Study on Avian diversity in Sacred groves of Sattari; with additional notes on activities of Malabar grey Hornbill

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Study on Avian diversity in Sacred groves of Sattari; with additional notes on activities of Malabar grey Hornbill" is based on the results of investigations carried out by me in the Zoology department at the School of Biological science and Biotechnology, Goa University under the Supervision of Dr. Minal Desai Shirodkar and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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This is to certify that the dissertation report **"Study on Avian diversity in Sacred groves of Sattari; with additional notes on activities of Malabar grey Hornbill"** is a bonafide work carried out by **Ms. Vaishnavi Rajesh Pokle** under my supervision in partial fulfillment of the requirements for the award of the degree of Masters in the Discipline Zoology at the Goa University.

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PREFACE

This dissertation attempts to provide an insight into the importance of avian diversity present in three sacred groves of Sattari. As a devoted zoology student with a fascination for birds, delving into avian diversity within sacred groves has been a natural and compelling journey for me. Sacred areas are distinguished by their untouched forests, which have been protected by indigenous communities for many generations as a result of their deeply rooted cultural and religious convictions. Conducting an evaluation of the abundance and variety of bird species residing in sacred groves can offer valuable insights into the overall environmental well-being within and surrounding the grove area, despite being small and fragmented in size, serve as pivotal habitats for the protection of rare species, thus highlighting their significant ecological importance. Birds, as indicator species, offer valuable insights into ecosystem health and environmental changes due to their sensitivity and wide-ranging habitats. Within these pages, you'll discover the diverse array of bird species thriving in these groves, from the chirping Passeriformes to the majestic Malabar Grey Hornbills. Hornbills are considered as excellent candidates for investigating ecological and behavioral inquiries as they are "keystone species".The investigation into the behavioral activities of Malabar Grey Hornbills provides valuable insights into their habitat utilization patterns, highlighting the interplay between ecological factors and avian behavior. While Sacred groves are acknowledged as vital habitats, there's a gap in research on bird diversity and Hornbill behavior within them in Goa. This gap spurred the choice of this dissertation topic, hence this thesis is aimed at filling these lacunae. I hope that this work will help to create awareness and understanding about the importance of this habitat in harboring bird diversity.

ACKNOWLEDGMENT

I would like to express my gratitude to all those who helped me to successfully complete this dissertation work entitled " **Study on Avian diversity in Sacred groves of Sattari; with additional notes on activities of Malabar grey Hornbill** ". I am very grateful to my guide Dr. Minal Desai Shirodkar for her constant support, encouragement, motivation and guidance to me throughout this work and helping me in every possible way for the successful completion of my dissertation.

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My sincere thanks goes to my parents and family who supported me financially and morally and always motivated me to complete my work successfully.

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TABLES

FIGURES

ABBREVIATION USED

Entity	Abbreviation
Devachi Rai	DR
Mharinganachi Rai	MR
Nirankarichi Rai	NR
Sacred Grove	SG
Resident	R
Migrant	M
Endemic	E
Least Concern	LC
Vulnerable	VU
Near Threatened	NT
Carnivores	C
Omnivores	O
Granivores	G
Frugivores	F
Insectivores	I
Piscivores	P
Nectarivores	N

ABSTRACT

This study examined the diversity of birds in three sacred groves in Sattari taluka over an eight-month period from August 2023 to March 2024. A total of 91 bird species were observed from 12 Orders and 40 families using the point count method. Of these, 82 species were residents, 9 migrants, 9 endemic & one was classified as endangered. Devachi Rai had the highest species richness with 62 species, followed by Mharinganachi Rai(57 species) & Nirankarachi Rai had least(50 species). The study showed peak species richness was in January 2024, due to an influx of migratory birds. Moreover, insectivores made up the majority of bird species at 41.8%. An increase in insectivore species was seen after the post monsoon. Calculations of the Sorensen coefficient indicated similar bird species compositions across the groves. A one-way ANOVA test was done to compare birds, showing no significant difference (P= 0.4827,F=0.754) in diversity across the three sacred groves. To understand behavioral activity of Malabar Grey Hornbill across 3 groves, Focal sampling method was used. A one-way ANOVA test was used to compare activities of Malabar grey Hornbill across the sacred groves, revealing significant variations in foraging, resting, and body maintenance behaviors. Positive correlation was seen between foraging and body maintenance activity. Highest foraging activity was seen in Mharinganachi rai having more ficus trees, whereas highest resting was seen in Nrankarachi rai having dense canopy and cooler climate. Sacred groves with large areas and low human disturbance showed high species richness. The findings highlight the significance of sacred groves in avian diversity conservation and providing refuge to endemic and threatened birds like the Malabar grey Hornbill. Being of small forest patches the sacred forests have higher potentialities for conserving the bird species.

CHAPTER I

INTRODUCTION

1.1 Background

“Sacred groves are regions of lush greenery that have been protected for religious reasons” (Jyothi & Nameer, 2015). They are characterized by their virgin forests, whose rich diversity has been safeguarded by indigenous communities for generations due to their deeply ingrained cultural and religious beliefs. Sacred spaces are believed to be inhabited by deities or divine entities that protect villagers from misfortunes, with any harm inflicted on trees or animals in these forests believed to provoke divine retribution (Khan et al.,2008; Gadgil & Vartak,1974; Dagal et al.,2007; Samati& Gogoi,2007). These small natural pockets of forest provide a shelter for a high number of endemic, endangered, and threatened species of flora and fauna. India is home to numerous sacred groves, with around 13,720 spread across 19 states, particularly in regions inhabited by indigenous communities like the Western Ghats, Central India, and Northeast India, each known by distinctive names provided by the local population (Malhotra et al., 2001). India is believed to have more than 4215 sacred groves covering 39,063 hectares, with South India having around 2000 in Kerala, 1600 in Maharashtra, 800 in Andhra Pradesh, and 448 in Tamil Nadu (Bhandary and Chandrashekar, 2003).

Large number of groves are present in South India, along Western Ghats which also include Goa State. Sacred groves are primarily found in hilly places of Goa, but can exist in the hinterland. The tradition of creating sacred groves has powerful historical origins in Goan culture, signifying an extensive respect for plants extending back to antiquity. Religious practices and traditions have had a tremendous impact on the mindset of environmental care in Goa, as well as throughout India. In the past, sacred

groves were common in villages but are now declining due to socio-economic and land use changes. Different names are used to identify sacred groves in various regions of Goa. Specifically, in Sattari, these areas are referred to as Devrais, in Ponda identified as Devgal, in Sanguem as Pann, and in Canacona as either Devaran or Devadano. It is noteworthy that Sanguem and Sattari stand out as the sole two talukas within Goa that possess substantial forested areas along with a significant presence of sacred groves (Kerkar, 2006).

Sacred groves are found in seven Talukas of Goa which includes Sattari, Sanguem, Canacona, Bicholim, Pernem, Quepem, and Dharbandora. There are a total of 93 sacred groves present in Goa. Out of which, Sattari has the most abundant number of sacred groves, which is 49 (Kerkar, 2019). However, there is limited scientific research on avifauna diversity in sacred groves.

Birds are essential for biodiversity, serving as bioindicators that reflect the ecological health of various habitats like protected forests and sacred groves, due to their adaptability to environmental changes, their presence and numbers can serve as indicators of ecological patterns observed in other forms of biodiversity (Furness and Greenwood, 1993). Additionally, birds play crucial roles as both seed dispersers and agents that pollinate flowers of native plant species (Nason, 1992). Their specific needs in terms of habitat make them highly sensitive to even the slightest alterations or disturbances within their ecosystem.

Numerous research studies have indicated that despite their small and fragmented nature, sacred groves play a crucial role in safeguarding the existence of rare species (Punde, 2007). Due to their highly specific habitat requirements, birds tend to exhibit a heightened level of intolerance towards even minor disturbances within the

ecosystem (Schwartz and Schwartz, 1951). Therefore, conducting an evaluation of the abundance and variety of bird species residing in sacred groves can offer valuable insights into the overall environmental well-being within and surrounding the grove area (Bowden, 1990). Preserving sacred groves is crucial not just for cultural and religious purposes, but also for biodiversity conservation and ecological equilibrium. They are typically undisturbed, are havens for diverse bird species and other wildlife. Research into bird diversity here aids in preserving both the birds and their habitats. Understanding the array of bird species in sacred groves reveals their ecological functions and they are reliable indicators of ecosystem health. Though Sacred grove is the important habitat no work has been done on bird diversity, hence the topic was chosen**.**

One of the significant birds found in selected sacred groves was Hornbill. This species is characterized by the presence of a distinctive casque positioned on top of their beak, resembling a horn, hence they are commonly referred to as 'Hornbills' (Kasambe, 2011). They are distributed throughout sub-Saharan Africa, as well as in India and southern Asia, and the Sunda Shelf islands of Indonesia. The Asian Hornbill species prefer mature forests with large trees for nesting and a variety of fruiting trees with strangler figs. (Kinnaird, 2007). There are a total of 62 hornbill species worldwide, with 31 species located in Asia and 9 species present in India (Mudappa & Raman, 2009 ; Nigam et al., 2023). Four species are found in the Western Ghats as well as in Goa are: the Malabar Pied Hornbill and Indian Grey Hornbill which exhibit endemism to the Indian subcontinent, the Malabar Grey Hornbill which is endemic to the Western Ghats, and the Great Hornbill which is classified as a threatened species according to the IUCN Red List of 2008, and has a broad distribution spanning

South-East Asia. Among these four species, two species recorded in the sacred grove were Malabar Grey Hornbill and Malabar Pied Hornbill.

According to Kinnaird (2007), hornbills are considered as excellent candidates for investigating ecological and behavioral inquiries. They exhibit a predominantly frugivorous diet when not breeding, but they switch to an omnivorous diet during breeding to provide calcium and protein for their nestlings.(Kasambe, 2011; Santhoshkumar & Balasubramanian 2014). The presence of fruits in the environment significantly impacts the habitat choice of a species or individual, subsequently affecting their behavior, physiology, abundance, and survival in a particular landscape (Nigam et al., 2023). Hornbills are considered 'keystone species' in their ecosystems and play a crucial role as primary 'flagship species' in conservation efforts due to their dietary habits as frugivores. The preservation of fruit-bearing plant species is crucial for their continued survival, and sacred groves offer an ideal environment with such plants.

Malabar grey Hornbill is threatened species, endemic to the Western Ghats & found in high rainfall areas from the plains to an altitude of about 1,600 m, clearly the most widely distributed in Western Ghats, distributed over a range of forest types from moist deciduous, riverine, and semi-evergreen forests to tropical wet evergreen forests (Mudappa & Raman,2009). The Malabar Grey Hornbill (*Ocyceros* griseus) was chosen as the focal study organism due to its frequent sightings. Despite being recognized as a significant endemic species of the Western Ghats, there is a notable absence of research conducted on its presence within sacred grove habitat.

1.2 Aim and Objectives

The study of bird diversity was conducted in selected three sacred groves of Sattari taluka namely Devachi Rai, Nirankarchi Rai and Mharinganachi Rai-

-To assess the community structure of birds in terms of resident, migrant, endemic, threatened species and based on their feeding guilds.

-To record the behavioral activities of Malabar Grey Hornbill across three selected sacred groves.

1.3 Hypotheses

Sacred grove inhibits rich bird diversity and provides an important habitat to Malabar Grey Hornbill, especially for foraging activity.

1.4 Scope

Sacred groves function as crucial refuges for biodiversity, providing shelter for a variety of plant and animal species and maintaining the native flora and fauna, despite their small size and fragmented state, they support various bird species and wildlife. One of the significant birds found in selected sacred groves was Malabar grey Hornbill which is a threatened species and endemic species of the Western Ghats. Despite the recognition of Sacred grove as an significantly important habitat, no research has been done on bird diversity and also there is a notable absence of research conducted on Malabar grey Hornbill behavioral activities within sacred grove habitat, thus leading to the selection of this topic for dissertation. A total of 93 sacred groves have been identified in Goa, with potential for further research on avian diversity in the remaining sacred groves.

CHAPTER II

REVIEW OF LITERATURE

The following review of literature was done on bird diversity of Sacred Groves. Sacred groves are highly esteemed areas of natural forests that hold spiritual importance for many different civilizations throughout the globe. Khan *et al.*, 2008 suggested that Sacred groves serve as an optimal focal point for the preservation of biodiversity.

A cumulative count of 411 bird species from 22 distinct families and 66 various species was documented by Kangah-Kesse *et al.,* (2009). Within this count, 211 birds of 41 species were observed at the border between the forest and cultivated land, 111 individuals (36 species) in undisturbed forest areas, and 89 specimens (40 species) within secondary forest environments. The Abiriw Sacred Grove is inhabited by a variety of bird species, predominantly the little greenbul (*Andropadus virens*). Another similar study, Using 20 randomly placed transect lines (500m each), Okosodo and Tinuoye,(2022) in Nigeria evaluated bird and tree species diversity throughout various seasons in sacred groves. Results showed a significant variety of 125 bird species belonging to 49 families and 18 orders. Passeriformes were the most common order (51%). Estrildidae and Pycnonotidae families were dominant, making up 74% of the observed species. Birds exhibited the highest species richness and Shannon diversity in both seasons, possibly attributed to the abundance of evergreen trees offering ample food resources such as flowers and insects.

Katuwal *et al., (*2016) conducted a study on bird diversity in four sacred forests in Kathmandu valley, Nepal, revealing the significance of these forests for resident bird populations,using point count method . They identified 144 resident bird species from

11 orders and 36 families, with the highest species count in Suryabinayak forest (168 species).

Mahabaleshwarkar *et al.,* (2023) research focused on the faunal diversity in sacred groves in Pune District, India, identifying 96 bird species from 45 families, with dominant families being Accipitridae and Muscicapidae, With resident species prevailing at 86%. Jyothi and Nameer, (2015) investigated the avian biodiversity in 15 sacred groves in northern Kerala, using point count and line transect method, revealing a total of 111 bird species from 49 families and 16 orders. These groves play a crucial role in supporting various resident forest birds, showcasing their significance in maintaining ecological balance. 25% of the avian population inhabiting the groves in the northern region of Kerala comprised species belonging to forest birds. Similarly, Pazhedath and Karumampoyil, (2022) conducted research on the distribution of avifauna in sacred groves of Northern Kerala, India, using the point count method across seven sites from December 2017 to May 2019, identifying 88 bird species. Their findings highlighted a correlation between habitat size and avian diversity, with larger areas supporting more bird species (Nelair Kottam, the largest site at 6.4 hectares, had highest diversity with 49 species, while Poil kavu, covering 4.4 hectares, had lowest diversity with 14 species). Passeriformes were the dominant order, comprising 67% of the recorded species.

Gangadharan et al. (2021) conducted a study on avian diversity and ecological dynamics in the Manjamalai Sacred Grove, Tamil Nadu, India using line transect method. Their research identified 61 resident bird species across 38 families and 13 orders in the grove, emphasizing its importance as a habitat for diverse resident avian fauna. December 2019 saw the highest number of bird species recorded. Joshi and

Sarnaik (2014) investigated the significance of sacred groves in preserving avian diversity in the Northern Western Ghats, India, by studying 19 groves in SangameshwarTaluka from September 2012 to March 2013, using Standard Point Count technique. The findings showed a total of 101 bird species from 43 families and 13 orders, Their study identified 85 resident bird species. Study highlighted the potential for avian biodiversity conservation through corridor management, underscoring the importance of these groves as crucial habitats for both resident and migratory bird species. The species richness of every sacred grove was evaluated through the application of Menhinick's richness index and Margalef's diversity index.

In the study conducted by Pradhan *et al.,* in 2016, an investigation was carried out on the avian diversity present in a sacred natural forest area in Odisha using point count method. The researchers discovered a total of 28 bird species belonging to 22 different families during their field expedition. The study emphasized the variations in species richness and diversity over time, showing the lowest values in August (14 species, diversity index 2.48) and the highest values in March (25 species, diversity index 3.07). Interestingly, it was observed that the species were predominantly located in the edge or peripheral areas rather than the interior region. Nair & Teji (2019) researched bird diversity in Malayatoor and Iringole Kavu sacred grove from January to December 2018. A total of 78 bird species were identified, 47 bird species were seen at Iringole Kavu and 31 at Malayattoor, with 23 species overlapping. Iringole Kavu had greater bird diversity than Malayattoor, possibly due to its dense forest which supports bird feeding and reproduction.

An effort was also made to study the sacred groves of Goa, which emphasized biodiversity, including avian species. In a recent investigation conducted by Kerkar

(2019) in Goa, a total of 17 sacred groves were studied, revealing a diverse range of species. The research findings indicated the presence of 35 bird species, 21 mammal species, 14 snake species, 42 butterfly species, 11 spider species, and 5 frog species in these specific areas. Kerkar emphasized the importance of tall trees in attracting birds and emphasized the significance of evergreen species such as ficus, which offer continuous food sources for avian species. The study ultimately emphasized the critical role of preserving these sacred groves in order to protect biodiversity.

