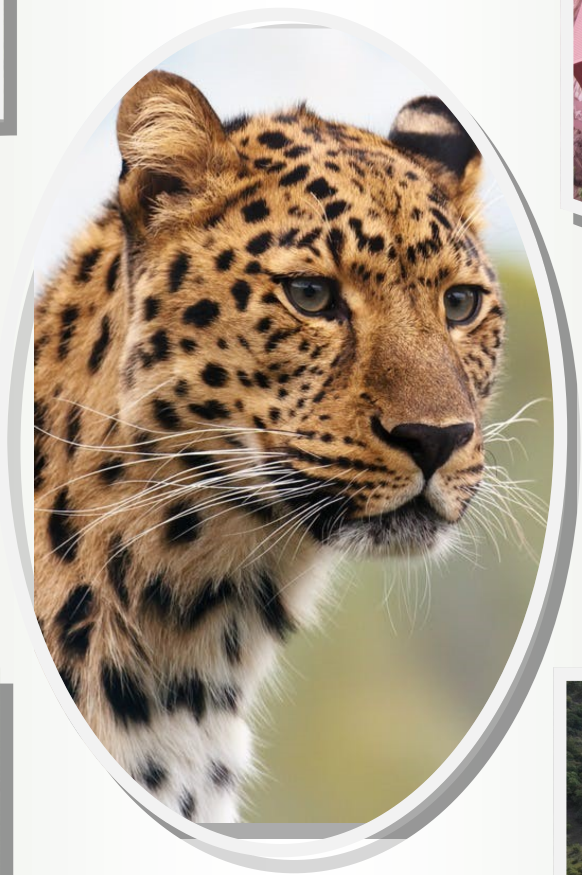
Evaluation of the Impact of Increased Timings of the Operation of Main Pipe Conveyor from Nandihalli Yard to JSW Plant on Wildlife

SEPTEMBER–2021



Prepared By:

Environmental Management & Policy Research Institute

(Department of Forest ,Ecology and Environment, Government of Karnataka)

Bengaluru-560078

Final Report
On

Evaluation of the Impact of Increased Timings of the Operation of Main Pipe Conveyor from Nandihalli Yard to JSW Plant on Wildlife

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Foreword

The effect/impact of noise and vibrations produced by various sources on human life is well known and is widely studied. But the impact of noise, vibrations and other associated factors on wildlife is lesser-known and not much study has been conducted.

The Government of Karnataka in its letter number FEE 11 FFM 2019 dated 23/03/2021 and the Karnataka Forest Department in its letter number Old File No A5(1). MNG. CR-9/2017-18 and E-office file no. KFD/HOFF/A5-1 (MNG)/46/2018-FC dated 26/03/2021 have entrusted the work of studying the "Evaluation of the impact of increased timings of the operation of the Main Pipe Conveyor from Nandihalli Yard to JSW Plant on Wildlife". In this connection experienced forest personnel having thorough knowledge about wildlife, experts from various wildlife institutions and qualified young personnel in the field of wildlife, conservation biology and ecology were given the task of conducting a study and to prepare a scientific report in this regard.

The study has been completed, and a comprehensive scientific report is being submitted. Since the study period was too short, several issues have been brought out in the report flagging for long term studies. It would be more appropriate to know the impacts of noise, vibrations and various associated factors on wildlife, by taking up long term studies for the issues which are flagged in the report.

Place:

Date: 30/09/2021

(Raj Kishore Singh)
Director General
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Bengaluru

Acknowledgements

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I also thank technical and non-technical staff of EMPRI who directly and indirectly contributed towards the completion of the project.

I Would like to put on record my gratitude to each member of the team who have worked tirelessly during the severe pandemic period.

(Raj Kishore Singh)
Director General
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EXECUTIVE SUMMARY

"The fragile weave of natural sound is being torn apart by our seemingly boundless need to conquer environment rather than to find a way to abide in consonance with it" by Bernie Krause, American musician, and soundscape ecologist.

With the objectives to identify impacts of existing and increased operations of Main Pipe Conveyor (MPC) of Jindal South-West Steel Limited on activity, habitat use of faunal elements and to assess the extent and significance of potential impacts, the proposed study on the '*Evaluation of the impact of increased timings of the operation of the Main Pipe Conveyor from Nandihalli Yard to JSW Plant on Wildlife'* was carried out. Details of the field research result and discussions are given in the form of individual chapters in this report.

Chapter 1 introduces the issue, objectives, terms of references of the project. It provides details on MPC, MPC operations and idlers. Details of the landscape, weather conditions and research methods followed in the projects are also given.

Chapter 2 is on the sound monitoring, noisescape mapping, vibrations and luminescence studied along the stretch of the MPC belt (ToR IV). A total of 16285 minutes of sound was recorded using sound monitoring stations, which includes existing and extended operations of MPC. The frequency spectrum of MPC was found between 10Hz to 5000Hz with higher amplitude. In ultrasonic recorders, spectral signatures of 25000 Hz to 45000 Hz were observed emanating from MPC. The broad spectrum of sound frequency masks the communication frequency of many insect, amphibian, bird and mammal species, including human beings. This will have a detrimental impact on faunal components, be it in communicating with mates, in selecting mates, in residing in a habitat or in selecting a suitable habitat. Spectral correlation between non-operational, operational and extended operation of MPC showed significant differences between them. This is indicative of the variations of frequency spectrograms of sounds from the three operational phases of MPC. Acoustic diversity indices showed that sound records from the MPC in different land-uses differ from sound records from the control sites in the existing MPC operations. Loudness emanating from MPC and attenuations are reported in this chapter based on 1587 sound (dB) measurements made within 250 m on either side of MPC. A maximum of 89.77 dB was recorded within 5 m of MPC, while a minimum of 34.9 dB was recorded at 250 m away from

MPC. A regression analysis explained sound attenuation with distance in this chapter. Sampling points with HDPE idlers were less loud, which was also indicated in sound monitoring station studies. Creating sound absorption spaces, sound barriers, planting a double row of trees along and on both sides of MPC can reduce the noise emission and propagation.

Chapter 3 deals with the assessment of present land use in the MPC belt corridor (ToR I). Six land-use classes are identified in the study area using satellite imagery and ground-truthing. Based on the 2012 and 2021 satellite imageries, change in land use has been detected. Agricultural land to an extent of 260.30 ha has decreased and forest areas up to 396.96 ha are converted to other land-use classes in the 10 km buffer area along MPC. The mining area has increased to an extent of 548.00 ha. About 167.15 ha of scrubland in 10 km buffer, which is 26.88 ha in 2 km buffer are converted to mining/industrial land use. Water bodies have increased by 170.22 ha. Both qualitative and quantitative analyses of Phytoplankton and Zooplanktons at different locations in Naarihalla dam were documented (ToR IV).

Chapter 4 identifies habitats of conservation significance in the study area (ToR II). Based on consolidated number of recorded species from all the taxonomic groups studied (Amphibians, Arthropoda, Aves, Mammals, Plants and Reptiles) and their Inverse Distance Weighted (IDW) interpolation method, the conservation significance area is obtained. Among six different areas along the MPC stretch, a dry deciduous forest patch at Narihalla and open scrub land at Bannihatti accounted for the maximum number of species richness regarding native species, scheduled species and threatened species.

Chapter 5 provides insight into the vegetation of the study area (ToR III and IV). A total of 217 species of flowering plants from 167 genera belonging to 54 different families were recorded in the study. A total of 4502 individuals were recorded from 35 quadrat plots (1.4 ha) in the MPC area while 1300 individuals were recorded from 10 quadrat plots (0.4 ha) of the control area. *Prosopis juliflora* as a tree species accounted for the maximum number of individuals (n=175) and appears to be a dominant species in the MPC stretch. Other invasive species like *Argemone mexicana*, *Lantana camara* var. *aculeate* and *Parthenium hysterophorus* abundantly covering the MPC stretch indicating disturbed forest canopy. Habitat specific faunal species associated with native vegetation also get impacted due to the colonization of invasive species and struggle to adapt to the changing habitat which will ultimately lead to the local extinction of them. Abundant growth of invasive species *Lantana* *camara* var. *aculeata* and *Chromolaena odorata* along the MPC area and it is shown through mean stand density of shrubs was 0.753 individual $m^{2.}$ The basal area of trees along MPC is half of the area covered by trees in control sites indicating the presence of a lower number of tree species along MPC stretch. This confirms the clearing of trees during the construction of MPC. The amount of Carbon stored along the MPC stretch is 9.35 tonnes/ha which is only 50% of the Carbon content stored in the control area. In the perspective of climate change, trees are a very important group that stores high carbon content comparatively.

Chapter 6 details the arthropod diversity in the study area (ToR III, IV, V and VI). One hundred and ninety-two species of insects were identified and about 80% of them were beneficial to the ecosystem as they play many roles as Natural enemies, pollinators, scavengers and many. This suggests that the study area is of high biological value considering the rich biodiversity. Most of the species are endemic to the eastern plains of Karnataka, regulating ecosystem function. Although the cricket calling pattern remains the same in all the habitats, the shift of few hours of late activity and also peaking of their activity after 1 AM during the 20 hours of belt run is of concern. The masking and overlapping effects of cricket and grasshopper calls may manifest in differential impacts, ecologically.

Chapter 7 deals with amphibian surveys in different land-uses of the study area (ToR III, IV, V and VI). Thirteen species of amphibians were recorded from the study. These are listed as least concern according to the IUCN Red List. It is important to conserve even the common species for maintaining the ecological balance. Overall diversity and abundance of amphibians varied between land-uses as well as between Phase I and Phase II of the study. The number of calling individuals declined to 70 in Phase II from 217 in Phase I. This could be attributed to the spectral masking from MPC on the call spectrum of frogs and toads. All the calling species of frogs and toads from this region have a call spectrum below 3500 Hz, while the frequency spectrum of MPC is about 5000 Hz.

Chapter 8 deals with the diversity and distribution of reptiles (ToR III, IV, V and VI). There were 38 species of reptiles recorded in the study area. Reptile diversity was higher in the agricultural land-use in Phase I, while it was built up in Phase II. Reptile diversity and richness decreased from Phase I to Phase II.

Chapter 9 deals with bird diversity and distribution in the study area (ToR III, IV, V and VI). A total of 125 species of birds belonging to 20 orders, 53 families were recorded from the study site. Order Passeriformes with 49 species is the highest, followed by Accipitriformes with 11 species of birds of prey which includes kites, hawks, and eagles. Among 125 bird species, 119 species are under Least Concerned and four (4) species are under Near-threatened and two (2) species under Vulnerable status of IUCN. 124 species are residents, and only one species is found to be migratory, which is a local migrant that is 'Barn Swallow'.

Chapter 10 presents a comprehensive account of the occurrence and abundance of terrestrial small, large mammals, bats and information on rodents (ToR III, IV, V and VI). 33 species of mammals have been documented from the study area. There were five threatened and four species with high priority for protection. Across all habitat types, the diversity of the terrestrial mammals, both large and small mammals was relatively higher in the forest area i.e., the Donimalai Forest Block, and the density of detections were found to be higher in the open scrublands and along the edges of the forest. Among large mammals, Black-Naped Hare was the most abundant species, which was followed by Sloth Bear. The Relative Abundance Index (RAI) values of mammals were relatively higher in control sites, compared to that of MPC area, which indicates that species were more abundant along the MPC. Among all the mammal's species, Four Horned Antelope is a completely forest-dwelling (open scrub) species, thus recorded only in the forest rather than along MPC.

Among Rodents, the squirrels were the dominant species followed by *Ratus rattus*. Most of the rodents were recorded foraging in the cultivated habitat compared to that in scrub and forest habitat. Interestingly systematic observations throughout the cultivated track revealed that rodent burrows were found only at 250 m away from MPC and the spot recorded 42.6 dB sound.

Among bats, the sound emitted from the MPC can result in different types of impact for various bat species depending on various factors. The activity pattern of both *Tadarida aegyptiaca* and *Chaerephon plicatus* show significant variation across each habitat. These bats forage in the open sky and catch their prey by gleaning in the air and detect their prey by echolocation (Arlettaz et al. 2001). This indicates their hunting performance was significantly reduced and their search times increased. This change in behaviour especially for these two species could be either due to the masking effect or a distraction from the ambient noise resulting in their inability to detect prey (Hage and Metzner 2013).

Among bats, Pipistrelle species belonging to Vespertilionidae were found to be more generalist and found across the MPC line irrespective of habitat, the *Miniopterus fuliginosus* was recorded only from forest patch and near streams running across agricultural land. The forest land had the highest diversity with 13 species while the agricultural land interspersed with streams accounted for the second-highest diversity with 11 species. As observed in the Arthropod study the cricket calls are getting masked by the sound from MPC and this could have a significant impact on the bat's ability to detect and hunt its prey. Currently, some of the species of mammals showed high variation in the coefficient value of Δ (overlap in the activity) between 12-hours and 24 hours of belt run, control site and also shift pattern e.g., Sloth Bear (12 h and 20 h belt run: Δ=0.62; MPC and control:Δ=0.50). The overlap curve indicates the delayed start in activity at post 18:00 and early retreat i.e., by 06:00 in both 12 h and 20 h. However, porcupines showed a shift in the start and started early i.e., around 17:00 during the 20 h belt run and the start was delayed by an hour at the control sites. Most free-tailed bats (Mollasidae's) found in India have a peak call frequency ranging from 12 kHz to 30 kHz and two species of mollasidae's namely *Tadarida aegyptiaca* and *Chaerephon plicatus* are present in the study area.

Chapter 11 looks into the aquatic fauna and flora (ToR IV). The qualitative and quantitative analysis report of Phytoplankton and Zooplanktons at different locations in Naarihalla dam were documented.

Chapter 12 is the synthesis of the report.

All these studies put together in the report suggest an impact of existing and extended operations of the MPC on wildlife. Though each wildlife group responds to the sound, frequency, change in landscape and human movements associated with the MPC in a relatively similar manner, these responses are mainly a) searching for impact-free habitats, b) adapting to the newer environment and c) local extinction. Each of these responses is complex depending on the species in question and to understand each of them needs a long term study. The report has highlighted issues associated with the existing and extended operation of MPC in each chapter with discussion and suggestions based on the state-of-the-art understanding about the group of animals being addressed in these chapters.

Chapters dealing with Terms of References

Terms of References

I. Assessment of the present land use in the main conveyor belt corridor
II. Identification of habitats of conservation significance within the area
III. Assessment of the current baseline with respect to habitat status and use by wild animals within the belt conveyor corridor with the current operation of the conveyor belt (for 12hr duration)
IV. Study the effect of conveyor belts associated factors such as physical disturbance, noise and any other disturbance on wildlife and their habitat.
V. Assessment of animal use of the area during the extended time of operation of the conveyor belt on an experimental basis
VI. Comparison of impacts of an increase in the period of conveyor belt operation on wildlife.

Chapter	Title	ToR
Chapter I	Introduction, Description of the MPC with its mechanics and dynamics, Brief note about local Weather parameters and Methodology followed to study various faunal elements and flora	
Chapter II	Sound Monitoring, Noisescape, Vibration And Luminescence	IV
Chapter III	Present Land Use Land Cover In The Main Conveyer Belt	I, IV
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Chapter I: Introduction

CHAPTER I
INTRODUCTION

The planet earth is the major source of minerals. The minerals are valuable natural resources that are deposited in the earth's crust as a mixture of different elements. The metals are extracted from mineral ores conveniently and profitably as these ores include a good proportion of metal. Copper, Iron, Bauxite, Phosphate rock and Gypsum are the top five mined minerals in the World (Brown et al. 2019). India is endowed with a wide variety of mineral resources. Both in terms of quantity and value, there has been a prominent growth in mineral production, since independence. Based on the published data in the annual report 2020-21 from the Ministry of mines (2021), our country produces 95 mineral resources which include 4 fuels, 10 metallic, 23 non-metallic, 3 atomic, 55 minor minerals. During 2020-21, 32 States / Union Territories were reported for mineral production of which the bulk of mineral production (about 87.40%) was confined to 10 States. Rajasthan is a leading state of the country in mineral production (17.14%), which is followed by Odisha (13.72%) and Andhra Pradesh (13.32%). While the Karnataka state stands in sixth position (6.94%). As of 2020-21, Karnataka stands in the third position in increasing its mineral production by 2.53%. The mining industry in India is characterized by a huge number of small operational mines. In the year 2019-20, India has accounted for 1303 mines which were reported for mineral production (excluding atomic, fuel, and minor minerals) (Ministry of Mines Annual Report 2021).

The utilization of mineral wealth deserves a huge amount of energy. The extraction of ore, transportation, processing and marketing are the major challenges in utilizing ores. However, the mining sector is a chief section of the Indian economy but unfortunately, the mining activities cause disturbances to the environment. Initially, in the process of excavation of hard depositions of mineral ores, the disturbance to the environment starts. As minerals are non-renewable natural resources, care has to be taken to use them judiciously.

Iron ore is one of the most common minerals used for the production of steel and cast iron (Semykina 2021). The extracted raw materials need to be transported from the mine yards to the processing unit. Loading of minerals is carried out by an excavator in a dump truck of various loading capacities, which later transports the ore to a processing unit. Throughout the World, there are several means of transportation adopted for transporting ores. The ore transportation systems account for the majority of the cost in mining which significantly impacts the overall profitability (Gonen 2012). The choice of ore transport method is affected by the ease and accessibility of mining sites and their production capacity. The ropeway, conveyor, railway and roadway are the major modes of transportation of bulk materials adopted universally by the steel industry (Kumar and Kumar 2015). Among these, roadways and railways are the maximum adopted system for ore transportation. In roadways, trucks are used for ore transportation in major countries (Semykina 2017). Ore transportation by trucks seems to be the most suitable economic method for many small and medium-sized mines.

The transportation area is considered to have a serious impact on people's health due to traffic and dust exposure (Raj and Karthikeyan 2020). The continuous movement of heavily loaded trucks produces an undesirable amount of dust from both roads and loaded mineral ores. Also, competition between trucks for achieving maximum trips has driven up the chances of accidents on the road.

In India, the total raw coal supplied was 842 million tonnes of which 63.3% of coal were transported through railways. The volume of coal carried by Indian Railways was 48 % and accounted for 45 % of its total freight revenue. Both in terms of volume and revenue, Coal is the largest freight product transported by Indian Railway (Kamboj and Tongia 2018). Though the railway transport system has high efficiency over longer distances high capital investment, less flexibility and high maintenance cost had made to think alternate ways of ore transportation (Buckeridge 1982). As the world's demands for mineral ores have been steadily growing and the whole world economy is expanding, the mining companies urging to adopt better operational practices and pollution-free transport technologies which are more cost-effective both in excavation and transportation of ores.

Every year, mineral-rich state Odisha is facing the problem of transportation of iron ore. More than fifty thousand trucks, twenty-seven railway sidings are engaged in ore transportation. The government decided to control the transport of minerals by road in 2011. The government proposes to limit transportation by road to ensure smooth operation of transportation of minerals to the user industries, ports without traffic congestion (Kumar and Kumar 2015).

Technological processes in mining industries consist of transportation of various raw materials consumes a significant quantity of energy and generate a considerable share of overall mining costs (Krolet al. 2017). An existing transportation system in a mine can still be improved to meet the growing requirements of reducing specific transportation costs and decreasing the CO_2 emissions, dust and also chances of road accidents.

The belt conveyor systems can transport all forms of ores (Krolet al. 2017). They cover a wide range of applications, from mining sites to in-plant or overland where they move material over long distances, passing through undulated terrains and curves. BBC News (2011) reported the world's longest belt conveyor conveys phosphate ore over a distance of 98 km from Bou Craa, in the interior of Western Sahara, to the Atlantic seaboard (Lewis 2011). Keeping such examples, JSW in Karnataka has adopted a belt conveyor system for the transportation of iron ore for the first time in 2019. The conveyor belt runs through reserved forests like Donimalai and Swamimalai forest blocks in the Sandur forest range of Ballari Forest Division, Karnataka (Annexure 1.1). The forest stretch along MPC is a dry deciduous type. On both sides, considerable forest area gets impacted than the area diverted under forest conservation act. The Deccan region is slowly in the recent past drawing attention in prioritising the habitat for biodiversity conservation e.g., Daroji Sloth Bear Sanctuary which is very close to the study area is the first-ever bear sanctuary in India, Ranebennuru Blackbuck Sanctuary which is known for its diversity of plains, Siruguppa in Ballari district is one of the Deccan patches having an endangered bird species Great Indian Bustard which prefers plains and scrub. The Deccan plateau has its unique species composition since the belt is passing through the Deccan Forest areas that would be having an area-specific species occurrence and movement.

Anthropogenic noise is a source of stress for wildlife (Wright et al. 2007; Blickley and Patricelli 2010). Noise pollution is known to affect the physiology and behaviour of many animal species (Warren et al. 2006; Kight and Swaddle 2011). Studies have shown that animals avoid foraging in noisy areas (Schaub et al. 2008), increase their vigilance in the presence of noise (Delaney et al., 1999; Karp and Root 2009), select quiet areas to perform their daily activities (Sousa-Lima and Clark 2009; Duarte et al. 2011) and can be distracted by noise, all of which can increase the risk of predation (Chan et al. 2010). Noise can also cause physiological stress (Campo et al. 2005; Kight and Swaddle 2011) and impact on ecological aspects of the lives of animals such as population distribution (Reijen et al. 1998; Bejder et al. 2006), species abundance (Bayne et al. 2008) and diversity (Proppe et al. 2013).

Acoustic communication is essential in the lives of many species as they use such signals to exchange biologically relevant information; for example, to recognize reproductive partners (Brumm et al. 2009), to inform others of their location and/or the type of predator (Chan et al. 2010; Ca¨sar et al. 2012) and to defend resources (Zuberbuehler et al. 1997). However, anthropogenic noise commonly impacts animal communication (Slabbekoorn and Ripmeester 2008; Barber et al. 2009; Laiolo 2010). Noise can interfere with the propagation and detection of signals by masking animal sounds and thus, prevent effective communication (Foote et al. 2004; Bee and Swanson 2007). Nonetheless, many studies have documented that animals use a range of vocal adjustments to minimize the immediate impact of noise on communication systems. These adjustments include frequency shifts (Slabbekoorn and Peet 2003; Parks et al. 2007; Nemeth and Brumm 2009), changes in amplitude (Brumm 2004; Brumm et al. 2009; Hage et al. 2013), calling rate (Sun and Narins 2005), number of notes (Slabbekoorn and Boer-Visser 2006), timing (Fuller et al. 2007), and duration of calls (Brumm et al. 2004). The direct impact of noise on animal behaviour and ecology, and incidental costs of maintaining an efficient communication system through compensatory mechanisms, can impose fitness costs on affected individuals (senders and receivers) and consequently on their survival and reproduction (Chan et al. 2010; Schroeder et al. 2012), and lead to population and community-level changes (Parks et al. 2007; Duarte et al. 2015).

Stereotypic behaviour (i.e., repetitive behaviours induced by frustration, repeated attempts to cope, and/or central nervous system dysfunction: Mason and Rushen 2008) has been related to noise exposure in primates (Patterson-Kane and Farnworth 2006), rodents (Anthony et al. 1959) and pandas (Powell et al. 2006). Anthropogenic noise, especially from transportation, has been known to affect birds and amphibians (Barber et al. 2010; Shannon et al. 2015) and can lower the survival rate and reduced reproductive success in many animals (Gomes et al. 2016). The anthropogenic noise associated with infrastructure could affect the habitat usage by bats (Barberet al. 2010; Bonsen et al. 2015; Francis and Barber 2013). Bats hunt using echolocation and to detect prey based on the sound emitted from them, these sounds could be masked by anthropogenic noise. Such noise could compromise foraging efficiency thus reducing the activity in the noisy areas (Senzaki et al. 2016). Some laboratory experiments have shown that gleaning bats exposed to certain kinds of noise showed a reduction in foraging efficiency and avoid hunting in noise (Schaub et al. 2008; Siemers and Schaub 2011). Reproductive behaviour such as calling behaviour, calling plasticity and mate attraction in amphibians are impacted by noise pollution. Vibrations had negative impacts on the physiology of amphibians (Schaijk 2013).

The exposure to the noise caused by compressors in natural gas fields of New Mexico showed a decrease in corticosterone amongst adults and nestlings and, conversely, increases acute stressor-induced corticosterone in nestlings and also documented fitness consequences with increased noise in the form of reduced hatching success in the western bluebird (Kleist et al. 2018). A 10-decibel increase in noise above natural levels can shrink an animal's listening area by 90 per cent.

Noise exposure has negative physiological effects on animals, including hearing impairment and deafness, disrupted responses of the hypothalamic-pituitary-adrenal axis, reproductive problems and immune suppression (Kightand Swaddle 2011). High amplitude noise elicited stress, which is possibly related to the acoustic features that mining noise and other sounds with threatening characteristics share (Mancera 2017).

Though conveyor belt has many merits regarding ore transportation, the impacts of noise produced by the belt required to be explored in the perspective of wild lives. Not only noise, but also it creates a vibration on the ground and other associated factors during the belt run, and also if the loading stations are operated during the night, then they use flood light to work in the night. These factors also can have a negative impact on the wild lives in the forest. Hence, the present short term study of 'Evaluation of the impacts of increased timing of the operation of the Main Conveyer Belt from Nandihalli Yard to JSW Plant on Wildlife in Sandur, Ballari district, Karnataka' was undertaken. This short term study aims to cover the larger landscape approach in the perspective of the impact of noise and its associated factors on wildlife behaviour and ecology.

The Issue

Main Pipe Conveyor (MPC) belt system was adapted by Jindal South-West Steel limited (JSW) in the year 2019 and is operating for iron ore transportation from Nandihalli yard to JSW plant at Thoranagallu, Ballari along 24km stretch. It is permitted to operate from 06.00 AM to 6.00 PM. While operating, MPC produces a sound of pressure crossing >40 dB. JSW has proposed to extend the time limit of belt run till 02.00 AM in the night. The MPC is running through forests and as well as human habitation areas. Both wildlife and humans were suspected to get affected by the sound generated by the MPC during nighttime. That too, nocturnal animals are suspected to get affected by the continuous sound. Amphibians, crickets and bats may undergo serious communication crises, while large mammals like Leopard and Sloth bear may avoid habitat due to noise and suffer to get preferred habitat. Even it may further lead to the overlap in their range between them and combating each other for food and habitats. That in turn may rise to a serious human-wildlife conflict around the area.

Objectives

1. Identify impacts of existing conveyor belt operations on activity and habitat use of important faunal elements.
2. Assess the extent and significance of potential impacts resulting from increased timing of the conveyor belt.

Terms of Reference

1. Assessment of the present land use in the main conveyer belt corridor.
2. Identification of habitats of conservation significance within the area.
3. Assessment of the current baseline concerning habitat status and use by wild animals within the belt conveyor corridor with the current operation of the conveyor belt (for a 12-hour duration).
4. Study the effect of conveyor belts associated factors such as physical disturbance, noise and any other disturbance on wildlife and their habitat.
5. Assessment of animal use of the area during an extended time of operation of the conveyer belt on an experimental basis.
6. Comparison of impacts of an increase in the period of conveyer belt operation on wildlife.

I- Description of Main Pipe Conveyor (MPC) with its Mechanics and Dynamics:

Jindal South-West Steel Ltd. (JSW) had adapted a conveyor system for iron ore transportation from different mines to the processing plant. It is covering a distance of 24 km working for JSW (Fig. 1.1 and 1.2). The construction of the Main Pipe Conveyor started in March 2017 and operation started in May 2019. The system consists of 3 flights of Pipe Conveyor to transport iron ore at 3,500 tons per hour from Nandihalli yard to JSW site at Toranagallu, Ballari district, Karnataka.

The pipe conveyor carries the Iron ore on the top belt of the conveyor from different mines yard to the JSW Plant. For each pipe conveyor, all drive motors start simultaneously on a load sharing basis through the Programmable Logic Control (PLC) system provided for the intended purpose. The speed control for the drives is achieved through Variable Voltage Variable Frequency (VVVF) units. The signal for starting of motor is transmitted through Optical Fibre Cable (OFC), installed along with the belt pipe conveyor gantry structures from the head end to tail end.

Out of the multiple drives for each Pipe Conveyor, one operates as the master drive and the others operating as slaves to the master drive by following the rotation per minute (rpm) and torque in a unique load-sharing mode. The stopping is controlled through VVVF under normal conditions. During emergency conditions i.e., when the pull cord is actuated or power failure, there will be an immediate stopping. This sudden stopping of the system triggers a disc brake provided on the capstan shaft in take-up, through gear and pinion arrangement. This arrests the movement of the trolley under emergency conditions. During start-up after such conditions, the brake is gradually released, commencing after 10 seconds, to balance the tension of the system and the applied tension. The take-up trolley and the counterweight are duly balanced, as the same is supported by 10 falls of a single rope. A single tension rope, originating from a motorized winch mounted on a take-up trolley, after making several loops via several sheaves, capstans and take-up cage for counterweight comes back to the motorized winch. The motorized winch provided for tensioning and de-tensioning during any adjustment at the time of belt splicing or positioning of trolley and counterweight at a particular distance/height.

The pipe conveyors at the ends are flat. After the material receiving zone, the toughing angle of the belt is gradually increased and ultimately pipe is formed through special rollers, finger roller and Pipe Shape Keeping (PSK) roller modules. Each PSK roller module has six rollers at the top carrying side and six rollers at the return side to maintain pipe form and shape at the top and the bottom side. All rollers are suitably placed on one side of the module frame with a small gap in between the roller edges so that belt does not get stuck in between the rollers. At the discharge end, the pipe is again open out to a trough shape and gradually become flat at the discharge pulley. Suitably designed discharge hood and discharge chute with liner provided for the conveyors.

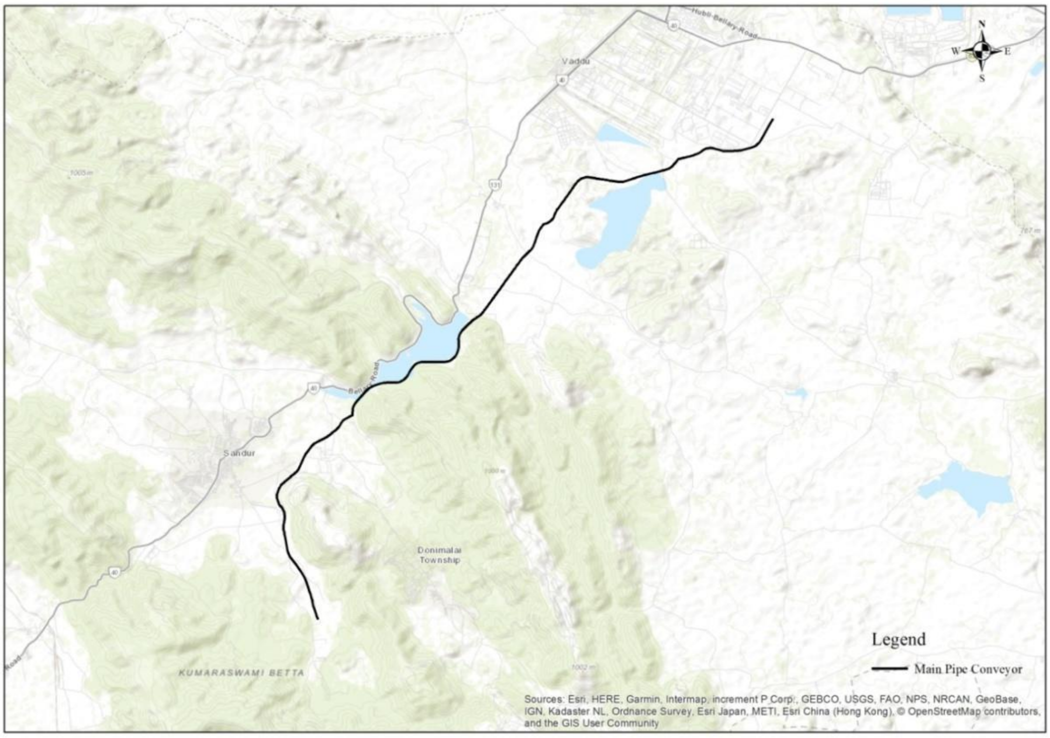


Figure 1.1. Location map of 24km stretch of Main Pipe Conveyor belt from Nandihalli yard to JSW plant

Figure 1.2. Field photograph depiction of Main Pipe Conveyor belt at Narihalla, Sandur, Karnataka**.**

Description of the conveyor item

The components of the conveyor consist of the belt, pulleys, pulley bearings-Plummer blocks, idlers, PSK modules, skirt board, deck plates, pulley frames, drive arrangement, drive base frames and take up arrangements etc. It is not limited to the above-mentioned items and is designed and supplied in line with requirement for completeness of the system. The above-mentioned items for Belt Pipe Conveyor are also similar in construction as of troughed Belt Conveyor, except some specific items as detailed below:

1) Idler (Carrying and Return), PSK (Pipe Shape Keeping) modules – Belt Pipe conveyor: PSK idlers consist of a roller, roller brackets, a module with a support frame (Fig. 1.3a). The number of rollers in each PSK module are 12 (6 for carrying and 6 for return). The PSK modules were fabricated from the MS plate to IS: 2062. The roller was secured with a bracket through fasteners and locking plates. The roller and bracket assembly was fitted with the module through fasteners. Modules were connected in series through pipes, studs and fasteners to impart adequate rigidity. Provision was made for the adjustment of modules by providing slotted holes. Two types of idlers have been used in MCP i.e., HDPE idlers and metallic idlers (Fig. 1.3b, 1.4 and 1.5)

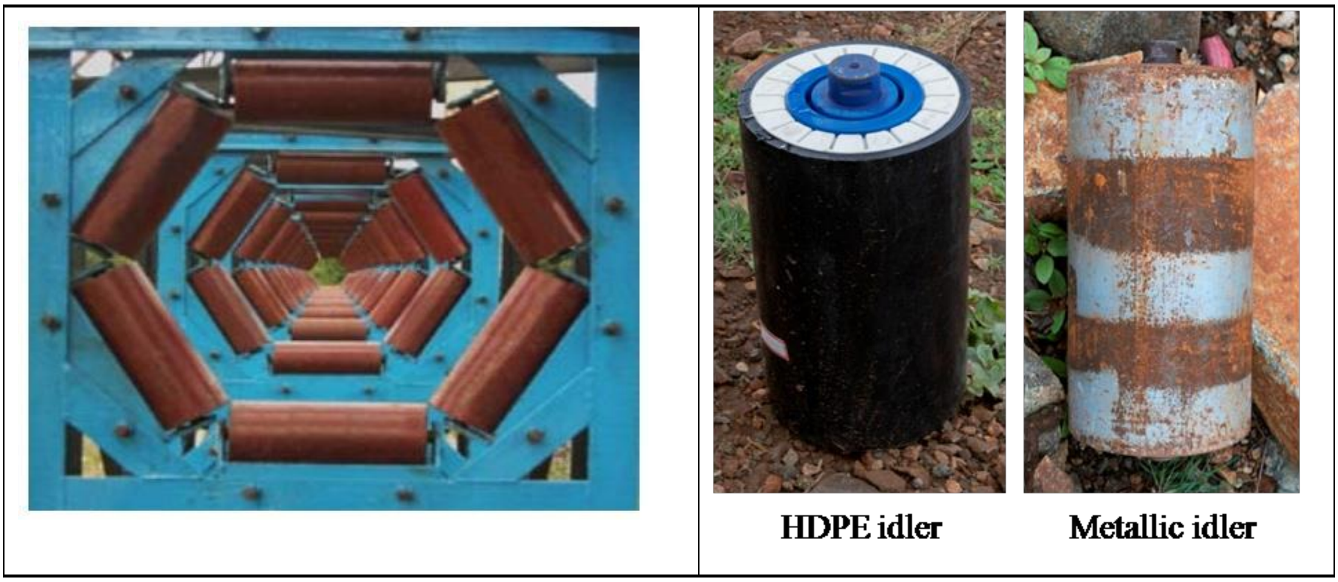


Figure 1.3. a. Organisation of idlers, **b.** HDPE idlers and Metallic idlers

For pipe conveyors, gradual formation of pipe is facilitated by providing adjustable offset type idlers followed by one/two roll idler sets and two-finger rollers. The idlers have been greased and sealed. The bearing housing is made out of deep-drawn quality Cold Rolled Cold Annealed (CRCA) steel sheets of 3.15 mm thickness. The pressed steel bearing housing is simultaneously welded on both sides to the tube using CO_2 welding to form a mono-block construction. Multi lip Nylon Labyrinth/ Zamakare provided to arrest ingress of moisture and dust. End caps are provided.

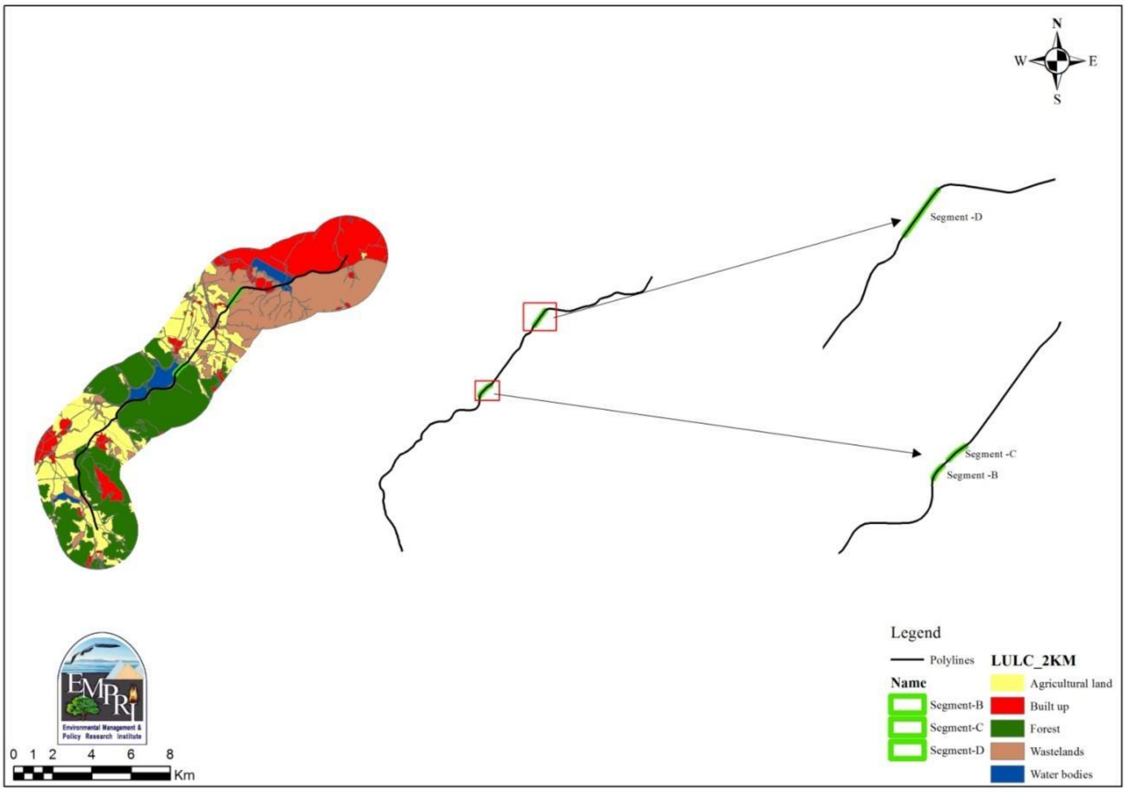


Figure 1.4: Location map of HDPE idlers

Section of MPC having HDPE Idlers, Narihalla, Sandur

Section of MPC having Metallic idlers, Bannihatti, Sandur.

Figure1.5. Field photographs of the sections having HDPE and metallic idlers

Seize resistant type ball bearing of Svenska Kullager fabriken (SKF) Fischer's Automatische Gussstahlkugel fabric (FAG) are used for all types of idlers. The bearings are greased and sealed for life. The idlers are guaranteed for belt speed and load.

The spindles of the idlers are made from C-45/Eqv. Grade steel conforming to IS 1570 or equivalent material. The spindles are precision machined following the standard practice. The brackets for the idlers are fabricated from rolled steel sections.

2) **Belting:** The design, construction, testing and performance of the conveyor belt comply with the latest revision of BS/DIN/JIS/IS. Belting is of steel cord, M24 grade with abrasion-resistant top and bottom covers and Nylon-Nylon type, M24 grade with abrasion-resistant top and bottom covers for the sacrificing conveyors.

