Biodiversity Assessment and Monitoring the Impacts of construction of tunnel for Goregaon-Mulund Link Road (GMLR) on Flora and Fauna of Sanjay Gandhi National Park (SGNP)

Prepared by

Bombay Natural History Society

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2022

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Team

The team comprised of scientists & researchers from BNHS. Field survey was carried out by the team by following latest COVID-19 guidelines.

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CHAPTER-1

Introduction

The Sanjay Gandhi National Park (SGNP) is a beautifully preserved green oasis within the confines of Mumbai metropolis in Maharashtra. extending over an area of 103.09 km^2, it occupies 20% of Mumbai's geographical area. Most part of SGNP has Southern Moist Teak bearing forest, Southern Moist Mixed Deciduous forest and broadly mixed deciduous forest (Champion and Seth, 1968). The vegetation shows a distinct seasonal variation from appearing extremely lush green after the monsoon showers to a dry and sparse appearance during the summer. The SGNP also includes a creek teeming with biodiversity and besides representations from elements typical of the Western Ghat plateau habitats. The National Park has an amazing in terrain shows a wide variation - beginning at just 30 meters above sea level, to almost 500 m. With a diverse range of available niches, the park is rich in floral and faunal diversity and shows an amazing variation in the biodiversity assemblages in relation to these diverse habitats.

The SGNP is valued for its ecosystem services, particularly in its role as the green lung of Mumbai and Thane (Bhale et al. undated, Anon 2019). The SGNP plays a vital role in air quality and temperature regulation, groundwater recharge and water storage for the city. The park also has immense cultural, educational and recreational value (Anon 2019). Preserving this chunk of the forest is thus vital for the well-being of Mumbai city.

Mumbai city is a cosmopolitan, densely populated and very important financial and commercial centre of India. The city due to its geographical constraints, has historically grown in a linear manner. In the course of the development of Greater Mumbai, commercial and business activities came to be concentrated in the southern part of the island city, while residential areas developed towards the north, along the Western and the Eastern Suburbs. As a result, people have had to commute from the residential areas to the business hubs on a day- to-day basis. The transportation corridors in Mumbai have also evolved longitudinally traversing along the North – South axis with very few East-West linkages. However, with the rapid growth of the Eastern and Western suburbs of Greater Mumbai in the last few decades, an urgent need has been felt for strengthening the East–West Road connectivity between the eastern and western suburbs. In order to ease traffic congestion and reduce commuting time, the Municipal Corporation of Greater Mumbai (MCGM) has proposed to construct the Goregaon-Mulund Link Road (GMLR).

GMLR Project Details

The proposed road is 12.3 km in length and incudes a stretch of 4.7 km running underneath the Sanjay Gandhi National Park. The tunnel is approximately 45 metres wide and 13-14.2 metres high. It is a two-barrel tunnel, with each barrel 15 metres wide and separated by a 15-meter partition. The tunnel's maximum and minimum depths from the ground are 160m and 20m, respectively. The connecting points of the GMLR are near Dindoshi Flyover on Western Express Highway and near Airoli Junction on Eastern Express Highway.

Assessment of GMLR project impacts

The MCGM had approached BNHS in 2019, to do a biodiversity assessment study. The study was to be conducted to evaluate the possible impacts of tunnel construction of GMLR and based on the findings, provide protocols to monitor the on the flora and fauna of Sanjay Gandhi National Park, Mumbai, Maharashtra (vide letter no Ch.Eng./GMLR/18/186 dated 19th January 2019).

BNHS-GMLR survey

The Bombay Natural History Society (BNHS) initiated the biodiversity assessment in June 2021. The study is being conducted to understand the potential impacts of construction of tunnel for Goregaon-Mulund Link Road (GMLR) on the resident biodiversity of the SGNP and followed by recommendations of mitigation measures for potential impacts (if identified). The project duration is for 3 years to be implemented in 3 phases.

Phase I: Biodiversity profile

Phase II: Measuring impacts during construction of GMLR

Phase III: Measuring post-construction impacts of GMLR

Objectives

1. **Comprehensive biodiversity assessment along the alignment of the tunnel including terrestrial and aquatic biodiversity (Phase I)**
2. **Prepare biodiversity maps with priority areas (Phase II)**
3. Suggest mitigation measures of impacts if any
4. Suggest monitoring mechanism and protocols during and post construction of impacts related to vibrations due to construction and subsequent tunnel traffic.
5. Undertake monitoring and document impact if any

Outcomes of Phase I

Phase I of the project undertaken from June 2021 to June 2022 has specifically addressed objectives 1 & 2. At the completion of Phase I, BNHS has come up with the following outcomes:

- Biodiversity survey report
- Outline of the Phase II and way forward

CHAPTER-2

Literature Review

Flora

First major work was done by John Graham in 'A Catalogue of Bombay Plants' (1839) and later by Dalzell & Gibson (1861). At the beginning of the 20th century, Cooke (1901-1908) studied the flora of the Presidency of Bombay while E. Blatter et al (1926 - 1935) did a revision of the same. Santapau along with his students studied sub-groups of the Sanjay Gandhi National Park. Ms. Aban J. Randeria, P.S. Herbert & R.R. Fernandez made collections from Sanjay Gandhi National Park (Almeida 1996). R.R. Fernandez studied Flora of Borivali (1954) while Aban J. Randeria (nee Daruwala) published thesis on Flora of Krishnagiri National Park (1959). 43 years later, the Botanical Survey of India (BSI) published flora of Sanjay Gandhi National Park (Pradhan et al 2005)., Addition to the flora of Sanjay Gandhi National Park four taxa have been recorded for the first time (Dr Rajendra Shinde et al 2012) Floristic Diversity indices in Sanjay Gandhi National Park disturbed and undisturbed habitat has been calculated (Ambika Joshi et al 2014). A brief account of Orchidaceae in Sanjay Gandhi National Park, has been published by Sweedle Cerejo-Shivkar & Rajendra D. Shinde (2015). Value of floral diversity of Sanjay Gandhi National Park has been studied by Ambika Joshi et al (2016).

Fauna

Arachnids: The Spider fauna of Sanjay Gandhi National Park (SGNP) is highly understudied. Over the years, only one attempt was made in the year 2006 by the Zoological Survey of India (ZSI) to make a comprehensive checklist of Spiders (Order: Araneae). The ZSI has reported about 20 spider families from SGNP in their findings (Bhale et. al., 2017). ZSI reports 61 species belonging to 18 different spider families. Spiders which were identified up to the family level or the generic level were not included in the checklist, due to lack of literature on the understudied spiders. The report also mentions species descriptions like the common name, diagnostic characters, and the distribution range. According to the report, 29 species were listed from the Orb-weaver family (Family: Araneidae) in SGNP. Only 2 species of Jumping Spiders have been included in the list. Other Arachnid groups like the Scorpions (Order: Scorpionida) and Whip-tailed scorpions (Order: Ambylpygi) including 5 Scorpion species and, and 1 whip-tailed scorpion species was included. In the recent years, many spider species *Langelurillus lacteus* and *Langelurillus onyx* (Sanap et. al., 2017), *Dictis mumbaiensis* (Javed et. al., 2015), *Peucetia phantasma* (Javed et. al., 2015), *Idiops rubrolimbatus* have been described from Aarey Milk Colony which is at the periphery of the SGNP (Mirza and Sanap, 2012). As per the current nomenclature, some of the spider species listed in the ZSI report have been revised. Many species have now been split or most of them are now synonymised. No further attempts were made by other scientists to edit or improve the published ZSI hecklist. In conclusion, the Sanjay Gandhi National Park and the adjoining areas are rich in terms of Arachnid diversity and offer an enormous scope for detailed surveys

Insects: Major documentation of Indian insect fauna was done during the British rule by various officers in their service tenure in the form of the series Fauna of British India (FBI) (Distant 1902, 1908, 1918; Fraser 1933, 1934, 1936; Gahan 1906; Jacoby 1908; Maulik 1919, 1926, 1936). This voluminous work consisted taxonomic catalogues of insects and included observations from parts of Mumbai and surroundings which were part of the then Bombay Presidency. These FBI volumes form the base of multiple further

studies on insects in India. In the recent times, many studies have documented insect fauna of Sanjay Gandhi National Park (SGNP). Surveys on different insect orders were conducted by scientists of Zoological Survey of India (ZSI) and local researchers and professors from various organisations. Publications by ZSI team were mainly done in the form of checklists. The invertebrate fauna of SGNP consisting of five insect orders was compiled in the conservation area series (Editor-Director 2006). Later on, more information was added to the lists covering 15 different insect orders (Editor-Director 2012). This latest publication provided much more elaborative lists giving separate chapters on different families of some of the orders viz. Coleoptera, Diptera, Hemiptera, and Hymenoptera. Shubhalaxmi and Chaturvedi (1999) studied moths of SGNP with emphasis on the families Saturniidae and Sphingidae. Butterflies are one of the most explored taxa in SGNP by researchers publishing checklists and behavioural studies (Bell 1919; Kasambe 2012; Patwardhan 2010, 2014, 2019). Beetles have also been documented explaining their habitat distribution and niche occupancy (Patwardhan and Danani 2021). There have not been any detailed studies on other insect orders in a long time apart from those mentioned above.

Amphibians and Reptiles: Proper documentation of Indian herpetofauna began in the late 1700s and early 1800s with the formation of the museum of the Asiatic Society of Bengal (now Indian Museum) and publications like the proceedings of the Asiatic Society of Bengal, series of catalogue of specimens in the British museum. This was followed by numerous individual publications in the early volumes of the Journal of the Bombay Natural History Society, Fauna of British India series (Boulenger 1890, Smith 1931 to 1943) and various individual contributions of people like Maj. Frank Wall (1868-1950), Col. R. H. Beddome (1830-1911) among others. These preliminary studies included descriptions of most of the species known from the Bombay Presidency (including present day Mumbai and surroundings) and formed the base for further studies on reptiles and amphibians and inspired important work like the book of Indian Reptiles and Amphibians by J. C. Daniels, Snakes of India by R. Whitaker and A. Captain. In the recent times, there has been an exponential rise in the studies of reptiles and amphibians leading to descriptions of many new species and various nomenclatural changes. There have not been many studies specific on the reptiles and amphibians of Sanjay Gandhi National Park (SGNP) other than the publication of a checklist (Mirza and Pal 2008). Although there have been many studies in the past decade from the northern Western Ghats on reptiles and amphibians, there have not been any detailed studies on the ecology or population from the region in a long time.

Birds: Due to its proximity to Mumbai city, many British officers visited the forests of Sanjay Gandhi National Park (SGNP) in pre-independence times and wrote about the birds found in Mumbai and Salsette islands in general (as there was no National Park then). The first book about avifauna of Mumbai area "The common birds of Bombay" was written by E.H. Aitken and published in 1900 and described common birds in and around Mumbai including the many islands (Salsette Islands).

Later more comprehensive studies and documentation was done by Dr. Sálim Ali and Humayun Abdulali, who wrote in detail about birds of Bombay (now Mumbai) and Salsette Islands (now suburbs of Mumbai, connected by reclamation) (1936–1940). The duo then published the book "The Birds of Bombay and Salsette" (Ali and Abdulali, 1941).

A comprehensive checklist of Borivli National Park (now SGNP) was published by Humayun Abdulali in 1981 with notes on their status around Mumbai (Abdulali 1981). Another report about birds (Yazdani et al. 1992) was mostly based on this checklist (Abdulali 1981).

Many bird watchers have explored and written about this park, mostly about the avifauna in it (Tyabji, 1968; Khan, 1977a, b; Naik 1986, Monga 1986).

The first attempt at using citizen science and document the avifauna of SGNP was done in 2014 using line transect method. This study resulted in finding 194 species of birds in SGNP (Pandya and Sawant, 2015). Similar citizen science initiative started by BNHS and SGNP during 2021-22 resulted in finding 186 bird species (Kasambe and Khan, in prep., 2022).

Mammals: Earlier studies have revealed that SGNP is very rich in faunistic composition. The SGNP boasts a wide variety of flora and fauna and wildlife, including many species of insects, types of mammals, and a countless bird species. The isolated past reports (Yazdani, Pradhan and Singh, 1992 and Pradhan, 2002) and studies carried out for preparation of the Management Plan for SGNP and Environmental Assessment Report by ECONET, Pune (Paranjape, 1997) have recorded 59 species of mammals. Leopards have drawn a wide attention in two decades due to their presence alongside people in an urban landscape. Research on leopards have included ecological studies as well as studies on various facets of their interaction with people (Edgaonkar and Chellam 1998; Athreya et. al., 2007, Bhale et. al., 2005, Tiwari and Apte 2006 & 2008, Mirza et. al., 2013, Surve et. al., 2015).

CHAPTER-3

Study Area

The Sanjay Gandhi National Park (SGNP) is situated between 72°53' to 72°58' East longitude and 19°88' to 19°21' North latitude and lies within the city limits of Mumbai (Figure 1). It is formed from basic lava flows. Basic lava flows consist of basalt and are called basic since they contain less than 45 percent of free silica. This type of geology gives the park's terrain an undulating topography of hills, valleys, lakes and open areas. The undulating scenery forms ideal catchments for the Powai, Vihar and Tulsi lakes. The temperature averages between 38o C in March to 12o C in January. The monsoons usually commence at the end of May and continue until the end of August and the mean annual rainfall is approximately 2,600 millimetres during an average period of 87 days per year (Bhale et al. undated).

The proposed tunnel alignment falls in the western part of the park starting near film city and Habalpada village with another opening near Khindipada. The proposed alignment passes between the two lakes, Tulsi and Vihar respectively.

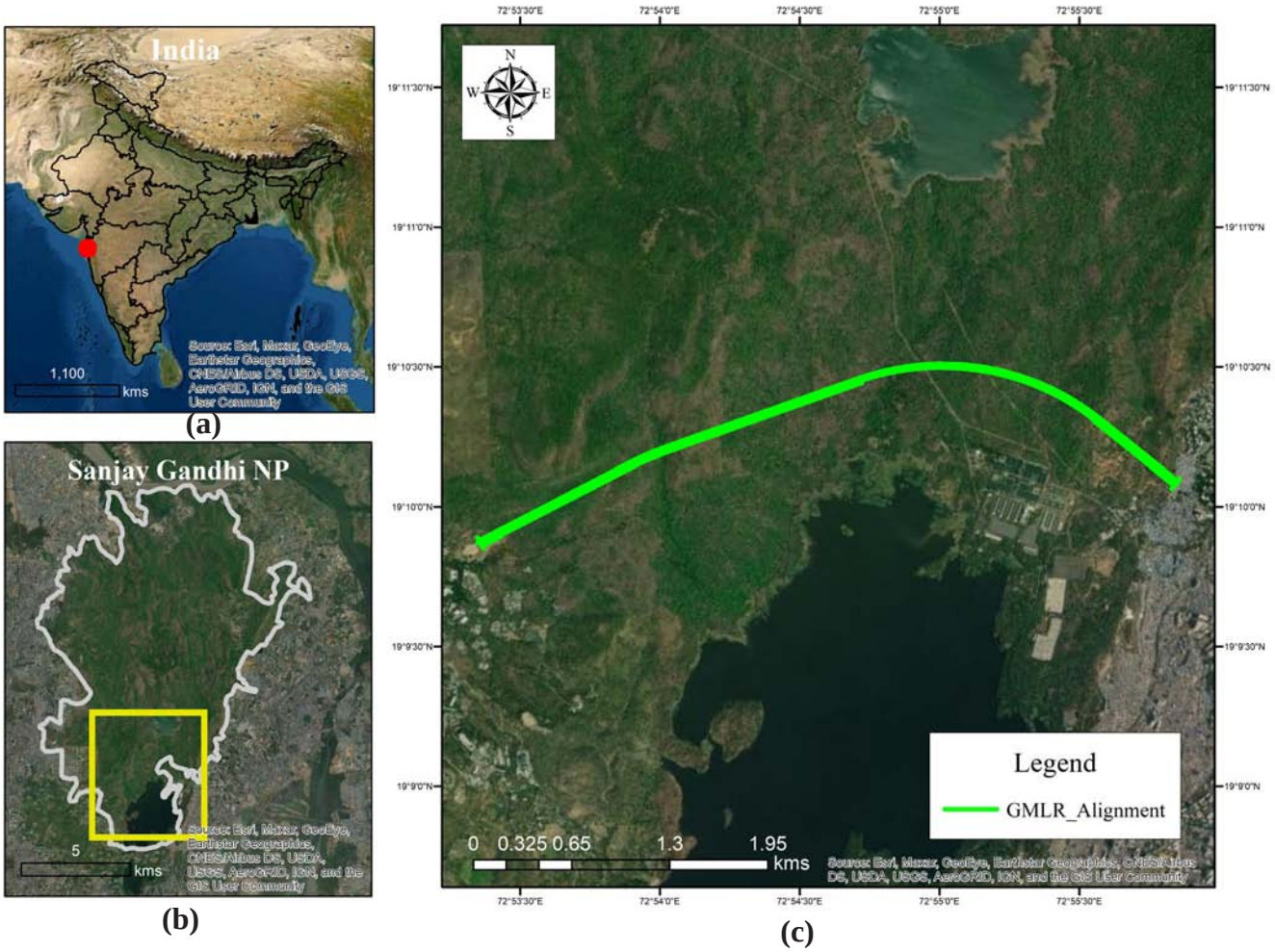

Fig. 1: Map of the tunnel alignment passing through a section of the Sanjay Gandhi National Park (SGNP) as part of the Goregaon-Mulund Link Road (GMLR). Inset 1(a) Location of SGNP in Maharashtra, India 1(b) Location of tunnel alignment within SGNP 1(c) Tunnel alignment linking Goregaon and Mulund at Habalpada and Khindipada respectively

CHAPTER-4

Methods

The Bombay Natural History Society (BNHS) conducted a survey along the tunnel alignment of the proposed Goregaon- Mulund Link Road (GMLR) located within the Sanjay Gandhi National Park (SGNP), Borivali starting from June 2021.

Reconnaissance Survey

The first one-month of the assessment survey primarily focused on gaining a better understanding of the study area. As a first step towards defining the study-design and data collection protocols, the location of the tunnel alignment was examined on a toposheet (1:50000) of SGNP (Figure 1). The GPS coordinates of the start and end points were georeferenced and then used to navigate to the location of the tunnel alignment on ground. Along the stretch of the tunnel alignment, the habitat gradient including the highest and lowest elevation points, diversity of habitats, and accessibility were all verified. This information was then used to stratify the study-site with respect to various topographic and landscape features on either side of the tunnel alignment. Following this, the final grid placements and survey trails were determined. This initial reconnaissance survey was crucial and helped to finalize the sampling grids and then further applied to design taxa-specific survey protocols. The following were the highlights of the reconnaissance surveys:

- Random trails and surveys across grids to understand the diversity and distribution of various species (Figure 2 & 3)
- The initial ad hoc surveys gave a good perception of the habitat diversity and altitudinal variation n and were indeed important factors in selection of sampling grids (Figure 3)
- The grid-size of 250 m on either side of the tunnel were finalized because larger grid sizes (e.g., 500 m) caused the grids to spatially overlap with each other and reduced the independence of the sampling units (Figure 4)
- Decisions were taken on the placement of plots in and around the grid-framework in relation to the tunnel alignment. A few plots were also chosen away from the tunnel line on either side so that the impact of any vibration on the floral and faunal diversity at varied distances from the proposed tunnel can be tested (Figure 4a)
- Following this, an equal number of sampling plots for each taxa across all grids were selected (see Chapter 6)
- Specifically, the entrance which would be the site of excavation for the proposed tunnel was considered for sampling and monitoring.

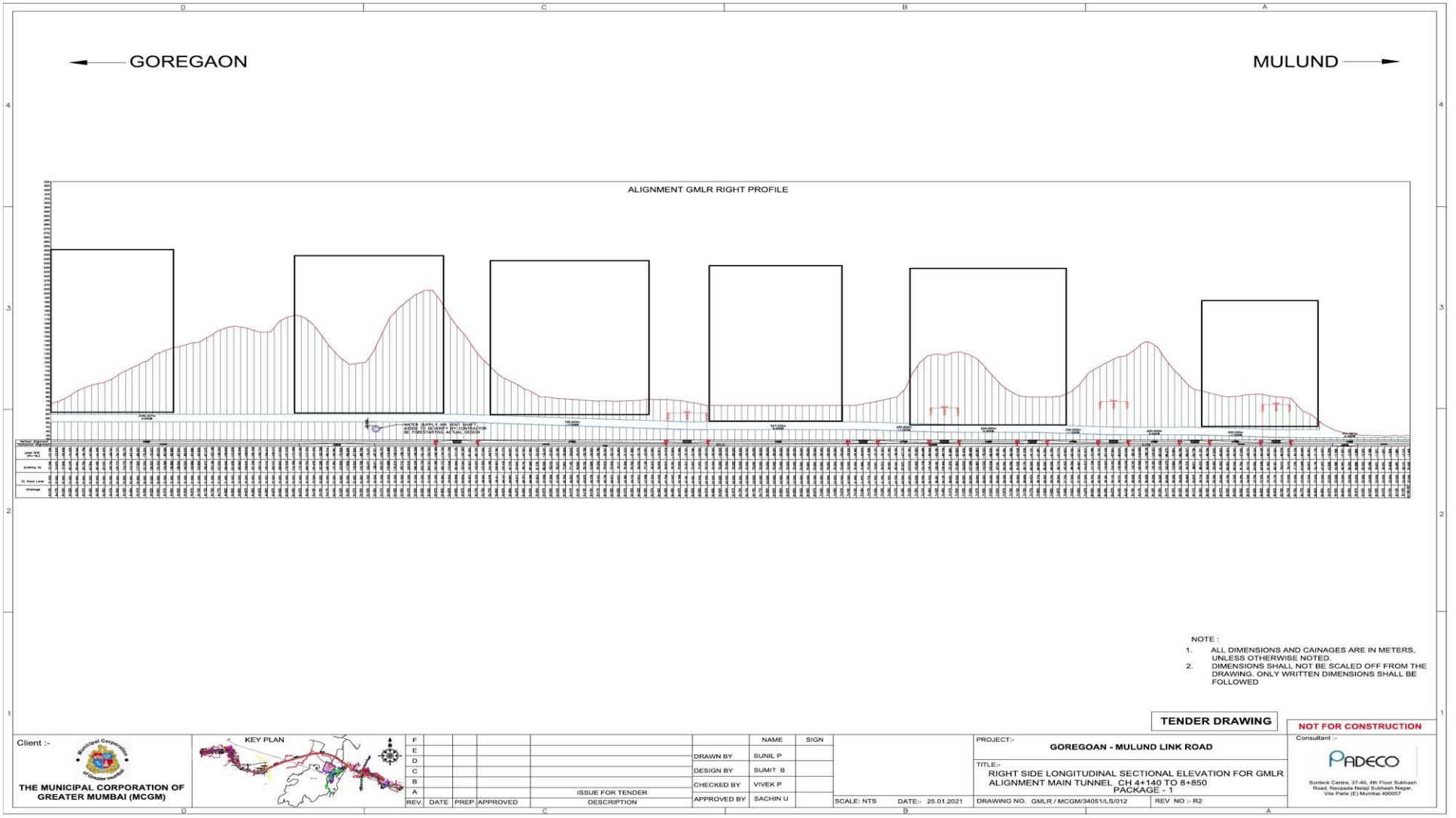

Fig. 2: Placement of grids in relation to habitat, terrain and other landscape features for biodiversity assessment for the BNHS-GMLR survey

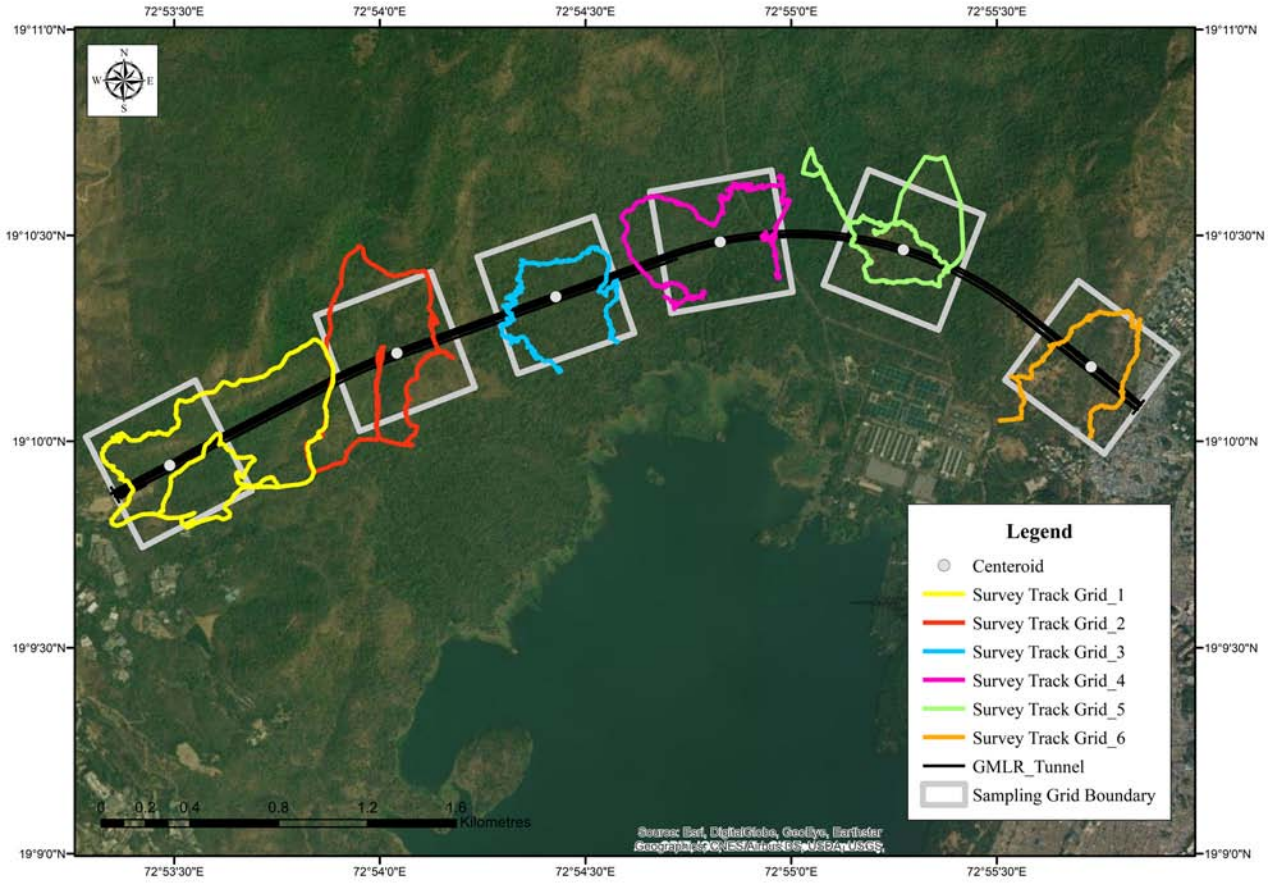

Fig. 3: Random trails or survey tracks to determine placement of plots for data-collection during the reconnaissance survey for the BNHS-GMLR projectsurvey for the BNHS-GMLR project

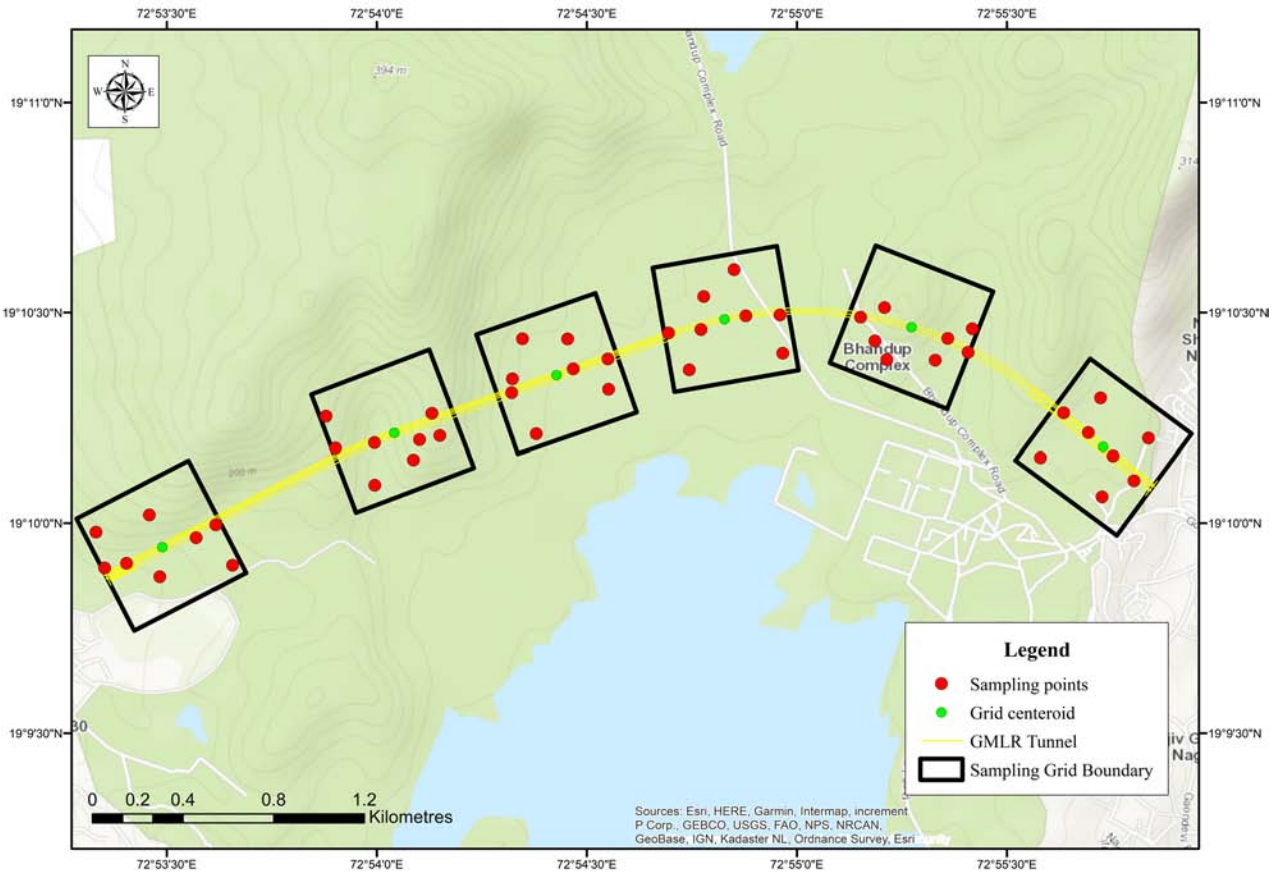

Fig. 4: Placement of grids and plots for recording species diversity for the BNHS-GMLR study

Grid 1

The 1st grid starts near Habalepada village, Film City. About 30-40% of the grid has a steep slope and hilly terrain. The accessible part of the grid starts with dense shrubs of *Eupatorium perfoliatum*. The vegetation and forest type changes along the gradient as we move to higher elevations. At lower elevation, the grids consist majorly of *Carissa carandus* and *Capparis sepiaria* which hampers the accessibility to the transect lines and sampling plots within the grid. This grid also has an annual stream flowing through it. Grid I has many houses and therefore has higher anthropogenic activities like agriculture and grazing.

Plate 1: View of habitat of Grid I

Grid II

The terrain and steep slopes like that of the 1st grid. It also has an accessible valley, which has an air vent for the water siphon pipeline which enhances the flow of the stream with continuous water flow, making it perennial. Along the proposed tunnel alignment, the highest elevation above the tunnel falls in this grid. This elevation is dominated by Teak (*Tectona grandis*). There are also some plateaus. The abundance of *Ecbolium ligustrinum* was observed near the stream whereas *Strobilanthes callosa* were observed on the slopes as well as on the top of the hill.

Plate 2: View of habitat of Grid II

Grid III

The beginning of Grid 3 has an elevation of 60m which further elevates a little more in the North west direction. The slope, following the elevation, is gravels and consists of *Ecbolium ligustrinum* and a few patches of *Capparis sepiaria*. It has many small annual streams along with a major annual stream that exhibits flash floods during heavy rainfall. Almost 25-30% of the gird is flat and is dominated by Teak (*Tectona grandis*). Nearly 85-90% of the grid is easily accessible

Plate 3: View of habitat of Grid III

Grid IV

The 4th grid is consistently plain and has a perennial stream that flows from Tulsi Lake to Vihar Lake. The vegetation has been cleared and made open around the 2 power lines providing good accessibiliy for sampling. These power lines create an edge effect since it cuts the forest which seems to enhance species diversity. *Cassia tora* was one of the major herbs found under these power lines. Major trees observed in this grid were *Ficus mysorensis* and *Borassus flabellifer* along with shrubs like *Macaranga peltate.*

Plate 4: View of habitat of Grid IV

Grid V

This grid is marked by undulating terrain where low-lying area towards the power lines is dominated by a thick growth of *Eupatorium spp*. Species *like Pongamia pinnata* and *Ficus spp*. are present along with the riparian habitat. The steep slopes of hills are covered by natural vegetation of ferns, woody trees, lianas with very little undergrowth.

Plate 5: View of habitat of Grid V

Grid VI

Grid 6 is closer to a plantation of what and human settlements of Khindipada village. Much of the terrain is flat interspersed with Toddy Palm. Many seasonal streams flow through the grid, lined by open grassy patches. *Gliricidia sepium* is planted in many parts of the grid.

Plate 6: View of habitat of Grid VI

CHAPTER 5

Individual Taxa Reports

Introduction

The ultimate objective for any wildlife status monitoring and biodiversity assessment is for the findings of the study to be useful for conservation management planning and policy formulation. Understanding the local distribution range of animals is important for assessing true species ranges and status across landscapes.

Thus, besides cataloguing local biodiversity and generating species distribution data, valuable habitats for preservation can be identified from such species distribution surveys. Similarly, the natural-history information of species provides an understanding of the factors responsible for the observed distribution patterns. Identification of the underlying key biotic and abiotic factors can explain fluctuation of species distribution in relation to seasons, resource-availability, ecological and anthropogenic factors. These serve as an important baseline for conservation planning. For instance, knowledge about the specific requirements of particular species for its survival can be used to nominate flagship species to achieve conservation of a larger ecosystem.

The BNHS-GMLR project was a biodiversity assessment survey along grids numbered from 1 to 6, overlaid on the tunnel to be constructed as part of the proposed Goregaon-Mulund Link Road (GMLR) passing through the SGNP. The reconnaissance surveys, survey design and data collection protocols, marking of survey plots and other baseline work was carried out in June 2021. The taxa-specific surveys were carried out from July 2021-June 2022. Floral diversity as well as faunal diversity including spiders, insects, amphibians, reptiles, birds and mammals were assessed through taxa-specific survey techniques. Habitat covariates were noted down for each species recorded and was used for broad interpretation and not applied in any statistical models. All data was based on field-based surveys and photo-documentation where no invasive sampling techniques were applied such as trapping, specimen collection, simulated calls, baits, lures etc. For mammal diversity study, camera traps were deployed in the winter and summer months.

Key definitions:

Seasons

Summer: March to May
Monsoon: June to September
Winter: October to February

Species accumulation curve or collector's curve

Records the total number of species revealed, during the process of data collection, as additional individuals are added to the pool of all previously observed or collected to give an idea of the number of species as a function of sampling effort. Plotting the species accumulation curves allow researchers to assess and compare diversity across populations and also to evaluate the necessity of additional sampling.

Diversity indices

Species richness: The number of different species present in an ecosystem
Species evenness: Relative abundance of individuals of each of those species
Species diversity: Measure of both the number of species in a community as well as a measure of the abundance of each species.

Species Diversity Indices (Magurran 1988)

Shannon Diversity Index (H')	$- \Sigma p_i * \ln pi$	n_i = importance value of the ith species N = importance value of all the species p = proportion i.e. n_i/N ln = natural logarithm
Simpson's Dominance Index (D)	Σp_i^2 i.e. $= \Sigma (n_i/N)^2$	n_i = importance value of the ith species N = Importance value of all the species P = proportion i.e. n_i/N
Pielou Evenness Index (E)	H'/ ln S	H' = Shannon Diversity Index S = Total number of species ln = natural logarithm

Methods

Flora

The Quadrat method was used to survey floral diversity across the six grids. In total, eight quadrats were selected in each grid considering the variable elevation and habitat. Out of eight quadrats, four were selected on the proposed tunnel alignment and other four were selected at varying distances from the tunnel alignment on either side. For documentation of trees, quadrats of size 10x10 meters were marked; similarly for shrubs 5x5 meters and for herbs 1x1 meter quadrats were marked. The corners of each quadrant were marked with coloured ribbons and GPS locations were recorded for conducting repetitive surveys. Plants were also documented using visual encounter surveys while walking from one sampling point to the other.

Different habitats like agriculture, mixed deciduous forest and plantation sites were documented. For trees, circumference at breast height (CBH) readings were taken along with the canopy cover at four different points. Additionally, documentation of shrubs and herbs along with its phenology was recorded for seasonal changes. We also noted down opportunistic observations of floral species encountered outside the demarcated survey- grids.

On analysing phenology of frequently occurring trees in the study area – 20 trees as summarized in Table 2, it was observed that the majority of the trees start flowering from December, followed by fruit-setting and seed dispersal from April to June. The reason for that is so that after the first shower or during monsoon seeds can germinate. Additionally, it has been noted that some species experience leaf-fall during flowering and fruiting. The likely reason is so that flowers and fruits are more visible to animals (a biotic element) and to lessen obstructions to wind-borne pollination or seed dissemination (an abiotic influence).

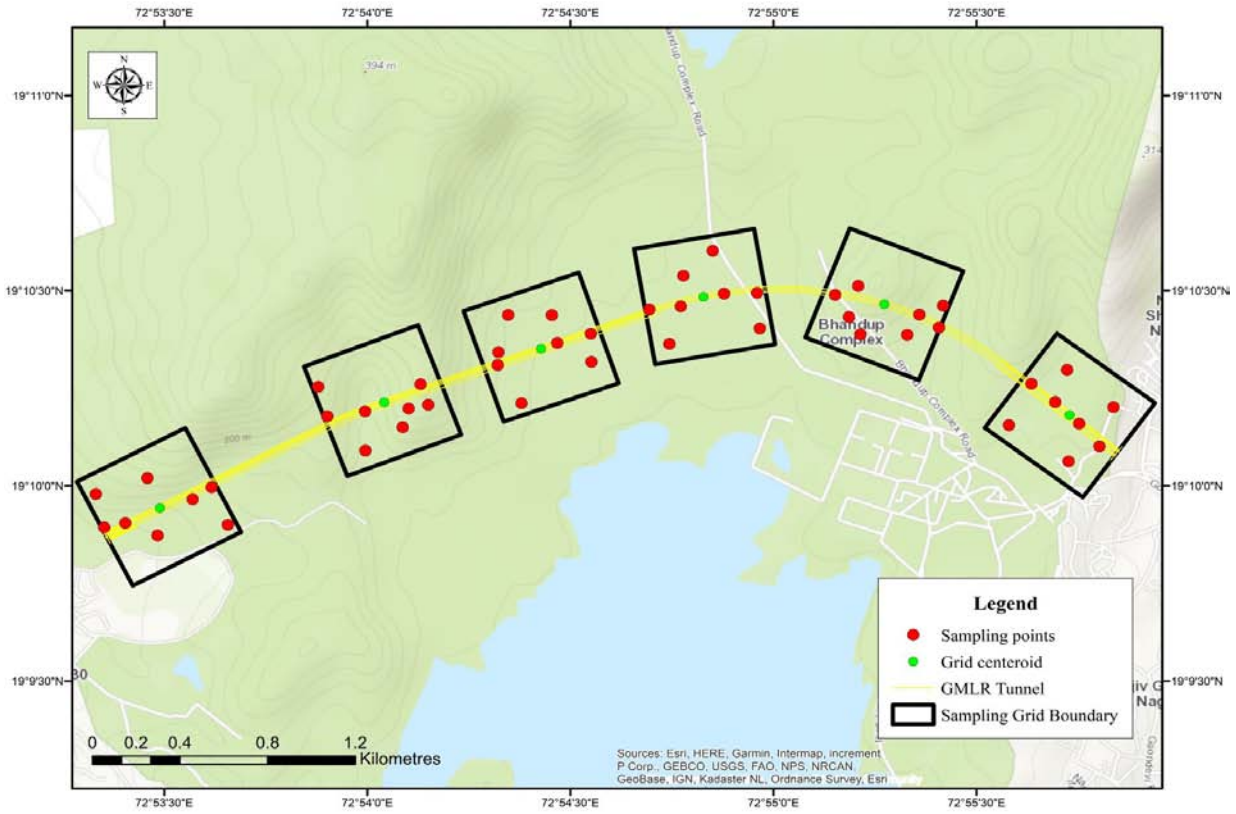

Fig. 5:Map showing the tunnel alignment of a section of the Goregaon-Mulund Link Road that will be passing through the Sanjay Gandhi National Park (SGNP). The sampling grids and sampling points are indicated for the months surveyed

Plate 7: Field work and data collection by plant team

Plot Marking

Herb sampling

Root measurement

CBH measurement

Table 1: Checklist of plants species including trees, herbs and shrubs recorded in the BNHS-GMLR Survey with distribution across the grids, along with their IUCN status (Dark green cells indicate species presence, blank indicate absence, '--' indicates IUCN status not applicable for unidentified taxon

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
1	Teak / Saag	*Tectona grandis*							NA
2	Garuga/Kakad	*Garuga pinnata*							NA
3	Indian Ash Tree/ Moi	*Lannea coromandelica*							LC
4	Kusum	*Schleichera oleosa*				-		-	LC
5	Governor's Plum/ Tambut	*Flacourtia indica*			-	-	-	-	LC
6	Sand paper tree / Kharoli	*Streblus asper*						-	LC
7	Phalsa	*Grewia asiatica*	-			-		-	LC
8	Dhaman	*Grewia tiliaefolia*		-	-	-	-	-	NA
9	Flame of the forest/ Palash	*Butea monosperma*		-	-		-		LC
10	Maula	*Butea parviflora*		-	-	-	-	-	NA
11	Wild Guava/ Kumbhi	*Careya arborea*		-	-	-	-		NA
12	Spinous Kino Tree, Asana	*Bridelia retusa*	-		-		-		LC
13	Behada	*Terminalia bellirica*			-	-	-	-	LC
14	Hoom/ Humb	*Miliusa tomentosa*				-	-		NA
15	Axle Wood Tree/ Dhawda	*Anogeissus latifolia*	-		-	-	-	-	NA
16	Red Silk Cotton Tree/ Katesawar	*Bombax ceiba*							LC
17	Kaim / Kalamb	*Mitragyna parvifolia*							NA
18	Silver grey wood / Ain	*Terminalia elliptica*			-		-		NA
19	Karaya gum tree/ Indian ghost tree	*Sterculia urens*			-		-		NA
20	Forest sandpaper fig/ Karvat	*Ficus exasperata*		-	-	-	-		LC
21	Indian Rock Fig Pimpli	*Ficus arnottiana*		-	-	-	-		NA
22	Khair	*Acacia catechu*	-	-			-	-	LC

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
23	Mother of cocoa / Undirmaar	*Gliricidia sepium*	■	-	-	-	-	■	LC
24	Sweet Indrajao, Kala Kuda	*Wrightia tinctoria*	-	■	■	-	■	■	NA
25	Muyna, Huloo	*Meyna laxiflora*	-	■		-	-	-	NA
26	Western Ghats Ixora	*Ixora brachiata*	-	■	■	-	■	-	NA
27	Waras	*Heterophragma quadriloculare*	-	■	■	-	-	■	NA
28	Haldu	*Haldina cordifolia*	-	-	■	-	■	-	NA
29	Indian Elm/ Vavla	*Holoptelea integrifolia*	-	■	■	■	-	■	NA
30	Wild Jujube	*Ziziphus oenoplia*	-	■	-	■	-	-	NA
31	Bauhinia	*Bauhinia Spp*	■	-	■	-	-	-	NA
32	Mountain Pomegranate/ Ghela	*Catunaregam spinosa*	-	-	■	-	-	-	LC
33	Karanda / Karvanda	*Carissa carandas*	■	■	■	■	■	■	NA
34	White fig/ Gadhaumbara	*Ficus virens*	-	-	-	-	■	■	LC
35	Indian Butter Tree/ Mahua	*Madhuca longifolia var. latifolia*	-	-	-	■	-	-	NA
36	Indian Mulberry/ Bartondi	*Morinda pubescens*	-	■	-	■	-	■	NA
37	Indian hog plum/ Ambada	*Spondias pinnata*	-	■	-	-	-	-	NA
38	Earleaf Acacia	*Acacia auriculiformis*	-	-	-	-	■	-	LC
39	Ben Teak / Nana	*Lagerstroemia microcarpa*	-	■	-	-	-	-	NA
40	Kaamala Tree/ Shendri	*Mallotus philippensis*	-	-	-	-	■	-	LC
41	Elm-Leaf Grewia / Hasoli	*Microcos paniculata*	■	■	■	■	-	■	LC
42	Palmyra Palm / Taad	*Borassus flabellifer*	-	-	-	■	-	■	LC
43	Banyan tree/ Vad	*Ficus benghalensis*	-	-	-	■	-	-	NA
44	Takoli/ Dandus	*Dalbergia lanceolaria*	-	-	-	-	-	■	LC
45	Hairy Xantolis / Kate Kumbal	*Xantolis tomentosa*	-	-	-	-	■	-	NA
47	Tamarind/ Chinch	*Tamarindus indica*	-	■	-	-	-	-	LC