Kangah-Kesse *et al.,*(2009) recorded only one migrant named Didric cuckoo (*Chrysococcyx caprius*). Similarly Katuwal *et al.,* (2016) also identified 51 migratory bird species in their study on bird diversity in sacred forests in Kathmandu valley, Nepal. Mahabaleshwarkar *et al.,*(2023) found that resident species prevailing at 86% and winter migratory species at 12.5%, migratory species namely Ashy Drongo(*Dicrurus leucophaeus*), Eurasian Crag-Martin (*Ptyonoprogne rupestris*), Gray Wagtail (*Motacilla cinerea)*, Greenish Warbler (*Phylloscopus trochiloides*), highlighting the habitats' importance for avian diversity in Pune District, India.

Similarly, Jyothi and Nameer (2015) identified 17 long-distance migratory bird species namely, Common Sandpiper, Blue-tailed Bee-eater, Brown Shrike, Blyth's Reed Warbler, Greenish Leaf Warbler, Wire-tailed Swallow, Indian Paradise-flycatcher, Whiskered Tern, Indian Golden Oriole Brown Shrike and Brown-breasted Flycatcher in the sacred groves of northern Kerala, India.

Gangadharan *et al.* (2021) identified 11 migrant bird species in the Manjamalai Sacred Grove, Tamil Nadu, India, namely Pied cuckoo, Indian golden oriole, White bellied drongo, Ashy drongo, Blue tailed bee-eater, Brown shrike,Asian brown flycatcher, Greenish warbler, Blyth’s reed warbler, Black headed cuckooshrike and Barn swallow

Same way Joshi and Sarnaik,(2014) found 13 migratory bird species, along with 2 local migratory species using point count method, during their study on avian diversity in sacred groves in the Northern Western Ghats, India.

Pazhedath and Karumampoyil,(2022) conducted study in sacred groves of northern kerala noted migratory birds namely, Chestnut tailed Starling, Crested tree swift, Indian golden oriole, Black naped oriole, Blue capped rock Thrush, Indian paradise flycatcher and Large billed leaf Warbler. Nair & Teji,(2019) researched bird diversity in Ernakulam District and found that Indian paradise flycatcher and brown breasted flycatcher are winter visitors. Black hooded oriole migrates, while White throated ground thrush, Crested serpent eagle, Brahminy kite show local migration based on monsoon and environmental changes.

Mahabaleshwarkar *et al.,(*2023) also cited 33 species of endemic birds, among that few were Malabar Grey Hornbill (*Ocyceros griseus*), Malabar Pied Hornbill (*Anthracoceros coronatus*), Gray-fronted Green Pigeon (*Treron affinis*), Nilgiri Wood-pigeon (*Columba elphinstonii*), Pale-billed flowerpecker (*Dicaeum erythrorhynchos*), White-bellied blue Flycatcher (*Cyornis pallipes*), Crimson-backed Sunbird (*Leptocoma minima*), Malabar Parakeet (*Psittacula columboides*), Brahminy Starling (*Sturnia pagodarum*). Similarly Jyothi and Nameer,(2015) found that sacred groves of northern Kerala also support two endemic bird species of the Western Ghats, such as the Malabar Grey Hornbill and Rufous Babbler. Joshi and Sarnaik, (2014) found Six species were endemic to Western Ghats.

Pazhedath and Karumampoyil, (2022) noted endemic birds like Nilgiri Flowerpecker, Malabar woodshrike, Crimson backed sunbird, Flame throated bulbul. Katuwal *et al.,*(2016) also identified one globally and five nationally threatened species like Barn

Owl, Steppe Eagle, Brown Wood Owl, Dark-sided Thrush and Brown Fish Owl, while 24 as rare categorized species in sacred forests in Kathmandu valley, Nepal .

Similarly Mahabaleshwarkar *et al.,(*2023) observed Malabar Grey Hornbill (*Ocyceros griseus*), Malabar Pied Hornbill (*Anthracoceros coronatus*), Nilgiri Wood-pigeon (*Columba elphinstonii*) and Tytler's Leaf-warbler *(Phylloscopus tytleri*) as threatened species. Joshi and Sarnaik, (2014) identified two species, namely the Great Hornbill (*Buceros bicornis*) and the Malabar Pied Hornbill (*Anthracoceros coronatus*), as falling within the near threatened classification of the IUCN Red List.

The only threatened species noted by Pazhedath and Karumampoyil, (2022) was white bellied sea eagle, which was seen nested in Edayile kadu sacred grove.

Mahabaleshwarkar et al., (2023) research focused on the faunal diversity in sacred groves in Pune, categorized birds based on feeding habits and migration status, revealing varied ecological roles within the ecosystems, such as insectivores (39.6%), aiding in pest control and omnivores (20.8%) contributing to ecological balance. Jyothi and Nameer (2015) categorized the primary feeding roles in these groves, with canopy insectivores and frugivores representing 23% and 21% of the bird species observed, respectively. This showcases the varied ecological niches found in the sacred groves that cater to different avian feeding behaviors.

Gangadharan et al. (2021) found that insectivorous birds dominated the avian community in the Manjamalai Sacred Grove, likely due to increased insect population in the post-monsoon season, thus enhancing food availability for insectivorous birds.

Insectivores were identified as the most dominant ecological guild among the avian communities studied by Joshi and Sarnaik (2014). The study also highlighted the diverse activities of bird communities within the groves, with foraging and perching being the dominant behaviors observed. Middle canopy nesters showed the highest

nesting preference, indicating the importance of groves in providing habitat for various bird species. Study by Pradhan et al. (2016) showed that the majority of the observed bird species were classified as insectivores, comprising the primary feeding guild with 11 species. Insectivores followed by graminivorous (5 species), frugivorous (2 species) and least nectivorous (1 species).

Various studies were conducted on behavior, feeding preferences, and habitat of hornbills. No previous research was done in a habitat like sacred grove. Wijerathne and Wickramasinghe's (2018) study focuses on the behavior of the Sri Lanka Grey Hornbill in the Mihintale Sanctuary. They used ad libitum focal animal sampling to create an ethogram with 35 behavioral occurrences classified into 11 acts spanning four distinct types of activities in terms of frequency of occurrence. The highest activity was perching. It was proposed that body maintenance may occur after foraging activity and perching is mostly for resting or foraging.Despite being not very active, the Sri Lanka Grey Hornbill displays a wide range of unique behaviors.

Same way, Cooper and Jordan's 2013 study examines time-activity budgets of captive Southern Ground Hornbills, comparing observed behaviors with expected behaviors in captivity. No significant difference was found between observed and expected behaviors after 26 hours of observations. Walking was the most common behavior (51%), followed by standing (18%), foraging (8%), perching (7%), and sitting (5%). Female hornbills called more frequently and spent more time perched than males, while juveniles foraged more and walked less than adults. The study offers insights into the natural behaviors of Southern Ground Hornbills in captivity, aiding in their management and welfare.

Similar study was done in 2020 by Nena focused on estimating the population and behaviors of Indian Grey Hornbills in Vallabh Vidyanagar. Behaviors observed included foraging, maintenance, flying, calling, and feeding on 12 plant species, offering insights into their ecology and behavior for conservation efforts. The population of IGHB is influenced by factors like area type, tree density, canopy cover, breeding habitat availability, and food availability. Sightings were mostly in areas with high tree density and canopy cover. Courtship display involved male offering various foods to females. Female hornbill incarcerated herself in a nest for egg incubation, relying on male for food, showcasing male devotion. Nest characteristics included tall live trees offering protection from predators and warmth, emphasizing the need for tree conservation in Vallabh Vidyanagar, especially during breeding season.

Mudappa's study in 2000 analyzed the breeding biology of Malabar Grey Hornbills in Southern Western Ghats. The research focuses on 10 nests in the Anamalai hills within the Indira Gandhi Wildlife Sanctuary. The nesting period lasts an average of 86 days with distinct pre- and post-hatching phases. Females and young leave nests together at the end of the period. Male hornbills deliver 2397 food items to the focal nest, including lipid-rich and sugar-rich fruits, and various types of animal matter. The diet includes lipid-rich fruits (37%), Ficus fruits (26%), and animal matter (13.8%). There is a higher frequency of lipid- and sugar-rich fruit delivery in the pre-hatching phase and an increase in animal food delivery in the post-hatching phase. The study underscores the importance of rare tropical trees producing lipid-rich fruits for the conservation of Malabar Grey Hornbill population.

Few records are available about its nesting ecology, Patel et al. 2022 study examines Malabar Grey Hornbill nesting ecology in the Southern Western Ghats. The researchers studied nest site features, breeding behavior, and diet over six years. 20 nesting attempts were observed in 13 nest-cavities in indigenous trees, with random reuse. The study shows a wide range of nest-tree preferences but a narrower range for nest-cavity features. This suggests the species may prioritize cavity characteristics for breeding. The research offers valuable insights into nesting behavior and habitat selection of the endemic species.

CHAPTER III

METHODOLOGY

3.1 Study Area

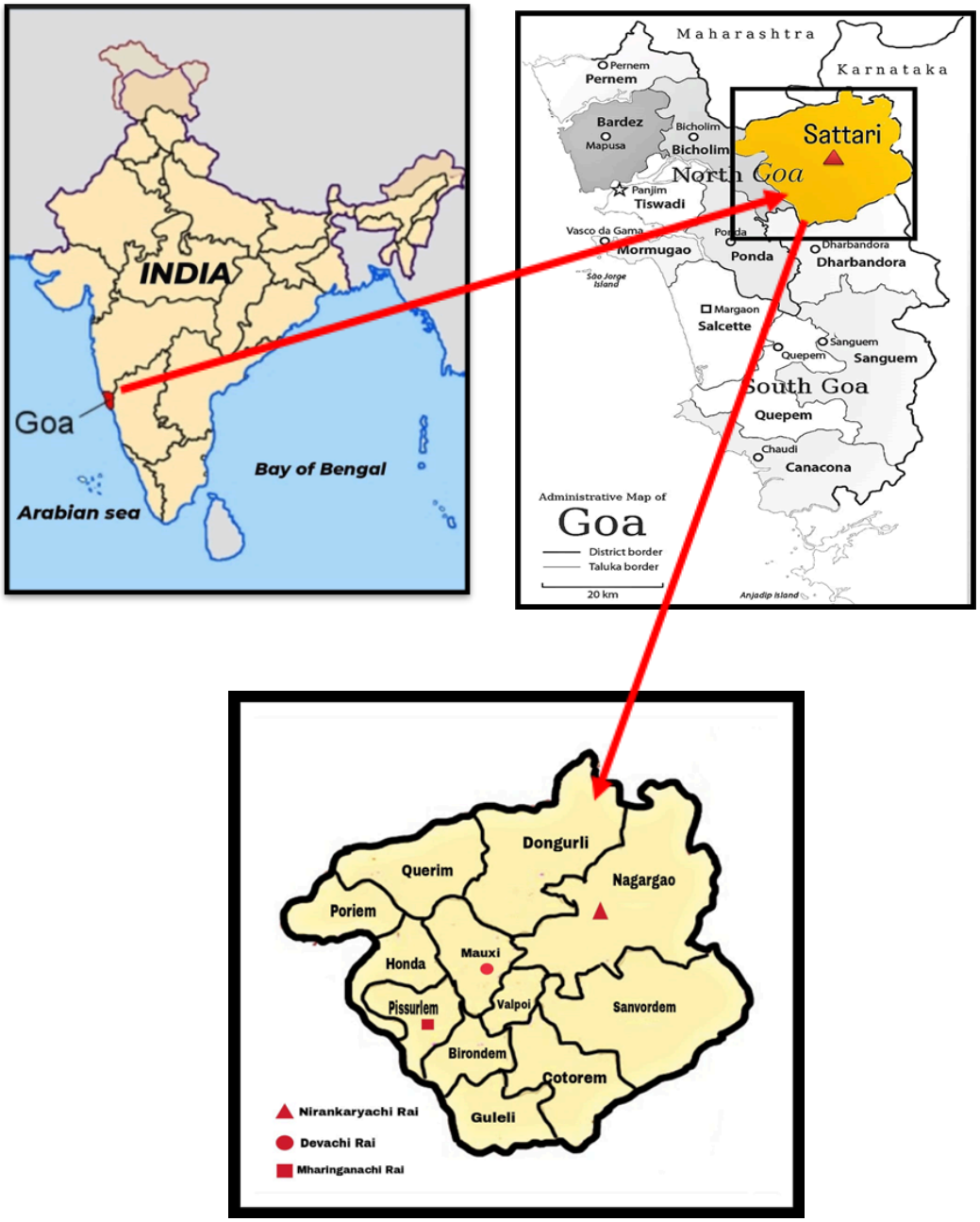


Figure no.3.1- A Map showing the three study sites in Sattari Goa

The three Sacred Groves were chosen randomly as study sites from Sattari Taluka, which are Devachi Rai (DR), Nirankarachi Rai (NR) and Mharinhanachi Rai (MR).

The exact mapping of three Distinct Study Sites in Sattari Taluka, Goa are mentioned in Fig no.3.1.

Sattari, situated in the North Goa district of Goa, India, is a Taluka known for its lush greenery and dense forests in the northeastern region of the state. The eastern part of the Sattari Taluka is formed by a section of the Western Ghats, while the Mandovi River, locally referred to as Mhadei in Sattari taluka, is regarded as the vital artery of the region. Sattari encompasses a total area of 495.13 km2.The Western Ghats with varied habitats provide a good number of avian diversity in the forest of Sattari.

The three sacred groves that are selected as study site are as follows:

1. Devachi Rai (DR) of Kopardem, Sattari
2. Nirankarachi Rai (NR) of Maloli, Sattari
3. Mharinganachi Rai (MR) of Pissurlem, Sattari

Devachi Rai (DR) of Kopardem, Sattari

The Devachi Rai is located at Kopardem (Figure no.3.2) village in Sattari Taluka, 3 km away from Valpoi. The grove is safeguarded under the name of "Brahmani Mahamaya", who is the main deity of the village. The grove covers an area <2ha of semi evergreen and semi deciduous forest. Climatic condition inside the grove is very soothing. Vegetation is predominantly composed of tree species such as *Terminalia bellerica, Terminalia crenulata, Careya arborea, Macaranga peltata, Terminalia paniculata, Ficus bengalensis, Caryota urens, Saraca indica, Acacia catechu, Holigarna arnottiana, Garcinia indica, Machilus macrantha, Hopea*

wightiana, Xylia xylocarpa, Pterocarpus marsupium, Holopteliaintegrifolia, Butea monosperma, Lagerstroemia lanceolata parviflora, Alstonia scholarias, Dillenia pentagyna, Morinda citrifolia, Ficus racemosa, Ziziphus oenoplia, Moringa oleifera, Mangifera indica etc..

Grove has a great cover of *Pandanus odorifer.* Nevertheless, large, tall and majestic trees such as *Tetrameles nudiflora* are noteworthy for their ability to provide support for various other forms of life (Kerkar, 2019). *Entada scandens*, a twining plant or climber or creeper, is surrounding diverse trees in the forest, forming a flourishing and verdant canopy. The grove provides a suitable habitat for a diverse array of animal species, including reptiles, mammals, spiders, moths, and butterflies. Endangered mammals such as Ratufa indica have been observed frequently during visits to the grove.

Nirankarachi Rai (NR) of Maloli, Sattari

The Nirankarachi Rai (Figure no.3.3) situated at Maloli Village in Sattari Taluka, located 11 km away from Valpoi, is presided over by the deity “Nirankar ". The total area of the grove is approximately between 1.70 to 1.80 hectares, with a Myristica swamp covering less than 1 hectare. The vegetation in the grove is predominantly composed of tree species like *Gymnacranthera canarica*, *Holigarnagrahamii*, *Polyalthia fragrans*, and *Lophopetalum wightianum* (Gaude & Janarthanam, 2015). It also has a great cover of *Myristica malabarica.*

It acts as a haven for distinctive woodland flora recognized as 'Myristica Swamp Forests', perceived as one of the oldest forms of vegetation with noteworthy

ecological significance. A notable characteristic of the trees in this environment is the abundance of aerial roots that form an inverted 'U' shape, curving over the muddy terrain. Grove also has good cover of other tree species such as *Mangifera indica, Caryota urens, Strychnos nux-vomica, Ficus racemosa, Psidium guajava, Ziziphus oenoplia, Carallia brachiata, Flacourtia Montana,Caryotaurens,* Some of the area also has cover of *Chromolaena odorata* and *Melastoma malabathricum.*The perennial spring within the protected sacred grove remains constant throughout the year.

Mharinganachi Rai (MR) of Pissurlem, Sattari

The Mharinganachi Rai (Figure no.3.4) is present at Pissurlem village in Sattari, at a distance 12 km from Valpoi. Mharinganachi Rai possesses a stone sculpture depicting the folk deity Mharingan, accompanied by a drum, which is revered by the local community. This area spans approximately or more than 2 hectares and contains elements of a semi-evergreen forest that is enhanced by key tree species, offering essential fruits for birds and a diverse array of biological resources. The grove is encompassed by a coconut plantation, grassland, and a depleted forest found on a lateritic plateau, highlighting the diverse array of vegetation (Gaude & Janarthanam, 2015).

