Red-breasted Flycatcher	*Ficedula parva*
	Taiga Flycatcher	*Ficedula albicilla*
	Pied Bushchat	*Saxicola caprata*
	Common Stonechat	*Saxicola torquatus*
	Blue Rock Thrush	*Monticola solitarius*
	Black Redstart	*Phoenicurus ochruros*
Turdidae	Orange-headed Thrush	*Geokichla citrina*
	Indian Blackbird	*Turdus simillimus*
Leiothrichidae	Large Grey Babbler	*Turdoides malcolmi*
	Rufous Babbler	*Turdoides subrufa*
	Jungle Babbler	*Turdoides striata*
Timaliidae	Indian Scimitar-babbler	*Pomatorhinus horsfieldii*
	Tawny-bellied Babbler	*Dumetia hyperythra*
Pellorneidae	Puff-throated Babbler	*Pellorneum ruficeps*
Sylviidae	Yellow-eyed Babbler	*Chrysomma sinense*
	Lesser Whitethroat	*Curruca curruca*
Dicruridae	Bronzed Drongo	*Dicrurus aeneus*
	Black Drongo	*Dicrurus macrocercus*
	Ashy Drongo	*Dicrurus leucophaeus*
	White-bellied Drongo	*Dicrurus caerulescens*
	Greater Racket-tailed Drongo	*Dicrurus paradiseus*
Pycnonotidae	Square-tailed Bulbul	*Hypsipetes ganeesa*
	Red-whiskered Bulbul	*Pycnonotus jocosus*
	Red-vented Bulbul	*Pycnonotus cafer*
	Yellow-browed Bulbul	*Acritillas indica*
Corvidae	Rufous Treepie	*Dendrocitta vagabunda*
	House Crow	*Corvus splendens*
	Jungle Crow	*Corvus culminatus*
Phylloscopidae	Tytler's Leaf Warbler	*Phylloscopus tytleri*
	Common Chiffchaff	*Phylloscopus collybita*

Family	Common name	Scientific name
	Greenish Warbler	*Phylloscopus trochiloides*
	Western Crowned Warbler	*Seicercus occipitalis*
	Whistler's Warbler	*Seicercus whistleri*
Acrocephalidae	Hume's Leaf-warbler	*Abrornis humei*
	Blyth's Reed-warbler	*Acrocephalus dumetorum*
	Clamorous Reed-warbler	*Acrocephalus stentoreus*
Monarchidae	Indian Paradise-flycatcher	*Terpsiphone paradisi*
	Black-naped Monarch	*Hypothymis azurea*
Sturnidae	Brahminy Starling	*Sturnia pagodarum*
	Common Myna	*Acridotheres tristis*
	Jungle Myna	*Acridotheres fuscus*
Campephagidae	Black-winged Cuckoo-shrike	*Lalage melaschistos*
	White-bellied Minivet	*Pericrocotus erythropygius*
	Small Minivet	*Pericrocotus cinnamomeus*
	Orange Minivet	*Pericrocotus flammeus*
	Scarlet Minivet	*Pericrocotus speciosus*
	Black-headed Cuckoo-shrike	*Lalage melanoptera*
	Large Cuckoo-shrike	*Coracina macei*
Laniidae	Brown Shrike	*Lanius cristatus*
	Bay-backed Shrike	*Lanius vittatus*
	Long-tailed Shrike	*Lanius schach*
	Southern Grey Shrike	*Lanius meridionalis*
	Isabelline Shrike	*Lanius isabellinus*
	Great Grey Shrike	*Lanius excubitor*
Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*