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
48	Indian screw fruit tree/ Murudsheng	*Helicteres isora*						-	NA
49	Bandicoot Berry / Karkany	*Leea indica*		-					LC
50	Mysore Fig / Burali Vad	*Ficus drupacea*		-	-		-	-	LC
51	Wild Caper Bush/ Mastodi	*Capparis sepiaria*							LC
52	Dragon Stalk Yam/ Shevala	*Amorphophallus commutatus*		-	-	-	-		NA
53	Pincushion Plant/ Golgonda	*Neuracanthus sphaerostachyus*			-	-	-	-	NA
54	Hill Turmeric / Ranhalad	*Curcuma pseudomontana*	-						VU
55	Heart-Leaf Sida/ Bala	*Sida cordifolia*	-			-	-	-	NA
56	Burr Mallow / Rankapshi	*Urena procumbens*		-	-	-	-	-	NA
57	Paired Flower Smithia / Naichibha	*Smithia conferta*		-	-	-	-	-	NA
58	Sensitive Smithia / Lajalu Kavla	*Smithia sensitiva*		-	-	-	-	-	LC
59	Ludwigia	*Ludwigia spp*		-	-	-	-	-	-----
60	Sanguinarea/ Kusal	*Alternanthera ficoidea*		-	-	-	-	-	NA
61	Corchorus	*Corchorus spp*		-	-	-	-	-	-------
62	Indian Sarsaparilla / Anantmul	*Hemidesmus indicus*		-	-	-	-	-	NA
63	Wire bush / Lahan Methrui	*Melochia corchorifolia*		-	-	-	-	-	LC
64	Kumarika/ Ghotvel	*Smilax ovalifolia*		-	-	-	-	-	NA
65	Wax Leaved Climber/ Dudhvel	*Cryptolepis buchananii*		-	-		-	-	NA
66	Lanceleaf forget-me-not	*Cynoglossum lanceolatum*	-		-	-	-	-	NA
67	Common Mallow/ Jungli Bhendi	*Thespesia lampas*	-			-		-	NA
68	Green Shrimp Plant / Dhakta Adulsa	*Ecbolium ligustrinum*	-			-	-	-	NA
69	Paper Flower Climber / Ukshi	*Getonia floribunda*	-	-					NA
70	Large-Leaf Leea / Dinda	*Leea macrophylla*	-	-		-			NA
71	Triangular Horse Bush / Chipate	*Dendrolobium triangulare*	-	-	-				NA
72	Creeping Hemp / Phatphati	*Crotalaria filipes*	-	-	-				NA

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
73	Velvet Leaf/ Lahan Padaval	*Cissampelos pareira*	-	-	-				NA
74	Indian Tolypanthus	*Tolypanthus lagenifer*	-	-	-		-	-	NA
75	Sal Leaved Desmodium / Salvan	*Desmodium gangeticum*	-	-	-		-	-	NA
76	Bengal Dayflower / Kena	*Commelina benghalensis*		-	-	-	-	-	LC
77	Kali Musli	*Curculigo orchioides*						-	NA
78	Water Willow / Karambal	*Justicia procumbems*		-	-		-	-	NA
79	Wavy-Leaf Basketgrass	*Oplismenus burmannii*			-			-	NA
80	Redbird Cactus	*Euphorbia tithymaloides*			-	-	-	-	LC
81	Jointed Buttonweed / Madanghanti	*Spermacoce articularis*		-	-	-	-	-	NA
82	Bush Grape	*Cayratia trifolia*		-	-	-	-	-	NA
83	Silver Cockscomb / Kurdu	*Celosia argentea*	-		-	-	-		LC
84	Jungle mat bean	*Vigna trilobata*			-	-	-	-	NA
85	Lesser Balsam	*Impatiens minor*			-	-		-	NA
86	Nilgonda	*Neuracanthus trinervius*	-		-	-	-	-	NA
87	Spur-Anther Flower / Undirkani	*Centranthera indica*	-	-	-	-	-		LC
88	Roundleaf Marsh Carpet	*Hygrophila serpyllum var. hookeriana*	-			-		-	NA
89	Spiral ginger / Pev	*Cheilocostus speciosus*		-	-	-	-		LC
90	Canegrass	*Eragrostis spp.*	-	-	-		-	-	----
91	Comb Rungia /Sut	*Justicia pectinata*	-		-	-	-		NA
92	Hill Blepharis / Dikna	*Cynarospermum asperrimum*	-		-	-	-	-	NA
93	Lesser Mallow /Dupari	*Hibiscus hirtus*	-		-	-	-	-	NA
94	Indian Borage / Chota Kalpa	*Trichodesma indicum*	-		-	-	-	-	NA
95	Rosy Eranthemum / Ran Aboli	*Eranthemum roseum*							LC
96	Indian turnsole / Bhurundi	*Heliotropium indicum*	-	-	-	-	-		NA

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
97	Variable-Leaf Desmodium	*Grona heterophylla*	■	-	-	-	■	-	NA
98	Jelly leaf / Sadeda	*Sida rhombifolia*	-	■	-	-	-	-	NA
99	Two-Shaped Dewflower	*Murdannia dimorpha*	-	-	-	■	-	■	NA
100	Changing Color Dewflower	*Murdannia versicolor*	-	-	■	-	-	-	NA
101	Little Bell / Ivali Bhonvari	*Ipomoea triloba*	-	-	-	-	-	■	LC
102	Job's Tears / Ranmaka	*Coix lacryma-jobi*	-	-	-	-	-	■	NA
103	Pink Barleria / Gulabi Koranti	*Barleria prattensis*	■	■	-	-	-	-	NA
104	Creeping Cradle Plant / Bechka	*Cyanotis axillaris*	■	-	-	-	-	-	LC
105	Brackish Smithia	*Smithia salsuginea*	■	-	-	-	-	-	NA
106	Brazilian Bachelor's Button	*Centratherum punctatum*	■	-	-	-	-	-	NA
107	Zombi pea / Wild mung	*Vigna vexillata*	■	-	-	-	-	-	NA
108	Sesame	*Sesamum spp.*	■	-	-	-	-	-	-----
109	Nilwanti	*Cyanotis fasciculata*	■	-	-	-	-	-	LC
110	Grasslike Zornia / landgu	*Zornia gibbosa*	■	-	-	-	-	-	NA
111	Shade Loving Coneflower / Morpankhi	*Hemigraphis latebrosa*	-	■	-	-	■	■	NA
112	Spreading Canscora /Titavi	*Consora diffusa*	-	-	■	-	■	-	NA
113	Scarlet Morning Glory /Lal Pungli	*Ipomoea hederifolia*	■	-	-	-	-	-	NA
114	Sword bean / Abai	*Canavalia ensiformis*	■	-	-	-	-	-	NA
115	Tentacled Haplanthodes / Nila Jakara	*Haplanthodes tentaculatus*	■	■	■	■	■	■	NA
116	Indian sphaeranthus / Gorakhmundi	*Sphaeranthus indicus*	■	-	-	-	-	-	LC
117	Wool-Flower Blumea	*Blumea eriantha*	■	■	■	■	■	■	NA
118	Prickly Chaff Flower / Aghada	*Achyranthes aspera*	■	-	-	-	-	-	NA
119	White Lady / Chimin	*Thunbergia fragrans*	-	■	-	-	■	-	NA
120	Nettle Leaved Wedelia	*Wedelia urticaefolia*	-	■	-	-	-	-	NA

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
121	Bitter Luffa / Kadudodki	*Luffa acutangula*	■	-	-	-	-	-	NA
122	Pipewort	*Eriocaulon spp.*		-	-	■	-	-	------
123	Wild Cucumber	*Cucumis sativus var. hardwickii*	■	-	-	-	-	-	NA
124	Western Hill Catmint/ Gopali	*Anisomeles heyneana*	■	-	-	-	-	-	NA
125	Duck flower / Sapsanda	*Aristolochia indica*	-	■	-	-	■	-	NA
126	Pointed-Leaf Lepidagathis / Kateadulsa	*Lepidagathis cuspidata*	-	-	-	-	■	-	NA
127	Devsavar	*Bombax insigne*	-	■	-	■	-	-	NA
128	Tridax Daisy / Ekdandi	*Tridax procumbens*	■	■	■	■	■	■	NA
129	Red Creeper / Sakalvel	*Ventilago maderaspatana*	-	-	-	■	-	-	NA
130	Diamond Flower / Pittapapda	*Oldenlandia corymbosa*	-	-	-	-	-	■	NA
131	Broom Creeper / Vasanvel	*Cocculus hirsutus*	-	-	-	■	-	-	NA
132	Velvet Leaf / Lahan Pahadvel	*Cissampelos pareira*	■	-	-	-	-	-	NA
133	Indian Husk-Pea/ Ran ghevda	*Paracalyx scariosus*	-	-	-	-	-	■	NA
134	Wild Hops / Kanphuti	*Flemingia strobilifera*	-	-	-	-	■	■	NA
135	HoneySuckle Mistletoe/ Vanda	*Dendrophthoe falcata*	-	-	-	-	-	■	NA
136	Butterfly Pea / Gokarna	*Clitoria ternatea*	-	-	-	-	-	■	NA
137	Piluki	*Combretum ovalifolium*	■	-	-	-	-	-	NA
138	Golden shower tree/ Bahava	*Cassia fistula*	■	-	-	-	-	-	LC
139	Bamboo	*Bamboo spp.*	■	-	-	-	-	-	-------
140	Copper pod/ Son mohar	*Peltophorum pterocarpum*	■	■	-	-	-	-	NA
141	Karvi	*Strobilanthes callosa*	■	-	-	-	-	-	NA
142	Burr Bush / Nichardi	*Triumfetta rhomboidea*	-	■	-	-	-	■	LC
143	Goat weed / Ghanera oosadi	*Ageratum conyzoides*	■	-	-	■	■	■	LC
144	Nutsedges	*Cyperus spp.*	-	-	-	■	-	-	----

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
145	Maidenhair fern	*Adiantum spp.*	-	-	-		-	-	----
146	Takla	*Cassia tora*	-	-	-			-	NA
147	Helicopter Flowe / Madhavi Lata	*Hiptage benghalensis*	-		-	-	-	-	LC
148	Mango / Amba	*Mangifera indica*	-		-	-	-	-	DD
149	Surangi	*Mammea suriga*	-		-	-	-	-	NA
150	Mexican Prickly Poppy / Pivla Dhotra	*Argemone mexicana*	-	-	-	-	-		NA
151	Cinderella Weed	*Synedrella nodiflora*	-	-	-	-	-		NA
152	Indian Coral Tree /Pangara	*Erythrina variegata*		-	-	-	-	-	LC
153	Pongam Tree/ Karanj	*Pongamia pinnata*	-		-		-	-	LC
154	Chilla / Mori	*Casearia graveolens*	-	-		-	-	-	NA
155	Brittle orchid/ Waghri	*Acampe praemorsa*	-	-	-	-	-		NA
156	Birdsville Indigo/ Bhuimuli	*Indigofera linnaei*	-	-	-	-	-		NA
157	Scarlet Sterculia / Kaushi	*Sterculia colorata*			-		-	-	NA
158	Indrajao / Pandhara Kuda	*Holarrhena antidysenterica*			-		-		LC
159	Indian Spurge Tree/ Mingut	*Euphorbia neriifolia*	-		-	-	-	-	LC
160	Siamese cassia / Kassod	*Senna siamea*	-	-	-	-	-		LC
161	Silver fern	*Cheilanthes spp.*	-	-	-		-	-	------
162	Indian Charcoal Tree/ Ghol	*Trema orientalis*	-	-	-		-	-	LC
163	Indian Tinospora / Guduchi/ Giloy	*Tinospora cordifolia*		-	-	-	-	-	NA
164	Milk and Wine Lily / Gulabi Karnaphula	*Crinum latifolium*			-	-	-	-	NA
165	Hairy Fig / Dhed Umbar	*Ficus hispida*	-	-	-	-	-		LC
166	Cluster fig / Umbar	*Ficus racemosa*	-		-	-	-	-	LC
167	Purple bane / Gangotra	*Cyathocline purpurea*	-	-		-	-	-	LC
168	Ground Cherry / Ran popti	*Physalis minima*	-	-	-	-	-		LC

S.No	Common Name	Scientific Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status
169	Nelthare / Phudguse	*Alseodaphne semecarpifolia*	-	-	-		-	-	LC
170	Grape-leaf Wood Rose / Navli	*Merremia vitifolia*		-	-	-	-	-	NA
171	Java plum / Jamun	*Syzygium cumini*	-	-	-	-	-		LC
172	Crown Flower/ Rui	*Calotropis gigantea*	-	-	-	-	-		NA
173	Giant Sword fern	*Nephrolepis biserrata*	-		-	-	-	-	NA
174	Indian cherry / Bhokar	*Cordia dichotoma*	-		-	-	-	-	LC
175	Woodrow's grape	*Cissus woodrowii*	-		-	-	-	-	NA
176	Whipcord Cobra Lily	*Ariesema tortuosum*		-	-	-	-	-	NA
177	Black Ebony / Tendu	*Diospyros melanoxylon*	-	-		-	-	-	NA
178	Tiger's Milk Spruce / Dudala	*Sapium insigne*		-	-	-	-	-	NA
179	Mukwa	*Pterocarpus spp.*	-	-		-	-	-	-----
180	Pavala Karmal	*Dillenia pentagyna*	-	-		-	-	-	NA
181	Bitter yam / Kadu Karanda	*Dioscorea bulbifera*		-	-	-	-	-	NA
182	Liverworts (Bryophyte)	*Riccia spp.*		-	-	-	-	-	----
183	Rose balsam / Terda	*Impatiens balsamina*	-	-	-	-	-		NA
184	Stinging nettle / Aagya	*Laportea interrupta*		-	-	-	-	-	NA
185	Roundleaf bindweed	*Evolvulus nummularius*	-	-	-	-	-		NA
186	Carry Me Seed / Bhui Avala	*Phyllanthus amarus*		-	-	-	-	-	NA
187	Wild Grape / Raan Dhraksha	*Ampelocissus latifolia*		-	-	-	-	-	NA
188	Adder's-tongue	*Ophioglossum spp.*		-	-	-	-	-	------
189	Pankusum	*Pancratium triflorum*		-	-	-	-	-	NA
190	Indian tolypanthus	*Tolypanthus spp.*	-		-	-	-	-	------

LC = Least Concern, VU= Vulnerable, DD = Data Deficient, NA = Not Assessed)

Table 2: Phenology (emergence of leaves, flowers and fruits) from July 2021 to June 2022 of twenty most common trees

Sr.no	Botanical name	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
1	*Tectona grandis*		Flowering				Fruiting						
2	*Garuga pinnata*									Flowering	Fruiting		
3	*Lannea coromandelica*								Flowering		Fruiting		
4	*Schleichera oleosa*									New leaves sprout & flowering	Fruiting		
5	*Streblus asper*								Flowering		Fruiting		
6	*Grewia asiatica*										Flowering	Fruiting	
7	*Butea monosperma*									Flowering			
8	*Bridelia retusa*		Flowering			Fruiting						New leaf	
9	*Terminalia bellirica*										New leaves & Flowering	Fruiting	
10	*Miliusa tomentosa*								Flowering & leaf fall		Fruiting & leaf fall	Fruiting	
11	*Mitragyna parvifolia*					Fruiting			Fruiting & leaf fall	fruiting	New leaf sprout & fruiting	Flowering	
12	*Terminalia elliptica*					Fruiting					Flowering		
13	*Ficus exasperata*						Flowering						
14	*Wrightia tinctoria*	Fruiting						Flowering	Leaf fall	Flowering			
15	*Ixora brachiata*						Flowering	flowering & fruiting	flowering & fruiting				

Table 2: Phenology (emergence of leaves, flowers and fruits) from July 2021 to June 2022 of twenty most common trees

Sr.no	Botanical name	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
16	*Heterophragma quadriloculare*									Flowering	Flowering & fruiting	Fruting	
17	*Holarrhena antidysenterica*	Fruting						Flowering				Flowering & fruiting	
18	*Morinda pubescens*	Fruting									Flowering & fruiting	Fruiting	
19	*Holoptelea integrifolia*		Fruiting			Leaf fall	Flowering & fruiting				Fruiting		
20	*Anogeissus latifolia*					Flowering	Fruiting						

Species accumulation curve

Trees: 57% of the trees were sampled by July 2021 the subsequent increase in the number of species are additions from opportunistic records outside the study-grids

Fig. 6: Species accumulation curve for trees sampled from July 2021 to June 2022 on SGNP during the BNHS-GMLR survey

Shrubs: 71% of species were recorded by July 2021 and the sampling saturation was observed by November

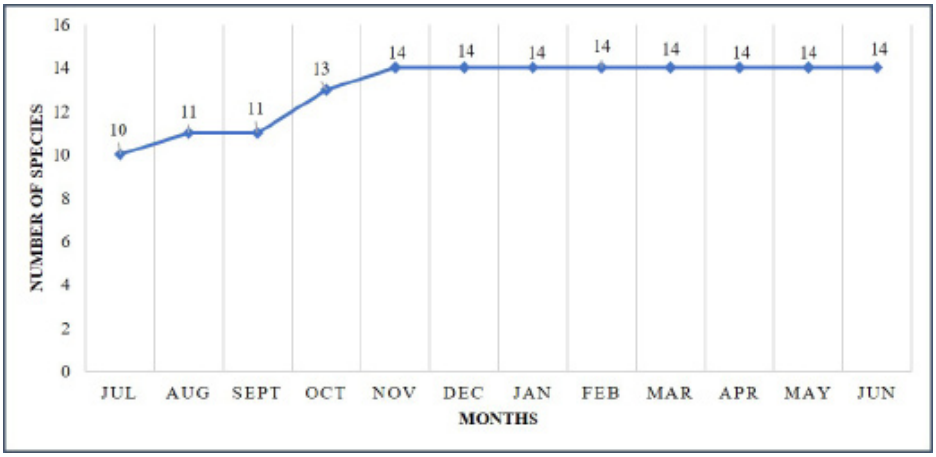

Fig. 7: Species accumulation curve for shrubs sampled from July 2021 to June 2022 in SGNP during the BNHS-GMLR survey

Herbs: 88% of the herb species were recorded by January 2022.

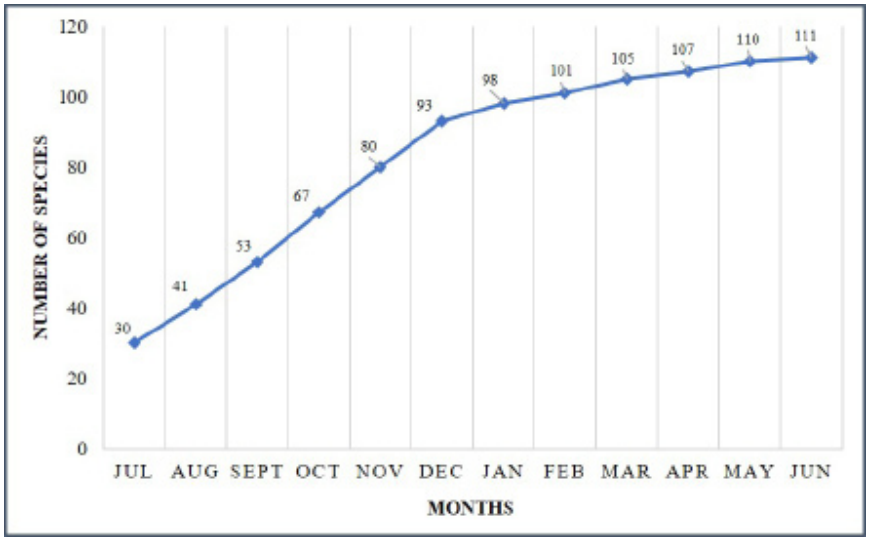

Fig. 8: Species accumulation curve for herbs sampled from July 2021 to June 2022 on SGNP during the BNHS-GMLR survey

Plant community characteristics

Communities on various habitats can be studied quantitatively by determining the following (Müeller Dombois and Ellenberg 1974).

I. Frequency
II. Density and Abundance
III. Basal cover
IV. Dominance
V. IVI of each species following the methods given

I. Frequency indicates the number of sampling units in which a given species occurs and thus expresses the distribution or dispersion of various species in a community. It is calculated using the following formula:

$$\textbf{Frequency} = \frac{\text{Number of sampling units in which the species occurred} \times 100\%}{\text{Total number of sampling units studied}}$$

II. Density and Abundance represent the numerical strength of species in the community. Density is expressed as the number of individuals of a species per unit area and is calculated as follows:

$$\textbf{Density} = \frac{\text{Total number of individuals of a species in all the sample units} \times 100\%}{\text{Total number of sample units studied}}$$

Abundance is expressed as the number of individuals per quadrat of occurrence and is calculated as follows:

$$\textbf{Abundance} = \frac{\text{Total no of individuals of a species}}{\text{Number of quadrats of occurrence of the species}}$$

III. Basal cover refers to the area of ground penetrated by the stem and is measured as follows:

$$\textbf{Basal cover} = \frac{(CBH)^2}{4\pi}$$

IV. Dominance is the function of density and basal cover which is given as follows:

Dominance = Mean basal area per individual x Total number of individuals in a species

V. Relative density, relative frequency, relative are expressed as follows:

$$\textbf{Relative Density of species A} = \frac{\text{No. of individuals of species A} * 100}{\text{Total no. of individuals of all species}}$$

$$\textbf{Relative Frequency of species A} = \frac{\text{Frequency of species A}}{\text{Sum of frequency values for all species}} * 100$$

$$\textbf{Relative Dominance of species A} = \frac{\text{Dominance of species A}}{\text{Total dominance of all species}} * 100$$

VI. Important Value Index (IVI):

The value of IVI was computed by summation of the values of the relative frequency, relative density and relative dominance (Curtis and McIntosh, 1950, 1951: Mishra, 1968). Basal cover is considered as the portion of ground surface occupied by a species (Greig-Smith, 1964). Important Value Index (IVI) was calculated separately for each species of the tree, shrub and herb layer. A species, which attains highest importance value, is the most dominant and the species with lowest importance value is the rare/least dominant species.

IVI (trees) = Relative frequency + Relative Density + Relative Dominance

IVI (shrubs and herbs) = Relative frequency + Relative Density

Quantitative data analysis comprises a total of 14 shrub species , it is observed that *Capparis sepiaria, Helicteres isora and Ageratum conyzoides* are the dominant species and were frequently found. *Cissus woodrowii , Triumfetta rhomboidea and Strobilanthes callosa* have less frequency.

Floral diversity

The analysis of biodiversity can be carried out by calculating Shannon Diversity Index (H′), Simpson Dominance Index (D) and Pielou Evenness Index (E). These indices are adopted for their low sensitivity to the sample size (Magurran, 1988).

Table 3: Species richness in different grids

Grid	Trees	Shrubs	Herbs	Total
Grid 1	24	6	9	39
Grid 2	27	6	8	41
Grid 3	20	6	3	29
Grid 4	17	5	8	30
Grid 5	20	5	7	32
Grid 6	13	4	10	27

Table 4: Frequency, density and abundance of plant species recorded in the study area during the BNHS-GMLR survey

Sr. No	Plants	Total number of individuals of a species in all the sample units	Number of sampling units in which the species occurred	Total number of sampling units studied	Frequency	Density (number of plants per sample unit)	Abundance
1	*Tectona grandis*	61	20	48	41.67	127.08	3.05
2	*Garuga pinnata*	17	10	48	20.83	35.42	1.70
3	*Lannea coromandelica*	11	11	48	22.92	22.92	1.00
4	*Schleichera oleosa*	15	10	48	20.83	31.25	1.50
5	*Flacourtia indica*	3	3	48	6.25	6.25	1.00
6	*Streblus asper*	34	12	48	25.00	70.83	2.83
7	*Grewia asiatica*	2	2	48	4.17	4.17	1.00
8	*Butea monosperma*	12	10	48	20.83	25.00	1.20
9	*Careya arborea*	3	3	48	6.25	6.25	1.00
10	*Bridelia retusa*	4	3	48	6.25	8.33	1.33
11	*Terminalia bellirica*	6	5	48	10.42	12.50	1.20
12	*Miliusa tomentosa*	2	2	48	4.17	4.17	1.00
13	*Anogeissus latifolia*	1	1	48	2.08	2.08	1.00
14	*Mitragyna parvifolia*	31	14	48	29.17	64.58	2.21
15	*Terminalia elliptica*	*6*	4	48	8.33	12.50	1.50
16	*Sterculia urens*	1	1	48	2.08	2.08	1.00
17	*Ficus exasperata*	4	2	48	4.17	8.33	2.00
18	*Acacia catechu*	10	7	48	14.58	20.83	1.43
19	*Gliricidia sepium*	*4*	2	48	4.17	8.33	2.00
20	*Wrightia tinctoria*	19	17	48	35.42	39.58	1.12
21	*Ixora brachiata*	5	3	48	6.25	10.42	1.67
22	*Heterophragma quadriloculare*	*4*	3	48	6.25	8.33	1.33
23	*Haldina cordifolia*	9	6	48	12.50	18.75	1.50
24	*Holoptelea integrifolia*	*20*	13	48	27.08	41.67	1.54
25	*Bauhinia Spp*	2	2	48	4.17	4.17	1.00
26	*Catunaregam spinosa*	1	1	48	2.08	2.08	1.00

Sr. No	Plants	Total number of individuals of a species in all the sample units	Number of sampling units in which the species occurred	Total number of sampling units studied	Frequency	Density (number of plants per sample unit)	Abundance
27	*Morinda pubescens*	*5*	3	48	6.25	10.42	1.67
28	*Spondias pinnata*	1	1	48	2.08	2.08	1.00
29	*Mallotus philippensis*	3	2	48	4.17	6.25	1.50
30	*Borassus flabellifer*	*6*	1	48	2.08	12.50	6.00
31	*Ficus benghalensis*	1	1	48	2.08	2.08	1.00
32	*Xantolis tomentosa*	1	1	48	2.08	2.08	1.00
33	*Sapindus trifoliatus*	1	1	48	2.08	2.08	1.00
34	*Tamarindus indica*	1	1	48	2.08	2.08	1.00
35	*Pongamia pinnata*	5	3	48	6.25	10.42	1.67
36	*Sterculia colorata*	1	1	48	2.08	2.08	1.00
37	*Holarrhena antidysenterica*	4	3	48	6.25	8.33	1.33
38	*Diospyros melanoxylon*	2	2	48	4.17	4.17	1.00
39	*Dalbergia sisso*	1	1	48	2.08	2.08	1.00

Table 5: Relative frequency (RF), Relative density (RD), Relative abundance (RA), mean basal area, dominance, relative dominance and Importance Value Index (IVI) of tree species

S. No	Plants	RF	RD	RA	Mean basal area	Dominance	Relative Dominance	IVI trees
1	*Tectona grandis*	6.35	13.23	3.07	29.66	1,809.50	1.21	20.79
2	*Garuga pinnata*	3.17	3.69	1.71	22.36	380.12	0.25	7.12
3	*Lannea coromandelica*	3.49	2.39	1.01	215.98	2,375.78	1.59	7.46
4	*Schleichera oleosa*	3.17	3.25	1.51	130.89	1,963.35	1.31	7.74
5	*Flacourtia indica*	0.95	0.65	1.01	75.66	226.98	0.15	1.75
6	*Streblus asper*	3.81	7.38	2.85	13.30	452.20	0.30	11.49
7	*Grewia asiatica*	0.63	0.43	1.01	981.74	1,963.48	1.31	2.38
8	*Butea monosperma*	3.17	2.60	1.21	55.04	660.48	0.44	6.22
9	*Careya arborea*	0.95	0.65	1.01	398.19	1,194.57	0.80	2.40
10	*Bridelia retusa*	0.95	0.87	1.34	268.80	1,075.20	0.72	2.54
11	*Terminalia bellirica*	1.59	1.30	1.21	265.07	1,590.42	1.06	3.95
12	*Miliusa tomentosa*	0.63	0.43	1.01	537.60	1,075.20	0.72	1.79

S. No	Plants	RF	RD	RA	Mean basal area	Dominance	Relative Dominance	IVI trees
13	*Anogeissus latifolia*	0.32	0.22	1.01	4,071.50	4,071.50	2.72	3.25
14	*Mitragyna parvifolia*	4.44	6.72	2.23	71.17	2,206.18	1.47	12.64
15	*Terminalia elliptica*	1.27	1.30	1.51	641.40	3,848.40	2.57	5.14
16	*Sterculia urens*	0.32	0.22	1.01	4,778.36	4,778.36	3.19	3.72
17	*Ficus exasperata*	0.63	0.87	2.01	1,734.94	6,939.78	4.63	6.13
18	*Acacia catechu*	2.22	2.17	1.44	418.53	4,185.30	2.79	7.18
19	*Gliricidia sepium*	0.63	0.87	2.01	346.36	1,385.44	0.92	2.43
20	*Wrightia tinctoria*	5.40	4.12	1.12	34.76	660.44	0.44	9.96
21	*Ixora brachiate*	0.95	1.08	1.68	76.02	380.10	0.25	2.29
22	*Heterophragma quadriloculare*	0.95	0.87	1.34	363.05	1,452.20	0.97	2.79
23	*Haldina cordifolia*	1.90	1.95	1.51	1,989.76	17,907.84	11.95	15.81
24	*Holoptelea integrifolia*	4.13	4.34	1.55	501.43	10,028.60	6.69	15.16
25	*Bauhinia Spp*	0.63	0.43	1.01	190.06	380.12	0.25	1.32
26	*Catunaregam spinosa*	0.32	0.22	1.01	380.13	380.13	0.25	0.79
27	*Morinda pubescens*	0.95	1.08	1.68	318.09	1,590.43	1.06	3.10
28	*Spondias pinnata*	0.32	0.22	1.01	4,300.84	4,300.84	2.87	3.40
29	*Mallotus philippensis*	0.63	0.65	1.51	1,433.61	4,300.83	2.87	4.16
30	*Borassus flabellifer*	0.32	1.30	6.03	3,563.74	21,382.46	14.27	15.89
31	*Ficus benghalensis*	0.32	0.22	1.01	10,568.31	10,568.31	7.05	7.59
32	*Xantolis tomentosa*	0.32	0.22	1.01	9,331.31	9,331.31	6.23	6.76
33	*Sapindus trifoliatus*	0.32	0.22	1.01	4,476.96	4,476.96	2.99	3.52
34	*Tamarindus indica*	0.32	0.22	1.01	13,478.21	13,478.21	8.99	9.53
35	*Pongamia pinnata*	0.95	1.08	1.68	546.79	2,733.95	1.82	3.86
36	*Sterculia colorata*	0.32	0.22	1.01	2,827.43	2,827.43	1.89	2.42
37	*Holarrhena antidysenterica*	0.95	0.87	1.34	70.88	283.53	0.19	2.01
38	*Diospyros melanoxylon*	0.63	0.43	1.01	245.43	490.86	0.33	1.40
39	*Dalbergia sisso*	0.32	0.22	1.01	730.61	730.61	0.49	1.02

Table 6: Frequency, Density and abundance of shrubs & herbs species

Sr. No	*Plants*	Total number of individuals of a species in all the sample units	Number of sampling units in which the species occurred	Total number of sampling units studied	Frequency	Density (number of plants per sample unit)	Abundance
1	*Carissa carandas*	3	2	48	4.17	6.25	1.5
2	*Microcos paniculata*	6	5	48	10.42	12.50	1.2
3	*Helicteres isora*	12	12	48	25.00	25.00	1
4	*Leea indica*	11	11	48	22.92	22.92	1
5	*Capparis sepiaria*	14	14	48	29.17	29.17	1
6	*Neuracanthus sphaerostachyus*	5	5	48	10.42	10.42	1
7	*Curcuma pseudomontana*	12	12	48	25.00	25.00	1
8	*Corchorus spp*	4	2	48	4.17	8.33	2
9	*Smilax ovalifolia*	2	1	48	2.08	4.17	2
10	*Cryptolepis buchananii*	3	3	48	6.25	6.25	1
11	*Thespesia lampas*	6	6	48	12.50	12.50	1
12	*Ecbolium ligustrinum*	5	5	48	10.42	10.42	1
13	*Getonia floribunda*	1	1	48	2.08	2.08	1
14	*Cissampelos pareira*	1	1	48	2.08	2.08	1
15	*Curculigo orchioides*	9	9	48	18.75	18.75	1
16	*Justicia procumbems*	3	2	48	4.17	6.25	1.5
17	*Oplismenus burmannii*	9	9	48	18.75	18.75	1
18	*Spermacoce articularis*	1	1	48	2.08	2.08	1
19	*Celosia argentea*	3	3	48	6.25	6.25	1
20	*Eragrostis spp.*	1	1	48	2.08	2.08	1
21	*Murdannia versicolor*	1	1	48	2.08	2.08	1
22	*Thunbergia fragrans*	5	1	48	2.08	10.42	5
23	*Lepidagathis cuspidata*	5	1	48	2.08	10.42	5
24	Amorphophallus	2	1	48	2.08	4.17	2
25	*Strobilanthes callosa*	3	3	48	6.25	6.25	1
26	*Triumfetta rhomboidea*	3	3	48	6.25	6.25	1
27	*Ageratum conyzoides*	10	10	48	20.83	20.83	1
28	*Cissus woodrowii*	1	1	48	2.08	2.08	1
29	*Ampelocissus latifolia*	1	1	48	2.08	2.08	1

Table 7: Relative frequency, density, abundance and Importance Value Index (IVI) of shrubs and herb species

Sr. No	*Plants*	Relative frequency	Relative density	Relative abundance	IVI (shrub+ herbs)
1	*Carissa carandas*	0.63	0.65	1.51	1.29
2	*Microcos paniculata*	1.59	1.30	1.21	2.89
3	*Helicteres isora*	3.81	2.60	1.01	6.41
4	*Leea indica*	3.49	2.39	1.01	5.88
5	*Capparis sepiaria*	4.44	3.04	1.01	7.48

Sr. No	*Plants*	Relative frequency	Relative density	Relative abundance	IVI (shrub+ herbs)
6	*Neuracanthus sphaerostachyus*	1.59	1.08	1.01	2.67
7	*Curcuma pseudomontana*	3.81	2.60	1.01	6.41
8	*Corchorus spp*	0.63	0.87	2.01	1.50
9	*Smilax ovalifolia*	0.32	0.43	2.01	0.75
10	*Cryptolepis buchananii*	0.95	0.65	1.01	1.60
11	*Thespesia lampas*	1.90	1.30	1.01	3.21
12	*Ecbolium ligustrinum*	1.59	1.08	1.01	2.67
13	*Getonia floribunda*	0.32	0.22	1.01	0.53
14	*Cissampelos pareira*	0.32	0.22	1.01	0.53
15	*Curculigo orchioides*	2.86	1.95	1.01	4.81
16	*Justicia procumbems*	0.63	0.65	1.51	1.29
17	*Oplismenus burmannii*	2.86	1.95	1.01	4.81
18	*Spermacoce articularis*	0.32	0.22	1.01	0.53
19	*Celosia argentea*	0.95	0.65	1.01	1.60
20	*Eragrostis spp.*	0.32	0.22	1.01	0.53
21	*Murdannia versicolor*	0.32	0.22	1.01	0.53
22	*Thunbergia fragrans*	0.32	1.08	5.03	1.40
23	*Lepidagathis cuspidata*	0.32	1.08	5.03	1.40
24	Amorphophallus	0.32	0.43	2.01	0.75
25	*Strobilanthes callosa*	0.95	0.65	1.01	1.60
26	*Triumfetta rhomboidea*	0.95	0.65	1.01	1.60
27	*Ageratum conyzoides*	3.17	2.17	1.01	5.34
28	*Cissus woodrowii*	0.32	0.22	1.01	0.53
29	*Ampelocissus latifolia*	0.32	0.22	1.01	0.53

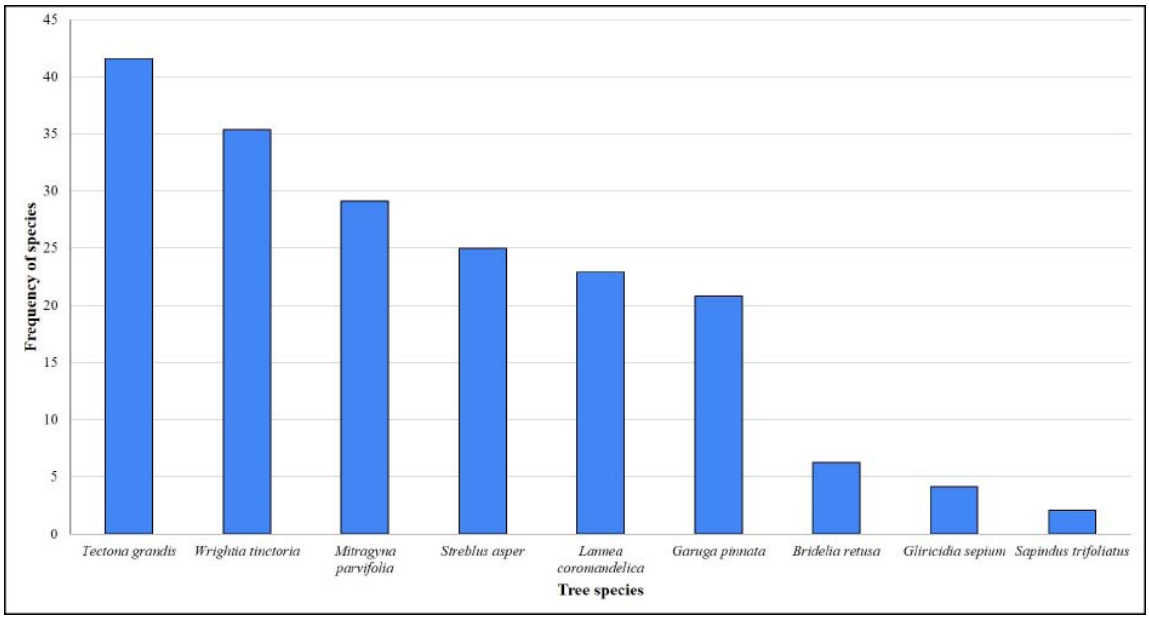

Fig. 9: Frequency Distribution of trees

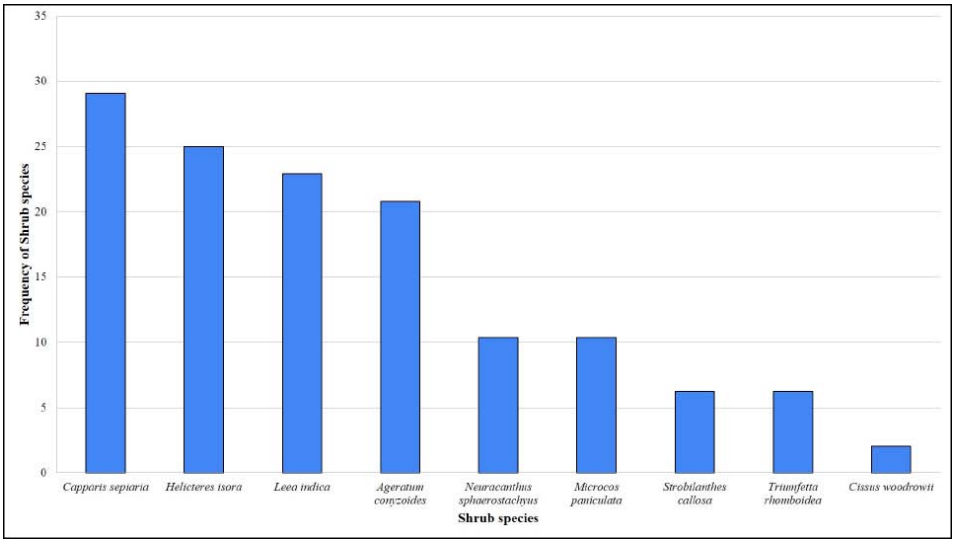

Fig. 10: Frequency Distribution of shrubs

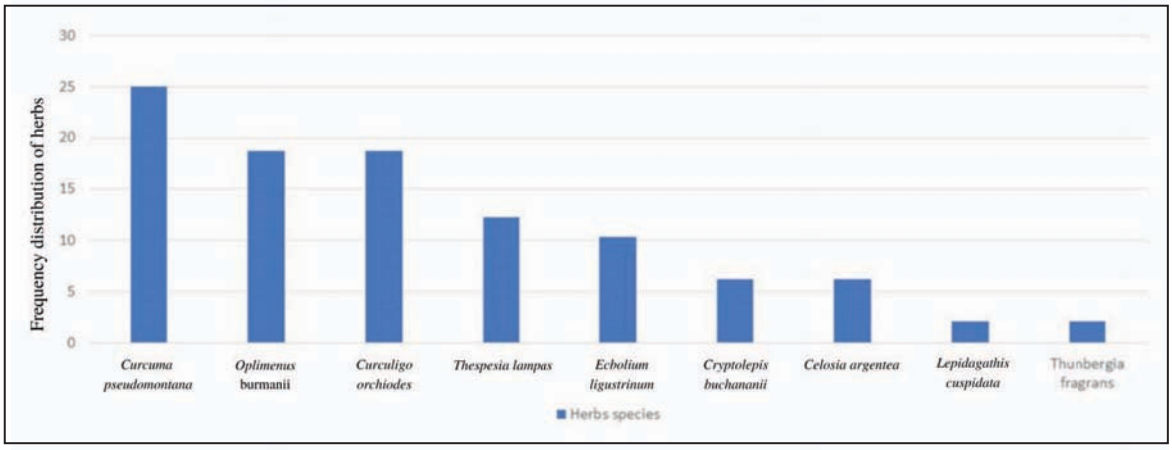

Fig. 11: Frequency distribution of herbs

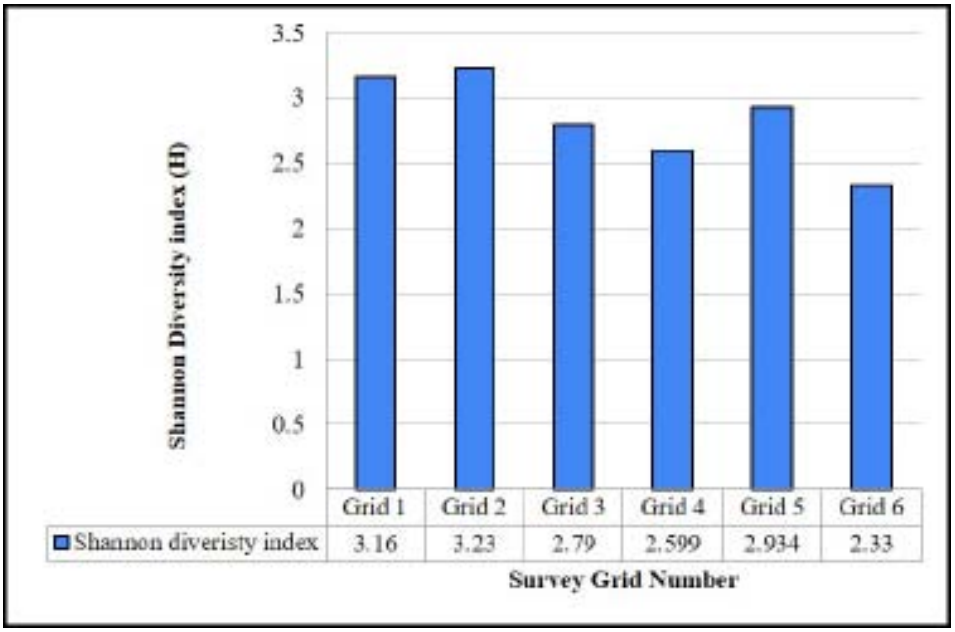

Fig. 12: Shannon diversity index for flora in different grids (I to VI) placed on the tunnel alignment for the BNHS-GMLR suveyvey

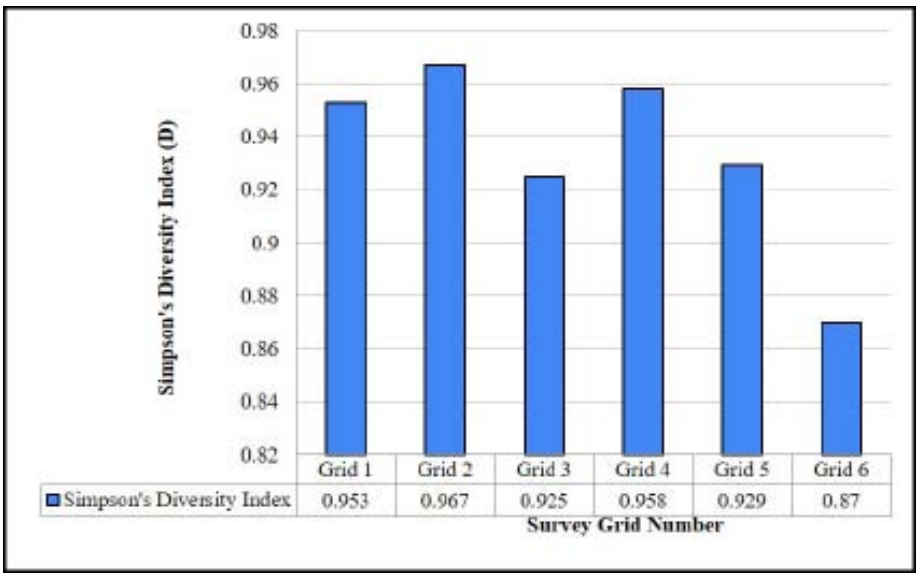

Fig. 13: Simpson's diversity index for flora in different grids (I to VI) placed on the tunnel alignment for the BNHS-GMLR suvey

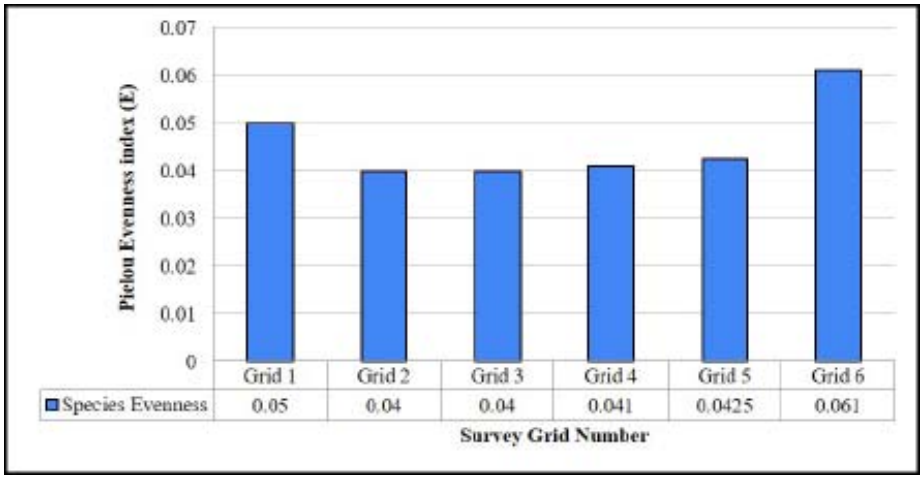

Fig. 14: Pielou Evenness Index (E) for flora in different grids (I to VI) placed on the tunnel alignment for the BNHS-GMLR suvey

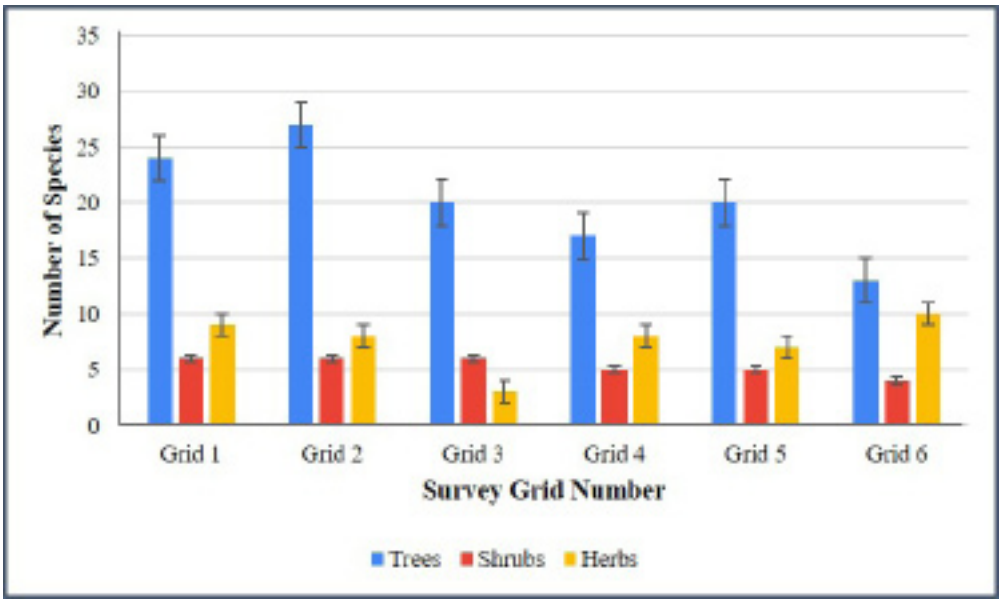

Fig. 15: Species Richness of flora in different grids (I to VI) placed on the tunnel alignment for the BNHS-GMLR suvey

Summary

In total 190 species of plants were observed in all the grids out of which 65 trees,111 herbs and 14 shrubs were recorded during the year-long survey (Table 2). IUCN status of some of the species (n=12) could not be obtained because identification was possible only till genus level. Similarly, the IUCN status of a large number of species (n=120) have not been assessed. Fifty-one species were recorded as Least Concern, *Curcuma pseudomontana* is recorded as Vulnerable and *Mangifera indica* is found to be Data Deficient. None of the species found in the grids are listed in the Wild Life (Protection) Act, 1971

On analysing phenology of frequently occurring trees in the study area – 20 trees as summarized in Table 3, it was observed that the majority of the trees start flowering from December, followed by fruit-setting and seed dispersal from April to June. The reason for that is so that after the first shower or during monsoon seeds can germinate. Additionally, it has been noted that some species experience leaf-fall during flowering and fruiting. The likely reason is so that flowers and fruits are more visible to animals (a biotic element) and to lessen obstructions to wind-borne pollination or seed dissemination (an abiotic influence).