3) **Couplings:** High-speed couplings for drivers are the resilient type for pipe conveyors and traction type fluid couplings for sacrificing conveyors. Low-speed couplings are geared type.

Trolley for maintenance of Pipe Conveyor

For each pipe conveyor (PC-1, PC-2, PC-3, PC-4 and PC-5), two self-propelled maintenance trolleys are provided to service the entire length of the Belt Pipe Conveyor. The trolley is specifically designed to allow complete access to all parts of the conveyor structure and conveyor components. The trolley is designed to operate up to 8 km/hr speed.

Terminal stations (Parking bays- by others) are provided at both ends of the conveyor for the vehicle, to allow parking, loading and unloading of personnel/equipment for maintenance. The maintenance trolley runs along track mounted on top chord of conveyor gantry structure (By others). The drive is transmitted to two wheels through differential gear drive to negotiate horizontal curves.

Two pairs of bogie type non-drive wheels are provided for load support and to take care of the undulation of rail. Side guide wheels are provided to ensure stability. The main long travel drive unit is a compact water-cooled 4 stroke 4 cylinder 54.5 hp 2300 rpm diesel engine with an automatic speed transmission system comprising of the gearbox, torque converter and differential unit.

The trolley is operated at any desired speed through the accelerator control. The hydraulic brake system is provided with a master cylinder and foot pedal. The maintenance trolley is controlled and operated via an operator console/dash panel. The dash panel is consisting of an hour meter, temperature gauge, oil pressure gauge, ammeter, voltmeter, fuel level gauge, starting switch, forward / reverse hand lever.

The hand lever is kept in a neutral position during parking. Provision is made in the trolley to carry the operator, assistants and spares along with other tools and tackles as required for maintenance and repair activities. The operator's seat is suitably located to have clear visibility during forward and also the backward movement of the trolley. The vehicle is fitted with driving lights and an overhead floodlight to facilitate operation during dark / night conditions.

The operation of the trolley is done through the dash panel. The start switch is first operated and the operating lever is moved to the forward/reverse direction as required. Thereafter, the accelerator is gradually pressed to move the trolley and then the trolley is driven at any desired speed up to the destination. On reaching the destination, the stop button in the dash panel is operated and the brake is applied for bringing the trolley to a stop position.

For any emergency stopping operation during travel, the hand brake is also used. A separate 5 KVA capacity diesel generator set is provided in the trolley to generate 230 V 1 Phase 50 cycles AC supply to meet the requirement for operation of welding set, grinding wheel. Along with other loads for lighting and auxiliary power requirements. The diesel generator set is in operation only when the trolley is in the "stop" i.e., stationary condition.

Belt monitoring system

A belt monitoring system is provided to monitor the health of the conveyor. As the belt moves, the Magnet Array (mounted on a frame above the belt on the return side) magnetise the steel cords of the belt. The sensor array measures the magnetic properties associated with steel cord damage, which is recorded as a function of belt position to create a damage map. In real-time, the information is transmitted via a control box to a remote computer screen while the results appear in the easy-to-interpret image output. By measuring new input against the map record, Cord Guard detects magnetic discontinuities associated with cord gaps, cord ends and damaged or deteriorated cords and alerts the operator.

Fire detection and protection system (MVWS Only)

The Fire Protection System is set to combat fire covering various areas of Conveying System based on TAC/equivalent standards. The MVWS /fire detection /alarm system is suitably provided for at areas/locations as stated above. The area is considered as "Low Hazard".

Medium Velocity Water Spray System (MVWS) are provided for the proposed 3 nos. sacrificing conveyors (entire length) and transition zones (head end and tail end only) of each of the 5 nos. pipe conveyors. It is assumed that the existing Hydrant System is adequate and water required for the MVWS is provided from the tap off points from these existing Hydrant Systems.

For each of the five pipe conveyors, MVWS are proposed for the feed and tail end transition zones only. The MVWS is designed as one zone at the feed end and one zone at the tail end for each pipe conveyor. Each of these water spray zones is controlled by one 80 NB deluge valve actuated through a solenoid control valve with an electrical emergency push-button for manual actuation. The water density has been calculated at 10.2 pm/sq. meter by TAC recommendations. The water on the discharge side is led through a network of appropriately designed piping networks with the water being sprayed on the conveyor by specially designed open nozzles to achieve the desired cooling on the conveyor. The deluge valve has provisions for remote annunciation of the water spray by pressure switches and local indication by pressure gauges besides the isolating valves for each of the deluge valves which are also have manually operated bypass valves for manual actuation. The fire detection system has been considered with linear heat sensing cables wired to a control panel operated either automatically or manually by the push button stations in case of an emergency.

Loading points

Main Pipe Conveyor has 4 loading points *viz*. Nandihalli, Devdari, Hosalli and Bannihatti transfer points (Fig. 1.6 and 1.7). Among these, the Devdari transfer point is not operating. The ores from nearby mines get transported by trucks and dumped into conveyors through hoppers. Devdari and Bannihatti transfer points have conveyors downhill pipe conveyor from which the ores are transported. Of these, the construction of the downhill pipe conveyor is completed in Devdari while in Bannihatti, it is under construction.

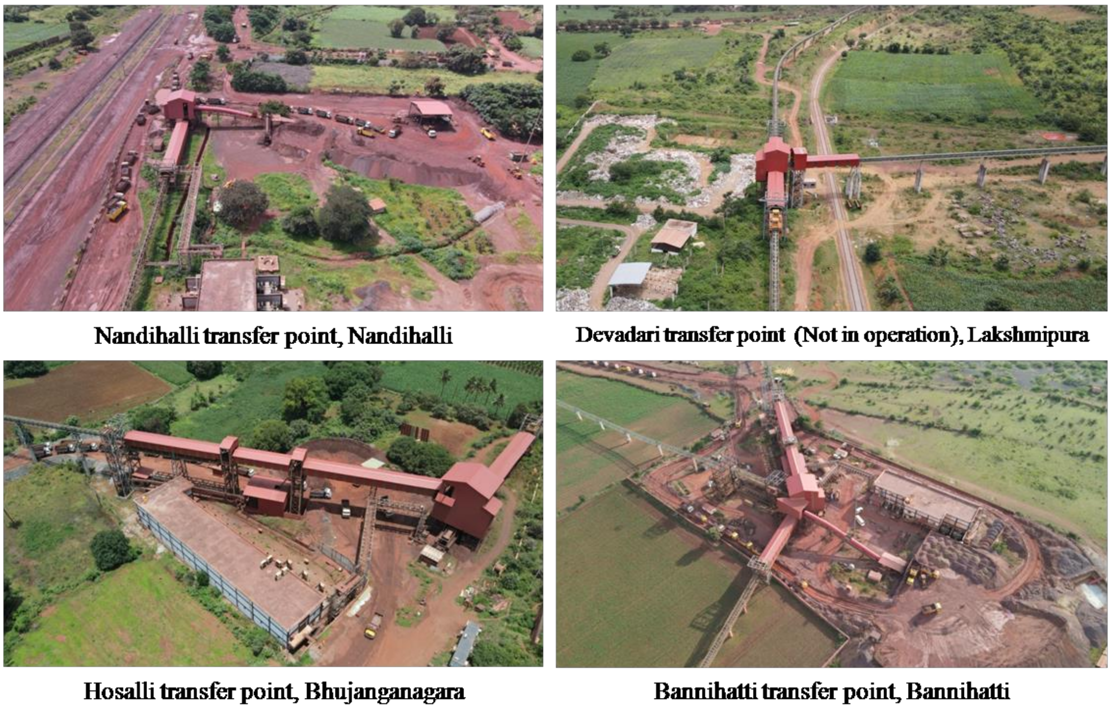


Figure1.6. Ore transfer points along MPC

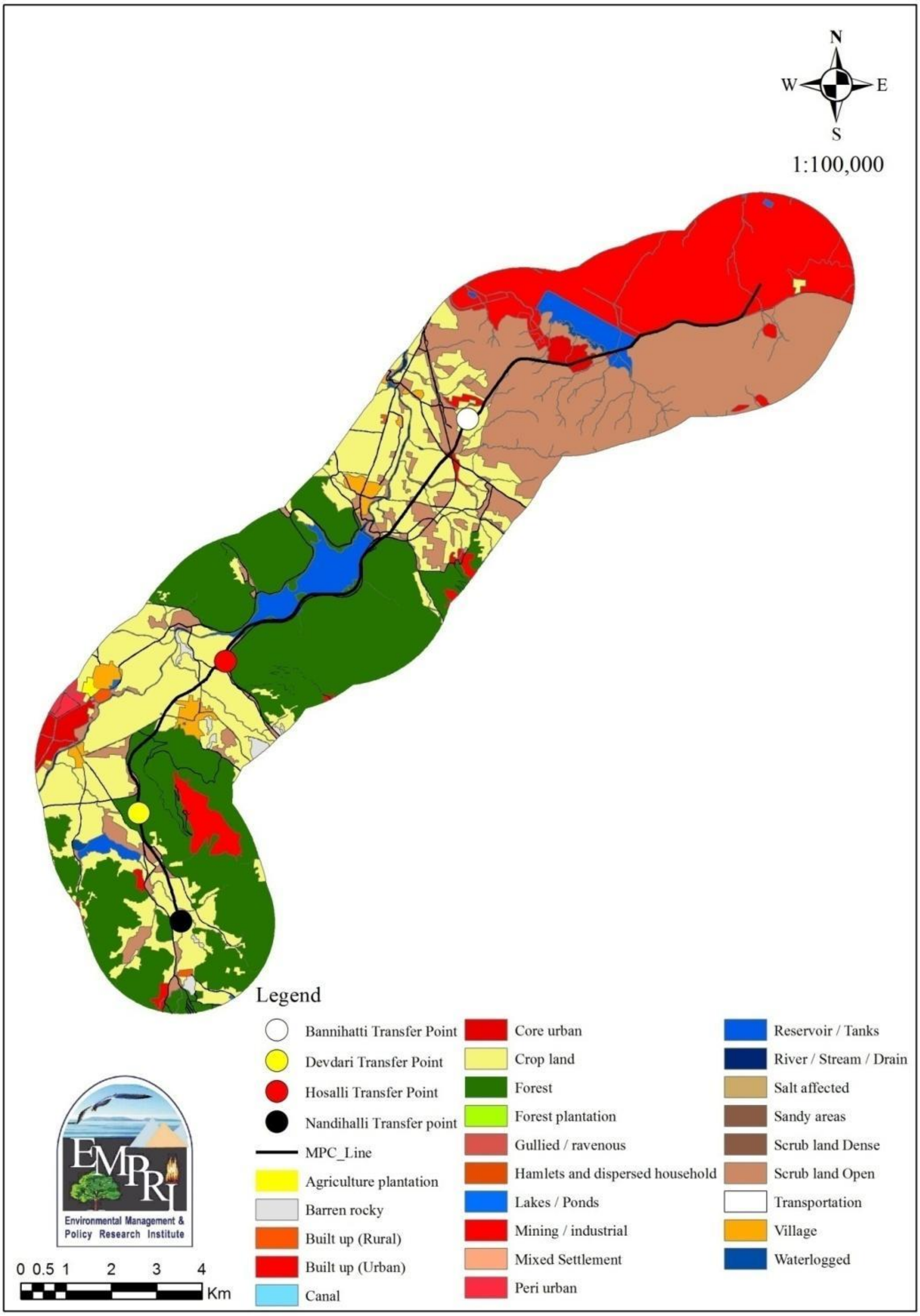


Figure1.7. Location map of transfer points along MPC

II- Brief note about the local weather parameters.

Sandur is located in the Ballari district of Karnataka, India. It has an average elevation of 565 m asl (above MSL) and a tropical savanna climate. It is surrounded by rocky mountains and has forest types of tropical dry deciduous, southern thorny, open scrub and mixed deciduous types. The ten years (2009-18) of weather pattern of Sandur is expressed here based on the meteorological data obtained from meteorological stations of the Karnataka state government authority.

Temperature

Temperature is a measure of degrees of hotness or coldness and is usually expressed in terms of degree Celsius (ºC). Among ten years, the maximum temperature (43.80^{o}C) was recorded during the peak summer season in the year 2009. The minimum temperature was recorded (38.12^{o}C) in the year 2015. The temperature details of ten years from 2009 to 2018 are depicted in Fig. 1.8.

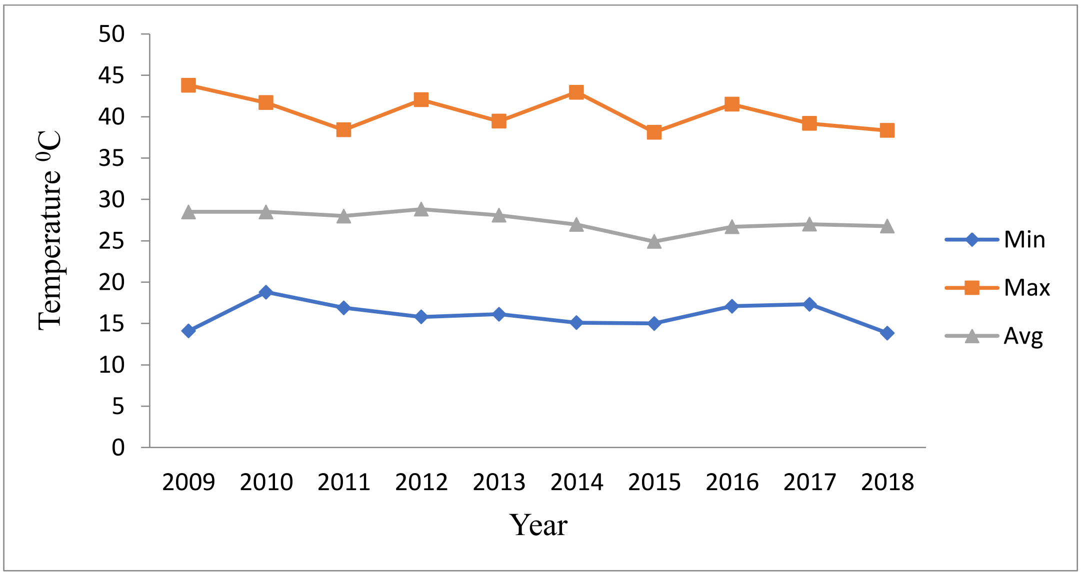


Figure 1.8. Minimum, maximum and average temperature of Sandur region (2009-18).

Relative Humidity

Humidity is the amount of water vapour present in the atmosphere. It indicates the likelihood of precipitation to be present in an area and depends on the temperature and pressure of an atmosphere. The relative humidity is often expressed as a percentage, specifying a present state of absolute humidity. Sandur region is recorded maximum humidity of 99.34 % in the years 2009 and 2012 while minimum humidity recorded (92.0) for the year 2015. The relative humidity of the Sandur region from 2009 to 2018 is depicted in Fig. 1.9.

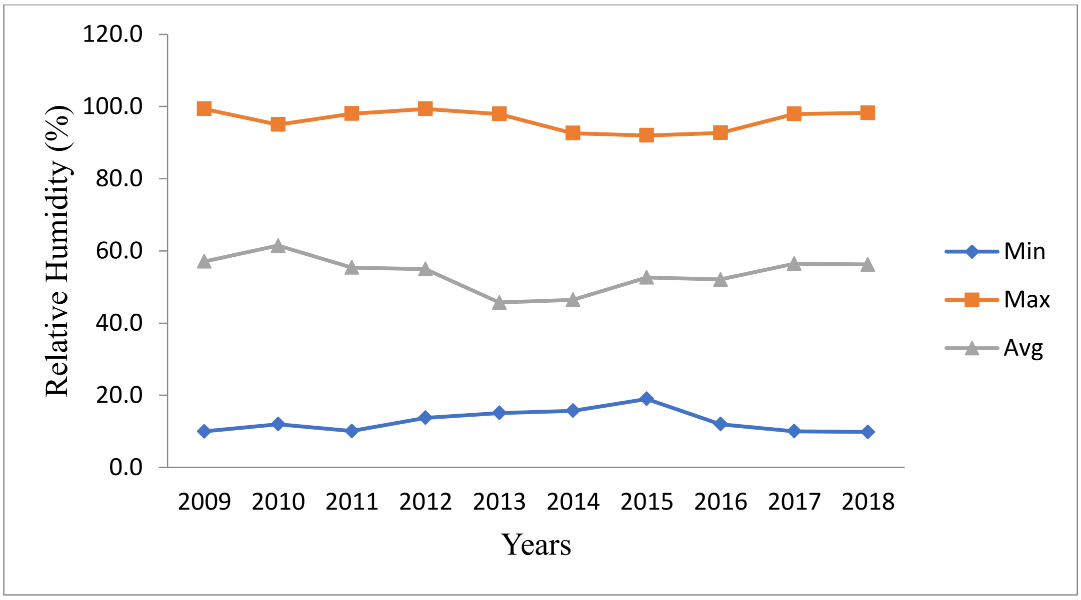


Figure 1.9. Minimum, maximum and average relative humidity of Sandur region (2009-18).

Rainfall

The Sandur region received a maximum rainfall of 803.80 mm of annual rainfall in the year 2009 and was followed by an annual rainfall of 705.50 mm in 2011, while from 2009 to 2018; the least annual rainfall in a region was recorded for the year 2016. The annual rainfall of the Sandur region for ten years (2009-18) is depicted in Fig. 1.10.

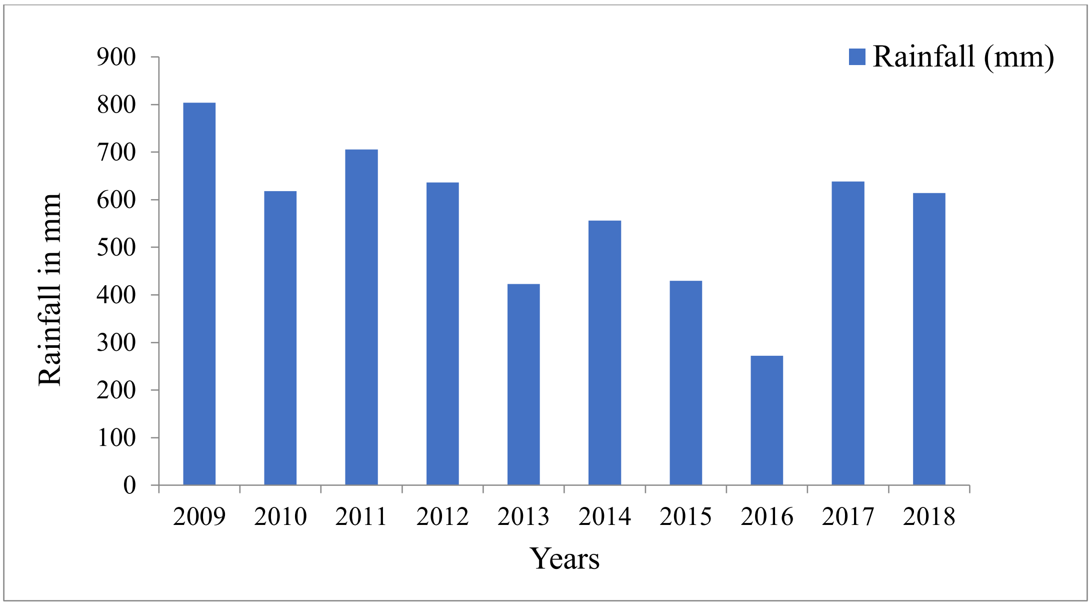


Figure 1.10. The annual rainfall of the Sandur region (2009-18).

III- Methodology followed to study for various faunal elements and flora

Each animal group require a different field technique to study their occurrence, assess their population, and their activity pattern. For the current study, the major group of animals selected includes flowering plants, Arthropods, Amphibians, Reptiles, Aves and Mammals. The field techniques adapted to assess their occurrence; abundance and activity pattern are mentioned in Table 1.1. The details of the each field techniques and the effort are provided in each respective chapter.

Table 1.1. The methodology followed to study the different flora and fauna

<table>
<tr><th colspan="2">Taxa group</th><th>Methodology followed</th></tr>
<tr><td colspan="2">Flowering plants</td><td>Quadrat method</td></tr>
<tr><td rowspan="5">Arthropod</td><td>Terrestrial</td><td>Visual count method along line transact</td></tr>
<tr><td>Airborne</td><td>Sticky trap method</td></tr>
<tr><td>Nocturnal</td><td>Solar LED Light trap method</td></tr>
<tr><td>Soil arthropod</td><td>Tullgrens's Biota extract method</td></tr>
<tr><td>Crickets</td><td>Bioacoustics method (Passive recorders)</td></tr>
<tr><td colspan="2">Amphibians</td><td>Visual encounter survey- Time constraint method, Bioacoustics method (Passive recorders)</td></tr>
<tr><td colspan="2">Reptiles</td><td>Visual encounter survey- Time constraint method</td></tr>
<tr><td colspan="2">Aves</td><td>Point transact method</td></tr>
<tr><td rowspan="3">Mammals</td><td>Bat</td><td>Bioacoustics method (Active and Passive recorders)</td></tr>
<tr><td>Large mammals</td><td>Belt transect, Line transect and Camera trapping method</td></tr>
<tr><td>Rodents</td><td>Sherman trap method</td></tr>
</table>

Chapter II: Sound Monitoring, Noisescape, Vibration and Luminescence

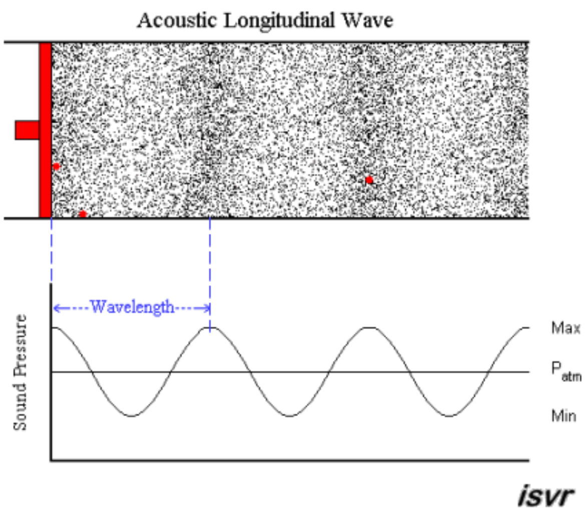
CHAPTER II
SOUND MONITORING, NOISESCAPE, VIBRATION AND LUMINESCENCE

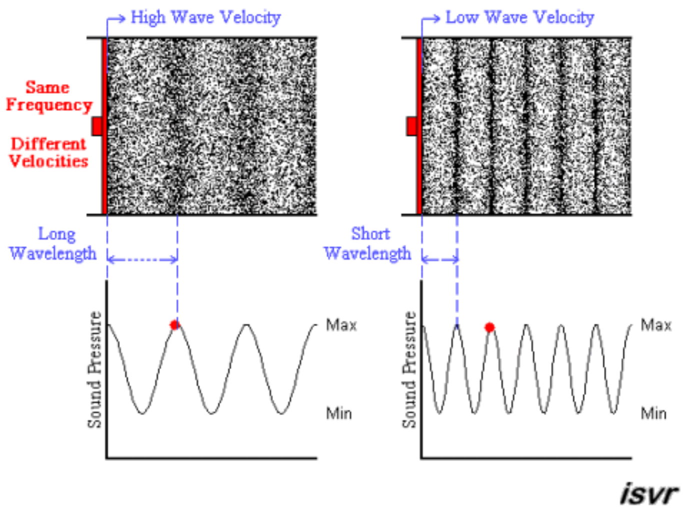
Sound Monitoring

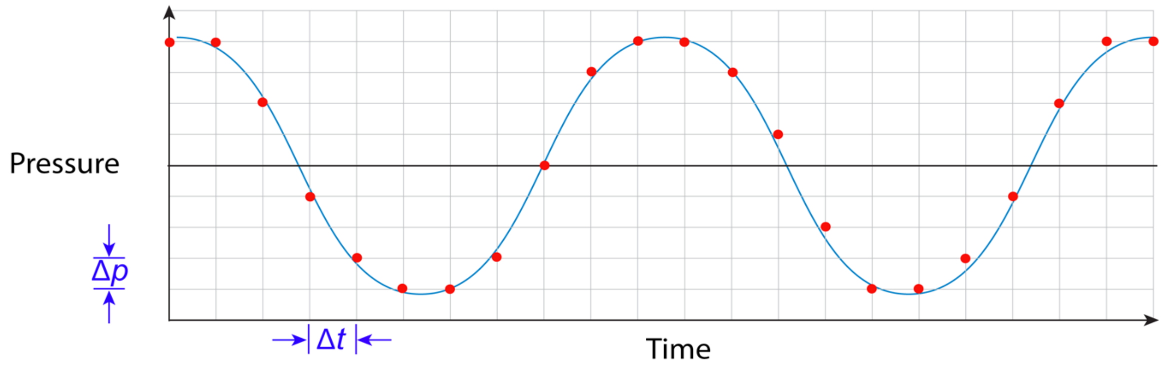
Introduction

Sound (or noise) is the result of pressure variations, or oscillations, in a medium (e.g., air, water, solids), generated by a vibrating surface, or turbulent fluid flow. Sound propagates in the form of longitudinal waves, involving a succession of compressions and rarefactions in the medium. Noise can be defined as a "disagreeable or undesired sound" or other disturbance. From the acoustics point of view, sound and noise constitute the same phenomenon of atmospheric pressure fluctuations about the mean atmospheric pressure; the differentiation is greatly subjective. The recognition of noise as a serious health hazard is a development of modern times. With modern industry, the multitude of sources has accelerated noise-induced hearing loss.

Sound waves are characterised by a) the amplitude of pressure changes, which can be described by the maximum pressure amplitude, or the root-mean-square amplitude, and is expressed in Pascal (Pa); b) the wavelength (λ), which is the distance travelled by the pressure wave during one cycle; c) the frequency (f), which is the number of pressure variation cycles in the medium per unit time, or simply, the number of cycles per second, and is expressed in Hertz (Hz) and d) the period (T), which is the time taken for one cycle of a wave to pass a fixed point.







Frequency plays an important role in speech, music, and animal acoustic communication. It is, therefore, crucial to describe properly the frequency features of the studied sound. To measure the frequency of a pure tone is made possible by directly scrutinizing the waveform and by estimating the time T. However, this measurement is arduous when the sound to analyse is made of several frequencies possibly changing with time. It is then necessary to find a way to travel back and forth between the time domain and the frequency domain. The time-frequency analysis is made using Fourier transformation and its inverse version and is systematically used in linear acoustics (Jerome, 2018).

Digital recording is a discrete process of data acquisition. The process of converting an analogue signal into serial binary data is called pulse code modulation (PCM). Sound is recorded through regular samples. These samples are taken at a specified rate, named the sampling frequency or sampling rate *fs* given in Hz or kHz. The most common rate is 44,100Hz (or 44.1 kHz), but the lower rate can be used for low-frequency sound (e.g. 22.05 kHz), or a higher rate can be used for high-frequency sound (up to 192kHz or even higher). (Charif et al, 2010).

Literature Review

This review is predominantly based on Deichmann et al, (2017). Sounds produced by human-induced landscape changes (traffic), construction machinery, camp maintenance and drilling may also mask acoustic signals of vocalizing species, potentially motivating individuals to alter the acoustic activity or relocate (Sun and Narins, 2005, Slabbekoorn and Ripmeester, 2008, Francis et al., 2010). Anthropogenic disturbance can, directly and indirectly, affect a variety of behaviours essential to the fitness and survival of species

including defence, courtship, mating and reproduction (Barber et al., 2010, Kight and Swaddle, 2011, Slabbekoorn et al., 2010, Weilgart, 2007).
While traditional ecological monitoring has focused on direct observations of focal organisms or visual signs of their presence (e.g. Heyer et al., 1994, Wilson et al., 1996), passive acoustic monitoring (PAM) uses recorders placed in a study area to record vocalizations and detect the presence of species (Blumstein et al., 2011). Acoustic methods offer a cost-effective way to autonomously collect large amounts of data, providing continuous, simultaneous and permanent records of vocal animals that can be revisited and reanalyzed to answer new questions or to apply new methods (Aide et al., 2013).

Passive acoustic monitoring has been used to evaluate the impacts of specific human-induced activities on specific focal species or taxonomic groups. In marine environments, it has been used along with visual methods to evaluate impacts of seismic exploration on whales and dolphins (Goold, 1996, Potter et al., 2007) and has recently been identified as a best practice for monitoring marine mammals during seismic activities (Nowacek et al., 2013). In tropical environments where species diversity is generally high, results regarding a single or even a few species are not likely to provide information that can be extrapolated to the community as a whole. This problem can be partially addressed by analyzing the soundscape (Pijanowski et al., 2011), which allows us to visualize all the frequencies that are dominant during certain times of the day or season, providing a framework to describe, compare and analyze acoustic information from many sites and many animal taxa simultaneously.

Soundscapes offer the potential to study biodiversity and community dynamics of vocal species in an ecosystem impacted by immediate threats such as logging, agricultural expansion, and energy development, as well as challenges with more latent impacts such as climate change.

In the present study Sound Monitoring Stations (SMS, also known as Passive Acoustic Monitoring PAM) are used to

1. Aggregate acoustic recordings along 24km long Main Pain Conveyor (MPC) Belt in different land-uses
2. Differentiate acoustic records based on MPC operation and non-operation for 12h duration (Phase I) and 20h duration (Phase II).

3. Visualize acoustic records using spectrograms, spectral correlation and masking effect on species that inhabit the landscape
4. Differentiate acoustic records using acoustics diversity indices

Materials and Methods

Instrument and measurements: Six sound monitoring stations (Figure 2.1 A and B) were deployed in the study based on the different land-uses as well as the noise scape (Figure 2.2 and 2.3). Each SMS consisted of a Raspberry Pi A+, a hygrometer sensor (AM2302), a Real-Time Clock (RTC, Adafruit PCF8523) and a waterproof omnidirectional condenser microphone (Kingstate KEEG1538WB-100LB) with a frequency response of 20 Hz – 20 kHz and a sensitivity of -42 dB. The stations were placed at about 1.5m above ground level and supplied with a Lapguard power bank (20000mAh) supply. The SMS were housed in a waterproof 248 mm x 197 mm x 71 mm MTM survivor box. Each SMS is placed in between 50-80 m from MPC in 5 different land-uses and one control beyond MPC.

A B

Figure 2.1. Sound Monitoring Stations. A. From outside, B. From inside.

Following Karlsson (2018), sounds were recorded at the sampling rate 44.1kHz (Nyquist Frequency range), a sample size of 16 bits and a gain of -28 dB. Recordings were 60 seconds long with 540 seconds of silence, repeated across 24 h. This would be 6 records per hour and 142 records each day.

Software used are Raven Pro 1.6.0, Audacity ®, SigView and *Seewave* plugin in R. These are used to visualize, compute and analyse sound data.

Spectrogram correlation: For quantitative comparisons between spectrograms, spectrogram correlations are performed. This is usually done by sliding two spectrograms of sound records past each other. The methods followed in this study is based on Charif et al., (2010). In Raven Pro 1.6, this is performed under correlation configuration either using waveform or spectrum. At each time offset, a correlation value between the inputs is calculated. These correlation values are then plotted versus time in a correlation plot to show a measure of similarity between the inputs. The time axis of the plot is shown relative to the first input, indicating how far the second input has been offset, so a peak at a positive lag, or time offset, indicates that the second signal occurs at an earlier time than the first. Usually, when correlating spectrograms, the most important information provided is the peak correlation value which shows the similarity between the spectrogram images.

In the present study, for spectrogram correlation at each lag Δt, a normalized correlation value $C_{\Delta t}$ between two spectrograms are calculated using the following formula:

$$C_{\Delta t} = \frac{\sum_{t=1}^{n} \sum_{f=1}^{FFT} (X_{t,f} \cdot Y_{t+\Delta t,f})}{\sqrt{\left(\sum_{t=1}^{n} \sum_{f=1}^{FFT} (X_{t,f})^2\right)\left(\sum_{t=1}^{n} \sum_{f=1}^{FFT} (Y_{t,f})^2\right)}}$$

where n equals (N1+N2) - 1 and N1 and N2 are the numbers of frames in the two spectrograms. Note that this formula corresponds to a correlation using a biased rather than an unbiased normalization. Fast Fourier Transformation (FFT) equals the number of frequency bins, which must be the same for the two spectrograms being correlated. $X_{t,f}$ and $Y_{t+\Delta t,f}$ are the amplitude values in the two spectrograms at frequency f and times t and t+Δt, respectively. The normalized correlation value for spectrograms can vary between 0 and 1. A correlation of 0 means that the non-zero values in the two spectrograms do not coincide at all; a correlation of 1 indicates that the two signals are identical.

Acoustical Diversity Indices (Jerome, 2018): All the acoustical diversity indices were calculated using the *seewave* plugin in R.

1. The amplitude index (M), which is an amplitude index that computes the median of the amplitude envelope, either the absolute or Hilbert amplitude envelope, scaled by the digitization depth of the recording.

2. The temporal entropy index (Ht), is an alpha index that estimates the Shannon evenness of the amplitude envelope. The amplitude envelope, usually the Hilbert amplitude envelope, is scaled by its sum so that the sum of the sample values equals 1. This is equivalent to transform the amplitude envelope into a probability mass function.

3. The acoustic richness index (AR), is based on the ranks of the indices M and Ht obtained for a set of n files. The indices M and Ht are first computed for each file and then sorted into ascending order. The position, or rank, of each file in this forward sort, is then used to compute AR. The index, which is scaled between 0 and 1, depends therefore on the set of the files considered.

Statistical Analysis: PAST, R and MS-excel are used for the statistical comparison of data at

a. Differences within each day (6 am-6 pm and 6 pm-6 am)
b. Differences between days
c. Differences between land-uses and control
d. Differences between Phase-1 and Phase-2

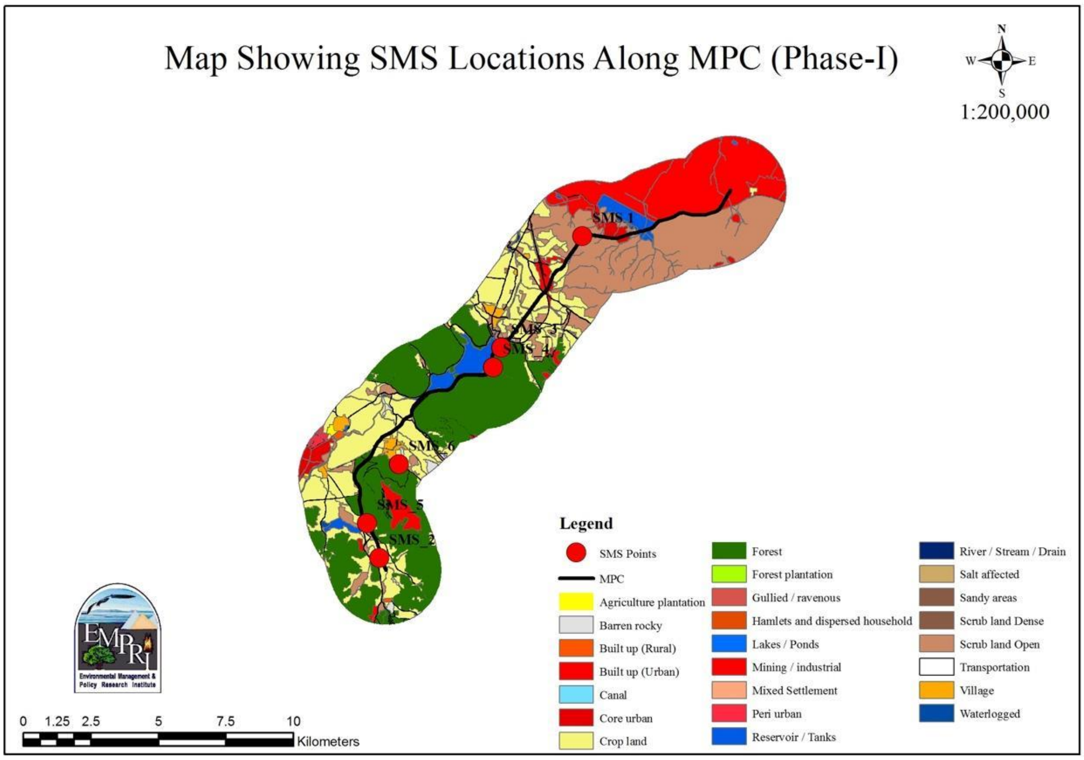


Figure 2.2. Phase-I Sound Monitoring Station installations across various land-uses.

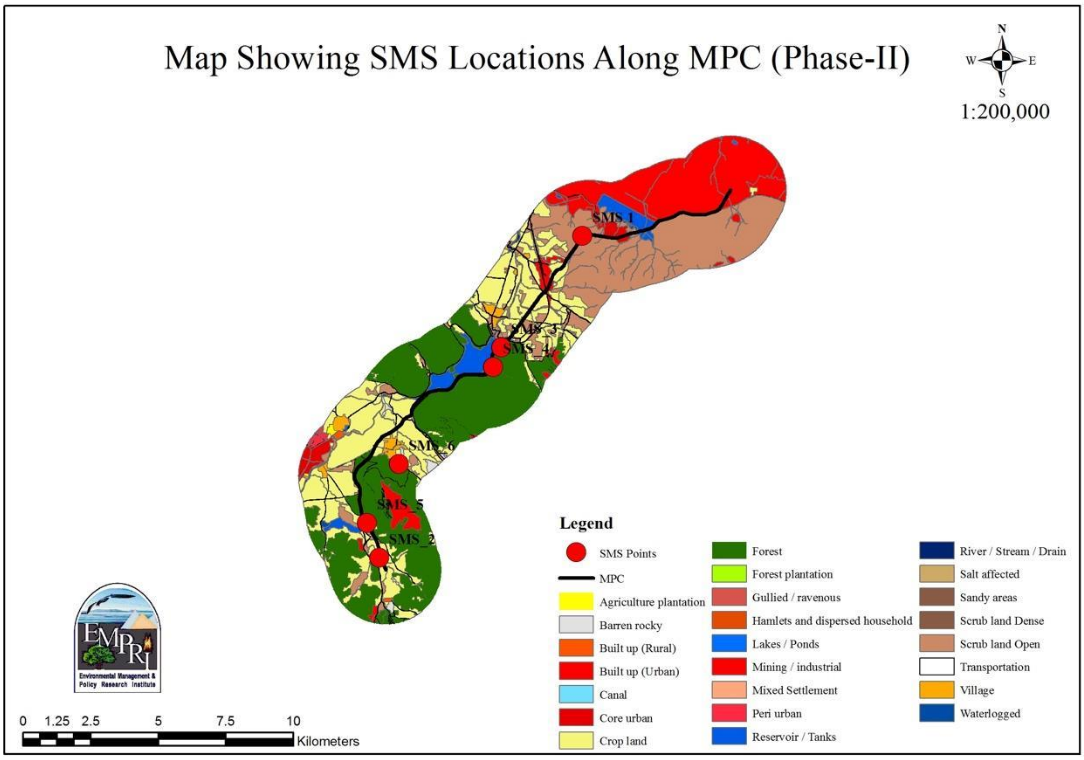


Figure 2.3. Phase-II Sound Monitoring Station installations across various land-uses.

Results

1. Sound recording in Phase I and Phase II

A total of 16285 sound records were collected during the study using 6 SMS (Table 2.1). This amounts to 271.42h of sound recording. In Phase I, which is 12h operation of MPC, 11266 sound records have been collected over 3 months. Similarly, 5019 sound records have been collected in Phase II, which is 20h MPC operations. In Phase II, due to a technical snag in the recording device, sound recorded in SMS3 and SMS5 were not used for any analysis.

Table 2.1. Sound Monitoring Stations with the number of sound records.

SMS #	Land-use	Begin Date	End Date	Total Records	Phase
06	Control	03 July 21	13 July 21	1336	Phase I
01	Grassland	15 July 21	25 July 21	1359	
02	Agriculture	15 July 21	25 July 21	1433	
03	Water	19 June 21	09 July 21	2775	
04	Forest	19 June 21	10 July 21	2633	
05	Builtup	25 July 21	06 August 21	1730	
06	Control	13 August 21	24 August 21	814	Phase II
01	Grassland	13 August 21	24 August 21	517	
02	Agriculture	13 August 21	24 August 21	1220	
03	Water*	13 August 21	24 August 21	1090	
04	Forest	13 August 21	24 August 21	1293	
05	Builtup*	13 August 21	13 August 21	85	

* Data not used for analysis due to technical snag.