	Black-headed Woodshrike	*Coracina melanoptera*
Ploceidae	Baya Weaver	*Ploceus philippinus*
Oriolidae	Black-hooded Oriole	*Oriolus xanthornus*
	Indian Golden Oriole	*Oriolus kundoo*
Aegithinidae	Common Iora	*Aegithina tiphia*
Zosteropidae	Oriental White-eye	*Zosterops palpebrosus*
Motacillidae	Tree Pipit	*Anthus trivialis*
	Paddyfield Pipit	*Anthus rufulus*
	Blyth's Pipit	*Anthus godlewskii*
	White-browed Wagtail	*Motacilla maderaspatensis*
	White Wagtail	*Motacilla alba*
	Yellow Wagtail	*Motacilla flava*
	Grey Wagtail	*Motacilla cinerea*
	Forest Wagtail	*Dendronanthus indicus*
	Citrine Wagtail	*Motacilla citreola*
Nectariniidae	Purple-rumped Sunbird	*Leptocoma zeylonica*
	Crimson-backed Sunbird	*Leptocoma minima*
	Purple Sunbird	*Cinnyris asiaticus*

Family	Common name	Scientific name
	Loten's Sunbird	*Cinnyris lotenius*
	Vigors's Sunbird	*Aethopyga vigorsii*
Paridae	Indian Yellow Tit	*Parus aplonotus*
	Great Tit	*Parus major*
Estrildidae	Indian Silverbill	*Euodice malabarica*
	Tricoloured Munia	*Lonchura malacca*
	Scaly-breasted Munia	*Lonchura punctulata*
Alaudidae	Rufous-tailed Lark	*Ammomanes phoenicura*
	Malabar Lark	*Galerida malabarica*
	Indian Bush Lark	*Mirafra erythroptera*
	Crested Lark	*Galerida cristata*
	Oriental Skylark	*Alauda gulgula*
	Eurasian Skylark	*Alauda arvensis*
Passeridae	House Sparrow	*Passer domesticus*
	Chestnut-shouldered Petronia	*Gymnoris xanthocollis*
Rhipiduridae	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*
	White-browed Fantail	*Rhipidura aureola*
	White-spotted Fantail	*Rhipidura albicollis*
Irenidae	Golden-fronted Leafbird	*Chloropsis aurifrons*
	Jerdon's Leafbird	*Chloropsis jerdoni*
Dicaeidae	Thick-billed Flowerpecker	*Dicaeum agile*
	Nilgiri Flowerpecker	*Dicaeum concolor*
	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*
Hirundinidae	Red-rumped Swallow	*Cecropis daurica*
	Wire-tailed Swallow	*Hirundo smithii*
	Barn Swallow	*Hirundo rustica*
	Eurasian Crag Martin	*Ptyonoprogne rupestris*
	Dusky Crag Martin	*Ptyonoprogne concolor*
Pellorneidae	Brown-cheeked Fulvetta	*Alcippe poioicephala*
Emberizidae	Red-headed Bunting	*Granativora bruniceps*
Pittidae	Indian Pitta	*Pitta brachyuran*
Fringillidae	Common Rosefinch	*Erythrina erythrina*
Ardeidae	Black-crowned Night-heron	*Nycticorax nycticorax*
	Striated Heron	*Butorides striata*
	Indian Pond-heron	*Ardeola grayii*
	Cattle Egret	*Bubulcus ibis*
	Intermediate Egret	*Ardea intermedia*
	Little Egret	*Egretta garzetta*