Highest number of species were recorded in the second grid followed by the first, fifth, third and fourth grids and sixth grid shows a least number of species. The variation across the grids is as summarized below (Figure 15, Table 8).

First Grid: In this grid anthropogenic activity like agriculture, forage of wild fruits and vegetables and cut trees were observed. *Ageratum conyzoides,* an invasive species, has been found to have a thick spread at the start of the grid, which is exposed to agriculture and human activity. However, as we move towards the forest, *Ageratum conyzoides* spread is seen to be reduced, and there is no *Ageratum conyzoides* on the hillock or highest point of the grid. Due to the mosaic ecosystem of agriculture, hills, an open plateau, and a stream, the grid shows good diversity of plant species. Major trees observed were *Garuga pinnata, Lanneacoromandelica, Bombax ceiba and Schleichera oleosa.* Following patches of shrubs and sessional herbs were also noted - *Strobilanthes callosa, Curculigo orchioides, Crinum latifolium and Chlorophytum tuberosum.*

Second Grid: This grid shows the highest diversity of species as compared with other grids as it is a less disturbed habitat. Grid has one of the highest points and open plateaus. Cover of seasonal herbs like *Curculigo orchioides* and *Crinum latifolium* were observed. The grid also shows dense patches of *Strobilanthes callosa* and a patch of *Ecbolium ligustrinum*n near water bodies.Major trees observed were *Mitragyna parvifolia, Anogeissus latifolia, and Lannea coromandelica. Tolypanthus lagenifer* which is aparasitic shrub was also recorded on this grid.

Third Grid: This grid has a dense canopy, an open patch of herbs and a stream passing through it. Grid has a row of *Peltophorum pterocarpum* trees and the invasion of *Ageratum conyzoides.* Major trees observed were *Mitragyna parvifolia, Wrightia tinctoria, Borassus flabellifer, and Schleicheraoleosa.*

Fourth grid: In one of the grid's quadrats, a tar road and a power line cross, while another quadrat has a water pipeline. On the edges of water bodies, a patch of *Cyperus spp*. was observed. Ground cover of *Cassia tora* were seen close to the powerline. *Borassus flabellifer, Tectona grandis, Streblus asper, and Schleichera oleosa* were the main plant species recorded in this grid.

Fifth grid: One of the grid's quadrats had a power line running through it, and *Ageratum conyzoides* invasion was seen along the line. The grid has one of the highest points of the study area, with a plateau

covered by herbs and grasses. *Viscum album* a hemiparasitic plant and *Sapindus trifoliatus* were found on this grid. Major tree species observed were *Mitragyna parvifolia,* and *Haldina cordifolia.*

Sixth grid: Due to frequent human *activity*, there has been significant anthropogenic disturbance in this grid. Cut-down trees and forage of wild fruits and vegetables have been observed. Grid has open grassland like habitat where plantations of native species like *Pongamia pinnata, Mitragyna parvifolia, Butea monosperma,Vitex negundo, Ficus racemosa, Cassia fistula* and so on were noted. Additionally, a bamboo patch and various grass species were planted. Sticks and a green shade net are used to create a protection for sapling. Plants that have been planted have a strong chance of surviving, and it is advised to routinely weed around saplings. Additionally, Grid contains non-native trees such *Peltophorum pterocarpum, Acacia auriculiformis,* and *Gliricidia sepium.*

Arachnids

Methods

Arachnid Survey was conducted using the quadrat sampling method. 8 plots of 10 x 10 metres were demarcatedin each grid(I to VI) in such a way that 4 plots were on the tunnel alignment and 2 plots each were placed on either side of the tunnel. The plots were identified from coloured ribbons and GPS coordinates during each monthly sampling session. Surveys were conducted in the morning hours only. The survey was conducted from July 2021 to June 2022, except in the months of February and March when arachnid sampling was not done.

Bark fissures, fallen branches, rock crevices, overturned rocks were examined for the presence of arachnids. Opportunistic sightings of spiders outside the survey-grids were also noted down.

Examination through a microscope is required to accurately identify spiders up to the species level. In this study, spider specimens were identified only from photographs. Therefore, species level identification was not possible in most cases where photographs could not be matched with reference keys. Spiders were identified up to the family level and where possible up to the genus and species level. Even though the most spiders could not be identified up to the species level, morphological differences were considered to estimate the no. of species in a given genus.

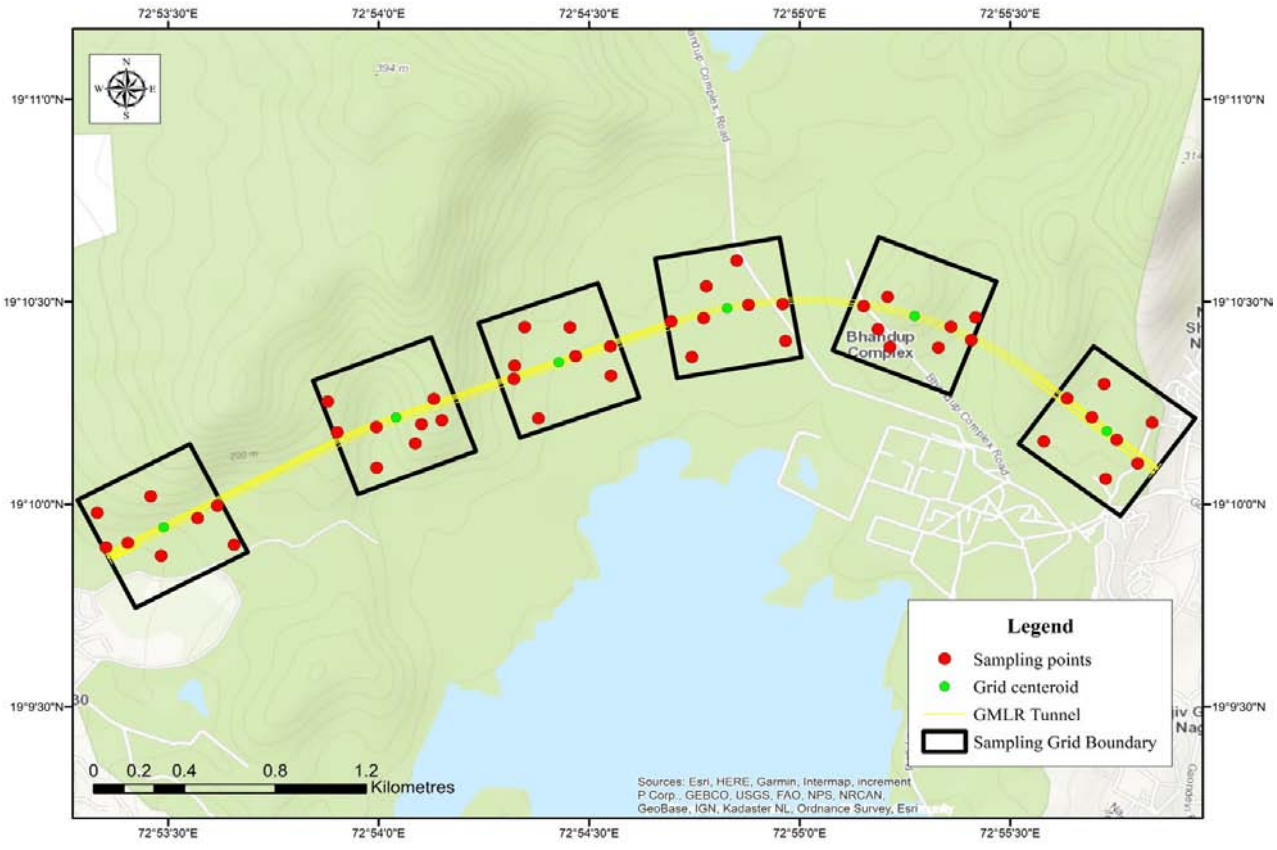

Figure 16: Map showing the tunnel alignment of a section of the Goregaon-Mulund Link Road that will be passing through the Sanjay Gandhi National Park (SGNP).
The sampling grids and sampling points are indicated for the months surveyed

Plate 8: Field work and data collection by Arachnid team

Intensive Search

Photographing spiders

Plot Marking

Intensive Search

Table 8: Checklist of Arachnid species recorded in the BNHS-GMLR conducted from June 2021 to July 2022

Sr. No.	Family	Species
1	Agelenidae	*Coelotes sp1*
2	Araneidae	*Araneidae sp1*
3	Araneidae	*Araneidae sp2*
4	Araneidae	*Araneus sp2*
5	Araneidae	*Araneus sp3*
6	Araneidae	*Argiope aemula*
7	Araneidae	*Argiope anasuja*
8	Araneidae	*Argiope sp1*
9	Araneidae	*Bijoaraneus mitificus*
10	Araneidae	*Chorizopes sp1*
11	Araneidae	*Cyclosa sp1*
12	Araneidae	*Cyclosa sp3*
13	Araneidae	*Cyrtophora cicatrosa*
14	Araneidae	*Cyrtophora sp1*
15	Araneidae	*Cyrtophora sp2*
16	Araneidae	*Eriovixia sp1*
17	Araneidae	*Eriovixia sp2*
18	Araneidae	*Eriovixia sp3*
19	Araneidae	*Eriovixia sp4*
20	Araneidae	*Gea spinipes*
21	Araneidae	*Herennia multipuncta*
22	Araneidae	*Hypsosinga sp.*
23	Araneidae	*Lipocrea sp.*
24	Araneidae	*Macracantha hasselti*
25	Araneidae	*Neoscona sp1*
26	Araneidae	*Neoscona sp11*
27	Araneidae	*Neoscona sp14*
28	Araneidae	*Neoscona sp3*
29	Araneidae	*Neoscona sp7*
30	Araneidae	*Nephila kuhlii*
31	Araneidae	*Nephila pilipes*
32	Araneidae	*Parawixia sp1*
33	Araneidae	*Poltys sp1*
34	Araneidae	*Porcataraneus sp1*
35	Araneidae	*Thelacantha brevispina*
36	Cheiracanthiidae	*Calamopus sp1*

Sr. No.	Family	Species
37	Cheiracanthiidae	*Cheiracanthium sp1*
38	Cithaeronidae	*Cithaeronidae sp1*
39	Cithaeronidae	*Inthaeron sp1*
40	Clubionidae	*Clubionidae sp1*
41	Clubionidae	*Matidia sp1*
42	Corinnidae	*Cambalida sp1*
43	Corinnidae	*Corinnidae sp2*
44	Corinnidae	*Corrinnidae sp1*
45	Corinnidae	*Echinax sp1*
46	Ctenidae	*Anahita sp1*
47	Ctenidae	*Ctenus sp1*
48	Ctenidae	*Ctenus sp2*
49	Ctenidae	*Ctenus sp3*
50	Filistatidae	*Pritha sp1*
51	Gnaphosidae	*Berlandina sp1*
52	Gnaphosidae	*Prodidomus sp1*
53	Gnaphosidae	*Scotophaeus sp1*
54	Gnaphosidae	*Zelotes sp1*
55	Hersiliidae	*Hersilia sp.*
56	Linyphiidae	*Linyphiidae sp1*
57	Linyphiidae	*Linyphiidae sp2*
58	Liocranidae	*Liocranidae sp1*
59	Liocranidae	*Sphingius sp1*
60	Lycosidae	*Evippa sp1*
61	Lycosidae	*Evippomma sp1*
62	Lycosidae	*Hippasa sp1*
63	Lycosidae	*Hippasa sp2*
64	Lycosidae	*Hippasa sp3*
65	Lycosidae	*Hippasa sp4*
66	Lycosidae	*Lycosa sp1*
67	Lycosidae	*Lycosidae sp1*
68	Lycosidae	*Lycosidae sp2*
69	Lycosidae	*Lycosidae sp3*
70	Lycosidae	*Pardosa sp1*
71	Lycosidae	*Trochosa sp1*
72	Lycosidae	*Wadicosa sp1*
73	Lycosidae	*Zoica sp1*
74	Oecobiidae	*Oecobius*

Sr. No.	Family	Species
75	Oonopidae	*Oonopidae sp1*
76	Oxyopidae	*Hamadruas sp.*
77	Oxyopidae	*Hamataliwa sp1*
78	Oxyopidae	*Hamataliwa sp2*
79	Oxyopidae	*Oxyopes shweta*
80	Oxyopidae	*Oxyopes sp1*
81	Oxyopidae	*Oxyopes sp2*
82	Oxyopidae	*Oxyopes sp3*
83	Oxyopidae	*Oxyopes sp4*
84	Oxyopidae	*Peucetia sp1*
85	Philodromidae	*Philodromidae sp1*
86	Philodromidae	*Psellonus sp1*
87	Philodromidae	*Tibellus sp1*
88	Pisauridae	*Dendrolycosa sp1*
89	Pisauridae	*Euprosthenops sp1*
90	Pisauridae	*Hygropoda sp1*
91	Pisauridae	*Perenethis sp1*
92	Pisauridae	*Pisaura sp1*
93	Pisauridae	*Pisauridae sp1*
94	Pisauridae	*Polyboea sp1*
95	Pisauridae	*Thalassius sp1*
96	Salticidae	*Afraflacilla sp1*
97	Salticidae	*Asemonea tenuipes*
98	Salticidae	*Bianor*
99	Salticidae	*Brancus sp1*
100	Salticidae	*Brettus sp1*
101	Salticidae	*Burmattus sp1*
102	Salticidae	*Carrhotus sp1*
103	Salticidae	*Carrhotus viduus*
104	Salticidae	*Chrysilla volupe*
105	Salticidae	*Cocalus sp1*
106	Salticidae	*Curubis sp1*
107	Salticidae	*Curubis sp2*
108	Salticidae	*Cyrba sp1*
109	Salticidae	*Epeus sp1*
110	Salticidae	*Epocilla sp1*
111	Salticidae	*Harmochirus sp1*
112	Salticidae	*Hasarius adansoni*

Sr. No.	Family	Species
113	Salticidae	*Hyllus semicupreus*
114	Salticidae	*Icius sp1*
115	Salticidae	*Jerzego sp1*
116	Salticidae	*Langelurillus lacteus*
117	Salticidae	*Langelurillus onyx*
118	Salticidae	*Lagona sp.*
119	Salticidae	*Madhyattus sp1*
120	Salticidae	*Menemerus bivittatus*
121	Salticidae	*Myrmarachne melanocephala*
122	Salticidae	*Myrmarachne sp1*
123	Salticidae	*Phaeacius sp1*
124	Salticidae	*Phanuelus sp1*
125	Salticidae	*Phintella cholkei*
126	Salticidae	*Phintella vittata*
127	Salticidae	*Phintelloides sp1*
128	Salticidae	*Plexippus paykulli*
129	Salticidae	*Plexippus sp2*
130	Salticidae	*Portia sp1*
131	Salticidae	*Rhene sp1*
132	Salticidae	*Salticidae sp1*
133	Salticidae	*Salticidae sp12*
134	Salticidae	*Salticidae sp15*
135	Salticidae	*Salticidae sp19*
136	Salticidae	*Salticidae sp2*
137	Salticidae	*Salticidae sp2*
138	Salticidae	*Salticidae sp22*
139	Salticidae	*Salticidae sp5*
140	Salticidae	*Stenaelurillus albus*
141	Salticidae	*Stenaelurillus sp.1*
142	Salticidae	*Stenaelurillus sp.2*
143	Salticidae	*Telamonia dimidiata*
144	Salticidae	*Vailimia sp.*
145	Scytodidae	*Dictis sp1*
146	Sparassidae	*Gnathopalystes sp1*
147	Sparassidae	*Heteropoda sp1*
148	Sparassidae	*Olios sp1*
149	Sparassidae	*Olios sp2*
150	Sparassidae	*Olios sp3*

Sr. No.	Family	Species
151	Sparassidae	*Olios lamarcki*
152	Sparassidae	*Spariolenus sp1*
153	Stenochilidae	*Stenochilus sp1*
154	Tetragnathidae	*Leucauge decorata*
155	Tetragnathidae	*Leucauge fastigata*
156	Tetragnathidae	*Orsinome sp1*
157	Tetragnathidae	*Tetragnatha sp1*
158	Tetragnathidae	*Tetragnatha sp2*
159	Tetragnathidae	*Tetragnathidae sp1*
160	Tetragnathidae	*Tylorida sp1*
161	Tetragnathidae	*Tylorida sp2*
162	Theraphosidae	*Chilobrachys fimbriatus*
163	Theraphosidae	*Plesiophrictus millardi*
164	Theridiidae	*Achaearanea sp1*
165	Theridiidae	*Argyrodes sp1*
166	Theridiidae	*Chrysso sp1*
167	Theridiidae	*Meotipa sp1*
168	Theridiidae	*Molione sp1*
169	Theridiidae	*Nihonhimea sp1*
170	Theridiidae	*Parasteatoda sp1*
171	Theridiidae	*Phycosoma sp1*
172	Theridiidae	*Phylloneta sp1*
173	Theridiidae	*Platnickina sp1*
174	Theridiidae	*Rhomphaea sp1*
175	Theridiidae	*Ruborridion sp1*
176	Theridiidae	*Steatoda sp1*
177	Theridiidae	*Steatoda sp2*
178	Theridiidae	*Theridiidae green sp1*
179	Theridiidae	*Theridiidae green sp2*
180	Theridiidae	*Theridiidae sp1*
181	Theridiidae	*Theridiidae sp1*
182	Theridiidae	*Theridiidae sp11*
183	Theridiidae	*Theridiidae sp12*
184	Theridiidae	*Theridiidae sp13*
185	Theridiidae	*Theridiidae sp14*
186	Theridiidae	*Theridiidae sp15*
187	Theridiidae	*Theridiidae sp16*
188	Theridiidae	*Theridiidae sp17*

189	Theridiidae	*Theridiidae sp18*
190	Theridiidae	*Theridiidae sp19*
191	Theridiidae	*Theridiidae sp2*
192	Theridiidae	*Theridiidae sp20*
193	Theridiidae	*Theridiidae sp21*
194	Theridiidae	*Theridiidae sp23*
195	Theridiidae	*Theridiidae sp24*
196	Theridiidae	*Theridiidae sp25*
197	Theridiidae	*Theridiidae sp26*
198	Theridiidae	*Theridiidae sp27*
199	Theridiidae	*Theridiidae sp28*
200	Theridiidae	*Theridiidae sp29*
201	Theridiidae	*Theridiidae sp3*
202	Theridiidae	*Theridiidae sp4*
203	Theridiidae	*Theridiidae sp5*
204	Theridiidae	*Theridiidae sp6*
205	Theridiidae	*Theridiidae sp7*
206	Theridiidae	*Theridiidae sp9*
207	Theridiidae	*Theridula sp1*
208	Theridiidae	*Theridiidae sp8*
209	Thomisidae	*Angeus sp.*
210	Thomisidae	*Camaricus sp1*
211	Thomisidae	*Indoxysticus sp1*
212	Thomisidae	*Massuria sp1*
213	Thomisidae	*Oxytate sp1*
214	Thomisidae	*Stiphropus sp1*
215	Thomisidae	*Strigoplus sp1*
216	Thomisidae	*Synema decoratum*
217	Thomisidae	*Talaus sp.*
218	Thomisidae	*Thomisidae sp1*
219	Thomisidae	*Thomisidae sp2*
220	Thomisidae	*Thomisidae sp3*
221	Thomisidae	*Thomisidae sp4*
222	Thomisidae	*Thomisidae sp5*
223	Thomisidae	*Thomisidae sp6*
224	Thomisidae	*Thomisus sp.*
225	Thomisidae	*Tmarus sp.*
226	Uloboridae	*Miagrammopes sp.*
227	Uloboridae	*Uloboridae sp1*

Sr. No.	Family	Species
228	Uloboridae	*Uloboridae sp2*
229	Uloboridae	*Uloborus sp1*
230	Uloboridae	*Uloborus sp2*
231	Uloboridae	*Uloborus sp3*
232	Zodariidae	*Mallinella sp1*
233	Zodariidae	*Tropizodium sp1*
227	Uloboridae	*Uloboridae sp1*
228	Uloboridae	*Uloboridae sp2*
229	Uloboridae	*Uloborus sp1*
230	Uloboridae	*Uloborus sp2*
231	Uloboridae	*Uloborus sp3*
232	Zodariidae	*Mallinella sp1*
233	Zodariidae	*Tropizodium sp1*

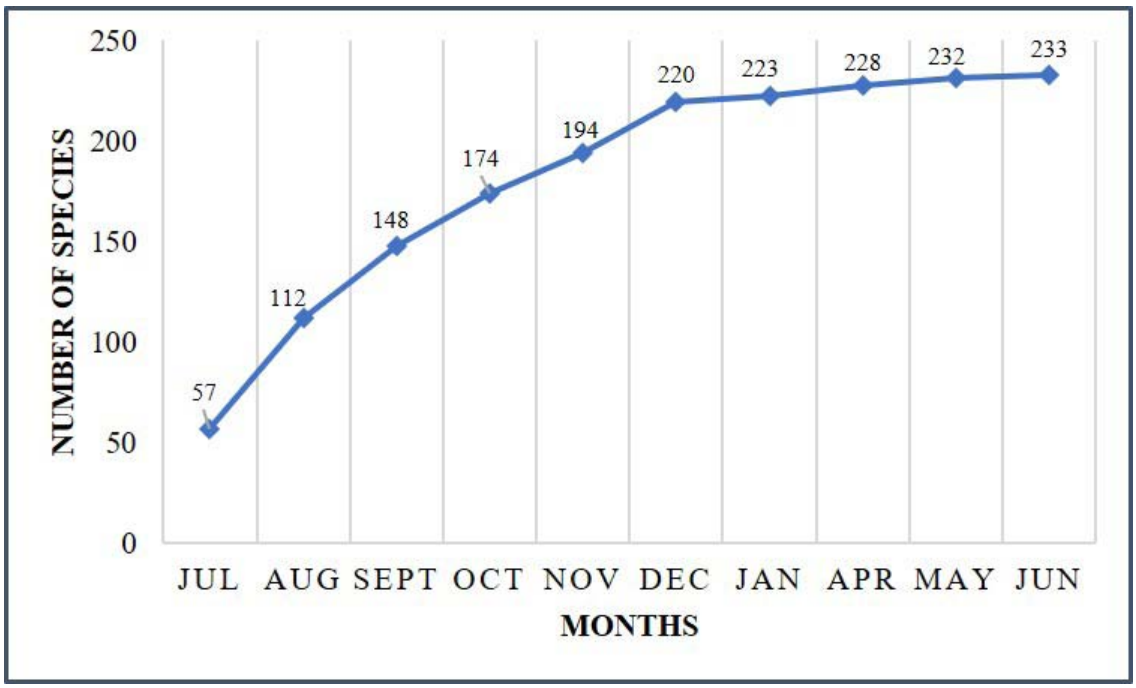

Fig.17: Species accumulation curve for spiders sampled from July 2021 to June 2022 on SGNP during the BNHS-GMLR survey

The graph (Figure 17) shows a continuous upward trends as new species were continued to be encountered every month. The highest proportion of new species was recorded on the post-monsoon season. Even in the summer season, despite the overall species count being low, nine new spider species were recorded.

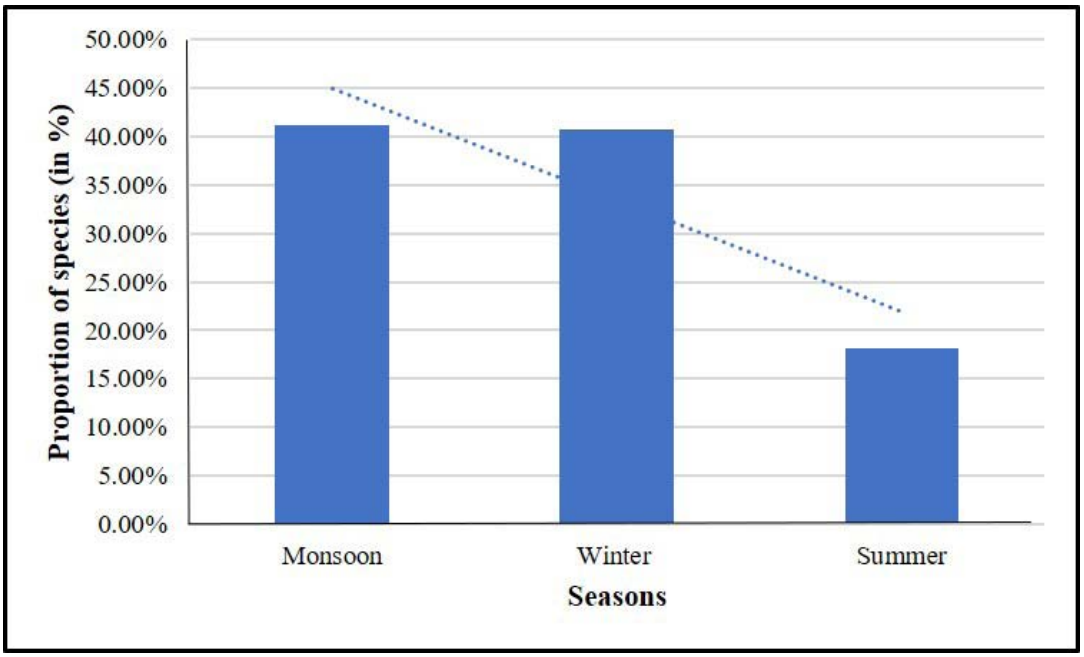

Fig. 18: Proportion of species recorded in different seasons from July 2021 to June 2022

Table 9: Month-wise record of checklist of Arachnids recorded during the BNHS-GMLR survey from July 2021 to June2022.

(Note: Surveys were not conducted in Fenruary and March 2022)

Sr. No.	Family	Species	July	Aug	Sep	Oct	Nov	Dec	Jan	April	May	June
1	Agelenidae	*Coelotes sp1*	−	−	−	+	−	−	−	−	−	−
2	Araneidae	*Araneidae sp1*	−	+	−	+	+	−	−	−	−	−
3	Araneidae	*Araneidae sp2*	+	+	−	−	−	−	−	−	−	−
4	Araneidae	*Araneus sp2*	−	+	+	+	+	−	+	−	−	−
5	Araneidae	*Araneus sp3*	−	−	−	−	−	+	−	−	−	−
6	Araneidae	*Argiope aemula*	+	−	−	+	+	+	−	−	−	−
7	Araneidae	*Argiope anasuja*	−	+	+	+	+	+	+	+	−	−
8	Araneidae	*Argiope sp1*	−	+	+	+	+	+	+	+	+	+
9	Araneidae	*Bijoaraneus mitificus*	−	+	−	−	−	+	−	−	−	+
10	Araneidae	*Chorizopes sp1*	−	+	−	−	+	+	−	−	−	−
11	Araneidae	*Cyclosa sp1*	−	−	+	+	+	+	+	+	+	
12	Araneidae	*Cyclosa sp3*	−	−	−	+	+	+	+	−	+	+
13	Araneidae	*Cyrtophora cicatrosa*	+	+	+	+	+	+	+	+	+	+
14	Araneidae	*Cyrtophora sp1*	−	+	+	−	+	−	−	−	−	−
15	Araneidae	*Cyrtophora sp2*	−	−	−	−	−	−	−	−	+	+
16	Araneidae	*Eriovixia sp1*	+	−	−	−	−	+	−	−	−	−
17	Araneidae	*Eriovixia sp2*	+	+	+	−	−	−	−	−	−	−
18	Araneidae	*Eriovixia sp3*	+	−	−	+	+	−	−	+	+	+
19	Araneidae	*Eriovixia sp4*	−	−	−	+	+	−	−	−	−	−
20	Araneidae	*Gea spinipes*	−	−	+	−	−	−	−	−	−	−
21	Araneidae	*Herennia multipuncta*	+	+	+	+	+	+	+	+	+	+
22	Araneidae	*Hypsosinga sp.*	−	+	+	+	+	−	−	−	+	+
23	Araneidae	*Lipocrea sp.*	−	−	−	−	−	−	−	−	+	−
24	Araneidae	*Macaracantha hasselti*	−	−	+	−	−	−	−	−	−	−
25	Araneidae	*Neoscona sp1*	+	+	−	+	+	+	−	+	−	−
26	Araneidae	*Neoscona sp11*	−	+	−	−	−	−	−	−	−	−
27	Araneidae	*Neoscona sp14*	−	−	−	−	−	+	−	−	−	−
28	Araneidae	*Neoscona sp3*	+	−	−	+	−	−	−	−	−	−
29	Araneidae	*Neoscona sp7*	+	−	−	−	−	−	−	−	−	−
30	Araneidae	*Nephila kuhlii*	−	+	−	−	−	−	−	−	−	−
31	Araneidae	*Nephila pilipes*	+	+	−	+	+	+	−	−	−	−
32	Araneidae	*Parawixia sp1*	−	+	−	−	−	−	−	−	−	−
33	Araneidae	*Poltys sp1*	−	−	−	+	−	−	−	−	−	−
34	Araneidae	*Porcataraneus sp1*	−	−	+	+	+	+	+	+	+	+
35	Araneidae	*Thelacantha brevispina*	−	+	−	−	+	+	−	−		+
36	Cheiracanthiidae	*Calamopus sp1*	−	−	−	−	+	+	+	+	+	+
37	Cheiracanthiidae	*Cheiracanthium sp1*	+	−	+	+	+	+	+	+	+	+
38	Cithaeronidae	*Cithaeronidae sp1*	−	−	+	+	−	+	+	−	−	−
39	Cithaeronidae	*Inthaeron sp1*	−	−	−	+	−	−	−	−	−	−
40	Clubionidae	*Clubionidae sp1*	−	−	−	−	+	−	−	−	−	−
41	Clubionidae	*Matidia sp1*	−	+	−	−	−	−	−	−	−	−
42	Corinnidae	*Cambalida sp1*	+	+	+	+	−	−	+	−	−	+

Sr. No.	Family	Species	July	Aug	Sep	Oct	Nov	Dec	Jan	April	May	June
43	Corinnidae	*Corinnidae sp2*	–	–	–	–	–	–	+	–	–	–
44	Corinnidae	*Corrinnidae sp1*	–	–	+	+	+	–	–	–	–	–
45	Corinnidae	*Echinax sp1*	+	–	–	–	–	–	–	–	–	–
46	Ctenidae	*Anahita sp1*	–	–	+	–	–	–	–	–	–	–
47	Ctenidae	*Ctenus sp1*	+	–	–	+	–	+	+	–	–	+
48	Ctenidae	*Ctenus sp2*	–	–	–	+	–	–	–	–	–	–
49	Ctenidae	*Ctenus sp3*	–	–	–	–	+	+	+	–	–	+
50	Filistatidae	*Pritha sp1*	–	–	+	+	+	+	–	–	–	–
51	Gnaphosidae	*Berlandina sp1*	–	–	+	+	–	+	+	–	–	–
52	Gnaphosidae	*Prodidomus sp1*	–	–	+	–	–	–	–	–	–	–
53	Gnaphosidae	*Scotophaeus sp1*	–	–	–	–	–	+	–	–	–	–
54	Gnaphosidae	*Zelotes sp1*	–	–	+	+	–	–	–	–	–	–
55	Hersiliidae	*Hersilia sp.*	+	+	+	+	+	+	+	+	+	+
56	Linyphiidae	*Linyphiidae sp1*	–	–	+	–	–	–	–	+	–	–
57	Linyphiidae	*Linyphiidae sp2*	–	–	–	–	–	–	–	+	+	–
58	Liocranidae	*Liocranidae sp1*	–	–	+	+	–	–	–	–	–	–
59	Liocranidae	*Sphingius sp1*	–	–	+	+	–	–	–	–	–	–
60	Lycosidae	*Evippa sp1*	+	–	+	+	+	+	–	–	+	+
61	Lycosidae	*Evippomma sp1*	–	–	+	+	+	+	–	–	–	–
62	Lycosidae	*Hippasa sp1*	+	–	+	+	+	+	–	–	+	–
63	Lycosidae	*Hippasa sp2*	+	+	+	+	–	–	–	–	–	–
64	Lycosidae	*Hippasa sp3*	–	–	+	+	+	–	+	–	–	–
65	Lycosidae	*Hippasa sp4*	–	–	–	–	+	+	–	–	+	+
66	Lycosidae	*Lycosa sp1*	–	–	–	–	+	–	–	–	–	+
67	Lycosidae	*Lycosidae sp1*	+	+	+	–	–	–	–	–	–	–
68	Lycosidae	*Lycosidae sp2*	–	–	+	–	–	–	–	–	–	–
69	Lycosidae	*Lycosidae sp3*	–	+	–	–	–	–	–	–	–	–
70	Lycosidae	*Pardosa sp1*	+	+	+	–	–	+	+	–	–	+
71	Lycosidae	*Trochosa sp1*	–	–	+	+	–	–	–	–	–	–
72	Lycosidae	*Wadicosa sp1*	–	–	–	+	–	–	–	–	–	–
73	Lycosidae	*Zoica sp1*	–	–	+	–	–	–	–	–	–	+
74	Oecobiidae	*Oecobius*	–	–	–	–	–	–	–	–	–	+
75	Oonopidae	*Oonopidae sp1*	–	–	–	+	–	–	–	–	–	–
76	Oxyopidae	*Hamadruas sp.*	+	+	+	–	+	+	+	+	+	+
77	Oxyopidae	*Hamataliwa sp1*	+	+	+	+	+	+	+	+	+	+
78	Oxyopidae	*Hamataliwa sp2*	+	–	–	–	–	–	–		+	+
79	Oxyopidae	*Oxyopes shweta*	+	–	–	–	+	+	+	+	+	+
80	Oxyopidae	*Oxyopes sp1*	+	+	–	+	–	+	–	–	–	–
81	Oxyopidae	*Oxyopes sp2*	–	+	+	–	+	+	–	+	+	+
82	Oxyopidae	*Oxyopes sp3*	+	–	+	–	–	–	–	–	–	–
83	Oxyopidae	*Oxyopes sp4*	–	–	–	–	+	+	–	–	–	–
84	Oxyopidae	*Peucetia sp1*	+	–	–	+	–	–	–	+	–	–
85	Philodromidae	*Philodromidae sp1*	+	–	–	–	–	–	–	–	–	–
86	Philodromidae	*Psellonus sp1*	–	–	–	–	–	+	–	–	–	–
87	Philodromidae	*Tibellus sp1*	–	+	+	–	–	–	–	–	+	+

Sr. No.	Family	Species	July	Aug	Sep	Oct	Nov	Dec	Jan	April	May	June
88	Pisauridae	*Dendrolycosa sp1*	+	+	−	+	+	+	+	+	+	+
89	Pisauridae	*Euprosthenops sp1*	−	+	−	−	−	−	−	−	−	−
90	Pisauridae	*Hygropoda sp1*	−	+	−	−	−	−	−	+	+	+
91	Pisauridae	*Perenethis sp1*	+	−	−	−	−	+	−	−	−	−
92	Pisauridae	*Pisaura sp1*	−	−	+	+	+	−	−	+	+	+
93	Pisauridae	*Pisauridae sp1*	+	+	+	−	−	−	−	−	−	−
94	Pisauridae	*Polyboea sp1*	−	+	−	−	−	−	−	−	−	−
95	Pisauridae	*Thalassius sp1*	+	−	−	−	−	−	−	−	−	−
96	Salticidae	*Afraflacilla sp1*	−	−	−	−	+	−	−	+	−	−
97	Salticidae	*Asemonea tenuipes*	+	+	+	+	+	+	+	+	+	+
98	Salticidae	*Bianor*	−	−	−	−	−	−	−	−	+	−
99	Salticidae	*Brancus sp1*	−	+	−	−	−	−	−	−	+	−
100	Salticidae	*Brettus sp1*	−	−	+	−	−	+	+	−	−	−
101	Salticidae	*Burmattus sp1*	−	+	+	−	−	−	−	−	−	−
102	Salticidae	*Carrhotus sp1*	−	+	−	−	−	−	−	−	−	−
103	Salticidae	*Carrhotus viduus*	+	−	−	+	+	−	−	−	−	−
104	Salticidae	*Chrysilla volupe*	−	−	−	−	−	−	−	−	+	−
105	Salticidae	*Cocalus sp1*	−	+	−	−	−	−	−	+	+	−
106	Salticidae	*Curubis sp1*	+	+	+	+	−	−	−	+	+	+
107	Salticidae	*Curubis sp2*	−	+	+	+	+	+	+	−	−	+
108	Salticidae	*Cyrba sp1*	−	−	−	−	+	+	+	−	−	+
109	Salticidae	*Epeus sp1*	−	+	+	−	+	+	−	+	+	+
110	Salticidae	*Epocilla sp1*	−	−	+	−	−	−	−	−	−	−
111	Salticidae	*Harmochirus sp1*	−	+	+	−	−	−	−	+	−	−
112	Salticidae	*Hasarius adansoni*	+	+	+	+	+	+	+	−	−	+
113	Salticidae	*Hyllus semicupreus*	+	+	+	+	+	+	+	+	+	+
114	Salticidae	*Icius sp1*	−	+	−	−	−	−	−	−	−	−
115	Salticidae	*Jerzego sp1*	−	−	−	−	+	−	+	−	−	−
116	Salticidae	*Langelurillus lacteus*	+	−	+	−	−	+	−	+	+	+
117	Salticidae	*Langelurillus onyx*	−	−	−	−	−	−	−	−	−	+
118	Salticidae	*Lanona sp.*	−	−	−	−	−	−	−	+	+	+
119	Salticidae	*Madhyattus sp1*	−	−	+	+	−	−	−	−	−	−
120	Salticidae	*Menemerus bivittatus*	−	+	+	+	+	+	+	+	+	+
121	Salticidae	*Myrmarachne melanocephala*	−	−	−	+	−	−	−	−	−	−
122	Salticidae	*Myrmarachne sp1*	+	+	−	−	−	−	−	+	−	+
123	Salticidae	*Phaeacius sp1*	−	−	+	−	−	−	−	−	+	−
124	Salticidae	*Phanuelus sp1*	+	+	−	+	−	+	+	−	−	−
125	Salticidae	*Phintella cholkei*	−	−	−	−	−	+	−	−	−	+
126	Salticidae	*Phintella vittata*	−	+	+	+	−	+	−	+	+	+
127	Salticidae	*Phintelloides sp1*	−	−	−	−	+	+	−	−	−	−
128	Salticidae	*Plexippus paykulli*	+	−	−	−	−	+	−	−	−	−
129	Salticidae	*Plexippus sp2*	−	−	+	+	+	−	+	−	+	+
130	Salticidae	*Portia sp1*	−	+	+	−	−	−	−	−	−	−
131	Salticidae	*Rhene sp1*	−	−	−	−	−	+	−	+	−	−
132	Salticidae	*Salticidae sp1*	−	+	−	−	−	−	−	−	−	−