This grove has vegetation good cover of many types of Ficus species like *Ficus benghalensis, Ficus religiosa, Ficus exasperata*, *Ficus racemosa* and *Ficus arnottiana*, most of them are evergreen species. Vegetation here also include tree species such as *Strychnos nux-vomica*, *Hydnocarpus pentandra*, *Mangifera indica, Garcinia indica*, *Holigarna arnottiana*, *Carissa carandas*, *Caryota urens*, *Ziziphus*

rugosa, *Ziziphus oenoplia*, *Clerodendrum infortunatum* and *Ixora coccinea*. Also most of the area is covered by *Chromolaena odorata.*

Figure no.3.2 Devachi Rai of Kopardem, Sattari-Goa

Figure no.3.3 Nirankarachi Rai of Maloli, Sattari-Goa

Figure no.3.4 Mharinganachi Rai of Pissurlem, Sattari-Goa

3.2 Materials and Methods

The study was carried out from August 2023 to March 2024. Present study was conducted at three sacred groves of Sattari Taluka, named Devachi Rai of Kopardem Village, Nirankarachi Rai of Maloli village and Mharinganachi Rai of Pissurlem.

To estimate the bird diversity, Point count method (Bibby et al. 1992; Sashikumar 2004) was used as all the selected sacred groves were less than 3ha. A minimum distance of 50 meters was upheld between each designated point to prevent any potential influence from double counting, ensuring the accuracy and reliability of the data collection process. All avian species encountered, whether seen or heard, were documented three times per month in each grove.

Observations were carried out during Morning (between 7:00 am to 11:00 am) and evening (between 3:00pm to 7:00 pm), as bird activity during these periods is at its peak. Through this systematic methodology, a detailed analysis of the avifauna within the specific groves was conducted to capture interactions of birds in their natural environment. Details such as the species name, the quantity of individual birds observed, the behavior or activity exhibited by the birds, the designated name of the Sacred grove within which they were sighted, as well as the plant name which they are interacting with were documented in the dedicated data sheet throughout the study.

The avian population was classified based on their residency status as resident (R), migratory (M), endemic (E) and threatened species (T). Activities of Bird species recorded during the survey encompassed activities such as foraging, flight, nesting, perching, calling (vocalizations) and body maintenance. The current study categorized

feeding guilds into five broad types, which include carnivores, frugivores, insectivores, omnivores, Nectarivores, Granivores and piscivores.

Monitoring the frequency of behaviors of Malabar Grey Hornbills in locations like sacred groves plays a vital role in understanding their behavioral tendencies and utilization of habitat. Behavioral activities were recorded based on their frequency (Maruyama *et al.,*2009). Frequency of behaviors refers to how often particular actions are carried out by individual animals or groups within a specified timeframe. For calculating frequency of activities Focal sampling method (Wijerathne & Wickramasinghe, 2018) was used. Focal sampling is a technique used in ecology and behavioral ethics to study the behavior of individual animals in a group or population. In focal sampling, an observer selects a specific individual, known as the focal animal, and systematically records its behaviors and interactions over a predetermined period.

For data analysis behavioral activities had broadly grouped into Foraging, flying, resting, body maintenance and calling as shown in table no.3.1 . Behavioral actions were recorded based on their frequency. Frequency often calculated by tallying up the occurrences of each activity. The frequency of each individual activity was summed up and subsequently, the percentage values corresponding to these frequencies were computed.

Sr no.	Activity	Behavioral event
1.	Foraging	Picking or plucking fruit, killing, feeding, holding fruit, searching, regurgitating
2.	Resting	Standing posture, sitting posture, Roosting, Perching
3.	Body maintenance	Preening, Stretching, scratching, bill cleaning, Defecation, sunbathing, head flicks, wing stretching, puffing plumage etc
4.	Locomotion	Hopping, Sliding, Flying, gliding, moving from one branch/tree to other
5.	Calling	Calls, whistling, aggressive calls
6.	Courtship behavior	Touching beaks, feeding each other, allopreening

Table no 3.1 showing different activities exhibited by Malabar Grey Hornbill

Identification of Birds

The birds were identified using binoculars (Celestron Upclose G2, 10x50) and field guides like A Photographic Guide to the Forest Birds of Goa (Parab et al., 2023), Birds of Goa (Grewal & Fonseca, 2015). Pocket guides like Bird Atlas's Common Birds of Goa and Goa's Endemic Birds of the Western Ghats are useful. A photographic guide to the 'Forest birds of Goa' was also useful especially for identification of migratory forest birds (Parab *et al.,*2022).

3.3 Data Analysis

The data thus collected was analyzed using GraphPad Prism 9.0.0 and Microsoft excel. One way anova was used followed by a post hoc Tukey test to compare species of birds across three sacred groves.

A diversity index, such as the Shannon Index or Simpson Index, was also calculated using Microsoft Excel.

The Sorensen Coefficient (Sumaila *et al.,* 2020) was also calculated using formulas to measure the similarity between sites. Sorensen coefficients would indicate the degree of similarity between the bird species compositions of the sacred groves (coefficient closer to 1 indicates a higher similarity & coefficient closer to 0 indicates a lower similarity). By comparing the Sorensen coefficients between all pairs of sacred groves, it was easy to identify which groves have similar bird diversity and which ones differ more significantly.

The comparison of every activity of Malabar grey Hornbill, across each sacred grove was conducted through the implementation of a One-way ANOVA test, followed by post hoc Tukey test. This analysis was beneficial in determining whether there are similarities or differences among activities performed across the three groves. Activities included foraging, resting, body maintenance, locomotion, calling and courtship behavior tested with one way anova.

Correlation test was used to check whether there is any significant correlation between foraging activity and body maintenance activity performed by Malabar grey Hornbill. The Pearson correlation test examines the relationship between two variables to determine if there is a linear correlation between them.

CHAPTER IV

ANALYSIS AND CONCLUSION

4.1 Observations

In the study period of 8 months, from August 2023 to March 2024, a total of 91 species were recorded belonging to 12 Orders and 41 families in selected Sacred Groves of Sattari (table no.4.1). Bird species were recorded in a sacred grove named Devachi Rai of Kopardem village, Nirankarachi Rai from Maloli village and Mharinganachi Rai of Pissurlem village, in Sattari taluka. Out of 91 species recorded, 82 species were resident and 9 Species were migrants, nine species were endemic to Western Ghats and one species was under threatened category. Though there was no significant difference among the sacred groves (F=0.75, P=0.48), the maximum bird species were recorded in Devachi Rai (62 species), followed by Mharinganachi Rai (57 species) and least number of species were found in Nirankarachi Rai (50 species) (Figure no. 4.2). The dominant order was Passeriformes (54 species), followed by Piciformes (9 species) and least was found in Trogoniformes (1 species) (Figure no. 4.1). Dominant family was Muscicapidae with 8 species followed by Nectariniidae with 6 numbers of species. Overall across all three groves, the highest number of species was recorded in the month of January 2024, followed by March 2024 and least in August 2023 (Figure no. 4.6 & 4.7). Maximum number of migratory birds was recorded in January.

Resident birds of Sacred Grove

Out of 91 species recorded, 82 species were resident. Highest number of resident birds was found in Devachi Rai (57 species), followed by Mharinganachi Rai (54 species) and least were found in Nirankarachi Rai (46 species) (Figure no. 4.3). The species that were recorded almost every month were Black Drongo (*Dicrurus*

macrocercus)(figure no.4.16), Asian koel (*Eudynamys scolopaceus)* (Figure no.4.17 & 18) Red whiskered Bulbul (*Pycnonotus jocosus*) (Figure no.4.19), Orange headed Thrush (*Geokichla citrina*) (figure no.4.20), Malabar grey Hornbill (*Ocyceros griseus*)(Figure no.4.21) and Racket tailed Drongo (*Dicrurus paradiseus*)(Figure no. 4.22).

Migratory birds in Sacred Grove

A total of 9 species were identified as migrants namely, Indian Golden Oriole (*Oriolus kundoo*) (Figure no.4.23), Black-naped Oriole (*Oriolus chinensis*), Long-tailed Shrike (*Lanius schach*)(Figure no.4.24), Asian Paradise flycatcher (*Terpsiphone paradisi*)(Figure no.4.25), Grey Wagtail (*Motacilla cinerea*), Green Warbler (*Phylloscopus nitidus*), Brown breasted Flycatcher (*Muscicapa muttui*)(Figure no.4.26), Verditer Flycatcher (*Eumyias thalassinus*) and Blue-throated Flycatcher (*Cyornis rubeculoides*)(Figure no.4.27). Indian Golden Oriole (*Oriolus kundoo*) was the only migratory bird found in all three groves. Maximum number of migratory birds was found in January. Highest number of migratory birds was found in Devachi Rai (5 species), followed by Nirankarachi Rai (4 species) and least in Mharinganachi Rai (3 species) (Figure no. 4.4).

Endemic birds in Sacred groves

A nine bird species endemic to the Western Ghats were documented within the grove, namely Malabar Imperial Pigeon (*Chalcophaps indica*), Malabar Grey Hornbill (*Ocyceros griseus*)(Figure no.4.21), Malabar Flameback (*Chrysocolaptes socialis*) (Figure no.4.28), Malabar Barbet (*Psilopogon malabaricus*) (Figure no.4.29), Malabar

Parakeet (*Psittacula columboides*), Nilgiri Flowerpecker (*Dicaeum concolor*) (Figure no.4.30), Vigors's Sunbird (*Aethopyga vigorsii),* Crimson-backed Sunbird (*Leptocoma minima*) and Flame-throated Bulbul (*Rubigula gularis*) (Figure no.4.31). Highest number of endemic birds was found in Nirankarachi Rai (7 species), Devachi followed by Rai (4 species) and least in Mharinganachi Rai (3 species) (Figure no. 4.5). Most dominant endemic species in all three areas were Malabar grey Hornbill (*Ocyceros griseus*) (Figure no.10) and Crimson-backed Sunbird (*Leptocoma minima*).

Threatened birds in sacred grove

Two birds belonged to the IUCN Red list Categorization of which Malabar Pied Hornbill (*Anthracoceros coronatus*) (Figure no.4.32) belonged to Near Threatened category and Malabar Grey Hornbill (*Ocyceros griseus*) was categorized in Vulnerable Category.

Feeding guild in Sacred Grove

The findings indicated that Sacred groves were dominated by insectivores (41.8%) with 38 species, followed by omnivores (19.8%) with 18 species, followed by frugivores (17.6%) with 16 species, followed by carnivores (11%) with 10 species, followed by nectarivores (6.6%) with 6 species, followed by granivores (2.2%) with 2 species and least were from piscivores (1.1%) with 1 species of Bird (Figure no. 4.8). Highest number of insectivores was recorded in January and the highest number of frugivores was observed in March.

Similarities of species among sacred groves

Total 33 species of birds were common between NR and MR, 44 species were common between MR and DR, 29 bird species were common between MR and NR and 28 species were found in all three groves as shown in Venn diagram (Figure no. 4.9).

Based on this Sorensen coefficient was calculated, results showed that the bird species compositions of DR and MR are more similar to each other (0.37), compared to DR-NR (0.29) and MR-NR (0.27). The bird species compositions of NR and MR are the least similar (0.27) (table no.4.3).One way-anova test for comparing the diversity of bird species across the three sacred groves, showed that there is no significant difference (P=0.4827, F=0.754).

Few common birds found in sacred groves were Rose ringed parakeet (*Psittacula krameri*) (Figure no.4.33), Black rumped flameback (*Dinopium benghalense*) (Figure no.4.34), Blue faced Malkoha (*Phaenicophaeus viridirostris*) (Figure no.4.35), Indian yellow tit (*Machlolophus aplonotus*) (Figure no.4.36), Orange Minivet (*Pericrocotus flammeus*) (Figure no.4.37), Oriental magpie-Robin (*Copsychus saularis*) (Figure no.4.38), Racket tailed drongo (*Dicrurus paradiseus*), Red vented bulbul (*Pycnonotus cafer*) (Figure no.4.39), Rufous Treepie(*Dendrocitta vagabunda*) (Figure no.4.40), Spotted dove(*Spilopelia chinensis*) (Figure no.4.41), Shikra(*Accipiter badius*) (Figure no.4.42), Tickell's Blue flycatcher(*Cyornis tickelliae*) (Figure no.4.43), White throated kingfisher(*Halcyon smyrnensis*) (Figure no.4.44), Puff throated babbler(*Pellorneum ruficeps*) (Figure no.4.45), Indian Pitta(*Pitta brachyura)* (Figure no.4.46), Brown cheeked fulvetta(*Alcippe poioicephala*) (Figure no.4.47), Indian robin(Copsychus fulicatus) (Figure no.4.48), Asian fairy bluebird(*Irena puella*) (Figure no.4.49),

Rufous Woodpecker (*Micropternus brachyurus*), Common Flameback (*Dinopium javanense*) and Brahminy Kite (*Haliastur indus)*.

Devachi Rai of Kopardem

A total of 62 species (Shannon Index=3.78, Simpson Index=0.97, table no.4.2) were recorded belonging to 12 Orders and 33 families. The dominant order was Passeriformes (43 species) and the dominant family was Muscicapidae with 7 species. Out of 62 species recorded in the grove, 57 species were resident, 5 species were migrant and 4 species were endemic to Western Ghats. The highest number of species was recorded in January with 40 species, followed by March with 34 species and least in August with 23 species (Figure no. 4.7).

Five migrant species recorded were Indian Golden Oriole, Black-naped Oriole , Asian Paradise flycatcher , Brown breasted Flycatcher and Green Warbler. Maximum number of migratory birds was found in January. Migratory species that have been frequently observed include the Indian Golden Oriole (*Oriolus kundoo)* and the Brown-breasted Flycatcher. Brown breasted Flycatcher was observed feeding on insects, while Indian Golden Oriole was observed feeding on *Macaranga peltata.*

Four endemic species were recorded namely, Malabar Grey Hornbill (*Ocyceros griseus*), Nilgiri Flowerpecker (*Dicaeum concolor*), Vigors's Sunbird (*Aethopyga vigorsii*) and Crimson-backed Sunbird (*Leptocoma minima*).

The results indicated that Sacred Grove was dominated by insectivores (37.1%) with 23 species, followed by omnivores (21%) with 13 species, and least were from

granivores (3.2%) with 2 species. Maximum number of insectivores was found in post monsoon months (Figure no.4.10).

The Highest number of birds belonging to nectarivorous feeding was observed in this grove, namely Little Spiderhunter (*Arachnothera longirostra*), Purple-rumped Sunbird (*Leptocoma zeylonica*), Purple Sunbird(*Cinnyris asiaticus*), Vigors's Sunbird(*Aethopyga vigorsii*) and Crimson-backed Sunbird (*Leptocoma minima*).

Throughout the study, three dominant bird species found in this grove are the Black Drongo (*Dicrurus macrocercus*), Red-whiskered Bulbul (*Pycnonotus jocosus*), and Malabar Grey Hornbill (*Ocyceros griseus*). Resident species like Malabar Trogon (*Harpactes fasciatus)* (Figure no.4.50) was only found in this grove.

Nirankarachi Rai of Maloli

A total of 50 species (Shannon Index=3.55, Simpson Index=0.96, table no.4.2) were recorded belonging to 11 Orders and 31 families. The dominant order was Passeriformes (32 species) and the dominant family was Muscicapidae with 5 species. Out of 50 species recorded in the grove, 46 were resident, 4 were migrant and 7 were endemic to Western Ghats. The highest number of species was recorded in January with 31 species, followed by February with 27 species and least in September with 16 species (Figure no. 4.7).

Migrant species recorded were Indian Golden Oriole (*Oriolus kundoo*), Asian Paradise flycatcher (*Terpsiphone paradisi*), Grey Wagtail (*Motacilla cinerea*) and Verditer Flycatcher (*Eumyias thalassinus)*. The migratory species that has been

documented on more than two occasions was the Asian Paradise flycatcher (*Terpsiphone paradisi)*. Maximum number of migratory birds was found in January.

Seven endemic species were recorded namely, Malabar Imperial Pigeon (*Chalcophaps indica*), Malabar Grey Hornbill (*Ocyceros griseus*), Malabar Flameback (*Chrysocolaptes socialis*), Malabar Barbet (*Psilopogon malabaricus*), Malabar Parakeet (*Psittacula columboides*), Crimson-backed Sunbird (*Leptocoma minima*) and Flame-throated Bulbul (*Rubigula gularis*). The endemic species most commonly observed in this particular grove included the Malabar Grey Hornbill (*Ocyceros griseus*) and the Flame-throated Bulbul (*Rubigula gularis*). Rarely observed endemic species included the Malabar Imperial Pigeon (*Chalcophaps indica*) and the Malabar Parakeet (*Psittacula columboides).*

The Flame-throated Bulbul was exclusively spotted in this particular grove, often in pairs or in the company of other bulbuls such as the Yellow Bulbul and Red-vented Bulbul, primarily feeding on insects, and fruits like *Ficus racemosa.*

Crimson-backed Sunbird is mostly seen feeding on *Melastoma malabathricum* and *Moullava spicata.* Malabar Imperial Pigeon sighted very few times, mostly attracted towards groves for feeding on *Caryota urens.*

The results indicated that Sacred Grove was dominated by insectivores (45.5%) with 20 species, followed by frugivores (20.9%) with 9 species and least were from piscivores (2.2%) with one species. The only piscivore species observed was Common Kingfisher (*Alcedo atthis*) (Figure no.4.10). Maximum number of insectivores was found in post monsoon months. Resident species like Ashy Woodswallow (*Artamus fuscus)*(Figure no.4.52) and Chestnut headed bee-eater (*Merops leschenaulti)*(Figure no.4.53) were observed only in this Grove.