Phalacrocoracidae	Little Cormorant	*Microcarbo niger*
Ciconiidae	Woolly-necked Stork	*Ciconia episcopus*
Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*
Picidae	Lesser Goldenback	*Dinopium lucidus*
	Lesser Yellow-nape	*Picus chlorolophus*

Family	Common name	Scientific name
	Eurasian Wryneck	*Jynx torquilla*
	Heart-spotted Woodpecker	*Hemicircus canente*
	Brown-capped Pygmy Woodpecker	*Dendrocopos nanus*
	Rufous Woodpecker	*Micropternus brachyurus*
	Yellow-crowned Woodpecker	*Dendrocopos mahrattensis*
	Greater Flameback	*Chrysocolaptes guttacristatus*
Ramphastidae	Brown-headed Barbet	*Psilopogon zeylanicus*
	White-cheeked Barbet	*Psilopogon viridis*
	Coppersmith Barbet	*Psilopogon haemacephalus*
Podargidae	Sri Lanka Frogmouth	*Batrachostomus moniliger*
Columbidae	Grey-fronted Green Pigeon	*Treron affinis*
	Spotted Dove	*Streptopelia chinensis*
	Rock Pigeon	*Columba livia*
	Nilgiri Wood Pigeon	*Columba elphinstonii*
	Oriental turtle dove	*Streptopelia orientalis*
	Laughing Dove	*Spilopelia senegalensis*
	Yellow-footed Green Pigeon	*Treron phoenicopterus*
	Emerald Dove	*Chalcophaps indica*
	Red Turtle-dove	*Streptopelia tranquebarica*
Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*
Laridae	River Tern	*Sterna aurantia*
Turnicidae	Barred Buttonquail	*Turnix suscitator*
Burhinidae	Indian Thick-knee	*Burhinus indicus*
Scolopacidae	Green Sandpiper	*Tringa ochropus*
	Common Sandpiper	*Actitis hypoleucos*
	Little Stint	*Calidris minuta*
Charadriidae	Red-wattled Lapwing	*Vanellus indicus*
Phasianidae	Indian Peafowl	*Pavo cristatus*
	Jungle Bush-quail	*Perdicula asiatica*
	King Quail	*Coturnix chinensis*
	Grey Junglefowl	*Gallus sonneratii*
	Red Spurfowl	*Galloperdix spadicea*
Psittaculidae	Plum-headed Parakeet	*Psittacula cyanocephala*
	Malabar Parakeet	*Psittacula columboides*
	Rose-ringed Parakeet	*Psittacula krameri*
	Vernal Hanging-parrot	*Loriculus vernalis*
Accipitridae	Osprey	*Pandion haliaetus*
	Oriental Honey Buzzard	*Pernis ptilorhynchus*
	White-eyed Buzzard	*Butastur teesa*
	White-bellied Sea-eagle	*Haliaeetus leucogaster*
	Crested Serpent-eagle	*Spilornis cheela*
	Black Eagle	*Ictinaetus malaiensis*
	Short-toed Snake-eagle	*Circaetus gallicus*

Family	Common name	Scientific name
	Bonelli'ss Eagle	*Aquila fasciata*
	Tawny Eagle	*Aquila rapax*
	Black-winged Kite	*Elanus caeruleus*
	Black-eared Kite	*Milvus migrans lineatus*
	Brahminy Kite	*Haliastur indus*
	Black Kite	*Milvus migrans*
	Pallid Harrier	*Circus macrourus*
	Montagu's harrier	*Circus pygargus*