Sr. No.	Family	Species	July	Aug	Sep	Oct	Nov	Dec	Jan	April	May	June
133	Salticidae	*Salticidae sp12*	−	+	−	−	+	+	−	−	−	−
134	Salticidae	*Salticidae sp15*	−	+	−	+	−	−	−	−	−	−
135	Salticidae	*Salticidae sp19*	−	−	−	+	−	−	−	−	−	−
136	Salticidae	*Salticidae sp2*	+	−	+	−	−	−	−	−	−	−
137	Salticidae	*Salticidae sp2*	−	−	−	+	−	−	−	−	−	−
138	Salticidae	*Salticidae sp22*	−	−	−	−	−	+	−	−	−	−
139	Salticidae	*Salticidae sp5*	+	−	+	−	+	−	−	−	−	−
140	Salticidae	*Stenaelurillus albus*	+	+	+	+	+	+	+	+	+	+
141	Salticidae	*Stenaelurillus sp.1*	−	−	−	−	−	−	−	+	−	+
142	Salticidae	*Stenaelurillus sp.2*	−	−	−	−	−	−	−	−	+	+
143	Salticidae	*Telamonia dimidiata*	+	−	+	+	+	+	+	+	+	−
144	Salticidae	*Vailimia sp.*	−	+	+	−	−	−	+	+	+	+
145	Scytodidae	*Dictis sp1*	+	+	+	+	+	+	+	−	−	−
146	Sparassidae	*Gnathopalystes sp1*	−	−	−	+	−	+	−	−	+	+
147	Sparassidae	*Heteropoda sp1*	−	−	−	−	+	−	−	−	−	+
148	Sparassidae	*Olios sp1*	−	−	+	−	−	−	−	−		−
149	Sparassidae	*Olios sp2*	−	−	−	+	−	−	−	−	−	−
150	Sparassidae	*Olios sp3*	−	−	−	−	−	+	−	+	−	−
151	Sparassidae	*Olios lamarcki*	−	−	−	−	−	+	−	−	−	−
152	Sparassidae	*Spariolenus sp1*	+	−	+	+	+	+	+	−	−	−
153	Stenochilidae	*Stenochilus sp1*	−	−	+	+	−	−	−	−	−	−
154	Tetragnathidae	*Leucauge decorata*	+	+	+	−	+	+	−	−	−	+
155	Tetragnathidae	*Leucauge fastigata*	+	+	+	+	+	−	−	−	−	−
156	Tetragnathidae	*Orsinome sp1*	−	+	+	+	−	−	−	−	−	−
157	Tetragnathidae	*Tetragnatha sp1*	−	+	−	+	+	−	−	−	−	−
158	Tetragnathidae	*Tetragnatha sp2*	−	−	−	+	−	−	−	−	−	−
159	Tetragnathidae	*Tetragnathidae sp1*	+	−	−	−	−	−	−	−	−	−
160	Tetragnathidae	*Tylorida sp1*	−	−	+	+	+	−	+	−	+	−
161	Tetragnathidae	*Tylorida sp2*	−	−	+	−	−	−	−	−	+	−
162	Theraphosidae	*Chilobrachys fimbriatus*	+	−	−	+	−	+	−	−	−	−
163	Theraphosidae	*Plesiophrictus millardi*	−	−	+	+	+	+	−	−	−	−
164	Theridiidae	*Achaearanea sp1*	−	−	−	+	+	−	+	−	+	−
165	Theridiidae	*Argyrodes sp1*	−	−	−	−	+	−	−	−	+	−
166	Theridiidae	*Chrysso sp1*	−	−	−	−	+	−	−	−	−	−
167	Theridiidae	*Meotipa sp1*	−	−	+	+	+	+	−	−	+	−
168	Theridiidae	*Molione sp1*	−	−	−	+	−	−	−	−	−	−
169	Theridiidae	*Nihonhimea sp1*	−	−	−	+	+	+	−	+	+	−
170	Theridiidae	*Parasteatoda sp1*	−	+	−	−	−	+	−	−	+	+
171	Theridiidae	*Phycosoma sp1*	−	−	−	+	+	−	−	−	−	−
172	Theridiidae	*Phylloneta sp1*	−	−	−	−	−	−	+	−	−	−
173	Theridiidae	*Platnickina sp1*	−	−	−	−	−	+	−	−	−	−
174	Theridiidae	*Rhomphaea sp1*	−	−	−	−	−	+	−	−	−	−
175	Theridiidae	*Ruborridion sp1*	−	−	−	−	−	+	+	−	−	−
176	Theridiidae	*Steatoda sp1*	+	−	−	+	+	−	−	+	−	+
177	Theridiidae	*Steatoda sp2*	−	−	−	+	−	−	−	−	−	−

Sr. No.	Family	Species	July	Aug	Sep	Oct	Nov	Dec	Jan	April	May	June
178	Theridiidae	*Theridiidae green sp1*	–	–	–	–	–	+	–	–	–	–
179	Theridiidae	*Theridiidae green sp2*	–	–	–	–	–	+	–	–	–	–
180	Theridiidae	*Theridiidae sp1*	+	+	+	+	–	–	–	–	–	–
181	Theridiidae	*Theridiidae sp1*	–	–	+	+	+	+	+	–		–
182	Theridiidae	*Theridiidae sp11*	–	–	–	+	–	–	–	–	–	–
183	Theridiidae	*Theridiidae sp12*	–	–	–	+	+	+	+	–	–	–
184	Theridiidae	*Theridiidae sp13*	–	–	–	+	–	+	–	–	–	–
185	Theridiidae	*Theridiidae sp14*	–	–	–	+	+	+	–	–	–	–
186	Theridiidae	*Theridiidae sp15*	–	–	–	+	–	+	–	–	–	–
187	Theridiidae	*Theridiidae sp16*	–	–	–	+	–	–	–	–	–	–
188	Theridiidae	*Theridiidae sp17*	–	–	–	–	+	+	–	–	–	–
189	Theridiidae	*Theridiidae sp18*	–	–	–	–	+	–	–	–	–	–
190	Theridiidae	*Theridiidae sp19*	–	+	–	–	+	+	–	–	–	–
191	Theridiidae	*Theridiidae sp2*	–	+	+	–	–	–	–	–	–	–
192	Theridiidae	*Theridiidae sp20*	–	–	–	–	–	+	+	–	–	–
193	Theridiidae	*Theridiidae sp21*	–	–	–	–	–	+	+	–	–	–
194	Theridiidae	*Theridiidae sp23*	–	–	–	–	–	+	–	–	–	–
195	Theridiidae	*Theridiidae sp24*	–	–	–	–	–	+	–	–	–	–
196	Theridiidae	*Theridiidae sp25*	–	–	–	–	–	+	–	–	–	–
197	Theridiidae	*Theridiidae sp26*	–	–	–	–	–	+	–	–	–	–
198	Theridiidae	*Theridiidae sp27*	–	–	–	–	–	+	–	–	–	–
199	Theridiidae	*Theridiidae sp28*	–	–	–	–	–	+	–	–	–	–
200	Theridiidae	*Theridiidae sp29*	–	–	–	–	–	+	–	–	–	–
201	Theridiidae	*Theridiidae sp3*	–	+	–	–	–	–	–	–	–	–
202	Theridiidae	*Theridiidae sp4*	–	+	–	–	+	+	–	–	–	–
203	Theridiidae	*Theridiidae sp5*	–	+	+	+	+	–	–	–	–	–
204	Theridiidae	*Theridiidae sp6*	–	+	–	–	–	–	–	–	–	–
205	Theridiidae	*Theridiidae sp7*	–	+	–	–	–	–	–	–	–	–
206	Theridiidae	*Theridiidae sp9*	–	+	+	+	–	+	–	–	–	–
207	Theridiidae	*Theridula sp1*	–	+	–	+	–	–	–	–	–	–
208	Theridiidae	*Theridiidae sp8*	–	+	–	–	–	–	–	–	–	–
209	Thomisidae	*Angeus sp.*	–	–	–	–	–	–	–	–	+	+
210	Thomisidae	*Camaricus sp1*	–	+	–	–	–	–	–	–	–	+
211	Thomisidae	*Indoxysticus sp1*	–	+	–	+	–	–	+	+	–	+
212	Thomisidae	*Massuria sp1*	–	–	–	–	+	–	–	–	–	–
213	Thomisidae	*Oxytate sp1*	–	–	+	–	–	+	–	–	–	–
214	Thomisidae	*Stiphropus sp1*	–	–	–	–	–	+	–	–	–	–
215	Thomisidae	*Strigoplus sp1*	–	+	–	–	+	+	–	+	+	–
216	Thomisidae	*Synema decoratum*	–	–	–	–	–	–	–	+	–	–
217	Thomisidae	*Talaus sp.*	+	–	–	–	–	–	–	–	–	–
218	Thomisidae	*Thomisidae sp1*	+	–	–	–	–	–	–	–	–	–
219	Thomisidae	*Thomisidae sp2*	–	–	–	–	+	–	–	–	–	–
220	Thomisidae	*Thomisidae sp3*	–	+	–	–	–	–	–	–	–	–
221	Thomisidae	*Thomisidae sp4*	–	–	–	–	+	–	–	–	–	–
222	Thomisidae	*Thomisidae sp5*	–	–	–	–	+	–	–	–	–	–

Sr. No.	Family	Species	July	Aug	Sep	Oct	Nov	Dec	Jan	April	May	June
223	Thomisidae	*Thomisidae sp6*	–	–	–	–	–	+	–	–	–	–
224	Thomisidae	*Thomisus sp.*	+	+	–	+	+	+	–	+	+	+
225	Thomisidae	*Tmarus sp.*	–	–	–	+	–	–	–	–	+	+
226	Uloboridae	*Miagrammopes sp.*	–	–	–	–	–	–	–	+	–	–
227	Uloboridae	*Uloboridae sp1*	–	–	–	–	–	+	–	–	–	–
228	Uloboridae	*Uloboridae sp2*	–	–	–	–	+	+	–	–	–	–
229	Uloboridae	*Uloborus sp1*	–	+	+	+	+	+	+	+	–	+
230	Uloboridae	*Uloborus sp2*	–	–	+	–	–	–	–	–	–	–
231	Uloboridae	*Uloborus sp3*	–	–	–	+	–	–	–	–	–	–
232	Zodariidae	*Mallinella sp1*	–	–	+	–	–	–	–	–	–	–
233	Zodariidae	*Tropizodium sp1*	–	+	–	–	–	–	–	–	–	–
229	Uloboridae	*Uloborus sp1*	–	+	+	+	+	+	+	+	–	+
230	Uloboridae	*Uloborus sp2*	–	–	+	–	–	–	–	–	–	–
231	Uloboridae	*Uloborus sp3*	–	–	–	+	–	–	–	–	–	–
232	Zodariidae	*Mallinella sp1*	–	–	+	–	–	–	–	–	–	–
233	Zodariidae	*Tropizodium sp1*	–	+	–	–	–	–	–	–	–	–

Table 10: Species presence across the study area across all grids (“ + ”) denotes presence while (“—”) denotes absence of species

Sr. No.	Family	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6
1	Agelenidae	–	–	–	–	+	–
2	Araneidae	+	+	+	+	+	+
3	Cheiracanthiidae	+	+	–	+	+	+
4	Cithaeronidae	+	+	–	–	–	+
5	Clubionidae	–	+	–	–	+	–
6	Corinnidae	+	+	+	+	+	+
7	Ctenidae	–	+	+	+	+	+
8	Filistatidae	+	–	+	–	+	–
9	Gnaphosidae	–	–	+	+	+	+
10	Hersiliidae	+	+	+	+	+	+
12	Linyphiidae	+	+	–	+	–	–
13	Liocranidae	+	+	+	+	–	+
14	Lycosidae	+	+	+	+	+	+
11	Oecobiidae	–	–	–	–	–	+
15	Oxyopidae	+	+	+	+	+	+
16	Philodromidae	–	+	+	–	–	+
17	Pisauridae	+	+	+	+	+	+
18	Salticidae	+	+	+	+	+	+
19	Scytodidae	+	+	+	+	+	+
20	Sparassidae	+	+	+	+	+	+
21	Stenochilidae	–	–	–	–	–	+
22	Tetragnathidae	+	+	+	+	+	+
23	Theraphosidae	+	+	+	+	+	+
24	Theridiidae	+	+	+	+	+	+
25	Thomisidae	+	+	+	+	+	+
26	Uloboridae	+	+	+	+	–	+
27	Zodariidae	–	–	–	–	+	–

Summary

The project site includes 233 species of spiders belonging to 28 families. Jumping spiders of the Salticidae family had the highest species richness (Table 10). Whereas, the Oecobiidae, Filistatidae, and the Agelenidae family were each represented by only one species.

Maximum number of spiders were recorded in the month of December while the least records were from the month of April (Table 10). Spider observations varied with seasons (Figure 19).A total of 161 species were recorded in monsoon. February and March surveys were not conducted. In any given month on an average 71 species were observed. The presence of the Theridiidae family was noteworthy in the winter season. Jumping Spider (*Stenaelurillus albus),* Heavy-bodied Jumping Spider (*Hyllus semicupreus*), Tailed Jumper (*Asemonea tenuipes*), Lynx Spider(*Hamataliwa* sp1), Two-tailed Spider (*Hersilia* sp.), Ornamental Tree trunk spider (*Herennia multipuncta*), and Tent-web Spider (*Cyrtophora cicatrosa*) were recorded in all the survey months.

Overall, monsoon season and post-monsoon seems to be a preferable period for most of the spider species (Figure 19). As the leaves start to fall on the ground, the leaf litter starts to accumulate in this deciduous forest.Many ground dwelling species like the several species belonging to the *Stenaelurillus* genus*, Langelurillus sp.,* and *Hasarius adansoni* become active in these seasons. Species like *Langelurillus lacteus* and *Langelurillus onyx* were seen only during the summer when the temperatures were high and there was an abundance of leaf litter. Grid VI has greater human activity, spiders that are characteristic of disturbed habitats were recorded. Wall spider (*Oecobius* sp.), a spider species which is seen near human settlements and is seen commonly on man-made vertical surfaces was seen at the periphery of the Grid VI. Species like the two-tailed Spider (*Hersilia* sp.), heavy-bodied Jumping Spider (*Hyllus semicupreus),* *Stenaelurillus albus,* Tailed Jumper (*Asemonea tenuipes),* etc. were seen in all the grids in all the seasons. Species like Cribellate orb weaver (*Miagrammopes sp.)* which require a forested habitat were seen in Grid V where the human disturbance is low.

The survey-grids also showed an interesting variation in spider diversity (Table 11).On an average, 89 spider species and 20 families were present in each grid. Grid VI with 22 Spider families was the highest across grids, whereas in the Grid V with 100+ morphologically different spider species can be considered the most speciose. The spiders belonging to family Araneidae, Corinnidae, Hersiliidae, Lycosidae, Oxyopidae, Pisauridae, Salticidae, Scytodidae, Sparassidae, Tetragnathidae, Theraphosidae, Theridiidae, and Thomisidae were seen in all the 6 grids. Zodariidae, Stenochilidae, Oecobiidae, and Agelenidae were seen only once in their respective grids.

As the conservation status of most of the spider species is unknown, commenting on the conservation status is not possible. However few spider species like the Indian Violet Tarantula (*Chilobrachys fimbriatus),* Ornamnetal Tree Trunk Spider (*Herennia multipuncta),* Adanson's Jumping Spider (*Hasarius adansoni)* are listed in the Least Concern category by the IUCN.

In conclusion, it can be said that the scope for a more detailed survey of Arachnids is tremendous. The effort will surely be valuable in documenting the local diversity in greater detail.

Insects

Methods

Insects were surveyed using a combination of three methods viz. quadrat method, line transect and visual encounter. Sampling was carried out between 0800hrs to 1300 hrs considering the peak activity period of a majority of insect species. Date and time of survey, humidity and temperature were recorded for each sampling session. In each grid, four quadrats of 10×10 meter were deployed at four sampling points for surveying ground-dwelling insects following the method by Gadakar et al. (1990) excluding the use of sweep-net. Two of these points were selected on the proposed tunnel alignment while the other two, were on either side of the alignment at varying distances and elevation. The corners of each quadrat were marked with coloured ribbons and GPS locations were noted. The underside of leaves and tree holes, overturned stones, leaf litter, and fallen logs were checked for presence of insects and evidence of their life stages (egg, pupa, larva). Covariates that are known to influence the occurrence of the ground-dwelling insects, such as canopy cover, leaf litter thickness (measured with steel scale) and ground cover (presence/absence of rock, soil, wooden log and leaf litter).

Additionally, a 300 m transect line within each grid was walked to record the presence of flying insects. We recorded the insects, especially butterflies by this method at all distances and height (Kunte 1997). Other opportunistic sightings of insects were also recorded. . Water bodies such as streams and water puddles were also specifically surveyed for aquatic insects.

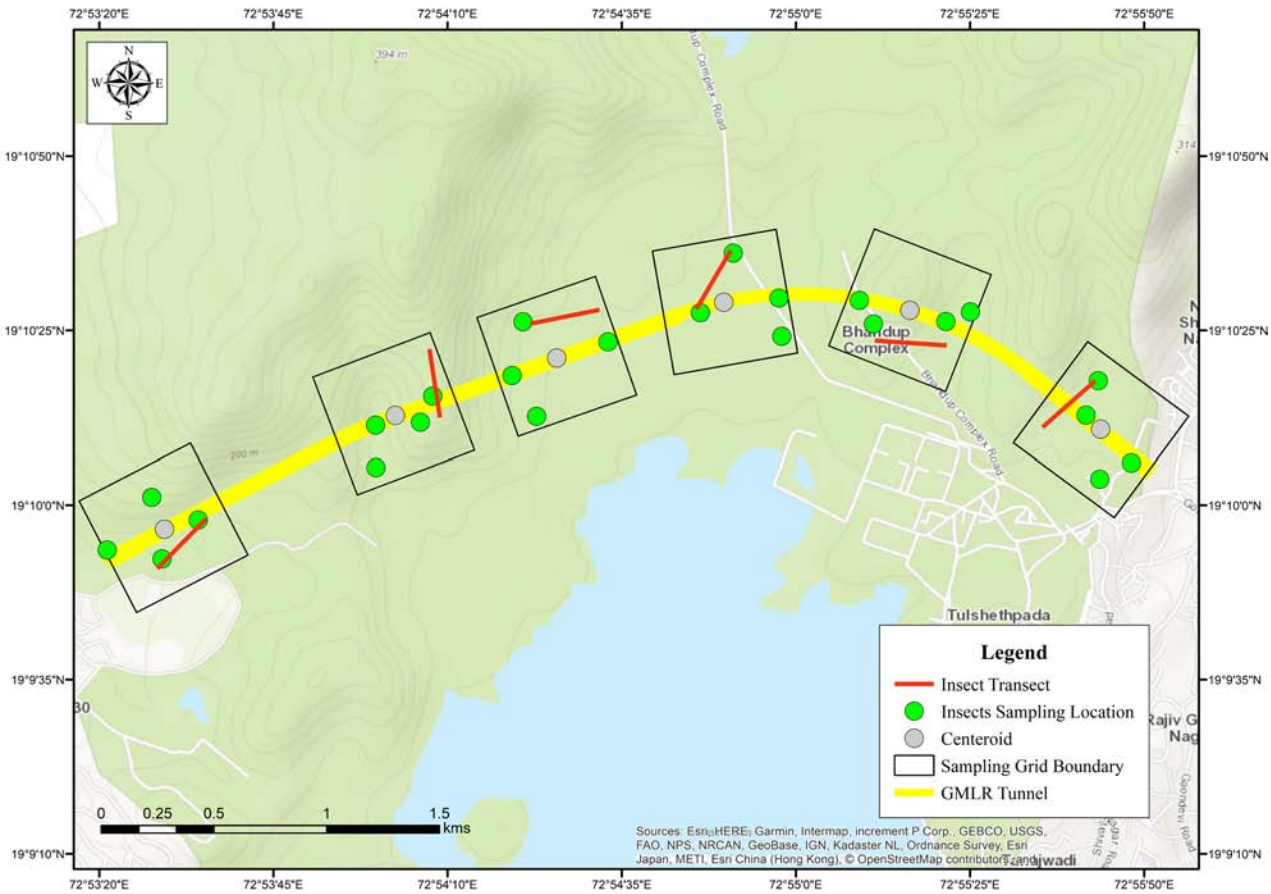

Figure 19: Map showing the tunnel alignment of a section of the Goregaon-Mulund Link Road that will be passing through the Sanjay Gandhi National Park (SGNP). The sampling grids and quadrats are shown

Plate 9: Fieldwork and data collection by insect team

Results

Table 11: Checklist of insects recorded with distribution across the grids, along with their IUCN status and Wildlife Protection Act Schedules (shaded cells indicate species presence)

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
1	Blattodea	--	--	Termite sp. 1	■		■	■	■		--	--
2	Blattodea	--	--	Termite sp. 2		■					--	--
3	Blattodea	Blattidae	--	Cockroach sp. 1			■	■	■	■	--	--
4	Blattodea	Blattidae	--	Cockroach sp. 2	■		■				--	--
5	Blattodea	Ectobiidae	*Hemithyrsocera palliata*	Pallid Sun Roach						■	NA	--
6	Coleoptera	Attelabidae	*Apoderus tranquebaricus*	Leaf Rolling Beetle					■		NA	--
7	Coleoptera	Attelabidae	*Paroplapoderus* sp.	Spiny Leaf-rolling Weevil	■	■		■			--	--
8	Coleoptera	Anthicidae	--	Ant-like beetle sp. 1		■	■			■	--	--
9	Coleoptera	Bostrichidae	--	False Powderpost Beetle						■	--	--
10	Coleoptera	Buprestidae	--	Jewel Beetle		■					--	--
11	Coleoptera	Carabidae	--	Ground Beetle			■				--	--
12	Coleoptera	Carabidae	*Cicindela* sp.	Tiger Beetle sp. 1	■	■	■	■	■	■	--	--
13	Coleoptera	Carabidae	--	Tiger Beetle sp. 2				■	■		--	--
14	Coleoptera	Carabidae	--	Tiger Beetle sp. 3						■	--	--
15	Coleoptera	Cerambycidae	*Oberea* sp.	Long-horned Beetle sp. 1						■	--	--
16	Coleoptera	Cerambycidae	--	Long-horned Beetle sp. 2					■		--	--
17	Coleoptera	Cerambycidae	*Olenecamptus* sp.	Long-horned Beetle sp. 3	■						--	--
18	Coleoptera	Chrysomelidae	*Altica* sp.	Flea Beetle	■						--	--
19	Coleoptera	Chrysomelidae	*Apophylia* sp.	Leaf-mining Beetles sp. 1						■	--	--
20	Coleoptera	Chrysomelidae	*Aspidimorpha* sp.	Tortoise-shell Beetle						■	--	--
21	Coleoptera	Chrysomelidae	*Aulacophora* sp.	Leaf-mining Beetles sp. 2			■				--	--
22	Coleoptera	Chrysomelidae	*Lilioceris* sp.	Leaf-mining Beetles sp. 3					■		--	--
23	Coleoptera	Chrysomelidae	*Sagra femorata*	Leaf-mining Beetle	■	■					NA	--
24	Coleoptera	Coccinellidae	--	Lady-bird beetle	■		■		■		--	--
25	Coleoptera	Curculionidae	--	Weevil		■			■		--	--
26	Coleoptera	Curculionidae	*Myllocerus* sp.	Broad-nosed Weevil	■					■	--	--
27	Coleoptera	Dytiscidae	*Copelatus* sp.	Diving Beetle sp 1					■		--	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
28	Coleoptera	Dytiscidae	*Hydaticus bivittatus*	Diving Beetle		■					NA	--
29	Coleoptera	Dytiscidae	*Hydaticus luzonicus*	Diving Beetle		■					NA	--
30	Coleoptera	Dytiscidae	*Laccophilus* sp.	Diving Beetle sp. 2		■					--	--
31	Coleoptera	Elateridae	--	Click Beetle sp. 1	■				■		--	--
32	Coleoptera	Elateridae	--	Click Beetle sp. 2	■						--	--
33	Coleoptera	Gyrinidae	--	Whirligig beetle		■					--	--
34	Coleoptera	Hydrophilidae	--	Water Scavenger Beetle		■					--	--
35	Coleoptera	Lampyridae	--	Firefly sp. 1	■	■					--	--
36	Coleoptera	Meloidae	*Mylabris* sp.	Blister Beetle	■						--	--
37	Coleoptera	Scarabaeidae	--	Chafer Beetle			■				--	--
38	Coleoptera	Scarabaeidae	--	Dung beetle sp. 1	■				■	■	--	--
39	Coleoptera	Scarabaeidae	--	Dung beetle sp. 2	■			■	■		--	--
40	Coleoptera	Staphylinidae	--	Rove Beetle sp. 1	■	■					--	--
41	Coleoptera	Tenebrionidae	--	Darkling Beetle			■		■		--	--
42	Dermaptera	--	--	Earwig		■	■			■	--	--
43	Diptera	Asilidae	--	Robberfly sp. 1	■		■		■	■	--	--
44	Diptera	Asilidae	--	Robberfly sp. 2					■		--	--
45	Diptera	Asilidae	--	Robberfly sp. 3			■				--	--
46	Diptera	Asilidae	--	Robberfly sp. 4						■	--	--
47	Diptera	Asilidae	--	Robberfly sp. 5		■					--	--
48	Diptera	Calliphoridae	--	Blue Blow Fly sp. 1	■	■			■	■	--	--
49	Diptera	Calliphoridae	--	Green Bottle Fly			■	■	■		--	--
50	Diptera	Celyphidae	--	Beetle-backed Fly	■						--	--
51	Diptera	Chironomidae	--	Midge sp. 1			■	■			--	--
52	Diptera	Chironomidae	--	Midge sp. 2	■			■			--	--
53	Diptera	Culicidae	*Aedes aegypti*	Mosquito	■						NA	--
54	Diptera	Diopsidae	--	Stalk-eyed Fly		■					--	--
55	Diptera	Dolichopodidae	--	Long-legged Fly	■	■	■	■			--	--
56	Diptera	Drosophilidae	--	Fruit Fly	■	■					--	--
57	Diptera	Lauxaniidae	--	--		■	■	■			--	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
58	Diptera	Micropezidae	--	Stilt-legged Fly				■			--	--
59	Diptera	Muscidae	*Musca* sp.	House Fly	■	■			■		--	--
60	Diptera	Sarcophagidae	--	Flesh Fly		■	■	■	■	■	--	--
61	Diptera	Stratiomyidae	--	Soldier Fly sp.1	■						--	--
62	Diptera	Stratiomyidae	*Ptepticus* sp.	Soldier Fly sp.2				■			--	--
63	Diptera	Syrphidae	--	Hover Fly	■	■	■	■	■	■	--	--
64	Diptera	Tabanidae	--	Horse Fly		■	■		■		--	--
65	Diptera	Tipulidae	--	Crane Fly	■	■	■	■		■	--	--
66	Embioptera	--	--	Webspinner				■			--	--
67	Hemiptera	Aleyrodidae	--	Whitefly	■	■	■	■		■	--	--
68	Hemiptera	Alydidae	--	Broad-headed Bug sp. 1		■	■				--	--
69	Hemiptera	Aradidae	--	Flat Bug			■				--	--
70	Hemiptera	Berytidae	--	Thread Bug sp. 1					■		--	--
71	Hemiptera	Cicadellidae	--	Leafhopper sp. 1	■	■	■	■	■		--	--
72	Hemiptera	Cicadidae	*Lemuriana apicalis*	Monsoon Cicada	■	■	■				NA	--
73	Hemiptera	Cicadidae	*Platypleura* cf. *capitata*	--	■			■	■		--	--
74	Hemiptera	Cicadidae	*Platypleura polita*	--	■	■	■	■	■	■	NA	--
75	Hemiptera	Cicadidae	*Platypleura* sp.	Cicada sp. 1	■	■	■	■			--	--
76	Hemiptera	Coreidae	*Mictis* sp.	Leaf-footed Bug sp. 2		■					--	--
77	Hemiptera	Coreidae	*Trematocoris* sp.	Leaf-footed Bug sp. 1			■	■	■		--	--
78	Hemiptera	Fulgoridae	--	Planthopper sp. 1			■	■			--	--
79	Hemiptera	Gerridae	--	Water Strider	■	■					--	--
80	Hemiptera	--	--	Spittle Froghopper Bug		■					--	--
81	Hemiptera	Membracidae	--	Treehopper sp. 1				■	■		--	--
82	Hemiptera	Pentatomidae	*Bagrada* sp.	Painted Stink Bug	■						--	--
83	Hemiptera	Pentatomidae	*Erthesina fullo*	Yellow-spotted Stink Bug						■	NA	--
84	Hemiptera	Pentatomidae	*Eocanthecona* cf. *furcellata*	Stink Bug			■		■	■	--	--
85	Hemiptera	Pyrrhocoridae	*Dysdercus cingulatus*	Red Silk Cotton Bug	■	■	■		■	■	NA	--
86	Hemiptera	Reduviidae	--	Assasin Bug	■	■	■	■	■	■	--	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
87	Hemiptera	--	--	Aphid		■			■		--	--
88	Hemiptera	Scutelleridae	--	Jewel Bug	■						--	--
89	Hymenoptera	Apidae	*Amegilla* sp.	Blue-banded Bee	■	■		■			--	--
90	Hymenoptera	Apidae	*Apis* sp.	--	■						--	--
91	Hymenoptera	Apidae	*Xylocopa* sp.	Carpenter bee		■	■	■	■	■	--	--
92	Hymenoptera	Chrysididae	--	Cuckoo wasp sp. 1		■		■	■	■	--	--
93	Hymenoptera	Formicidae	--	Black Small Ants sp. 1	■		■	■	■	■	--	--
94	Hymenoptera	Formicidae	*Camponotus* sp.	--	■						--	--
95	Hymenoptera	Formicidae	*Cataulacus taprobanae*	--			■				NA	--
96	Hymenoptera	Formicidae	*Crematogaster* sp.	--		■	■	■			--	--
97	Hymenoptera	Formicidae	*Oecophylla smaragdina*	Weaver Ants		■			■		NA	--
98	Hymenoptera	Formicidae	*Pheidole* sp.	Harvester Ant						■	--	--
99	Hymenoptera	Formicidae	*Tetraponera rufonigra*	Bicolored Ant	■			■			NA	--
100	Hymenoptera	Ichneumonidae	--	Ichneumon Wasp		■				■	--	--
101	Hymenoptera	Mutillidae	--	Velvet Ant	■			■	■		--	--
102	Hymenoptera	Pompilidae	--	Spider Wasp sp. 1	■	■	■		■		--	--
103	Hymenoptera	Pompilidae	*Pepsis* sp.	Spider Wasp sp. 2		■				■	--	--
104	Hymenoptera	Vespidae	*Delta pyriforme*	Potter Wasp				■			NA	--
105	Hymenoptera	Vespidae	*Phimenes flavopictus*	Potter Wasp					■		NA	--
106	Hymenoptera	Vespidae	*Vespa tropica*	Greater Banded Hornet				■		■	NA	--
107	Lepidoptera	Coleophoridae		Case-bearer moth				■			--	--
108	Lepidoptera	Crambidae	--	Grass Moth sp. 1		■				■	--	--
109	Lepidoptera	Crambidae	*Pygospila tyres*	Grass Moth		■					NA	--
110	Lepidoptera	Crambidae	*Tyspanodes linealis*	Grass Moth	■						NA	--
111	Lepidoptera	Erebidae	*Adrapsa* sp.	--	■						--	--
112	Lepidoptera	Erebidae	*Erebus macrops*	Owl Moth	■	■	■				NA	--
113	Lepidoptera	Erebidae	*Eudocima homaena*	Fruit-piercing Moth	■						NA	--
114	Lepidoptera	Erebidae	*Eudocima maternal*	Fruit-piercing Moth	■						NA	--
115	Lepidoptera	Erebidae	*Digama marchalii*	--	■						NA	--
116	Lepidoptera	Erebidae	--	Underwing Moth sp. 1		■	■		■		--	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
117	Lepidoptera	Erebidae	--	Tussock Moth sp. 1				■			--	--
118	Lepidoptera	Erebidae	--	Tiger Moth sp. 1	■	■	■				--	--
119	Lepidoptera	Eupterotidae	--	Monkey Moth sp. 1	■						--	--
120	Lepidoptera	Geometridae	--	Looper Moth sp. 1	■	■					--	--
121	Lepidoptera	Hesperiidae	*Arnetta vindhiana*	Vindhyan Bob	■	■				■	NA	--
122	Lepidoptera	Hesperiidae	*Badamia exclamationis*	Brown Awl		■		■			NA	--
123	Lepidoptera	Hesperiidae	*Borbo* sp.	Swift butterfly					■		--	--
124	Lepidoptera	Hesperiidae	*Borbo cinnara*	Rice Swift	■						NA	--
125	Lepidoptera	Hesperiidae	*Caprona ransonnetii*	Golden Angle	■	■	■	■		■	NA	--
126	Lepidoptera	Hesperiidae	*Celaenorrhinus ambareesa*	Malabar Spotted Flat	■	■		■			NA	--
127	Lepidoptera	Hesperiidae	*Celaenorrhinus putra*	Bengal Spotted Flat	■						NA	--
128	Lepidoptera	Hesperiidae	*Coladenia indrani*	Tricolour Pied Flat	■						NA	--
129	Lepidoptera	Hesperiidae	*Hasora chromus*	Common Banded Awl		■	■	■			NA	--
130	Lepidoptera	Hesperiidae	*Iambrix salsala*	Chestnut Bob		■		■	■		NA	--
131	Lepidoptera	Hesperiidae	*Suastus gremius*	Palm Bob				■		■	NA	--
132	Lepidoptera	Hesperiidae	*Sarangesa dasahara*	Common Small Flat	■	■					NA	--
133	Lepidoptera	Hesperiidae	*Sarangesa purendra*	Spotted Small Flat			■			■	NA	--
134	Lepidoptera	Hesperiidae	*Udaspes folus*	Grass Demon	■	■			■		NA	--
135	Lepidoptera	Lasiocampidae	--	Lappet Moth				■		■	--	--
136	Lepidoptera	Lasiocampidae	*Trabala vishnou*	Rose-myrtle Lappet Moth	■						NA	--
137	Lepidoptera	Lecithoceridae	*Deltoplastis* sp.	Long-horned Moth	■		■	■			--	--
138	Lepidoptera	Limacodidae	--	Slug Moth	■	■	■	■			--	--
139	Lepidoptera	Lycaenidae	*Acytolepis puspa*	Common Hedge Blue			■				NA	--
140	Lepidoptera	Lycaenidae	*Amblypodia anita*	Purple Leaf Blue	■		■				NA	--
141	Lepidoptera	Lycaenidae	*Arhopala centaurus*	Centaur Oakblue			■				NA	--
142	Lepidoptera	Lycaenidae	*Caleta decidia*	Angled Pierrot		■					NA	--
143	Lepidoptera	Lycaenidae	*Castalius rosimon*	Common Pierrot	■			■	■	■	NA	--
144	Lepidoptera	Lycaenidae	*Catochrysops Strabo*	Forget-me-not						■	NA	--
145	Lepidoptera	Lycaenidae	*Chilades lajus*	Lime Blue						■	NA	--

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146	Lepidoptera	Lycaenidae	*Chilades pandava*	Plains Cupid	■	■	■	■	■	■	NA	--
147	Lepidoptera	Lycaenidae	*Chilades parrhasius*	Small Cupid						■	NA	--
148	Lepidoptera	Lycaenidae	*Curetis thetis*	Indian Sunbeam	■		■			■	NA	--
149	Lepidoptera	Lycaenidae	*Euchrysops cnejus*	Gram Blue		■		■	■	■	NA	Schedule II
150	Lepidoptera	Lycaenidae	*Iraota timoleon*	Silverstreak Blue				■			NA	--
151	Lepidoptera	Lycaenidae	*Jamides celeno*	Common Cerulean	■	■		■	■	■	NA	--
152	Lepidoptera	Lycaenidae	*Lampides boeticus*	Pea Blue	■			■		■	LC	Schedule II
153	Lepidoptera	Lycaenidae	*Leptotes plinius*	Zebra Blue						■	NA	--
154	Lepidoptera	Lycaenidae	*Loxura atymnus*	Yamfly	■					■	NA	--
155	Lepidoptera	Lycaenidae	*Prosotas dubiosa*	Tailless Lineblue		■	■			■	NA	--
156	Lepidoptera	Lycaenidae	*Rathinda amor*	Monkey Puzzle	■	■	■	■	■		NA	--
157	Lepidoptera	Lycaenidae	*Tarucus nara*	Striped Pierrot		■					NA	--
158	Lepidoptera	Lycaenidae	*Zizeeria karsandra*	Dark Grass Blue	■				■		LC	--
159	Lepidoptera	Lycaenidae	*Zizula hylax*	Tiny Grass Blue				■	■	■	LC	--
160	Lepidoptera	Noctuidae	*Episteme* sp.	Forester moth					■		--	--
161	Lepidoptera	Notodontidae	--	Prominent Moth				■			--	--
162	Lepidoptera	Nymphalidae	*Ariadne merione*	Common Castor	■				■	■	NA	--
163	Lepidoptera	Nymphalidae	*Charaxes psaphon*	Tawny Rajah		■			■		NA	--
164	Lepidoptera	Nymphalidae	*Charaxes solon*	Black Rajah		■		■			NA	--
165	Lepidoptera	Nymphalidae	*Danaus chrysippus*	Plain Tiger		■	■	■		■	LC	--
166	Lepidoptera	Nymphalidae	*Danaus genutia*	Striped Tiger		■		■	■	■	NA	--
167	Lepidoptera	Nymphalidae	*Elymnias hypermnestra*	Common Palmfly				■	■		NA	--
168	Lepidoptera	Nymphalidae	*Euploea core*	Common Crow	■	■	■	■	■	■	LC	--
169	Lepidoptera	Nymphalidae	*Euploea klugii*	Brown King Crow	■	■	■	■		■	NA	--
170	Lepidoptera	Nymphalidae	*Euploea Sylvester*	Double Banded Crow		■		■	■		NA	--
171	Lepidoptera	Nymphalidae	*Euthalia aconthea*	Common Baron				■			NA	--
172	Lepidoptera	Nymphalidae	*Euthalia lubentina*	Gaudy Baron	■						NA	Schedule IV
173	Lepidoptera	Nymphalidae	*Hypolimnas bolina*	Great Eggfly	■	■		■	■	■	NA	--
174	Lepidoptera	Nymphalidae	*Hypolimnas misippus*	Danaid Eggfly		■		■	■		LC	Schedule I

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
175	Lepidoptera	Nymphalidae	*Junonia almana*	Peacock Pansy			■	■	■	■	LC	--
176	Lepidoptera	Nymphalidae	*Junonia atlites*	Grey Pansy	■		■	■	■	■	NA	--
177	Lepidoptera	Nymphalidae	*Junonia hierta*	Yellow Pansy	■	■	■				LC	--
178	Lepidoptera	Nymphalidae	*Junonia iphita*	Chocolate Pansy	■	■	■	■	■	■	NA	--
179	Lepidoptera	Nymphalidae	*Junonia lemonias*	Lemon Pansy	■	■	■	■	■	■	NA	--
180	Lepidoptera	Nymphalidae	*Junonia orithya*	Blue Pansy				■			NA	--
181	Lepidoptera	Nymphalidae	*Kallima horsfieldii*	Blue Oakleaf	■	■	■	■	■		NA	--
182	Lepidoptera	Nymphalidae	*Melanitis leda*	Common Evening Brown	■	■	■		■		NA	--
183	Lepidoptera	Nymphalidae	*Moduza procris*	Commander	■	■	■	■	■		NA	--
184	Lepidoptera	Nymphalidae	*Mycalensis perseus*	Common Bushbrown	■	■	■	■	■	■	NA	--
185	Lepidoptera	Nymphalidae	*Neptis jumbah*	Common Sailer	■	■	■	■	■	■	NA	--
186	Lepidoptera	Nymphalidae	*Parantica aglea*	Glassy Tiger	■	■	■	■	■		NA	--
187	Lepidoptera	Nymphalidae	*Phalanta phalantha*	Common Leopard	■	■	■	■	■	■	LC	--
188	Lepidoptera	Nymphalidae	*Polyura athamas*	Common Nawab					■	■	NA	--
189	Lepidoptera	Nymphalidae	*Symphaedra nais*	Baronet	■	■	■	■	■	■	NA	--
190	Lepidoptera	Nymphalidae	*Tirumala limniace*	Blue Tiger		■		■	■	■	NA	--
191	Lepidoptera	Nymphalidae	*Ypthima Asterope*	Common Threering				■	■		NA	--
192	Lepidoptera	Nymphalidae	*Ypthima baldus*	Common Fivering						■	NA	--
193	Lepidoptera	Nymphalidae	*Ypthima huebneri*	Common Fourring			■				NA	--
194	Lepidoptera	Papilionidae	*Graphium Agamemnon*	Tailed Jay	■	■	■	■	■		NA	--
195	Lepidoptera	Papilionidae	*Graphium doson*	Common Jay	■	■					NA	--
196	Lepidoptera	Papilionidae	*Graphium nomius*	Spot Swordtail	■	■	■	■	■	■	NA	--
197	Lepidoptera	Papilionidae	*Graphium teredon*	Common Bluebottle		■	■	■			NA	--
198	Lepidoptera	Papilionidae	*Pachliopta aristolochiae*	Common Rose	■	■	■	■	■		NA	--
199	Lepidoptera	Papilionidae	*Pachliopta hector*	Crimson Rose	■	■					LC	Schedule I
200	Lepidoptera	Papilionidae	*Papilio clytia*	Common Mime				■		■	NA	--
201	Lepidoptera	Papilionidae	*Papilio demoleus*	Lime Butterfly				■	■		NA	--
202	Lepidoptera	Papilionidae	*Papilio polymnestor*	Blue Mormon		■					NA	--
203	Lepidoptera	Papilionidae	*Papilio polytes*	Common Mormon	■		■	■		■	NA	--
204	Lepidoptera	Pieridae	*Appias albina*	Common Albatross		■		■			NA	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
205	Lepidoptera	Pieridae	*Catopsilia pomona*	Common Emigrant	■	■	■	■	■	■	NA	--
206	Lepidoptera	Pieridae	*Catopsilia pyranthe*	Mottled Emigrant	■		■		■	■	NA	--
207	Lepidoptera	Pieridae	*Cepora nerissa*	Common Gull	■	■	■	■		■	NA	--
208	Lepidoptera	Pieridae	*Colotis aurora*	Plain Orange Tip	■						NA	--
209	Lepidoptera	Pieridae	*Delias eucharis*	Common Jezebel		■					NA	--
210	Lepidoptera	Pieridae	*Eurema hecabe*	Common Grass Yellow	■	■	■	■	■	■	NA	--
211	Lepidoptera	Pieridae	*Eurema laeta*	Spotless Grass Yellow					■		NA	--
212	Lepidoptera	Pieridae	*Hebomoia glaucippe*	Great Orange Tip	■	■	■	■	■	■	NA	--
213	Lepidoptera	Pieridae	*Ixias marianne*	White Orange Tip	■	■	■	■	■	■	NA	--
214	Lepidoptera	Pieridae	*Ixias pyrene*	Yellow Orange Tip	■	■	■	■	■	■	NA	--
215	Lepidoptera	Pieridae	*Leptosia nina*	Psyche	■	■	■	■	■	■	NA	--
216	Lepidoptera	Pieridae	*Pareronia hippia*	Common Wanderer	■	■			■	■	NA	--
217	Lepidoptera	Psychidae	--	Bagworm		■	■				--	--
218	Lepidoptera	Pyralidae	--	Snout Moth		■			■		--	--
219	Lepidoptera	Riodinidae	*Abisara bifasciata*	Double-banded Judy	■					■	NA	--
220	Lepidoptera	Sphingidae	*Cephonodes* sp.	Bee Hawk Moth				■			--	--
221	Lepidoptera	Sphingidae	*Daphnis nerii*	Oleander Hawk Moth	■						NA	--
222	Lepidoptera	Sphingidae	*Marumba dyras*	Dull Swirled Hawkmoth	■						NA	--
223	Lepidoptera	Sphingidae	*Nephele* sp.	Brown Hawk Moth	■						--	--
224	Lepidoptera	Thyrididae	--	Picture-winged Leaf Moth			■				--	--
225	Lepidoptera	Tortricidae	--	Leafroller Moth			■				--	--
226	Mantodea	--	--	Bark Mantis	■	■	■	■	■	■	--	--
227	Mantodea	--	--	Boxer Mantis		■				■	--	--
228	Mantodea	--	--	Stick Mantis			■				--	--
229	Mantodea	Empusidae	*Gongylus gongylodes*	Violin Mantis		■					NA	--
230	Mecoptera	--	--	Scorpion Fly	■	■	■	■	■		--	--
231	Neuroptera	Ascalaphidae	--	Owlfly		■		■			--	--
232	Neuroptera	Myrmeleontidae	--	Antlion sp. 1	■	■	■	■	■		--	--
233	Neuroptera	Myrmeleontidae	--	Antlion sp. 2		■		■			--	--
234	Neuroptera	Myrmeleontidae	--	Antlion sp. 3					■		--	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
235	Odonata	Aeshnidae	*Anax guttatus*	Lesser Green Emperor		■		■			LC	--
236	Odonata	Aeshnidae	*Anax immaculifrons*	Blue Darner		■		■			LC	--
237	Odonata	Calopterygidae	*Vestalis apicalis*	Black-tipped Forest Glory		■	■				LC	--
238	Odonata	Coenagrionidae	*Agriocnemis pygmaea*	Pygmy Dartlet		■					LC	--
239	Odonata	Coenagrionidae	*Ischneura senegalensis*	Senegal Golden Dartlet		■	■				NA	--
240	Odonata	Coenagrionidae	*Pseudagrion rubriceps*	Saffron-faced Blue Dart				■			LC	--
241	Odonata	Gomphidae	*Ictinogomphus rapax*	Common Clubtail	■	■					LC	--
242	Odonata	Gomphidae	*Macrogomphus annulatus*	--						■	DD	--
243	Odonata	Lestidae	*Lestes* cf. *concinnus*	Dusky Spreadwing		■					--	--
244	Odonata	Lestidae	*Lestes viridulus*	Emerald-striped Spreadwing		■					LC	--
245	Odonata	Libellulidae	*Acisoma panorpoides*	Trumpet-tail					■		LC	--
246	Odonata	Libellulidae	*Brachythemis contaminate*	Ditch Jewel		■		■		■	LC	--
247	Odonata	Libellulidae	*Bradinopyga geminate*	Granite Ghost	■						LC	--
248	Odonata	Libellulidae	*Cratilla lineata*	Emerald-banded Skimmer		■					LC	--
249	Odonata	Libellulidae	*Crocothemis servilia*	Scarlet Skimmer		■				■	LC	--
250	Odonata	Libellulidae	*Diplacodes trivialis*	Blue Ground Skimmer	■	■	■	■	■	■	LC	--
251	Odonata	Libellulidae	*Lathrecista asiatica*	Asiatic Bloodtail	■	■	■	■	■	■	LC	--
252	Odonata	Libellulidae	*Neurothemis fulvia*	Fulvous Forest Skimmer		■		■			LC	--
253	Odonata	Libellulidae	*Neurothemis intermedia*	--		■					LC	--
254	Odonata	Libellulidae	*Orthetrum Chrysis*	Brown-backed Marsh Hawk	■						LC	--
255	Odonata	Libellulidae	*Orthetrum glaucum*	Blue Marsh Hawk		■					LC	--
256	Odonata	Libellulidae	*Orthetrum luzonicum*	Tri-colored marsh Hawk			■			■	LC	--
257	Odonata	Libellulidae	*Orthetrum pruinosum*	Crimson-tailed Marsh Hawk	■		■	■		■	LC	--
258	Odonata	Libellulidae	*Orthetrum sabina*	Green Marsh Hawk	■	■		■	■	■	LC	--
259	Odonata	Libellulidae	*Pantala flavescens*	Wandering Glider	■	■		■	■	■	LC	--
260	Odonata	Libellulidae	*Potamarcha congener*	Yellow-tailed Ashy Skimmer				■			LC	--
261	Odonata	Libellulidae	*Rhyothemis variegate*	Common Picturewing		■				■	LC	--