Throughout the study, four dominant bird species found in this grove are the Black Drongo (*Dicrurus macrocercus*), Malabar Pied Hornbill (*Anthracoceros coronatus*) and Yellow browed bulbul (4.51).

Mharinganachi Rai of Pissurlem

A total of 57 species (Shannon Index=3.73, Simpson Index=0.97, table no.4.2) were recorded belonging to 11 Orders and 32 families. The dominant order was Passeriformes (37 species) and the dominant family were Nectariniidae, Pycnonotidae, Muscicapidae with 4 numbers of species. Out of 57 species recorded in the grove, 54 species were resident, 3 species were migrant and 3 species were endemic to Western Ghats. The highest number of species was recorded in March with 39 species, followed by February with 35 species and least in August with 21 species (Figure no. 4.7).

Three migrant species recorded were Indian Golden Oriole (*Oriolus kundoo*), Long-tailed Shrike (*Lanius schach*) and Blue-throated Flycatcher (*Cyornis rubeculoides*). The migratory species has been documented on more than two occasions: Indian Golden Oriole (*Oriolus kundoo*) and Blue-throated Flycatcher (*Cyornis rubeculoides*). Maximum number of migratory birds was found in February and March. Blue-throated Flycatcher was observed more than 2 times in this grove, predominantly observed engaging in the consumption of insects.

Three endemic species were recorded namely, Malabar Grey Hornbill (*Ocyceros griseus*), Crimson-backed Sunbird (*Leptocoma minima*) and Nilgiri Flowerpecker (*Dicaeum concolor*). The endemic species most commonly observed in this particular

grove included the Malabar Grey Hornbill (*Ocyceros griseus*) and Crimson-backed Sunbird (*Leptocoma minima*).

The results indicated that Sacred Grove was dominated by insectivores (29.8%) with 17 species, followed by frugivores (21.1%) with 12 species and least was from granivores (3.5%) with 2 species (Figure no.4.10). Maximum number of frugivore species was recorded in March.

Few frequently observed frugivores species were Thick-billed Flowerpecker (*Dicaeum agile*)(Figure no.4.54), Indian Golden Oriole (*Oriolus kundoo*), Coppersmith Barbet (*Psilopogon haemacephalus*) (Figure no.4.55), White-cheeked Barbet (*Psilopogon viridis*), Brown-headed Barbet (*Psilopogon zeylanicus*) (Figure no.4.56). Insectivores species like Spot-breasted Fantail (Figure no.4.57) were recorded only in this grove and mostly seen foraging. Birds like Jungle Babblers (Figure no.4.58), Jungle Mynas (Figure no.4.59), Red vented Bulbul, Asian Koel, Black hooded Oriole(Figure no.4.60), Common Myna (Figure no.4.61) and Red whiskered Bulbul were mostly seen feeding on *Ziziphus oenopolia* (Figure no.4.62) and *Ficus exasperata*.

Throughout the study, four dominant bird species found in this grove are the Black Drongo (*Dicrurus macrocercus*), Malabar Grey Hornbill (*Ocyceros griseus*), Red-whiskered Bulbul (*Pycnonotus jocosus*) and Malabar Pied Hornbill (*Anthracoceros coronatus*).

Behavioral activities of Malabar Grey Hornbill (*Ocyceros griseus*) in sacred groves.

A total of 18 individuals of Malabar Grey Hornbills were seen in Devachi rai of Kopardem. Highest activity performed was resting (25.4%) (Figure no.4.63), followed by foraging (21.6%), followed by body maintenance (18.3%), followed by calling (17.8%), followed by locomotion (14.1%) and least activity noted was courtship behavior (2.8%) (Figure no.4.11).

A total of 17 individuals of Malabar Grey Hornbills were seen in Nirankarachi rai of Maloli. Highest activity performed was resting (27.8%) (Figure no.4.64), followed by foraging (19.7%), followed by calling (19.3%), followed by body maintenance (17.9%), followed by locomotion (14.8%) and least activity noted was courtship behavior (0.4%) (Figure no.4.12).

A total of 20 individuals of Malabar Grey Hornbills were seen in Mharinganachi rai of Pissurlem. Highest activity performed was foraging (27.8%), followed by body maintenance (19.7%), followed by calling (18.9%), followed by resting (18.1%) (Figure no.4.65), followed by locomotion (12.0%) and least activity noted was courtship behavior (3.5%) (Figure no.4.13).

One-way ANOVA results showed that there is a significant difference in foraging behavior among the three sacred groves (P=0.0016, F=14.21) (figure no.4.14.a). Tukey's multiple comparisons test showed that there was no significant difference in foraging behavior between the sacred grove "DR" and "NR" (P=0.7945). Conversely, there was a significant difference in foraging behavior between the "DR" and "MR" (P=0.0054). There was also a significant difference in foraging behavior between the "NR" and "MR" sacred grove (P=0.0022). The correlation test examined the

relationship between foraging activity and body maintenance activity and the result indicated a strong positive linear relationship between the two variables (r=0.8779, P= 0.0002) (Figure no.4.15).

.One-way ANOVA for resting behavior across groves demonstrated that there was a significant difference in resting behavior among the three different sacred groves (P=0.0082, F=8.593) (figure no.4.14.b). Tukey's multiple comparisons test showed that there was no significant difference in resting behavior between the "DR" and "NR" (P=0.1228) sacred grove, similarly there was no significant difference in resting behavior between the "DR" and "MR" grove (P=0.1850). But there was a significant difference in resting behavior between the "NR" and "MR" grove (P=0.0064), demonstrating a significant distinction in resting behavior between these two groves.

About locomotion activity, One-way ANOVA results showed there was no significant difference in locomotion activity among the different locations within sacred groves (P=0.7965, F=0.2333) (figure no.4.14.c). Also there was no significant difference in calling activity among the three different sacred groves (P=0.3067., F=1.351) (figure no.4.14.d).

Similarly, after performing a one-way ANOVA test for body maintenance activity showed that there was significant difference in body maintenance activity among the different three sacred groves (P=0.0412, F=4.640) (figure no.4.14.e). Tukey's multiple comparisons test indicated that there was no significant difference in body maintenance activity between the "DR" and "NR" (P=0.9717) and "NR" and "MR" (P=0.0768). Conversely, there was a significant difference in body maintenance activity between the "DR" and "MR" sacred grove (P=0.0538). Body maintenance

activity included acts like Preening, Stretching, scratching, bill cleaning, Defecation, sunbathing, head flicks, wing stretching, puffing plumage etc. and most of this activities were observed soon after foraging, especially bill cleaning is a necessary activity after a feeding session, where the bird rubs its beak against a tree branch to remove food particles or debris (Figure no.4.66 & 4.67). The correlation test examined the relationship between foraging activity and body maintenance activity and the result indicated a strong positive linear relationship between the two variables (r=0.8779, P= 0.0002) (figure no.4.15).

Lastly for courtship behavior, both the one-way ANOVA test (P=0.3647, F=1.131)(figure no.4.14.f) indicate that there are no significant differences in courtship behavior activity among the three sacred groves.

Sr No	Order/Family/Species	Common name	Konkani names	DR	NR	MR	R/M	IUCN status	Endemic	Feeding habit
	Ciconiiformes:Ardeidae									
1	*Bubulcus ibis*	Cattle Egret	गोरवा बळार			+	R	LC	-	C
2	*Ardeola grayii*	Indian Pond Heron	बके		+		R	LC	-	C
	Galliformes : Phasianidae									
3	*Pavo cristatus*	Indian Peafowl	मोर	+		+	R	LC	-	O
4	*Galloperdix spadicea*	Red spurfowl	कोकतारें			+	R	LC	-	O
	Columbiformes: Columbidae									
5	*Columba livia*	Blue rock Pegion	पारवो	+		+	R	LC	-	G
6	*Spilopelia chinensis*	Spotted Dove	कवडो	+		+	R	LC	-	G
7	*Chalcophaps indica*	Malabar Imperial Pigeon	खवण		+		R	LC	E	F
	Cuculiformes: Cuculidae									
8	*Centropus sinensis*	Greater coucal	कुमात्तर	+		+	R	LC	-	O
9	*Phaenicophaeus viridirostris*	Blue-faced malkoha	निळ्या डोळ्याचो	+		+	R	LC	-	O
10	*Eudynamys scolopaceus*	Asian koel	कोगुळ, कोकीळ	+	+	+	R	LC	-	F
11	*Cacomantis sonneratii*	Banded bay Cuckoo	पट्या कोगुळ		+		R	LC	-	I
	Accipitriformes:Accipitridae									
12	*Haliastur indus*	Brahminy Kite	तांबशी घोण	+	+	+	R	LC	-	C
13	*Spilornis cheela*	Crested serpent Eagle	मोरायलो, हारें	+	+		R	LC	-	C
14	*Milvus migrans*	Black kite	घोण	+	+	+	R	LC	-	C
15	*Accipiter badius*	Shikra	गीदगे	+			R	LC	-	C
	Strigiformes:Strigidae									
16	*Glaucidium radiatum*	Jungle Owlet	नातूक , रानघुगे	+		+	R	LC	-	C

17	*Strix leptogrammica*	Brown Wood Owl	घुगे	+			R	LC	-	C
	Trogoniformes:Trogonidae									
18	*Harpactes fasciatus*	Malabar Trogon	कर्णो	+			R	LC	-	I
	Bucerotiformes: Bucerotidae									
19	*Ocyceros griseus*	Malabar Grey Hornbill	गोव्री/शेळ्या वायरें	+	+	+	R	VU	E	F
20	*Anthracoceros coronatus*	Malabar Pied Hornbill	वायरें, गुड्इ्वायरें	+	+	+	R	NT	-	F
	Piciformes: Picidae									
21	*Dinopium javanense*	Common Flameback	रानातलो पाडेली	+		+	R	LC	-	I
22	*Micropternus brachyurus*	Rufous Woodpecker	मेस्त	+	+	+	R	LC	-	I
23	*Dinopium benghalense*	Black-rumped Flameback	पाडेली			+	R	LC	-	I
24	*Chrysocolaptes socialis*	Malabar flameback	खोटखोटो		+		R	LC	E	I
25	*Picumnus innominatus*	Speckled Piculet	पिटकुलो मेस्तुलो		+		R	LC	-	I
	:Megalaimidae									
26	*Psilopogon haemacephalus*	Coppersmith Barbet	कुटूरगो, कांसार	+	+	+	R	LC	-	F
27	*Psilopogon viridis*	White-cheeked Barbet	कुटूरगो	+		+	R	LC	-	F
28	*Psilopogon malabaricus*	Malabar Barbet	आंबाडगो, ठुकठुको		+		R	LC	E	F
29	*Psilopogon zeylanicus*	Brown-headed Barbet	रान कुटुर्गो, कुटुंबो	+		+	R	LC	-	F
	Coraciiformes: Meropidae									
30	*Merops orientalis*	Asian green Bee-eater	पाचवी पत्ताकिल्ली	+	+		R	LC	-	I
31	*Merops leschenaulti*	Chestnut-headed Bee-eater	पत्ताकिल्ली ,किरांटी		+		R	LC	-	I
	:Coraciidae									
32	*Coracias benghalensis*	Indian Roller	ताडो			+	R	LC	-	C
	: Alcedinidae									

33	*Halcyon smyrnensis*	White-throated Kingfisher	किरकिरो	+	+	+	R	LC	-	C
34	*Alcedo atthis*	Common Kingfisher	चिटो		+		R	LC	-	P
	Psittaciformes: Psittaculidae									
35	*Psittacula krameri*	Rose-ringed Parakeet	कीर	+		+	R	LC	-	F
36	*Psittacula columboides*	Malabar Parakeet	रान कीर		+		R	LC	E	F
37	*Loriculus vernalis*	Vernal Hanging Parrot	किरांटी, किरांटो			+	R	LC	-	F
	Passeriformes: Pittidae									
38	*Pitta brachyura*	Indian Pitta	नवरंग	+			R	LC	-	I
	:Campephagidae									
39	*Pericrocotus cinnamomeus*	Small Minivet	धाकले शेंदरें	+	+	+	R	LC	-	I
40	*Pericrocotus flammeus*	Orange Minivet	व्हडले शेंदरें	+	+		R	LC	-	I
	:Oriolidae									
41	*Oriolus xanthornus*	Black-hooded Oriole	तामुसो, हळदुळो	+	+	+	R	LC	-	O
42	*Oriolus kundoo*	Indian Golden Oriole	सोन हळदुवो	+	+	+	M	LC	-	F
43	Oriolus chinensis	Black-naped Oriole	हडवो	+			M	LC	-	F
	:Artamidae									
44	*Artamus fuscus*	Ashy woodswallow	रान पाकोळी		+		R	LC	-	I
	:Aegithinidae									
45	*Aegithina tiphia*	Common Iora	सोनयाळे	+	+		R	LC	-	I
	:Dicruridae									
46	*Dicrurus macrocercus*	Black Drongo	खाप्री किरकावळो	+	+	+	R	LC	-	I
47	*Dicrurus paradiseus*	Racket tailed Drongo	कारागोळ, काळेर	+	+	+	R	LC	-	I
48	*Dicrurus aeneus*	Bronzed Drongo	काशे काटको	+			R		-	I

	:Rhipiduridae									
49	*Rhipidura albogularis*	Spot-breasted Fantail	-			+	R	LC	-	I
	:Laniidae									
50	*Lanius schach*	Long-tailed Shrike	कसाय			+	M	LC	-	I
	:Corvidae									
51	*Dendrocitta vagabunda*	Rufous Treepie	सोनकावळो	+		+	R	LC	-	O
52	*Corvus macrorhynchos*	Large-billed Crow	सोनकावळो	+	+	+	R	LC	-	O
53	*Corvus splendens*	House Crow	कावळो	+	+	+	R	LC	-	O
	:Monarchidae									
54	*Terpsiphone paradisi*	Asian Paradise flycatcher (B)	पाद्री, पिटकोळेचो कोमो	+	+		M	LC	-	I
	:Dicaeidae									
55	*Dicaeum agile*	Thick-billed Flowerpecker	किटुर, चुकचुकें	+	+	+	R	LC	-	F
56	*Dicaeum concolor*	Nilgiri Flowerpecker	किटुर, चुकचुकें	+		+	R	LC	E	F
	:Alcippeidae									
57	*Alcippe poioicephala*	Brown-cheeked fulvetta	तपकिरी पत्री	+			R	LC	-	I
	:Nectariniidae									
58	*Arachnothera longirostra*	Little Spiderhunter	नळें, बोणयाळे	+	+	+	R	LC	-	N
59	*Leptocoma zeylonica*	Purple-rumped Sunbird	पिचपिचें चिरकें	+		+	R	LC	-	N
60	*Cinnyris asiaticus*	Purple Sunbird	जांभळे चिरकें	+	+	+	R	LC	-	N
61	*Aethopyga vigorsii*	Vigors's Sunbird	तांबडे पिचपीचे	+			R	LC	E	N
62	*Leptocoma minima*	Crimson-backed Sunbird	झेटुक, पिचपीचे	+	+	+	R	LC	E	N
63	*Cinnyris lotenius*	Loten's Sunbird	काळुंदर		+		R	LC	-	N
	:Irenidae									

64	*Irena puella*	Asian Fairy-bluebird	निळाक्सो	+		+	R	LC	-	F
65	*Chloropsis aurifrons*	Golden-fronted Leafbird	हरयाटें, पाचवो, तिरुली		+		R	LC	-	O
66	*Chloropsis jerdoni*	Jerdon's Leafbird	हरयाटें, पाचवो	+		+	R	LC	-	O
	:Motacillidae									
67	*Motacilla cinerea*	Grey Wagtail	गोब्रें पिटपीटें		+		M	LC	-	I
	:Paridae									
68	*Machlolophus aplonotus*	Indian yellow Tit	गुजूलें	+	+	+	R	LC	-	I
	:Cisticolidae									
69	Prinia socialis	Ashy Prinia	गोबरे शेटुक	+			R	LC	-	I
70	*Prinia hodgsonii*	Grey-breasted Prinia	धाकलें शेटुक			+	R		-	I
71	*Orthotomus sutorius*	Common Tailorbird	किटूर	+	+	+	R	LC	-	I
	:Phylloscopidae									
72	Phylloscopus nitidus	Green Warbler	चिरपुटें	+			M	LC	-	I
	:Hirundinidae									
73	*Hirundo smithii*	Wire-tailed swallow	काट्याळें			+	R	LC	-	I
	:Pycnonotidae									
74	*Pycnonotus jocosus*	Red whiskered Bulbul	पाखली पीटकोळी	+	+	+	R	LC	-	O
75	*Pycnonotus cafer*	Red vented Bulbul	खाप्री पीटकोळी	+	+	+	R	LC	-	O
76	*Acritillas indica*	Yellow-browed Bulbul	हळदुवी पीटकोळी		+	+	R	LC	-	O
77	*Rubigula gularis*	Flame-throated Bulbul	रान पीटकोळी		+		R	LC	E	O
	:Pellorneidae									
78	*Pellorneum ruficeps*	Puff-throated Babbler	शेळोणी प्रत्री			+	R	LC	-	I