	Changeable hawk-eagle	*Nisaetus cirrhatus*
	Shikra	*Accipiter badius*
Cuculidae	Sirkeer Malkoha	*Taccocua leschenaultii*
	Common Hawk-cuckoo	*Hierococcyx varius*
	Indian Cuckoo	*Cuculus micropterus*
	Jacobin Cuckoo	*Clamator jacobinus*
	Southern Coucal	*Centropus parroti*
	Asian Koel	*Eudynamys scolopaceus*
	Lesser Cuckoo	*Cuculus poliocephalus*
Alcedinidae	Common Kingfisher	*Alcedo atthis*
	Pied Kingfisher	*Ceryle rudis*
	White-throated Kingfisher	*Halcyon smyrnensis*
Meropidae	Green Bee-eater	*Merops orientalis*
Coraciidae	Indian Roller	*Coracias benghalensis*
Bucerotidae	Great Hornbill	*Buceros bicornis*
	Malabar Pied Hornbill	*Anthracoceros coronatus*
	Malabar Grey Hornbill	*Ocyceros griseus*
	Indian Grey Hornbill	*Ocyceros birostris*
Upupidae	Common Hoopoe	*Upupa epops*
Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*
Falconidae	Laggar Falcon	*Falco jugger*
	Peregrine Falcon	*Falco peregrinus*
	Common Kestrel	*Falco tinnunculus*
Caprimulgidae	Jungle Nightjar	*Caprimulgus indicus*
	Indian Nightjar	*Caprimulgus asiaticus*
	Savanna Nightjar	*Caprimulgus affinis*
Apodidae	Indian Swiftlet	*Aerodramus unicolor*
	Crested Tree Swift	*Hemiprocne coronata*
Strigidae	Spotted Owlet	*Athene brama*
	Short-eared Owl	*Asio flammeus*
	Brown Wood Owl	*Strix leptogrammica*
	Brown Fish Owl	*Ketupa zeylonensis*
	Indian Scops Owl	*Otus bakkamoena*
	Mottled Wood Owl	*Strix ocellata*
Tytonidae	Barn Owl	*Tyto alba*
Apodidae	Asian Palm Swift	*Cypsiurus balasiensis*
Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*

Appendix 2. Distribution of bird species in different ranges of STR

S. N.	Species	Chandoli	Koyna	Dhebewadi	Helwak	Bamnoli
1	Ashy Drongo	+	+	-	-	-
2	Ashy Prinia	+	+	+	-	-
3	Asian Koel	+	+	-	-	+
4	Asian Palm Swift	+	-	-	-	-
5	Barn Owl	+	-	-	-	+
6	Barn Swallow	+	+	-	-	-
7	Barred Buttonquail	-	-	-	-	-
8	Baya Weaver	+	-	-	-	-
9	Bay-backed Shrike	+	-	-	-	-
10	Black Drongo	+	+	+	-	+
11	Black Eagle	+	-	-	-	-
12	Black eared Kite	+	+	-	-	-
13	Black-headed Woodshrike	-	-	-	-	+
14	Black Kite	+	-	-	-	-
15	Black Redstart	-	-	-	-	-
16	Black-crowned Night-heron	+	-	-	-	-
17	Black-headed Cuckoo-shrike	+	-	-	-	+
18	Black-headed Ibis	-	-	-	-	-
19	Black-hooded Oriole	+	+	-	-	+
20	Black-winged Cuckoo-shrike	-	-	-	-	-
21	Black-winged Kite	+	-	-	-	+
22	Black-winged Stilt	-	-	-	-	-
23	Black-naped Monarch	-	-	-	-	+
24	Blue-throated Blue Flycatcher	-	-	+	-	-
25	Blyth's Pipit	+	-	-	-	-
26	Blyth's Reed-warbler	+	+	+	-	+
27	Blue Rock Thrush	+	-	-	-	+