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
262	Odonata	Libellulidae	*Tholymis tillarga*	Coral-tailed Cloudwing	■			■	■		LC	--
263	Odonata	Libellulidae	*Tramea basilaris*	Red Marsh Trotter	■	■			■		LC	--
264	Odonata	Libellulidae	*Trithemis aurora*	Crimson Marsh Glider	■				■		LC	--
265	Odonata	Libellulidae	*Trithemis festiva*	Black Stream Glider		■				■	LC	--
266	Odonata	Libellulidae	*Urothemis signata*	Greater Crimson Glider		■					LC	--
267	Odonata	Macromiidae	*Epophthalmia vittate*	Common Torrent Hawk	■	■		■			LC	--
268	Odonata	Platycnemididae	*Copera vittata*	Blue Bush Dart				■			LC	--
269	Odonata	Platycnemididae	*Copera marginipes*	Yellow Bush Dart		■		■			LC	--
270	Odonata	Platycnemididae	*Disparoneura quadrimaculata*	Black-winged Bambootail				■			LC	--
271	Odonata	Platycnemididae	*Elattoneura nigerrima*	--				■			DD	--
272	Odonata	Platystictidae	*Protosticta gravelyi*	Pied Reedtail				■			LC	--
273	Orthoptera	Acrididae	--	Short-horned Grasshopper sp. 1	■	■	■	■	■	■	--	--
274	Orthoptera	Acrididae	--	Short-horned Grasshopper sp. 2		■		■	■	■	--	--
275	Orthoptera	Acrididae	--	Short-horned Grasshopper sp. 3		■			■	■	--	--
276	Orthoptera	Acrididae	*Xenocatantops* sp.	Short-horned Grasshopper sp. 4			■				--	--
277	Orthoptera	Acrididae	--	Long-horned Grasshopper sp. 1			■		■		--	--
278	Orthoptera	Gryllidae	*Teleogryllus* sp.	Cricket sp. 1	■	■	■	■	■	■	--	--
279	Orthoptera	Gryllidae	*Velarifictorus* sp.	Cricket sp. 2		■	■				--	--
280	Orthoptera	Gryllidae	--	Cricket sp. 3				■			--	--
281	Orthoptera	Gryllidae	--	Cricket sp. 4					■		--	--
282	Orthoptera	Gryllotalpidae	--	Mole Cricket sp. 1		■					--	--
283	Orthoptera	Tettigonidae	--	Katydid	■	■				■	--	--
284	Phasmatodea	--	--	Stick Insect			■	■	■	■	--	--
285	Zygentoma	Lepismatidae	*Lepisma* sp.	Silverfish	■	■	■		■	■	--	--

(Dark cells indicate species presence, blank cell indicate absence, '--' indicates IUCN status not applicable for unidentified taxon and non-protected in case of WPA status; LC = Least Concern, DD = Data Deficient, NA = Not Assessed)

Table 12: Monthwise checklist of insects recorded from July 2021 to June 2022 during the BNHS-GMLR survey (shaded cells indicate species presence)

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Blattodea	--	Termite sp. 1		■					■		■	■		■
2	Blattodea	--	Termite sp. 2			■						■	■		
3	Blattodea	--	Cockroach sp. 1	■								■	■		■
4	Blattodea	--	Cockroach sp. 2								■	■		■	
5	Blattodea	*Hemithyrsocera palliata*	Pallid Sun Roach								■				
6	Coleoptera	*Apoderus tranquebaricus*	Leaf Rolling Beetle									■			
7	Coleoptera	*Paroplapoderus* sp.	Spiny Leaf-rolling Weevil									■	■		
8	Coleoptera	--	Ant-like beetle sp. 1	■									■		■
9	Coleoptera	--	False Powderpost Beetle									■			
10	Coleoptera	--	Jewel Beetle							■			■		
11	Coleoptera	--	Ground Beetle			■								■	
12	Coleoptera	*Cicindela* sp.	Tiger Beetle sp. 1						■						■
13	Coleoptera	--	Tiger Beetle sp. 2						■						
14	Coleoptera	--	Tiger Beetle sp. 3						■						
15	Coleoptera	*Oberea* sp.	Long-horned Beetle sp. 1									■			
16	Coleoptera	--	Long-horned Beetle sp. 2							■					
17	Coleoptera	*Olenecamptus* sp.	Long-horned Beetle sp. 3								■				
18	Coleoptera	*Altica* sp.	Flea Beetle										■		
19	Coleoptera	*Apophylia* sp.	Leaf-mining Beetles sp. 1									■			
20	Coleoptera	*Aspidimorpha* sp.	Tortoise-shell Beetle							■	■				
21	Coleoptera	*Aulacophora* sp.	Leaf-mining Beetles sp. 2										■		
22	Coleoptera	*Lilioceris* sp.	Leaf-mining Beetles sp. 3								■				
23	Coleoptera	*Sagra femorata*	Leaf-mining Beetle								■	■			
24	Coleoptera	--	Lady-bird beetle	■							■	■			
25	Coleoptera	--	Weevil			■					■		■		
26	Coleoptera	*Myllocerus* sp.	Broad-nosed Weevil									■	■		
27	Coleoptera	*Copelatus* sp.	Diving Beetle sp 1							■					
28	Coleoptera	*Hydaticus bivittatus*	Diving Beetle												■
29	Coleoptera	*Hydaticus luzonicus*	Diving Beetle												■

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30	Coleoptera	*Laccophilus* sp.	Diving Beetle sp. 2												■
31	Coleoptera	--	Click Beetle sp. 1			■									■
32	Coleoptera	--	Click Beetle sp. 2				■								
33	Coleoptera	--	Whirligig beetle										■		
34	Coleoptera	--	Water Scavenger Beetle												■
35	Coleoptera	--	Firefly sp. 1							■					
36	Coleoptera	*Mylabris* sp.	Blister Beetle									■	■		
37	Coleoptera	--	Chafer Beetle								■				
38	Coleoptera	--	Dung beetle sp. 1					■	■						
39	Coleoptera	--	Dung beetle sp. 2					■	■						
40	Coleoptera	--	Rove Beetle sp. 1									■			
41	Coleoptera	--	Darkling Beetle					■	■			■			■
42	Dermaptera	--	Earwig				■					■		■	
43	Diptera	--	Robberfly sp. 1					■				■	■		
44	Diptera	--	Robberfly sp. 2				■								
45	Diptera	--	Robberfly sp. 3						■						
46	Diptera	--	Robberfly sp. 4									■			
47	Diptera	--	Robberfly sp. 5						■						
48	Diptera	--	Blue Blow Fly sp. 1			■					■	■	■	■	■
49	Diptera	--	Green Bottle Fly						■			■			
50	Diptera	--	Beetle-backed Fly										■		
51	Diptera	--	Midge sp. 1										■	■	
52	Diptera	--	Midge sp. 2									■	■		
53	Diptera	*Aedes aegypti*	Mosquito									■			
54	Diptera	--	Stalk-eyed Fly									■			
55	Diptera	--	Long-legged Fly								■	■	■	■	
56	Diptera	--	Fruit Fly										■	■	
57	Diptera	--	--										■		
58	Diptera	--	Stilt-legged Fly										■		
59	Diptera	*Musca* sp.	House Fly			■			■			■	■		

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
60	Diptera	--	Flesh Fly						■	■	■			■	■
61	Diptera	--	Soldier Fly sp.1										■		
62	Diptera	*Ptepticus* sp.	Soldier Fly sp.2									■			
63	Diptera	--	Hover Fly		■	■	■	■		■			■		
64	Diptera	--	Horse Fly					■	■						
65	Diptera	--	Crane Fly		■					■	■	■	■		
66	Embioptera	--	Webspinner									■			
67	Hemiptera	--	Whitefly		■						■	■	■		
68	Hemiptera	--	Broad-headed Bug sp. 1	■											■
69	Hemiptera	--	Flat Bug										■		
70	Hemiptera	--	Thread Bug sp. 1												■
71	Hemiptera	--	Leafhopper sp. 1										■		■
72	Hemiptera	*Lemuriana apicalis*	Monsoon Cicada						■	■					
73	Hemiptera	*Platypleura* cf. *capitata*	--				■				■				
74	Hemiptera	*Platypleura polita*	--		■		■								
75	Hemiptera	*Platypleura* sp.	Cicada sp. 1					■	■						
76	Hemiptera	*Mictis* sp.	Leaf-footed Bug sp. 2							■					
77	Hemiptera	*Trematocoris* sp.	Leaf-footed Bug sp. 1	■					■						
78	Hemiptera	--	Planthopper sp. 1										■	■	
79	Hemiptera	--	Water Strider				■		■		■	■	■		
80	Hemiptera	--	Spittle Froghopper Bug									■			
81	Hemiptera	--	Treehopper sp. 1	■							■				■
82	Hemiptera	*Bagrada* sp.	Painted Stink Bug					■							
83	Hemiptera	*Erthesina fullo*	Yellow-spotted Stink Bug							■					
84	Hemiptera	*Eocanthecona* cf. *furcellata*	Stink Bug				■					■		■	■
85	Hemiptera	*Dysdercus cingulatus*	Red Silk Cotton Bug	■			■	■	■		■		■	■	■
86	Hemiptera	--	Assasin Bug		■			■	■	■	■	■	■	■	■
87	Hemiptera	--	Aphid		■	■									
88	Hemiptera	--	Jewel Bug												■

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
89	Hymenoptera	*Amegilla* sp.	Blue-banded Bee			■	■	■							
90	Hymenoptera	*Apis* sp.	--										■		
91	Hymenoptera	*Xylocopa* sp.	Carpenter bee		■	■	■	■				■	■	■	
92	Hymenoptera	--	Cuckoo wasp sp. 1	■	■				■					■	
93	Hymenoptera	--	Black Small Ants sp. 1		■			■	■				■		
94	Hymenoptera	*Camponotus* sp.	--						■						
95	Hymenoptera	*Cataulacus taprobanae*	--		■										
96	Hymenoptera	*Crematogaster* sp.	--	■						■			■		
97	Hymenoptera	*Oecophylla smaragdina*	Weaver Ants							■					■
98	Hymenoptera	*Pheidole* sp.	Harvester Ant		■										■
99	Hymenoptera	*Tetraponera rufonigra*	Bicolored Ant	■						■					
100	Hymenoptera	--	Ichneumon Wasp	■								■			
101	Hymenoptera	--	Velvet Ant							■					
102	Hymenoptera	--	Spider Wasp sp. 1								■	■	■		
103	Hymenoptera	*Pepsis* sp.	Spider Wasp sp. 2									■			
104	Hymenoptera	*Delta pyriforme*	Potter Wasp				■								
105	Hymenoptera	*Phimenes flavopictus*	Potter Wasp											■	
106	Hymenoptera	*Vespa tropica*	Greater Banded Hornet					■	■			■			
107	Lepidoptera		Case-bearer moth	■											
108	Lepidoptera	--	Grass Moth sp. 1						■		■	■	■		
109	Lepidoptera	*Pygospila tyres*	Grass Moth						■						
110	Lepidoptera	*Tyspanodes linealis*	Grass Moth							■					
111	Lepidoptera	*Adrapsa* sp.	--							■					
112	Lepidoptera	*Erebus macrops*	Owl Moth						■	■		■			
113	Lepidoptera	*Eudocima homaena*	Fruit-piercing Moth							■					
114	Lepidoptera	*Eudocima materna*	Fruit-piercing Moth							■					
115	Lepidoptera	*Digama marchalii*	--							■					
116	Lepidoptera	--	Underwing Moth sp. 1						■						
117	Lepidoptera	--	Tussock Moth sp. 1											■	
118	Lepidoptera	--	Tiger Moth sp. 1									■	■		

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
119	Lepidoptera	--	Monkey Moth sp. 1							■					
120	Lepidoptera	--	Looper Moth sp. 1								■			■	
121	Lepidoptera	*Arnetta vindhiana*	Vindhyan Bob		■							■	■		
122	Lepidoptera	*Badamia exclamationis*	Brown Awl							■		■	■		
123	Lepidoptera	*Borbo* sp.	Swift butterfly		■										
124	Lepidoptera	*Borbo cinnara*	Rice Swift									■	■		
125	Lepidoptera	*Caprona ransonnetii*	Golden Angle							■	■		■	■	
126	Lepidoptera	*Celaenorrhinus ambareesa*	Malabar Spotted Flat				■	■				■			
127	Lepidoptera	*Celaenorrhinus putra*	Bengal Spotted Flat										■		
128	Lepidoptera	*Coladenia indrani*	Tricolour Pied Flat									■			
129	Lepidoptera	*Hasora chromus*	Common Banded Awl					■	■			■			
130	Lepidoptera	*Iambrix salsala*	Chestnut Bob	■									■		
131	Lepidoptera	*Suastus gremius*	Palm Bob					■			■				
132	Lepidoptera	*Sarangesa dasahara*	Common Small Flat									■	■	■	
133	Lepidoptera	*Sarangesa purendra*	Spotted Small Flat									■		■	
134	Lepidoptera	*Udaspes folus*	Grass Demon							■	■	■			
135	Lepidoptera	--	Lappet Moth										■		
136	Lepidoptera	*Trabala vishnou*	Rose-myrtle Lappet Moth										■		
137	Lepidoptera	*Deltoplastis* sp.	Long-horned Moth									■	■		
138	Lepidoptera	--	Slug Moth							■			■	■	
139	Lepidoptera	*Acytolepis puspa*	Common Hedge Blue				■								
140	Lepidoptera	*Amblypodia anita*	Purple Leaf Blue				■							■	■
141	Lepidoptera	*Arhopala centaurus*	Centaur Oakblue		■										
142	Lepidoptera	*Caleta decidia*	Angled Pierrot				■							■	
143	Lepidoptera	*Castalius rosimon*	Common Pierrot		■					■			■	■	■
144	Lepidoptera	*Catochrysops strabo*	Forget-me-not			■									
145	Lepidoptera	*Chilades lajus*	Lime Blue											■	
146	Lepidoptera	*Chilades pandava*	Plains Cupid		■	■									■
147	Lepidoptera	*Chilades parrhasius*	Small Cupid		■										

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
148	Lepidoptera	*Curetis thetis*	Indian Sunbeam						■				■	■	
149	Lepidoptera	*Euchrysops cnejus*	Gram Blue		■	■				■				■	
150	Lepidoptera	*Iraota timoleon*	Silverstreak Blue			■									
151	Lepidoptera	*Jamides celeno*	Common Cerulean		■	■		■	■	■	■	■	■	■	■
152	Lepidoptera	*Lampides boeticus*	Pea Blue		■										
153	Lepidoptera	*Leptotes plinius*	Zebra Blue		■										
154	Lepidoptera	*Loxura atymnus*	Yamfly					■		■		■			
155	Lepidoptera	*Prosotas dubiosa*	Tailless Lineblue		■	■									
156	Lepidoptera	*Rathinda amor*	Monkey Puzzle			■			■	■	■	■	■	■	■
157	Lepidoptera	*Tarucus nara*	Rounded Pierrot				■								
158	Lepidoptera	*Zizeeria karsandra*	Dark Grass Blue						■	■					
159	Lepidoptera	*Zizula hylax*	Tiny Grass Blue		■				■					■	■
160	Lepidoptera	*Episteme* sp.	Forester moth							■					
161	Lepidoptera	--	Prominent Moth										■		
162	Lepidoptera	*Ariadne merione*	Common Castor			■							■	■	■
163	Lepidoptera	*Charaxes bernardus*	Tawny Rajah						■				■		
164	Lepidoptera	*Charaxes solon*	Black Rajah		■				■						
165	Lepidoptera	*Danaus chrysippus*	Plain Tiger		■				■					■	■
166	Lepidoptera	*Danaus genutia*	Striped Tiger		■	■	■	■					■	■	■
167	Lepidoptera	*Elymnias hypermnestra*	Common Palmfly							■				■	
168	Lepidoptera	*Euploea core*	Common Crow		■	■	■		■	■	■	■	■	■	■
169	Lepidoptera	*Euploea klugii*	Brown King Crow							■	■		■	■	■
170	Lepidoptera	*Euploea sylvester*	Double Banded Crow			■	■	■	■			■	■		
171	Lepidoptera	*Euthalia aconthea*	Common Baron		■										
172	Lepidoptera	*Euthalia lubentina*	Gaudy Baron										■		
173	Lepidoptera	*Hypolimnas bolina*	Great Eggfly			■			■	■		■	■	■	
174	Lepidoptera	*Hypolimnas misippus*	Danaid Eggfly					■	■	■	■	■		■	
175	Lepidoptera	*Junonia almana*	Peacock Pansy			■	■			■				■	■
176	Lepidoptera	*Junonia atlites*	Grey Pansy	■						■			■	■	■
177	Lepidoptera	*Junonia hierta*	Yellow Pansy			■					■				

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
178	Lepidoptera	*Junonia iphita*	Chocolate Pansy			■	■	■	■	■	■	■	■	■	■
179	Lepidoptera	*Junonia lemonias*	Lemon Pansy		■	■	■	■	■	■			■	■	■
180	Lepidoptera	*Junonia orithya*	Blue Pansy				■								
181	Lepidoptera	*Kallima horsefieldii*	Blue Oakleaf				■		■	■	■	■	■	■	
182	Lepidoptera	*Melanitis leda*	Common Evening Brown		■	■			■				■	■	■
183	Lepidoptera	*Moduza procris*	Commander		■					■	■	■	■	■	■
184	Lepidoptera	*Mycalensis perseus*	Common Bushbrown	■	■		■	■			■	■	■	■	■
185	Lepidoptera	*Neptis jumbah*	Common Sailer		■	■				■		■	■	■	■
186	Lepidoptera	*Parantica aglea*	Glassy Tiger					■				■	■	■	■
187	Lepidoptera	*Phalanta phalantha*	Common Leopard			■	■	■	■				■	■	■
188	Lepidoptera	*Polyura athamas*	Common Nawab									■		■	
189	Lepidoptera	*Symphaedra nais*	Baronet		■	■	■	■	■	■	■	■	■	■	■
190	Lepidoptera	*Tirumala limniace*	Blue Tiger		■		■	■	■				■	■	■
191	Lepidoptera	*Ypthima asterope*	Common Threering										■	■	■
192	Lepidoptera	*Ypthima baldus*	Common Fivering												■
193	Lepidoptera	*Ypthima huebneri*	Common Fourring							■					
194	Lepidoptera	*Graphium agamemnon*	Tailed Jay					■			■	■	■		■
195	Lepidoptera	*Graphium doson*	Common Jay				■		■						
196	Lepidoptera	*Graphium nomius*	Spot Swordtail		■	■	■	■	■					■	■
197	Lepidoptera	*Graphium teredon*	Common Bluebottle					■		■		■	■		
198	Lepidoptera	*Pachliopta aristolochiae*	Common Rose			■	■	■	■	■			■	■	■
299	Lepidoptera	*Pachliopta hector*	Crimson Rose		■				■						
200	Lepidoptera	*Papilio clytia*	Common Mime				■	■							
201	Lepidoptera	*Papilio demoleus*	Lime Butterfly							■		■			
202	Lepidoptera	*Papilio polymnestor*	Blue Mormon										■	■	■
203	Lepidoptera	*Papilio polytes*	Common Mormon			■				■		■	■	■	■
204	Lepidoptera	*Appias albina*	Common Albatross			■			■	■					
205	Lepidoptera	*Catopsilia pomona*	Common Emigrant		■	■	■	■	■		■	■	■	■	■
206	Lepidoptera	*Catopsilia pyranthe*	Mottled Emigrant				■	■	■					■	

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
207	Lepidoptera	*Cepora nerissa*	Common Gull		■	■	■	■	■	■	■	■	■		■
208	Lepidoptera	*Colotis aurora*	Plain Orange Tip						■						
209	Lepidoptera	*Delias eucharis*	Common Jezebel									■			
210	Lepidoptera	*Eurema hecabe*	Common Grass Yellow	■					■	■		■	■	■	■
211	Lepidoptera	*Eurema laeta*	Spotless Grass Yellow												■
212	Lepidoptera	*Hebomoia glaucippe*	Great Orange Tip		■	■	■			■	■	■	■	■	■
213	Lepidoptera	*Ixias marianne*	White Orange Tip			■	■	■	■	■					
214	Lepidoptera	*Ixias pyrene*	Yellow Orange Tip		■	■	■	■	■	■		■	■	■	■
215	Lepidoptera	*Leptosis nina*	Psyche		■	■	■		■	■	■	■	■	■	■
216	Lepidoptera	*Pareronia hippia*	Common Wanderer		■			■		■		■	■	■	■
217	Lepidoptera	--	Bagworm									■	■		
218	Lepidoptera	--	Snout Moth		■				■						
219	Lepidoptera	*Abisara bifasciata*	Double-banded Judy							■					
220	Lepidoptera	*Cephonodes* sp.	Bee Hawk Moth				■								
221	Lepidoptera	*Daphnis nerii*	Oleander Hawk Moth							■					
222	Lepidoptera	*Marumba dyras*	Dull Swirled Hawkmoth							■					
223	Lepidoptera	*Nephele* sp.	Brown Hawk Moth					■							
224	Lepidoptera	--	Picture-winged Leaf Moth									■			
225	Lepidoptera	--	Leafroller Moth											■	
226	Mantodea	--	Bark Mantis		■			■	■	■	■	■			
227	Mantodea	--	Boxer Mantis								■				■
228	Mantodea	--	Stick Mantis										■		
229	Mantodea	*Gongylus gongylodes*	Violin Mantis									■			
230	Mecoptera	--	Scorpion Fly					■			■	■	■		
231	Neuroptera	--	Owlfly						■			■	■		
232	Neuroptera	--	Antlion sp. 1			■	■			■	■			■	
233	Neuroptera	--	Antlion sp. 2							■		■	■		
234	Neuroptera	--	Antlion sp. 3							■					
235	Odonata	*Anax guttatus*	Lesser Green Emperor					■	■						
236	Odonata	*Anax immaculifrons*	Blue Darner					■						■	

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
237	Odonata	*Vestalis apicalis*	Black-tipped Forest Glory				■	■	■					■	
238	Odonata	*Agriocnemis pygmaea*	Pygmy Dartlet										■		
239	Odonata	*Ischneura senegalensis*	Senegal Golden Dartlet		■								■		
240	Odonata	*Pseudagrion rubriceps*	Saffron-faced Blue Dart					■							
241	Odonata	*Ictinogomphus rapax*	Common Clubtail							■		■			■
242	Odonata	*Macrogomphus annulatus*	Keiser's Forktail							■					
243	Odonata	*Lestes* cf. *concinnus*	Dusky Spreadwing			■									
244	Odonata	*Lestes viridulus*	Emerald-striped Spreadwing									■			■
245	Odonata	*Acisoma panorpoides*	Trumpet-tail									■			
246	Odonata	*Brachythemis contaminata*	Ditch Jewel							■	■		■		
247	Odonata	*Bradinopyga geminata*	Granite Ghost		■										
248	Odonata	*Cratilla lineata*	Emrald-banded Skimmer					■	■						
249	Odonata	*Crocothemis servilia*	Scarlet Skimmer							■			■	■	
250	Odonata	*Diplacodes trivialis*	Blue Ground Skimmer						■	■	■		■	■	■
251	Odonata	*Lathrecista asiatica*	Asiatic Bloodtail				■						■		■
252	Odonata	*Neurothemis fulvia*	Fulvous Forest Skimmer			■	■	■							
253	Odonata	*Neurothemis intermedia*	--				■								
254	Odonata	*Orthetrum chrysis*	Brown-backed Marsh Hawk											■	
255	Odonata	*Orthetrum glaucum*	Blue Marsh Hawk											■	
256	Odonata	*Orthetrum luzonicum*	Tri-colored marsh Hawk									■		■	
257	Odonata	*Orthetrum pruinosum*	Crimson-tailed Marsh Hawk						■			■	■	■	
258	Odonata	*Orthetrum sabina*	Green Marsh Hawk						■	■	■	■	■	■	
259	Odonata	*Pantala flavescens*	Wandering Glider			■			■	■			■	■	
260	Odonata	*Potamarcha congener*	Yellow-tailed Ashy Skimmer					■		■					
261	Odonata	*Rhyothemis variegata*	Common Picturewing								■		■		
262	Odonata	*Tholymis tillarga*	Coral-tailed Cloudwing						■					■	
263	Odonata	*Tramea basilaris*	Red Marsh Trotter							■	■				
264	Odonata	*Trithemis aurora*	Crimson Marsh Glider											■	
265	Odonata	*Trithemis festiva*	Black Stream Glider					■			■		■	■	
266	Odonata	*Urothemis signata*	Greater Crimson Glider									■			

Sr. No.	Order	Species	Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
268	Odonata	*Copera vittata*	Blue Bush Dart								■		■		
269	Odonata	*Copera marginipes*	Yellow Bush Dart			■		■	■				■	■	■
270	Odonata	*Disparoneura quadrimaculata*	Black-winged Bambootail							■					
271	Odonata	*Elattoneura nigerrima*	--								■	■			
272	Odonata	*Protosticta gravelyi*	Pied Reedtail										■		
273	Orthoptera	--	Short-horned Grasshopper sp. 1			■		■	■	■		■	■	■	■
274	Orthoptera	--	Short-horned Grasshopper sp. 2			■		■		■		■			
275	Orthoptera	--	Short-horned Grasshopper sp. 3						■		■	■			
276	Orthoptera	*Xenocatantops* sp.	Short-horned Grasshopper sp. 4								■				
277	Orthoptera	--	Long-horned Grasshopper sp. 1										■	■	
278	Orthoptera	*Teleogryllus* sp.	Cricket sp. 1			■	■		■		■	■	■		
279	Orthoptera	*Velarifictorus* sp.	Cricket sp. 2									■	■		
280	Orthoptera	--	Cricket sp. 3									■			
281	Orthoptera	--	Cricket sp. 4									■			
282	Orthoptera	--	Mole Cricket sp. 1									■			
283	Orthoptera	--	Katydid							■		■	■	■	
284	Phasmatodea	--	Stick Insect	■				■						■	
285	Zygentoma	*Lepisma* sp.	Silverfish				■	■				■	■		

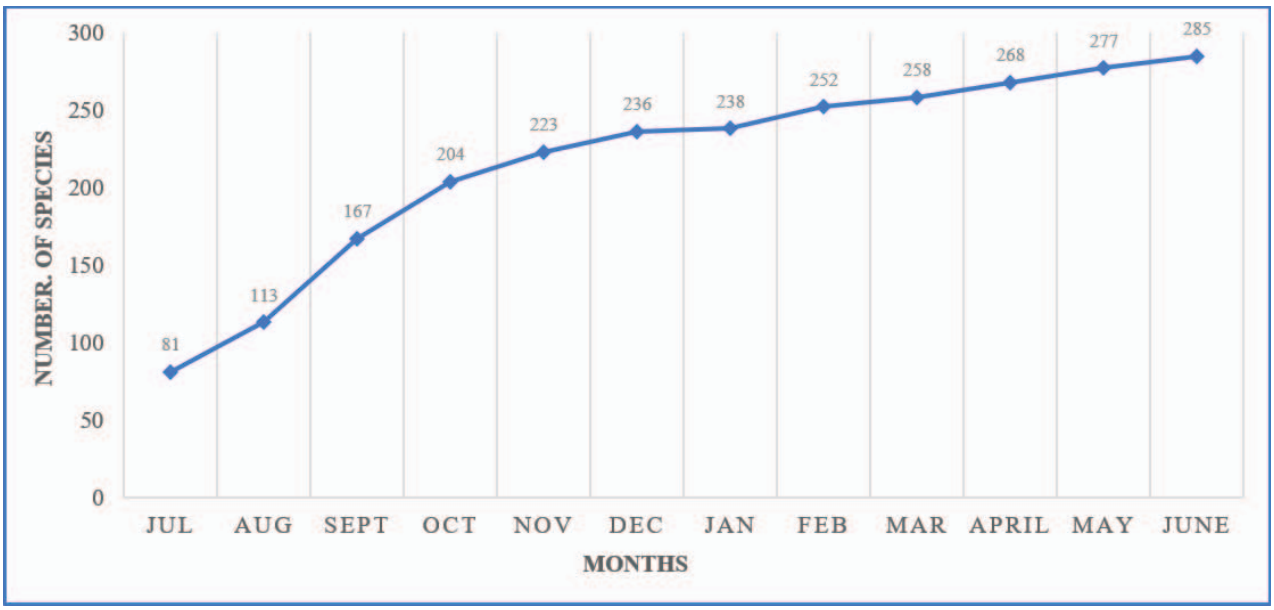


Fig. 20: Species accumulation curve for insects sampled from July 2021 to June 2022 in SGNP during the BNHS-GMLR survey

The insect species accumulation curve as shown above, indicates a gradual increase in the number of species with increasing sampling efforts. It also indicates that many insect species may yet be undetected as the graph is yet to plateau. Therefore, further sampling is needed to document the insect diversity in the study-site.

Arthropods are the largest group within the animal kingdom and occupy a wide variety of niches and are also taxonomically complex. Therefore, the trends indicated (Fig. 20) are expected considering the time and other sampling constraints of the present study. In other words, that much of the insect diversity remains unreported.

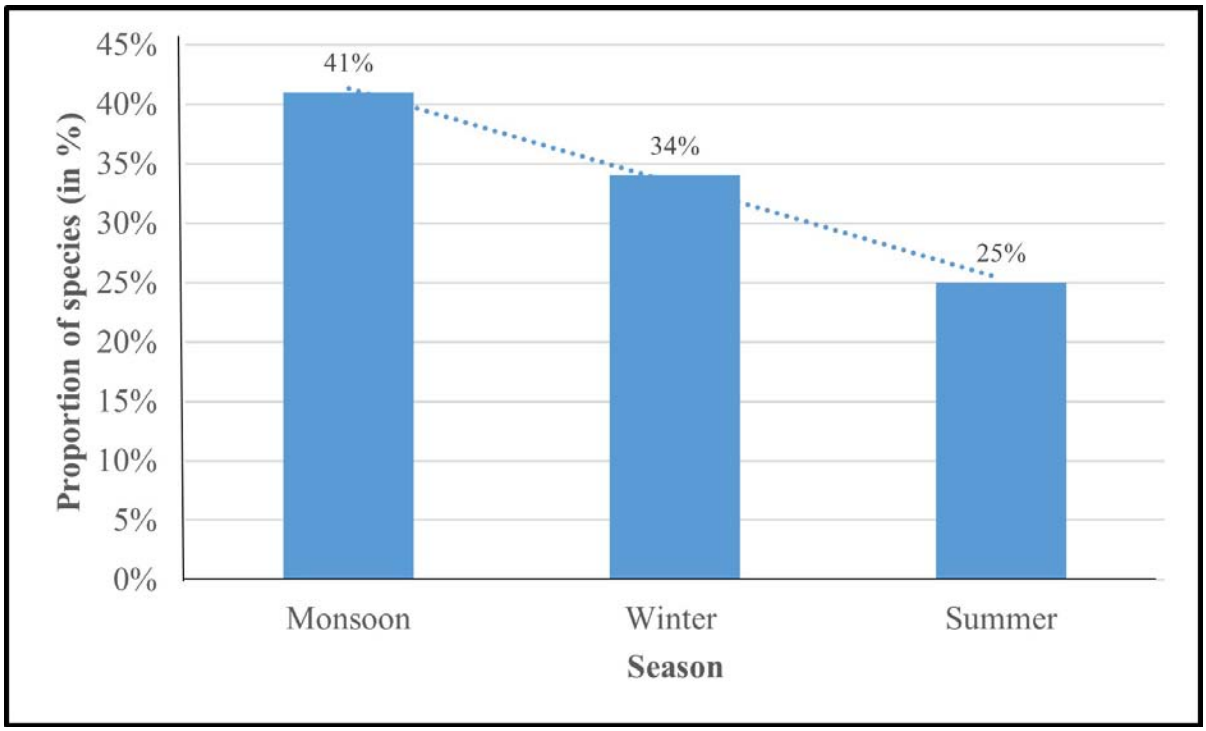


Fig. 21: Proportion of insect records (%) in different seasons in study-sites during the BNHS-GMLR survey

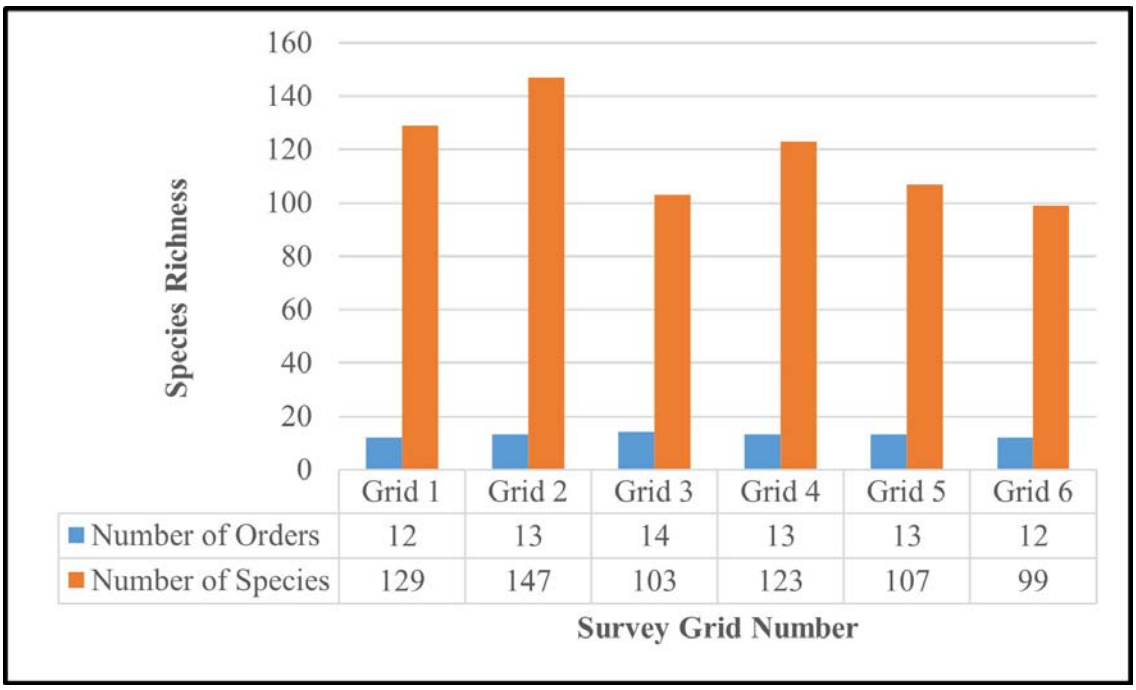


Fig. 22: Variation of species richness of insects across the study-grids (I to VI) located within the SGNP recorded during the BNHS-GMLR survey

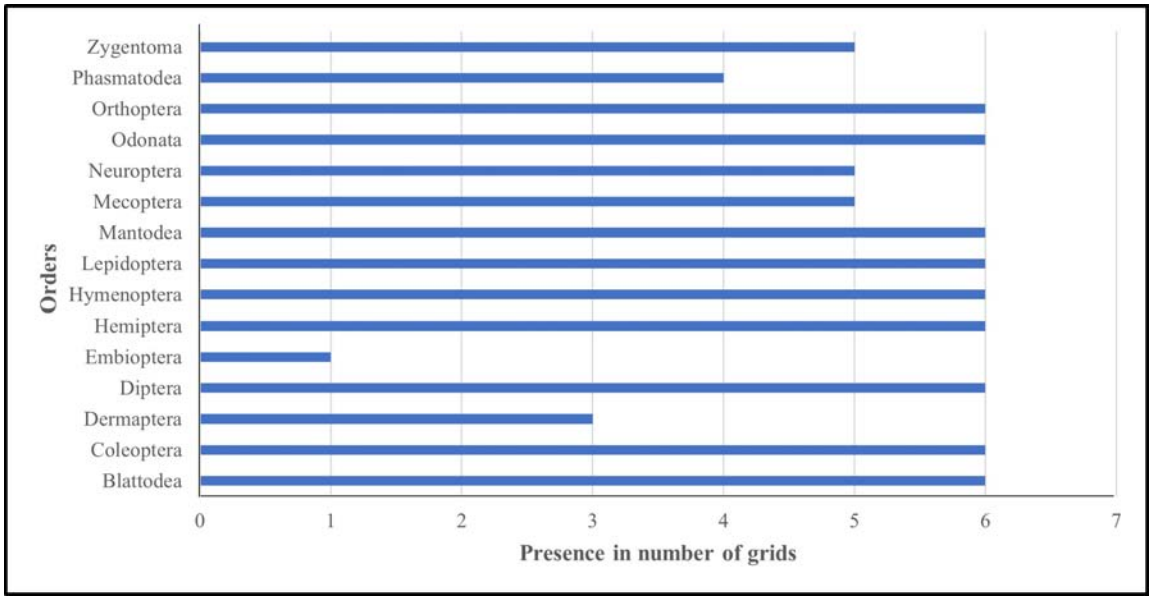


Fig. 23: Representation of different Insect Orders with respect to study-grids (I to VI) located within the SGNP recorded during the BNHS-GMLR survey

Summary

Overall, 285 species of insects belonging to 106 families and 15 orders were recorded in the study area during the year-long survey (Table 12). Highest number of families were observed under the order Lepidoptera (n=21) followed by order Coleoptera (n=18). Both the orders Diptera and Hemiptera were represented by 16 families. Most number of species were recoded from the order Lepidoptera (n=119) followed by the orders Odonata (n=38) and Coleoptera (n=36). IUCN status of most of the species (n=132) could not be obtained due to identification only till genus or family level. Similarly, the IUCN status of a large number of species (n=107) was found to be not assessed. Forty-four species were recorded as Least Concern and only two odonate species, *Macrogomphus annulatus* and *Elattoneura nigerrima* were Data Deficient. Two butterfly species each under Schedule I and Schedule II are protected according to the Wild Life (Protection) Act, 1971. Gaudy Baron butterfly (*Euthalia lubentina*) is included under Schedule IV as per this act (Table 12).

Some species were recorded as an opportunistic observation e.g. Common Albatross (*Appias albina*) was only seen at mud-puddling sites. A single individual of Bengal Spotted Flat (*Celaenorrhinus putra*) was observed in monsoon season. Large congregations of Tiger (*Tirumala limniace, Danaus* spp.) and Crow (*Euploea* spp.) butterflies were observed in winter season October onwards till March in summer which is their migratory season. The butterflies occupied the cooler and shady areas in valleys and dry stream beds.

Insect species occurrence varied greatly across the grids and seasons throughout the year but following species were encountered commonly throughout the area and time - Flesh Fly, Hover Fly (Order: Diptera); Assassin Bug (Order: Hemiptera); Carpenter Bee (Order: Hymenoptera); Common Crow, Chocolate Pansy, Baronet, Common Emigrant, Yellow Orange Tip and Psyche (Order: Lepidoptera); Blue Ground Skimmer (Order: Odonata). Species that were captured rarely were Silverstreak Blue, Centaur Oakblue (Order: Lepidoptera); Pied Reedtail and *Macrogomphus annulatus* (Order: Odonata) (Table 13).

Earwigs (Order: Dermaptera) and webspinners (Order: Embioptera) were only represented in three out of six grids and one grid respectively. Earwigs are nocturnal and can be found hiding during the day in the rock crevices or small cavities by day. Most of the webspinners, especially females remain inside or around the galleries of silk woven by them while the males are known to be short-lived. A single individual of the webspinner was found in Grid IV in the monsoon season. As the sampling was done only during the daytime, it is possible that earwig species as well as well-concealed webspinners have been missed out and therefore the reason why they were not recorded in other grids. On the other hand, the higher species richness recorded in case of Orders Lepidoptera and Odonata was because these are comparatively well-studied and taxonomically resolved groups unlike other orders which are difficult to identify to species level visually in field or based on the photographs. In case of the order Coleoptera, which is considered the most speciose order among insects, we were able to record species in higher numbers than Diptera and Hymenoptera, as is the trend seen usually. Insects are one of the most diverse taxa and more sampling efforts would certainly yield more species in the study sites within SGNP as indicated by the increasing graph of accumulation curve (Table 13, Figure 20).

Life cycles of most insects are significantly influenced by the prevailing biotic and abiotic conditions in a given area. Their presence or occupancy of insects in a particular area is seasonal and also determined by availability of specific habitat conditions. For insects to grow and multiply, suitable vegetation and aquatic habitats are required at various phases of their development. In general, monsoon is known as the best season when the climatic conditions, vegetation, water and other resources are optimum (Kunte 1997, Arun 2000). These favourable conditions prevail in the post-monsoon and early winter as well.

In the study area, the majority of species recorded can be considered as generalists yet an interesting seasonal pattern could be observed at the Order level (Figure 21, Table 13). Maximum number of insect species were recorded in the monsoon season. Least number of species were seen in the summer season owing to the dry and hot climatic conditions which affected both the species richness as well as the activity period (Figure 21).

Among beetles (Order Coleoptera), species belonging to the families such as Attelabidae (Leaf-rolling beetles and weevils), Carabidae (Tiger beetles), Scarabaeidae (Dung Beetles), Chrysomelidae (Leaf-mining beetles), Cerambycidae (Long-horned beetles), Meloidae (Blister beetles) were mainly seen in the monsoon. Congregations of fireflies (family Lampyridae) were also seen in the dark hours in the early monsoon. Larval or nymph stages of Hemiptera (true bugs, cicadas, planthoppers and leafhoppers), Lepidoptera (moths and butterflies), and Orthoptera (crickets, grasshoppers and katydids) were abundant and commonly observed throughout the area indicating their breeding season. In early winter (October), detection of insects was very high due to the favourable weather conditions - sporadic rainfall and plenty of sunlight that enhanced insect activity. Many butterflies and odonates were recorded in their adult stage in September and October months.

Stick insects (Order: Phasmatodea) were predominantly recorded in the summer and winter season. The overall detection and species richness declined towards the late winter (December and January) due to cold weather. Among the Oder Hemiptera, cicadas (*Platypleura* spp.) displayed the seasonality unlike their sister groups- true bugs and hoppers. While nymphs of cicadas were observed underground in monsoon, the adults emerged only in late summer. In late March and April many empty nymph cases were seen on tree barks, stones etc. The loud calls of adults were heard throughout the study area. In the month of May, many dead adult individuals of these short-lived insects were seen and population of other species such as the Monsoon cicada (*Lemuriana apicalis*) started increasing.

The pre-monsoon showers in the month of June triggered the swarming of social insects. Winged individuals of ants and termites were observed in the sampling area. Thus, while species records showed a steady increase with sampling effort, individual species detection showed a wide and interesting variation with seasonal changes.

Most of the insect orders (9 out of 15) were present in all the six grids indicating the presence of generalist insects in these orders (Figure 22 & 23) These insects can be detected easily as they can be observed actively flying or foraging in the daytime. Highest number of species were recorded in Grid II followed by Grid 1 and Grid IV. Grid III and Grid V grids had almost equal number of species followed by the least speciose Grid VI.

Grid I and Gird II are part of a hillock which has the highest altitude within the study area and is a mosaic of different small habitats - hillock with slopes covered by Karwi *Strobilanthes* sp.; open plateau on the top; streams flowing through the valleys with riparian vegetation with dense canopy

at some places. Different microhabitats created within these grids support a variety of aquatic and terrestrial insect fauna. Insect diversity of Grid I, shows a mixture of species that are found in forests as well as those that proliferate due to anthropogenic activities like agriculture. This can be considered as the edge effect at the human habitation-forest interface.

In contrast such an edge effect as witnessed in the case of Grid I, is not seen in the case of Grid VI which is also subject to anthropogenic disturbance. The flat terrain and easy access permits more human activity. The patches of monoculture plantations of exotic and invasive plants like *Gliricidia sepium* support a smaller number of insect species as compared to the indigenous and diverse vegetation in other grids. Grid VI therefore harbours the least number of species among all the sampled grids because the habitat is more open and relatively more degraded. However, some insects such as *Macrogomphus annualtus* (Odonata: Gomphidae) and *Pareronia hippia* form Philomela (Lepidoptera: Pieridae) were recorded only in this grid.