2. Visualizing sound records

An audio file consisting of the audio signals can be used viewed using specific software. Raven Pro 1.6, SigView, Audacity® and seewave plugin in R is used in the present study. Here a 60 second sound record is viewed using Raven Pro 1.6. In this study, sounds of the arthropods, amphibians, birds and mammals (bats) are recorded, either in the sound monitoring stations or using specific devices (eg., echo meter for bats, Zoom H1n for amphibians and so on). Each group of the animals and their acoustical characteristic features are discussed separately in the respective chapters. However, all the sound representation follows a similar method and annotations discussed below.

Figure 2.4 demonstrates the waveform (longitudinal waves) of the sound recorded on 29^{th} June 2021 from the control region. Much hidden information within waveform can be viewed if a Fourier transformation is applied to sound. Figure 2.5 illustrates the spectrogram of the above-mentioned sound file. A select spectrum view provides the amplitude within a part of the spectrogram (Figure 2.6). Annotation and spectrum slice is illustrated in Figure 2.7. Waveform and spectrogram of MPC running at 8:10 am recorded in SMS is given in Figure 2.7a. Due to the Nyquist frequency given for sound recording at 44.1 kHz, some ultrasounds emitted from MPC are not recorded in the SMS.

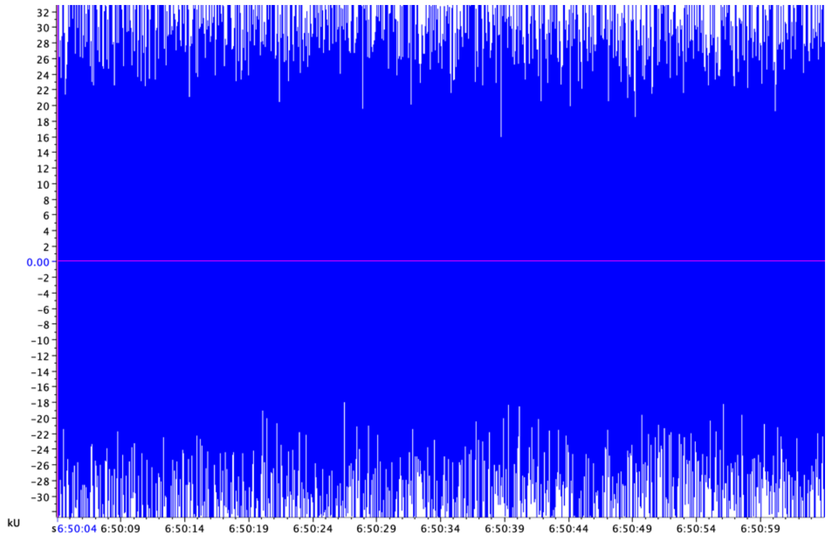


Figure 2.4. Waveform representation of sound recording.

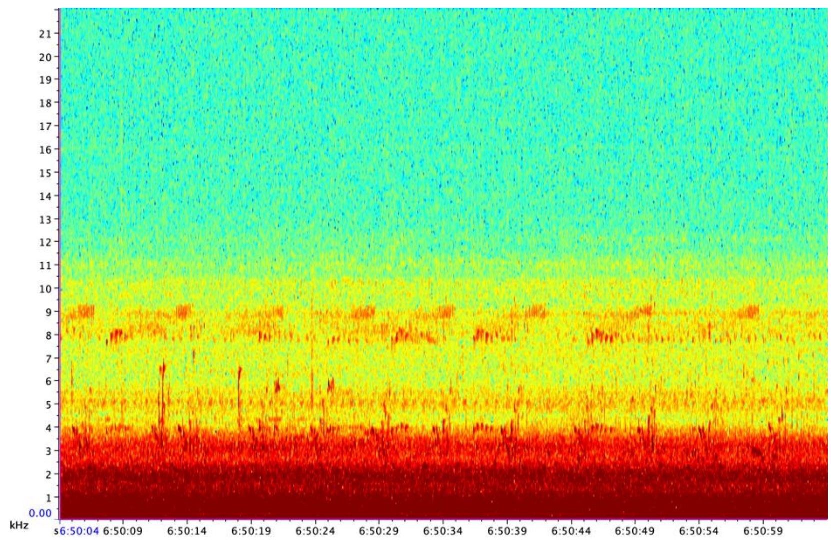


Figure 2.5. Spectrogram view of the sound.

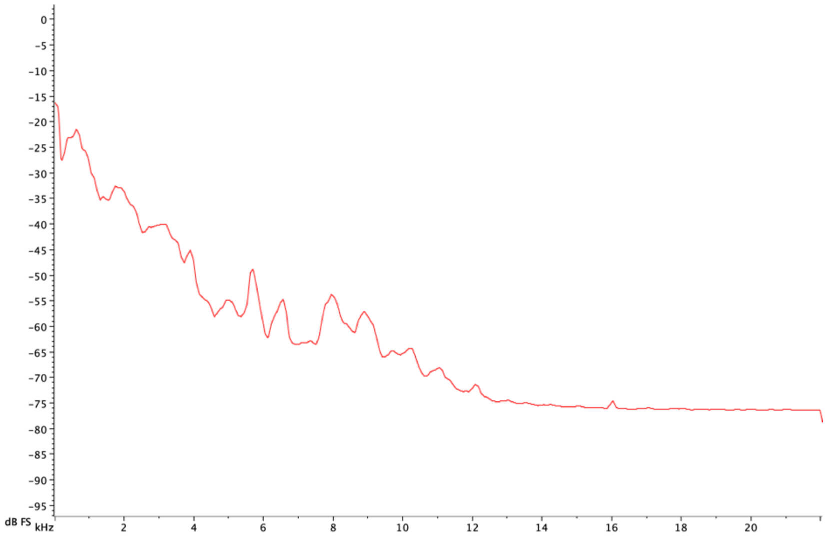


Figure 2.6. Spectrum view of the spectrogram.

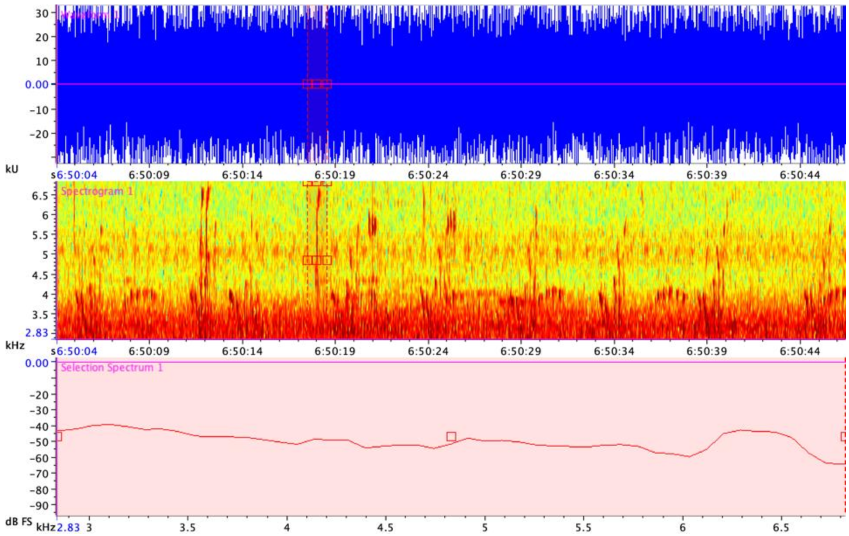


Figure 2.7. Annotation and a respective spectrum view of a bird species.

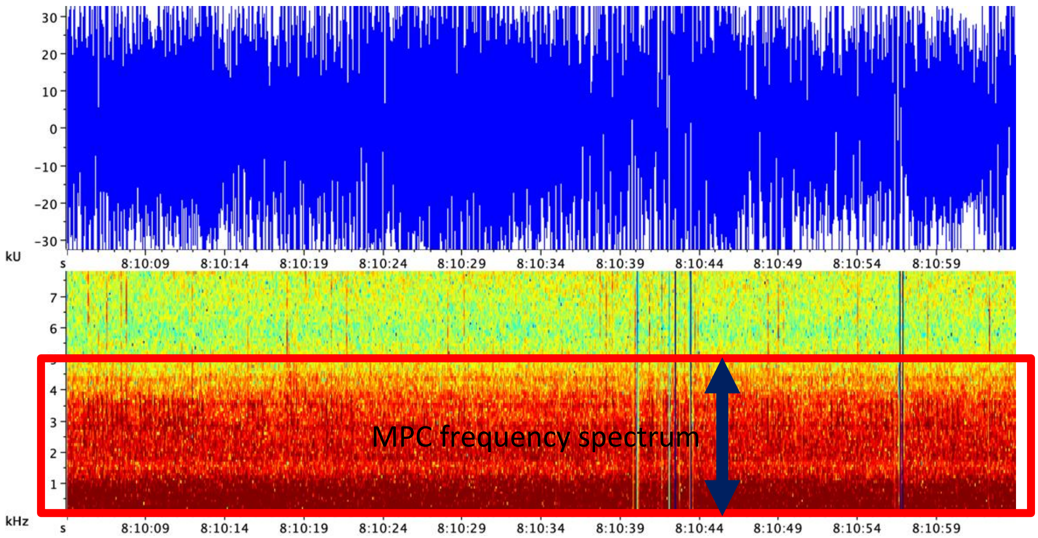
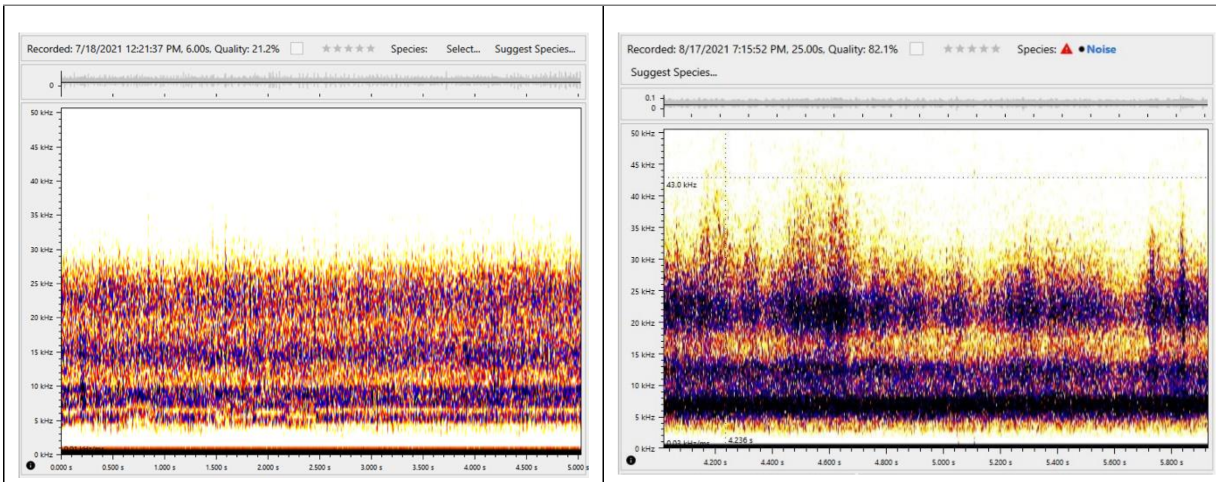


Figure 2.7a. Waveform and spectrogram of MPC running at 8:10 am.

Ultrasonic Sound emission from MPC

The MPC during its operations does emit sound due to the movement of its Steel and HDPE idlers and the belt. The frequency emitted by the MPC varies depending on the speed at which the MPC system is running, and the type of idlers used at the specific section. The average frequency of the sound emitted from the MPC recorded during its regular operational time (06:00 to 18:00 hrs) was up to 25 kHz (Figure 2.7b). The highest frequency from the MPC has been up to 45 kHz when the speed of MPC is at its peak speed. Such high frequency has been documented even at lower speeds wherever the steel idlers are used.

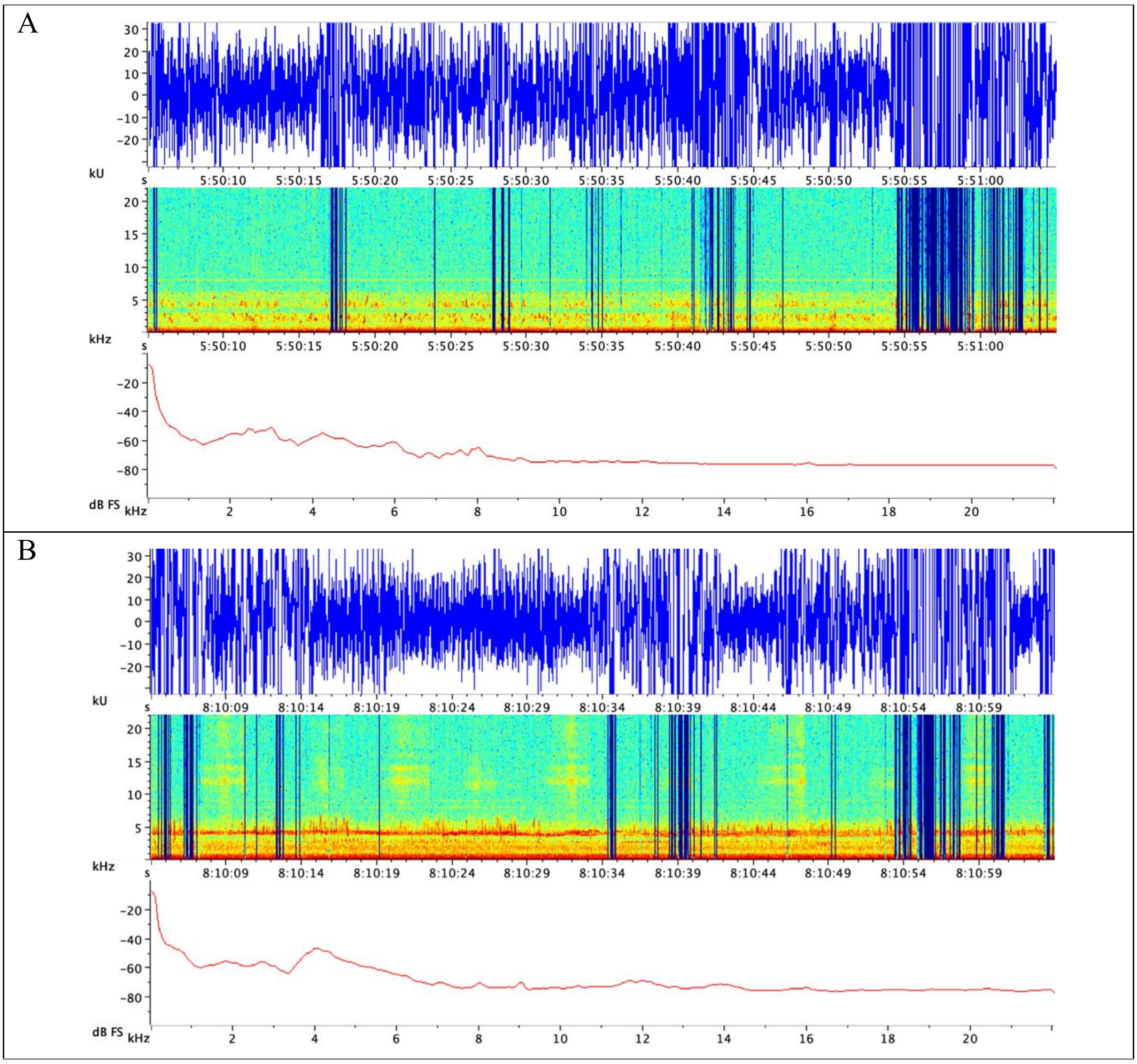


(a) (b)

Figure 2.7b. Frequency of the sound emitted from the MPC. The frequency of the sound was recorded close to 30kHz (a); The frequency of the sound was recorded close to 45kHz, during 20 hours operation (b)

3. Waveform and spectrograms of sound recording in Phase I (ToR III and IV)

A sample audio record from each SMS, as well as different periods (A. 2:00 am to 6:00 am, B. 6:00 am to 6:00 pm, and C. 6:00 pm to 2:00 am), are given for visual understanding. Figure 2.8A depicts a sound record from the grassland area at 5:50 am on 17th July 2021. In the waveform of the sound, it is not possible to distinguish various sounds, however, a spectrogram depicts bird calls and insect sounds very clearly. MPC is not running in this period. In Figure 2.8B, a sound recorded at 8:10 am on 17th July 2021, there is clear evidence of MPC running with a prominent band of 3500 – 4500Hz. In the night sound sample at 7:10 pm on the same date, the spectrum visible between 7000 – 9000Hz is due to insect chorus calls. Less loudness (dB) in the gain of sounds here is relatable to HDPE idlers used, however, the predominant frequency from MPC operation remains at around 3500-4500Hz.



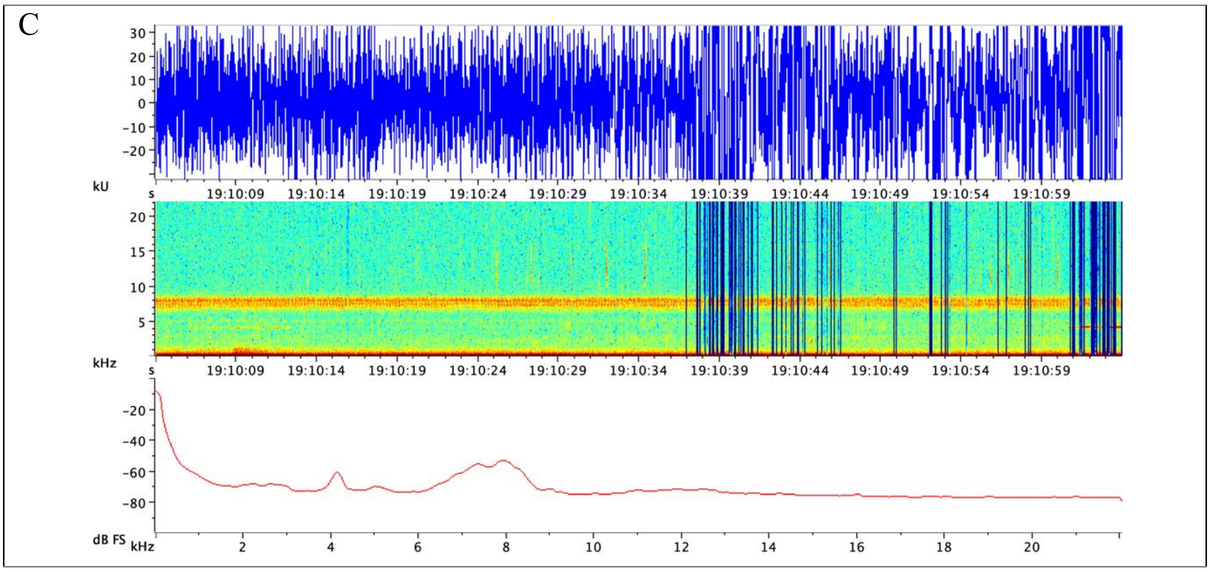
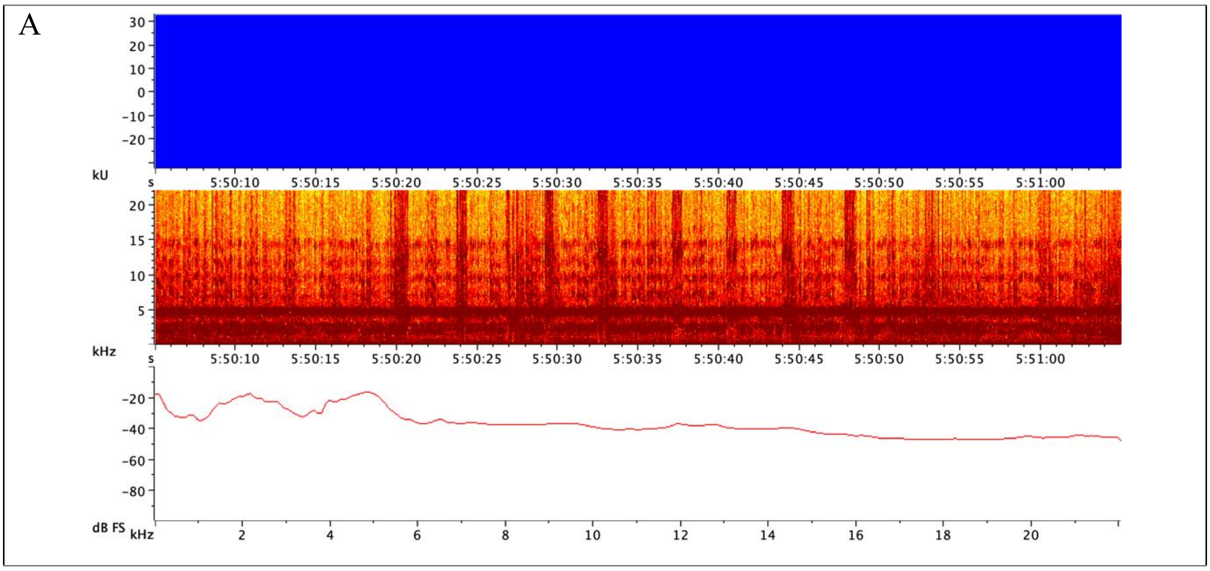


Figure 2.8. A 60 second sound record from SMS1 at Grassland on 17th July 2021 at A. 5:50 am, B. 8:10 am, and C. 7:10 pm.

Agricultural field sound records are depicted in Figure 2.9. This was recorded on 18th July 2021. Insect chorus and bird calls predominantly occupy the spectrum visible in Figure 2.9A. They have two peaks in the spectrum view, one around 2000Hz and the second around 5000Hz. In Figure 2.9B, the spectrum demonstrates MPC running with a broad frequency range from 10Hz to 4500Hz. It is interesting to note a similar trend at 5:50 am (Figure 2.9C), however, the insect chirps are coming up to 5500Hz.



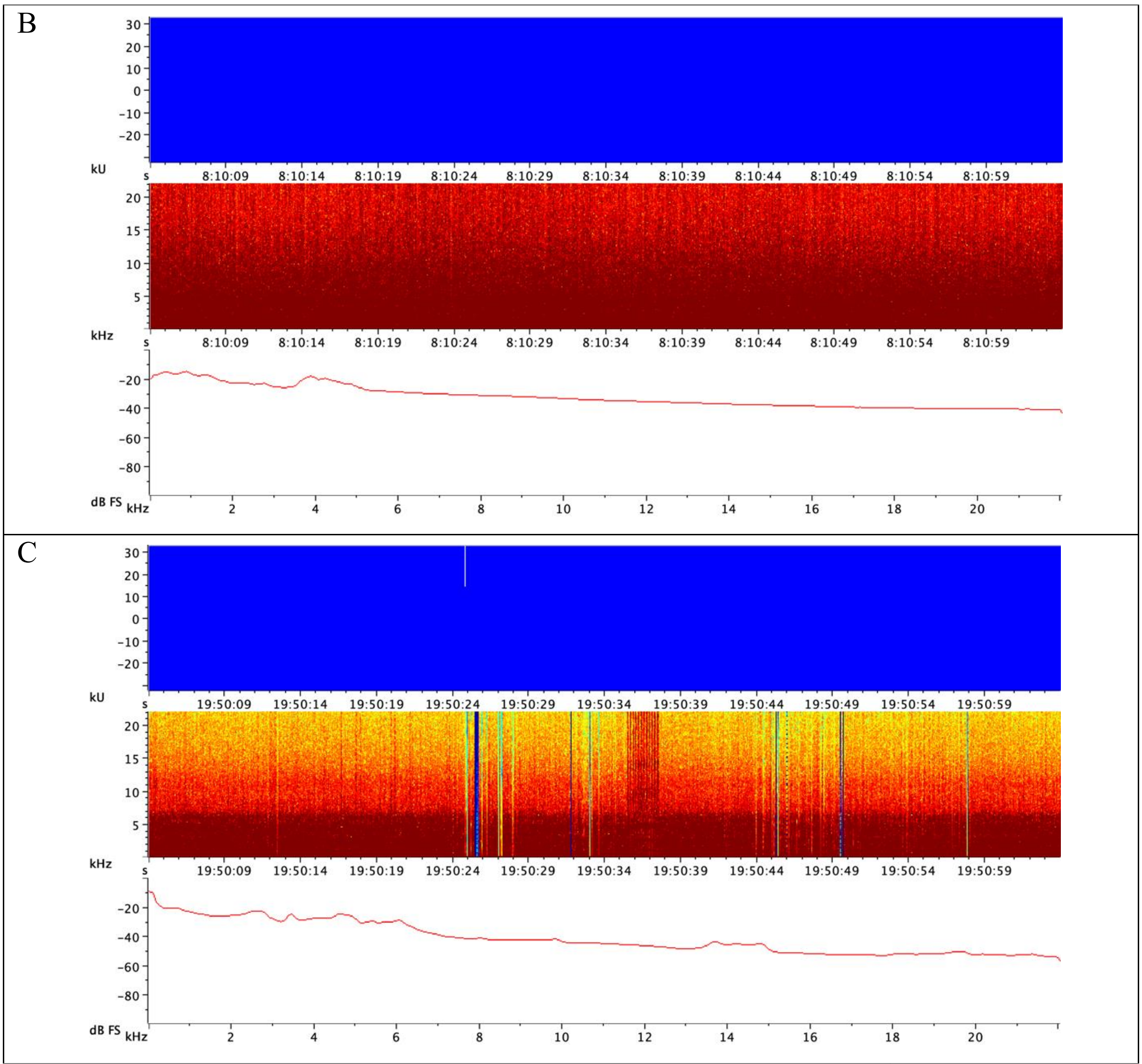


Figure 2.9. A 60 second sound record from SMS2 at Agriculture on 18th July 2021 at A. 5:50 am, B. 8:10 am, and C. 7:50 pm.

Sound recordings from the water bodies are given in Figure 2.10. Insects, amphibians (frogs and toads) and birds make most of the sound spectrum in the morning and late evening sound records (Figure 2.10A and 2.10C). Insect chirping predominates in the night sound record. MPC's frequency spectrum is depicted in Figure 2.10B with values from 3500 to 5000Hz. There are a few birds call spectrum visible between 8:10:29 sec to 8:10:59 sec.

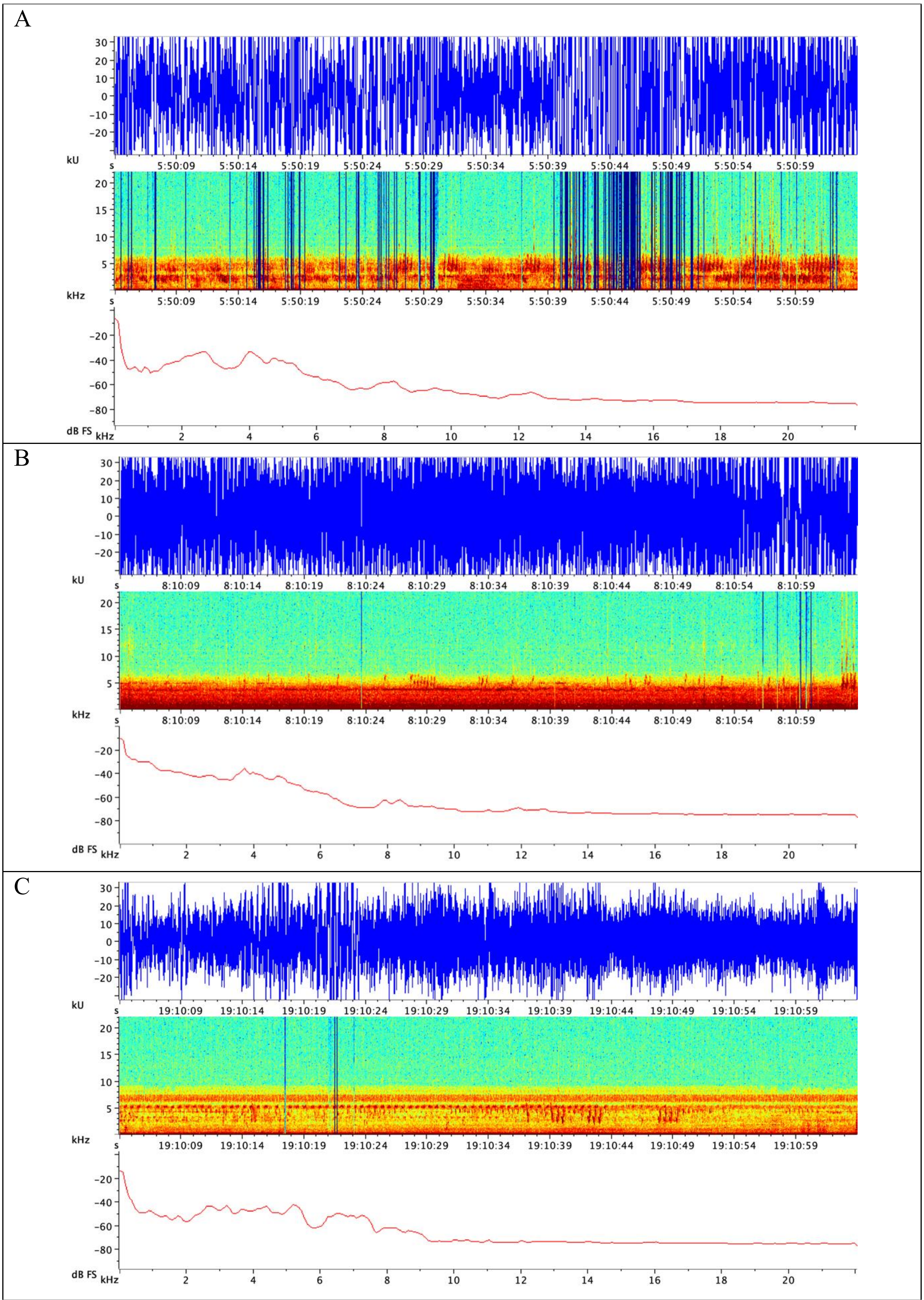
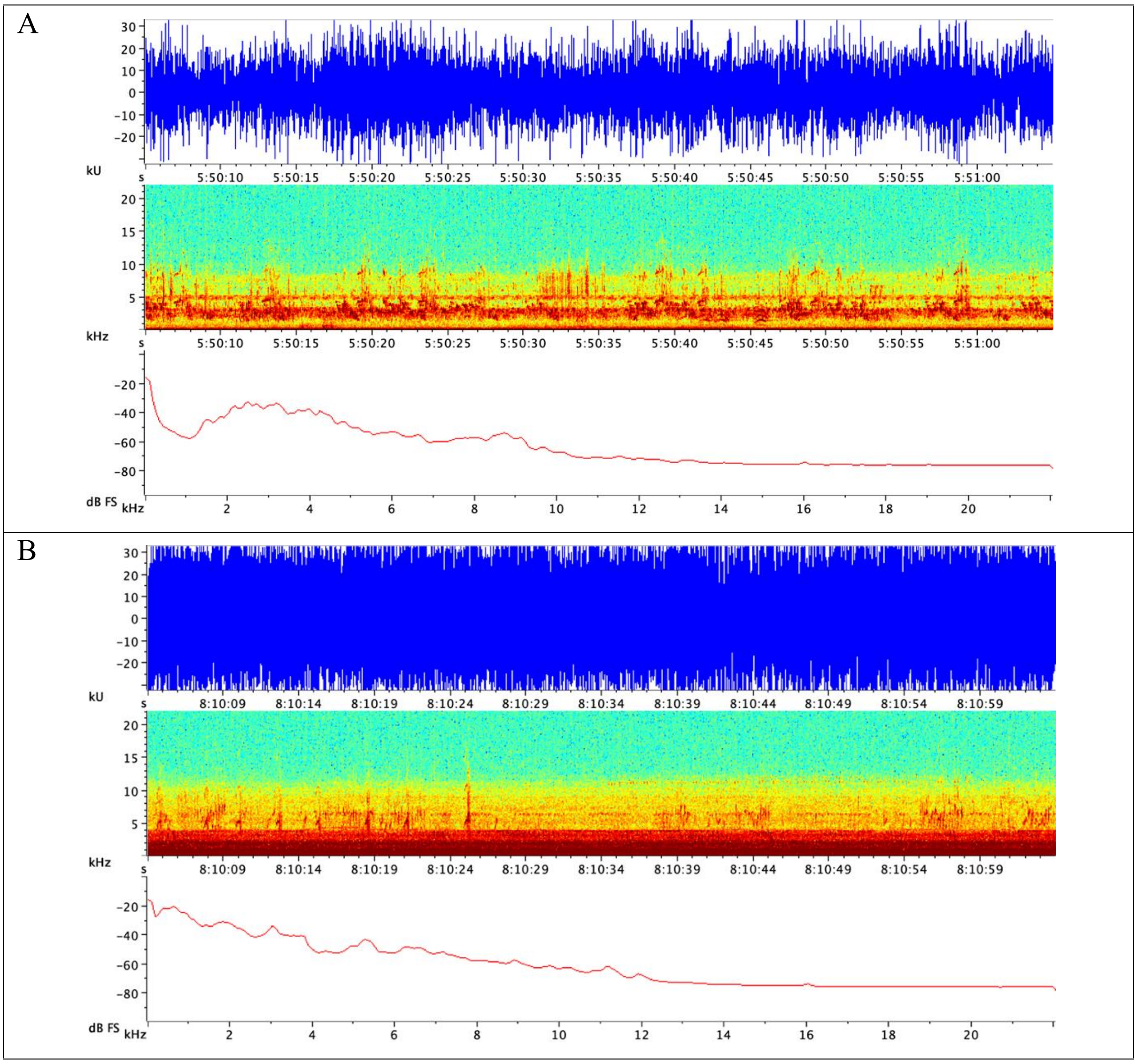


Figure 2.10. A 60 second sound record from SMS3 at waterbody on 28th June 2021 at A. 5:50 am, B. 8:10 am, and C. 7:50 pm.

The diversity of sound spectrum is highly visible in sound recorded from forest areas (Figure 2.11). Bird calls and insect buzz can be seen clearly in the morning call spectrum (Figure 2.11A). Although a few bird activities are visible in Figure 2.11B, which is recorded while MPC is running, it has a consistent band of the spectrum at 2000 – 5000Hz. Night sound spectrum has call records of Indian Night Jar and various insect species (Figure 2.11C).



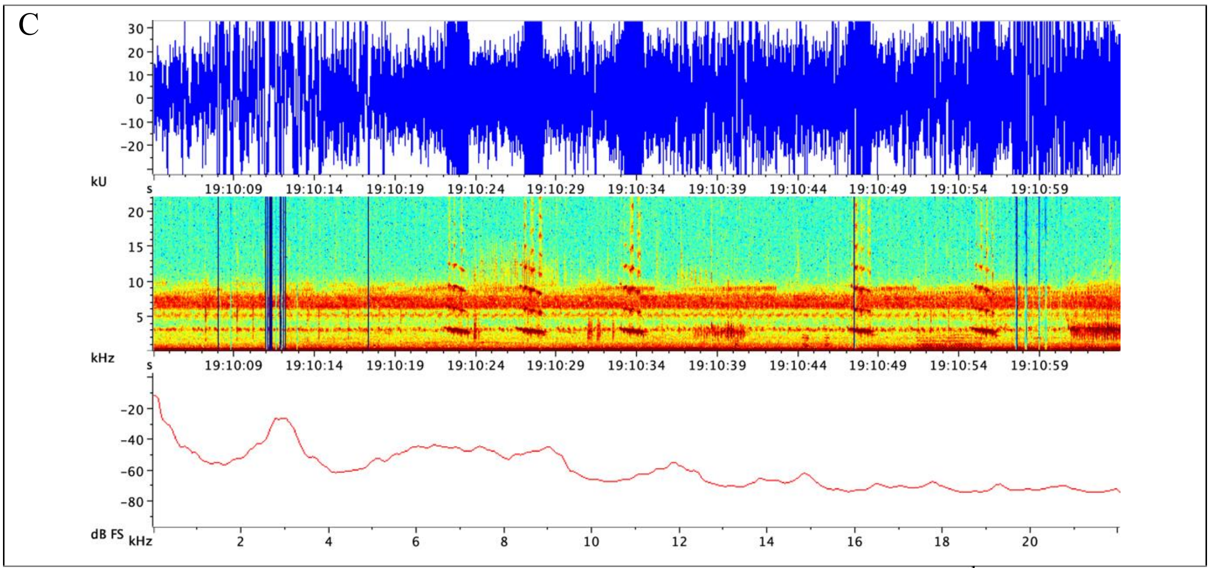
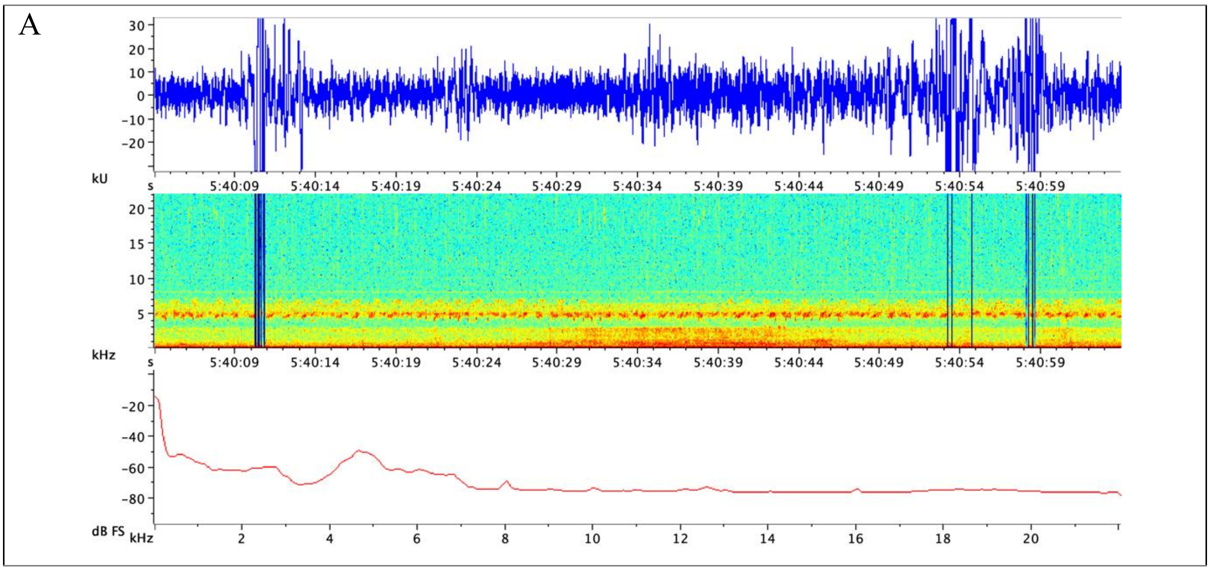


Figure 2.11. A 60 second sound record from SMS4 at forest area on 28th June 2021 at A. 5:50 am, B. 8:10 am, and C. 7:10 pm.

The sound record from the built-up area is shown in Figure 2.12. It is interesting to note that insect chirping in the morning sound record along with a vehicular movement (5:40:29 sec to 5:40:49 sec Figure 2.12A). A contrasting spectrum is observed during MPC activity, with the spectrogram showing up to a frequency of 7000Hz (Figure 2.12B). The night sound spectrum is diverse with insect chirping, amphibian chorusing and bird calls and the spectrum bands are also unique at 1000Hz, 2500Hz, 4000Hz, 5000 to 7000Hz (Figure 2.12C).