28	Bonelli's Eagle	+	+	-	-	-
29	Brahminy Kite	+	+	-	+	-
30	Brahminy Starling	+	-	-	-	-
31	Bronzed Drongo	-	-	-	-	-
32	Brown-cheeked Fulvetta	+	+	+	+	+
33	Brown Fish Owl	-	-	-	-	-
34	Brown Shrike	+	+	-	-	-
35	Brown Wood Owl	-	+	-	-	-
36	Brown-capped Pygmy Woodpecker	-	-	-	-	-
37	Brown-headed Barbet	+	+	+	+	+
38	Cattle Egret	+	+	-	-	-
39	Chestnut-shouldered Petronia	+	+	-	-	+
40	Citrine Wagtail	-	-	-	-	-
41	Clamorous Reed-warbler	+	-	-	-	-
42	Common Chiffchaff	+	-	-	-	-
43	Common Hawk-cuckoo	+	-	-	-	-

S. N.	Species	Chandoli	Koyna	Dhebewadi	Helwak	Bamnoli
44	Common Hoopoe	+	-	-	-	-
45	Common Iora	+	+	+	+	+
46	Common Kestrel	+	+	-	-	-
47	Common Kingfisher	+	+	-	-	+
48	Common Myna	+	+	-	-	+
49	Common Rosefinch	+	+	-	-	-
50	Common Sandpiper	+	+	+	-	-
51	Common Stonechat	-	+	-	-	+
52	Common Tailorbird	+	+	-	+	-
53	Common Woodshrike	+	+	-	-	-
54	Coppersmith Barbet	+	+	-	-	-
55	Crested Serpent-eagle	-	+	+	-	+
56	Crested Hawk-eagle	-	-	-	-	+
57	Crested Treeswift	-	-	-	-	-
58	Crested Lark	+	-	+	-	-
59	Crimson-backed Sunbird	+	+	+	-	+
60	Dusky Crag Martin	+	-	-	-	+
61	Emerald Dove	+	+	+	-	+
62	Eurasian Crag Martin	+	+	-	+	+
63	Eurasian Wryneck	-	-	-	-	-
64	Forest Wagtail	+	-	-	-	-
65	Golden-fronted Leafbird	+	+	+	+	-
66	Greater Flameback	-	-	-	-	+
67	Great Hornbill	-	+	-	-	-
68	Great Tit	+	+	-	-	-
69	Greater Coucal	+	-	-	-	-
70	Great Cormorant	+	-	-	-	-
71	Greater Racket-tailed Drongo	-	-	-	-	-
72	Green Bee-eater	+	+	+	+	+
73	Green Sandpiper	+	-	-	-	-
74	Greenish Warbler	+	+	-	+	-
75	Grey Junglefowl	+	+	+	+	+
76	Grey Wagtail	+	+	-	-	-
77	Grey-breasted Prinia	+	+	-	-	-
78	Grey-fronted Green Pigeon	+	+	+	+	+
79	Heart-spotted Woodpecker	-	+	-	-	-
80	House Crow	+	+	-	-	-
81	House Sparrow	-	+	-	-	+
82	Hume's Leaf-warbler	-	-	-	-	-
83	Indian Blackbird	+	+	+	+	-
84	Indian Blue Robin	+	-	-	-	-
85	Indian Bush Lark	-	-	-	-	-
86	Indian Cuckoo	+	-	-	-	-
87	Indian Golden Oriole	+	+	-	-	+

S. N.	Species	Chandoli	Koyna	Dhebewadi	Helwak	Bamnoli
88	Indian Grey Hornbill	+	+	-	-	+
89	Indian Nightjar	+	-	-	-	-
90	Indian Paradise-flycatcher	+	-	-	-	+
91	Indian Peafowl	+	+	+	+	+
92	Indian Pitta	+	+	-	-	-
93	Indian Pond-heron	+	+	-	-	-
94	Indian Robin	+	+	+	+	+
95	Indian Roller	+	-	-	-	-
96	Indian Scimitar-babbler	+	+	+	+	+
97	Indian Scops Owl	-	+	-	-	-
98	Indian Silverbill	+	-	-	-	-
99	Indian Swiftlet	+	+	-	-	-
100	Indian Thick-knee	-	-	-	-	-
101	Indian Yellow Tit	+	-	-	+	-
102	Intermediate Egret	+	-	-	-	-
103	Isabelline Shrike	-	-	-	-	-
104	Jacobin Cuckoo	+	+	-	-	-