Flat terrain of Grid IV interspersed with the riverine patches along the stream flowing towards Vihar Lake makes a good habitat for many insects including many butterflies and odonates congregating at the cooler, damp and shady parts in post-monsoon and summer seasons (Table 13).

In conclusion, the insect diversity survey indicated that the monsoon and winter seasons supported maximum number of insect species. Additionally, some of the uncommon species were recorded as opportunistic observations at mud-puddling sites and near water bodies. In this study 91 butterfly species have been recorded whereas Kasambe (2012) found 172 species. This variation is because the latter study covered the entire Sanjay Gandhi National Park including areas near Vasai creek which has a high insect diversity. It would be interesting to undertake a long-term study on the seasonal trends and life-cycles of different insect species in the future. For example, as compared to previous records, we have recorded a greater number of odonates in the study area (n=38) compared to Kulkarni et al. (2006) (n=27). Odonates are habitat specifics and focused sampling on aquatic habitats could reveal presence of more species.

Amphibians and Reptiles

Methods

The surveys for reptiles and amphibians were conducted only during the daytime between 0800 to 1300 hours. Quadrats were laid in each of the six selected grids for sampling forest-floor reptiles and amphibians. The sampling design described by Campbell and Christman (1982) was modified as relevant for this study– four quadrats of 20 X 20 m were marked, two of which was selected on the proposed tunnel alignment while the other two were on either side of the alignment at varying distances and elevation. The corners of each quadrat were marked with coloured ribbons and GPS locations was also recorded for sampling repeatability. Date and time of sampling, temperature and humidity were recorded for each sampling session/day. Direct sightings of reptiles and amphibians were noted down. Overturned leaf litter, fallen branches and stones, rock crevices, tree holes, fissures and buttresses were examined for presence of herpetofauna. Covariates that are known to influence the occurrence of the amphibians and reptiles such as canopy cover, leaf litter thickness (measured with steel scale) and ground cover (presence/absence of rock, soil, wooden log and leaf litter) were documented. The recorded variables were used to interpret distribution of amphibians and reptiles and were not specifically applied in statistical models considering the sparse data. Additionally, reptiles and amphibians encountered outside survey sites, either opportunistically or during the course of ad hoc surveys around water bodies such as seasonal and perennial streams, stagnant water pools, were also noted down. Even though it was not possible to conduct systematic surveys during the evening hours, nocturnal species that were located in and around the field station at these hours were added to the overall checklist.

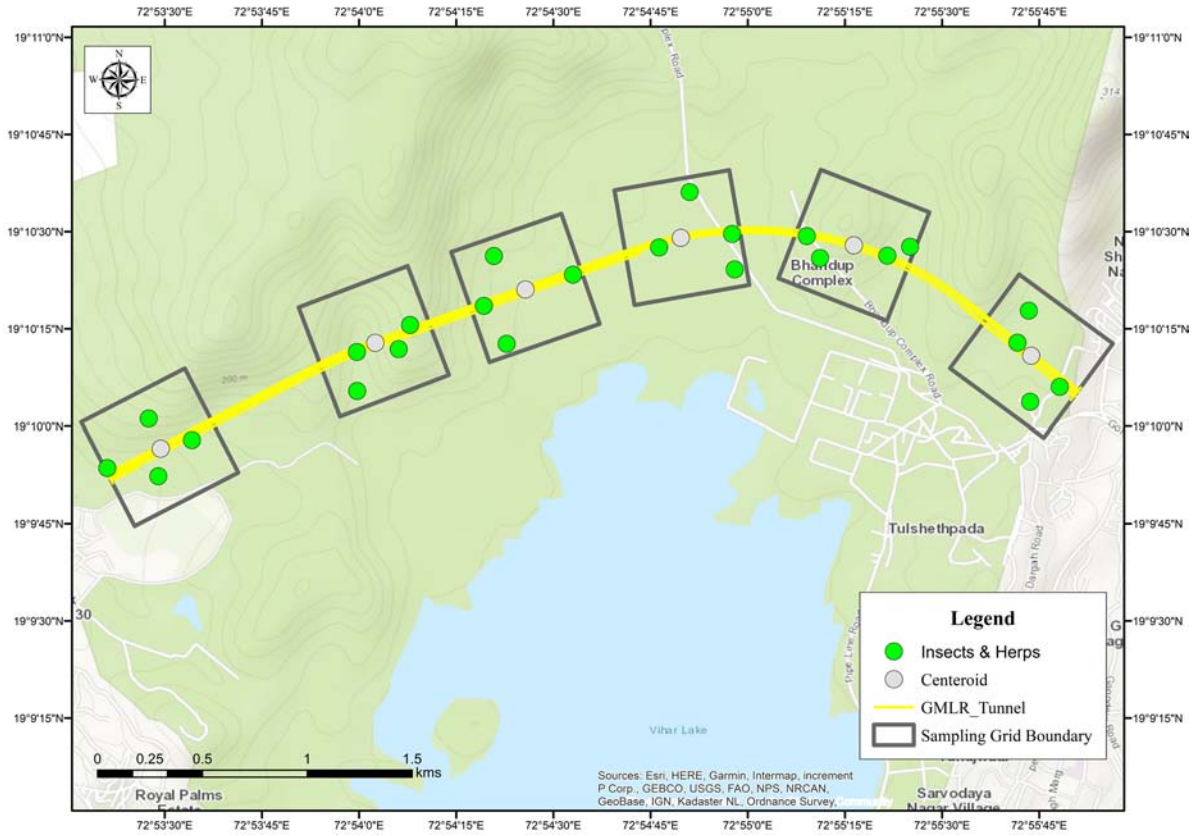
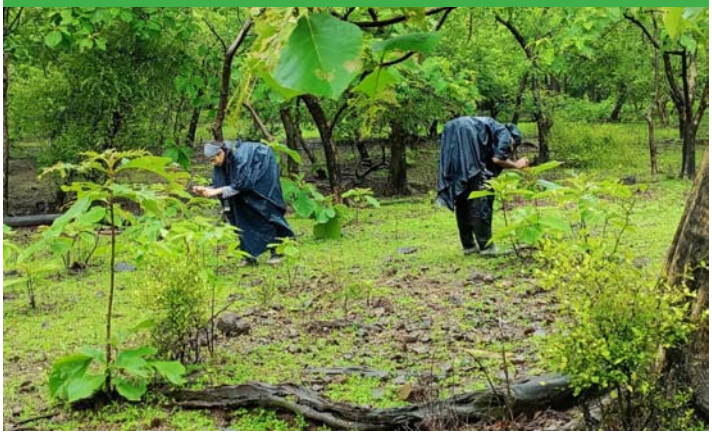


Fig. 24: Map showing the tunnel alignment of a section of the GMLR that will be passing through the Sanjay Gandhi National Park (SGNP). The sampling grids and quadrats are shown in different colours for the months surveyed

Plate 10: Field work and data collection by team herpetofauna

Intensive Search

Photographing herpetofauna



Plot marking

Results

Amphibians

Table 13: A checklist of Amphibians recorded in the study area with distribution across the grids, along with their IUCN status and Wildlife Protection Act Schedules (Blue cells indicate species presence, blank indicate absence; LC = Least Concern, VU = Vulnerable, NA = Not Assessed).

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Schedule
1	Anura	Bufonidae	*Duttaphrynus melanostictus*	Common Indian Toad							LC	IV
2	Anura	Microhylidae	*Microhyla* cf. *ornata*	Ornate Narrow-mouthed Frog							LC	IV
3	Anura	Ranidae	*Hydrophylax bahuvistara*	Wide-spread Fungoid Frog							NA	IV
4	Anura	Dicroglossidae	*Minervarya* sp.	Cricket Frog							NA	IV
5	Anura	Dicroglossidae	*Indirana leithii*	Leith's Leaping Frog							VU	IV
6	Anura	Dicroglossidae	*Hoplobatrachus tigerinus*	Indian Bull Frog							LC	IV
7	Anura	Dicroglossidae	*Sphaerotheca maskeyi*	Maskey's Burrowing Frog							NA	IV
8	Anura	Dicroglossidae	*Euphlyctis cyanophlyctis*	Common Skittering Frog							LC	IV
9	Anura	Rhachophoridae	*Polypedates maculatus*	Common Indian Tree Frog							LC	IV

Table 14:Monthwise checklist of amphibians recorded from July 2021 to June 2022 during the BNHS-GMLR survey (shaded cells indicates species presence)

Sr. No.	Species	Common Name	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	*Duttaphrynus melanostictus*	Common Indian Toad												
2	*Microhyla* cf. *ornata*	Ornate Narrow-mouthed Frog												
3	*Minervarya* sp.	Cricket Frog												
4	*Indirana leithii*	Leith's Leaping Frog												
5	*Hydrophylax bahuvistara*	Wide-spread Fungoid Frog												
6	*Hoplobatrachus tigerinus*	Indian Bull Frog												
7	*Polypedates maculatus*	Common Indian Tree Frog												
8	*Sphaerotheca maskeyi*	Burrowing Frog												
9	*Euphlyctis cyanophlyctis*	Common Skittering Frog												

Table 15: Seasonal occurrence of amphibians in the study area (Blue cell indicate species presence)

Sr. No.	Species	Common Name	Monsoon	Winter	Summer
1	*Duttaphrynusm elanostictus*	Common Indian Toad			
2	*Microhyla* cf. *ornata*	Ornate Narrow-mouthed Frog			
3	*Minervarya* sp.	Cricket Frog			
4	*Indirana leithii*	Leith's Leaping Frog			
5	*Hydrophylax bahuvistara*	Wide-spread Fungoid Frog			
6	*Hoplobatrachus tigerinus*	Indian Bull Frog			
7	*Polypedates maculatus*	Common Indian Tree Frog			
8	*Sphaerotheca maskeyi*	Maskey's Burrowing Frog			
9	*Euphlyctis cyanophlyctis*	Common Skittering Frog			

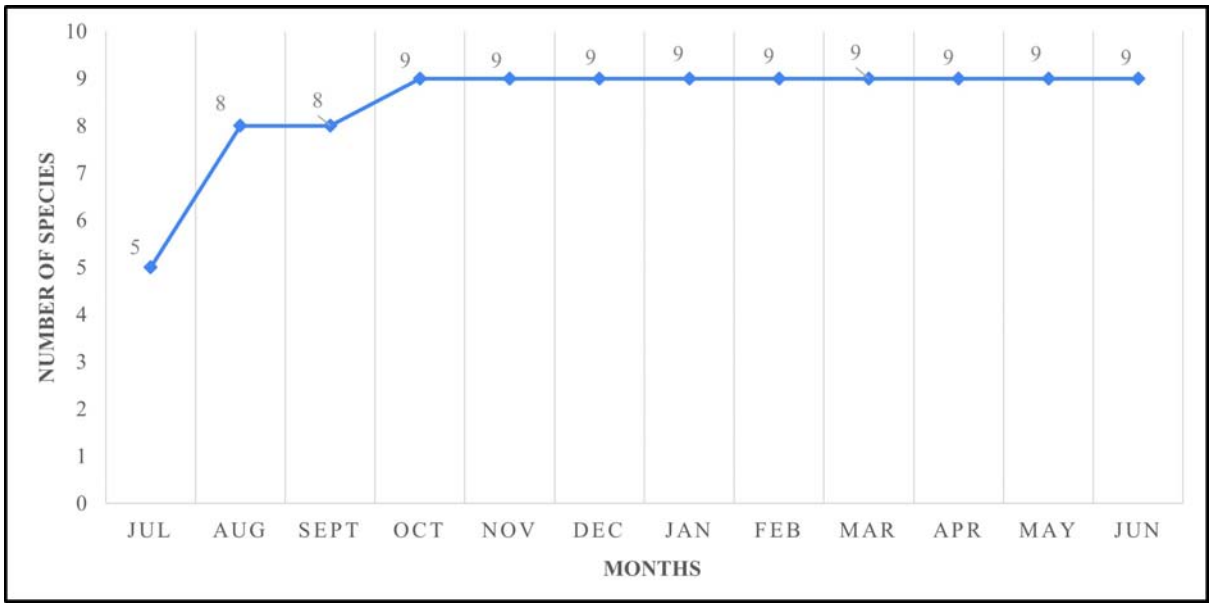


Fig. 25: Species accumulation curve for amphibians surveyed from July 2021 to June 2022 on SGNP during the BNHS-GMLR survey

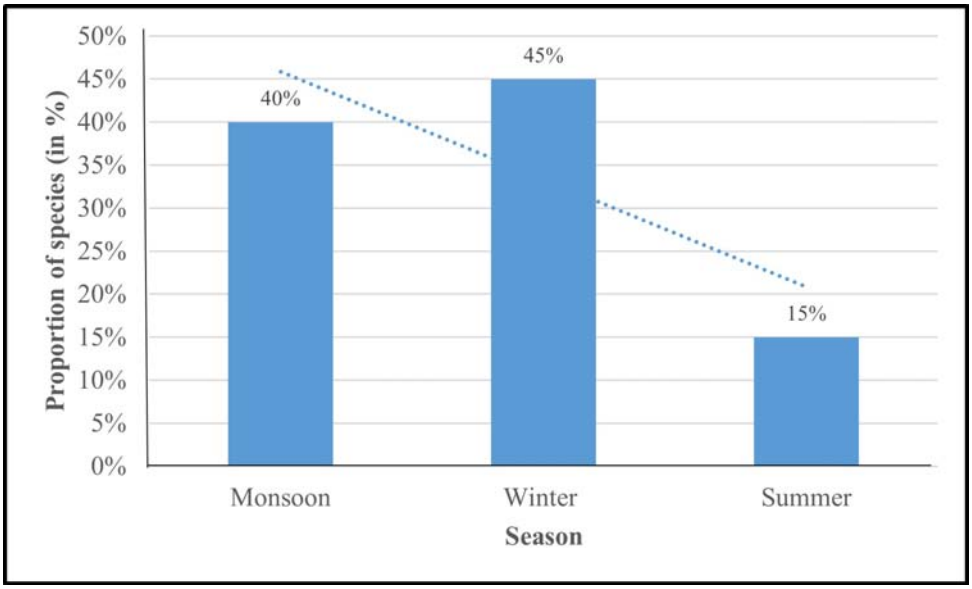


Fig. 26: Proportion of amphibians across seasons BNHS-GMLR survey

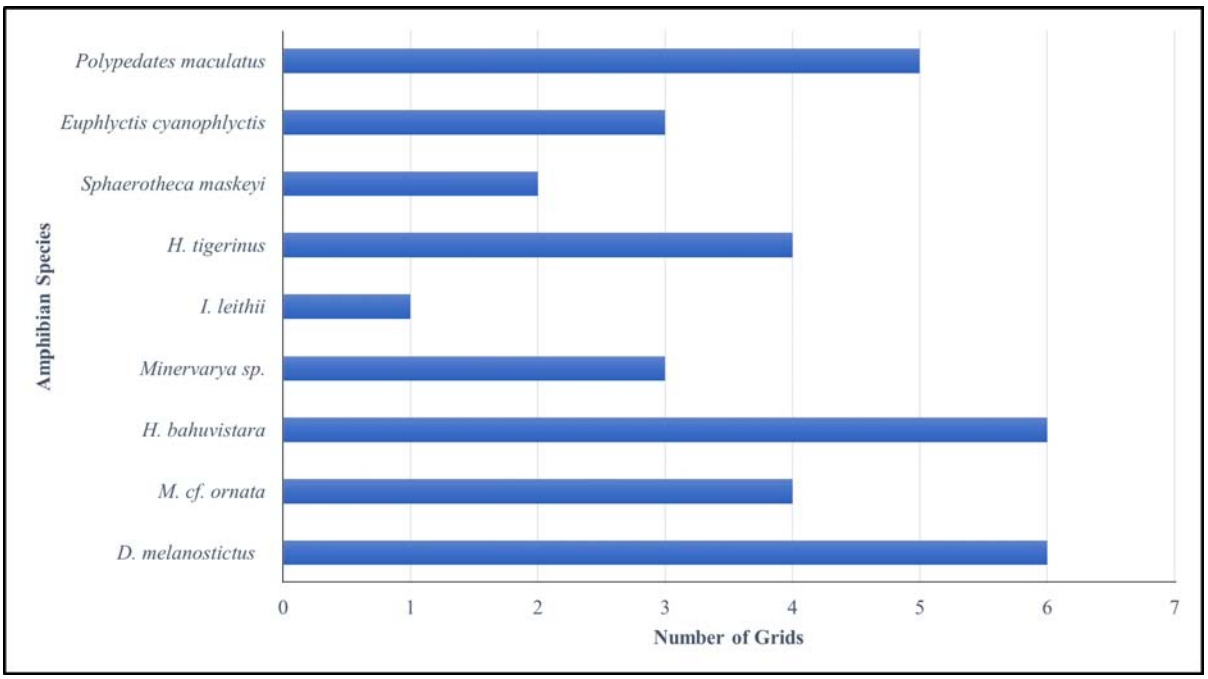


Fig. 27: Amphibian species presence in relation to sampling grids

Table 16: A checklist of Reptiles recorded in the study area with distribution across the grids, along with their IUCN status and Wildlife Protection Act Schedules (Blue cells indicate species presence, blank cell indicates absence).

Sr. No.	Order	Family	Species	Common Name	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	IUCN Status	WPA Status
1	Squamata	Agamidae	*Calotes vultosus*	Common Garden Lizard	■	■		■		■	NA	IV
2	Squamata	Agamidae	*Monilesaurus rouxii*	Roux's Forest Lizard	■	■	■	■	■		LC	IV
3	Squamata	Gekkonidae	*Hemidactylus* cf. *murrayi*	Murray's Leaf-toed Gecko	■	■	■	■	■	■	LC	IV
4	Squamata	Gekkonidae	*Hemidactylus leschnaultii*	Bark Gecko		■	■		■		LC	IV
5	Squamata	Gekkonidae	*Hemidactylus maculatus*	Spotted Rock Gecko	■						LC	IV
6	Squamata	Gekkonidae	*Hemidactylus frenatus*	Southern House Gecko	■	■	■	■	■		LC	IV
7	Squamata	Gekkonidae	*Cyrtodactylus deccanensis*	Deccan Banded Gecko	■						LC	IV
8	Squamata	Scincidae	*Eutropis allapallensis*	Allapalli Grass Skink	■	■	■	■	■	■	LC	IV
9	Squamata	Scincidae	*Eutropis carinata*	Common Keeled Skink	■					■		IV
10	Squamata	Scincidae	*Eutropis macularia*	Bronze Grass Skink	■						LC	IV
11	Squamata	Scincidae	*Riopa lineata*	Lined Supple Skink					■		LC	IV
12	Squamata	Lacertidae	*Ophisops* cf. *beddomei*	Beddome's Snake-eye		■		■	■		NA	IV
13	Squamata	Varanidae	*Varanus bengalensis*	Bengal Monitor	■		■				NT	I
14	Squamata	Chamaeleonidae	*Chamaeleo zeylanicus*	Indian Chamaeleon	■						LC	II
15	Squamata	Colubridae	*Ahaetulla oxyrhyncha*	Indian Vine Snake	■						LC	IV
16	Squamata	Colubridae	*Amphiesma stolatum*	Buff-striped Keelback	■						LC	IV
17	Squamata	Colubridae	*Oligodon arnensis*	Banded Kukri	■						LC	IV
18	Squamata	Colubridae	*Oligodon taeniolatus*	Variegated Kukri	■						LC	IV
19	Squamata	Colubridae	*Ptyas mucosa*	Indian Rat Snake	■	■	■	■	■		LC	II
20	Squamata	Colubridae	*Grypotyphlops* cf. *acutus*	Beaked Worm Snake						■	LC	IV
21	Squamata	Viperidae	*Echis cariantus*	Saw-scaled Viper	■	■	■			■	LC	IV
22	Squamata	Viperidae	*Craspedocephalus gramineus*	Bamboo Pit Viper	■						LC	IV
23	Squamata	Boidae	*Eryx conicus*	Common Sand Boa	■						LC	IV
24	Squamata	Elapidae	*Naja naja*	Spectacled Cobra	■	■					LC	II

LC = Least Concern, NT = Near Threatened, NA = Not Assessed)

Table 17: Monthwise checklist of reptiles recorded from July 2021 to June 2022 during the BNHS-GMLR survey (shaded cells indicates species presence)

Sr. No.	Species	Common Name	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	*Calotes vultosus*	Common Garden Lizard	■			■	■	■	■	■	■	■	■	■
2	*Monilesaurus rouxii*	Roux's Forest Lizard	■	■	■	■	■	■	■	■	■	■	■	■
3	*Hemidactylus* cf. *murrayi*	Murray's Leaf-toed Gecko	■	■	■		■	■	■	■	■	■	■	■
4	*Hemidactylus leschnaultii*	Bark Gecko	■	■			■	■	■	■		■		■
5	*Hemidactylus maculatus*	Spotted Rock Gecko	■							■		■		■
6	*Hemidactylus frenatus*	Southern House Gecko	■	■	■			■	■	■				■
7	*Cyrtodactylus deccanensis*	Deccan Banded Gecko						■		■			■	■
8	*Eutropis allapallensis*	Allapalli Grass Skink	■	■	■	■	■	■	■	■	■	■	■	■
9	*Eutropis carinata*	Common Keeled Skink	■						■	■				■
10	*Eutropis macularia*	Bronze Grass Skink								■				
11	*Riopa lineata*	Lined Supple Skink								■				
12	*Ophisops* cf. *beddomei*	Beddome's Snake-eye	■		■			■		■		■	■	■
13	*Varanus bengalensis*	Bengal Monitor				■					■			
14	*Chamaeleo zeylanicus*	Indian Chamaeleon					■			■				
15	*Ahaetulla oxyrhyncha*	Indian Vine Snake			■									
16	*Amphiesma stolatum*	Buff-striped Keelback						■						
17	*Oligodon arnensis*	Banded Kukri									■			
18	*Oligodon taeniolatus*	Varigated Kukri								■				
19	*Ptyas mucosa*	Indian Rat Snake	■		■		■	■			■	■		■
20	*Grypotyphlops* cf. *acutus*	Beaked Worm Snake								■				
21	*Echis cariantus*	Saw-scaled Viper	■							■	■	■		■
22	*Craspedocephalus gramineus*	Bamboo Pit Viper	■				■			■		■		■
23	*Eryx conicus*	Common Sand Boa				■								
24	*Naja naja*	Spectacled Cobra	■									■		

Table 18: Seasonal occurrence of reptiles in the study area (Blue cell indicate species presence)

Sr. No.	Species	Common Name	Monsoon	Winter	Summer
1	*Calotes vultosus*	Common Garden Lizard			
2	*Monilesaurus rouxii*	Roux's Forest Lizard			
3	*Hemidactylus* cf. *murrayi*	Murray's Leaf-toed Gecko			
4	*Hemidactylus leschnaultii*	Bark Gecko			
5	*Hemidactylus maculatus*	Spotted Rock Gecko			
6	*Hemidactylus frenatus*	Southern House Gecko			
7	*Cyrtodactylus deccanensis*	Deccan Banded Gecko			
8	*Eutropis allapallensis*	Allapalli Grass Skink			
9	*Eutropis carinata*	Common Keeled Skink			
10	*Eutropis macularia*	Bronze Grass Skink			
11	*Riopa lineata*	Lined Supple Skink			
12	*Ophisops* cf. *beddomei*	Beddome's Snake-eye			
13	*Varanus bengalensis*	Bengal Monitor			
14	*Chamaeleo zeylanicus*	Indian Chamaeleon			
15	*Ahaetulla oxyrhyncha*	Indian Vine Snake			
16	*Amphiesma stolatum*	Buff-striped Keelback			
17	*Oligodon arnensis*	Banded Kukri			
18	*Oligodon taeniolatus*	Varigated Kukri			
19	*Ptyas mucosa*	Indian Rat Snake			
20	*Grypotyphlops* cf. *acutus*	Beaked Worm Snake			
21	*Echis cariantus*	Saw-scaled Viper			
22	*Craspedocephalus gramineus*	Bamboo Pit Viper			
23	*Eryx conicus*	Common Sand Boa			
24	*Naja naja*	Spectacled Cobra			

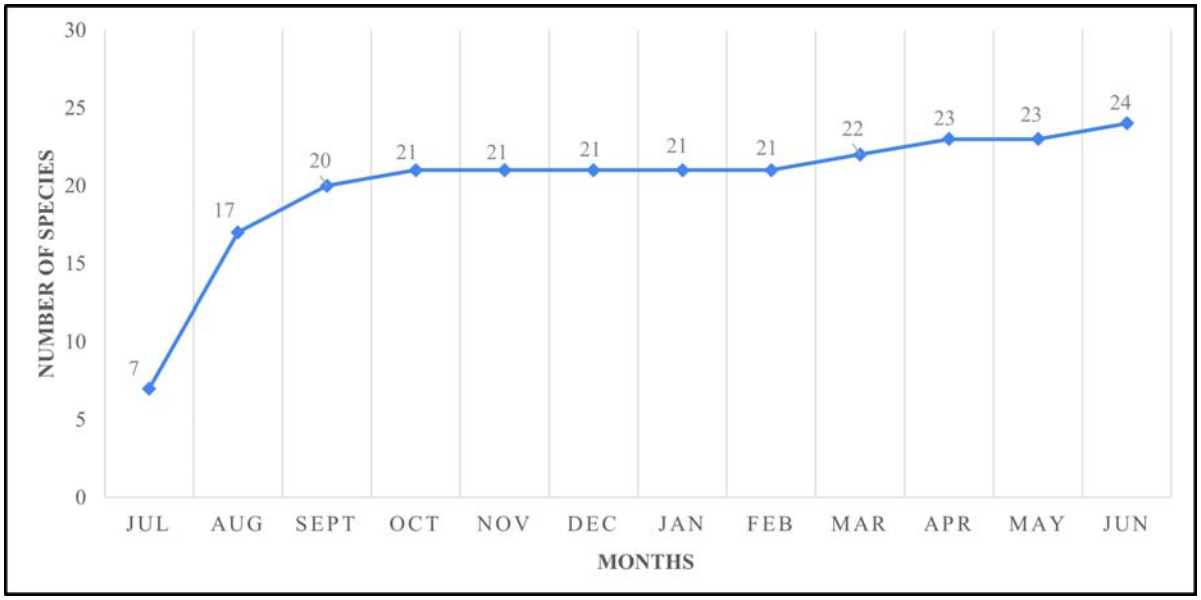


Fig.28: Species accumulation curve for reptiles surveyed from July 2021 to June 2022 on SGNP during the BNHS-GMLR survey

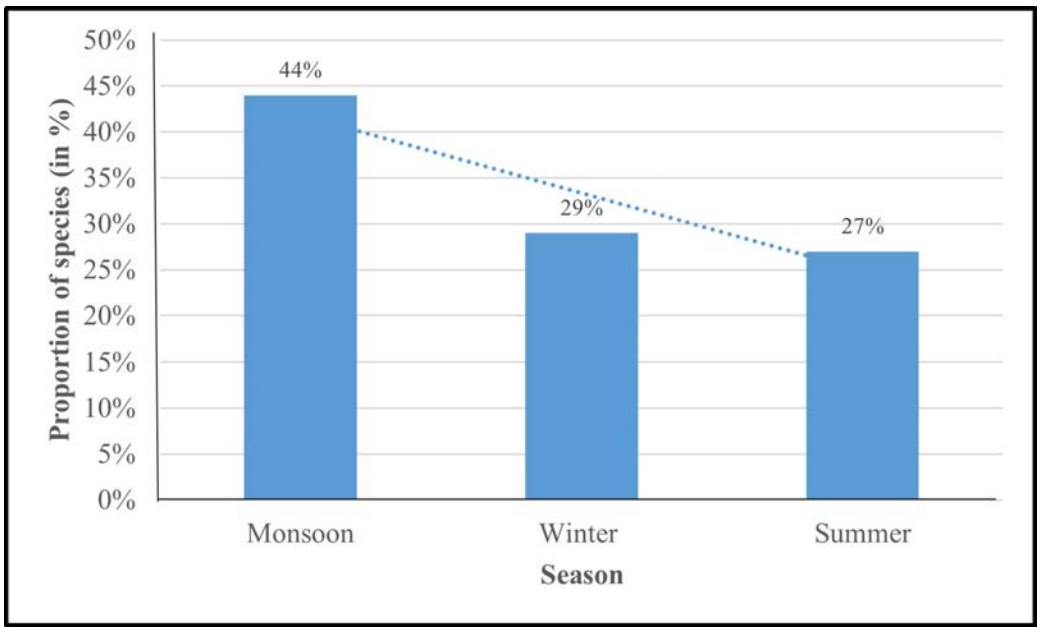


Fig.29: Proportion of reptiles across seasons

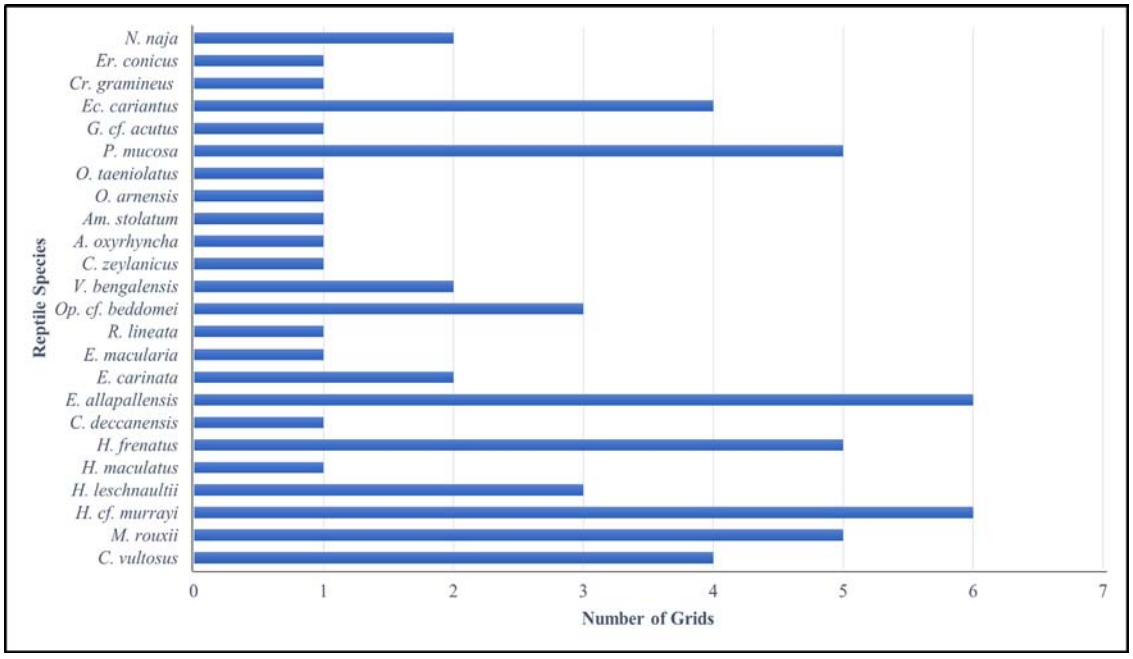


Fig. 30: Reptile species presence in relation to sampling grids 1-6 from July 2021 - June 2020 during the BNHS-GMLR survey

Summary

After completion of a year-long survey (July 2021- June 2022), a total nine species of amphibians belonging to five families and 24 species of reptiles belonging to 10 families are reported to be present in the study-site.

Of all the nine recorded amphibians, only the Leith's Leaping Frog (*Indirana leithii*) has been assessed as Vulnerable according to the IUCN. This ground dwelling frog is endemic to forests of the northern Western Ghats and during the survey, was observed only in a single site - near the edge of a plateau on the higher elevations of Grid II. The other amphibians recorded in the study have a much wider distribution and are assessed as Least Concern (Table 14). The amphibian Family Dicroglossidae had the highest species richness with five species while the other four families were each represented by a single species (Table 14).

Amphibian species richness was found to be highest in the winter period when all nine species were recorded (Table 15 &16, Figure 26). The monsoon season was represented by eight species whereas only three species of amphibians were recorded in summer (Table 16). Cricket frog (*Minervarya* sp.) was observed restricted to shallow water pools and along moist stream banks in summer while both Widespread Fungoid Frog (*Hydrophylax bahuvistara*) and Maskey's Burrowing Frog (*Sphaerotheca maskeyi*) were observed in evening hours near the field station (Grid I) after mild pre-monsoon showers in the month of May.

In the case of amphibians, the highest species richness was observed in Grid II and Grid III with eight species each. Grid V had the lowest richness for amphibians with three species. Of the nine recorded amphibians, five were observed to be widely distributed occurring in four or more of the six grids (Figure 27, Table 14).

The Common Skittering Frog (*Euphlyctis cyanophlyctis*) are strictly aquatic and hence were only found in stagnant water pools and man-made water holes within the study-area. On the other hand, Maskey's Burrowing Frog (*Sphaerotheca maskeyi*), a ground dwelling frog which is most active during monsoon, was observed on the forest floor of Grid I and Grid III. The Common Indian Tree Frog (*Polypedates maculatus*) was the only arboreal frog species recorded. The Common Indian Toad (*Duttaphrynus melanostictus*) and Widespread Fungoid Frog (*Hydrophylax bahuvistara*) were the most widely distributed across the study area occurring in all the six grids. This was followed by the Common Indian Tree Frog (*Polypedates maculatus*) occurring in five grids. All the three species were found in both forested as well as disturbed habitats. Ornate Narrow-mouthed Frog *(Microhyla* cf. *ornata*), a small ground dwelling frog was observed among leaf litter and fallen logs inside forested habitats across four grids. Leith's Leaping Frog (*Indirana leithii*) was only recorded twice in the entire study period and in both the observations the frogs were found hidden under rocks on the forest floor in the post-monsoon season inside forest next to a plateau on the top of Grid II (Table 14).

Of all the recorded reptiles, only the Bengal Monitor (*Varanus bengalensis*) has been assessed as Near Threatened according to the IUCN and also protected under the Schedule I of the Wildlife Protection Act (Table 17). Even though the species is known to have a wide distribution, it is threatened primarily due to illegal hunting and trade. The species was observed in two of the six grids in the study period. The reptilian Family Colubridae had the highest species richness with six species followed by Gekkonidae and Scincidae, represented by 5 and 4 species respectively. Of the 24 recorded reptiles, 14 were lizards while the other 10 were snakes (Table 17).

In the case of reptiles, the species richness was found to be highest in the monsoon period with 21 species, followed by winter represented by 14 species and summer with 13 species (Table 18 &19, Figure 29). All the 14 recorded lizard species were observed in the monsoon (Table 19). Geckos of the genus *Hemidactylus* were found to be most speciose in the study area, represented by four species followed by skinks of the genus *Eutropis* with three representative species. Seven species of snakes were recorded in monsoon while both in winter and summer seasons four snake species were recorded. Seven species of lizards were observed across all seasons while among snakes only two species, the Indian Rat Snake (*Ptyas mucosa*) and Bamboo Pit Viper (*Craspedocephalus gramineus*) were recorded across all three seasons. Indian Vine Snake (*Ahaetulla oxyrhyncha*) and the Spectacled Cobra (*Naja naja*) were observed only in the summer (Table 17).

Grid 1 had highest species diversity with 20 species followed by Grid II with 10 species for reptiles (Table 17, Figure 30). The higher richness in Grid I is due to addition of nocturnal observations in this site (coincides with field station location). Grid VI had lowest diversity with six species. Nocturnal species like Spotted Rock Gecko (*Hemidactylus maculatus*), Deccan Banded Gecko (*Cyrtodactylus deccanensis*), Banded Kukri (*Oligodon arnensis*), Bamboo Pit Viper (*Craspedocephalus gramineus*) were only recorded from Grid 1, during night trails around the field station.

Among lizards, the Murray's Leaf-toed Gecko (*Hemidactylus* cf. *murrayi*) and Allapalli Grass Skink (*Eutropis allapallensis*) were found to be most widely distributed occurring in all the six study-grids while the Lined Supple Skink (*Riopa lineata*) and the Bronze Grass Skink (*Eutropis macularia*) were recorded only form a single site during the diurnal surveys. Roux's Forest Lizard (*Monilesaurus rouxii*), Southern House Gecko (*Hemidactylus frenatus*) were most abundant and was recorded throughout the entire study period. The Common Garden Lizard (*Calotes vultosus*) was both recorded from four of the six grids. Lined Supple Skink (*Riopa lineata*), a small, fossorial lizard, was recorded only once from the higher elevations of Grid V. Species that are known to occur in open habitats and near human habitations like the Common Keeled Skink (*Eutropis carinata*) and Bronze Grass Skink (*Eutropis macularia*) were recorded only from outside forested areas in Grid I and Grid VI (Figure 30)

Among snakes, the Indian Rat Snake (*Ptyas mucosa*) was the most widespread, occurring in five grids followed by the Saw-scaled Viper (*Echis carinatus*) occurring four of the six grids. Two species of vipers were recorded of which the Saw Scaled Viper (*Echis carinatus*) was recorded from four of the six grids while the Bamboo Pit Viper (*Craspedocephalus gramineus*) was only observed in Grid I. The genus *Oligodon* was the only genus of snakes represented by two species (Table 17, Figure 30).

Overall, monsoon and post monsoon season seemed to be the preferred period for both amphibians and reptiles with few reptiles also specifically being observed in the summer season (Figure 31). This was also found to be true for abundance, with many juveniles and sub adults being observed in this period. Generalist and widely distributed amphibians and reptiles were found to occur in both forested and disturbed habitats while some species like Leith's Leaping Frog and Lined Supple Skink were observed only a few times from specific habitats. Forest dwelling species like Allapalli Grass Skink, a forest floor lizard and Roux's Forest Lizard, an arboreal Agamid lizard were observed to be the most abundant species and spread across the forested patches. Generalist and widely distributed species like Common Skittering Frog (*Euphlyctis cyanophlyctis*), Common Garden Lizard (*Calotes vultosus*) and Common Keeled Skink (*Eutropis carinata*) were found to be common in Grid VI, a relatively disturbed habitat with human intervention while strictly forest dwelling

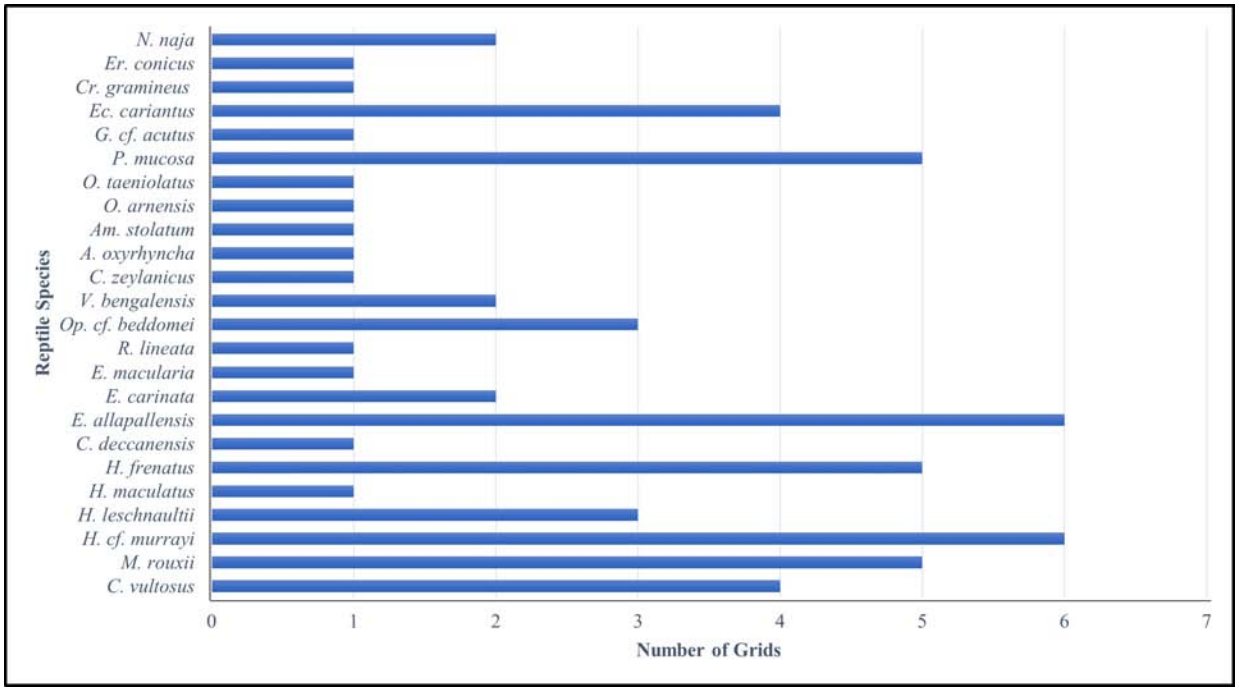


Fig. 31: Amphibian and Reptile species richness across the grids

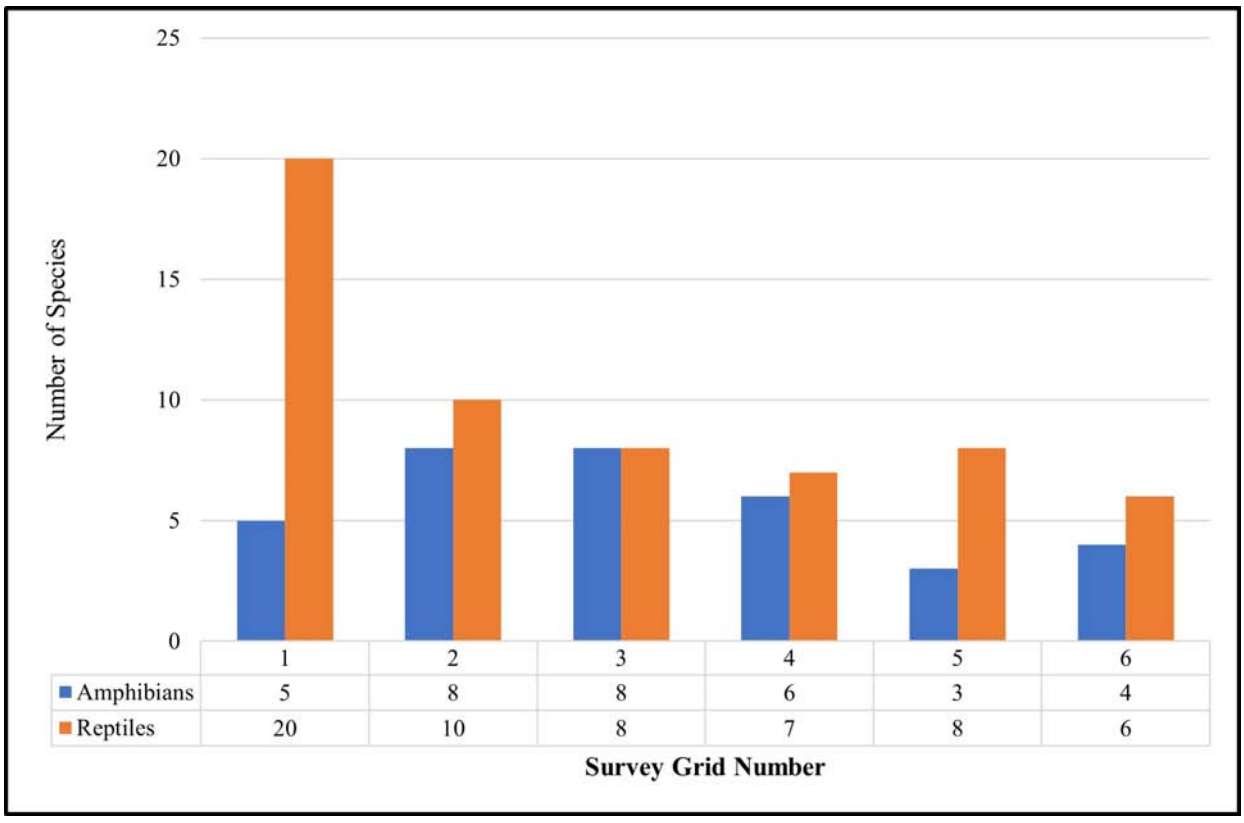


Fig. 32: Species richness of amphibians and reptiles across grids

species were rare in this grid. Therefore, all grids, from I to VI may support different assemblage of reptiles and amphibians and are important from a conservation point of view. However, given the relatively high richness for both amphibians and reptiles, presence of habitat specialist species like Leith's Leaping Frog (*Indirana leithii*), Beddomes's Snake-eye (*Ophisops* cf. *beddomei*) and availability of diverse microhabitats like high elevation plateau, primary forest and streams, it can be concluded that Grid II is an important hotspot for herpetofauna. (Figure 32).

Amphibian species records were observed to reach a plateau during the post-monsoon month of October with a total of nine species (Figure 25). The reptile diversity was also observed to reach a plateau during the same period but then the numbers started increasing again in summer (Figure 28) The increase in species numbers was primarily based on addition of snake species based on opportunistic observations. However, it is to be noted that the observed saturation of species accumulation curve for both amphibians and reptiles are an artefact of restricted field-sampling. A majority of herpetofauna diversity in the SGNP are unrecorded or undetected because i) only diurnal surveys were conducted and ii) the sampling was predominantly conducted on the tunnel alignment. Thus, the checklist is not representative of SGNP but may adequately represent the study area.