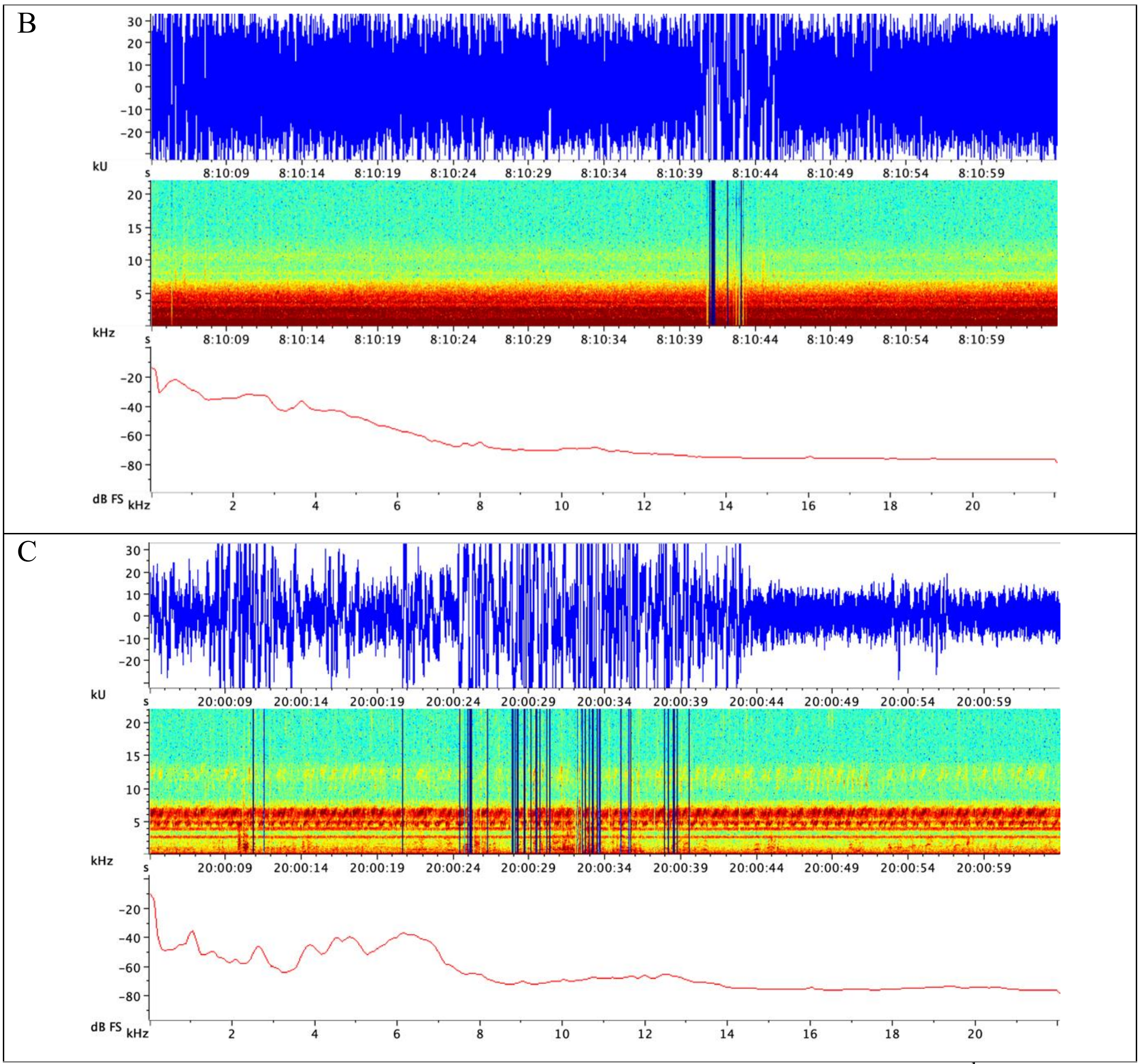


Figure 2.12. A 60 second sound record from SMS5 at the built-up area on 29th July 2021 at A. 5:40 am, B. 8:10 am, and C. 8:00 pm.

The control region, which is away from the direct sound impacts of MPC has shown an interesting pattern of the spectrogram (Figure 2.13). Based on the activity of animals (insects, amphibians, and birds) along with human-made sounds are predominant in the spectrograms irrespective of the time of the recordings. Spectrograms of insect chirping, amphibian chorus and bird calls are seen in the morning as well as late evening records, while human-made sounds, cattle and vehicles are part of the spectrum during the rest of the day.

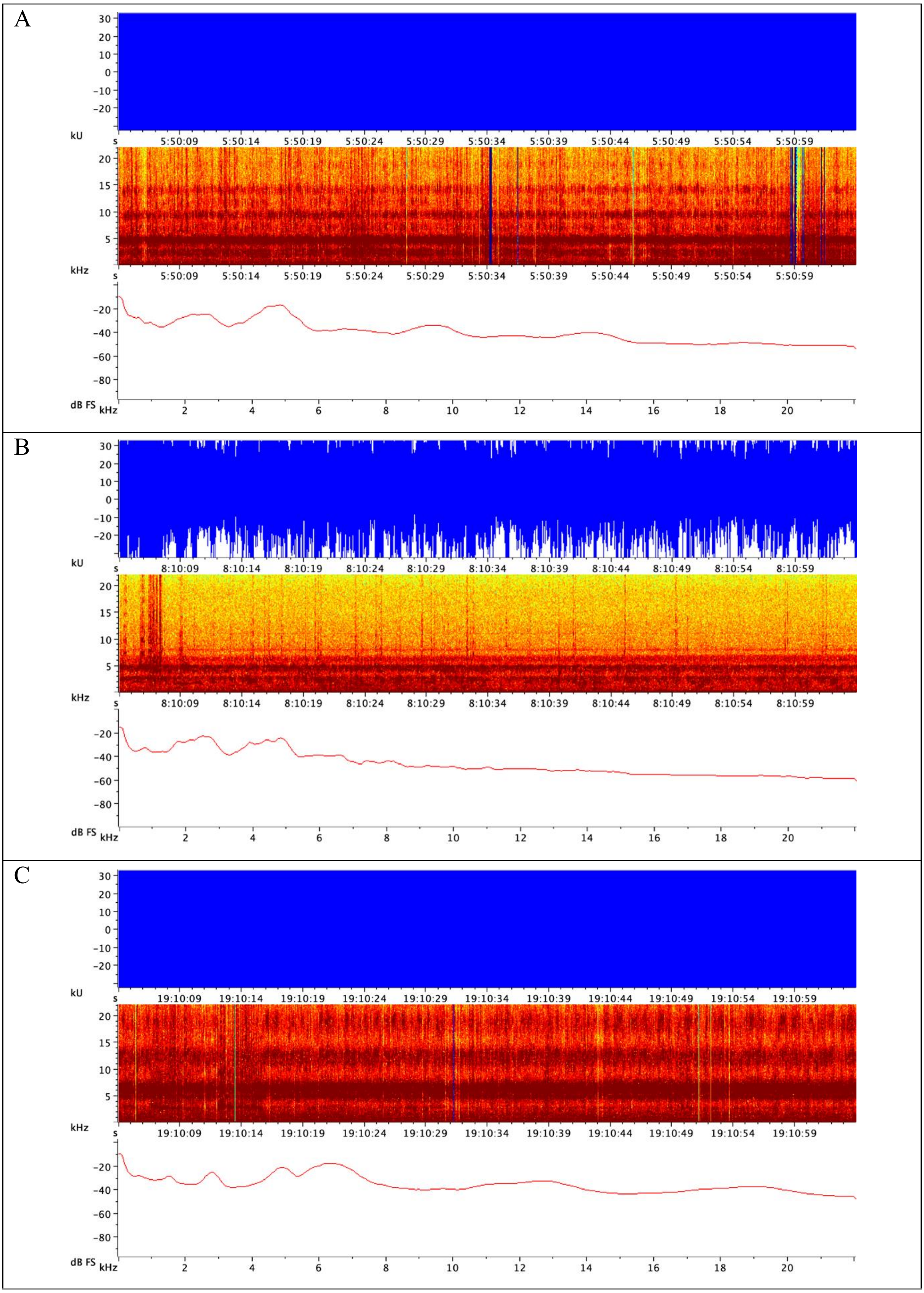
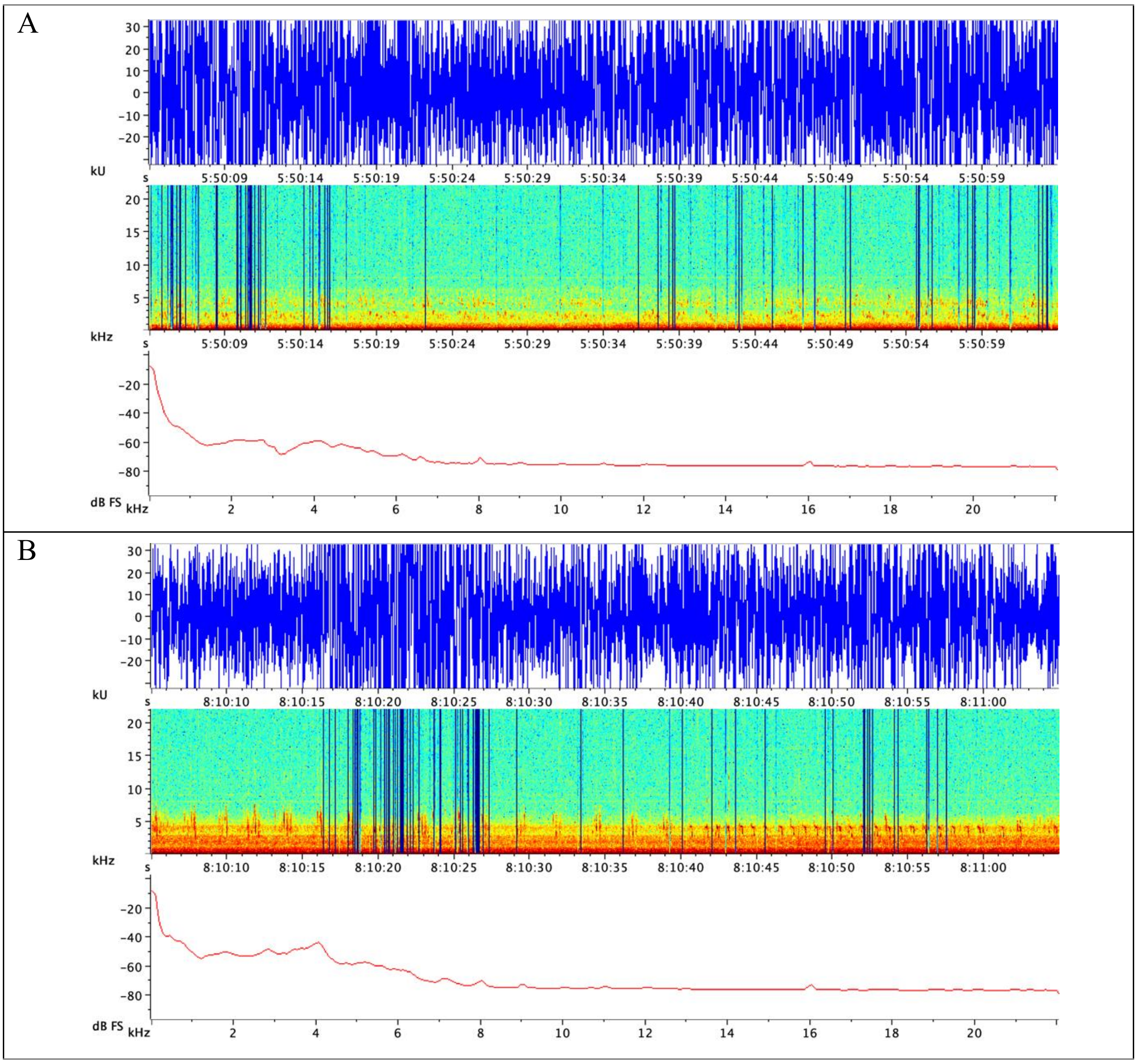


Figure 2.13. A 60 second sound record from SMS6 at the control area on 16th July 2021 at A. 5:50 am, B. 8:10 am, and C. 7:10 pm.

4. Waveform and spectrograms of sound recording in Phase II (ToR VI)

To record the frequency spectrum during the extended period of MPC operations (Phase II, from 12h to 20h), Sound Monitoring Stations were installed at the same localities as Phase I. Due to a technical snag, sound recordings in SMS's 3 and 5 were not used for further analysis. In Phase II, sound recorded from Grassland (SMS1) during the non-operative time of MPC has spectral signatures of wind blowing, insect chirping and bird calls (Figure 2.14A). During the operation phase, MPC running frequency spectrum is between 3500-4500Hz. Bird calls observed during this period (8:10:40 sec to 8:11:00) seem to have been masked by the MPC frequency spectrum (Figure 2.14B). During the continuous operation of MPC at 5:50 am (Figure 2.14C), three broad spectral regions are visible, i.e., 3500-4500Hz representing MPC; 6500-7500Hz and 11000-12000Hz representing insects). It appears that due to the use of HDPE idlers, loudness due to MPC operation is less, but the frequency spectrum remains at around 3500-4500Hz band.



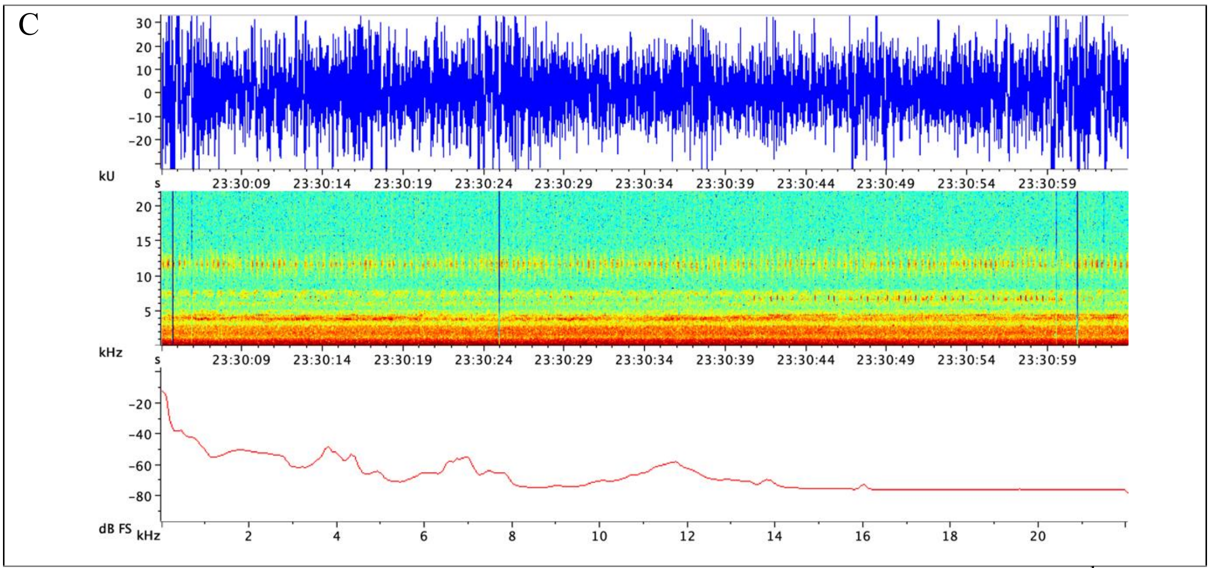
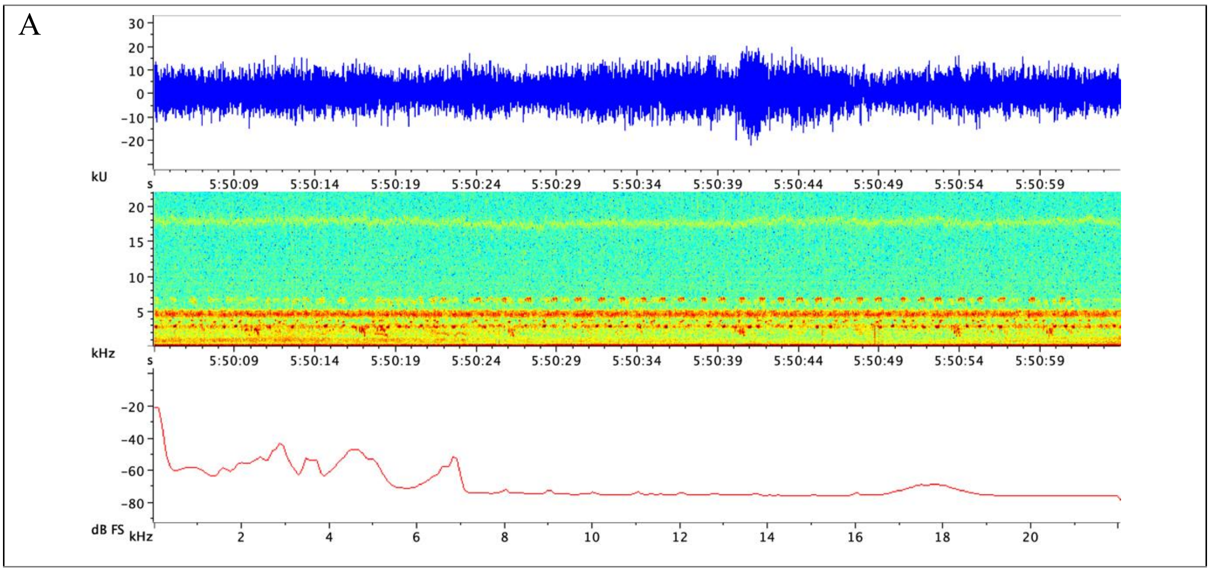


Figure 2.14. A 60 second sound record from Phase II, SMS1 at Grassland on 22nd August 2021 at A. 5:50 am, B. 8:10 am, and C. 15th August 2021 at 11:30 pm.

Use of steel idlers, along with other operational procedures of MPC (volume of inside MPC, speed and acceleration of MPC and so on) seem to induce loudness. This is very evident in the sound spectrum from agricultural field SMSs. Spectrogram of animal sounds is visible before MPC operations (Figure 2.15). In Figures 2.15B and 2.15C, the loudness along with the frequency spectrogram of MPC dominates the sound records. A similar pattern is observed in forest areas too (Figure 2.16). Sound records and spectrograms from Phase II control were very similar to that of Phase I control. The spectrogram is mainly from the sounds of animals, humans and human-made sounds (Figure 2.17).



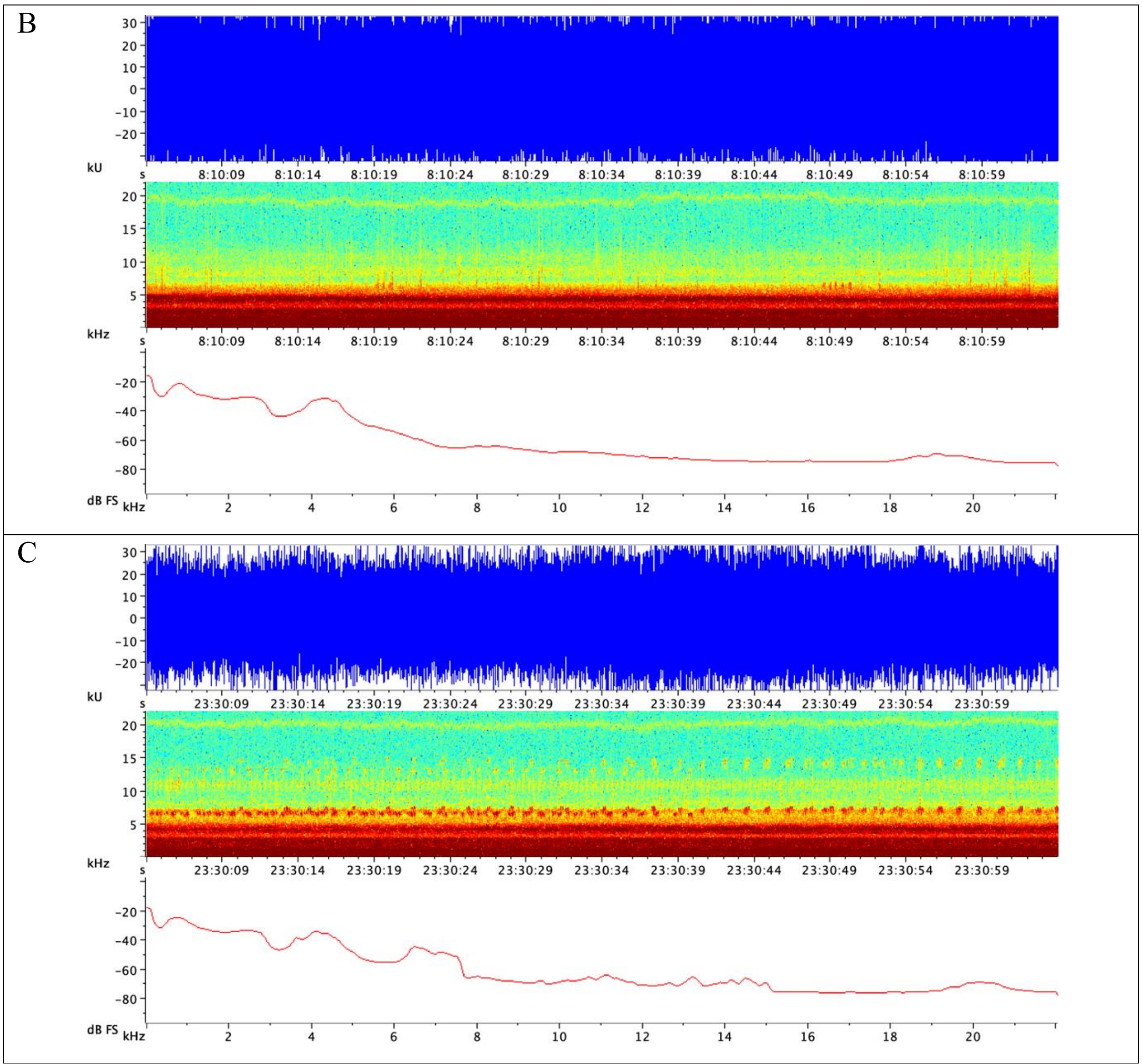
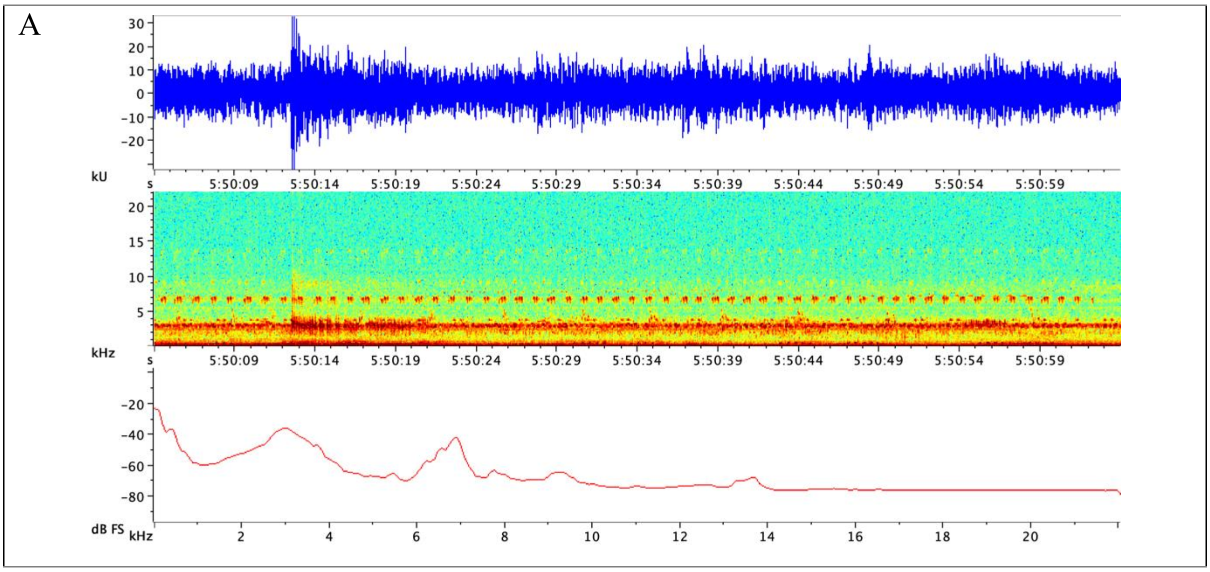


Figure 2.15. A 60 second sound record from Phase II, SMS2 at the agriculture area on 22nd August 2021 at A. 5:50 am, B. 8:10 am, and C. 11:30 pm.



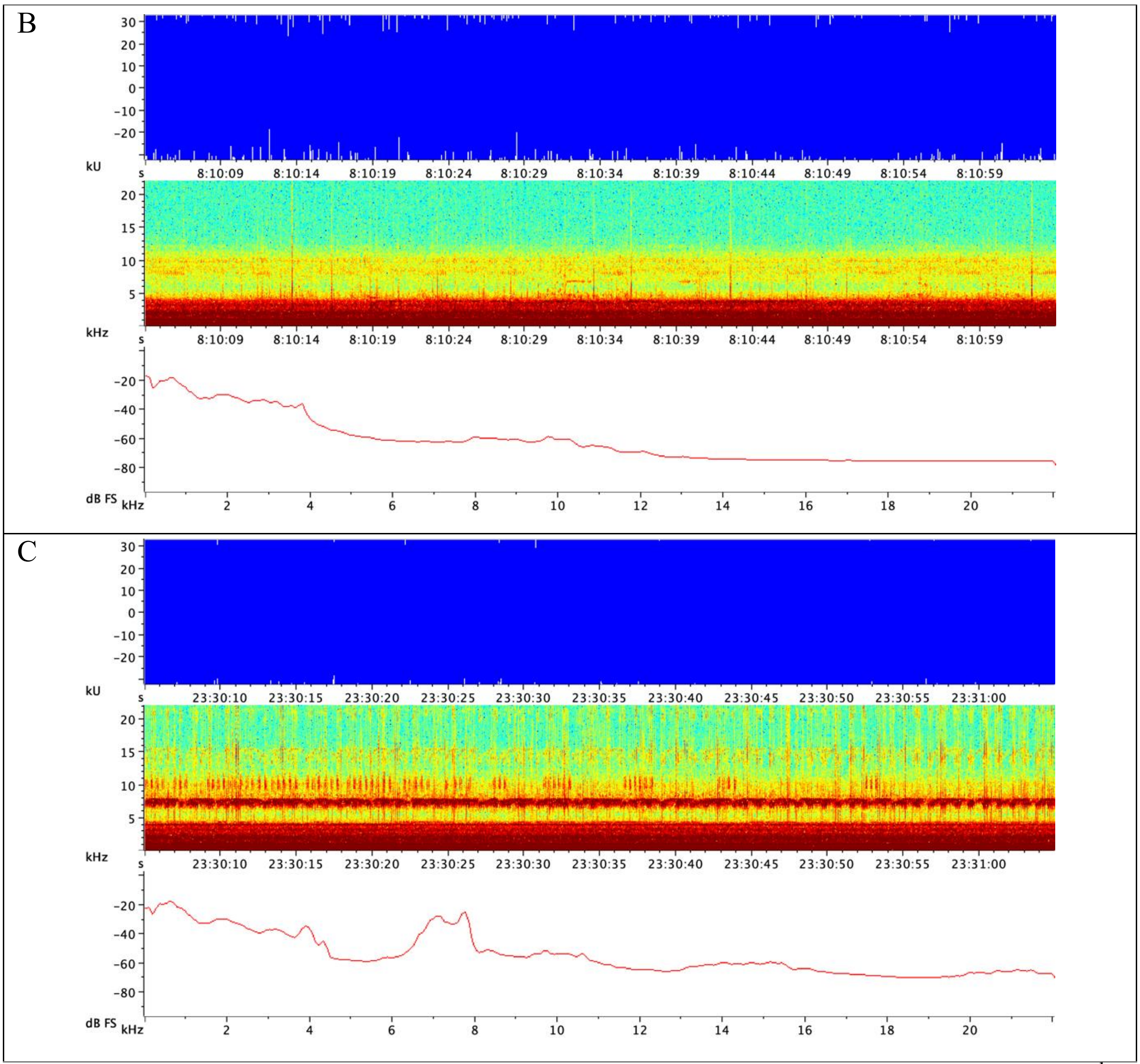
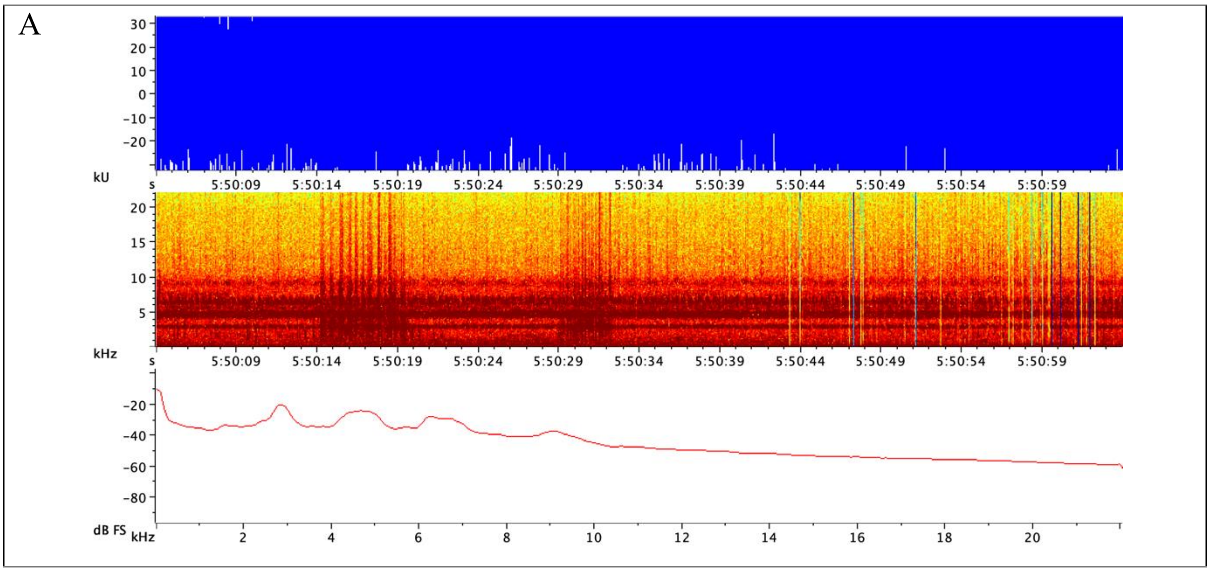


Figure 2.16. A 60 second sound record from Phase II, SMS4 at the forest area on 22nd August 2021 at A. 5:50 am, B. 8:10 am, and C. 11:30 pm.



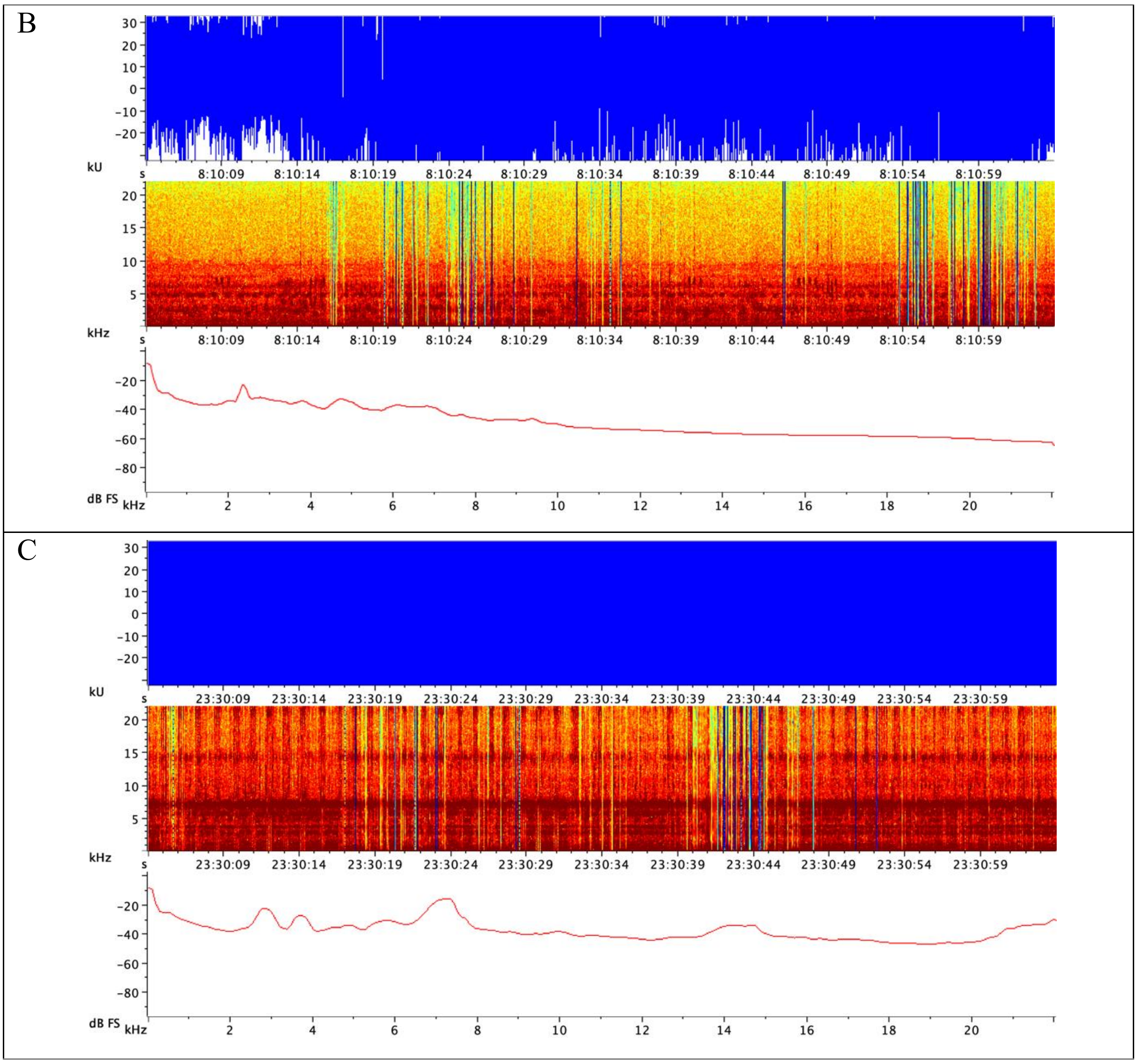


Figure 2.17. A 60 second sound record from Phase II SMS6 at the control area on 18th August 2021 at A. 5:50 am, B. 8:10 am, and C. 11:30 pm.

4. Spectral correlation analysis

Figure 2.18-2.27 and Table 2.2 detail the spectrogram correlations calculated for a sample audio record from the SMS's in both Phase I and Phase 2. A value closer to 1 indicates similarity between spectrograms, while a value closer to 0 indicates complete dissimilarity. The spectral correlation was least in agriculture land-use (U=0.07) between non-operative MPC (before 6 am and after 6 pm) and operative MPC (between 6 am and 6 pm). This indicates a drastic change in the sound spectrum during different times of the day regarding MPC operations. Grassland showed positive spectral correlations (U=0.54, U=0.48). The least spectral correlation observed in control (U=0.26 and U=0.27) are due to natural variations in the animal activities in these times. In Phase II, the spectral correlation between non-operational MPC and operational MPC, Forest exhibited the least spectral correlation

(U=0.2), while it was higher in grassland and control (U=0.46 and U=0.45 respectively). For the extended operation period, all the three land-uses showed low spectral correlation (Grassland, U=0.37; Agriculture, U=0.36 and Forest, U=0.36).

Table 2.2. Spectral correlation (U) calculated for sounds recorded between non-operational MPC and operational MPC.

SMS	2:00 AM - 6:00 AM and 6:00 AM - 6:00 PM	6:00 PM - 2:00 AM and 6:00 AM - 6:00 PM	Phase
Grassland	0.54	0.48	Phase I
Agriculture	0.07	0.15	
Water	0.45	0.34	
Forest	0.32	0.31	
Builtup	0.38	0.42	
Control	0.26	0.28	
Grassland	0.46	0.37	Phase II
Agriculture	0.34	0.36	
Forest	0.20	0.36	
Control	0.45	0.47	

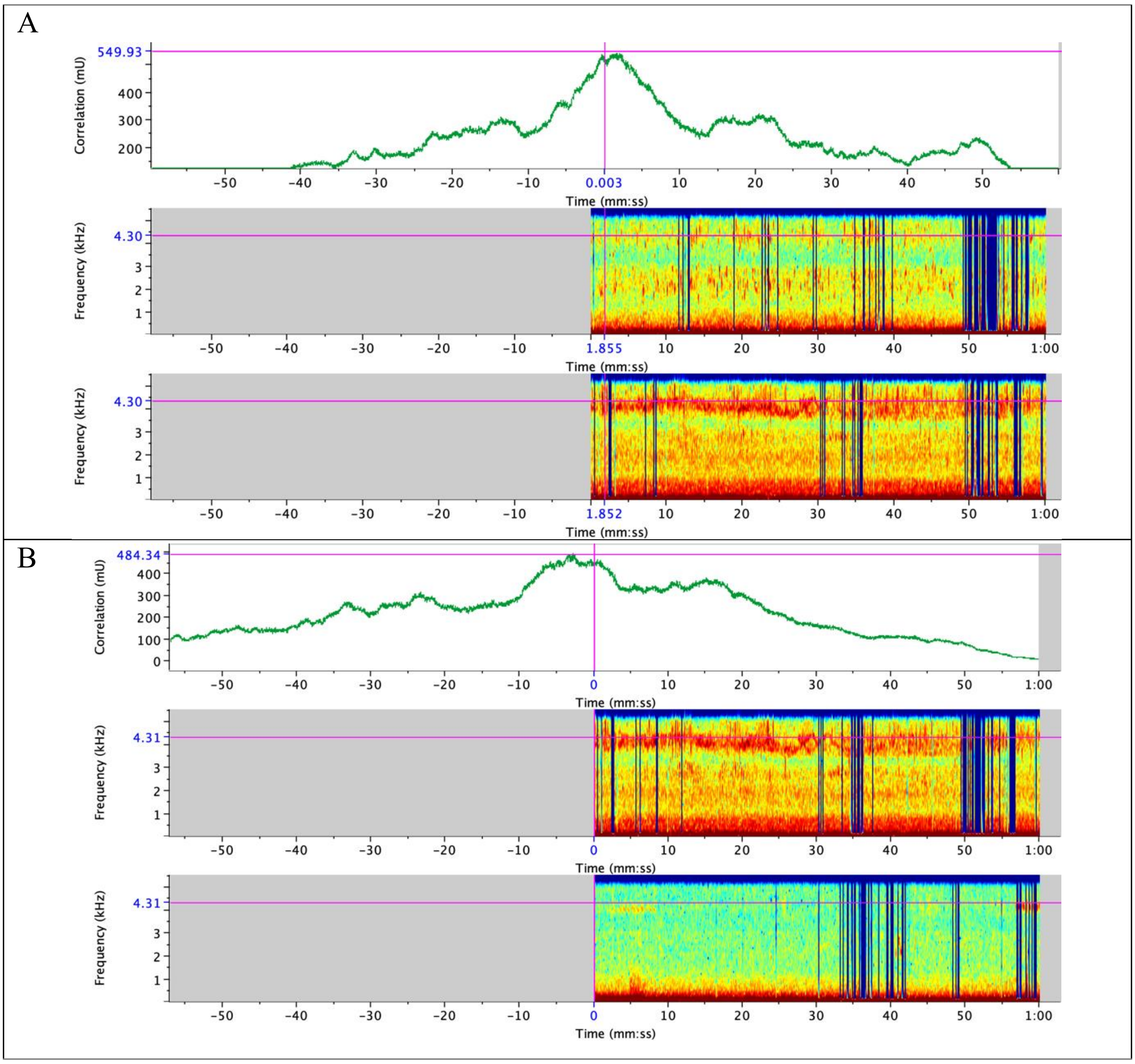


Figure 2.18. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS1, Phase I.