	:Leiothrichidae										
79	*Argya striata*	Jungle Babbler	बजबजे	+	+	+	**R**	LC	-		**O**
	:Sittidae										
80	*Sitta frontalis*	Velvet-fronted Nuthatch	विल्वट सरकोटो		+		**R**	LC	-		**I**
	:Sturnidae										
81	*Acridotheres fuscus*	Jungle Myna	वक्ला साळोरी	+	+	+	**R**	LC	-		**O**
82	*Acridotheres tristis*	Common Myna	रान साळोरी			+	**R**	LC	-		**O**
	:Muscicapidae										
83	*Copsychus saularis*	Oriental magpie-Robin	मडवळ	+	+	+	**R**	LC	-		**I**
84	Copsychus fulicatus	Indian Robin	कांटाकोय	+		+	**R**	LC	-		**I**
85	*Copsychus malabaricus*	White-rumped Shama	शेळोणी, शम्मा	+	+	+	**R**	LC	-		**I**
86	*Cyornis tickelliae*	Tickell's Blue flycatcher	निळे इटकुलें	+			**R**	LC	-		**I**
87	*Muscicapa muttui*	Brown breasted Flycatcher	तपकिरी इटकुलें	+			**M**	LC	-		**I**
88	*Myophonus horsfieldii*	Malabar Whistling Thrush	पान कावळो, शिळो	+			**R**	LC	-		**I**
89	*Eumyias thalassinus*	Verditer Flycatcher	इटकुलें		+		**M**	LC	-		**I**
90	*Cyornis rubeculoides*	Blue-throated Flycatcher	धट्या पोटाचे इटकुलें			+	**M**	LC			**I**
	:Turdidae										
91	*Geokichla citrina*	Orange headed Thrush	मुसाजी, कस्तुर	+	+	+	**R**	LC	-		**O**

Table no. 4.1 Checklist of birds found in three selected sacred groves

Diversity indices	DR	NR	MR
Shannon Index	3.78	3.55	3.73
Simpson Index	0.97	0.96	0.97

Table no. 4.2 Comparison of bird diversity index in selected sacred groves

.

Sr no	Sacred groves	Sorensen Coefficient
1	DR-NR	0.29
2	MR-DR	0.37
3	MR-NR	0.27

Table no. 4.3 Calculated Sorensen Coefficient to show similarities among sacred groves

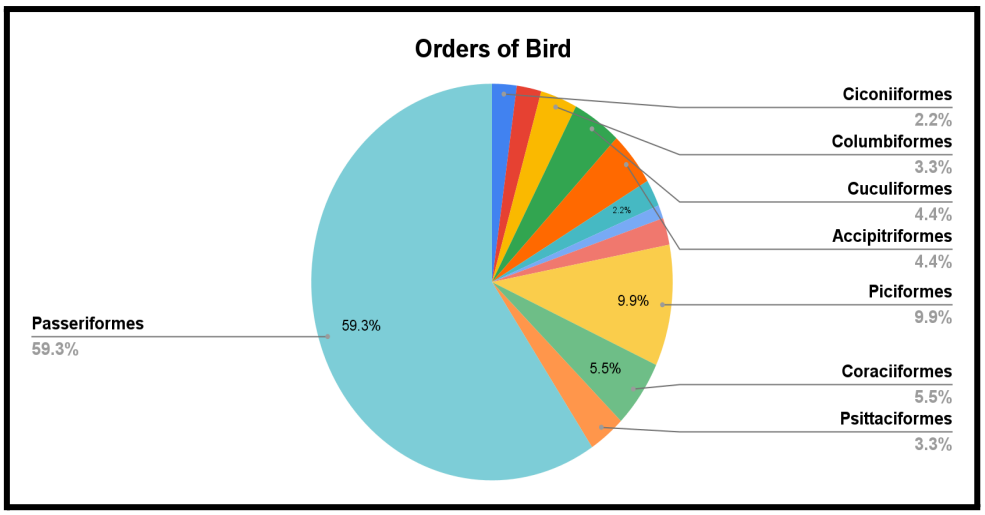


Figure no.4.1 Pie chart showing the percentage of orders of birds

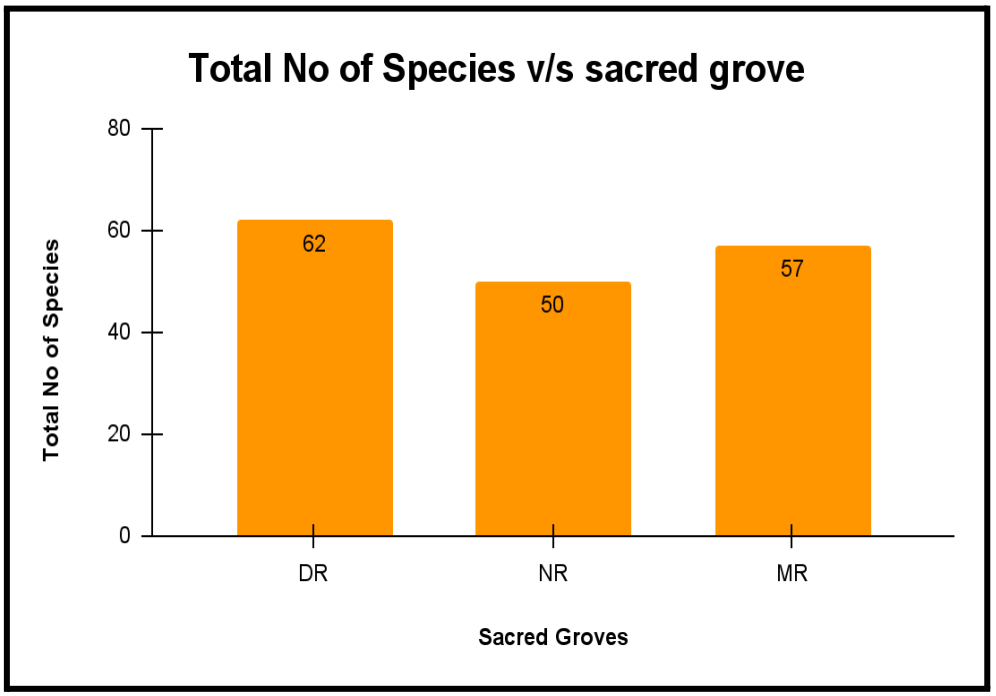


Figure no.4.2 Graph showing total bird Species found in each Sacred Groves

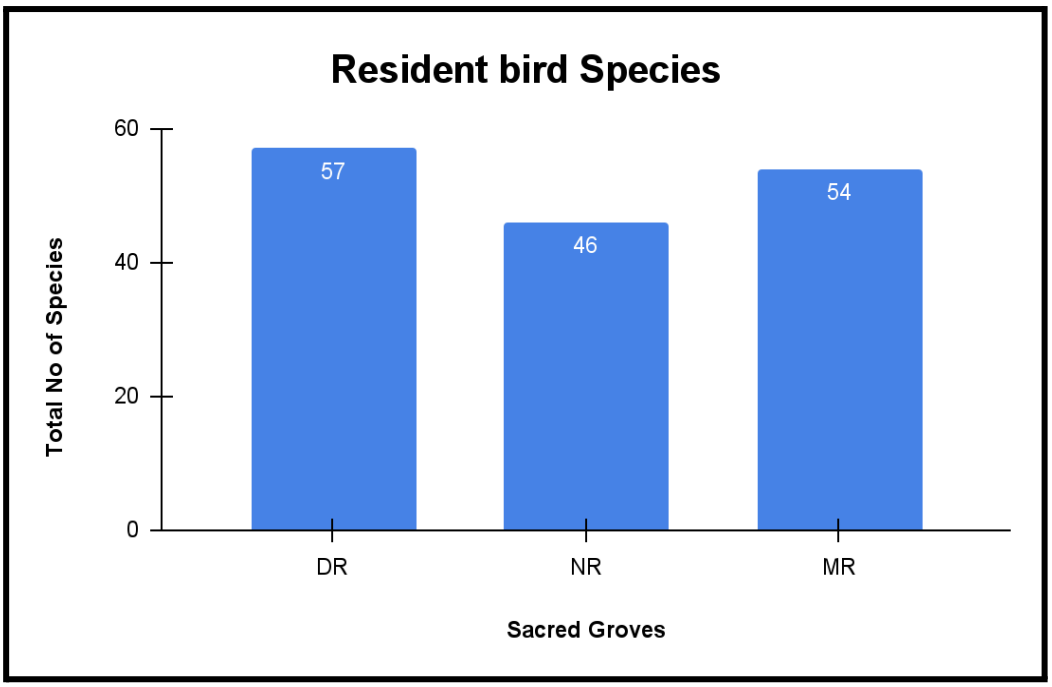


Figure no.4.3 Graph showing total no of resident bird Species found in each Sacred Groves

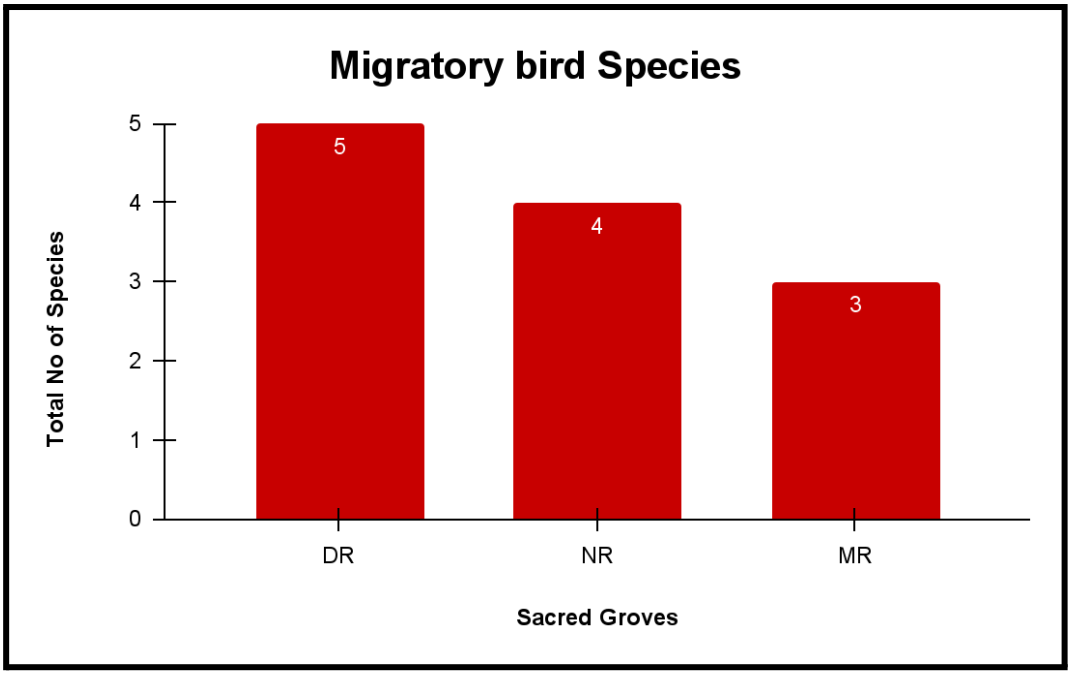


Figure no. 4.4 Graph showing total no of Migratory bird Species found in each Sacred Groves

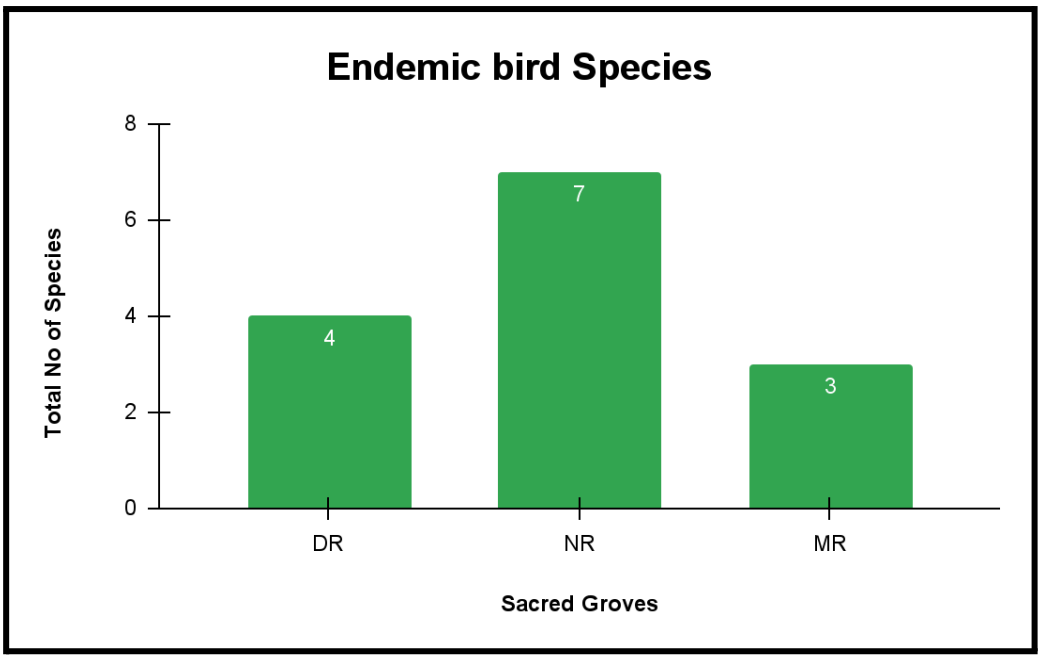


Figure no.4.5 Graph showing total no of Endemic bird Species found in each Sacred Groves

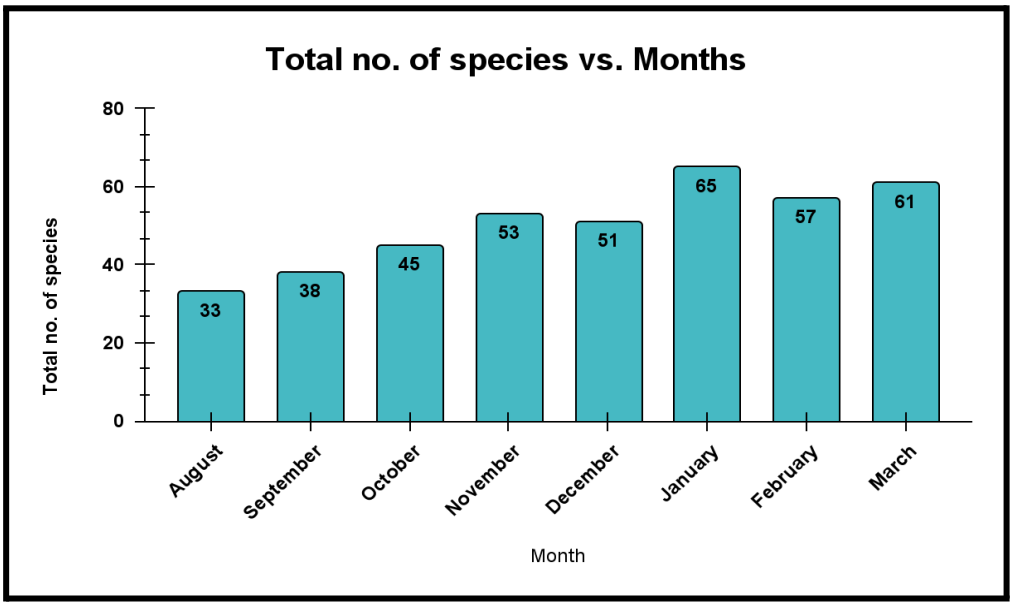


Figure no.4.6 Graph showing monthly variation in total number of species

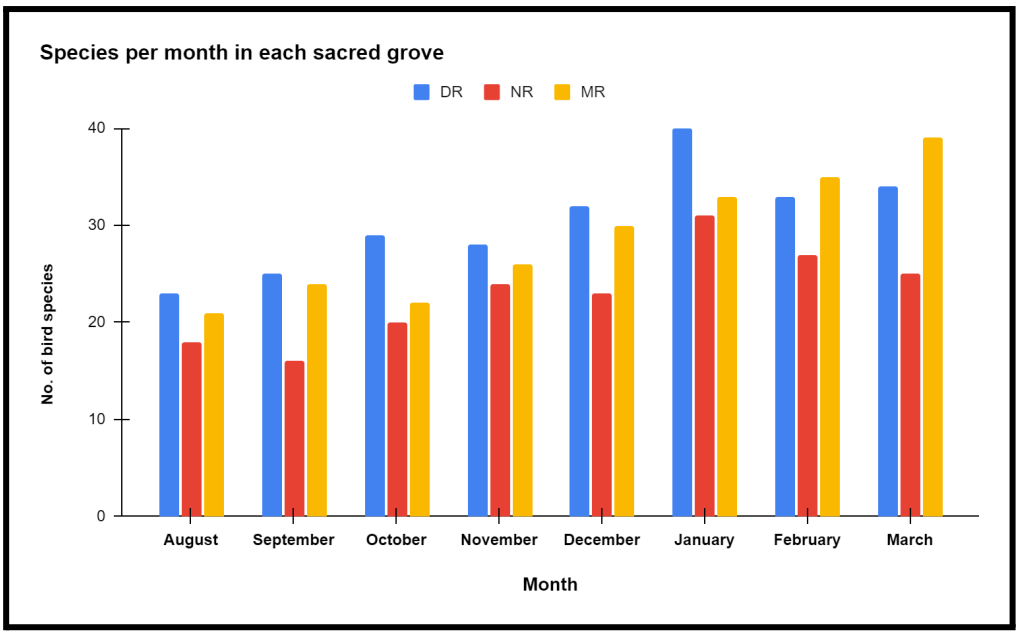


Figure no.4.7 Bar graph showing number of species found per month in each sacred grove