Avifauna

Methods

The line transect method (Buckland et al., 2001; Karanth, Thomas & Kumar, 2002) was used for assessment of bird diversity. In this method, the observer walks along a predetermined route at a fixed pace recording birds on the line as well as on either side of the line (Buckland *et al.*, 2001). Bird surveys were conducted during 07:30 and 09:30 hours involving 3 participants. Ensuring efficiency in visual detection, call recording and data transcription. The transects were placed perpendicular to the tunnel alignment across the 6 grids to sample across the existing habitat gradients. Birds were observed with binoculars (10x50, 8x42 or 8x40). Transect starting-point, end point and every 100m point was demarcated with coloured ribbons. The same transect line was surveyed during all the 12 months of sampling. The species detected, number of individuals, distance from the line (in case of calls), section of the transect (truncated every 100m), other opportunistic sightings and other natural history observations such as resident/migratory species, nest status (active or old), feeding behaviour in relation to seasonal fruiting/flowering etc. were noted. Bird species identification was confirmed with the help of field guides of Ali and Ripley (1987), Grimmet *et al.* (1998), Kazmierczak (2000) and Rasmussen & Anderton (2005). The data was further analyzed to prepare a comprehensive bird species checklist and further summarized to understand seasonal and other variations.

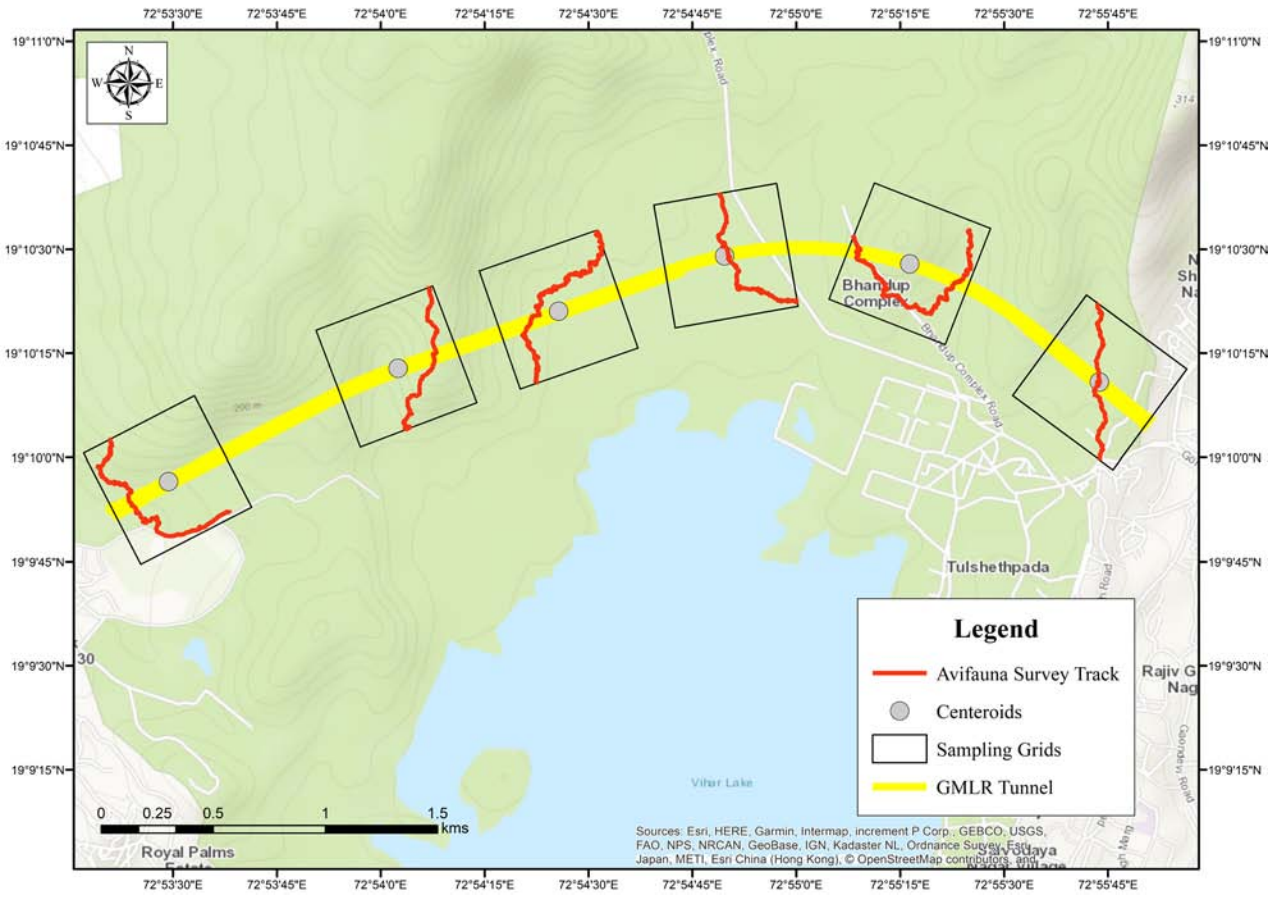


Figure 33: Map showing the tunnel alignment of a section of the GMLR that will be passing through the Sanjay Gandhi National Park (SGNP). The transects for avifauna survey are indicated

Plate 11: Field work and data collection by team Avifauna

Table 19: Checklist of birds species recorded during the BNHS-GMLR Survey with distribution across the grids, along with their IUCN status (Dark green cells indicate species presence, blank indicate absence)

Sr. No.	Common Name	Scientific Name	Diet preference	Migration	Grid Number						Status
					1	2	3	4	5	6	
1	Indian Peafowl	*Pavo cristatus*	Frugivorous	R							LC
2	Grey Junglefowl	*Gallus sonneratii*	Omnivorous	R							LC
3	Red Spurfowl	*Galloperdix spadicea*	Omnivorous	R							LC
4	Rock Dove	*Columba livia*	Granivorous	R							LC
5	Yellow-footed Green-pigeon	*Treron phoenicopterus*	Frugivorous	R							LC
6	Western Spotted Dove	*Spilopelia suratensis*	Granivorous	R							LC
7	Grey-capped Emerald Dove	*Chalcophaps indica*	Granivorous	R							LC
8	Asian Palm-swift	*Cypsiurus balasiensis*	Insectivorous	R							LC
9	Alpine Swift	*Tachymarptis melba*	Insectivorous	R							LC
10	Little Swift	*Apus affinis*	Insectivorous	R							LC
11	Greater Coucal	*Centropus sinensis*	Carnivorous	R							LC
12	Western Koel	*Eudynamys scolopaceus*	Frugivorous	R							LC
13	Square-tailed Drongo-cuckoo	*Surniculus lugubris*	Insectivorous	R							LC
14	Common Hawk-cuckoo	*Hierococcyx varius*	Insectivorous	R							LC
15	Indian Cuckoo	*Cuculus micropterus*	Insectivorous	M							LC
16	Jacobin Cuckoo	*Clamator jacobinus*	Insectivorous	M							LC
17	White-breasted Waterhen	Amaurornis phoenicurus	Omnivorous	R							LC
18	Asian Openbill	*Anastomus oscitans*	Carnivorous	R							LC
19	Red-naped Ibis	*Pseudibis papillosa*	Omnivorous	R							LC
20	Little Egret	*Egretta garzetta*	Insectivorous	R							LC
21	Western Reef-egret	*Egretta gularis*	Carnivorous	M							LC
22	Intermediate Egret	*Ardea intermedia*	Carnivorous	R							LC
23	Cattle Egret	*Bubulcus ibis*	Insectivorous	R							LC
24	Black-crowned Night-heron	*Nycticorax nycticorax*	Piscivorous	R							LC
25	Indian Pond-heron	*Ardeola grayii*	Carnivorous	R							LC
26	Little Cormorant	*Microcarbo niger*	Piscivorous	R							LC
27	Brown Boobook	*Ninox scutulata*	Carnivorous	R							LC
28	Spotted Owlet	*Athene brama*	Carnivorous	R							LC
29	Jungle Owlet	*Glaucidium radiatum*	Carnivorous	R							LC
30											

Sr. No.	Common Name	Scientific Name	Diet preference	Migration	Grid Number						Status
					1	2	3	4	5	6	
31	Greater Spotted Eagle	*Clanga clanga*	Carnivorous	M							VU
32	Booted Eagle	*Hieraaetus pennatus*	Carnivorous	M							LC
33	Brahminy Kite	*Haliastur indus*	Carnivorous	R							LC
34	Crested Serpent-eagle	*Spilornis cheela*	Carnivorous	R							LC
35	Changeable Hawk-eagle	*Nisaetus cirrhatus*	Carnivorous	R							LC
36	Bonelli's Eagle	*Aquila fasciata*	Carnivorous	R							LC
37	Shikra	*Accipiter badius*	Carnivorous	R							LC
38	Black Kite	*Milvus migrans*	Carnivorous	R							LC
39	Indian Grey Hornbill	*Ocyceros birostris*	Frugivorous	R							LC
40	Common Hoopoe	*Upupa epops*	Insectivorous	R							LC
41	Blue-tailed Bee-eater	*Merops philippinus*	Insectivorous	BM							LC
42	Asian Green Bee-eater	*Merops orientalis*	Insectivorous	R							LC
43	Oriental Dwarf-kingfisher	*Ceyx erithaca*	Carnivorous	BM							LC
44	White-breasted Kingfisher	*Halcyon smyrnensis*	Carnivorous	R							LC
45	Coppersmith Barbet	*Psilopogon haemacephalus*	Frugivorous	R							LC
46	Brown-headed Barbet	*Psilopogon zeylanicus*	Frugivorous	R							LC
47	Black-rumped Flameback	*Dinopium benghalense*	Insectivorous	R							LC
48	Rufous Woodpecker	*Micropternus brachyurus*	Insectivorous	R							LC
49	Amur Falcon	*Falco amurensis*	Insectivorous	M							LC
50	Peregrine Falcon	*Falco peregrinus*	Carnivorous	M							LC
51	Common Kestrel	*Falco tinnunculus*	Carnivorous	M							LC
52	Plum-headed Parakeet	*Psittacula cyanocephala*	Frugivorous	R							LC
53	Rose-ringed Parakeet	*Psittacula krameri*	Frugivorous	R							LC
54	Alexandrine Parakeet	*Psittacula eupatria*	Frugivorous	R							NT
55	Indian Pitta	*Pitta brachyura*	Insectivorous	BM							LC
56	Black-hooded Oriole	*Oriolus xanthornus*	Frugivorous	R							LC
57	Black-naped Oriole	*Oriolus chinensis*	Frugivorous	M							LC
58	Indian Golden Oriole	*Oriolus kundoo*	Frugivorous	R							LC

Sr. No.	Common Name	Scientific Name	Diet preference	Migration	Grid Number						Status
					1	2	3	4	5	6	
59	Common Woodshrike	*Tephrodornis pondicerianus*	Insectivorous	R							LC
60	Common Iora	*Aegithina tiphia*	Insectivorous	R							LC
61	White-spotted Fantail	*Rhipidura albogularis*	Insectivorous	R							LC
62	Ashy Drongo	*Dicrurus leucophaeus*	Insectivorous	M							LC
63	Black Drongo	*Dicrurus macrocercus*	Insectivorous	R							LC
64	White-bellied Drongo	*Dicrurus caerulescens*	Insectivorous	R							LC
65	Bronzed Drongo	*Dicrurus aeneus*	Insectivorous	R							LC
66	Greater Racquet-tailed Drongo	*Dicrurus paradiseus*	Insectivorous	R							LC
67	Black-naped Monarch	*Hypothymis azurea*	Insectivorous	R							LC
68	Indian Paradise-flycatcher	*Terpsiphone paradisi*	Insectivorous	R							LC
69	Long-tailed Shrike	*Lanius schach*	Carnivorous	LM							LC
70	House Crow	*Corvus splendens*	Omnivorous	R							LC
71	Large-billed Crow	*Corvus macrorhynchos*	Omnivorous	R							LC
72	Rufous Treepie	*Dendrocitta vagabunda*	Omnivorous	R							LC
73	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	Insectivorous	M							LC
74	Grey-breasted Prinia	*Prinia hodgsonii*	Insectivorous	R							LC
75	Ashy Prinia	*Prinia socialis*	Insectivorous	R							LC
76	Common Tailorbird	*Orthotomus sutorius*	Insectivorous	R							LC
77	Blyth's Reed-warbler	*Acrocephalus dumetorum*	Insectivorous	M							LC
78	Barn Swallow	*Hirundo rustica*	Insectivorous	M							LC
79	Red-whiskered Bulbul	*Pycnonotus jocosus*	Omnivorous	R							LC
80	Red-vented Bulbul	*Pycnonotus cafer*	Omnivorous	R							LC
81	White-browed Bulbul	*Pycnonotus luteolus*	Omnivorous	R							LC
82	Sulphur-bellied Warbler	*Phylloscopus griseolus*	Insectivorous	M							LC
83	Greenish Warbler	*Phylloscopus trochiloides*	Insectivorous	M							LC
84	Indian Scimitar-babbler	*Pomatorhinus horsfieldii*	Insectivorous	R							LC
85	Puff-throated Babbler	*Pellorneum ruficeps*	Insectivorous	R							LC

Sr. No.	Common Name	Scientific Name	Diet preference	Migration	Grid Number						Status
					1	2	3	4	5	6	
86	Jungle Babbler	*Turdoides striata*	Insectivorous	R							LC
87	Chestnut-tailed Starling	*Sturnia malabarica*	Insectivorous	M							
88	Common Myna	*Acridotheres tristis*	Omnivorous	R							LC
89	Orange-headed Thrush	*Geokichla citrina*	Insectivorous	R							LC
90	Oriental Magpie-robin	*Copsychus saularis*	Insectivorous	R							LC
91	White-rumped Shama	*Kittacincla malabarica*	Insectivorous	R							LC
92	Brown-breasted Flycatcher	*Muscicapa muttui*	Insectivorous	M							LC
93	Asian Brown Flycatcher	*Muscicapa dauurica*	Insectivorous	M							LC
94	Tickell's Blue-flycatcher	*Cyornis tickelliae*	Insectivorous	R							LC
95	Red-breasted Flycatcher	*Ficedula parva*	Insectivorous	M							LC
96	Indian Robin	*Saxicoloides fulicatus*	Insectivorous	R							LC
97	Black Redstart	*Phoenicurus ochruros*	Insectivorous	M							LC
98	Golden-fronted Leafbird	*Chloropsis aurifrons*	Insectivorous	R							LC
99	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	Frugivorous	R							LC
100	Thick-billed Flowerpecker	*Dicaeum agile*	Frugivorous	R							LC
101	Purple-rumped Sunbird	*Leptocoma zeylonica*	Nectarivorous	R							LC
102	Purple Sunbird	*Cinnyris asiaticus*	Nectarivorous	R							LC
103	Loten's Sunbird	*Cinnyris lotenius*	Nectarivorous	R							LC
104	Sahyadri Sunbird	*Aethopyga vigorsii*	Nectarivorous	R							LC
105	Scaly-breasted Munia	*Lonchura punctulata*	Granivorous	R							LC
106	House Sparrow	*Passer domesticus*	Granivorous	R							LC
107	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis*	Granivorous	R							LC
108	Grey Wagtail	*Motacilla cinerea*	Insectivorous	M							LC
109	Western Yellow Wagtail	*Motacilla flava*	Insectivorous	M							LC
110	Forest Wagtail	*Dendronanthus indicus*	Insectivorous	M							LC

LC = Least Concern, VU= Vulnerable, DD = Data Deficient, NT = Near Threatened, NA = Not Assessed)

Table 20: Monthwise record of checklist of birds recorded during the BNHS-GMLR survey fro July 2021 to June 2022. Resident birds are shaded in green and migratory birds are indicated with blue-colour

Sr. No	Common Name	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	Indian Peafowl												
2	Grey Junglefowl												
3	Red Spurfowl												
4	Rock Dove												
5	Yellow-footed Green-pigeon												
6	Western Spotted Dove												
7	Grey-capped Emerald Dove												
8	Asian Palm-swift												
9	Alpine Swift												
10	Little Swift												
11	Greater Coucal												
12	Western Koel												
13	Square-tailed Drongo-cuckoo												
14	Common Hawk-cuckoo												
15	Indian Cuckoo												
16	Jacobin Cuckoo												
17	White-breasted Waterhen												
18	Asian Openbill												
19	Red-naped Ibis												
20	Little Egret												
21	Western Reef-egret												
22	Intermediate Egret												
23	Cattle Egret												
24	Black-crowned Night-heron												
25	Indian Pond-heron												
26	Little Cormorant												
27	Brown Boobook												
28	Spotted Owlet												
29	Jungle Owlet												
30	White-eyed Buzzard												
31	Greater Spotted Eagle												
32	Booted Eagle												
33	Brahminy Kite												
34	Crested Serpent-eagle												
35	Changeable Hawk-eagle												
36	Bonelli's Eagle												
37	Shikra												
38	Black Kite												
39	Indian Grey Hornbill												
40	Common Hoopoe												

Sr. No	Common Name	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
41	Blue-tailed Bee-eater												
42	Asian Green Bee-eater												
43	Oriental Dwarf-kingfisher												
44	White-breasted Kingfisher												
45	Coppersmith Barbet												
46	Brown-headed Barbet												
47	Black-rumped Flameback												
48	Rufous Woodpecker												
49	Amur Falcon												
50	Peregrine Falcon												
51	Common Kestrel												
52	Plum-headed Parakeet												
53	Rose-ringed Parakeet												
54	Alexandrine Parakeet												
55	Indian Pitta												
56	Black-hooded Oriole												
57	Black-naped Oriole												
58	Indian Golden Oriole												
59	Common Woodshrike												
60	Common Iora												
61	White-spotted Fantail												
62	Ashy Drongo												
63	Black Drongo												
64	White-bellied Drongo												
65	Bronzed Drongo												
66	Greater Racquet-tailed Drongo												
67	Black-naped Monarch												
68	Indian Paradise-flycatcher												
69	Long-tailed Shrike												
70	House Crow												
71	Large-billed Crow												
72	Rufous Treepie												
73	Grey-headed Canary-flycatcher												
74	Grey-breasted Prinia												
75	Ashy Prinia												
76	Common Tailorbird												
77	Blyth's Reed-warbler												
78	Barn Swallow												
79	Red-whiskered Bulbul												
80	Red-vented Bulbul												
81	White-browed Bulbul												

Sr. No	Common Name	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
82	Sulphur-bellied Warbler												
83	Greenish Warbler												
84	Indian Scimitar-babbler												
85	Puff-throated Babbler												
86	Jungle Babbler												
87	Chestnut-tailed Starling												
88	Common Myna												
89	Orange-headed Thrush												
90	Oriental Magpie-robin												
91	White-rumped Shama												
92	Brown-breasted Flycatcher												
93	Asian Brown Flycatcher												
94	Tickell's Blue-flycatcher												
95	Red-breasted Flycatcher												
96	Indian Robin												
97	Black Redstart												
98	Golden-fronted Leafbird												
99	Pale-billed Flowerpecker												
100	Thick-billed Flowerpecker												
101	Purple-rumped Sunbird												
102	Purple Sunbird												
103	Loten's Sunbird												
104	Sahyadri Sunbird												
105	Scaly-breasted Munia												
106	House Sparrow												
107	Chestnut-shouldered Bush-sparrow												
108	Grey Wagtail												
109	Western Yellow Wagtail												
110	Forest Wagtail												

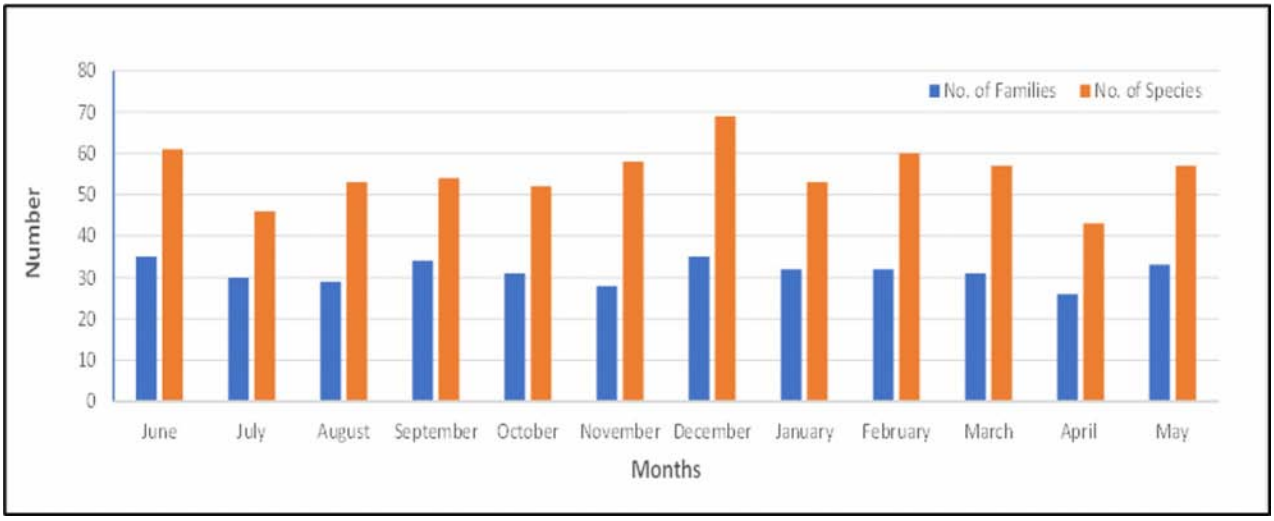


Fig. 34: Number of bird Families (blue) and number of species (orange) recorded from June 2021 to July 2022 during BNHS-GMLR survey

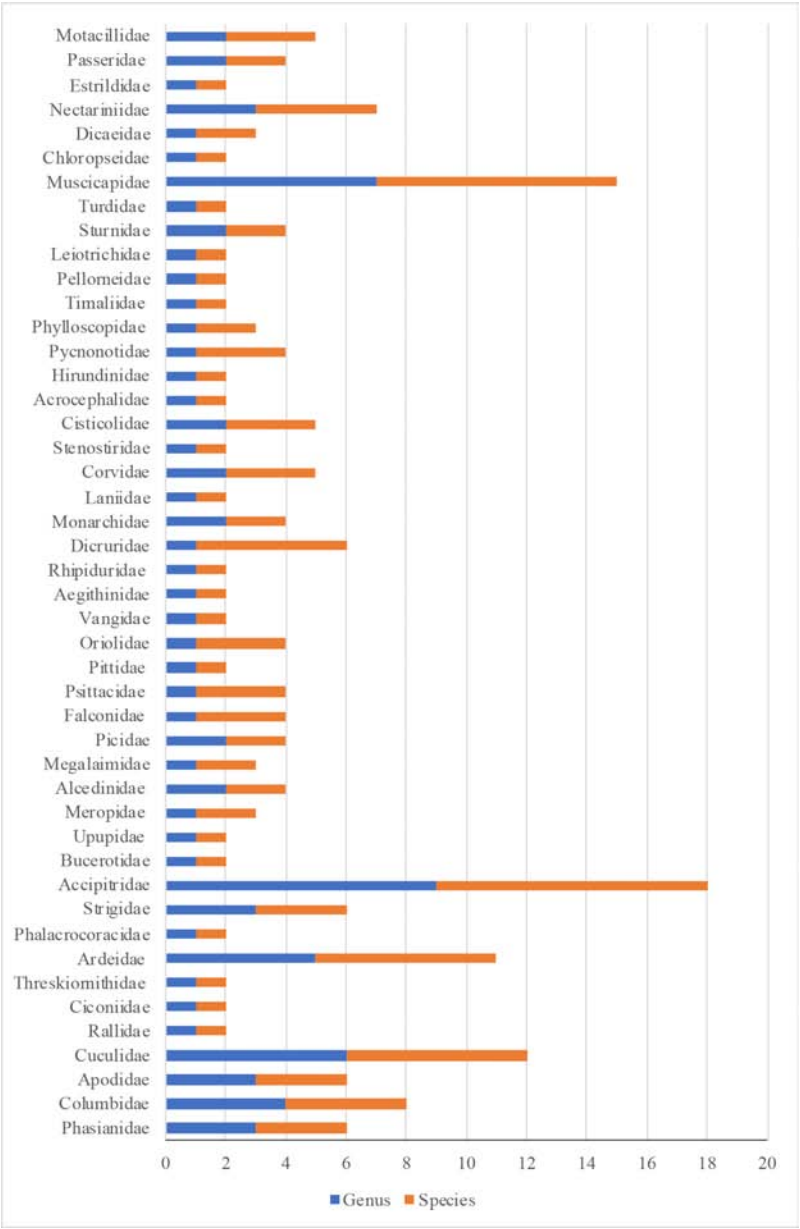


Fig. 35: Representation of bird Family, Genus and Species Diversity

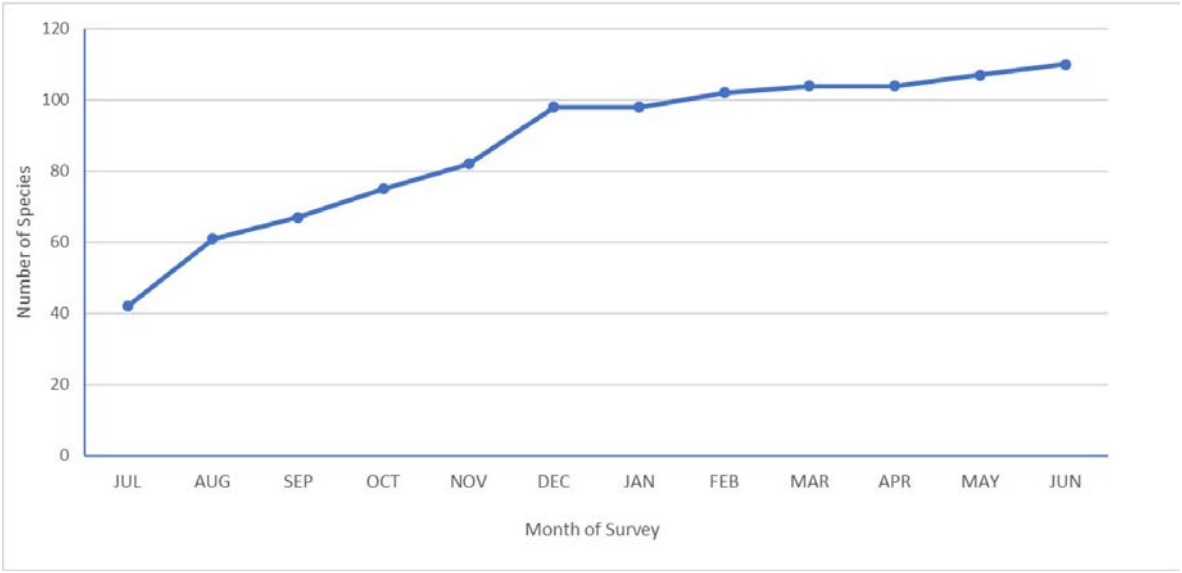


Fig. 36: Bird species accumulation curve indicating the number of individuals recorded with increasing sampling effort. The figure indicates that nearly 90% of bird diversity was sampled by January 2022

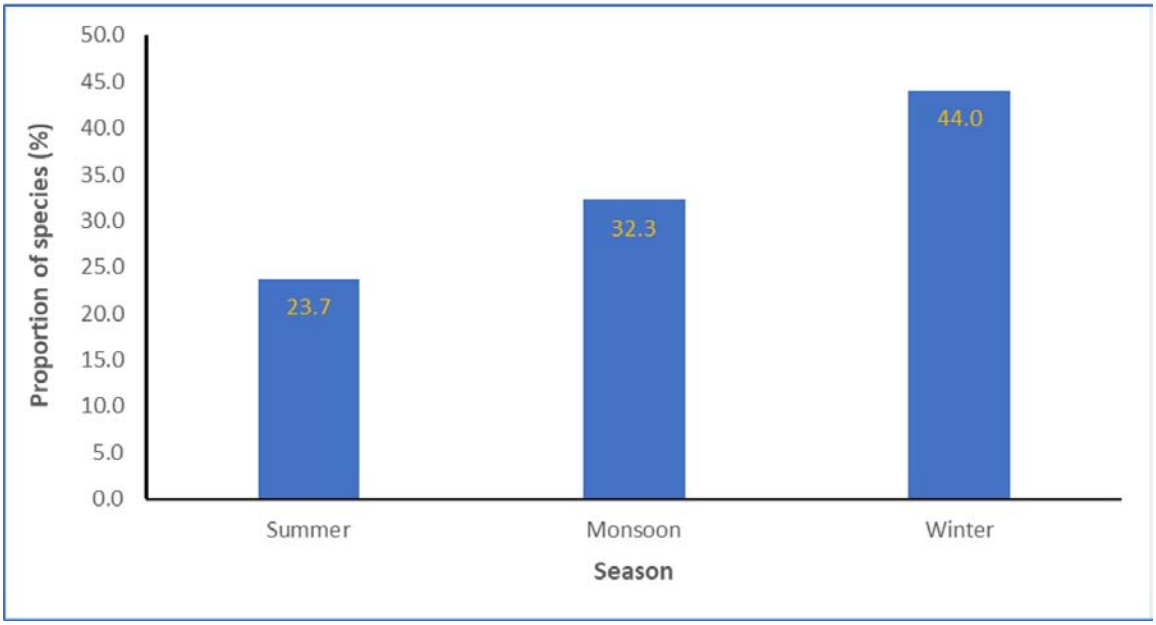


Fig. 37: Proportion of sightings across seasons - summer (March to May), monsoon (June to September) and post-monsoon / winter (October to February) from June 2021-June 2022

Summary

A total 110 species of birds belonging to 46 families and 88 genera were recorded from June 2021 to June 2022. Most abundant species were House Crow *Corvus splendens* and Large-billed Crow *Corvus macrorhynchos* which were sighted in all grids and also the most frequently encountered among all species. Five species of ground nesting birds, Red Spurfowl *Galloperdix spadicea,* Indian Peafowl *Pavo cristatus,* Grey Junglefowl *Gallus sonneratii*, Indian Scimitar-babbler *Pomatorhinus horsfieldii* and Puff-throated Babbler *Pellorneum ruficeps* were reported during this survey. Sahyadri Sunbird (Vigor's Sunbird) *Aethopyga vigorsii*, a species endemic to northern Western Ghats, was reported in all seasons in the study area.

In June 2022 we have reported three Cuculidae family species, namely, Square-tailed Drongo-cuckoo *Surniculus lugubris*, Indian Cuckoo *Cuculus micropterus* and Jacobin Cuckoo *Clamator jacobinus*. Greater Spotted Eagle *Clanga clanga* is listed as Vulnerable and Alexandrine Parakeet *Psittacula eupatria* is listed at Near Threatened by the IUCN. Indian Peafowl *Pavo cristatus* is listed in Schedule -I of the Wildlife Protection Act (1972) of India.

Our survey recorded 27 migratory species (Country/breeding migrations) as given below: Indian Cuckoo *Cuculus Cuculus micropterus* , Jacobin Cuckoo *Clamator jacobinus*, Western Reef-egret *Egretta gularis*, Greater Spotted Eagle *Clanga clanga*, Booted Eagle *Hieraaetus pennatus*, Blue-tailed Bee-eater *Merops philippinus*, Oriental Dwarf-kingfisher *Ceyx erithaca*, Amur Falcon *Falco amurensis,* Peregrine Falcon *Falco peregrinus*, Common Kestrel *Falco tinnunculus,* Indian Pitta *Pitta brachyura*, Black-naped Oriole *Oriolus chinensis*, Ashy Drongo *Dicrurus leucophaeus*, Long-tailed Shrike *Lanius schach* , Grey-headed Canary-flycatcher *Culicicapa ceylonensis*, Blyth's Reed-warbler *Acrocephalus dumetorum*, Barn Swallow *Hirundo rustica*, Sulphur-bellied Warbler *Phylloscopus griseolus*, Greenish Warbler *Phylloscopus trochiloides*, Chestnut-tailed Starling *Sturnia malabarica*, Brown-breasted Flycatcher *Muscicapa muttui,* Asian Brown Flycatcher *Muscicapa dauurica*, Red-breasted Flycatcher *Ficedula parva*, Black Redstart *Phoenicurus ochruros*, Grey Wagtail *Motacilla cinerea*, Western Yellow Wagtail *Motacilla flava*, and Forest Wagtail *Dendronanthus indicus*.

In the post-monsoon or winter season there is widespread influx of migratory birds arriving from different parts of the world to various habitats in India.

Oriental Dwarf Kingfisher *Ceyx erithaca* which is a local migratory species migrates from south India in early monsoon during its breeding season. It is a forest dwelling species mostly found along the flowing streams. It was reported during the months of June and July during the surveys. Another breeding migrant is Indian Pitta *Pitta brachyura* which arrives here in late summer or early monsoon for breeding.

Table 21: Species richness of avifauna across the 6 sample grids with details of their residential and migratory status in BNHS-GMLR survey

Grid Number	1	2	3	4	5	6
No. of Species	64	56	63	61	67	75
Resident	56	47	54	52	57	62
Migrant*	8	9	9	9	10	13

*Migrant species include breeding migrants (3), local migrants (3) as well as winter migrants (21).

Natural history

In the month of November 2021, an active nest of the Purple-rumped Sunbird *Leptocoma zeylonica* was seen. During the January 2022 birds survey, we saw an abandoned nest of Common Iora *Aegithina tiphia*. In May 2022, juveniles of Orange-headed Thrush *Geokichla citrina* were seen. In May 2022 Indian Pitta *Pitta brachyura*, a local breeding migrant was reported in two grids. Active nest of Large-billed Crow and Common Myna were seen in two grids, apart from that Oriental Magpie-robin and House Crows, which were seen carrying nesting material. Juveniles White-eyed Buzzard *Butastur teesa*, Red Spurfowl *Galloperdix spadicea* and Black-naped Monarch *Hypothymis azurea* were seen indicating breeding in the area. An eclipse male of Grey Junglefowl *Gallus sonneratii* was also photographed during the survey in June 2022.

Mammals

Methods

The following methods were applied to assess the diversity and distribution of mammals in relation to sample-grids (I to VI) located at different segments of the tunnel alignment of the proposed GMLR project from July 2021-June 2022:

Sign Survey: In order to optimize effort and also record mammal diversity across all parts of the grid, ad-hoc sign-surveys along random tracks were conducted while ensuring that they did not overlap spatially. The trails were thoroughly searched for presence of indirect signs of mammals. The signs were included hoof mark, foot mark, pugmarks, scats, pellets, scent marks, rake marks, scrape marks, vocalization, animal parts and direct sighting **(plate no.13).** Each hoofmark/pugmark trail was considered as one sign. Information of the forest type and the terrain was also recorded to understand habitat preference. Distance covered and time spent during each survey was noted down.

Camera-Trap Survey: Actively used mammal trails were identified during the course of the sign survey and were used to further demarcate locations for deploying camera traps. Systematic survey was carried out by deploying two camera-traps in each grid for 7 days from November 2021 to May 2022 (Poudyal et al., 2019) Camera-traps (Cuddeback C2 IR) were positioned 25 cm above ground and mounted on trees, perpendicular to, and 5-7 meter away from trails, forest roads, and any waterbody. The cameras captured two pictures per trigger with no lag between the triggers when any animal crossed it. Photograph of a species taken within an hour from a location was considered an independent detection. Camera trap survey was conducted only during the winter and summer months due to logistic considerations.

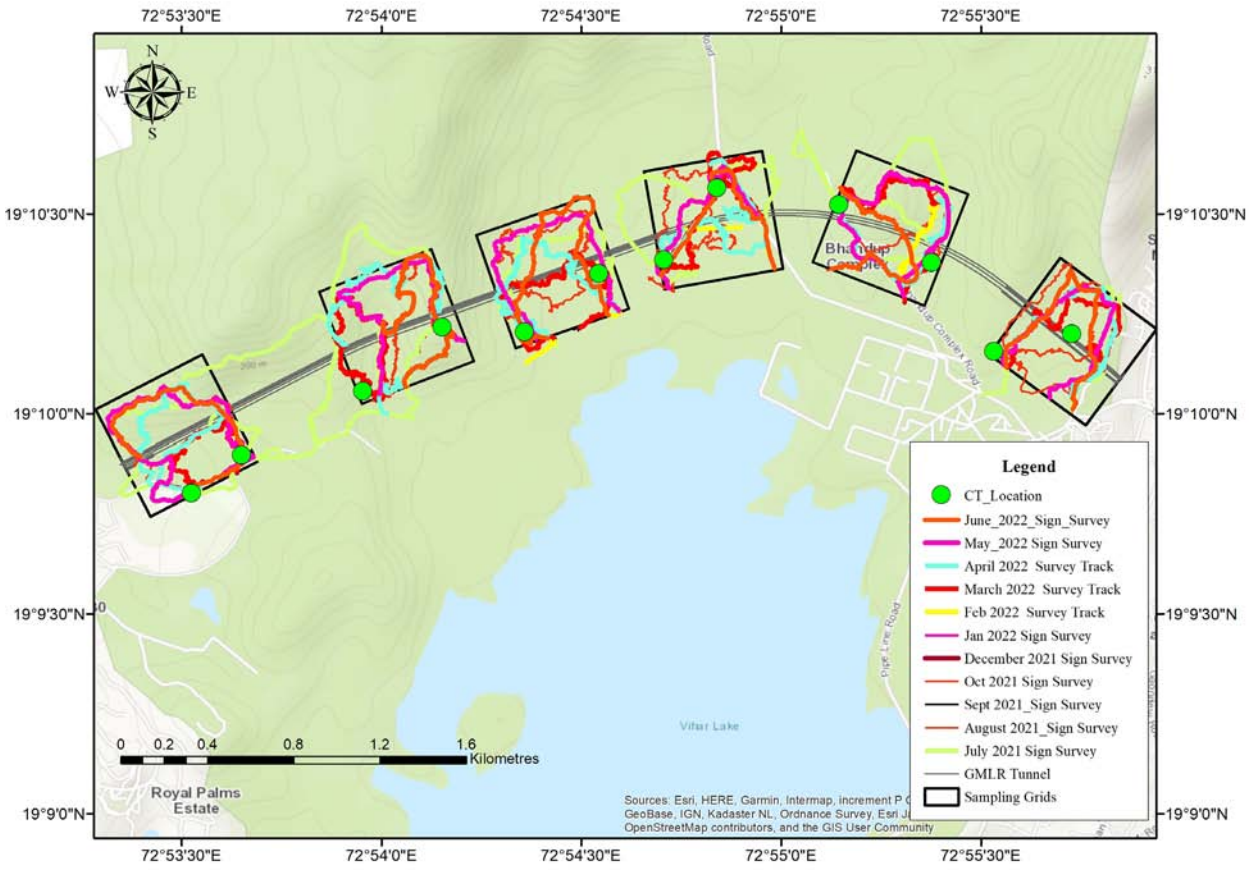


Fig. 38: Map showing the tunnel alignment of a section of the Goregaon-Mulund Link Road that will be passing through the Sanjay Gandhi National Park (SGNP). The sampling grids and the sign survey transects for mammal diversity assessment are shown in different colours for the months surveyed

Plate 12: Fieldwork and data collection by Mammals team

On field data entry in ODK Collet Application

Examining the scrape mark

Examining pellets

Examining the rake mark

Data Analysis

A checklist of all mammals encountered as well as the camera images was prepared. Conservation status of each individual species from both IUCN status and listing in the WPA was also highlighted. The data was analyzed to understand seasonal variability and grid-wise presence-absence.

The signs recorded were used to estimate encounter rates. Encounter rates are expressed as number of individuals/groups against effort (time or distance covered) (Buckland et al., 2008**)**. Encounter rates have long been used in conservation ecology but rarely used these days for two reasons – 1) There is a bias associated due to variation in detectability across species and habitats, 2) actual population estimates rather than relative abundance indices are required for wildlife management**.** The objective of the present study was to determine relative abundances in relation to seasons and the sample-grids (I to VI) on different sections of the tunnel alignment. Mammal encounter rates summarized the data adequately for this purpose.

Photos obtained in camera traps were systematically sorted species-wise into folders categorized according to date of capture and grid number. The data was summarized as given below:

1. Camera station ID
2. Identity of species
3. Number of independent detections (where possible)
4. Detection rate for each species were calculated from the camera trap photographs.

The Detection rate for species photographed during survey was calculated using the following formula.

$$\text{Camera Trap Survey Detection rate} = \frac{\text{Number of independent detections of a species}}{\text{Total effort (trap days) of entire survey}}$$

Results

Table 22: Checklist of mammals recorded in the study area, along with their IUCN status and Wildlife Protection Act Schedules

Sr No	Species	Scientific Name	IUCN Status	WPA Status
1	Spotted Deer	*Axis axis*	LC	Schedule III
2	Sambar	*Rusa unicolor*	VU	Schedule III
3	Barking Deer	*Muntiacus muntjak*	LC	Schedule III
4	Indian Spotted Chevrotain	*Moschiola indica*	LC	Schedule III
5	Wild Boar	*Sus scrofa*	LC	Schedule III
6	Common Langur	*Semnopithecus hypoleucos*	LC	Schedule II
7	Rhesus Macaque	*Macaca mulatta*	LC	Schedule II
8	Bonnet Macaque	*Macaca radiata*	VU	Schedule II
9	Indian Grey Mongoose	*Herpestes edwardsii*	LC	Schedule II

Sr No	Species	Scientific Name	IUCN Status	WPA Status
10	Ruddy Mongoose	*Herpestes smithii*	LC	Schedule II
11	Small Indian Civet	*Viverricula indica*	LC	Schedule II
12	Asian Palm Civet	*Paradoxurus hermaphroditus*	LC	Schedule II
13	Indian Hare	*Lepus nigricollis*	LC	Schedule IV
14	Indian Porcupine	*Hystrix indica*	LC	Schedule IV
15	Indian Palm Squirrel	*Funambulus palmarum*	LC	Schedule IV
16	Asiatic Long-tailed climbing mouse	*Vandeleuria oleracea*	LC	Schedule IV
17	Jungle Cat	*Felis chaus*	LC	Schedule II
18	Rusty Spotted Cat	*Prionailurus rubiginosus*	NT	Schedule I
19	Indian Leopard	*Panthera pardus*	VU	Schedule I
20	Common Pipistrelle	*Pipistrellus pipistrellus*	LC	Schedule IV
21	Greater Short-nosed Fruit Bat	*Cynopterus sphinx*	LC	Schedule IV

(LC = Least Concern, VU = Vulnerable, NT= Near Threatened, NA = Not Assessed).