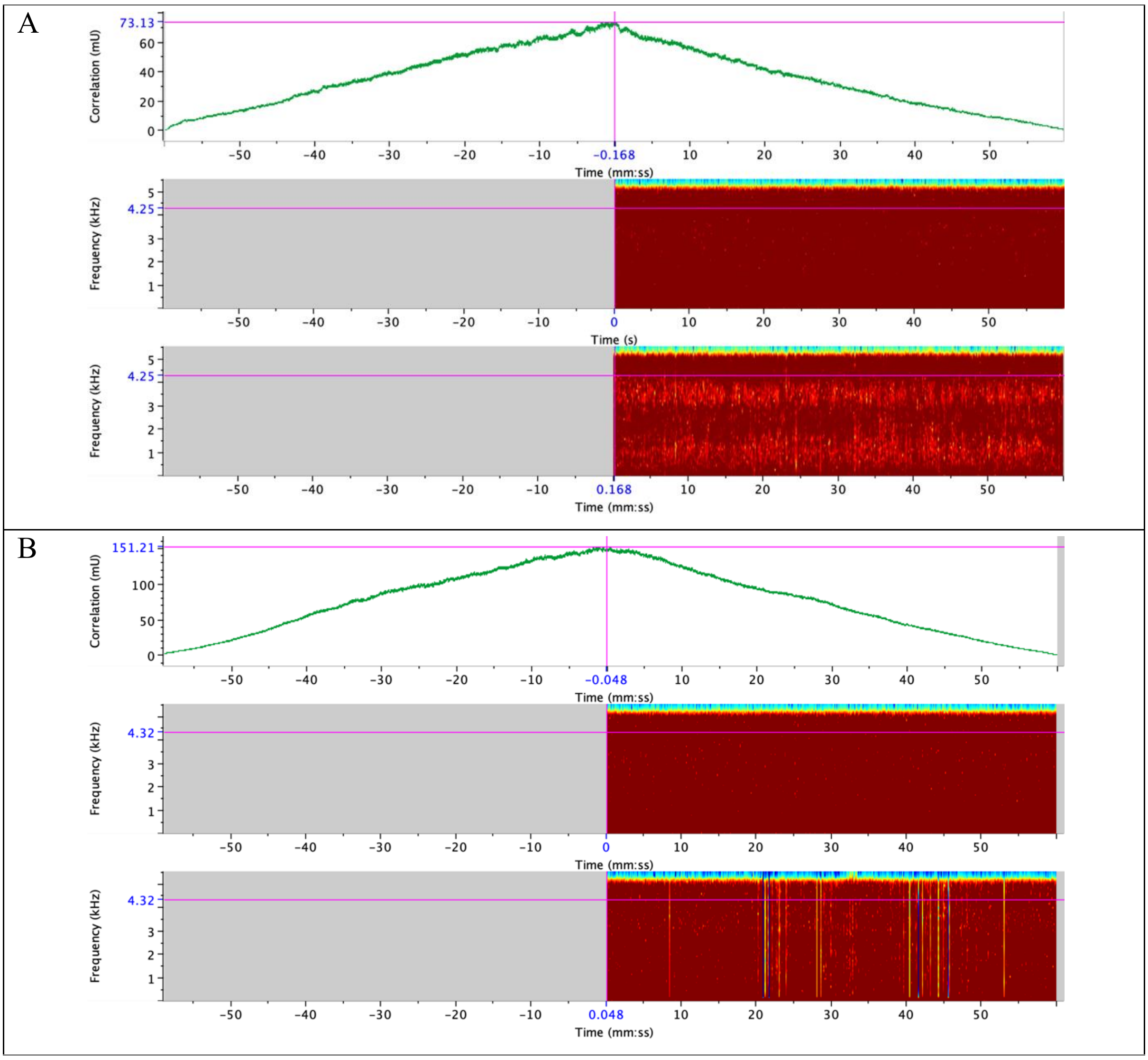


Figure 2.19. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS2, Phase I.

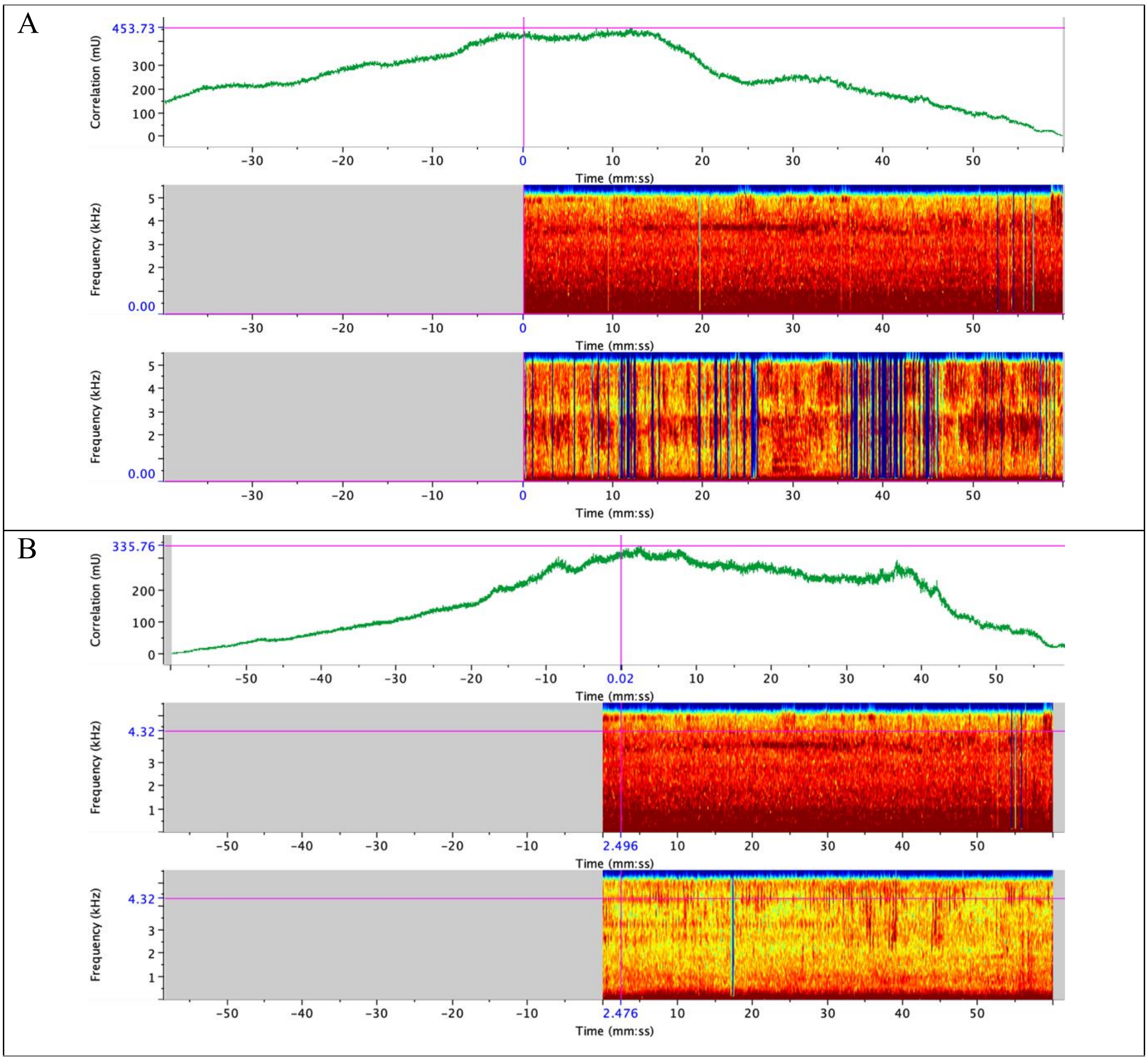


Figure 2.20. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS3, Phase I.

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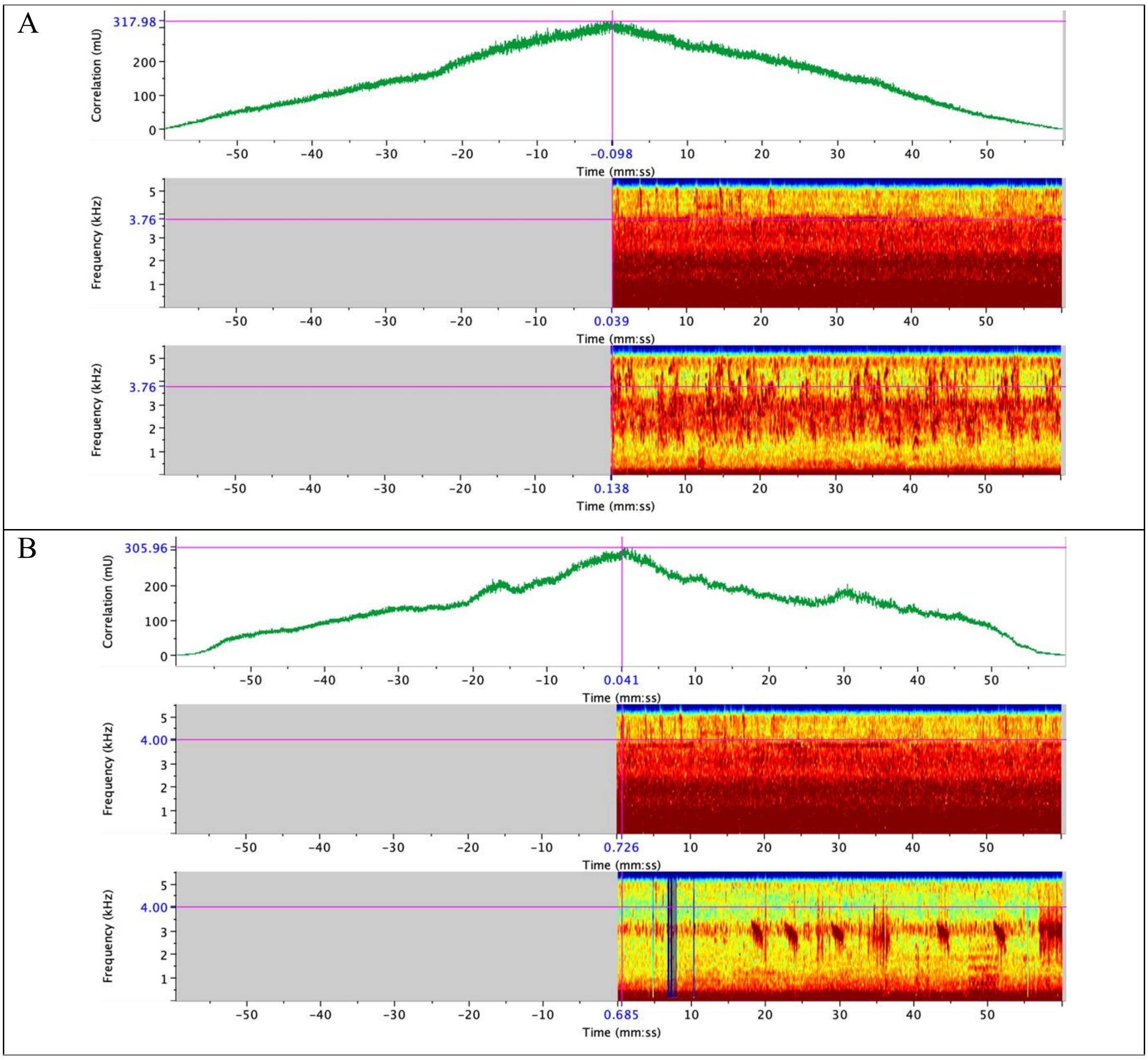


Figure 2.21. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS4, Phase I.

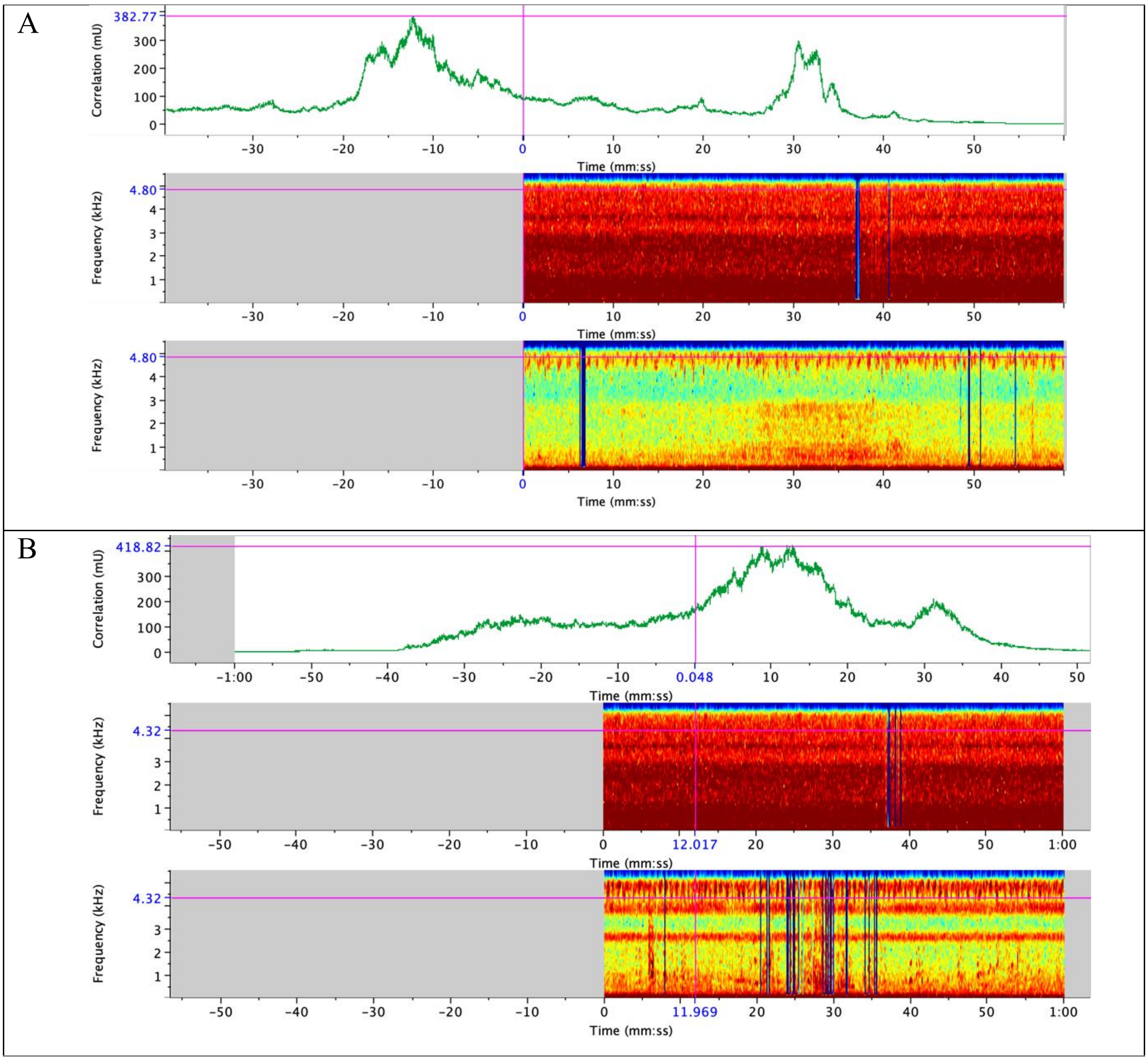


Figure 2.22. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS5, Phase I.

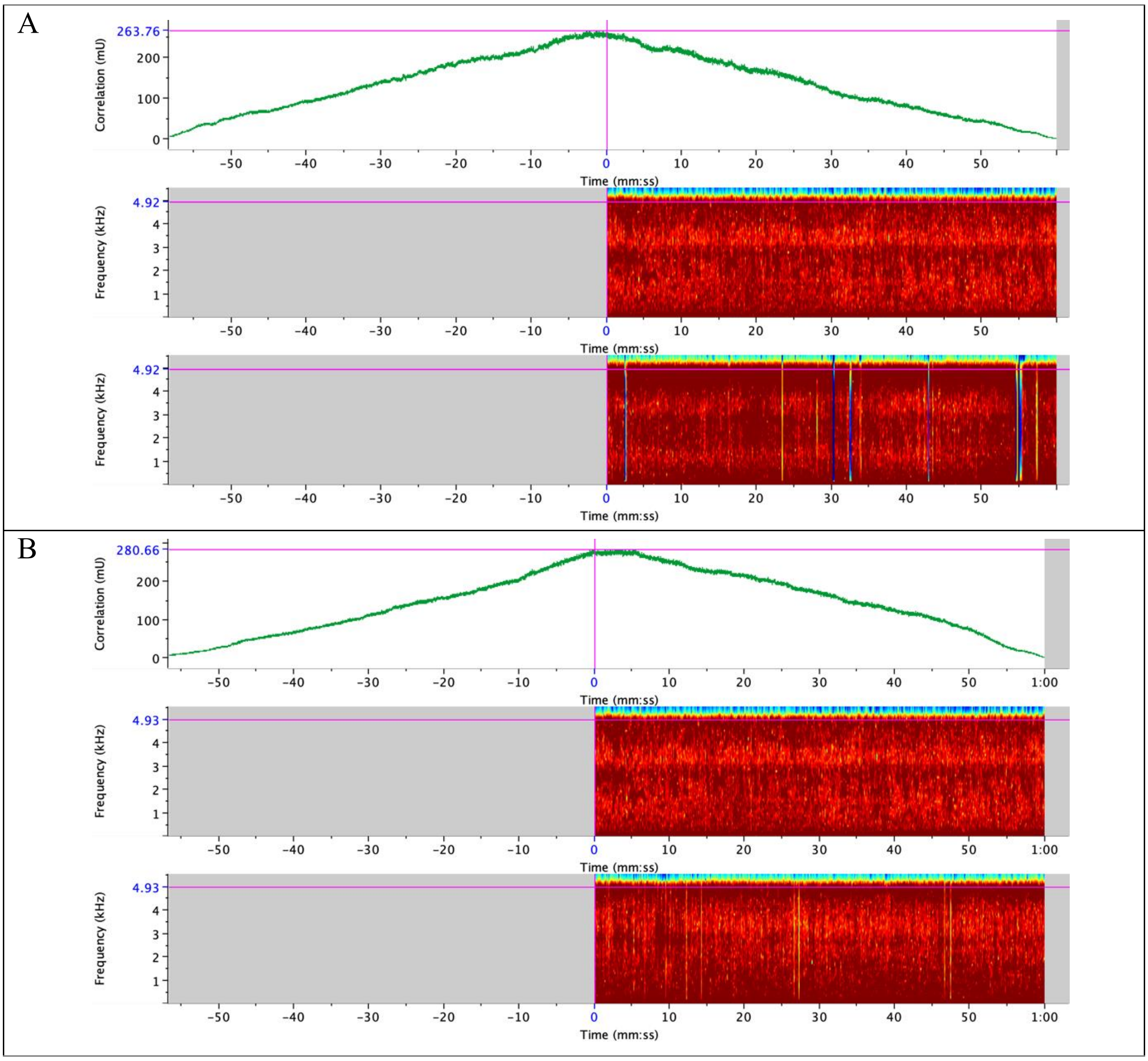


Figure 2.23. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS6, Phase I.

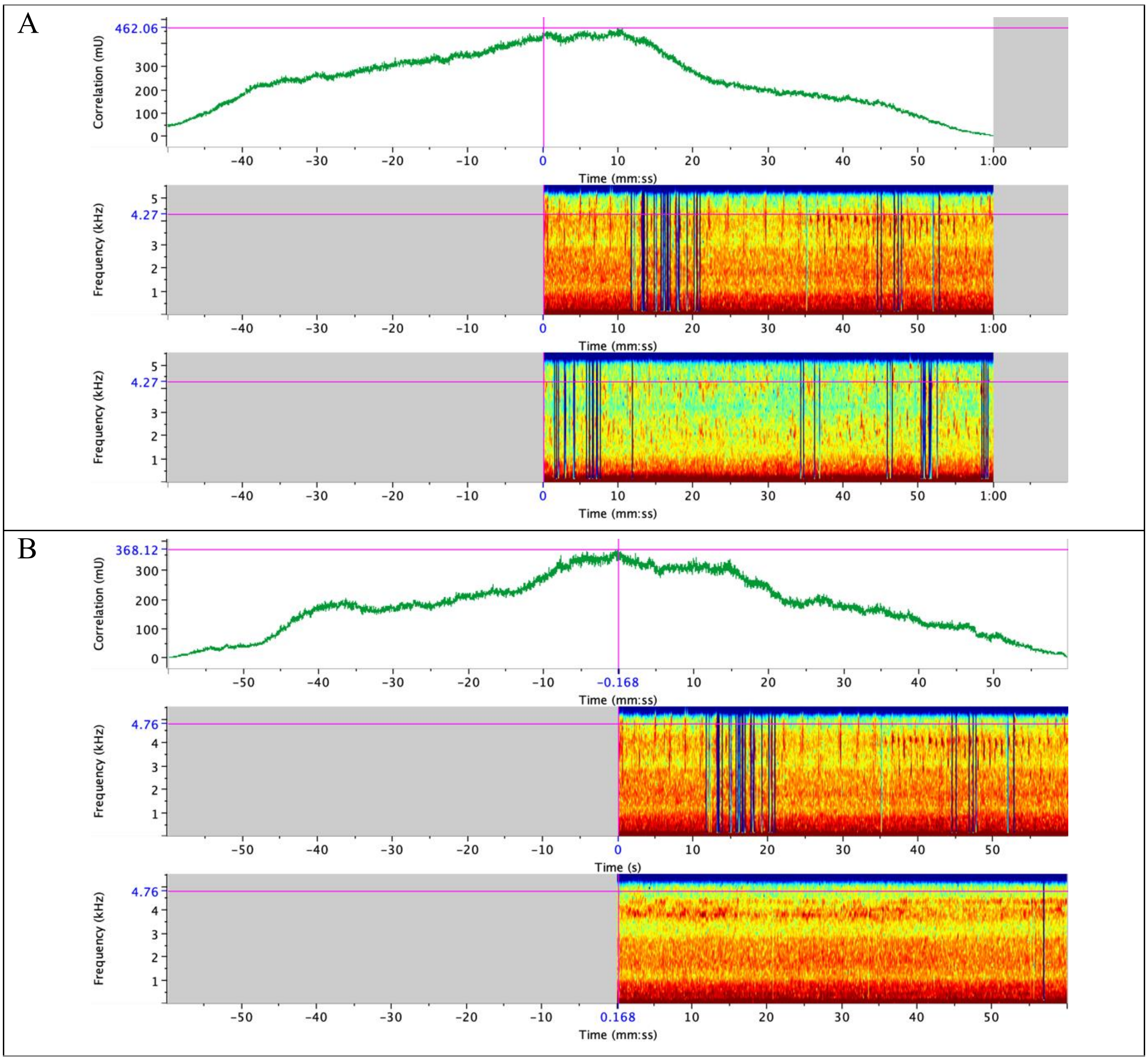


Figure 2.24. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS1, Phase II.

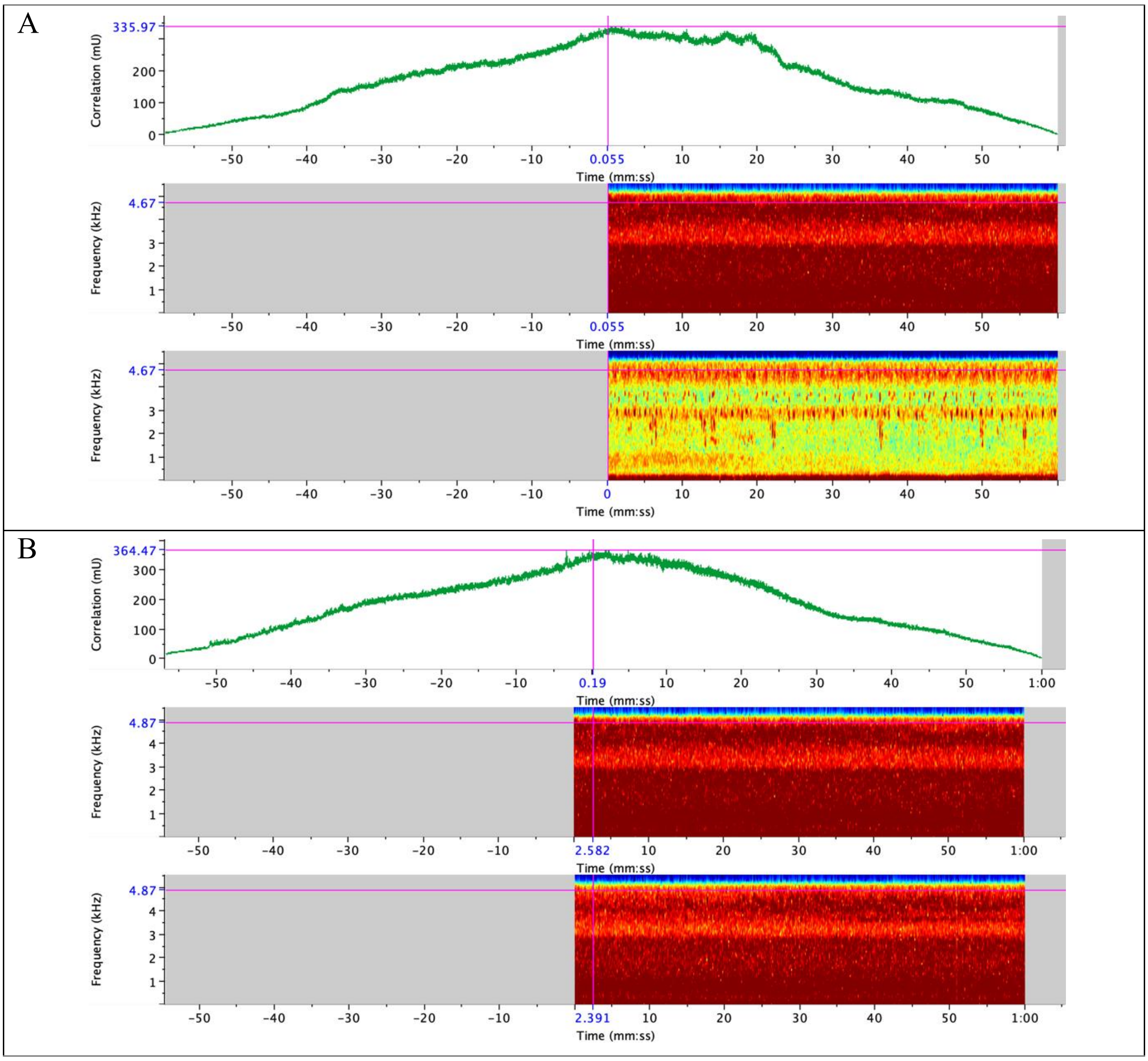


Figure 2.25. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS2, Phase II.

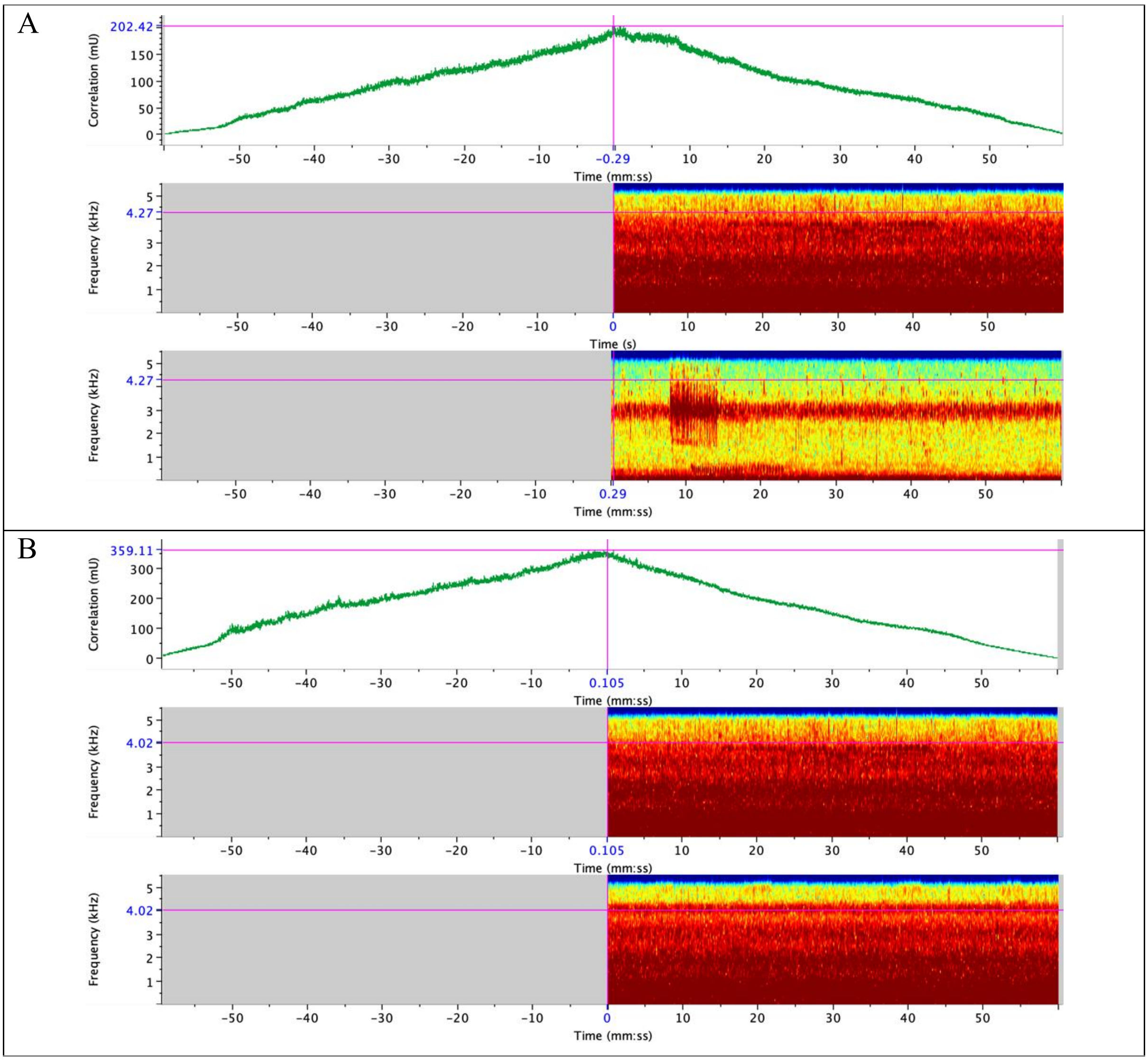


Figure 2.26. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS4, Phase II.

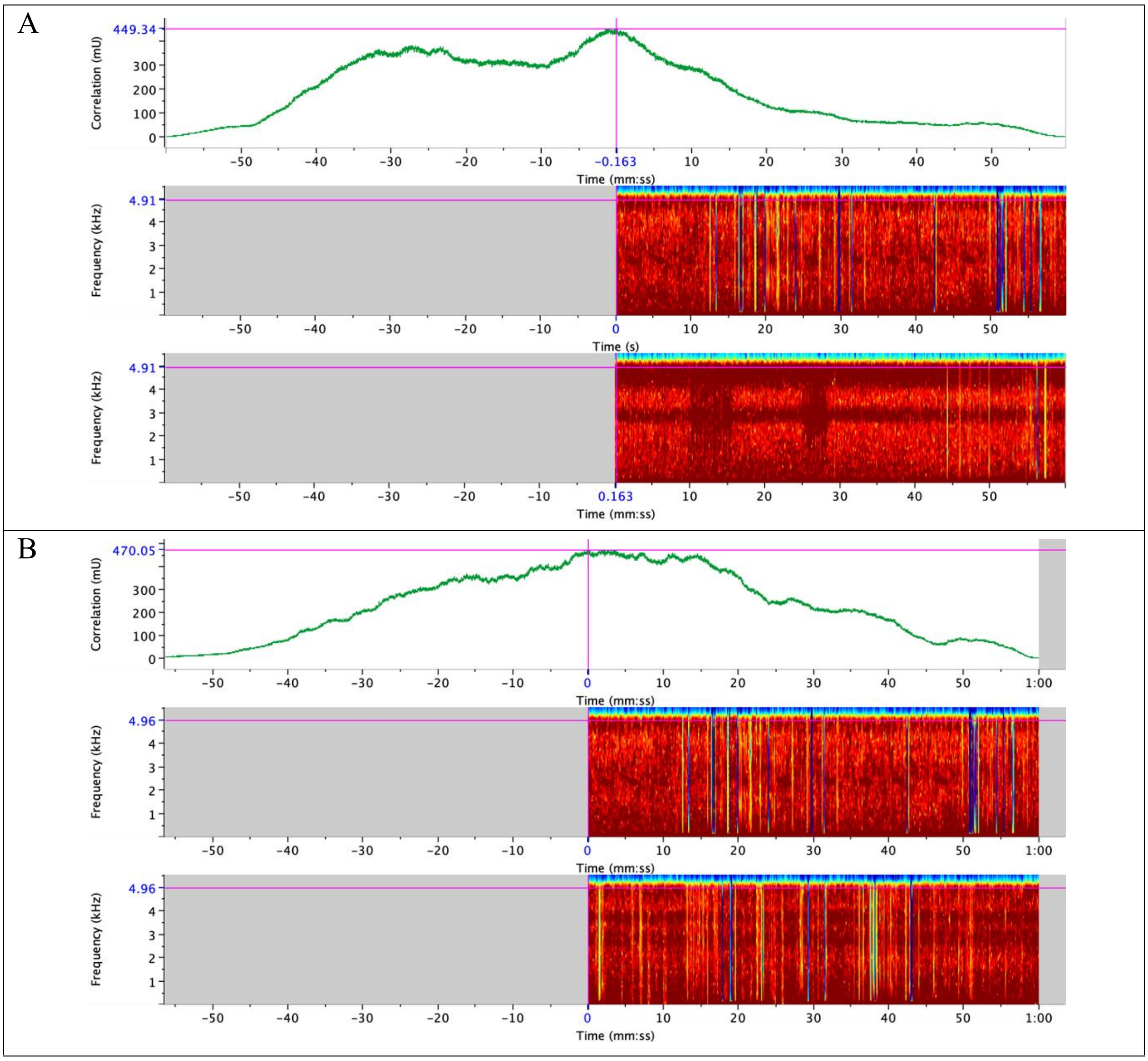
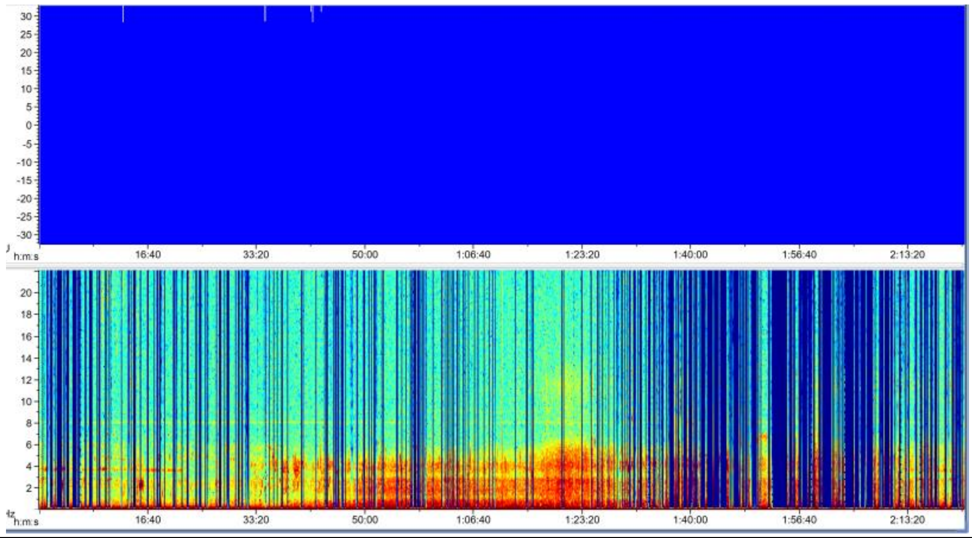


Figure 2.27. Spectrogram correlation between operational MPC spectrum with non-operational MPC spectrum in SMS6, Phase II.

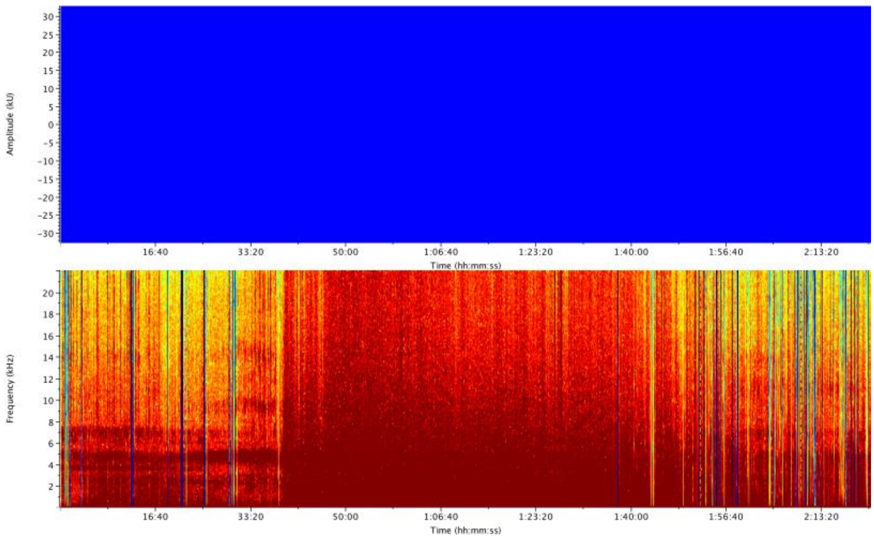
5. 24h sound recording through Sound Monitoring Stations – Phase I.

Sound monitoring stations record 142 recordings per day. To understand the spectral variation for a 24h duration, all 142 files were compressed as a single file using Raven Pro 1.6 and a spectrogram is obtained. Figure 2.28 (A, B, C, D, E and F) depicts the 24h spectrograms of Grassland, Agriculture, Waterbody, Forest, Builtup and Control respectively. In Phase I, like the observations made between non-operative MPC and operational MPC, all these 24h spectrograms marks spectral distinction of MPC's operations. Figure 2.28B has a spectrogram resulting from train honking and movement. But these are of very short durations. Spectrogram from the control (Figure 2.28F) shows that animal activities are more during the night and early morning, than daytime.