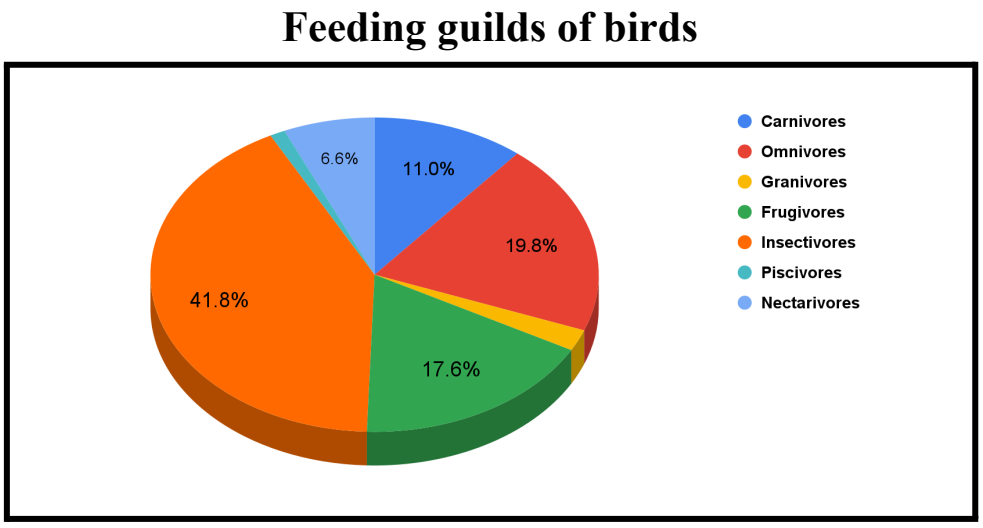


Figure no.4.8 Pie chart showing feeding guilds of birds

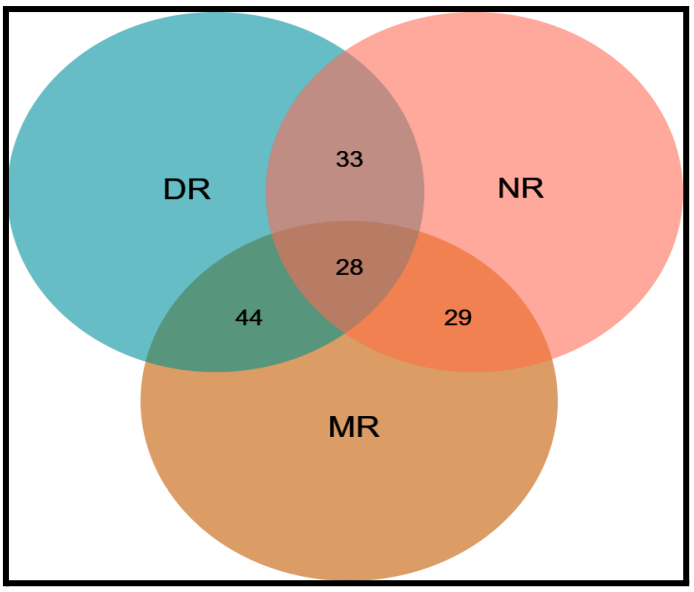


Figure no.4.9 Venn Diagram showing feeding guilds of birds

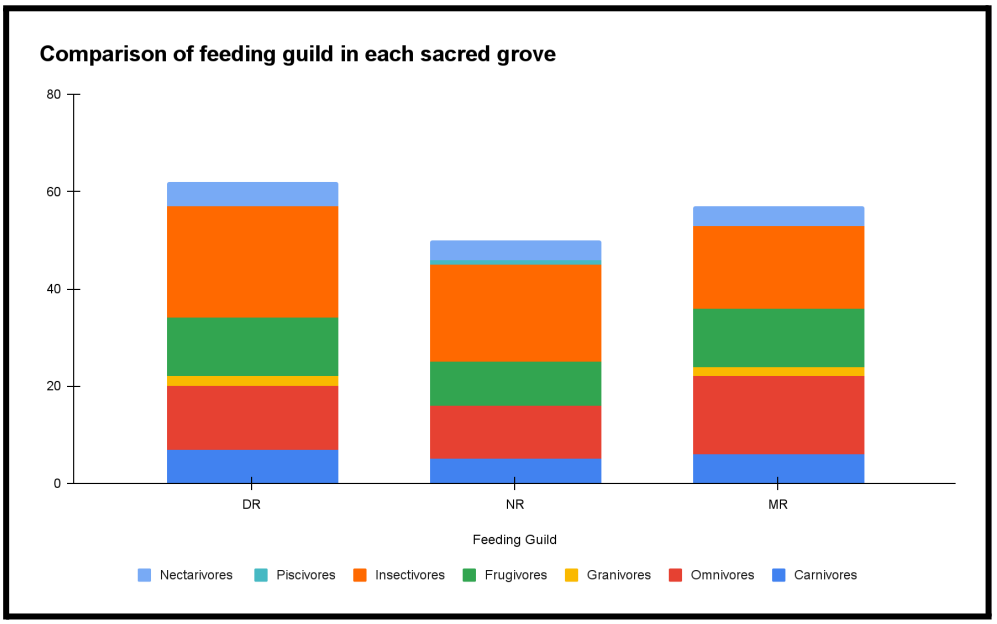


Figure no.4.10 Bar graph showing comparative feeding guilds in each sacred groove

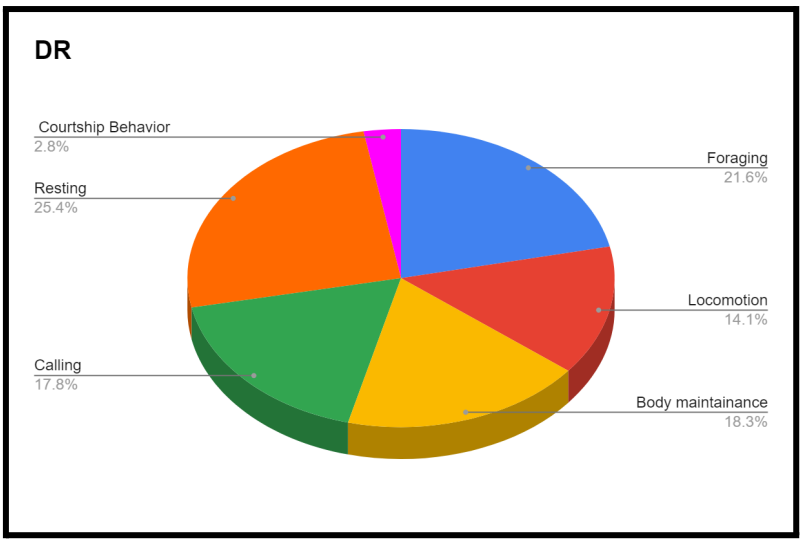


Figure no.4.11 Pie chart showing % of activity performed by Malabar grey Hornbill in DR

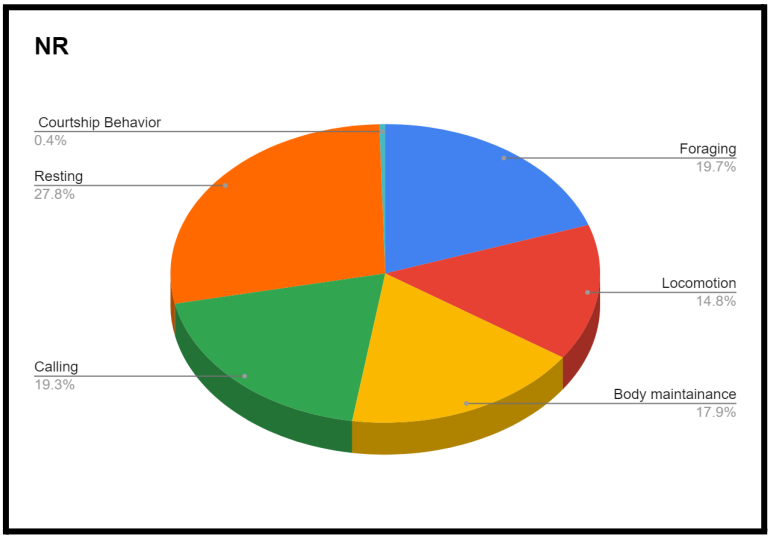


Figure no.4.12 Pie chart showing % of activity performed by Malabar grey Hornbill in NR

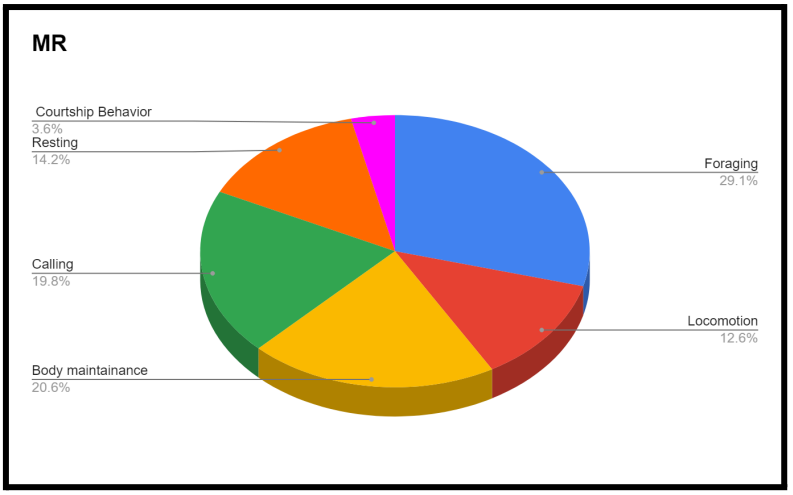
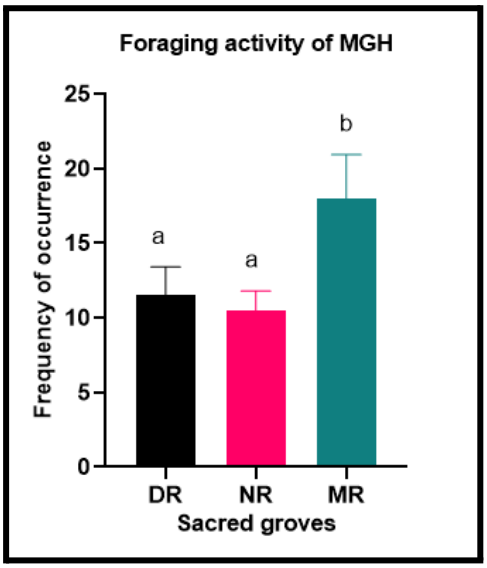
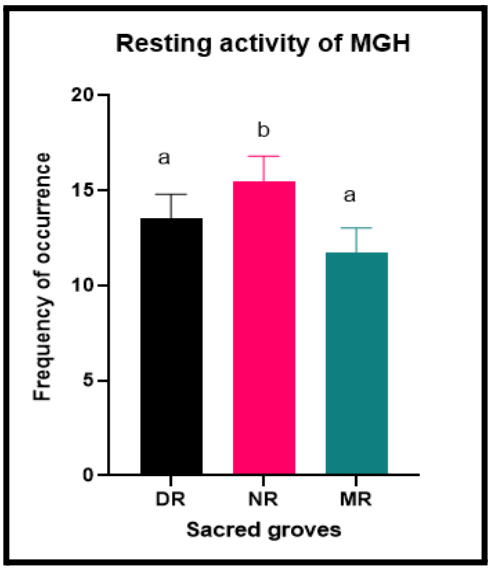
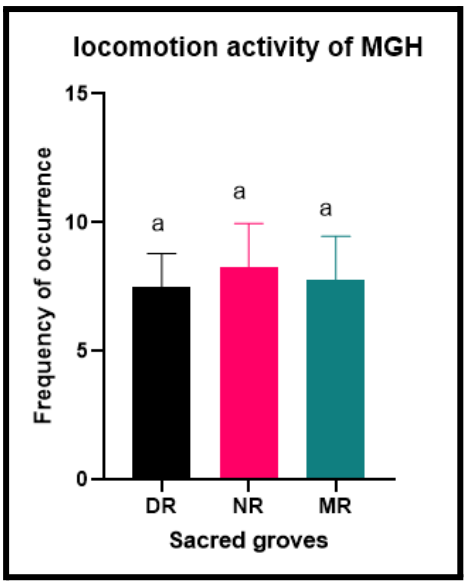


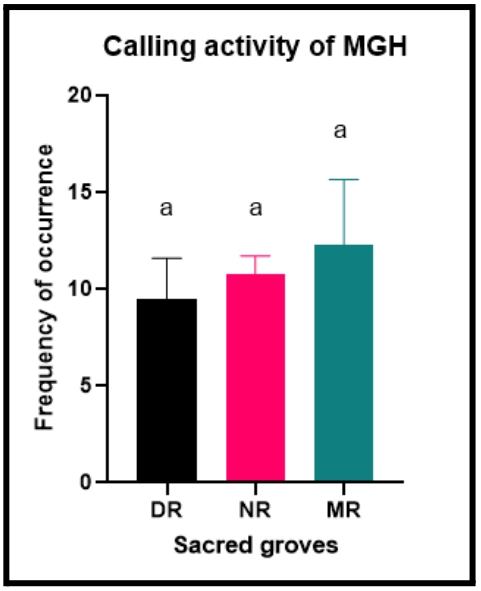
Figure no.4.13 Pie chart showing % of activity performed by Malabar grey Hornbill in MR



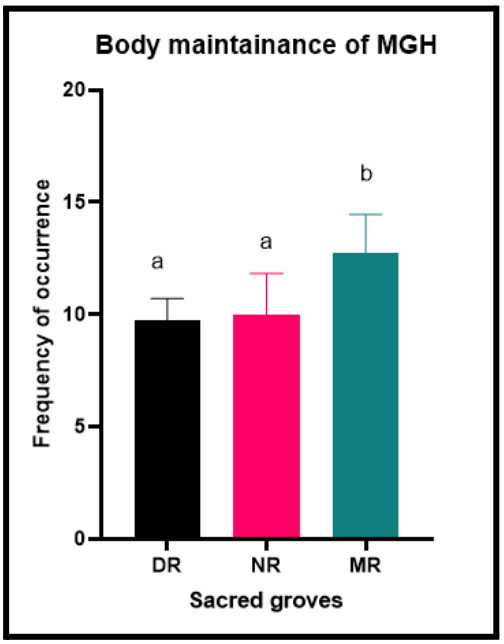


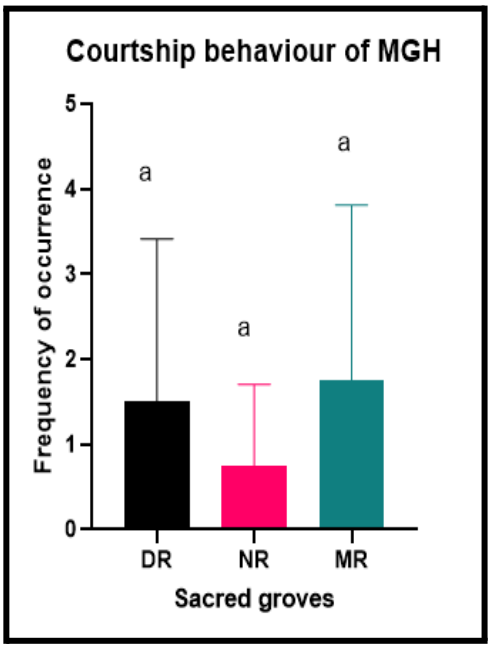
a **b**





c **d**





e **f**

Figure no. 4.14 Graph a, b, c, d, e, f showing comparison of each activity across three groves