105	Jerdon's Leafbird	+	+	-	-	+
106	Jungel Crow	+	+	+	+	+
107	Jungle Babbler	+	+	+	+	+
108	Jungle Bush-quail	+	-	-	+	+
109	Jungle Myna	+	+	+	+	+
110	Jungle Nightjar	+	-	-	-	-
111	Jungle Prinia	+	-	-	-	-
112	King Quail	+	+	-	-	-
113	Laggar Falcon	-	+	-	-	-
114	Large Cuckoo-shrike	-	-	-	-	+
115	Large Grey Babbler	+	+	-	-	-
116	Large Grey Shrike	-	+	-	-	-
117	Laughing Dove	+	+	+	+	+
119	Lesser Cuckoo	-	-	-	-	-
120	Lesser Goldenback	-	+	-	-	-
121	Lesser Whitethroat	-	+	-	-	-
122	Lesser Yellow-naped	-	-	-	-	-
123	Little Cormorant	+	+	-	-	-
124	Little Egret	+	+	-	-	+
125	Little Stint	-	+	-	-	-
126	Long-tailed Shrike	+	+	-	-	+
127	Loten's Sunbird	+	+	-	-	+
128	Malabar Grey Hornbill	+	-	-	-	+
129	Malabar Lark	+	-	-	-	-
130	Malabar Parakeet	+	+	-	-	+
131	Malabar Pied Hornbill	+	+	-	+	-
132	Malabar Whistling-thrush	+	+	+	+	+

S. N.	Species	Chandoli	Koyna	Dhebewadi	Helwak	Bamnoli
133	Montagu's Harrier	-	-	-	-	-
134	Mottled Wood Owl	-	-	-	-	-
135	Nilgiri Flowerpecker	-	+	-	-	-
136	Nilgiri Wood Pigeon	-	-	+	+	-
137	Orange Minivet	+	-	-	-	-
138	Orange-headed Thrush	+	+	+	+	-
139	Oriental Honey Buzzard	+	+	+	-	-
140	Oriental Magpie-robin	+	+	-	+	+
141	Oriental Skylark	-	-	-	-	-
142	Oriental Turtle Dove	+	+	+	+	+
143	Oriental White-eye	+	-	+	+	+
144	Osprey	-	-	-	-	-
145	Paddyfield Pipit	+	-	-	-	+
146	Pale-billed Flowerpecker	+	+	-	-	+
147	Pallid Harrier	+	-	-	-	-
148	Peregrine Falcon	+	-	-	-	+
149	Pied Bushchat	+	+	-	+	+
150	Pied Kingfisher	+	+	-	-	-
151	Plain Prinia	+	+	-	-	-
152	Plum-headed Parakeet	+	+	+	-	+
153	Puff-throated Babbler	+	+	+	+	+
154	Purple Sunbird	+	+	+	+	+
155	Purple-rumped Sunbird	+	+	-	-	-
156	Red Spurfowl	+	+	-	-	-
157	Red Turtle-dove	+	-	-	-	-
158	Red-breasted Flycatcher	+	+	+	+	+
159	Red-headed Bunting	-	+	-	-	-
160	Red-rumped Swallow	+	+	-	-	-
161	Red-vented Bulbul	+	+	+	+	+
162	Red-wattled Lapwing	+	+	+	-	-
163	Red-whiskered Bulbul	+	+	+	+	+
164	River Tern	+	+	-	-	+
165	Rock Pigeon	+	+	-	-	-
166	Rose-ringed Parakeet	+	+	-	-	+
167	Rufous Babbler	-	+	-	-	+
168	Rufous Treepie	+	+	-	-	-
169	Rufous Woodpecker	+	-	-	-	-
170	Rufous-tailed Lark	-	-	-	-	-
171	Savanna Nightjar	-	-	-	-	-
172	Scaly-breasted Munia	+	-	-	-	-
173	Scarlet Minivet	+	+	-	-	-
174	Shikra	+	+	-	-	+
175	Short-eared Owl	+	-	-	-	-
176	Short-toed Snake-eagle	+	-	-	-	-

S. N.	Species	Chandoli	Koyna	Dhebewadi	Helwak	Bamnoli
177	Sirkeer Malkoha	-	-	-	-	-
178	Sky's Lark	+	-	-	-	-
179	Small Minivet	+	+	-	+	+
180	Southern Coucal	+	+	+	+	+
181	Southern Grey Shrike	-	-	-	-	-