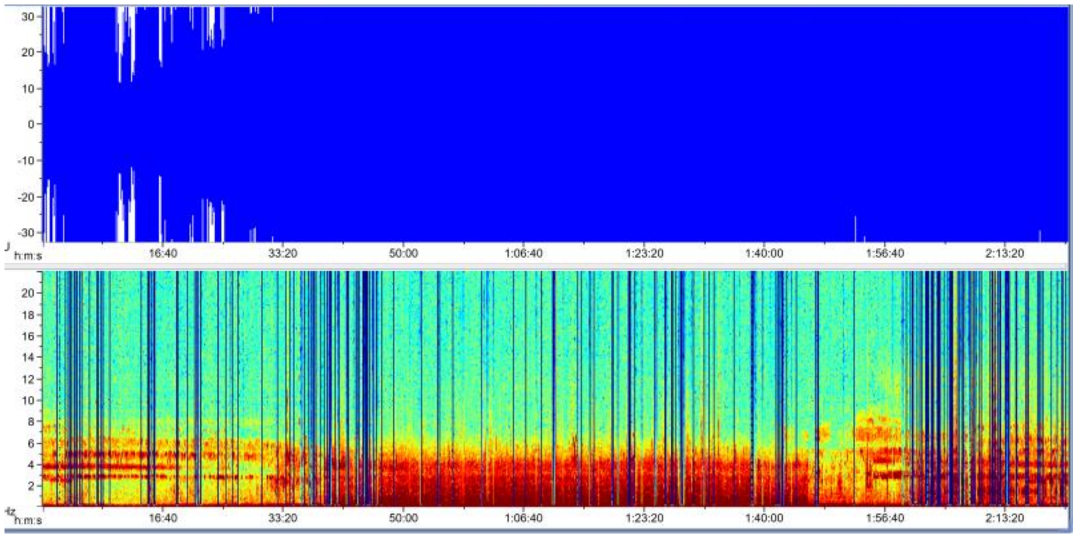
A



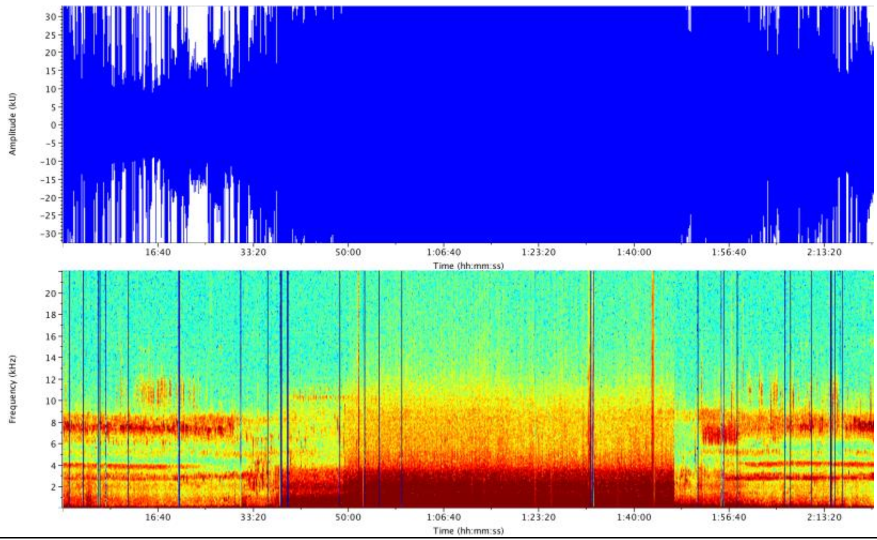
B



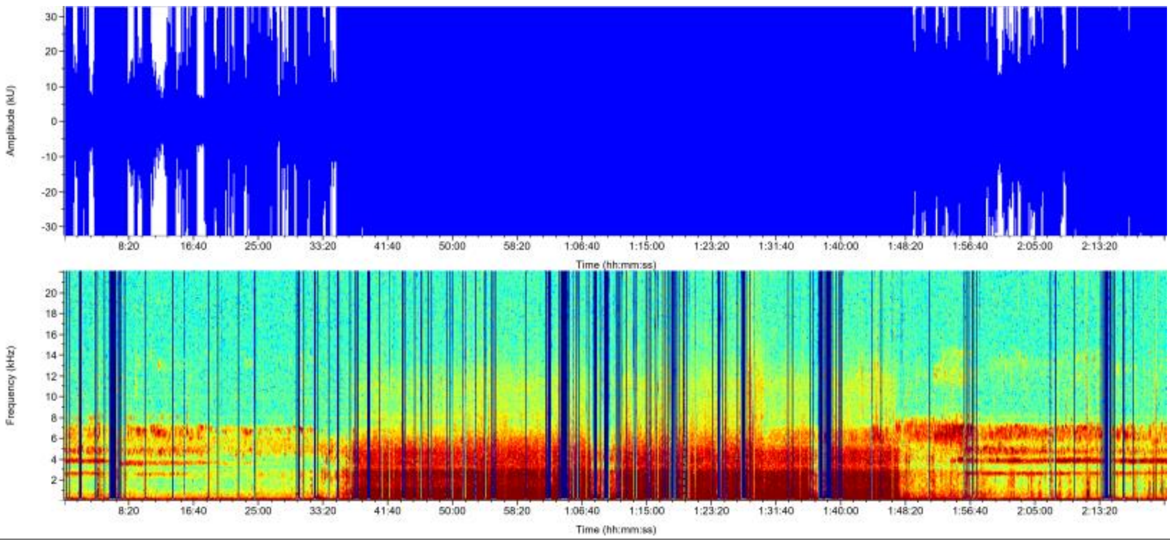
C


h:m:s
16:40
33:20
50:00
1:06:40
1:23:20
1:40:00
1:56:40
2:13:20

D


Amplitude (kU)
Frequency (kHz)
Time (hh:mm:ss)
16:40
33:20
50:00
1:06:40
1:23:20
1:40:00
1:56:40
2:13:20

E


Amplitude (kU)
Frequency (kHz)
Time (hh:mm:ss)
8:20
16:40
25:00
33:20
41:40
50:00
58:20
1:06:40
1:15:00
1:23:20
1:31:40
1:40:00
1:48:20
1:56:40
2:05:00
2:13:20

F

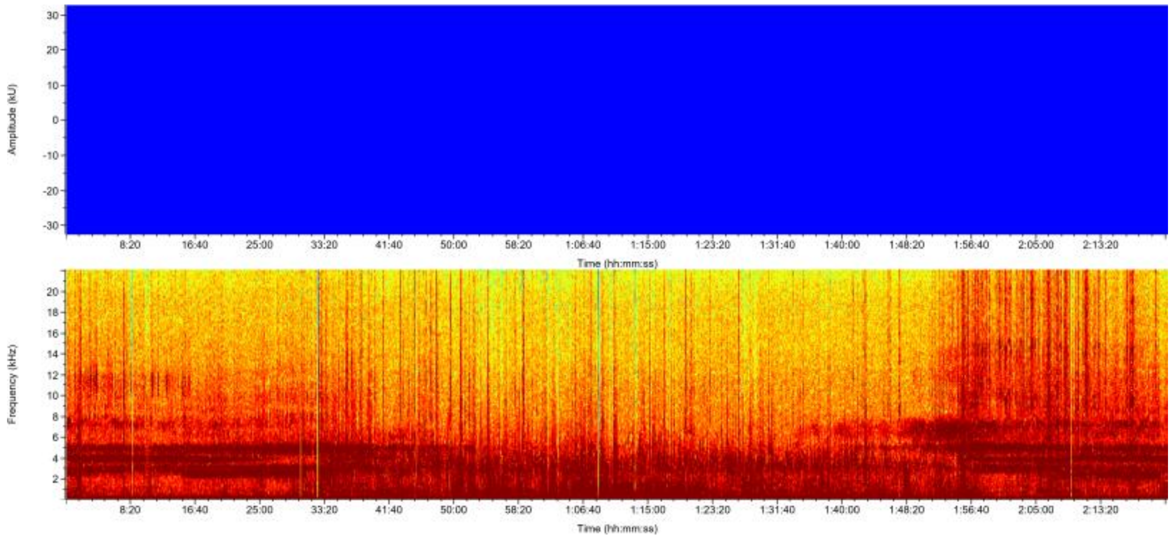
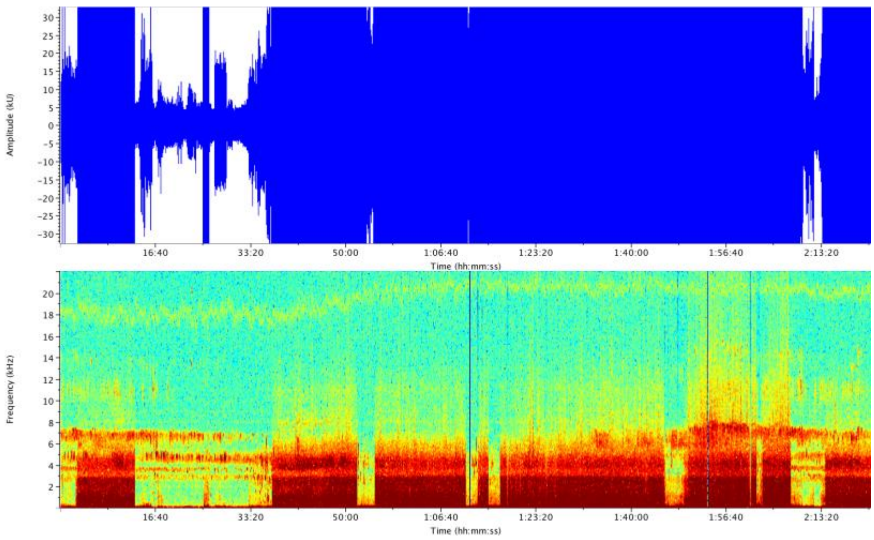


Figure 2.28. Waveform and spectrogram of 142 sound recordings made on a single day during Phase I. A. Grassland, B. Agriculture, C. Waterbody, D. Forest, E. Builtup and F. Control.

6. 24h sound recording through Sound Monitoring Stations – Phase II.

Figure 2.29 (A, B, C and D) depicts the 24h spectrograms of Grassland, Agriculture, Forest, and Control respectively. Very similar to Phase I, spectrograms from Phase II demonstrates the increased MPC activity and its frequency spectrum.

A



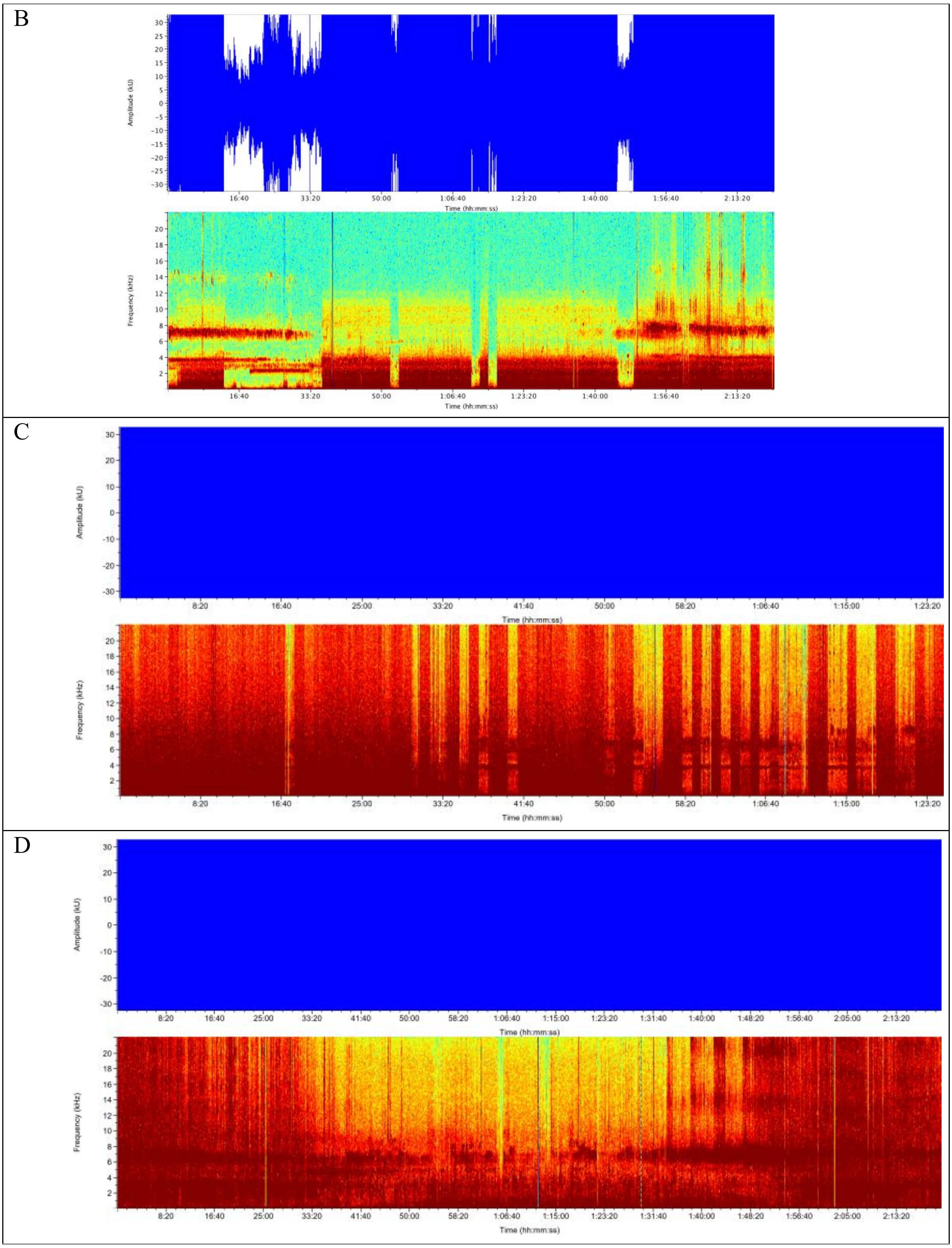
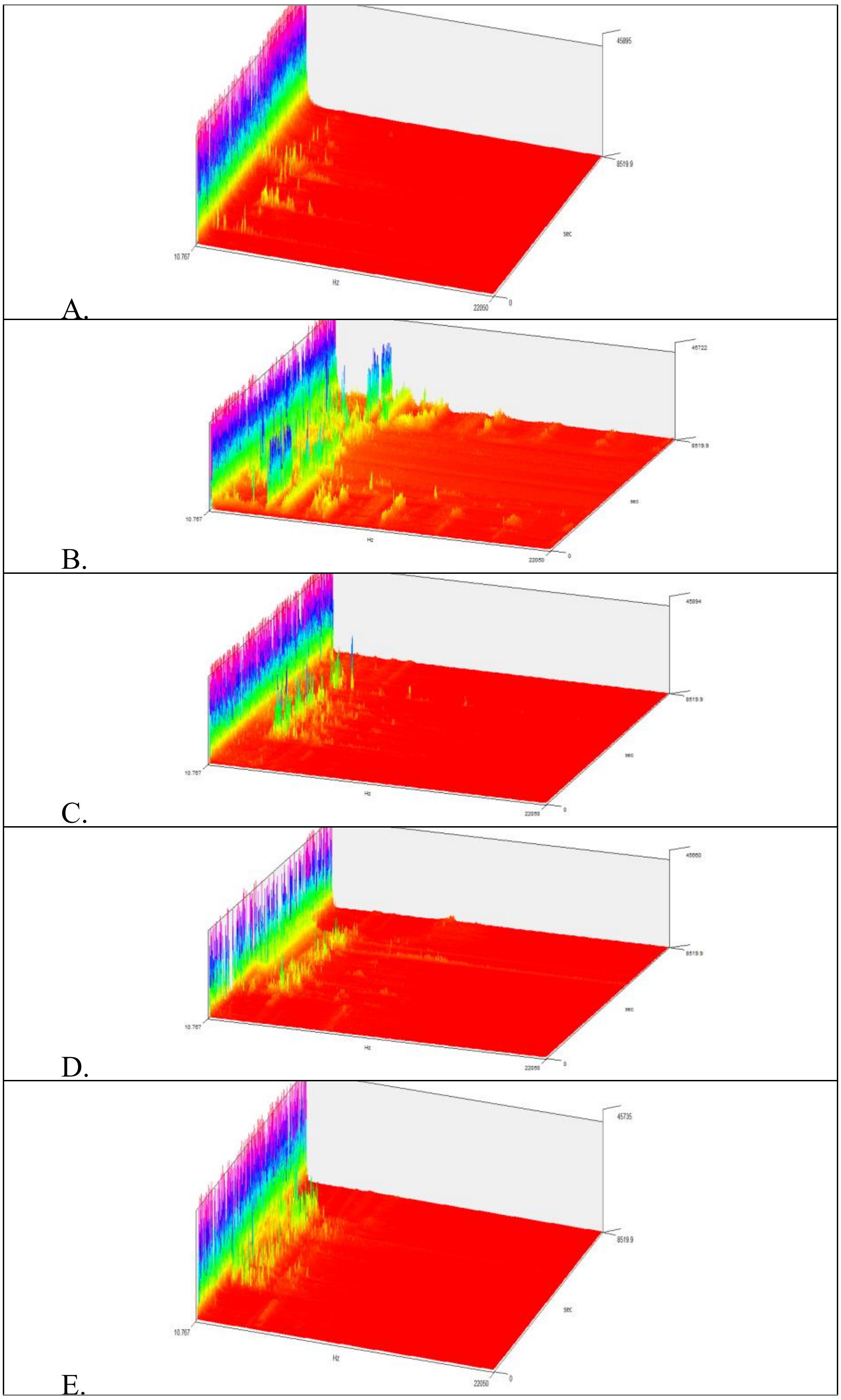


Figure 2.29. Waveform and spectrogram of 142 sound recordings made on a single day during Phase II. A. Grassland, B. Agriculture, C. Forest, and d. Control.

7. 3D spectrogram of 24h sound recording through Sound Monitoring Stations – Phase I and II.

To get a 3D perspective of frequency, time and energy of the sound recording, 24h sound records were plotted using SigView® (Figure 2.30). These graphs re-iterate the frequency spectrum explained earlier.



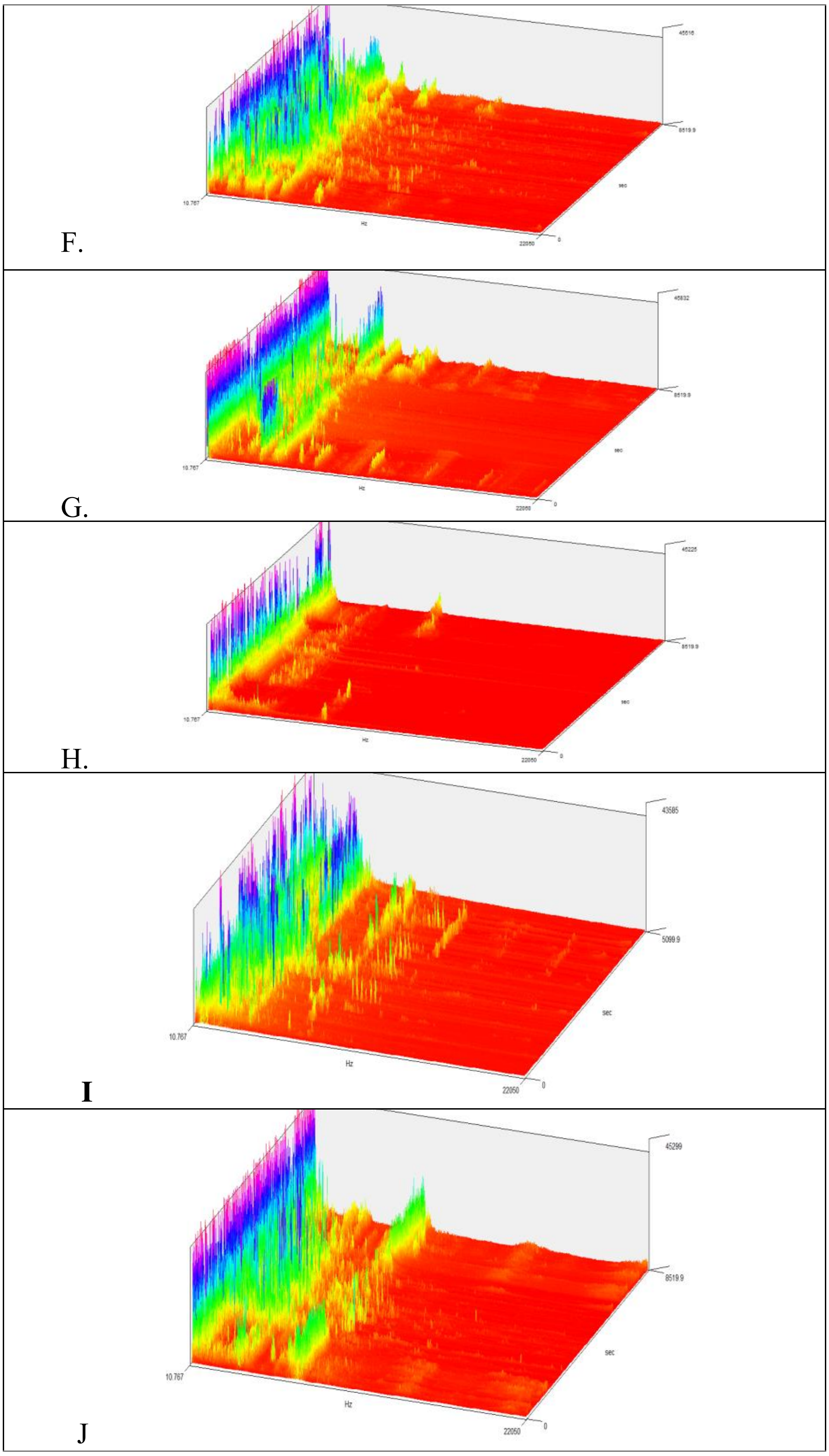


Figure 2.30. 3D spectrogram of 24h sound recording. Hz indicates frequency domain, sec indicates time, while z-axis indicates amplitude. A. Grassland, B. Agriculture, C. Waterbody, D. Forest, E. Builtup, F. Control for Phase I; G. Grassland, H. Agriculture, I. Forest and J. Control for Phase II.

8. Acoustical diversity indices for Phase I.

Sound records using SMS provides insights on ecoacoustics and acoustic indices help to address the ecology questions in acoustic space (Sueur and Farina 2015). These acoustic indices are similar to biodiversity indices. In this study, α acoustic indices that are designed to evaluate the acoustic diversity of a single unit, defined as a population, a community, or a landscape at a specific time is used. Three main indices M, Ht and AR are calculated and presented here (Table 2.3) for the duration of 6 am to 6 pm. Higher index values along with greater variation in values indicate diversity in terms of amplitude and frequency modulation. A principal component analysis (PCA) is carried out based on the three diversity indices and six different land-uses. Figure 2.31 illustrates the PCA, clearly showing the clustering of the rest of the land uses from control. Table 4 lists the factor loadings for the PCA carried out.

Table 2.3. Acoustical Diversity Index calculated from different land-uses between 6 am-6 pm sound records. Sample size, N=73.

	Min	Max	Mean	St.dev	Median
M_CONTROL	0.425	1.058	0.816	0.180	0.849
M_GRASS	0.633	1.126	1.025	0.094	1.048
M_AGRI	0.761	1.140	1.096	0.070	1.135
M_WATER	0.571	1.125	1.038	0.101	1.055
M_FOREST	0.194	1.122	0.699	0.202	0.701
M_BUILT	0.394	1.129	0.988	0.157	1.034
Ht_CONTROL	0.988	0.995	0.992	0.002	0.992
Ht_GRASS	0.987	0.997	0.993	0.002	0.994
Ht_AGRI	0.992	0.997	0.996	0.001	0.997
Ht_WATER	0.985	0.997	0.994	0.002	0.995
Ht_FOREST	0.972	0.997	0.991	0.004	0.992
Ht_BUILT	0.979	0.997	0.993	0.003	0.994
AR_CONTROL	0.000	0.979	0.351	0.300	0.317
AR_GRASS	0.000	0.979	0.390	0.316	0.358
AR_AGRI	0.017	0.890	0.509	0.273	0.659
AR_WATER	0.001	0.965	0.364	0.308	0.275
AR_FOREST	0.008	0.986	0.539	0.247	0.503
AR_BUILT	0.010	0.986	0.500	0.283	0.486

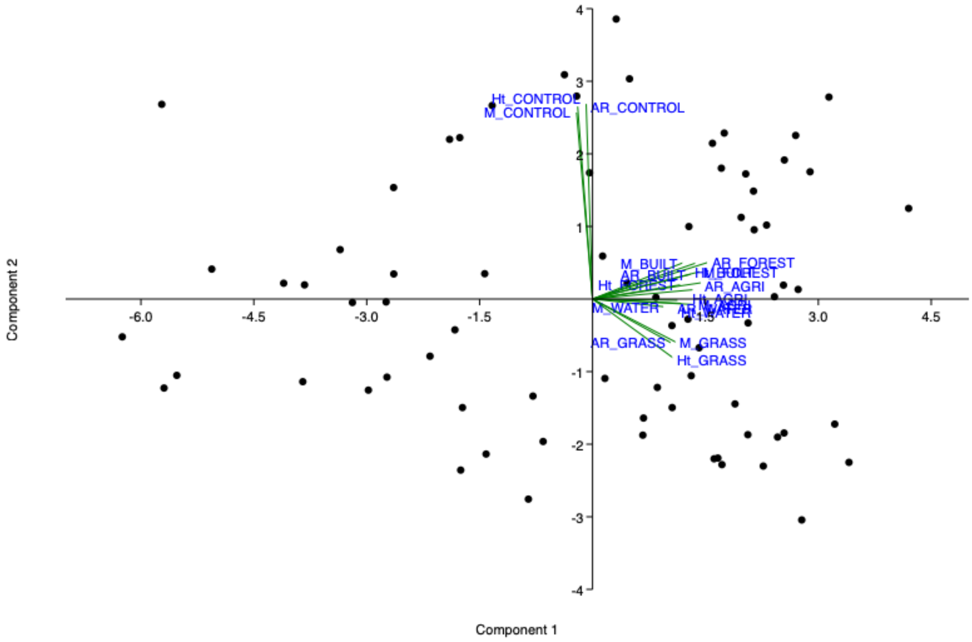


Figure 2.31. Principal Component Analysis based on three acoustic indices (M, Ht and AR) in six different land-use during operational MPC.

Table 2.4. Component loading for the PCA

PC	% variance
1	36.64
2	16.379
3	12.092
4	11.06
5	8.0965
6	6.6022
7	2.2676
8	1.8188
9	1.3925
10	1.17
11	0.65729
12	0.55917
13	0.41311
14	0.28263
15	0.24223
16	0.16191
17	0.089171
18	0.076798

Acoustical diversity indices were also calculated between different land-uses from 6pm to 6am acoustic records (Table 2.5). A PCA for the obtained values showed that, without MPC operation, the acoustic diversity doesn't for different clusters (Figure 2.32). A factor loading for the same is provided in Table 2.6. On comparing the mean values of Acoustic indices (M, Ht and AR) for 6am to 6pm with 6pm to 6am, for a paired Wilcoxon Test, it showed a significant difference between them (W=136, p = 0.00044).

Table 2.5. Acoustical Diversity Index calculated from different land-uses between 6pm-6am sound records. Sample size, N=69.

	Min	Max	Mean	St.dev	Median
M_CONTROL	0.445	1.076	0.765	0.181	0.715
M_GRASS	0.331	1.137	0.998	0.125	1.032
M_AGRI	0.460	1.140	0.934	0.211	1.033
M_WATER	0.379	1.123	1.005	0.161	1.048
M_FOREST	0.111	1.138	0.297	0.193	0.235
M_BUILT	0.167	1.125	0.650	0.317	0.594
Ht_CONTROL	0.988	0.996	0.992	0.002	0.992
Ht_GRASS	0.983	0.997	0.993	0.002	0.993
Ht_AGRI	0.987	0.997	0.994	0.003	0.994
Ht_WATER	0.981	0.997	0.993	0.004	0.994
Ht_FOREST	0.961	0.997	0.982	0.007	0.984
Ht_BUILT	0.975	0.997	0.987	0.006	0.988
AR_CONTROL	0.000	1.000	0.306	0.303	0.160
AR_GRASS	0.000	1.000	0.276	0.272	0.199
AR_AGRI	0.000	0.655	0.144	0.147	0.099
AR_WATER	0.000	0.951	0.302	0.289	0.188
AR_FOREST	0.000	1.000	0.099	0.141	0.071
AR_BUILT	0.000	0.993	0.158	0.207	0.067

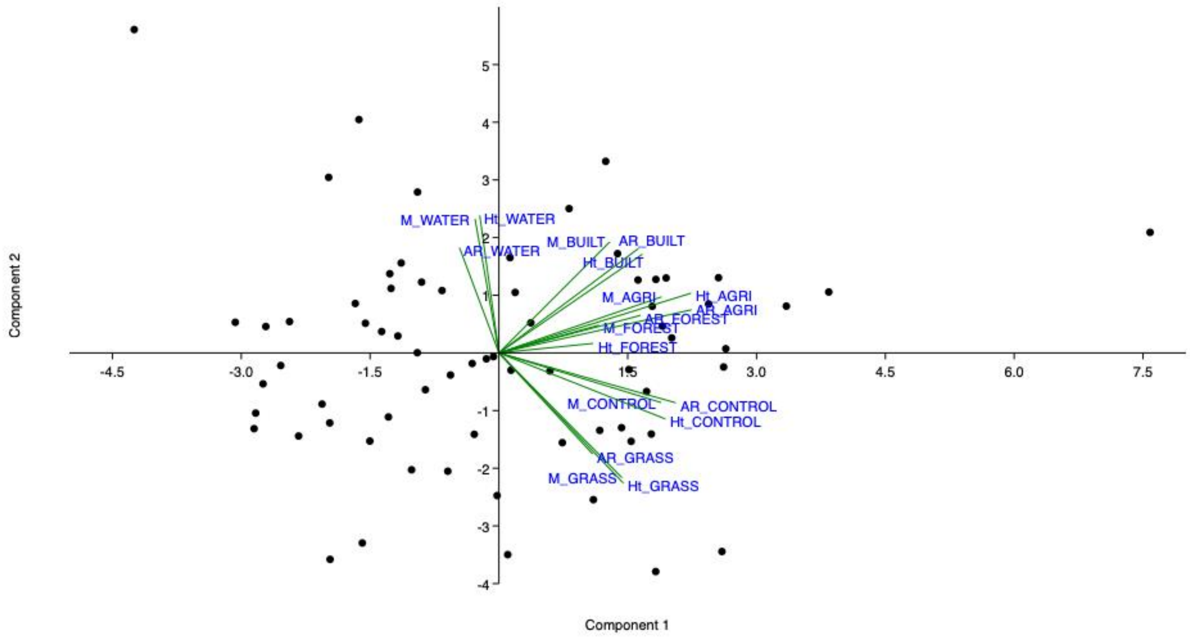


Figure 2.32. Principal Component Analysis based on three acoustic indices (M, Ht and AR) in six different land uses during non-operational MPC.

Table 2.6. Component loading for the PCA

PC	% variance
1	22.966
2	18.106
3	15.248
4	13.199
5	9.327
6	7.627
7	4.241
8	2.669
9	1.873
10	1.195
11	0.941
12	0.818
13	0.644
14	0.376
15	0.274
16	0.226
17	0.158
18	0.113

Discussion

Sound recording, in addition to measuring loudness (dB) helps in understanding the landscape. From this study, a total of 16285 minutes of sounds have been recorded. Apart from providing acoustical data for the current study, it will additionally help as a baseline acoustic data in a long-term monitoring programme.

Noisescape map has shown the sound attenuation (reduction in loudness, dBA) while moving away from the MPC. In the present study, soundscape recording provided amplitude and frequency of the sound in each area. Irrespective of the land-use, it was found that the MPC has a frequency band between 10-5000Hz as shown in spectrograms and spectrum slice view. There were also couple of instances where the spectrogram showed a band around 10000Hz and 20000Hz. Perhaps this could be due to level of harmonics generated in the MPC.

It is important to mention here that the frequency range of 10-5000Hz has an adverse impact on species that use acoustics to communicate, including human beings. The majority of insects, amphibians, birds and mammals have audio reception and signalling range within the range of 10-5000Hz and hence will get masked. To overcome such masking to their acoustic communications, acoustically active species will increase the pitch, which might result in non-acceptance by the signal receiving individual (Boekle, 2009). As an immediate response to the noise and higher frequency, a species may stop calling (Sun and Narins, 2005), just as humans do. In a prolonged exposure to such a noisy environment, species would a. stop calling from the area and move away from it, b. change calling patterns and call complexity (pulse rate, duration, pitch, peak frequency and amplitude), and c. change in spatial and temporal as of a call (in constant search for the less noisy environment or less noisy time of the day or night and move). All these have a significant influence on the evolution and adaptation of the species to a given landscape.

Spectral correlation clearly showed differences in spectrograms of the sounds coming from MPC with the non-operational time of MPC. None of the spectral correlations was above 0.6. In agriculture, it was the least (U=0.07) in Phase I, while it was the least in the forest (U=0.2) in Phase II. These are clear indications of differences in spectrograms from the region. However, long-term monitoring is needed to understand the spectral correlation better. In grasslands, which has HDPE idlers along with the MPC, the noise levels are lower. However, the frequency band of the MPC is still in the same region (10-5000Hz).

It is observed using ultrasonic recording devices, the frequency emitted from MPC is in the range of 35000Hz-45000Hz, which was not captured in SMS. Such frequency range also has an impact on insects ultrasound dependent species like bats.

Acoustic diversity indices showed that control is very different from the rest of the land-uses. Perhaps higher diversity of acoustically active species in control and lack of it in other land-uses could be the reason behind such variation. The noise and frequency of MPC may have reduced the acoustically active species in the land-uses where MPC runs through. However, the lack of baseline data (prior to implementation of MPC) makes it hard to draw that conclusion.

From this study, it is clear that MPC has a noise and frequency band (10-5000Hz), which will have a serious impact on wildlife even if it runs for 12h. Running MPC for 20h will have a deleterious impact on wildlife, especially with respect to animals that are active during the night as well as that use acoustic for communication.

Noisescape Map

Introduction

Sound is a vibration that propagates as an acoustic wave, through a medium such as a gas, liquid or solid. Sound immission is a spatial phenomenon and maps are used to represent noise with appropriate colour coding, resulting in noise maps (Weninger, 2015). Noise mapping is used in modelling noise generating from landscapes, traffic, industries and cities. Similarly, noise maps are used for planning purposes, for setting up noise reduction measures and for long term monitoring in environmental noise (Manwar et al 2015; Knauss, 2020). The primary aims of noisescape map were (i) to determine and map noise along MPC, (ii) to predict noise attenuation with distance and, (iii) to predict noise attenuation in various land-uses in the study area.

Materials and Methods

1. Instrument and measurements: Calibrated sound measuring instruments (1. 3M Sound Detector SD-200, 2. Sound Lever Meter S12, and 3. SL-4023SD) are used to record sound pressure levels (dBA). Sound measurements were made near Main Pipe Conveyor Belt (MPC) and at different distance intervals randomly moving away from the MPC during the operational time between 6am to 6pm. Sound pressure measurements were recorded for about 30sec. Maximum dBA values were noted along with Longitude, Latitude and predominant land use of the place of recording.
2. QGIS 3.20.2 with plugin *v.distance* and *contour* are used for mapping and creating sound scape. PAST® and MS Excel are used for regression analysis. Colour coding for the noise contours are based on Weninger (2015).

Result

Sound measurements: A total of 1587 sound (dB) measurements were collected from 7th July 2021 to 22nd August 2021 during the day time operation of MPC (6am to 6pm). Table 2.7a details the distance from MPC and recorded sound (dB) values. Among 1587 sound measurements, 1378 unique data are used for analysis, which falls within 250m on either sides of MPC (Figure 2.33). Minimum sound measured was 34.9dB, while the maximum was 89.77. In various land-uses, agriculture fields had 685 points, while grassland had 25 data points (Table 2.7).

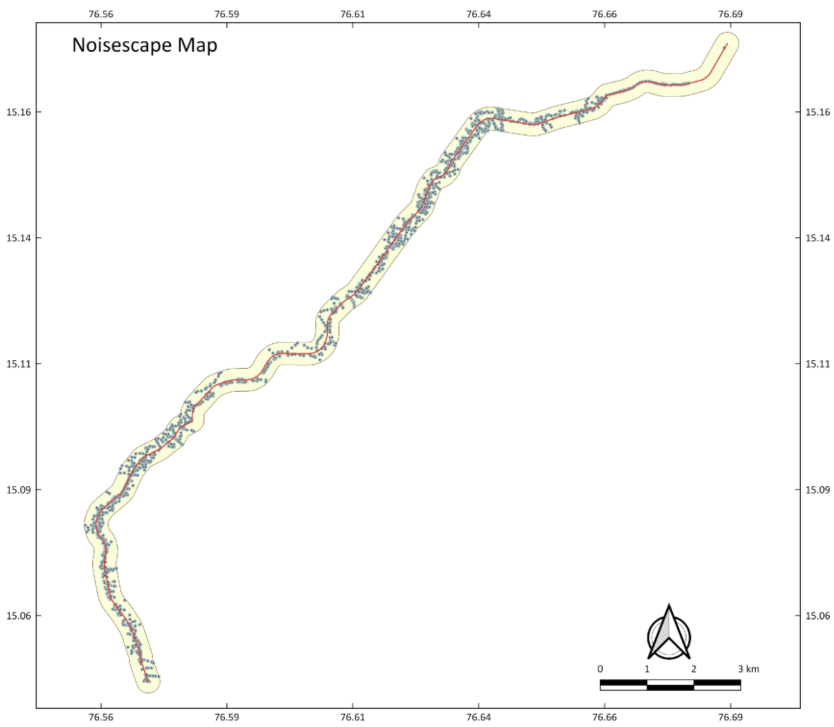


Figure 2.33. Sound measurement points along MPC.

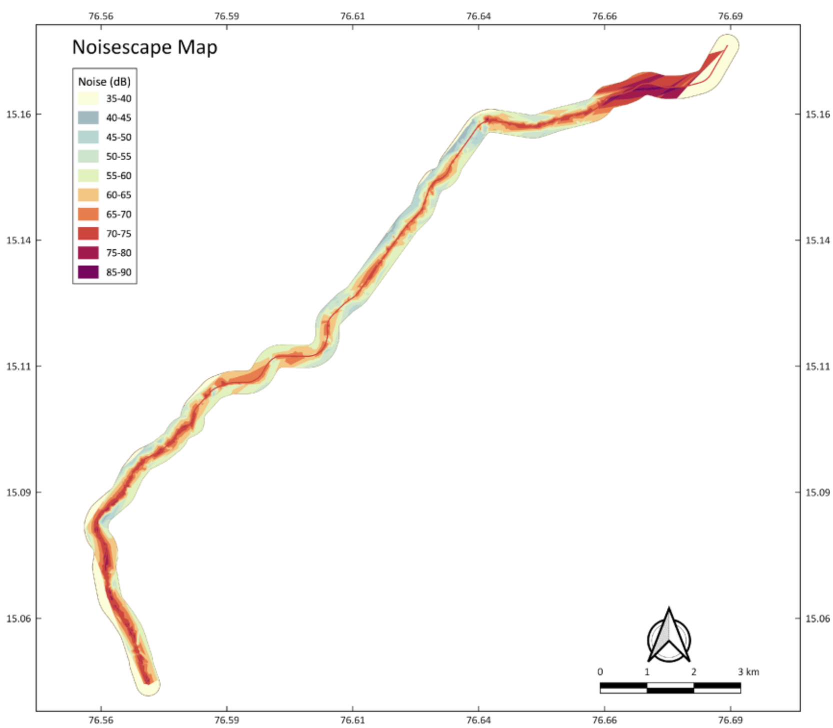


Figure 2.34. Noisescape Map with MPC.

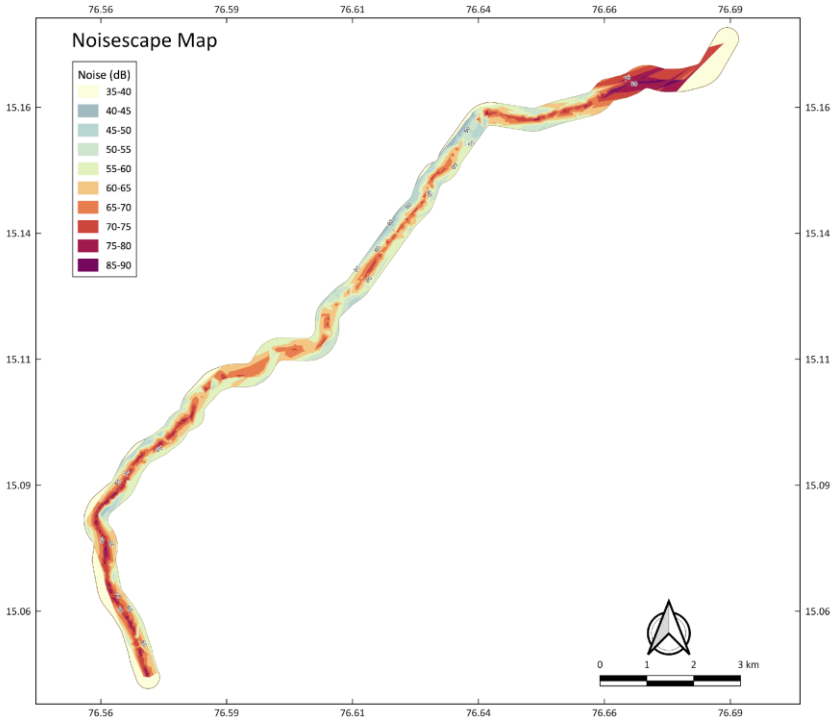


Figure 2.35. Noisescape Map with noise contours.

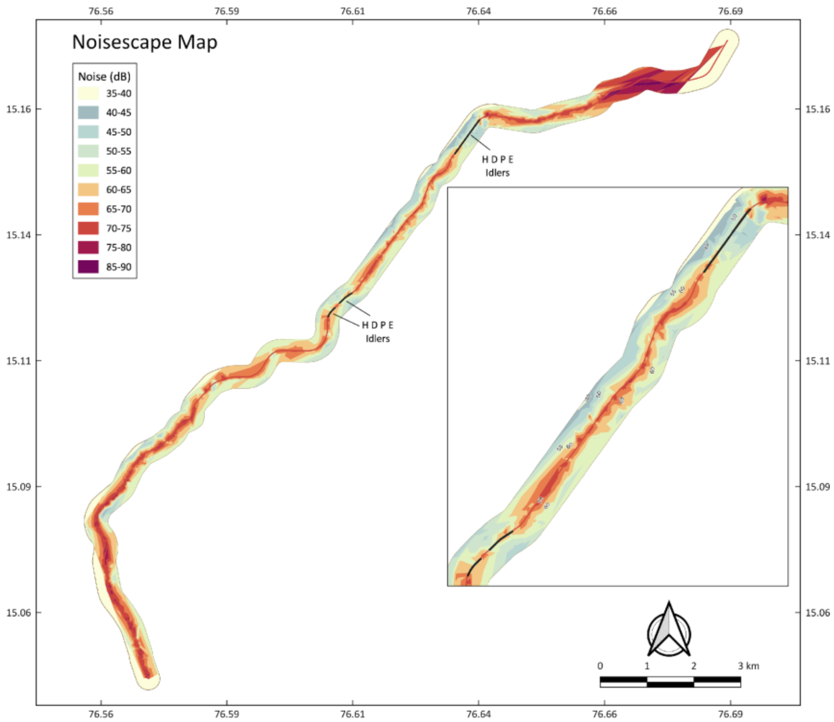


Figure 2.36. Noisescape Map with HDPE idlers in the inset.