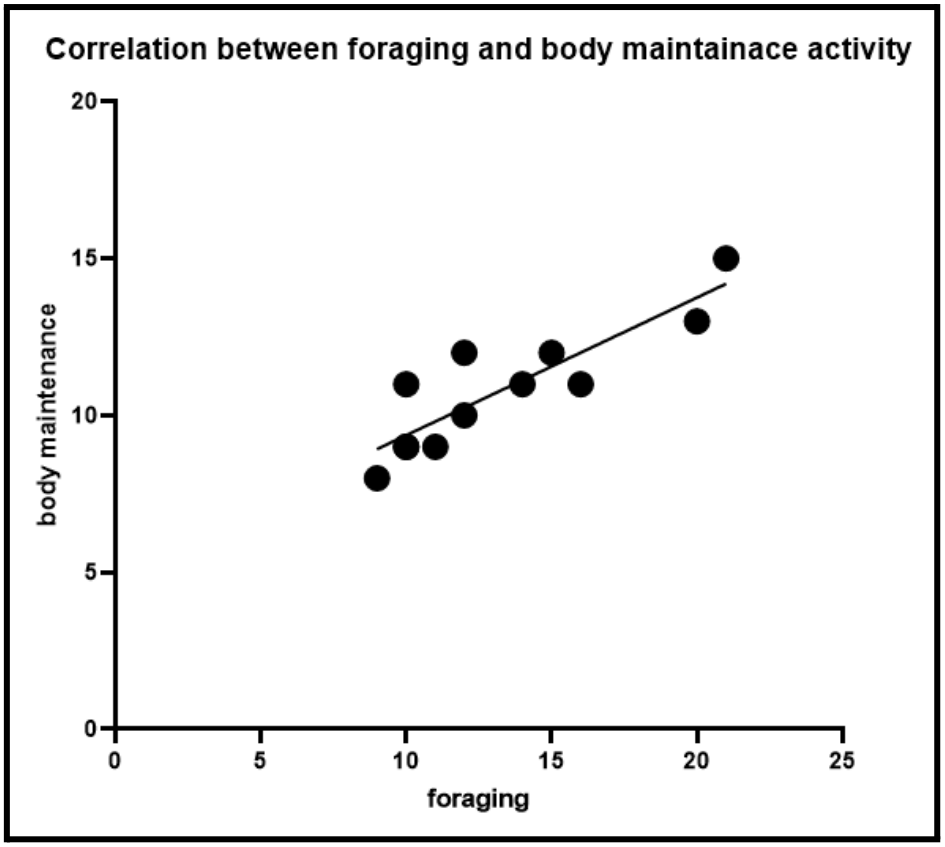


Figure no. 4.15 Graph showing correlation between foraging and body maintenance activity

Figure no. 4.16 Black Drongo

Figure no. 4.17 Asian koel (Male)

Figure no.4.18 Asian koel (Female)

Figure no.4.19 Red Whiskered Bulbul

Figure no. 4.20 Orange headed Thrush

Figure no.4.21 Malabar Grey Hornbill

Figure no.4.22 Racket tailed Drongo

Figure no. 4.23 Indian Golden Oriole

Figure no. 4.24 Long-tailed Shrike

Figure no. 4.25 Asian Paradise flycatcher

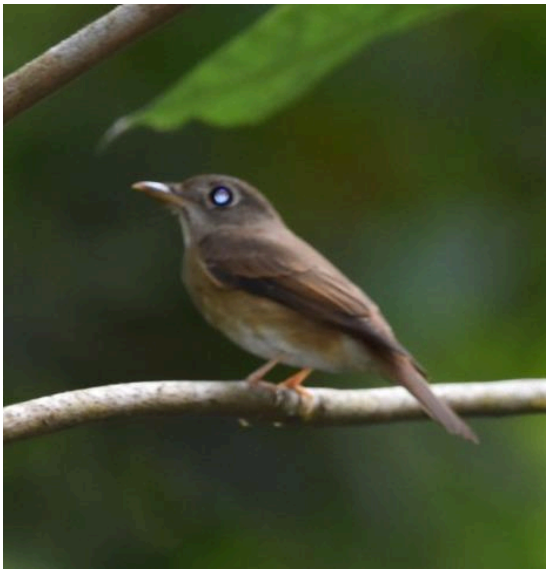


Figure no.4.26 Brown breasted Flycatcher

Figure no.4.27 Blue-throated Flycatcher

Figure no.4.28 Malabar Flameback

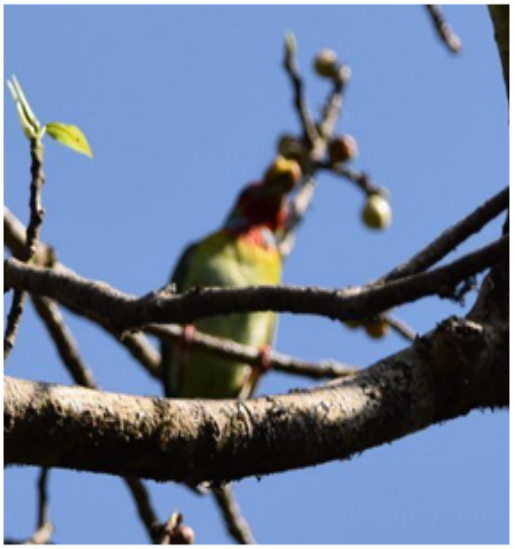


Figure no.4.29 Malabar Barbet

Figure no.4.30 Nilgiri Flowerpecker

Figure no. 4.31 Flame-throated Bulbul

Figure no.4.32 Malabar Pied Hornbill

Figure no.4.33 Rose ringed Parakeet

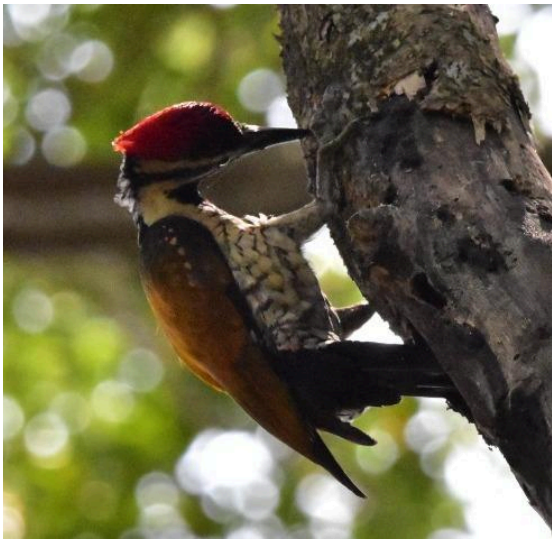


Figure no.4.34 Black-rumped Flameback

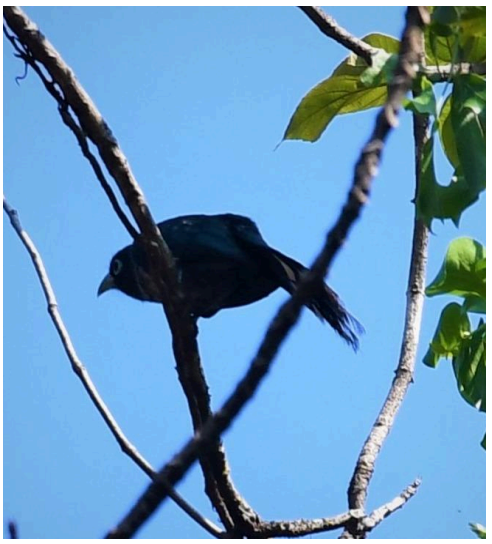


Figure no.4.35 Blue faced Malkoha

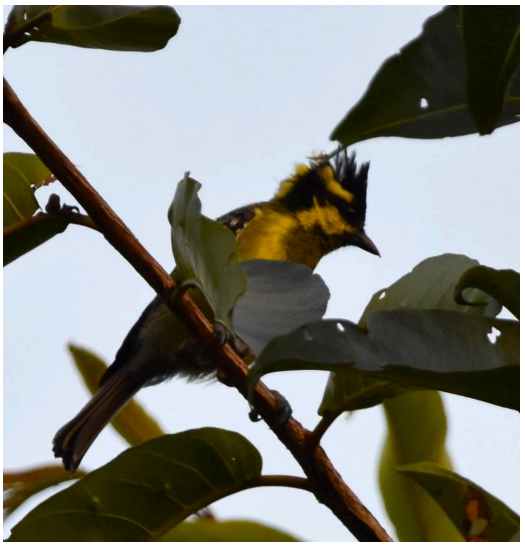


Figure no.4.36 Indian yellow Tit

Figure no.4.37 Orange minivet

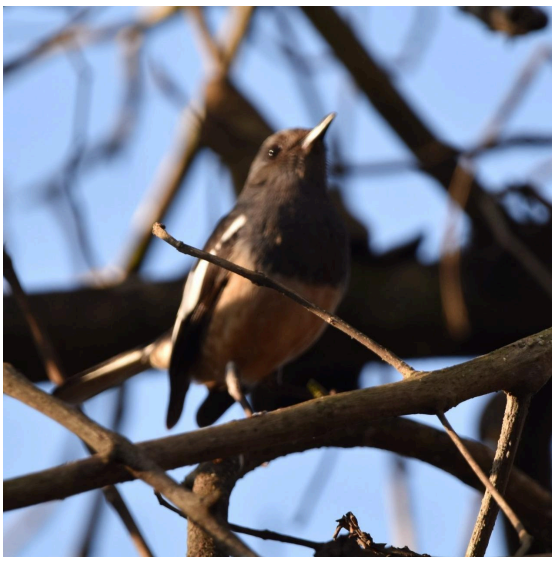


Figure no.4.38 Oriental magpie-Robin

Figure no.4.39 Red vented Bulbul

Figure no.4.40 Rufous Treepie

Figure no.4.41 Spotted Dove

Figure no 4.42 Shikra

Figure no.4.43 Tickell's blue Flycatcher

Figure no.4.44 White throated Kingfisher

Figure no.4.45 Puff-throated Babbler

Figure no.4.46 Indian Pitta

Figure no.4.47 Brown-cheeked fulvetta

Figure no.4.48 Indian Robin

Figure no.4.49 Asian Fairy-bluebird

Figure no.4.50 Malabar Trogon

Figure no.4.51 Yellow-browed Bulbul

Figure no.4.52 Ashy woodswallow

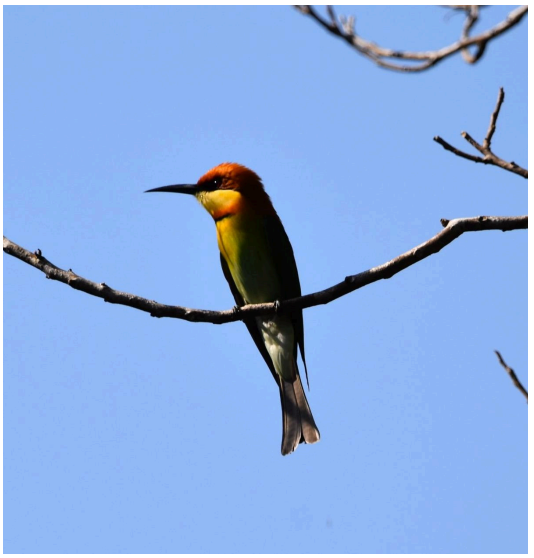


Figure no.4.53 Chestnut-headed Bee-eater

Figure no.4.54 Thick bellied flowerpecker

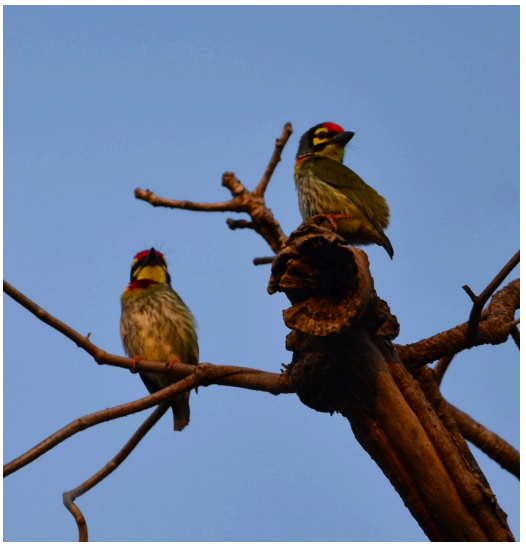


Figure no.4.55 Coppersmith Barbet

Figure no.4.56 Brown-headed Barbet

Figure no.4.57 Spot-breasted Fantail

Figure no.4.58 Jungle Babbler

Figure no.4.59 Jungle Myna

Figure no.4.60 Black-hooded Oriole

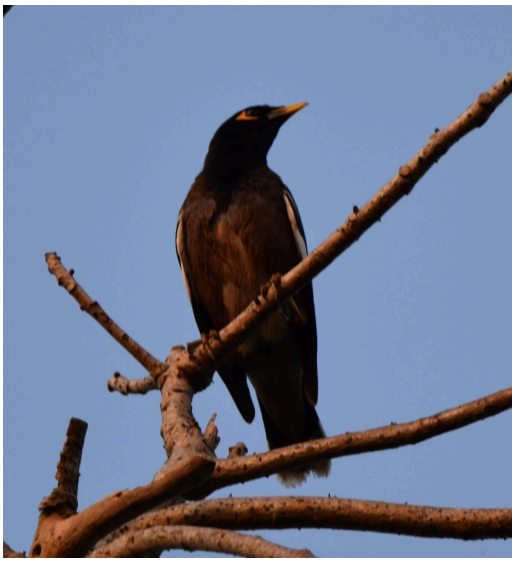


Figure no.4.61 Common Myna

Figure no.4.62 Red whiskered Bulbul

Figure no. 4.63 Malabar Grey hornbill male Resting at DR

Figure no. 4.64 Malabar Grey hornbill male Resting at NR

Figure no. 4.65 Malabar Grey hornbill female Resting at MR

Figure no. 4.66 Malabar Grey hornbill male scratching its beak

Figure no. 4.67 Malabar Grey hornbill female scratching its beak

4.2 DISCUSSION

During the Eight-month study period, spanning from August 2023 to March 2024, a total of 91 species were documented, categorized into 12 Orders and 40 families in the three Sacred Groves of Sattari. The avian species were observed in the sacred groves known as Devachi Rai in Kopardem village, Nirankarachi Rai in Maloli village and Mharinganachi Rai in Pissurlem village located in the Sattari taluka. The findings indicated that the Sacred Grove provides habitat to a significant diversity of avian species. According to the checklist compiled by Baidya & Bhagat (2018) on the bird species in Goa, a total of 473 species have been identified, now the bird count has increased to 481 species. Among these species, 18.91% were observed in the three selected sacred groves within the region.

Few research studies have investigated the variety of bird species present in sacred groves, such as those carried out by Jyothi & Nameer (2015), Rajesh *et al.,*(2021), Joshi and Sairnaik, (2014), and Kangah-Kesse *et al.,*(2009). These investigations offer significant understanding into the bird populations that reside in these distinct ecosystems, revealing insights into their ecological significance and implications for conservation. Jyothi & Nameer, (2015) surveyed 15 sacred groves in Northern Kerala over two years and documented a total of 111 bird species, including 17 migrant species, with in one-year study, Rajesh *et al.,*(2021) documented 72 bird species within the Manjamalai Sacred grove, Joshi and Sairnaik, (2014) observed 101 out of which 13 were migrant in sacred groves of Northern Western ghats, and Kangah-Kesse *et al.,*(2009) observed 411 species in sacred grove of Eastern region of Ghana.

Resident species from the Dicruridae family that is Black Drongo and Racket tailed Drongo were encountered during almost every visit in all three sacred groves. Throughout study in all three groves maximum individuals were found of Black Drongo. Also Black Drongo was observed as a dominant residential species in other studies by Jyothi & Nameer,(2015);Gangadharan *et al.,(*2021) (Southern India), Mahabaleshwarkar *et al.,(*2023) (Puna). Also in Goa, Baidya & Bhagat,(2018) identified Black Drongo & Racket-tailed Drongo as the dominant resident species in Cotigao.

Malabar Trogon, a resident species, was only documented in Devachi rai, particularly in a high-altitude region of grove where it was commonly observed while perching. This observation is consistent with the research conducted by Panigrahi and Jins, (2018) as well as Praveen & Nameer,(2015), who studied bird diversity in hilly regions and also encountered the Malabar Trogon, highlighting the significance of high-altitude species and their respective habitats. Harischandra *et al.,* (2016) revealed that the Malabar Trogon predominantly favors dense canopy forests, indicating a broader habitat preference extending beyond just high altitudes. Additionally, noted the species' preference for forest habitats with a closed canopy, extending its range across foothill and mid-elevation regions. Concluding this can be the reason it was mostly seen at higher regions of the grove. Yellow-browed Bulbul was exclusively found in Nirankarachi rai as one of the dominant species. Research by Jha,(2023) showed that prefers humid, it is abundant in undisturbed forests, also found in forest edges, anthropogenic disturbance negatively affects population abundance. same species was sighted in forest habitat of Goa by Shanbhag and Desai,(2008), however were not sighted at the Plateau (Desai & Shanbhag, 2012) this could be because their

habitat is restricted to forest only. This can be a possible reason they are found in dominance at Nirankarachi rai at Maloli.