182	Spotted Dove	-	+	+	+	+
183	Spotted Owlet	-	-	-	-	-
184	Square-tailed Bulbul	+	+	+	+	-
185	Sri Lanka Frogmouth	-	-	-	-	-
186	Striated Heron	+	+	-	-	-
187	Taiga Flycatcher	+	+	-	-	-
188	Tawny Eagle	+	-	-	-	-
189	Tawny-bellied Babbler	+	-	-	-	+
190	Thick-billed Flowerpecker	+	+	-	+	+
191	Tickell's Blue Flycatcher	+	-	-	+	-
192	Tree Pipit	-	-	-	-	-
193	Tricoloured Munia	-	-	-	-	-
194	Tytler's Leaf Warbler	+	+	-	-	-
195	Verditer Flycatcher	+	+	-	-	-
196	Vernal Hanging-parrot	+	+	-	-	-
197	Vigors's Sunbird	+	+	-	-	-
198	Western Crowned Warbler	-	+	-	-	-
199	White-spotted Fantail	-	-	-	-	-
200	White Wagtail	+	+	-	-	-
201	White-bellied Drongo	+	+	+	-	+
202	White-bellied Minivet	-	-	-	-	-
203	White-bellied Sea-eagle	-	+	-	-	-
204	White-breasted Waterhen	+	-	-	-	-
205	White-browed Fantail	+	+	-	-	-
206	White-browed Wagtail	+	-	-	+	-
207	White-cheeked Barbet	+	+	+	+	+
208	White-eyed Buzzard	+	-	-	-	-
209	White-throated Kingfisher	+	+	-	+	+
210	Whistler's warbler	+	-	-	-	-
211	Wire-tailed Swallow	+	+	-	-	-
212	Woolly-necked Stork	+	-	-	-	-
213	Yellow Wagtail	+	-	-	-	-
214	Yellow-browed Bulbul	+	+	+	+	+
215	Yellow-crowned Woodpecker	-	-	-	-	-
216	Yellow-eyed Babbler	+	+	+	-	+
217	Yellow-footed Green Pigeon	+	-	-	+	-
218	Zitting Cisticola	-	+	-	-	-

Appendix 3. Checklist of plant species found in STR

Family	Species	Local name
Anacardiaceae	*Lannea coromandelica*	Shemat, Shimati
	Mangifera indica	Aamba
Annonaceae	*Meiogyne pannosa*	Malabar Fingersop
Apocynaceae	*Holarrhena pubescens*	Indrajav, Kutaja, Pandhra Kuda
	Tabernaemontana alternifolia	Nag Kuda
Arecaceae	*Caryota urens*	Fishtail Palm
Bignoniaceae	*Heterophragma quadriloculare*	Waras
	Holigarna grahamii	Waras
Boraginaceae	*Cordia dichotoma*	Shelu
Burseraceae	*Garuga pinnata*	Kakad
Caesalpiniaceae	*Moullava spicata*	Wagati
Cannabaceae	*Trema orientalis*	Ghol, Kapshi
Celastraceae	*Maytenus rothiana*	Lokhandi, Makar Khana, Lechi
Clusiaceae	*Garcinia talbotii*	Tavir
Combretaceae	*Anogeissus sp.*	
	Terminalia bellirica	Behada
	Terminalia chebula	Harra
	Terminalia elliptica	Ain
Dilleniaceae	*Dillenia pentagyna*	Piwala Karmal
Ebenaceae	*Diospyros ebenum*	Abnus, Karmar
	Diospyros montana	Lohari
	Diospyros nigrescens	Rakta Roda
	Diospyros sylvatica	Karimaram
Elaeagnaceae	*Elaeagnus conferta*	Nurgi, Ambgul, Amguli
Euphorbiaceae	*Dimorphocalyx lawianus*	Jodpakli
	Macaranga peltata	Chandada
	Mallotus phillipinensis	Shendri
Fabaceae	*Butea monosperma*	Palaas
	Cassia fistula	Amaltas, Bahava