Table 2.7a. Noise data collection from adjoining areas along MPC.

Date	Latitude	Longitude	Habitat	Distance (m)	Average (dB)
30/07/21	15.04686	76.56963	Agriculture	23.98	71.20
30/07/21	15.04692	76.56919	Agriculture	20.40	75.60
30/07/21	15.04698	76.56852	Agriculture	87.06	65.00
30/07/21	15.04699	76.56947	Agriculture	10.91	72.30
30/07/21	15.04723	76.56874	Agriculture	55.82	68.30
30/07/21	15.04740	76.56918	Agriculture	5.42	84.40
30/07/21	15.04764	76.56895	Agriculture	20.00	76.90
30/07/21	15.04788	76.57149	Agriculture	247.29	58.20
30/07/21	15.04795	76.57081	Agriculture	180.12	62.20
30/07/21	15.04798	76.57034	Agriculture	132.81	64.30
30/07/21	15.04803	76.56979	Agriculture	78.68	69.90
30/07/21	15.04803	76.56950	Agriculture	50.00	71.20
30/07/21	15.04820	76.56883	Agriculture	13.17	76.50
30/07/21	15.04827	76.56902	Agriculture	9.42	77.80
30/07/21	15.04928	76.56816	Agriculture	42.18	73.40
30/07/21	15.04955	76.56905	Agriculture	58.36	67.20
30/07/21	15.04956	76.57006	Agriculture	161.16	62.50
30/07/21	15.04960	76.56940	Agriculture	95.04	61.10
30/07/21	15.05043	76.56796	Agriculture	21.80	74.60
30/07/21	15.05053	76.57044	Agriculture	234.43	59.00
30/07/21	15.05076	76.57009	Agriculture	206.99	60.70
30/07/21	15.05081	76.56775	Agriculture	34.55	74.20
30/07/21	15.05099	76.56931	Agriculture	133.55	64.60
30/07/21	15.05106	76.56825	Agriculture	23.41	75.03
30/07/21	15.05117	76.56857	Agriculture	59.19	64.50
30/07/21	15.05128	76.56757	Agriculture	45.56	70.70
30/07/21	15.05129	76.56806	Agriculture	6.46	78.30
30/07/21	15.05142	76.56784	Agriculture	14.76	75.80
30/07/21	15.05199	76.56786	Agriculture	1.11	83.30
30/07/21	15.05202	76.56776	Agriculture	10.34	80.60
30/07/21	15.05228	76.56752	Agriculture	27.61	74.40
30/07/21	15.05244	76.56792	Agriculture	19.51	76.50
30/07/21	15.05247	76.56605	Agriculture	172.09	56.90
30/07/21	15.05258	76.56725	Agriculture	44.59	71.90
30/07/21	15.05276	76.56623	Agriculture	144.51	54.80
30/07/21	15.05286	76.56706	Agriculture	55.60	68.90
30/07/21	15.05286	76.56786	Agriculture	26.99	74.40
30/07/21	15.05299	76.56608	Agriculture	152.86	59.30
30/07/21	15.05309	76.56783	Agriculture	30.48	62.60
30/07/21	15.05352	76.56760	Agriculture	20.29	75.20
30/07/21	15.05355	76.56644	Agriculture	96.55	69.50
30/07/21	15.05371	76.56537	Agriculture	201.62	51.13
30/07/21	15.05384	76.56679	Agriculture	51.71	73.10
30/07/21	15.05384	76.56762	Agriculture	33.71	60.80
30/07/21	15.05391	76.56629	Agriculture	100.04	61.77
30/07/21	15.05399	76.56715	Agriculture	8.94	74.07
30/07/21	15.05414	76.56683	Agriculture	36.96	74.40

30/07/21	15.05423	76.56786	Agriculture	71.49	68.60
30/07/21	15.05446	76.56758	Agriculture	50.22	68.10
30/07/21	15.05476	76.56749	Agriculture	51.02	64.00
30/07/21	15.05497	76.56648	Agriculture	45.59	71.10
30/07/21	15.05506	76.56733	Agriculture	44.15	55.06
30/07/21	15.05550	76.56651	Agriculture	25.33	72.50
30/07/21	15.05561	76.56694	Agriculture	22.07	74.30
30/07/21	15.05593	76.56647	Agriculture	16.23	75.30
30/07/21	15.05629	76.56581	Agriculture	69.88	68.50
30/07/21	15.05635	76.56539	Agriculture	109.31	67.00
30/07/21	15.05638	76.56667	Agriculture	20.71	76.80
30/07/21	15.05697	76.56686	Agriculture	62.43	70.50
30/07/21	15.05704	76.56599	Agriculture	21.22	77.70
30/07/21	15.05737	76.56645	Agriculture	39.27	68.90
12/07/21	15.05739	76.56594		10.69	77.90
30/07/21	15.05747	76.56594	Agriculture	7.04	78.80
30/07/21	15.05753	76.56614	Agriculture	15.01	78.40
30/07/21	15.05759	76.56594	Agriculture	0.91	75.23
30/07/21	15.05773	76.56588	Agriculture	0.06	79.80
30/07/21	15.05794	76.56683	Agriculture	101.25	63.33
31/07/21	15.05794	76.56566	Agriculture	9.43	81.23
31/07/21	15.05798	76.56597	Agriculture	21.60	74.50
31/07/21	15.05810	76.56548	Agriculture	17.60	78.53
31/07/21	15.05811	76.56494	Agriculture	68.02	67.17
31/07/21	15.05813	76.56525	Agriculture	37.52	67.53
31/07/21	15.05814	76.56449	Agriculture	108.65	67.40
30/07/21	15.05820	76.56771	Agriculture	199.61	56.23
31/07/21	15.05834	76.56580	Agriculture	25.33	67.23
31/07/21	15.05846	76.56542	Agriculture	3.98	81.60
31/07/21	15.05848	76.56437	Agriculture	101.38	67.37
31/07/21	15.05875	76.56632	Agriculture	96.24	68.90
31/07/21	15.05885	76.56673	Agriculture	140.18	63.27
31/07/21	15.05897	76.56448	Agriculture	63.54	70.90
31/07/21	15.05923	76.56575	Agriculture	68.58	69.07
31/07/21	15.05927	76.56485	Agriculture	12.17	74.63
31/07/21	15.06007	76.56355	Agriculture	74.63	61.40
31/07/21	15.06008	76.56396	Agriculture	38.36	71.83
31/07/21	15.06010	76.56570	Agriculture	114.22	67.30
31/07/21	15.06036	76.56339	Agriculture	70.39	66.20
31/07/21	15.06058	76.56368	Agriculture	30.39	73.13
31/07/21	15.06111	76.56284	Agriculture	70.06	66.53
31/07/21	15.06111	76.56360	Agriculture	4.46	74.13
31/07/21	15.06111	76.56463	Agriculture	87.01	69.83
31/07/21	15.06117	76.56346	Agriculture	12.59	72.73
31/07/21	15.06119	76.56310	Agriculture	41.98	69.90
12/07/21	15.06123	76.56392		31.50	72.40
31/07/21	15.06125	76.56238	Agriculture	99.95	66.23
31/07/21	15.06165	76.56336	Agriculture	10.86	78.47
31/07/21	15.06171	76.56271	Agriculture	40.74	70.50
31/07/21	15.06189	76.56380	Agriculture	64.61	69.27

31/07/21	15.06191	76.56274	Agriculture	23.85	73.73
31/07/21	15.06212	76.56274	Agriculture	9.57	76.97
31/07/21	15.06227	76.56297	Agriculture	19.74	76.07
31/07/21	15.06303	76.56473	Agriculture	220.81	60.63
31/07/21	15.06319	76.56184	Agriculture	29.39	74.30
31/07/21	15.06337	76.56188	Agriculture	18.16	75.00
31/07/21	15.06361	76.56267	Agriculture	70.65	72.03
31/07/21	15.06362	76.56152	Agriculture	45.94	71.37
31/07/21	15.06389	76.56200	Agriculture	13.03	81.43
31/07/21	15.06426	76.56120	Agriculture	58.64	69.23
31/07/21	15.06452	76.56126	Agriculture	44.91	71.27
31/07/21	15.06474	76.56146	Agriculture	19.63	74.33
31/07/21	15.06476	76.56203	Agriculture	41.44	72.30
31/07/21	15.06479	76.56247	Agriculture	88.55	66.97
31/07/21	15.06489	76.56162	Agriculture	0.89	80.67
31/07/21	15.06519	76.56161	Agriculture	5.93	81.63
31/07/21	15.06522	76.56117	Agriculture	40.61	72.03
31/07/21	15.06531	76.56094	Agriculture	62.69	70.07
31/07/21	15.06556	76.56084	Agriculture	68.01	69.87
31/07/21	15.06580	76.56287	Agriculture	151.12	64.03
31/07/21	15.06584	76.56261	Forest	124.71	56.70
31/07/21	15.06596	76.56196	Agriculture	57.78	64.23
31/07/21	15.06603	76.56183	Agriculture	45.34	72.50
31/07/21	15.06606	76.56133	Agriculture	7.59	77.47
31/07/21	15.06611	76.56145	Forest	6.88	68.40
31/07/21	15.06618	76.56166	Forest	30.63	64.20
31/07/21	15.06645	76.56072	Agriculture	63.56	67.17
31/07/21	15.06660	76.56148	Agriculture	19.94	75.27
31/07/21	15.06674	76.56271	Forest	152.56	52.30
31/07/21	15.06675	76.56245	Forest	124.93	51.77
31/07/21	15.06679	76.56062	Agriculture	67.07	62.87
31/07/21	15.06763	76.56041	Agriculture	73.13	56.63
31/07/21	15.06764	76.56122	Agriculture	13.00	74.87
31/07/21	15.06793	76.56072	Agriculture	35.04	72.73
31/07/21	15.06818	76.56045	Agriculture	58.87	64.40
31/07/21	15.06855	76.56129	Agriculture	37.16	71.27
31/07/21	15.06860	76.56073	Agriculture	21.14	74.40
31/07/21	15.06888	76.56160	Agriculture	76.29	70.43
14/07/21	15.06895	76.56231	Forest	152.82	62.47
14/07/21	15.06909	76.56081	Forest	3.83	73.30
14/07/21	15.06916	76.56221	Forest	146.18	59.30
12/07/21	15.06916	76.56194		117.63	51.50
14/07/21	15.06918	76.56124	Forest	44.01	70.60
14/07/21	15.06921	76.56261	Forest	189.97	58.80
14/07/21	15.06926	76.56171	Forest	95.65	65.80
31/07/21	15.06926	76.56081	Agriculture	0.06	76.53
31/07/21	15.06932	76.56011	Agriculture	73.12	69.50
14/07/21	15.06936	76.56309	Forest	242.92	59.40
31/07/21	15.06937	76.56034	Agriculture	47.77	71.43
31/07/21	15.06963	76.56090	Agriculture	16.49	78.10

31/07/21	15.06967	76.55985	Agriculture	94.63	67.63
31/07/21	15.06988	76.56012	Agriculture	62.74	68.03
31/07/21	15.07043	76.56017	Agriculture	56.45	70.03
31/07/21	15.07061	76.56088	Agriculture	17.62	76.60
31/07/21	15.07063	76.56017	Agriculture	58.96	67.00
31/07/21	15.07080	76.56042	Agriculture	33.90	68.67
31/07/21	15.07114	76.56065	Agriculture	15.38	76.40
31/07/21	15.07131	76.56084	Agriculture	2.36	81.70
31/07/21	15.07170	76.56068	Agriculture	22.24	75.53
31/07/21	15.07193	76.56035	Agriculture	62.36	69.63
31/07/21	15.07213	76.56034	Agriculture	67.18	68.33
02/08/21	15.07236	76.56091	Agriculture	10.69	84.50
02/08/21	15.07265	76.56122	Agriculture	19.66	76.13
31/07/21	15.07271	76.56070	Agriculture	36.56	73.33
31/07/21	15.07280	76.56094	Agriculture	10.76	79.50
05/08/21	15.07320	76.56104	Agriculture	4.36	81.60
02/08/21	15.07330	76.56118	Agriculture	20.99	76.77
02/08/21	15.07337	76.56094	Agriculture	3.68	78.10
02/08/21	15.07345	76.56077	Agriculture	19.95	73.73
05/08/21	15.07355	76.56113	Agriculture	20.12	76.63
02/08/21	15.07362	76.56084	Agriculture	9.46	76.57
02/08/21	15.07403	76.56157	Agriculture	75.42	67.20
05/08/21	15.07415	76.56113	Agriculture	33.41	74.50
02/08/21	15.07430	76.56121	Agriculture	46.88	71.37
02/08/21	15.07435	76.56040	Agriculture	31.97	72.90
12/07/21	15.07465	76.56205		144.84	63.20
02/08/21	15.07480	76.56059	Agriculture	7.91	79.00
02/08/21	15.07486	76.56050	Agriculture	3.35	78.27
05/08/21	15.07492	76.56091	Agriculture	44.60	73.36
02/08/21	15.07505	76.56086	Agriculture	47.37	70.40
02/08/21	15.07508	76.56042	Agriculture	10.04	77.20
02/08/21	15.07532	76.55996	Agriculture	12.18	73.80
02/08/21	15.07534	76.55996	Agriculture	10.99	74.30
02/08/21	15.07547	76.56030	Agriculture	26.60	72.73
02/08/21	15.07554	76.55951	Agriculture	34.33	67.63
02/08/21	15.07562	76.55981	Agriculture	3.64	77.10
05/08/21	15.07590	76.56044	Agriculture	68.39	70.16
02/08/21	15.07602	76.55936	Agriculture	21.01	72.90
02/08/21	15.07635	76.55925	Agriculture	18.39	74.03
02/08/21	15.07637	76.55938	Agriculture	4.44	77.50
02/08/21	15.07650	76.55844	Agriculture	93.21	63.30
02/08/21	15.07658	76.55720	Agriculture	217.82	51.40
05/08/21	15.07665	76.55981	Agriculture	50.02	72.66
02/08/21	15.07680	76.55944	Agriculture	19.20	74.50
02/08/21	15.07699	76.55983	Agriculture	65.69	70.10
02/08/21	15.07699	76.55836	Agriculture	86.26	66.10
02/08/21	15.07701	76.55754	Agriculture	172.23	61.20
02/08/21	15.07708	76.55942	Agriculture	26.97	73.50
02/08/21	15.07728	76.55845	Agriculture	70.35	67.03
05/08/21	15.07738	76.55912	Agriculture	2.39	81.00

02/08/21	15.07741	76.55990	Agriculture	85.21	69.60
02/08/21	15.07746	76.55744	Agriculture	176.59	60.53
02/08/21	15.07760	76.55904	Agriculture	3.87	80.00
05/08/21	15.07771	76.55891	Agriculture	16.72	80.13
07/08/21	15.07774	76.56011	Forest	112.09	62.90
02/08/21	15.07779	76.55845	Agriculture	65.22	67.87
02/08/21	15.07783	76.55965	Agriculture	63.70	71.57
02/08/21	15.07784	76.55876	Agriculture	31.50	74.57
02/08/21	15.07792	76.55689	Agriculture	231.92	57.93
02/08/21	15.07794	76.55811	Agriculture	101.31	65.13
07/08/21	15.07830	76.55975	Forest	75.23	62.07
02/08/21	15.07836	76.55864	Agriculture	44.17	71.00
07/08/21	15.07838	76.56038	Forest	141.32	53.20
07/08/21	15.07839	76.56043	Forest	145.96	53.83
07/08/21	15.07843	76.55994	Forest	94.08	58.37
02/08/21	15.07863	76.55945	Agriculture	38.54	72.50
07/08/21	15.07872	76.55908	Forest	2.22	76.67
05/08/21	15.07877	76.55912	Agriculture	1.36	79.13
07/08/21	15.07901	76.56029	Forest	115.51	43.57
05/08/21	15.07911	76.55946	Agriculture	28.00	75.13
02/08/21	15.07913	76.55843	Agriculture	77.75	66.53
07/08/21	15.07918	76.56022	Forest	102.62	47.43
07/08/21	15.07919	76.55965	Forest	44.04	51.40
02/08/21	15.07937	76.55965	Agriculture	37.83	62.07
07/08/21	15.07938	76.56005	Forest	76.93	46.73
07/08/21	15.07966	76.55935	Forest	4.30	78.77
02/08/21	15.07971	76.55873	Agriculture	68.05	68.47
02/08/21	15.07980	76.55864	Agriculture	80.30	66.27
02/08/21	15.07987	76.55916	Agriculture	32.57	71.47
05/08/21	15.07992	76.55978	Agriculture	25.54	75.06
07/08/21	15.07998	76.56036	Forest	79.35	46.80
02/08/21	15.08029	76.55943	Agriculture	25.68	72.80
07/08/21	15.08034	76.55966	Forest	5.47	77.50
07/08/21	15.08039	76.56121	Forest	124.93	43.07
07/08/21	15.08044	76.56094	Forest	100.64	47.20
02/08/21	15.08046	76.56032	Agriculture	49.02	69.27
02/08/21	15.08050	76.55973	Agriculture	6.12	77.70
07/08/21	15.08084	76.56234	Forest	170.17	46.27
07/08/21	15.08089	76.56178	Forest	125.97	48.90
07/08/21	15.08098	76.56216	Forest	145.62	51.23
02/08/21	15.08100	76.55938	Agriculture	67.81	66.37
07/08/21	15.08115	76.56238	Forest	148.02	50.80
02/08/21	15.08117	76.56018	Agriculture	14.36	76.30
02/08/21	15.08120	76.55982	Agriculture	43.76	69.27
05/08/21	15.08132	76.56130	Agriculture	55.75	72.50
02/08/21	15.08136	76.55919	Agriculture	107.85	67.50
07/08/21	15.08140	76.56066	Forest	2.74	79.73
12/07/21	15.08150	76.56223		108.09	53.50
07/08/21	15.08152	76.56229	Forest	111.08	50.43
05/08/21	15.08157	76.56170	Agriculture	64.22	72.16

02/08/21	15.08163	76.56171	Agriculture	60.00	70.27
02/08/21	15.08164	76.56045	Agriculture	31.69	69.47
02/08/21	15.08183	76.56002	Agriculture	78.93	62.77
07/08/21	15.08190	76.56236	Forest	84.50	55.63
07/08/21	15.08206	76.56142	Forest	4.28	79.60
02/08/21	15.08233	76.56144	Agriculture	16.80	73.90
02/08/21	15.08233	76.56254	Agriculture	62.03	69.17
02/08/21	15.08237	76.56162	Agriculture	7.56	75.07
07/08/21	15.08242	76.56299	Forest	86.89	56.23
05/08/21	15.08254	76.56204	Agriculture	8.80	79.33
02/08/21	15.08255	76.56282	Agriculture	64.05	71.67
07/08/21	15.08271	76.56362	Forest	107.22	50.03
02/08/21	15.08275	76.56266	Agriculture	36.08	73.70
05/08/21	15.08276	76.56234	Agriculture	12.25	80.63
07/08/21	15.08278	76.56220	Forest	0.79	81.27
05/08/21	15.08296	76.56249	Agriculture	6.57	79.50
02/08/21	15.08304	76.56279	Agriculture	21.23	78.13
05/08/21	15.08306	76.56273	Agriculture	15.32	79.23
02/08/21	15.08312	76.56234	Agriculture	17.47	74.93
02/08/21	15.08317	76.56270	Agriculture	4.03	83.27
05/08/21	15.08330	76.56299	Agriculture	13.71	82.73
07/08/21	15.08337	76.56367	Forest	56.15	63.90
07/08/21	15.08354	76.56310	Forest	0.96	80.50
02/08/21	15.08356	76.56271	Agriculture	27.61	72.77
05/08/21	15.08367	76.56332	Agriculture	6.21	79.36
07/08/21	15.08371	76.56403	Agriculture	53.53	66.53
07/08/21	15.08372	76.56450	Agriculture	86.81	62.87
05/08/21	15.08390	76.56355	Agriculture	3.31	73.33
07/08/21	15.08394	76.56529	Agriculture	131.60	55.80
07/08/21	15.08394	76.56493	Agriculture	102.63	62.60
05/08/21	15.08400	76.56396	Agriculture	24.68	72.60
05/08/21	15.08414	76.56413	Agriculture	25.47	71.30
07/08/21	15.08414	76.56475	Agriculture	73.00	60.57
05/08/21	15.08419	76.56443	Agriculture	44.37	70.86
02/08/21	15.08424	76.56168	Agriculture	157.51	61.00
07/08/21	15.08432	76.56507	Agriculture	88.12	63.30
02/08/21	15.08449	76.56125	Agriculture	208.21	55.30
05/08/21	15.08452	76.56449	Agriculture	24.15	72.46
05/08/21	15.08457	76.56428	Agriculture	3.87	77.56
05/08/21	15.08464	76.56450	Agriculture	17.55	74.53
05/08/21	15.08478	76.56445	Agriculture	4.57	75.40
07/08/21	15.08486	76.56447	Agriculture	1.53	74.37
05/08/21	15.08489	76.56450	Agriculture	2.46	78.53
05/08/21	15.08491	76.56455	Agriculture	6.44	78.66
07/08/21	15.08514	76.56561	Agriculture	98.89	58.50
07/08/21	15.08516	76.56523	Agriculture	61.59	59.90
05/08/21	15.08517	76.56462	Agriculture	1.37	77.40
05/08/21	15.08520	76.56464	Agriculture	1.95	76.26
07/08/21	15.08520	76.56493	Agriculture	30.16	64.87
05/08/21	15.08528	76.56466	Agriculture	0.23	76.40

07/08/21	15.08533	76.56468	Agriculture	0.23	73.90
05/08/21	15.08536	76.56474	Agriculture	4.30	76.33
05/08/21	15.08537	76.56477	Agriculture	6.75	78.23
05/08/21	15.08551	76.56483	Agriculture	6.05	77.33
05/08/21	15.08572	76.56488	Agriculture	1.09	79.10
07/08/21	15.08580	76.56634	Agriculture	141.09	55.03
07/08/21	15.08588	76.56513	Agriculture	18.24	65.20
07/08/21	15.08589	76.56518	Agriculture	22.87	60.50
05/08/21	15.08589	76.56495	Agriculture	0.04	77.36
05/08/21	15.08606	76.56502	Agriculture	0.61	72.66
05/08/21	15.08610	76.56506	Agriculture	1.58	77.16
05/08/21	15.08612	76.56516	Agriculture	10.57	74.13
05/08/21	15.08620	76.56532	Agriculture	22.85	77.30
05/08/21	15.08640	76.56525	Agriculture	7.15	74.63
05/08/21	15.08655	76.56538	Agriculture	13.39	73.73
07/08/21	15.08673	76.56609	Agriculture	76.23	63.10
07/08/21	15.08674	76.56577	Agriculture	43.47	66.33
05/08/21	15.08681	76.56552	Agriculture	16.13	74.36
05/08/21	15.08681	76.56542	Agriculture	6.21	75.20
05/08/21	15.08689	76.56561	Agriculture	21.65	72.23
07/08/21	15.08692	76.56555	Agriculture	14.42	69.47
05/08/21	15.08701	76.56557	Agriculture	12.56	73.53
05/08/21	15.08702	76.56564	Agriculture	19.08	74.20
05/08/21	15.08728	76.56557	Agriculture	1.05	76.53
07/08/21	15.08729	76.56554	Agriculture	1.96	72.83
05/08/21	15.08755	76.56573	Agriculture	4.90	75.36
12/08/21	15.08781	76.56603	Agriculture	21.59	76.07
12/08/21	15.08784	76.56728	Agriculture	143.72	62.20
12/08/21	15.08787	76.56627	Agriculture	41.68	71.17
12/08/21	15.08791	76.56679	Agriculture	91.71	65.37
12/08/21	15.08803	76.56552	Agriculture	38.68	70.47
12/08/21	15.08828	76.56385	Agriculture	212.09	53.97
12/08/21	15.08830	76.56467	Agriculture	134.11	58.40
12/08/21	15.08832	76.56632	Agriculture	27.77	71.80
12/08/21	15.08859	76.56655	Agriculture	35.82	66.73
12/08/21	15.08874	76.56683	Agriculture	50.62	64.87
12/08/21	15.08880	76.56559	Agriculture	65.80	65.10
12/08/21	15.08881	76.56726	Agriculture	82.29	65.50
29/07/21	15.08890	76.56864	Builtup	194.02	55.40
12/08/21	15.08915	76.56390	Agriculture	247.69	45.30
12/08/21	15.08920	76.56661	Agriculture	0.58	76.10
29/07/21	15.08921	76.56773	Agriculture	95.27	62.80
12/08/21	15.08931	76.56694	Agriculture	21.31	70.17
12/08/21	15.08935	76.56766	Agriculture	79.85	67.17
12/08/21	15.08936	76.56561	Agriculture	95.59	60.67
12/08/21	15.08946	76.56699	Agriculture	15.11	73.33
12/08/21	15.08950	76.56821	Agriculture	116.91	65.27
12/08/21	15.08950	76.56887	Agriculture	173.72	67.47
12/08/21	15.08953	76.56841	Agriculture	132.23	66.43
29/07/21	15.08955	76.56685	Agriculture	2.44	74.40

12/08/21	15.08965	76.56510	Agriculture	158.81	57.23
12/08/21	15.08967	76.56611	Agriculture	74.02	64.53
12/08/21	15.08972	76.56648	Agriculture	45.64	67.57
12/08/21	15.08975	76.56421	Agriculture	247.07	44.97
12/08/21	15.08983	76.56705	Agriculture	4.12	77.30
12/08/21	15.08994	76.56829	Agriculture	95.06	65.53
12/08/21	15.08995	76.56847	Agriculture	108.65	63.97
12/08/21	15.08996	76.56889	Agriculture	144.52	63.90
12/08/21	15.09015	76.56779	Agriculture	38.07	69.93
12/08/21	15.09026	76.56659	Agriculture	72.63	58.67
12/08/21	15.09031	76.56624	Agriculture	105.52	53.40
30/07/21	15.09039	76.56972	Builtup	165.49	52.70
30/07/21	15.09047	76.56924	Builtup	130.46	57.00
30/07/21	15.09054	76.56875	Builtup	91.26	62.07
12/08/21	15.09055	76.56786	Agriculture	16.58	75.83
30/07/21	15.09062	76.56829	Builtup	48.07	72.60
13/07/21	15.09065	76.56990	Builtup	148.84	54.80
12/08/21	15.09070	76.56608	Agriculture	145.50	47.47
30/07/21	15.09072	76.56776	Builtup	3.41	77.63
13/07/21	15.09072	76.56943	Builtup	118.59	63.10
13/07/21	15.09078	76.56897	Builtup	85.71	66.30
12/08/21	15.09080	76.56546	Agriculture	205.72	45.00
13/07/21	15.09086	76.56861	Builtup	55.68	71.30
12/08/21	15.09092	76.56802	Agriculture	4.84	75.60
29/07/21	15.09096	76.56794	Agriculture	4.88	71.90
13/07/21	15.09100	76.56802	Builtup	0.70	77.20
12/08/21	15.09130	76.57044	Agriculture	109.83	63.87
12/08/21	15.09132	76.56850	Agriculture	7.44	74.30
12/08/21	15.09132	76.56887	Agriculture	30.12	68.73
12/08/21	15.09137	76.57007	Agriculture	85.48	61.50
12/08/21	15.09138	76.56671	Agriculture	137.10	46.73
29/07/21	15.09142	76.56612	Agriculture	190.32	53.70
12/08/21	15.09163	76.57026	Agriculture	69.58	63.70
12/08/21	15.09186	76.56995	Agriculture	30.71	66.27
12/08/21	15.09188	76.56977	Agriculture	19.22	68.50
12/08/21	15.09194	76.57071	Agriculture	60.96	69.77
12/08/21	15.09194	76.56894	Agriculture	25.18	69.87
12/08/21	15.09198	76.57051	Agriculture	47.00	68.53
12/08/21	15.09211	76.56693	Agriculture	171.04	44.07
12/08/21	15.09214	76.56836	Agriculture	75.40	60.90
12/08/21	15.09221	76.56772	Agriculture	121.34	59.47
12/08/21	15.09232	76.57055	Agriculture	16.48	73.50
12/08/21	15.09255	76.56916	Agriculture	75.34	60.37
12/08/21	15.09280	76.57150	Agriculture	17.04	76.40
12/08/21	15.09305	76.56904	Agriculture	130.58	51.80
12/08/21	15.09308	76.56936	Agriculture	117.82	52.70
13/07/21	15.09328	76.57186	Agriculture	4.99	79.90
12/08/21	15.09331	76.56890	Agriculture	163.31	46.57
12/08/21	15.09339	76.56938	Agriculture	147.21	48.37
12/08/21	15.09346	76.57451	Agriculture	160.09	62.47

12/08/21	15.09348	76.57426	Agriculture	141.69	65.33
12/08/21	15.09351	76.57399	Agriculture	119.57	64.63
12/08/21	15.09352	76.57024	Agriculture	116.50	51.03
12/08/21	15.09354	76.57063	Agriculture	99.99	60.43
12/08/21	15.09359	76.57346	Agriculture	75.39	62.53
12/08/21	15.09363	76.57374	Agriculture	92.12	59.77
12/08/21	15.09364	76.56974	Agriculture	153.79	46.60
13/07/21	15.09367	76.57165	Agriculture	53.14	70.60
12/08/21	15.09378	76.57397	Agriculture	95.92	63.47
13/07/21	15.09392	76.57618	Agriculture	239.50	56.90
12/08/21	15.09397	76.57448	Agriculture	113.30	66.43
12/08/21	15.09406	76.57395	Agriculture	70.15	65.57
13/07/21	15.09415	76.57590	Agriculture	201.01	58.60
13/07/21	15.09415	76.57135	Agriculture	115.22	64.80
12/08/21	15.09424	76.57343	Agriculture	18.92	72.63
12/08/21	15.09430	76.57322	Agriculture	0.65	74.37
13/07/21	15.09439	76.57562	Agriculture	160.17	59.20
12/08/21	15.09447	76.57231	Agriculture	78.37	61.40
12/08/21	15.09450	76.57351	Agriculture	2.56	76.40
13/07/21	15.09457	76.57111	Agriculture	168.33	58.70
13/07/21	15.09461	76.57534	Agriculture	122.10	63.40
12/08/21	15.09488	76.57288	Agriculture	73.14	65.90
12/08/21	15.09488	76.57196	Agriculture	138.16	49.93
13/07/21	15.09493	76.57504	Agriculture	74.42	66.20
13/07/21	15.09499	76.57083	Agriculture	222.65	57.10
12/08/21	15.09504	76.57569	Agriculture	123.94	61.63
13/07/21	15.09508	76.57470	Agriculture	36.37	71.30
12/08/21	15.09514	76.57140	Agriculture	198.02	43.53
12/08/21	15.09520	76.57477	Agriculture	33.79	66.43
12/08/21	15.09524	76.57452	Agriculture	10.24	76.13
13/07/21	15.09531	76.57438	Agriculture	5.58	78.20
12/08/21	15.09532	76.57236	Agriculture	146.43	52.33
12/08/21	15.09544	76.57331	Agriculture	92.60	66.47
12/08/21	15.09546	76.57372	Agriculture	65.70	67.10
12/08/21	15.09548	76.57400	Agriculture	47.43	68.20
12/08/21	15.09550	76.57565	Agriculture	96.29	62.63
12/08/21	15.09560	76.57464	Agriculture	4.03	77.17
12/08/21	15.09568	76.57591	Agriculture	112.18	64.10
12/08/21	15.09595	76.57291	Agriculture	163.85	60.20
12/08/21	15.09598	76.57342	Agriculture	130.08	58.00
12/08/21	15.09610	76.57246	Agriculture	205.75	55.63
12/08/21	15.09618	76.57473	Agriculture	25.71	71.73
12/08/21	15.09620	76.57444	Agriculture	54.44	67.40
12/08/21	15.09625	76.57589	Agriculture	80.36	66.13
12/08/21	15.09657	76.57842	Agriculture	212.88	57.23
12/08/21	15.09666	76.57436	Agriculture	85.13	62.33
12/08/21	15.09678	76.57802	Agriculture	172.27	57.57
12/08/21	15.09683	76.57708	Agriculture	121.37	63.67
12/08/21	15.09688	76.57324	Agriculture	203.91	51.63
12/08/21	15.09691	76.57307	Agriculture	222.25	53.67

12/08/21	15.09692	76.57372	Agriculture	159.72	57.73
12/08/21	15.09699	76.57657	Agriculture	78.27	66.23
12/08/21	15.09700	76.57432	Agriculture	106.60	59.73
12/08/21	15.09707	76.57629	Agriculture	54.47	70.40
12/08/21	15.09715	76.57608	Agriculture	33.38	71.63
12/08/21	15.09727	76.57571	Agriculture	2.67	76.30
12/08/21	15.09733	76.57389	Agriculture	165.43	58.33
12/08/21	15.09733	76.57389	Agriculture	165.45	55.33
14/08/21	15.09737	76.57615	Agriculture	18.86	74.23
14/08/21	15.09744	76.57644	Agriculture	28.24	73.63
14/08/21	15.09757	76.57586	Agriculture	17.46	74.60
12/08/21	15.09761	76.57428	Agriculture	146.86	56.40
12/08/21	15.09764	76.57486	Agriculture	98.93	63.57
14/08/21	15.09782	76.57545	Agriculture	67.05	62.90
12/08/21	15.09787	76.57411	Agriculture	178.55	55.37
14/08/21	15.09803	76.57671	Agriculture	14.19	77.73
14/08/21	15.09828	76.57712	Agriculture	19.88	74.90
14/08/21	15.09831	76.57547	Agriculture	108.60	63.17
14/08/21	15.09838	76.57591	Agriculture	89.82	65.27
14/08/21	15.09848	76.57677	Agriculture	56.28	67.20
14/08/21	15.09850	76.57751	Agriculture	21.37	70.53
14/08/21	15.09866	76.57799	Agriculture	12.22	78.73
14/08/21	15.09880	76.57589	Agriculture	131.20	62.50
14/08/21	15.09904	76.57668	Agriculture	115.71	65.53
14/08/21	15.09914	76.57778	Agriculture	39.41	66.70
14/08/21	15.09931	76.57643	Agriculture	154.95	61.23
14/08/21	15.09942	76.57735	Agriculture	84.24	61.33
14/08/21	15.09955	76.57563	Agriculture	217.20	58.07
14/08/21	15.09979	76.57710	Agriculture	110.85	59.20
14/08/21	15.09995	76.57584	Agriculture	245.91	53.57
14/08/21	15.09999	76.57689	Agriculture	134.46	54.23
14/08/21	15.10034	76.57688	Agriculture	140.72	54.43
14/08/21	15.10057	76.57829	Agriculture	0.60	72.07
14/08/21	15.10074	76.57761	Agriculture	74.46	61.47
14/08/21	15.10075	76.57711	Agriculture	127.03	59.17
14/08/21	15.10119	76.57826	Agriculture	27.00	69.00
14/08/21	15.10146	76.57732	Agriculture	129.14	53.53
14/08/21	15.10155	76.57783	Agriculture	86.95	62.13
14/08/21	15.10164	76.57843	Agriculture	36.54	67.13
14/08/21	15.10182	76.57932	Agriculture	29.41	68.40
14/08/21	15.10183	76.57791	Agriculture	94.85	63.50
14/08/21	15.10186	76.57896	Agriculture	2.88	70.30
14/08/21	15.10204	76.57971	Agriculture	44.74	63.23
14/08/21	15.10226	76.57727	Agriculture	178.59	57.07
14/08/21	15.10236	76.57676	Agriculture	231.56	49.63
14/08/21	15.10240	76.58016	Agriculture	53.59	66.60
14/08/21	15.10244	76.57762	Agriculture	158.52	59.97
12/07/21	15.10297	76.58122		98.44	61.80
14/08/21	15.10303	76.58079	Agriculture	58.94	61.87
03/08/21	15.10342	76.58164	Forest	100.77	57.33

14/08/21	15.10351	76.58103	Agriculture	43.91	61.97
20/08/21	15.10357	76.58111		46.24	64.43
14/08/21	15.10357	76.58178	Forest	100.40	52.23
14/08/21	15.10358	76.58224	Forest	136.92	57.77
12/07/21	15.10374	76.58203		108.63	60.00
20/08/21	15.10374	76.58193		100.75	59.60
14/08/21	15.10392	76.58211	Agriculture	101.53	54.37
03/08/21	15.10393	76.58093	Forest	5.78	78.83
14/08/21	15.10394	76.58183	Agriculture	77.79	61.30
14/08/21	15.10407	76.58227	Forest	103.25	50.47
14/08/21	15.10408	76.58230		103.78	45.50
20/08/21	15.10412	76.58169		53.22	66.37
14/08/21	15.10417	76.58183	Agriculture	60.63	65.60
14/08/21	15.10417	76.58128	Agriculture	16.78	72.50
14/08/21	15.10422	76.58157	Agriculture	35.91	69.00
20/08/21	15.10431	76.57887		189.91	54.70
20/08/21	15.10433	76.58157		27.95	70.63
20/08/21	15.10451	76.57922		175.80	53.93
20/08/21	15.10460	76.57996		121.86	62.10
20/08/21	15.10497	76.58074		85.67	64.97
20/08/21	15.10522	76.58094		88.73	64.17
20/08/21	15.10554	76.58164		57.53	71.70
20/08/21	15.10561	76.58393		54.82	67.00
20/08/21	15.10564	76.58393		51.69	56.90
20/08/21	15.10565	76.58395		51.38	46.30
20/08/21	15.10567	76.58382		44.57	55.23
20/08/21	15.10567	76.58375		42.02	66.37
20/08/21	15.10568	76.58381		43.16	68.57
20/08/21	15.10589	76.58176		77.18	63.90
12/07/21	15.10594	76.58501		58.59	54.50
20/08/21	15.10597	76.58417		26.07	69.93
20/08/21	15.10606	76.58426		19.97	71.23
20/08/21	15.10607	76.58488		40.94	65.50
20/08/21	15.10611	76.58446		21.86	72.17
20/08/21	15.10620	76.58246		64.65	54.57
20/08/21	15.10623	76.58541		42.76	59.47
20/08/21	15.10628	76.58606		48.65	60.73
20/08/21	15.10632	76.58459		4.54	75.67
21/08/21	15.10632	76.58826		50.58	53.83
20/08/21	15.10633	76.58571		38.30	66.53
20/08/21	15.10634	76.58260		72.23	69.60
21/08/21	15.10634	76.58717		47.41	56.67
22/08/21	15.10634	76.58855	Forest	48.83	61.30
05/08/21	15.10635	76.59273	Forest	216.91	54.27
21/08/21	15.10639	76.58868		43.50	62.03
21/08/21	15.10640	76.58767		40.93	65.80
22/08/21	15.10641	76.58881	Forest	41.49	66.83
21/08/21	15.10642	76.58749		38.66	67.53
22/08/21	15.10643	76.58836	Forest	38.57	63.40
21/08/21	15.10647	76.58717		33.03	65.60