Out of 91 species documented, 82 species were classified as resident, 9 species were identified as migrants namely Indian Golden Oriole, Black-naped Oriole, Long-tailed Shrike, Asian Paradise flycatcher, Grey Wagtail, Green Warbler, Brown breasted Flycatcher, Verditer Flycatcher and Blue-throated Flycatcher. The vast majority of avian species observed in the course of this study were resident species, with few numbers of migratory species. Majority of the migratory species recorded belong to the insectivores guild.

The presence of the Indian Golden Oriole, as migratory bird, across all three sacred groves in Sattari Taluka suggests a stable and suitable habitat for this species. It was observed feeding on *Macaranga peltata* in Devachi rai and on Ficus species like *Ficus benghalensis*, *F. exasperata* in Mharinganachi rai. As indicated by Baidya *et al.,* (2018), the Indian Golden Oriole is a common local migrant, predominantly observed during the winter period in Goa, which is the peak migratory season preceded by the post-monsoon season and attracts a majority of the passage migrants. Similarly, Jyothi & Nameer,(2015), Pazhedath & Karumampoyil,(2022) and Gangadharan *et al.,*(2021), also recorded the same species as migratory birds in sacred groves of Northern Kerala, Manjamalai, respectively. This indicates that Indian golden oriole acts as one of the common migratory species in habitat like sacred grove.

Migratory species like Green Warbler (*Phylloscopus nitidus*) was only recorded in Devachi Rai in Kopardem. It was seen feeding in low bushes, keeps on singing and prominently seen perching, feeding on *Endata scandens* during morning hours. Baidya et al. (2018) similarly noted Green Warbler as one the dominant and evenly

distributed migratory species in forested areas exemplified by its presence in the Cotigao wildlife sanctuary. Studies by various researchers such as Mahabaleshwarkar *et al.,*(2023), Jyothi and Nameer,(2015), and Gangadharan *et al.,*(2021) have observed the Greenish Warbler (*Phylloscopus trochiloides*) as a migratory bird in sacred groves outside Goa.

Only one threatened species recorded was Malabar Grey Hornbill (*Ocyceros griseus*), categorized in Vulnerable Category. Despite being classified as Vulnerable, the Malabar Grey Hornbill can be observed in abundance within all three groves. Malabar pied hornbill was also sighted in all three grove. The largest flock of Malabar Pied Hornbills, consisting of six individuals, was observed at Devachi rai. It mostly seen feeding on *Strychnos nux-vomica, Caryota urens, Holigarna arnottiana, Polyalthia fragrans*, *Carallia brachiata, F. benghalensis,* and *F. exasperata* in selected grove.

According to checklist compiled by Baidya & Bhagat,(2018) and chart of endemic birds of the Western Ghats in Goa (Porob *et.al,* 2024) 18 species are Endemic birds of western Ghats found in Goa, out of which 9 species making up 50% of total endemic species found in Goa, were identified in a sacred grove selected as study site, highlighting the significance of this particular habitat as a refuge for endemic birds.

Out of 9 endemic species, Malabar Grey Hornbill and Crimson-backed Sunbird were common in all three groves. The Malabar Grey Hornbill (*Ocyceros griseus*), a species endemic to the region, exhibited dominance in all three sacred groves. Likewise, Jyothi & Nameer,(2015); Sashikumar, C,(2004), and Pazhedath & Karumampoyil, (2022) documented the Malabar Grey Hornbill as an endemic species within their chosen sacred grove present in Northern Kerala, signifying its significance as a key endemic species of the Western Ghats that can be found in sacred groves that are in

close vicinity to Western Ghats. Despite being classified as Vulnerable, the Malabar Grey Hornbill can be observed in abundance within all three groves. Hornbills are seen as indicators of ecosystem health, Sightings of many hornbills suggest healthy forests by Baidya & Bhagat,(2018).

Crimson-backed Sunbird (*Leptocoma minima*) also exhibited dominance in all three sacred groves, whereas Vigors's Sunbird (*Aethopyga vigorsii)* was present only in sacred grove (Devachi rai). Flowering plants like *Saraca indica, Mimusops elengi, Ixora coccinea* and *Melastoma malabathricum* and *Moullava spicate* present in study areas acted as food plants for all nectarivore birds including Crimson-backed Sunbird. Similarly, Baidya *et al.,*(2018) also observed that Crimson-backed Sunbird as the most abundant endemic species found in Cotigao forest. Likewise, Mahabaleshwarkar *et al.,*(2023) in Pune, Pazhedath & Karumampoyil,(2022), Joshi & Sarnaik,(2014) in South India also documented the Crimson-backed Sunbird, an endemic species within their chosen sacred grove. Signifying one of the important endemic birds present in habitat like sacred groves. Nilgiri Flowerpecker was present in two groves and observed feeding on *Ziziphus oenoplia, Ficus racemosa, Ficus exasperata* and *Careya arborea.*

The Flame-throated Bulbul, which serves as the state bird of Goa, has been predominantly sighted in the periphery region of Nirankarachi rai, often spotted in pairs or in mix hunting parties with other bulbuls such as the Yellow browed Bulbul and Red vented Bulbul. Its diet primarily consists of insects and fruits like *Ficus racemosa*. According to Jha (2022), this species tends to inhabit areas around foothills, showing a preference for semi-evergreen forests and sacred grove, showing a preference for thickets located near bodies of water. The presence of a perennial

stream, in Nirankarachi rai, could potentially create an appealing habitat for this bird species, aligning well with its habitat preferences.

Though Nirankarachi Rai is a small grove in terms of area, the highest number of endemic birds were recorded. This phenomenon could potentially be attributed to its strategic location on the outskirts of the Mhadei Wildlife Sanctuary, a designated Important Bird and Biodiversity Area (IBA) site. Endemic species like Malabar Imperial Pigeon, Malabar Flameback, Malabar Barbet, Malabar Parakeet and Flame-throated Bulbul were only sited in Nirankarachi Rai.

The Sorensen coefficient results indicated that the bird species compositions of DR and MR are more similar to each other (coefficient of 0.37), compared to DR-NR (0.29) and MR-NR (0.27). The bird species compositions of NR and MR are the least similar (coefficient of 0.27). A comparable Sorensen coefficient formula was also employed by Sumaila et al. (2020) to assess the similarities among bird species in two distinct research locations .

The highest number of bird species was observed in Devachi Rai with 62 species (Shannon Index= 3.78, Simpson Index=0.97), followed by Mharinganachi Rai with 57 species (Shannon Index=3.73, Simpson Index=0.97), the lowest number of species found in Nirankarachi Rai with 50 species (Shannon Index=3.55, Simpson Index=0.96) (table no.) sacred grove. One way anova test showed that there is not a significant difference in the means of bird diversity across the three sacred groves (P=0.48, F=0.75). It can be inferred that there is no statistically meaningful variability in the diversity of bird species observed in the Devachi Rai, Nirankarchi Rai, and Mharinganachi Rai sacred groves. This could be due to all three sacred groves having thick forest, indicating similar habitat conditions across the sites. Although the

number of species might vary slightly in each grove, the types of birds present are largely the same.

A highest of bird species was documented in Devachi Rai with 62 species, reason for this may be, the grove is situated at the periphery of a hill, which may have contributed to the increased diversity of bird species. The different altitudes and relatively undisturbed nature of this forest compared to others may contribute to the preference of various bird species. The presence of a variety of vegetation and indigenous trees which are huge and tall, supports the large number of birds in this study site. This was supported by findings from H.B. Katuwal,(2006), research on birds in sacred groves of Nepal, highlighting the edge-of-hill location and undisturbed nature of the Suryabinayak sacred grove as promoting factors for a higher bird species richness. The presence of varying altitudes and dense, old-growth vegetation in sacred groves likely supports diverse bird species habitats.

Least number of species was found in Nirankarachi Rai, this could be due to disturbance factor and small size of grove. Similarly, Pazhedath & Karumampoyil, (2022) emphasized that area of a sacred grove is a major factor that determines the bird species diversity, the relationship between the species and the area of these groves exhibits similarities with findings from previous research studies by Brashares *et al.,*(2001) and Olivier *et al.,*(2013). Originally, this grove encompassed an area of 6 acres(Kerkar, 2018). However, rising human settlements, as well as agricultural operations, are causing its size to decrease. But this groove is said to be the oldest and has tremendous ecological significance.

The varied feeding guilds including Insectivores, Frugivores, Carnivores, Omnivores, Nectarivores Granivores and Piscivores by different avian species facilitate the management of the dense population of birds within the study area. Rajesh et al., (2021) proposed that diverse feeding habits of birds help manage high populations in sacred groves with limited resources. The results demonstrated that insectivores were the most prevalent group in Sacred groves, making up 41.8% of the species with a total of 38 species. Among three groves, Devachi Rai and Nirankarachi rai had the highest number of insectivores, especially in January.

Insectivorous species make up the majority of the population in all three study sites. A rise in insectivorous species was observed after the monsoon season. Imam *et al.,* (2016) suggested that Shady and dumpy habitats within sacred groves can indeed support insect diversity. Similar findings were reported by various studies such as Jyothi & Nameer (2015), Gangadharan *et al.,* (2021), Rajesh *et al.,*(2021), Joshi and Sairnaik,(2014), Pradhan *et al.,*(2016), and H.B. Katuwal,(2006), all supporting the idea that post-monsoon conditions enhance the insect population due to the attraction of insects to lush foliage, indicating that the food supply for these bird species belonging to this feeding guild was relatively abundant. Following the culmination of the monsoon period, the flourishing vegetation creates a conducive habitat for insect populations, thereby benefiting insectivorous avifauna.

Considerably Mharinganachi Rai (57speceis) also supported a good number of bird species, Highest frugivorous species was found in Mharainganachi Rai, as vegetation is dominated by trees of Ficus species (*Ficus benghalensis*, *F. religiosa*, *F. exasperata* and *F. arnottiana*), *Caryota urens* and also has great cover of shrubs such as *Carissa carandas*, *Ziziphus rugosa*, *Ziziphus oenopolia* which attracts many frugivorus. Ficus

species provide ample amounts of food for the birds, especially frugivores. The population of frugivores significantly increased in February and March, aligning with the period when many ficus species in the grove were bearing fruit. Study by Kerkar,(2019) found that evergreen species like Ficus works as a keystone species, attracting more birds to this Mharinganachi Rai sacred grove. Similarly Mahanty,(2021) stated that grooves with Ficus species have more birds than those without Ficus. “Sacred groves with Ficus trees attract birds more frequently and support double the number of birds compared to groves without Ficus”.

The highest concentration of Nectarivores species was observed in Devachi Rai, possibly due to the presence of flowering trees like *Saraca indica* and *Mimusops elengi*. Studies conducted by Hails and Kavanagh,(2013) proposed that Saraca sp. and Mimusops elengi are appealing to nectar-eating birds, while the fruits of Mimusops elengi also attract large fruit-eating birds. The only species of Piscivores that was documented was the Common kingfisher (*Alcedo atthis*) in Nirankarachi Rai, this could be due to perennial stream providing food source .

Observing the occurrence rate or frequency of behavioral activities exhibited by Malabar Grey Hornbills in habitat such as sacred forests is crucial for comprehending their behavioral patterns and habitat utilization. Behavioral activities had broadly grouped into Foraging, flying, resting, body maintenance and calling. These all activities were compared across three sacred groves. The documentation of activities of avian species across various sites was also conducted by Syaqina et al.,(2018), in which activities of avian species were documented in 8 distinct sites.

One-way ANOVA results showed that there is a significant difference in foraging behavior among the three sacred groves (P=0.0016, F=14.21), indicating that foraging activity differs significantly between these groves. Highest foraging activity was noted in Mharinganachi rai (27.8%) in comparison to all other groves, due to the vegetation cover of trees from the Ficus genus (*Ficus benghalensis, F. religiosa, F. exasperata and F. arnottiana*) and also by non-fig like *Strychnos nux-vomica*, *Caryota urens, Holigarna arnottiana* and *Ziziphus oenopolia* on which the Hornbill was seen feeding. Malabar grey Hornbill was also seen feeding on tender leaves and animal matter like insects in selected sacred groves. Food of hornbill species predominant dependence on Figs, also observed by Kinnaird and O'Brien,(2007). Numerous scholars have examined the significance of fruits in the dietary habits of Asian hornbills. Poonswad *et al.,(*1998), Wijerathne and Wickramasinghe,(2018), as well as Sherub & Singh,(2020), have done study in Thailand, Sri Lanka, and Bhutan respectively. In the context of India, Mudappa,(2000), Datta and Rawat,(2003), Santhoshkumar & Balasubramania,(2014), Balasubramaniam *et al.,*(2007), and Balasubramanian *et al.,(*2004) have investigated the utilization of fruits by hornbills. The collective research underscores the importance of figs in the diet of hornbills, identifying figs as a primary source of nutrition for these avian species. The research by Balasubramaniam *et al.,(*2007) also demonstrated that *Strychnos nux-vomica* constitutes 20% of the overall dietary intake of Hornbills . Availability of fruits is one of the reasons for the high abundance of Malabar Grey Hornbill in Mharinganachi Rai, totaling 20 individuals throughout the study. In other two Sacred groves it was seen foraging on *Carallia brachiata*, *Caryota urens*, *Polyalthia fragrans*, *Macaranga peltata* and *Holigarna arnottiana*. Foraging activity was mostly recorded during morning and evening hours.

One-way ANOVA for resting behavior across groves demonstrated that there was a significant difference in resting behavior among the three different sacred groves (P=0.0082, F=8.593). Resting activity was the highest performed in Nirankarachi Rai, followed by Devachi Rai. The dense canopy and tall trees found in both sacred groves, especially Nirankarachi rai provide ample shade and coolness, making them ideal spots for resting, especially during hot weather. The existence of a perennial stream contributing to a cooler climate within the nirankarachi rai could contribute to higher resting activity. A comparable finding was also reported by Wijerathne and Wickramasinghe,(2018) when documenting the frequency of behaviors of Sri Lanka Grey Hornbill, the outcome revealed that the most prominent behavior exhibited was Resting activity. Similarly, Hatton *et al.,(*2015) also observed resting was the highest performing activity in Javan rhinoceros hornbill (*Buceros rhinoceros silvestris*). The primary resting behavior of hornbills, as outlined by Wijerathne and Wickramasinghe (2018), resting activity is perching and they prefer shady trees for perching. Preferably, resting activity is conducted during the midday hours or in hot weather conditions.

Similarly, after performing a one-way ANOVA test for body maintenance activity showed that there was significant difference in body maintenance activity among the different three sacred groves (P=0.0412, F=4.640). Highest body maintenance activity was observed in Mharainganachi rai (19.7%) followed by other two sacred groves. A correlation test was used to examine the relationship between foraging activity and body maintenance activity and the result indicated a strong positive linear relationship between the two variables (r=0.8779, P= 0.0002). The strong positive correlation between foraging activity and body maintenance activity suggests that as foraging activity increases, body maintenance activity also tends to increase. This finding may

indicate that individuals who are more active in foraging also allocate more time and energy towards maintaining their body condition. Therefore, the level of body maintenance activity was most prominent in the Mharinganachi rai, which also exhibited the highest level of foraging activity. Most preferably body maintenance activities were observed soon after foraging, especially bill cleaning is a necessary activity after a feeding session, where the bird rubs its beak against a tree branch to remove food particles or debris. Wijerathne and Wickramasinghe,(2018) conducted research on the Behavioral Pattern of the endemic Sri Lanka Grey Hornbill and also found that there is a link between foraging and perching activity. Following a feeding session, the process of bill cleaning takes place, where the bird rubs its beak against a tree branch with either a closed or open bill.

One-way ANOVA results showed there was no significant difference in locomotion activity, calling activity and courtship behavior across the three different sacred groves. It suggests that the mean activity levels observed in each grove are statistically similar and there is no evidence to suggest that one sacred grove consistently has higher or lower activity levels compared to the others.

4.3 Conclusion

This dissertation provides valuable insights into the avian diversity and hornbill activity within three sacred groves situated in Sattari taluka. During the Eight-month study period, spanning from August 2023 to March 2024, identified a total of 91 bird species belonging to 12 Orders and 40 families, accounting for 18.91% of total birds found in Goa. Out of 91 species recorded, 82 species were resident and 9 Species were migrants, 9 species were endemic & one species was under threatened category. The maximum bird species recorded in Devachi Rai and the least species were found in Nirankarachi Rai. Diverse feeding habits help manage high populations in sacred groves with limited resources, insectivores feeding guild dominated all 3 groves. In parallel, the investigation into activities of Malabar Grey Hornbills in sacred groves, provided understanding of their habitat utilization. Highest forging activity was performed in the sacred grove which had a high number of fleshy fruited plant species, indicating figs forming a major source of food. A positive correlation was identified between foraging and body maintenance activities, individuals who are more active in foraging also allocate more time and energy towards maintaining their body condition. The existence of a perennial stream, dense canopy and tall trees offers ample shade and coolness in Nirankarachi rai, creating ideal resting places for the Malabar grey hornbill. The findings highlight the significance of sacred groves in avian diversity conservation and providing refuge to endemic and threatened birds like the Malabar grey Hornbill. Sacred groves with large areas and low human disturbance showed high species richness. Being of small forest patches the sacred forests have higher potentialities for conserving the bird species, not only for the resident but also for the migratory species.

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