	Erythrina suberosa	Pangara
	Pterocarpus marsupium	Bibla
	Xylia xylocarpa	Yerul, Jamba
Icacinaceae	*Mappia foetida*	Narkya
	Nothapodytes nimmoniana	Ghanera
Lamiaceae	*Callicarpa tomentosa*	Ayamsar, Insara, Kaarivaati
Lauraceae	*Alseodaphne semecarpifolia*	Phudgus
	Beilschmiedia dalzellii	Dalzell's Walnut
	Cinnamomum verum	Dalchini
	Litsea josephii	Varikeera
	Neolitsea cassia	Chirchira, Kanvel
	Persea macarantha	Gulaamba
Lecythidaceae	*Careya arborea*	Kumbha
Lythraceae	*Lagerstroemia microcarpa*	Nana

Family	Species	Local name
	Woodfordia fruticosa	Dowari
Malvaceae	*Bombax ceiba*	Semal
	Grewia nervosa	Shiral
Melastomataceae	*Memecylon umbellatum*	Anjan
Meliaceae	*Aglaia elaeagnoidea*	Priyangu
	Cipadessa baccifera	Ranabili
Mimosaceae	*Acacia auriculiformis*	Earleaf Acacia
Moraceae	*Artocarpus hirsutus*	Wild Jackfruit
	Ficus amplissima	Piper
	Ficus exasperata	Karvat
	Ficus microcarpa	Chinese Banyan
	Ficus racemosa	Umber
	Ficus sp.	
	Ficus tsjahela	Fig Tree
	Ficus virens	Bassari, Gandhaumbara
Myristicaceae	*Myristica malabarica*	Raampatri
Myrtaceae	*Eucalyptus globulus*	Nilgiri
	Eugenia corymbosa	Bhedsi
	Syzygium cumini	Jamun
	Syzygium phillyraeoides	Ran Jambhul
	Syzygium rubicundum	Ran Lavang
Olacaceae	*Strombosia ceylanica*	
Oleaceae	*Chionanthus mala-elengi*	Heddi
	Olea dioica	Parjamb
Phyllanthaceae	*Bridelia retusa*	Asana
	Bridelia scandens	Ran Phatarphad
	Phyllanthus emblica	Amla
	Glochidion ellipticum	Bhoma
	Securinega leucopyrus	Pandharphali
Putranjivaceae	*Drypetes venusta*	
Rhamnaceae	*Scutia myrtina*	Cheemat
	Ziziphus rugosa	Toran
Rhizophoraceae	*Carallia brachiata*	Phanshi
Rosaceae	*Prunus ceylanica*	Dhaka, Kaula, Kogal
Rubiaceae	*Canthium dicoccum*	Arsul
	Catunaregam spinosa	Ghela
	Ixora lanceolaria	
	Ixora nigricans	Katkuda
	Meyna laxiflora	Huloo
	Murraya koenigii	Curry leaves
	Neolamarckia cadamba	Kadamb
	Psychotria truncata	
	Wendlandia thyrsoidea	Showla

Family	Species	
Rutaceae	*Atalantia racemosa*	Ran Limbi
	Clausena anisata	Horsewood
	Murraya paniculata	Kunti
Salicaceae	*Casearia championii*	
	Flacourtia latifolia	Tanbat
	Flacourtia montana	Raan Tambut
	Homalium ceylanicum	Homali
Santalaceae	*Osyris quadripartita*	Chimat
Sapindaceae	*Allophylus cobbe*	Theepani
	Dimocarpus longan	Umb
	Schleichera oleosa	Kusumb
Sapotaceae	*Mimusops elengi*	Bakuli
	Xantolis tomentosa	Kate Kumbal
Symplocaceae	*Symplocos racemosa*	Lodha
Thymelaeaceae	*Gnidia glauca*	Rameta
Tiliaceae	*Grewia tiliifolia*	Dhaman
Vitaceae	*Leea indica*	Karkani