Table 23: A checklist of mammals recorded in the study area with distribution across the grids

S No	Species	Grid					
		1	2	3	4	5	6
1	Spotted Deer	■	■	■	■	■	■
2	Sambar	■	■	■	■	■	■
3	Barking Deer	■		■	■	■	
4	Indian Spotted Chevrotain	■	■	■	■	■	■
5	Wild Boar	■	■	■	■	■	■
6	Common Langur	■	■	■	■	■	■
7	Rhesus Macaque	■					■
8	Bonnet Macaque	■	■	■	■	■	■
9	Indian Grey Mongoose	■					
10	Ruddy Mongoose	■	■			■	
11	Small Indian Civet	■	■		■	■	
12	Asian Palm Civet	■			■		
13	Indian Hare				■	■	■
14	Indian Porcupine			■	■		
15	Indian Palm Squirrel	■	■	■	■	■	■
16	Asiatic Long-tailed climbing mouse	■					
17	Jungle Cat					■	■
18	Rusty Spotted Cat		■				■
19	Indian Leopard	■	■	■	■	■	■
20	Common Pipistrelle	■					
21	Greater Short-nosed Fruit Bat	■					

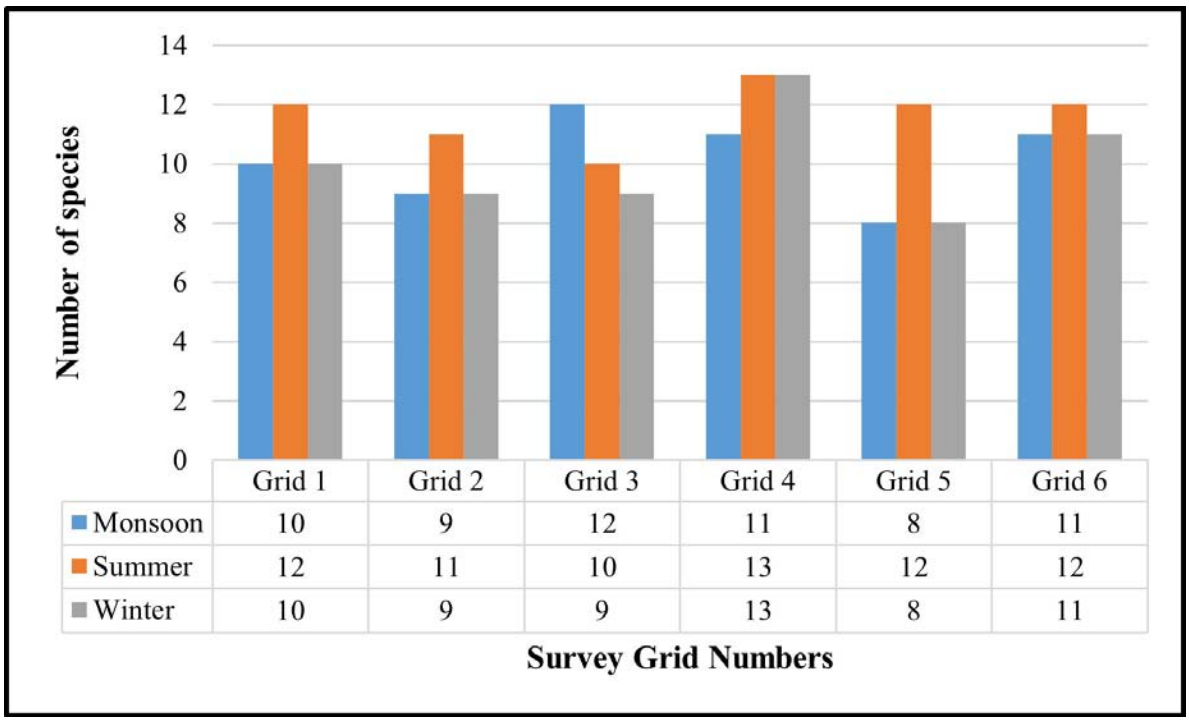


Fig. 39: Gridwise record of mammal species

Table 24:A checklist of mammals recorded in the study area from July 2021 to June 2022
(Green cells indicate species presence, blank cells indicate absence)

Species	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Spotted Deer												
Sambar												
Barking Deer												
Indian Spotted Chevrotain												
Wild Boar												
Gray Langur												
Bonnet Macaque												
Rhesus Macaque												
Indian Hare												
Indian Porcupine												
Indian Palm Squirrel												
Asiatic Long-tailed climbing mouse												
Indian Grey Mongoose												
Ruddy Mongoose												
Small Indian Civet												
Asian Palm Civet												
Indian Leopard												
Jungle Cat												
Rusty Spotted Cat												
Common Pipistrelle												
Greater Short-nosed Fruit Bat												

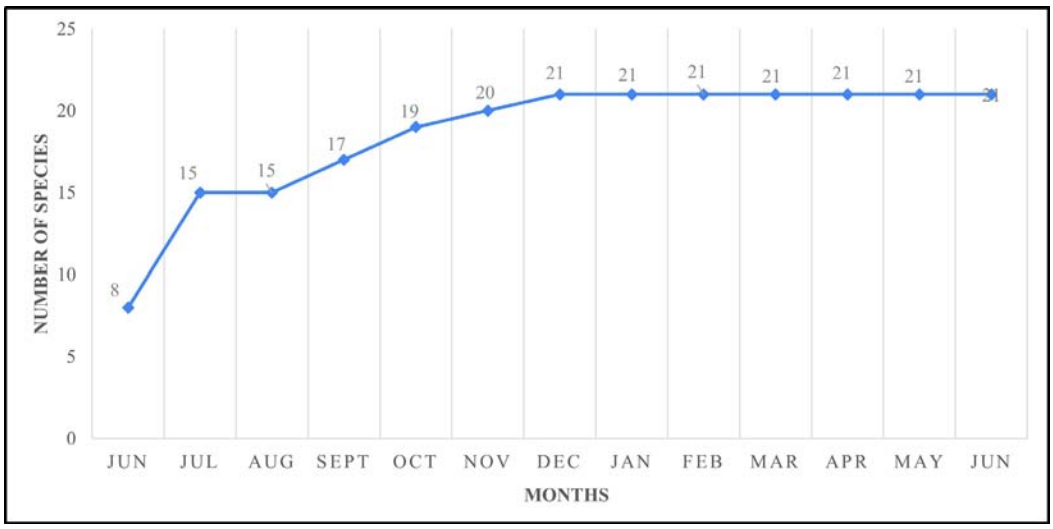


Fig. 40: Mammal species accumulation curve indicating the number of individuals recorded with increasing sampling effort. The figure indicates that mammal species diversity was all sampled by December 2021

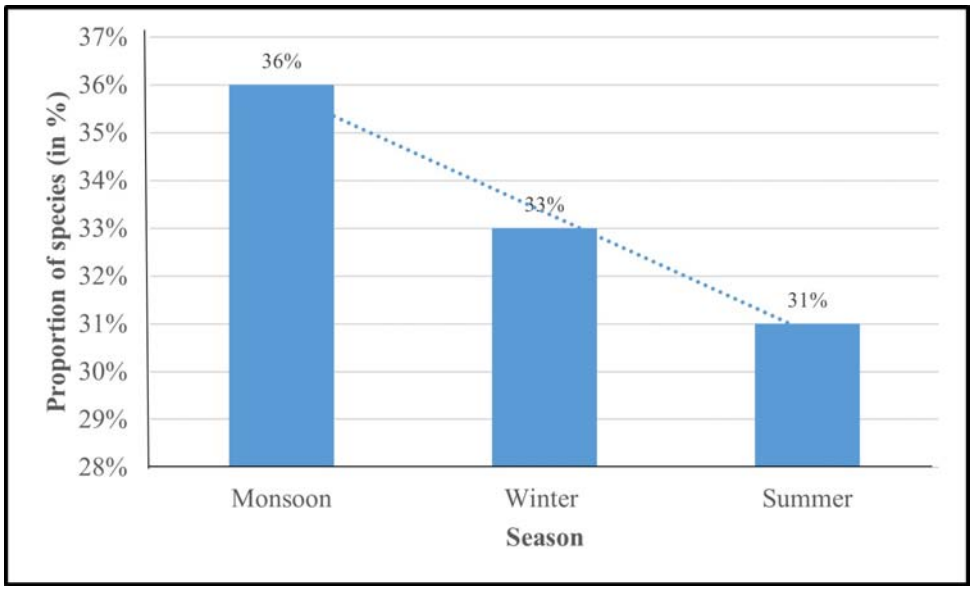


Fig. 41: Proportion of species (%) recorded in each season from the overall species diversity (N=21)

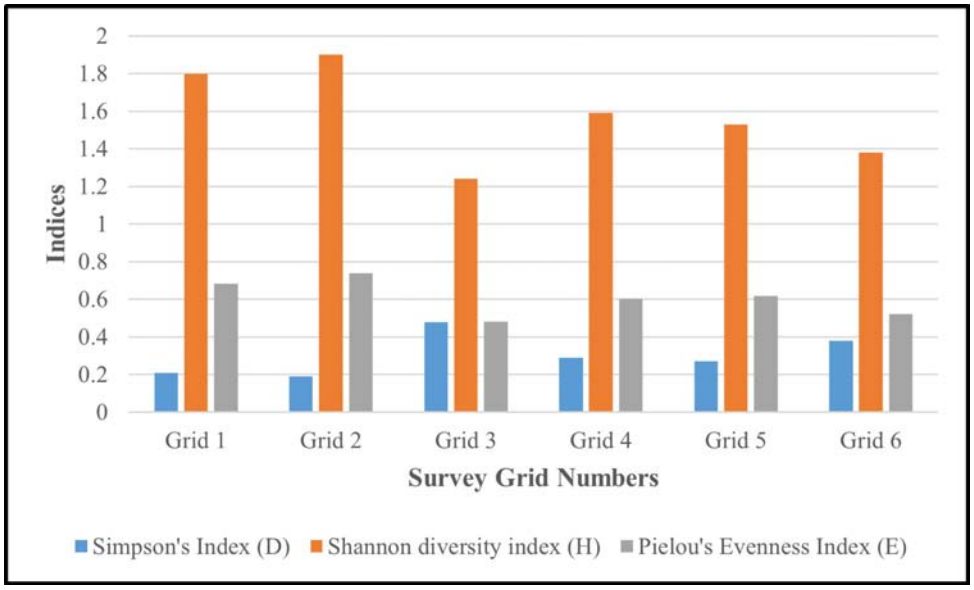


Fig. 42: Summary of diversity indices for mamals in sample-grids (I to VI) during BNHS-GMLR survey

Table 25: Sign Encounter rates (Signs/km) for mammals from random trails along the tunnel alignment within SGNP during the BNHS-GMLR survey

Data Summary	Season	Grid Number	Chital	Sambar	Gray Langur	Bonnet Macaque	Wild Boar	Barking Deer	Indian Leopard	Effort
Encounter Rates	Monsoon	1	5.27	4.47	0.60	0.13	0.46	0.86	0.53	
		2	7.06	7.43	1.12	0.22	0.75	1.72	0.45	
		3	15.7	2.66	1.45	0.08	1.37	3.17	0.08	
		4	14.71	1.88	1.32	0.37	4.71	3.39	0.28	
		5	11.31	1.62	0.91	0.13	1.62	0.58	0.52	
		6	19.6	0.65	2.13	0.55	1.57	0.74	0.83	
		Overall	12.28	3.12	1.25	0.25	1.75	1.74	0.45	76.68 km
	Winter	1	5.77	4.46	1.22	0.17	0.17	0.78	0.96	
		2	10.28	5.09	1.15	0.19	0.28	1.05	0.67	
		3	16.11	0.7	1.29	0	0.23	1.17	0	
		4	8.17	1.21	0.97	0.36	6.21	1.95	0	
		5	8.44	1.93	0.5	0.2	5.39	0.5	0.5	
		6	16.89	0.23	2.79	0.11	2.79	0.93	0.11	
		Overall	10.94	2.27	1.32	0.17	2.51	1.06	0.37	56.94 km
	Summer	1	4.14	2.2	0.17	0	0.35	0.35	0.17	
		2	6.13	2.71	0.5	0.2	0	0.7	0.5	
		3	7.97	0.4	0.5	0.1	0.2	1.61	0	
		4	5.48	0.32	0.32	0.1	4.73	0.21	0	
		5	4.24	0.74	0.24	0.16	3.41	0.16	0.24	
		6	9.04	0.42	0.63	0.1	1.27	0.21	0.63	
		Overall	6.16	1.13	0.39	0.11	1.66	0.54	0.25	61.91 km
Capture Rates	Winter	1	2.42	0.76	0	1.23	1.42		0.42	
(individuals/trap night		2	0.04	1.9	0.38	0	0.47		0.04	
		3	13.42	0.38	0.95	0.09	0.09		0.19	
		4	10.52	4.38	0.57	0.47	2.61		0.04	
		5	0.8	3.33	1.38	0	2.61		0.09	
		6	1.04	0.8	0.19	0	0.9		0	
		Overall	4.71	1.92	0.57	0.3	1.35		0.13	1153 images/21days

Data Summary	Season	Grid Number	Chital	Sambar	Gray Langur	Bonnet Macaque	Wild Boar	Barking Deer	Indian Leopard	Effort
	Summer	1	1.02	0.42	0.47	0.3	3.23	0.08	0.89	
		2	0.55	0.8	0.67	0.19	1.93	0.06	0.87	
		3	3.78	0.73	0.3	0.29	1.26	0	0.37	
		4	1.71	0.94	0.52	0.38	1.25	0	0.2	
		5	8.7	5.12	3.37	0.47	2.11	0	0.32	
		6	0.53	0.74	0.03	0.01	1.23	0	0.03	
		Overall	2.72	1.46	0.89	0.27	1.83	0.02	0.45	3700 images/78 days

Table 26: Sign Encounter rates (Signs/km) for rare, nocturnal and cryptic mammals from random trails along the tunnel alignment within SGNP during the BNHS-GMLR surveySign Encounter rate (Signs/km)

Grid	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Average
Monsoon							
Indian Spotted Chevrotain	0.86	1.72	3.17	3.39	0.58	0.74	1.74
Indian Palm Squirrel	0	0.07	0.25	0.09	0.13	0.09	0.10
Indian Hare	0	0	0	0.28	0	0.09	0.06
Rhesus Macaque	0	0	0.08	0	0	0.27	0.06
Rusty Spotted Cat	0	0	0	0	0	0.18	0.03
Jungle Cat	0	0	0.08	0.09	0	0	0.03
Indian Crested Porcupine	0	0.07	0.08	0	0	0	0.02
Common Pipestralle	0.06	0	0	0	0	0	0.01
Greater Short-Nosed Fruit Bat	0.06	0	0	0	0	0	0.01
Winter							
Indian Palm Squirrel	0.17	0	0.35	0.24	0	0.11	0.14
Indian Hare	0	0	0	0.36	0	0.11	0.08
Indian Crested Porcupine	0	0.09	0	0.36	0	0	0.07
Small Indian Civet	0	0.09	0	0	0	0.23	0.05
Jungle Cat	0	0	0	0.24	0	0	0.04
Common Pipestralle	0.17	0	0	0	0	0	0.02
Indian Grey Mongoose	0	0	0	0	0	0.11	0.01
Asiatic Long tailed climbing mouse	0.08	0	0	0	0	0	0.01
Summer							
Indian Palm Squirrel	0.08	0.1	0.1	0.1	0	0	0.06
Indian Hare	0	0	0	0.21	0	0	0.03
Jungle Cat	0	0	0.1	0.1	0	0	0.03
Indian Spotted Chevrotain	0	0	0	0.1	0	0	0.01
Ruddy Mongoose	0	0	0	0	0	0.1	0.01
Rusty Spotted Cat	0	0	0	0	0	0.1	0.01
Small Indian Civet	0	0	0	0	0	0.1	0.01
Common pipestralle	0.08	0	0	0	0	0	0.01

Table 27: Camera trap detection rate (individuals/days) during BNHS-GMLR survey July 2021 to June 2022

Capture rate (individuals/days)

Winter	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Overall
Indian Hare	0.00	0.00	0.00	0.00	0.71	0.00	0.11
Asian Palm Civet	0.00	0.00	0.00	0.09	0.00	0.00	0.01
Summer	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5	Grid 6	Overall
Indian hare	0.00	0.00	0.01	0.03	0.37	0.02	0.07
Ruddy Mongoose	0.05	0.26	0.00	0.00	0.01	0.00	0.05
Small Indian Civet	0.03	0.06	0.00	0.06	0.05	0.00	0.03
Asian Palm Civet	0.12	0.03	0.00	0.01	0.00	0.00	0.02
Barking Deer	0.08	0.06	0.00	0.00	0.00	0.00	0.02
Indian Palm Squirrel	0.03	0.01	0.01	0.01	0.02	0.00	0.01
Jungle Cat	0.00	0.01	0.00	0.00	0.02	0.01	0.01
Rhesus Macaque	0.00	0.00	0.00	0.00	0.00	0.03	0.01

Summary

A total of 21 mammal species were reported during July 2021 to June 2022 which comprised of 4 carnivores, 5 ungulates, 3 primates, 1 lagomorph, 2 rodent and 2 bat species from direct sightings, indirect signs and camera trapping.

Monsoon: Out of the total 76.68 km sign survey walk during monsoon season, the average sign encounter rate for spotted deer was found to be highest (12.28 signs /km) in all the 6 grids, with Grid VI having maximum (19.60 signs /km) followed by Grid III (15.71 signs /km) and Grid IV (14.71 signs /km).

Winter: Out of the total 56.94 km sign survey walk during winter season, the average sign encounter rate for spotted deer was found to be highest (10.94 signs /km) in all the 6 grids, with Grid VI having maximum (16.90 signs /km) followed by Grid III (16.11 signs /km) and Grid II (10.28 signs /km). The sign encounter rate for all species decreased in this season due to the increase in leaf litter concealing signs like spoor tracks, scats etc.

Summer: Out of the total 61.91 km sign survey walk during summer season, the average sign encounter rate for spotted deer was found to be highest (10.94 signs /km) in all the 6 grids, with Grid VI having maximum (16.89signs /km) followed by Grid 3 (16.11 signs /km) and Grid II (10.28signs /km).

Camera trap exercise provided a fascinating range of mammal photographs capturing cryptic, nocturnal species and also some interesting records of behaviour (Plate no. 14)

Winter: Around 1153 independent individual photographs were captured during 21 days (3 months – 7 days each month) of camera trapping (trap nights) exercise during this season in which average detection rate of Spotted Deer was highest (4.7 individuals/ trap night) with highest detection rate in Grid III (13.42 individuals/ trap night). Asian palm civet had the lowest detection rate (0.015 individuals/ trap night) and it was detected only in Grid IV.

Summer: During Summer survey, the camera traps were initially deployed for 7 days for February and March 2022. In order to improve the capture success, it was decided to deploy the cameras continuously for 2 months from April to May. Thus, the efforts of camera trapping were increased, resulting photo capturing the elusive jungle cat for the first time. Around 3700 independent individual photographs were captured during 78 days of camera trapping (trap nights). The average detection rate of spotted deer was highest (2.72 individuals/ trap night) with highest detection rate in Grid V (8.7 individuals/ trap night). The arboreal Rhesus macaque had the lowest detection rate (0.038 individuals/ trap night) and it was detected only in Grid VI.

Considering the overall indices, Grid IV and Grid VI are the grids having maximum species richness. The overall diversity indices for mammals reveal that Grid II shows high diversity followed by Grid I and Grid IV. The relatively high diversity index in all the grids followed by almost similar evenness values for all the grids shows that community of species doesn't differ much in between different grids. The Simpson's diversity index was found to be highest for Grid III followed by Grid VI whereas it was lowest for Grid II and Grid I respectively.

During the overall survey period of one year, mammals were observed to be well distributed across all the grids. The sample grids varied among themselves in terms of terrain and human presence. Grid III and IV are mostly preferred by ungulates probably due to flat terrain with elevation ranging from (50-70m) and (30-50m) respectively as compared to other grids. These two grids are located between the 2 lakes Vihar and Tulsi,. The impact of tunnelling on mammals might be more predominant in these 2 grids as the tunnel dept is lowest in these 2 grids (approx. 20m). There is good diversity of mammal species observed in Grid I and Grid VI where the start and end point of the tunnel is proposed .

Plate 13

Mammal Species Survey Relied On Indirect Signs (Rake-Marks, Scats/Pellets, Spoor Marks, Bones) As Well As Direct Sightings

Photo 1 Rake Mark of Leopard

Photo 2 Scat of Leopard

Photo 3 Pug Mark of Leopard

Photo 4 Scrape Mark of Leopard

Photo 5 Pug Mark of Rusty spotted cat

Photo 6 Pellets of Spotted Deer

Photo 7 Pellets of Sambar

Photo 8 Rake mark of Spotted Deer

Photo 9 Resting place of Spotted Deer

Photo 10 Hoof mark of Barking Deer

Photo 11 Animal part (Jaw of spotted deer)

Photo 12 Hoof mark of Sambar

Photo 13 Indian Palm Squirrel

Photo 14 Sambar

Photo 15 Wild Boar

Plate 14

Camera Trap Images

Photo 1 Indian leopard

Photo 2 Indian hare

Photo 3 Sambar

Photo 4 Ruddy mongoose

Photo 5 Small Indian civet

Photo 6 Barking deer

Photo 7 Jungle cat

Photo 8 Bonnet macaque

Photo 9 Asian palm civet

Photo 10 Spotted deer

Photo 11 Gray Langur

Photo 12 Rhesus macaque

131 *Photo 13 Wild boar*

Photo 14 Indian palm squirrel

CHAPTER-6

Synthesis

Highlights of the survey and the significance of the biodiversity assessment

Phase I of the BNHS-GMLR project has been completed and a comprehensive biodiversity checklist has been prepared. The survey has been conducted by accounting for variations across seasons, habitats, terrain and human presence by appropriate placement of sampling grids and data-collection plots within the 4.5km stretch of the tunnel alignment. All the grids and plots have been found to be equally significant in their representation of diversity of the various taxonomic groups surveyed.

The IUCN red list is well known as the global inventory of the conservation status of various biological species based on prescribed criteria. In this study, the IUCN red-listing was not suitable for highlighting the status of individual species across taxa. This is because many species recorded from the study-site have not been assessed by the IUCN particularly in the case of plants, spiders and insects. In some other instances, we have not been able to identify our observations up to the species level. Overall, there were no records of Endangered or Critically Endangered species that require specific or focused conservation efforts.

The Wildlife (Protection) Act 1972 lists wild species under 6 schedules with varying degree of protection. Schedule I species are the most endangered animals/plants of the country and awarded the highest degree of protection. From our checklist, two butterfly species – danaid eggfly and crimson rose; one reptile species – the Bengal monitor; the Indian peafowl among birds; the Indian leopard and the rusty spotted cat among mammals are listed under Schedule I. Overall, the species conservation status – both IUCN red list and Schedule categories of the Wildlife (Protection) Act 1972 - may not be the best indicator of the significance of the natural forest patches and its biodiversity lying along the tunnel alignment.

Biodiversity studies offer scope for interpretations from wider conservation perspectives. Intensive field-based surveys, although demanding by way of time, effort, human and financial resources, are worthwhile as they provide valuable insights about a given place. Apart from accurate checklists, the effort translates to meaningful outcomes by providing valuable ecological and natural history information about the local flora and fauna. Our year-long and systematic study is a case in point, as we have demonstrated many important aspects of natural history and ecology (Plate No. 15). The study has established that the forest patches are vital for many species across taxa for completing various stages of their life cycle (Plate No. 15). These events related to species' life-cycles are linked to the phenology of trees, herbs and shrubs. We have documented spiders and insects at various stages of development, congregations and mass emergence of certain insects in different times of the year (Plate No. 16). Congregation of Harvestmen (Order: Opilione) were also observed several times across the year. Sightings of juveniles and sub-adults of herpetofauna, nest-building behaviour, locations of active nests, chicks and juveniles of birds have all been documented and reported in the study. In the case of mammals also the seasonal changes of forage availability on the distribution of large ungulates - evident from the encounter rates- mating calls, presence of newborn calves in the group were all documented throughout the study (Plate No. 23). Even in the case of leopards, we had a rare sighting of a mating pair and on another occasion a female with cubs. The female from the mating pair was a radio-collared individual which is known to range well into the urban areas of the bustling metropolis. The female leopard could be identified from camera trap images and capture histories from previous studies (Surve et al.2015). The data indicated that her home-range included human land-use areas outside the SGNP also (Surve et al.2015). We can infer that the source habitats within SGNP maybe important for leopards to raise their cubs successfully.

Additionally, we have reported 3 breeding migrants, 3 local migrant and 21 winter migrants of birds indicating the importance of the forest habitats in completing the life-history of these birds that are not resident

to SGNP. The natural history notes from the study, emphasize the importance of the forest in all its entirety (Plate No. 15 and 16).

The sampling grids that represented relative variations in the habitat such as elevation, canopy cover, presence of streams, human disturbance mostly had representation from generalist species. Yet it was possible to point out some differences in species composition to highlight importance of specific habitats:

Seasonal and perennial water sources are integral to the overall biodiversity richness. For aquatic insects (odonates, water bugs, aquatic beetles, certain species of flies), spiders (Fishing spiders and certain species of wolf spiders), amphibians and many species of birds, the riparian habitats are very important. For example, we observed Tiger (*Danaus* spp., *Tirumala limniace*) and Crow (*Euploea* spp.) butterflies gathered in the valleys and stream beds in the post-monsoon season and were found either resting together along the streams and on trees or mud-puddling near wet soil or water puddles (see Boggs and Jackson 1979; Sculley and Boggs 1996). Apart from these habitats, the high elevation habitats (Grid II and V), seem to be important for specific species like Leith's Leaping Frog *Indirana leithii*, Beddomes's Snake-eye *Ophisops* cf. *beddomei* and Lined Supple Skink *Riopa lineata*. Bird species such as the Brown Flycatcher *Muscicapa dauurica* were seen only in the least disturbed habitats (Grid IV). The grids that were in proximity to human activity (Grid I & Grid VI) will be the entrance and exit points of the tunnel. The species recorded along these sampling points need to be monitored as they each showed a distinct composition of flora and fauna as discussed in the earlier chapters (Chapter 6). The forest-human land-use ecotones showed a characteristic species assemblage. In addition, we also recorded invasive species like *Ageratum conyzoides* and non-native trees such as Peltophorum *pterocarpum, Acacia auriculiformis,* and *Gliricidia sepium*. Birds such as House Crow *Corvus splendens* and Large-billed Crow *Corvus macrorhynchos* and Rock Dove *Columba livia* were both common and numerous. Primates and also Chital *Axis axis* were found to be widespread even near human settlements. Other ungulates such as Sambar *Rusa unicolor*, Wild Boar *Sus scrofa*, Barking Deer *Muntiacus muntjac,* Indian Spotted Chevrotain *Moschiola indica* were encountered more in the forest habitats of other sample grids.

Leopards are shy, solitary animals and the most adaptive among all cat species, especially in their ability to live close to human habitations and coexist with people. We have evidence of leopard movement (camera-trap images, sign surveys, direct sightings) in these interface areas throughout the year irrespective of the extent of human activity. This indicates that by temporarily avoiding certain disturbed parts of their ranges, they continue to use and also move in these areas. Leopards are also known to frequent village areas located at the edge of SGNP (Grid I &VI) looking for domestic prey, which is a predominant part of their diet. Therefore, when the villages are relocated to make way for tunnel construction, the integrity of the forest should be maintained to minimize the risk of human-leopard encounters and also allow free movement of the resident leopard within their home-range.

These observations show that the various habitats and micro-habitats along the tunnel alignment traversing from forest edge through pristine habitats within SGNP, support distinct species assemblages. The grids close to anthropogenic presence and activity not only have characteristic biodiversity, but also include invasive and non-native elements that should not be allowed to colonize in the intact forested areas. By preparing grid-wise species checklists we provide the baseline information required for future monitoring.

Conclusion

The output of the BNHS-GMLR survey includes a checklist of flora and fauna, natural history observations and evidence of the importance of these forested habitats. How sensitive the plants and animals of SGNP would be to changes or perturbations caused due to the tunnel construction is to be studied and monitored in subsequent phases.

Plate 15 (a): Natural History Observation

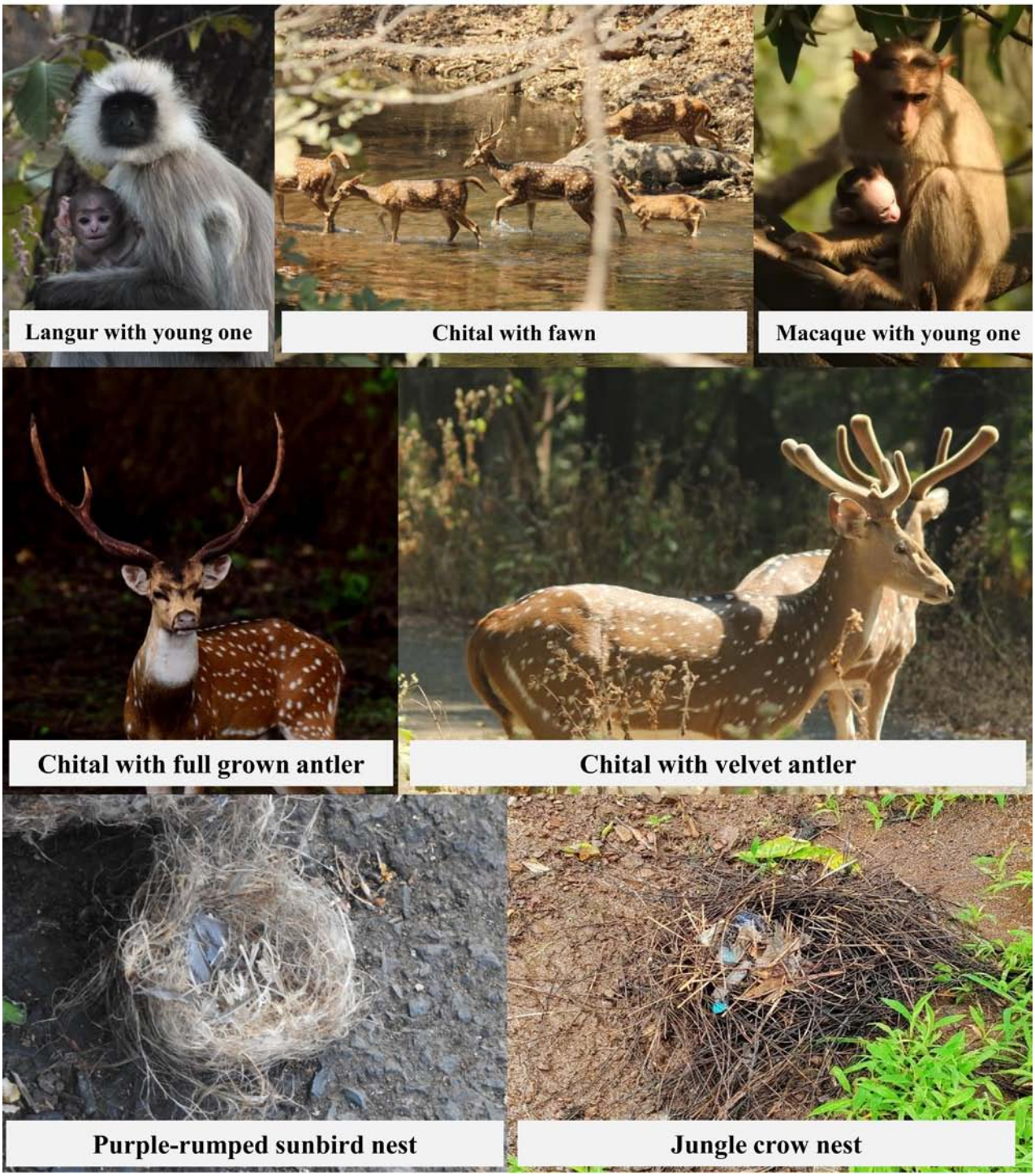


Plate 15 (b): Natural History Observation

Palm Dart Butterfly mating

Brwon King Crow egg laying

Common Mime butterfly caterpillar

Orange Tip butterfly pupation

Tailed Jay butterfly pupa

Butterfly mud pudding

Bush Dart damselfly mating

Plate 15 (c): Natural History Observation

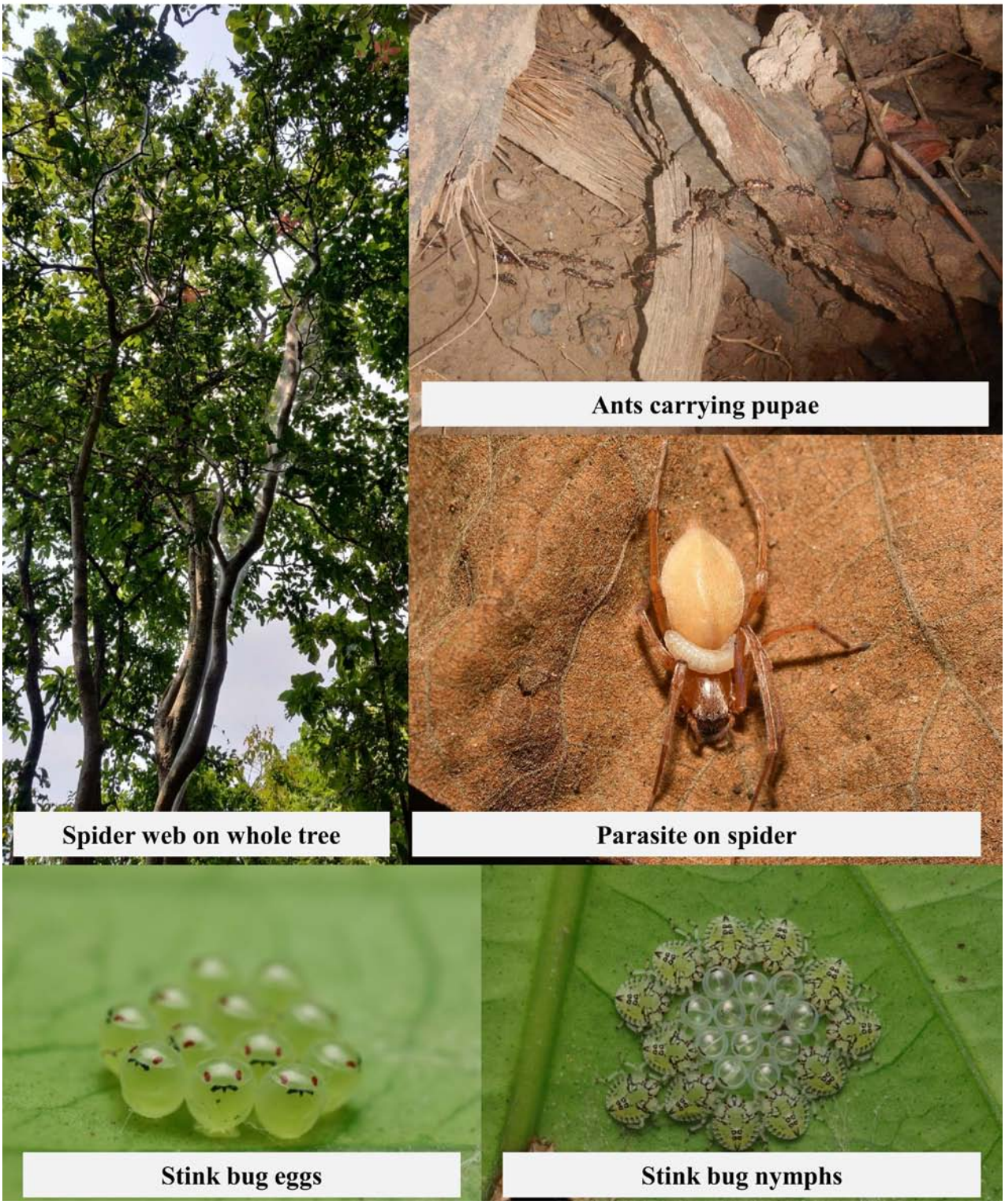
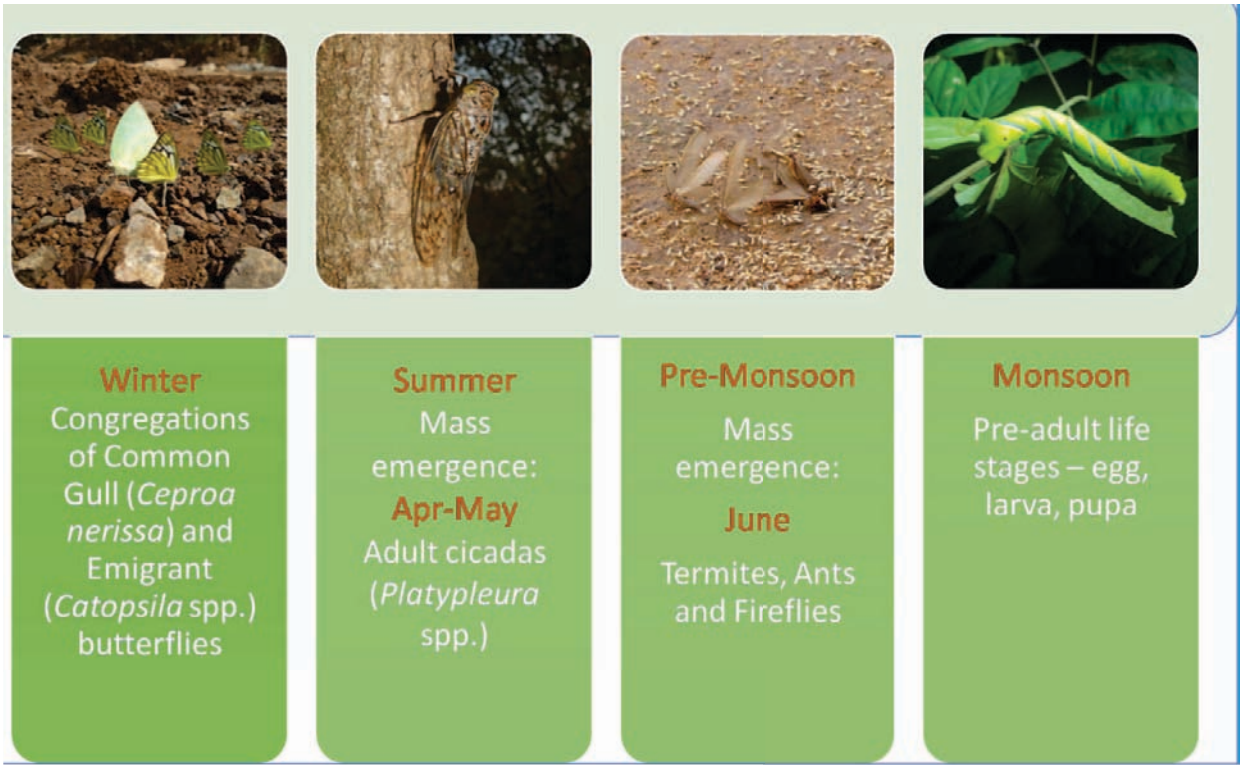


Plate 16: Seasonality and life-cycles of insects observed throughout the study duration



CHAPTER-7

Way Forword

PHASE II of BNHS-GMLR Project

Survey and Monitoring during construction of the tunnel through SGNP in the GMLR project

Components:

1. Information generated from Phase I
2. What environmental impacts will be measured during construction
3. What are the effects on biodiversity that will be measured?
4. Analyzing the potential for mitigating impacts
5. Way forward Phase III

I. Phase I: Biodiversity assessment review

- **Flora**: Checklist, phenology and habitat characteristics
- **Fauna**: Checklist of spider, insect, amphibians, reptiles, birds, mammals; life-history and habitat preferences

II. Environment Impacts

The potential environment impacts of construction of the tunnel passing through SGNP can be appraised under the following categories:

1. Air Pollution
2. Noise Pollution
3. Land degradation and land-use changes
4. Effects on the water table
5. Vibration emanating during the tunneling process (substrate bound disturbance or noise)

It is possible some of the listed impacts may be negligeable to absent. However, systematic testing and quantification can give a very clear picture and indicate how and where interventions and mitigation measures should be directed.

III. Study of environment impacts on biodiversity

1. Monitoring biodiversity and species composition
2. Monitoring habitat-level changes

3. Effects on environmental variables (soil surface temperature, soil moisture)
4. Nominating 5 representative species from each taxa and testing for effects of environment impacts of life-history process (phenology, migrant records, activity patterns, inter-intra-specific interactions- plant-animal interactions, life-history observations)
5. Experimental designs for testing impacts (optional as requires field permission)

IV. Examining the scope for mitigation

In the situation where any evidence of environment impacts on the biodiversity is indicated from the Phase II studies, possible mitigation measures will be devised and recommended

V. Phase III

The impacts on the environment due to tunnel construction activity as identified in Phase II and then later mitigated based on the recommendations, will be monitored after construction is completed and the GMLR is operational. The specific monitoring protocols will be provided at the end of Phase II

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Appendix - 1

Plate 17: Representative photographs of Flora species observed during the survey

Mitragyna parvifolia

Viscum album

Acampe praemorsa

Cassia fistula

Hemidesmus indicus

Chlorophytum tuberosum

Argemone mexicana

Sterculia colorata

Getonia floribunda

Curculigo orchioides

Erythrina variegata

Eranthemum roseum

Plate 18 : Representative photographs of Arachnid species observed during the survey

Ctenus spp.

Meemerus bivitattus

Hersilia spp.

Eriovixia spp.

Epeus spp.

Heterometrus spp.

Dictis spp.

Cocalus spp.

Dedralycosa spp.

Cyclosa spp.

Tick

Trombidiidae spp.

Plate 19 : Representative photographs of Insect species observed during the survey

Common Nawab caterpillar

Common torrent hawk

Plant hopper

Leaf Beetle

Harvester Ants nest

Hover Fly

Antlion Larva

Geometrid Looper moth

Ants preying on cricket

Black Rajah feeding on animal dropping

Robberfly feeding on a winged termite

Cataulacus taprobanae

Plate 20: Representative photographs of Herpetofauna species observed during the survey

Cyrtodactylus deccanensis

Cyrtodactylus varadgirii

Hemidectalus cf *murryi*

Polypedates maculatus

Microhyla ornata

Sphaerotheca maskeyi

Hoplobatrachus tigerinus

Hydrophylax bahuvistara

Chamaeleo zeylanicus

Eutropis allapallensis

Echis carinatus

Craspedocephalus gramineus

Plate 21 : Representative photographs of Avifauna species observed during the survey

Grey Junglefowl

Asian Green Bee-eater

Indian Grey Hornbill

Indian Pitta

Greater Racquet-tailed Drongo

Brown-breasted Flycatcher

Black-hooded Oriole

Spotted Owlet

Golden-fronted Leafbird

Brown Boobook

White-eyed Buzzard

Rufous Treepie

Plate 22 : Representative photographs of Mammal species observed during the survey

Spotted deer

Sambar

Barking deer

Wild boar

Indian palm squirrel

Common pipistrelle

Wild boar

Bonnet macaque

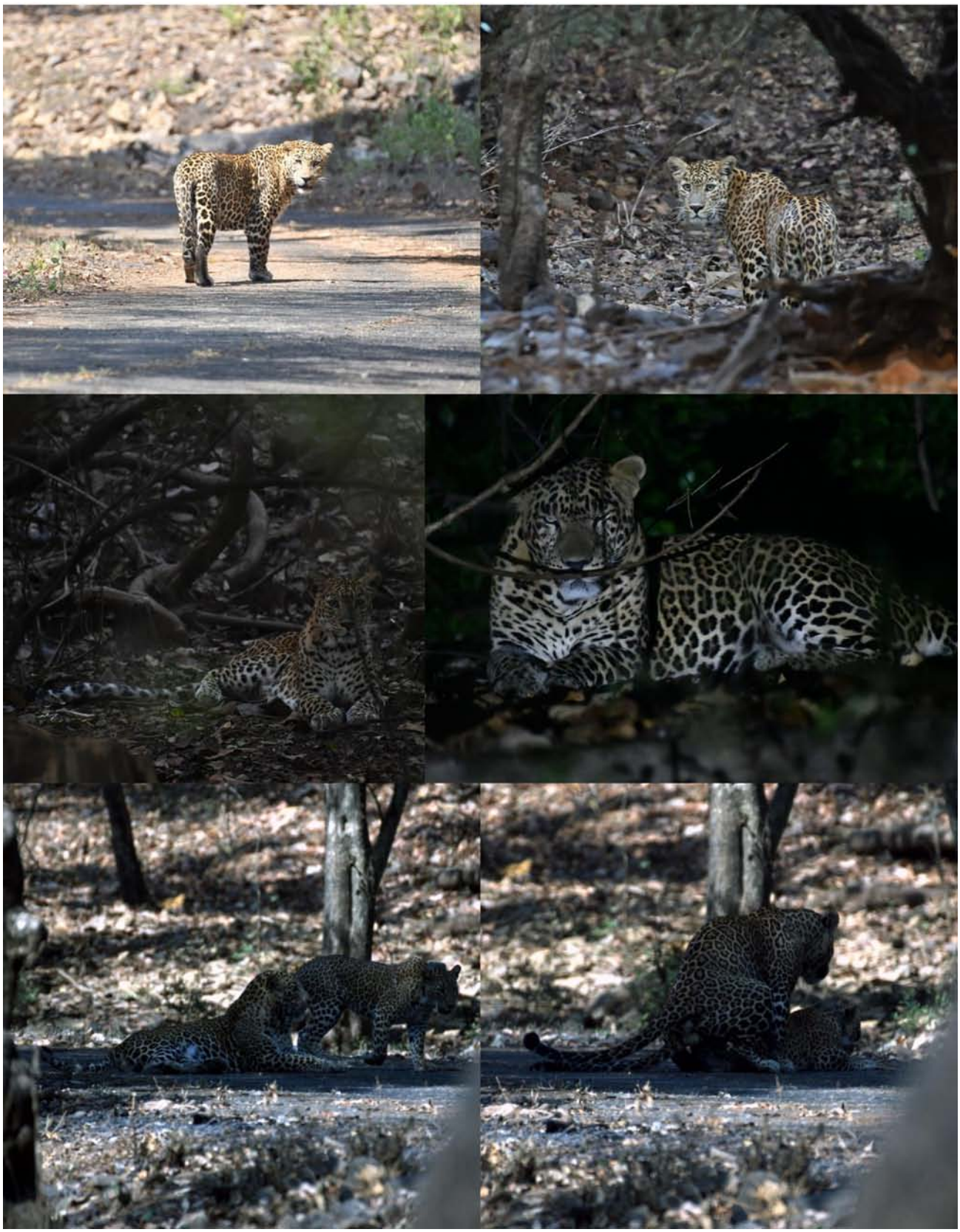
Rhesus macaque

Jungle cat

Asian palm civet

Small Indian civet

Plate 23: Leopards observed during the survey



Appendix - 2

Plate 24 : Root Length Measurement

Appendix - 2 (contd.)

Roots depth data

To study the growth of roots, measurements of fallen tree roots, trees near streams with exposed roots were taken from different grids. Measurements of root depth and transverse as was possible were noted down.

Sr.no	Tree name	Root depth downward	Transverse
1	*Pongamia pinnata*	6ft-10ft	21ft
2	*Lannea coromandelica*	-	40ft
3	*Streblus asper*	5ft	15ft
3	*Tectona grandis*	-	42ft
4	*Anogeissus latifolia*	13ft	20ft
5	*Garuga pinnata*	-	12ft

We may infer from the study that since the roots of herbs and shrub species do not go very deep, they may not be affected by the tunnel's construction across the grids. Geology study of soil columns is advised to determine root depth in order to understand the impact of tunnels on tree roots. It is advised to conduct a thorough analysis of the first, second, and sixth grids due to tunnel alignment and the start and end point of the tunnel, as the likelihood of trees being affected there is highest due to construction. Additionally, it is advised to assess the impact of construction vibration on trees across streams because of their exposed roots.
Limitations (Plate No.24)

- Fall trees, depth primary roots mostly stuck underground and even transverse roots are broken.
- In some trees, it was difficult to measure transverse root and in some cases root depth.
- In many trees it was difficult to identify the primary root.