21/08/21	15.10654	76.58801		25.85	66.73
05/08/21	15.10659	76.59103	Forest	84.68	62.50
22/08/21	15.10660	76.59018	Forest	44.72	66.97
22/08/21	15.10666	76.59044	Forest	50.21	63.97
21/08/21	15.10667	76.58780		11.14	70.00
05/08/21	15.10673	76.59090	Forest	64.53	62.03
05/08/21	15.10676	76.59278	Forest	188.95	54.73
21/08/21	15.10676	76.58785		1.26	74.63
21/08/21	15.10677	76.58731		0.13	75.53
20/08/21	15.10678	76.58730		1.23	72.37
05/08/21	15.10679	76.59132	Forest	83.60	62.60
20/08/21	15.10679	76.58278		111.34	67.47
21/08/21	15.10680	76.58712		3.50	72.80
21/08/21	15.10681	76.58820		3.72	73.93
21/08/21	15.10681	76.58797		4.08	74.03
21/08/21	15.10682	76.58767		5.54	73.90
21/08/21	15.10682	76.58810		4.99	76.47
05/08/21	15.10684	76.59179	Forest	107.37	60.17
21/08/21	15.10686	76.58787		9.77	72.23
21/08/21	15.10686	76.58755		10.01	73.43
21/08/21	15.10688	76.58815		11.55	71.70
21/08/21	15.10688	76.58749		12.24	72.97
21/08/21	15.10695	76.58722		20.07	68.57
21/08/21	15.10696	76.58804		20.57	68.50
05/08/21	15.10699	76.59110	Forest	52.25	65.00
22/08/21	15.10702	76.59111	Forest	49.90	66.90
20/08/21	15.10750	76.58331		164.56	66.47
20/08/21	15.10795	76.58343		207.05	62.73
22/08/21	15.10814	76.59224	Forest	51.24	67.67
22/08/21	15.10825	76.59236	Forest	55.23	66.57
20/08/21	15.10826	76.58386		224.03	61.10
05/08/21	15.10837	76.59239	Forest	50.49	67.90
22/08/21	15.10843	76.59244	Forest	51.34	69.13
22/08/21	15.10857	76.59254	Forest	51.70	66.97
22/08/21	15.10872	76.59267	Forest	54.12	65.13
22/08/21	15.10890	76.59271	Forest	47.62	67.63
22/08/21	15.10893	76.59282	Forest	56.27	64.93
22/08/21	15.10912	76.59288	Forest	51.49	66.77
22/08/21	15.10925	76.59299	Forest	54.67	66.20
22/08/21	15.10937	76.59312	Forest	60.26	63.73
22/08/21	15.10938	76.59303	Forest	51.30	68.60
22/08/21	15.10939	76.59311	Forest	58.23	67.23
22/08/21	15.10940	76.59306	Forest	53.01	67.37
22/08/21	15.10954	76.59317	Forest	55.64	66.60
22/08/21	15.10966	76.59311	Forest	43.47	68.57
22/08/21	15.10977	76.59325	Forest	50.55	65.97
22/08/21	15.10985	76.59337	Forest	57.40	66.63
22/08/21	15.10993	76.59324	Forest	40.87	69.60
22/08/21	15.10996	76.59337	Forest	51.38	69.53
05/08/21	15.10998	76.59338	Forest	50.85	65.60

22/08/21	15.10999	76.59341	Forest	53.48	66.23
22/08/21	15.11006	76.59335	Forest	43.93	66.57
22/08/21	15.11009	76.59329	Forest	36.70	69.37
22/08/21	15.11020	76.59364	Forest	61.78	61.93
22/08/21	15.11032	76.59368	Forest	58.22	56.53
31/07/21	15.11075	76.60347	Forest	196.38	51.87
22/08/21	15.11086	76.59435	Forest	67.51	51.87
05/08/21	15.11090	76.59450	Forest	73.80	54.80
22/08/21	15.11101	76.59455	Forest	68.02	52.27
22/08/21	15.11115	76.59476	Forest	65.72	62.17
12/07/21	15.11116	76.59446		49.36	51.20
31/07/21	15.11128	76.60259	Forest	108.81	56.10
28/07/21	15.11141	76.60210	Forest	79.69	62.40
05/08/21	15.11148	76.59548	Forest	53.20	65.00
05/08/21	15.11153	76.60234	Forest	73.69	62.87
05/08/21	15.11159	76.60026	Forest	40.49	65.40
12/07/21	15.11164	76.60156		43.12	64.30
05/08/21	15.11168	76.59717	Forest	34.51	66.80
05/08/21	15.11171	76.59953	Forest	24.01	69.13
05/08/21	15.11180	76.60391	Forest	119.04	54.17
05/08/21	15.11180	76.59795	Forest	21.09	71.13
05/08/21	15.11187	76.59855	Forest	10.82	72.00
05/08/21	15.11188	76.60335	Forest	81.16	62.30
21/08/21	15.11192	76.59499	Waterbody	1.60	70.80
05/08/21	15.11206	76.60374	Forest	85.15	60.63
21/08/21	15.11210	76.59415	Waterbody	57.49	61.33
21/08/21	15.11232	76.59522	Waterbody	42.17	65.67
21/08/21	15.11236	76.59705	Waterbody	41.09	65.17
21/08/21	15.11238	76.59593	Waterbody	43.29	65.33
21/08/21	15.11263	76.60299	Waterbody	10.47	71.43
21/08/21	15.11274	76.60288	Waterbody	27.10	64.63
21/08/21	15.11278	76.59345	Waterbody	160.48	56.13
05/08/21	15.11292	76.60458	Forest	82.17	46.87
12/07/21	15.11302	76.60387		16.42	72.10
21/08/21	15.11306	76.60182	Waterbody	104.03	61.00
21/08/21	15.11315	76.59792	Waterbody	128.07	60.57
21/08/21	15.11319	76.60103	Waterbody	133.56	62.47
21/08/21	15.11326	76.60277	Waterbody	82.18	60.50
12/07/21	15.11331	76.60446	Forest	45.13	65.00
31/07/21	15.11365	76.60639	Forest	211.75	51.33
21/08/21	15.11368	76.60037	Waterbody	190.68	61.40
21/08/21	15.11371	76.59861	Waterbody	193.66	60.77
31/07/21	15.11392	76.60542	Forest	104.74	55.70
05/08/21	15.11395	76.60515	Forest	76.68	61.00
21/08/21	15.11396	76.60293	Waterbody	128.75	57.03
05/08/21	15.11405	76.60663	Forest	221.50	52.83
31/07/21	15.11406	76.60452	Forest	10.61	72.47
21/08/21	15.11410	76.59903	Waterbody	238.71	59.43
05/08/21	15.11412	76.60539	Forest	91.69	53.50
12/07/21	15.11417	76.60556		107.13	61.20

21/08/21	15.11432	76.60296	Waterbody	150.81	56.60
05/08/21	15.11440	76.60602	Forest	147.74	55.83
12/07/21	15.11447	76.60557		99.19	61.20
05/08/21	15.11448	76.60574	Forest	116.33	60.17
21/08/21	15.11476	76.60320	Waterbody	150.95	57.63
05/08/21	15.11520	76.60550	Forest	69.44	56.93
21/08/21	15.11520	76.60362	Waterbody	125.11	61.00
05/08/21	15.11523	76.60587	Forest	107.54	62.47
21/08/21	15.11559	76.60391	Waterbody	107.16	60.63
05/08/21	15.11624	76.60550	Forest	55.42	65.73
21/08/21	15.11637	76.60445	Waterbody	56.70	67.40
21/08/21	15.11661	76.60480	Waterbody	18.97	69.00
05/08/21	15.11667	76.60545	Forest	51.01	66.57
17/08/21	15.11676	76.60538	Forest	43.69	65.57
21/08/21	15.11678	76.60498	Waterbody	0.74	74.13
21/08/21	15.11697	76.60498	Waterbody	1.45	72.73
21/08/21	15.11711	76.60487	Waterbody	10.07	76.23
21/08/21	15.11723	76.60480	Waterbody	16.55	70.07
17/08/21	15.11732	76.60537	Forest	45.14	66.50
05/08/21	15.11740	76.60555	Forest	64.89	63.87
17/08/21	15.11756	76.60537	Forest	46.40	66.80
21/08/21	15.11763	76.60455	Waterbody	41.91	66.40
17/08/21	15.11802	76.60534	Forest	40.10	73.37
21/08/21	15.11820	76.60420	Waterbody	83.53	64.07
05/08/21	15.11826	76.60555	Forest	59.84	63.93
21/08/21	15.11874	76.60383	Waterbody	131.56	65.87
05/08/21	15.11883	76.60540	Forest	26.04	68.07
12/07/21	15.11886	76.60558		42.97	63.10
17/08/21	15.11887	76.60537	Forest	21.55	65.67
21/08/21	15.11932	76.60346	Waterbody	188.44	53.20
17/08/21	15.11998	76.60599	Forest	30.97	58.33
17/08/21	15.12013	76.60627	Forest	49.59	64.20
17/08/21	15.12031	76.60666	Forest	75.82	64.47
21/08/21	15.12032	76.60367	Waterbody	213.47	50.37
21/08/21	15.12054	76.60427	Waterbody	162.42	59.07
05/08/21	15.12057	76.60590	Forest	8.92	63.47
21/08/21	15.12070	76.60494	Waterbody	106.70	56.67
21/08/21	15.12085	76.60578	Waterbody	36.26	56.30
21/08/21	15.12087	76.60679	Waterbody	53.18	68.80
21/08/21	15.12088	76.60660	Waterbody	35.82	66.27
21/08/21	15.12095	76.60637	Waterbody	10.97	64.17
21/08/21	15.12104	76.60674	Waterbody	38.19	66.10
12/07/21	15.12111	76.60806		147.81	55.60
23/07/21	15.12112	76.60803	Waterbody	145.00	60.10
31/07/21	15.12123	76.61031	Forest	246.80	45.23
21/08/21	15.12125	76.60663	Waterbody	16.15	63.13
17/08/21	15.12149	76.60783	Forest	102.69	55.60
31/07/21	15.12166	76.61032	Forest	202.53	45.63
21/08/21	15.12168	76.60765	Waterbody	74.72	56.37
17/08/21	15.12171	76.60762	Forest	69.86	55.23

21/08/21	15.12178	76.60761	Waterbody	64.10	56.50
31/07/21	15.12180	76.61026	Forest	185.22	47.07
31/07/21	15.12188	76.61023	Forest	175.98	49.60
31/07/21	15.12198	76.61018	Forest	164.27	49.37
21/08/21	15.12199	76.60749	Waterbody	38.71	54.53
21/08/21	15.12200	76.60630	Waterbody	61.25	51.63
31/07/21	15.12214	76.61010	Forest	144.65	51.57
31/07/21	15.12237	76.61017	Forest	123.23	52.40
31/07/21	15.12254	76.60993	Forest	96.54	53.33
31/07/21	15.12264	76.60989	Forest	85.08	55.03
31/07/21	15.12282	76.60976	Forest	62.58	57.23
21/08/21	15.12287	76.60702	Waterbody	64.81	48.30
21/08/21	15.12289	76.60580	Waterbody	164.29	51.20
31/07/21	15.12292	76.60966	Forest	48.30	58.73
21/08/21	15.12299	76.60657	Waterbody	109.49	52.90
31/07/21	15.12307	76.60956	Forest	29.65	59.23
17/08/21	15.12309	76.61191	Forest	177.50	55.43
17/08/21	15.12309	76.61171	Forest	161.48	57.33
28/07/21	15.12312	76.60926	Forest	16.59	65.50
21/08/21	15.12315	76.60624	Waterbody	147.63	49.10
17/08/21	15.12324	76.60881	Forest	6.97	64.53
21/08/21	15.12325	76.60595	Waterbody	177.52	47.63
21/08/21	15.12326	76.60555	Waterbody	211.23	48.13
17/08/21	15.12328	76.61094	Forest	88.94	61.50
17/08/21	15.12333	76.61148	Forest	125.33	57.43
17/08/21	15.12343	76.60904	Forest	22.08	68.50
17/08/21	15.12348	76.61101	Forest	76.62	61.43
17/08/21	15.12355	76.61067	Forest	47.67	64.77
05/08/21	15.12357	76.60887	Forest	41.30	56.40
04/08/21	15.12398	76.61238	Agriculture	157.46	57.43
04/08/21	15.12413	76.61354	Agriculture	248.01	55.40
17/08/21	15.12413	76.61194	Forest	109.52	60.23
04/08/21	15.12415	76.61298	Agriculture	198.25	54.80
12/07/21	15.12419	76.61254	Agriculture	157.27	55.90
04/08/21	15.12421	76.61151	Agriculture	67.03	63.60
04/08/21	15.12422	76.61150	Agriculture	65.51	59.30
17/08/21	15.12424	76.61122	Forest	39.95	67.20
12/07/21	15.12429	76.61289		181.64	50.10
04/08/21	15.12432	76.61272	Agriculture	164.58	56.23
12/07/21	15.12432	76.61209	Agriculture	110.31	59.30
17/08/21	15.12433	76.61044	Forest	31.83	64.63
17/08/21	15.12434	76.60929	Forest	111.03	53.37
17/08/21	15.12434	76.60981	Forest	77.53	57.53
04/08/21	15.12441	76.61319	Agriculture	199.43	54.23
04/08/21	15.12443	76.61272	Agriculture	157.36	51.80
04/08/21	15.12450	76.61217	Agriculture	105.14	61.60
12/07/21	15.12457	76.61167	Agriculture	57.23	62.60
04/08/21	15.12458	76.61090	Agriculture	10.37	67.00
04/08/21	15.12469	76.61095	Agriculture	12.85	65.90
04/08/21	15.12473	76.61193	Agriculture	69.27	60.60

04/08/21	15.12474	76.61283	Agriculture	146.66	56.93
04/08/21	15.12486	76.61186	Agriculture	54.67	63.57
04/08/21	15.12486	76.61141	Agriculture	15.71	66.50
04/08/21	15.12493	76.61101	Agriculture	23.87	65.80
04/08/21	15.12493	76.61149	Agriculture	18.04	67.53
04/08/21	15.12499	76.61271	Agriculture	119.99	57.20
04/08/21	15.12500	76.61121	Agriculture	10.99	67.50
12/07/21	15.12517	76.61083		54.86	62.90
04/08/21	15.12529	76.61311	Agriculture	135.41	58.00
04/08/21	15.12542	76.61128	Agriculture	32.30	62.10
04/08/21	15.12565	76.61161	Agriculture	18.80	67.50
04/08/21	15.12586	76.61142	Agriculture	48.60	67.30
04/08/21	15.12594	76.61129	Agriculture	65.90	66.80
04/08/21	15.12634	76.61196	Agriculture	33.05	61.30
04/08/21	15.12642	76.61259	Agriculture	16.82	71.87
04/08/21	15.12651	76.61239	Agriculture	5.95	69.80
04/08/21	15.12656	76.61189	Agriculture	53.43	66.90
04/08/21	15.12677	76.61328	Agriculture	54.27	66.50
04/08/21	15.12714	76.61289	Agriculture	3.45	70.50
04/08/21	15.12752	76.61349	Agriculture	25.04	74.03
04/08/21	15.12773	76.61330	Agriculture	4.98	72.00
04/08/21	15.12796	76.61353	Agriculture	1.11	72.50
04/08/21	15.12804	76.61469	Agriculture	98.16	62.63
04/08/21	15.12814	76.61386	Agriculture	18.55	71.73
04/08/21	15.12842	76.61537	Agriculture	134.20	55.10
04/08/21	15.12845	76.61515	Agriculture	112.88	61.73
04/08/21	15.12874	76.61414	Agriculture	5.68	72.70
04/08/21	15.12881	76.61595	Agriculture	160.16	53.20
04/08/21	15.12900	76.61528	Agriculture	89.30	63.13
04/08/21	15.12917	76.61439	Agriculture	0.55	72.60
04/08/21	15.12955	76.61566	Agriculture	87.20	62.50
04/08/21	15.12960	76.61585	Agriculture	100.61	63.43
04/08/21	15.12970	76.61506	Agriculture	25.04	67.57
04/08/21	15.12980	76.61620	Agriculture	118.39	60.13
04/08/21	15.13004	76.61530	Agriculture	24.18	66.43
04/08/21	15.13030	76.61473	Agriculture	42.38	70.00
04/08/21	15.13032	76.61569	Agriculture	40.31	68.20
04/08/21	15.13063	76.61558	Agriculture	10.75	73.87
04/08/21	15.13086	76.61614	Agriculture	45.44	64.03
04/08/21	15.13105	76.61646	Agriculture	61.80	60.93
04/08/21	15.13110	76.61672	Agriculture	81.66	58.50
04/08/21	15.13112	76.61572	Agriculture	7.65	63.60
04/08/21	15.13117	76.61529	Agriculture	49.17	65.00
04/08/21	15.13151	76.61638	Agriculture	25.78	66.90
04/08/21	15.13165	76.61596	Agriculture	19.73	68.40
04/08/21	15.13187	76.61684	Agriculture	43.83	64.97
04/08/21	15.13222	76.61691	Agriculture	28.01	66.13
04/08/21	15.13275	76.61800	Agriculture	91.10	57.70
04/08/21	15.13293	76.61652	Agriculture	50.58	61.00
04/08/21	15.13299	76.61774	Agriculture	53.00	61.70

04/08/21	15.13318	76.61811	Agriculture	73.76	57.37
04/08/21	15.13318	76.61755	Agriculture	24.24	68.53
04/08/21	15.13328	76.61682	Agriculture	46.74	72.40
04/08/21	15.13328	76.61738	Agriculture	2.82	70.20
04/08/21	15.13339	76.61858	Agriculture	101.62	54.53
21/08/21	15.13339	76.61912	Agriculture	148.80	54.87
21/08/21	15.13344	76.61878	Agriculture	115.97	56.63
04/08/21	15.13347	76.61824	Agriculture	66.65	58.63
04/08/21	15.13367	76.61807	Agriculture	38.95	66.43
04/08/21	15.13367	76.61786	Agriculture	20.51	68.60
21/08/21	15.13376	76.61997	Agriculture	200.54	57.93
21/08/21	15.13382	76.61929	Agriculture	136.21	58.97
04/08/21	15.13384	76.61783	Agriculture	6.73	68.40
12/07/21	15.13388	76.61740		33.30	64.50
21/08/21	15.13390	76.61866	Agriculture	76.06	62.67
21/08/21	15.13394	76.61792	Agriculture	8.27	72.33
21/08/21	15.13425	76.61709	Agriculture	84.16	53.77
21/08/21	15.13429	76.62015	Agriculture	181.56	61.90
21/08/21	15.13434	76.61962	Agriculture	132.66	62.77
21/08/21	15.13449	76.61908	Agriculture	75.26	63.47
21/08/21	15.13457	76.61835	Agriculture	5.59	71.97
21/08/21	15.13463	76.61632	Agriculture	176.05	48.77
21/08/21	15.13472	76.61716	Agriculture	108.04	52.50
21/08/21	15.13474	76.62087	Agriculture	216.77	56.00
21/08/21	15.13482	76.62041	Agriculture	170.70	57.23
21/08/21	15.13496	76.61953	Agriculture	85.00	61.50
21/08/21	15.13502	76.61911	Agriculture	43.84	64.63
21/08/21	15.13504	76.61886	Agriculture	20.80	63.30
21/08/21	15.13515	76.61842	Agriculture	24.86	60.83
21/08/21	15.13523	76.61787	Agriculture	78.27	54.17
21/08/21	15.13526	76.61729	Agriculture	131.12	48.60
15/07/21	15.13533	76.61942	Agriculture	51.45	63.30
30/07/21	15.13533	76.61890	Agriculture	5.95	73.67
15/07/21	15.13534	76.61923	Agriculture	34.13	67.15
21/08/21	15.13540	76.62045	Agriculture	137.68	59.90
21/08/21	15.13552	76.61948	Agriculture	45.25	63.43
21/08/21	15.13562	76.61866	Agriculture	33.81	59.23
21/08/21	15.13563	76.61912	Agriculture	5.64	71.87
29/07/21	15.13569	76.62160	Agriculture	219.59	47.20
21/08/21	15.13572	76.61874	Agriculture	33.17	57.23
30/07/21	15.13576	76.61804	Agriculture	97.08	69.17
21/08/21	15.13578	76.61840	Agriculture	66.86	54.60
21/08/21	15.13591	76.61784	Agriculture	124.34	49.30
30/07/21	15.13601	76.61707	Agriculture	198.66	47.37
21/08/21	15.13605	76.62069	Agriculture	117.08	62.07
21/08/21	15.13630	76.61798	Agriculture	136.96	48.40
21/08/21	15.13639	76.62235	Agriculture	240.08	58.20
29/07/21	15.13643	76.61977	Agriculture	12.41	72.10
21/08/21	15.13646	76.62170	Agriculture	178.88	61.37
21/08/21	15.13654	76.61808	Agriculture	143.51	44.90

21/08/21	15.13663	76.62111	Agriculture	116.58	60.57
21/08/21	15.13668	76.62017	Agriculture	31.07	66.80
21/08/21	15.13669	76.62054	Agriculture	63.29	63.50
21/08/21	15.13672	76.61990	Agriculture	4.95	75.10
21/08/21	15.13677	76.61993	Agriculture	4.16	69.97
21/08/21	15.13678	76.61936	Agriculture	46.50	60.47
21/08/21	15.13682	76.62202	Agriculture	183.88	59.90
21/08/21	15.13690	76.61884	Agriculture	99.81	55.30
21/08/21	15.13697	76.61823	Agriculture	157.82	48.20
21/08/21	15.13708	76.61788	Agriculture	195.50	40.27
21/08/21	15.13713	76.62249	Agriculture	201.33	61.37
21/08/21	15.13714	76.62121	Agriculture	92.91	67.63
21/08/21	15.13719	76.62061	Agriculture	36.67	66.73
21/08/21	15.13723	76.61760	Agriculture	229.66	39.50
21/08/21	15.13743	76.61822	Agriculture	188.12	43.13
21/08/21	15.13755	76.62012	Agriculture	29.05	61.47
21/08/21	15.13779	76.62071	Agriculture	7.01	73.47
21/08/21	15.13779	76.62034	Agriculture	25.17	63.30
21/08/21	15.13792	76.62258	Agriculture	145.80	61.63
21/08/21	15.13792	76.62133	Agriculture	51.18	65.80
21/08/21	15.13811	76.62026	Agriculture	52.71	59.33
21/08/21	15.13820	76.62060	Agriculture	28.69	58.53
21/08/21	15.13820	76.62108	Agriculture	10.31	67.40
21/08/21	15.13821	76.62080	Agriculture	11.80	60.53
21/08/21	15.13821	76.62080	Agriculture	11.80	61.50
20/08/21	15.13835	76.62279	Scrub	127.28	63.20
21/08/21	15.13836	76.62149	Agriculture	28.80	68.33
20/08/21	15.13842	76.62326	Scrub	157.10	49.67
21/08/21	15.13860	76.62115	Agriculture	15.94	64.47
20/08/21	15.13862	76.62391	Scrub	192.44	53.93
29/07/21	15.13878	76.62004	Agriculture	114.91	59.40
21/08/21	15.13887	76.62167	Agriculture	1.74	73.13
29/07/21	15.13896	76.61910	Agriculture	209.12	48.10
20/08/21	15.13898	76.62278	Scrub	76.70	60.13
20/08/21	15.13909	76.62321	Scrub	101.82	56.80
21/08/21	15.13909	76.62174	Agriculture	10.25	64.60
21/08/21	15.13918	76.62262	Agriculture	48.84	61.33
29/07/21	15.13928	76.62211	Agriculture	2.34	73.20
20/08/21	15.13937	76.62225	Scrub	5.98	79.50
21/08/21	15.13938	76.62223	Agriculture	3.68	70.07
21/08/21	15.13953	76.62189	Agriculture	33.76	63.50
12/07/21	15.13970	76.62447		158.87	58.40
20/08/21	15.13998	76.62365	Scrub	71.04	63.67
20/08/21	15.14000	76.62418	Scrub	113.70	60.17
20/08/21	15.14005	76.62476	Scrub	159.09	59.53
21/08/21	15.14010	76.62330	Agriculture	33.52	66.30
20/08/21	15.14034	76.62442	Scrub	111.04	59.37
20/08/21	15.14038	76.62383	Scrub	57.93	66.57
21/08/21	15.14044	76.62308	Agriculture	8.64	68.57
20/08/21	15.14062	76.62410	Scrub	66.17	63.77

21/08/21	15.14089	76.62320	Agriculture	30.25	63.67
21/08/21	15.14092	76.62418	Agriculture	59.04	61.30
20/08/21	15.14097	76.62472	Scrub	108.55	61.47
20/08/21	15.14108	76.62522	Scrub	154.60	54.93
20/08/21	15.14110	76.62428	Scrub	59.76	67.40
20/08/21	15.14111	76.62377	Scrub	10.21	75.47
21/08/21	15.14128	76.62290	Agriculture	81.88	56.40
21/08/21	15.14128	76.62360	Agriculture	14.55	66.43
20/08/21	15.14129	76.62468	Scrub	92.10	63.53
20/08/21	15.14139	76.62487	Scrub	107.51	56.43
21/08/21	15.14155	76.62345	Agriculture	42.00	60.43
20/08/21	15.14172	76.62442	Scrub	49.57	64.77
21/08/21	15.14176	76.62297	Agriculture	98.43	48.93
21/08/21	15.14182	76.62322	Agriculture	75.44	56.77
20/08/21	15.14187	76.62482	Scrub	84.31	61.30
20/08/21	15.14188	76.62541	Scrub	143.54	55.93
21/08/21	15.14188	76.62436	Agriculture	37.46	66.13
30/07/21	15.14189	76.62596	Scrub	198.96	52.33
20/08/21	15.14193	76.62595	Scrub	196.47	48.87
21/08/21	15.14201	76.62293	Agriculture	111.93	47.90
20/08/21	15.14210	76.62558	Scrub	152.78	53.03
21/08/21	15.14215	76.62319	Agriculture	90.96	57.30
20/08/21	15.14217	76.62495	Scrub	86.09	60.73
21/08/21	15.14218	76.62378	Agriculture	32.48	62.43
20/08/21	15.14219	76.62418	Scrub	7.55	74.47
30/07/21	15.14220	76.62506	Scrub	96.40	64.33
21/08/21	15.14221	76.62384	Agriculture	27.56	62.93
21/08/21	15.14229	76.62352	Agriculture	62.91	58.97
20/08/21	15.14251	76.62476	Scrub	54.80	62.27
21/08/21	15.14270	76.62393	Agriculture	36.48	60.23
20/08/21	15.14280	76.62449	Scrub	17.11	70.77
20/08/21	15.14287	76.62484	Scrub	50.34	62.60
21/08/21	15.14289	76.62368	Agriculture	68.64	57.07
20/08/21	15.14297	76.62519	Scrub	82.52	60.30
21/08/21	15.14310	76.62324	Agriculture	120.86	46.70
20/08/21	15.14317	76.62549	Scrub	106.09	55.57
21/08/21	15.14352	76.62441	Agriculture	16.29	63.53
21/08/21	15.14353	76.62308	Agriculture	152.25	45.13
20/08/21	15.14354	76.62504	Scrub	47.24	60.27
12/07/21	15.14355	76.62311		150.10	56.60
21/08/21	15.14364	76.62427	Agriculture	34.78	61.53
20/08/21	15.14369	76.62639	Scrub	179.04	56.73
21/08/21	15.14373	76.62443	Agriculture	21.62	60.83
20/08/21	15.14385	76.62557	Scrub	90.21	59.43
21/08/21	15.14391	76.62440	Agriculture	30.99	55.03
20/08/21	15.14392	76.62522	Scrub	52.23	60.07
20/08/21	15.14393	76.62480	Scrub	9.10	69.80
20/08/21	15.14399	76.62592	Scrub	120.15	67.40
20/08/21	15.14412	76.62627	Scrub	150.47	58.43
21/08/21	15.14419	76.62447	Agriculture	33.75	60.87

21/08/21	15.14420	76.62501	Agriculture	20.33	64.70
21/08/21	15.14449	76.62431	Agriculture	61.38	60.87
21/08/21	15.14469	76.62455	Agriculture	44.84	59.37
15/07/21	15.14472	76.62719	Scrub	210.03	48.60
21/08/21	15.14483	76.62525	Agriculture	19.93	65.73
20/08/21	15.14486	76.62605	Scrub	98.05	63.77
15/07/21	15.14504	76.62682	Scrub	156.67	50.20
15/07/21	15.14518	76.62514	Builtup	5.88	70.70
15/07/21	15.14534	76.62645	Scrub	105.40	51.10
21/08/21	15.14548	76.62550	Agriculture	11.91	68.17
20/08/21	15.14551	76.62582	Scrub	38.68	72.53
21/08/21	15.14560	76.62499	Agriculture	41.06	60.13
15/07/21	15.14565	76.62606	Scrub	50.94	67.40
20/08/21	15.14572	76.62657	Scrub	91.95	60.07
20/08/21	15.14591	76.62578	Scrub	10.43	73.70
15/07/21	15.14595	76.62571	Scrub	1.85	73.20
20/08/21	15.14600	76.62718	Scrub	112.73	59.40
21/08/21	15.14612	76.62562	Agriculture	16.82	65.67
31/07/21	15.14630	76.62486	Scrub	96.21	59.60
21/08/21	15.14661	76.62566	Agriculture	45.70	62.53
20/08/21	15.14684	76.62668	Scrub	6.50	71.60
31/07/21	15.14688	76.62417	Scrub	193.43	45.50
17/08/21	15.14699	76.62705	Agriculture	5.72	73.37
17/08/21	15.14703	76.62753	Agriculture	22.33	70.80
17/08/21	15.14706	76.62819	Agriculture	55.83	64.90
17/08/21	15.14727	76.62673	Agriculture	35.35	67.80
17/08/21	15.14730	76.62930	Agriculture	117.08	60.00
21/08/21	15.14744	76.62556	Agriculture	110.70	46.33
17/08/21	15.14768	76.63024	Agriculture	174.03	57.93
17/08/21	15.14768	76.62826	Agriculture	7.38	71.90
17/08/21	15.14771	76.62559	Scrub	130.76	52.33
17/08/21	15.14779	76.62882	Agriculture	42.63	67.60
17/08/21	15.14780	76.62695	Agriculture	82.18	65.43
17/08/21	15.14797	76.62726	Agriculture	81.96	64.13
21/08/21	15.14801	76.62573	Agriculture	151.70	47.10
17/08/21	15.14803	76.62927	Agriculture	64.60	64.17
17/08/21	15.14804	76.62611	Scrub	139.54	44.37
17/08/21	15.14810	76.62659	Scrub	126.70	53.77
17/08/21	15.14811	76.62839	Agriculture	15.44	69.63
17/08/21	15.14819	76.62986	Agriculture	110.94	62.00
17/08/21	15.14824	76.62608	Agriculture	161.61	52.33
17/08/21	15.14835	76.62662	Agriculture	151.44	54.67
17/08/21	15.14846	76.63025	Agriculture	137.65	61.43
17/08/21	15.14854	76.62832	Agriculture	51.22	65.53
17/08/21	15.14858	76.63091	Agriculture	198.98	59.00
17/08/21	15.14887	76.62868	Agriculture	35.53	66.70
17/08/21	15.14901	76.62917	Agriculture	6.30	69.90
17/08/21	15.14916	76.63017	Agriculture	103.31	61.80
17/08/21	15.14929	76.62924	Agriculture	3.88	70.43
17/08/21	15.14938	76.62967	Agriculture	44.64	65.73

17/08/21	15.14953	76.62901	Agriculture	28.48	66.37
17/08/21	15.14958	76.63020	Agriculture	90.94	61.57
17/08/21	15.14974	76.62882	Agriculture	54.72	62.33
17/08/21	15.14987	76.62995	Agriculture	53.57	63.20
31/07/21	15.14988	76.62856	Scrub	86.52	63.80
17/08/21	15.14994	76.62840	Agriculture	105.08	60.17
12/07/21	15.15007	76.62850		98.62	61.20
31/07/21	15.15011	76.62759	Scrub	193.52	53.70
17/08/21	15.15023	76.62895	Agriculture	60.75	62.47
17/08/21	15.15030	76.62930	Agriculture	30.06	64.80
17/08/21	15.15042	76.62956	Agriculture	13.65	65.87
17/08/21	15.15045	76.62789	Agriculture	175.31	54.27
17/08/21	15.15052	76.63000	Agriculture	18.93	68.17
17/08/21	15.15062	76.63039	Agriculture	47.17	63.70
17/08/21	15.15075	76.63102	Agriculture	94.67	59.90
17/08/21	15.15095	76.62924	Agriculture	75.27	61.90
17/08/21	15.15104	76.63095	Scrub	70.20	61.40
17/08/21	15.15125	76.63126	Scrub	84.26	60.03
17/08/21	15.15129	76.62884	Agriculture	132.19	53.23
17/08/21	15.15152	76.62843	Agriculture	182.83	49.30
17/08/21	15.15156	76.63118	Scrub	57.14	61.87
17/08/21	15.15157	76.62972	Agriculture	72.36	61.10
17/08/21	15.15165	76.63030	Agriculture	25.38	64.67
17/08/21	15.15165	76.62933	Agriculture	111.85	56.47
17/08/21	15.15172	76.63177	Scrub	98.08	58.87
17/08/21	15.15174	76.63063	Agriculture	2.10	70.20
17/08/21	15.15184	76.63259	Scrub	161.63	59.27
17/08/21	15.15186	76.63219	Scrub	125.53	57.90
17/08/21	15.15190	76.63115	Scrub	32.43	65.73
17/08/21	15.15192	76.63159	Scrub	69.41	59.27
17/08/21	15.15198	76.62833	Agriculture	220.01	41.47
17/08/21	15.15203	76.63275	Scrub	163.46	56.23
17/08/21	15.15209	76.63049	Agriculture	37.51	63.27
17/08/21	15.15211	76.63147	Scrub	46.62	63.80
17/08/21	15.15221	76.63163	Scrub	54.04	62.10
17/08/21	15.15229	76.63279	Scrub	150.77	55.83
17/08/21	15.15248	76.63162	Scrub	35.62	62.07
17/08/21	15.15252	76.63282	Scrub	139.07	56.20
17/08/21	15.15261	76.63075	Grassland	48.84	55.43
17/08/21	15.15281	76.63100	Grassland	39.24	59.67
17/08/21	15.15284	76.63085	Grassland	54.53	46.57
17/08/21	15.15287	76.63283	Scrub	118.09	57.23
17/08/21	15.15292	76.63220	Scrub	59.05	49.23
17/08/21	15.15294	76.63264	Scrub	96.86	56.93
17/08/21	15.15296	76.63131	Grassland	22.38	62.33
21/07/21	15.15310	76.63156	Scrub	9.00	65.10
17/08/21	15.15315	76.63142	Grassland	24.30	58.60
17/08/21	15.15319	76.63227	Scrub	48.40	53.70
17/08/21	15.15320	76.63254	Scrub	71.74	57.10
12/07/21	15.15326	76.63247		61.78	54.60

17/08/21	15.15331	76.63272	Scrub	80.85	55.27
17/08/21	15.15353	76.63256	Scrub	52.90	54.43
17/08/21	15.15362	76.63143	Grassland	53.14	53.53
17/08/21	15.15371	76.63170	Grassland	34.43	58.03
17/08/21	15.15391	76.63284	Scrub	53.57	52.77
17/08/21	15.15407	76.63324	Scrub	78.71	50.30
01/08/21	15.15417	76.63137	Scrub	92.49	44.80
12/07/21	15.15417	76.63172		61.66	49.30
17/08/21	15.15418	76.63340	Scrub	85.85	50.07
17/08/21	15.15424	76.63203	Grassland	38.59	52.87
17/08/21	15.15437	76.63329	Scrub	64.12	50.87
17/08/21	15.15457	76.63186	Grassland	74.64	49.80
17/08/21	15.15467	76.63328	Scrub	44.24	50.47
01/08/21	15.15474	76.63067	Scrub	190.59	44.37
01/08/21	15.15477	76.63515	Scrub	203.96	45.17
17/08/21	15.15479	76.63332	Scrub	40.20	50.07
17/08/21	15.15481	76.63248	Grassland	35.24	52.00
17/08/21	15.15485	76.63218	Grassland	64.22	50.90
17/08/21	15.15489	76.63184	Grassland	96.67	45.43
17/08/21	15.15496	76.63369	Scrub	62.44	50.97
17/08/21	15.15497	76.63202	Grassland	86.06	44.53
17/08/21	15.15517	76.63379	Scrub	58.20	47.30
01/08/21	15.15531	76.63438	Scrub	102.19	44.13
17/08/21	15.15534	76.63459	Scrub	118.61	45.23
17/08/21	15.15537	76.63480	Scrub	135.38	46.87
17/08/21	15.15541	76.63431	Scrub	89.38	51.43
17/08/21	15.15544	76.63441	Scrub	96.38	46.40
17/08/21	15.15552	76.63412	Scrub	65.64	51.37
17/08/21	15.15569	76.63490	Scrub	124.17	47.67
17/08/21	15.15582	76.63301	Grassland	51.32	50.60
17/08/21	15.15597	76.63612	Scrub	214.36	45.13
17/08/21	15.15599	76.63486	Scrub	101.80	47.37
17/08/21	15.15607	76.63574	Scrub	174.72	47.23
17/08/21	15.15620	76.63324	Grassland	54.88	50.80
22/08/21	15.15621	76.63628	Scrub	212.04	66.20
17/08/21	15.15622	76.63563	Scrub	155.52	48.50
17/08/21	15.15622	76.63290	Grassland	86.26	48.30
22/08/21	15.15624	76.63596	Scrub	183.09	57.40
17/08/21	15.15625	76.63339	Grassland	45.06	50.83
22/08/21	15.15625	76.63648	Scrub	223.90	57.80
21/07/21	15.15627	76.64832	Builtup	189.96	49.70
22/08/21	15.15627	76.63684	Scrub	246.84	56.93
17/08/21	15.15628	76.63297	Grassland	84.10	48.10
22/08/21	15.15631	76.63947	Scrub	231.68	60.23
17/08/21	15.15632	76.63627	Scrub	202.20	45.40
22/08/21	15.15633	76.63985	Scrub	223.45	59.93
17/08/21	15.15635	76.63268	Grassland	114.21	43.87
22/08/21	15.15635	76.63976	Scrub	222.65	53.53
17/08/21	15.15636	76.63276	Grassland	107.54	46.47
17/08/21	15.15637	76.63465	Scrub	59.36	53.57

22/08/21	15.15637	76.63976	Scrub	219.79	58.80
22/08/21	15.15639	76.63577	Scrub	156.10	55.77
22/08/21	15.15641	76.63576	Scrub	153.77	55.50
17/08/21	15.15643	76.63538	Scrub	120.11	46.03
22/08/21	15.15647	76.63684	Scrub	229.23	56.70
22/08/21	15.15656	76.63873	Scrub	217.45	59.53
17/08/21	15.15657	76.63460	Scrub	42.38	50.23
22/08/21	15.15657	76.63895	Scrub	212.22	56.07
22/08/21	15.15658	76.63564	Scrub	133.19	58.93
17/08/21	15.15659	76.63259	Grassland	136.99	43.57
17/08/21	15.15661	76.63521	Scrub	93.57	46.57
22/08/21	15.15661	76.63559	Scrub	126.17	55.43
21/07/21	15.15664	76.64800	Builtup	139.17	52.20
22/08/21	15.15664	76.63850	Scrub	211.31	58.27
17/08/21	15.15670	76.63637	Scrub	178.27	44.80
22/08/21	15.15672	76.63969	Scrub	183.28	58.67
17/08/21	15.15675	76.63481	Scrub	49.68	49.60
22/08/21	15.15676	76.63523	Scrub	85.52	57.70
17/08/21	15.15681	76.63510	Scrub	70.91	47.47
22/08/21	15.15684	76.63519	Scrub	76.91	71.33
22/08/21	15.15688	76.63838	Scrub	187.02	65.73
22/08/21	15.15689	76.63519	Scrub	73.69	69.53
22/08/21	15.15690	76.63960	Scrub	164.85	61.23
01/08/21	15.15697	76.64946	Builtup	157.88	56.27
22/08/21	15.15700	76.63509	Scrub	57.83	60.30
21/07/21	15.15703	76.64774	Builtup	89.88	61.30
22/08/21	15.15709	76.63841	Scrub	163.83	62.47
22/08/21	15.15714	76.63702	Scrub	164.69	64.27
17/08/21	15.15717	76.63380	Grassland	65.90	51.17
17/08/21	15.15723	76.63659	Scrub	141.77	44.97
22/08/21	15.15724	76.63826	Scrub	148.16	62.30
22/08/21	15.15728	76.63825	Scrub	143.92	63.53
22/08/21	15.15730	76.63974	Scrub	118.93	61.47
22/08/21	15.15737	76.63703	Scrub	140.18	57.93
22/08/21	15.15738	76.63490	Scrub	14.57	61.57
22/08/21	15.15738	76.63493	Scrub	17.33	69.53
22/08/21	15.15739	76.63701	Scrub	136.93	56.87
22/08/21	15.15739	76.63492	Scrub	15.41	77.50
01/08/21	15.15744	76.64920	Builtup	100.31	59.43
21/07/21	15.15745	76.64771	Builtup	44.40	65.70
17/08/21	15.15746	76.63373	Grassland	90.27	49.60
17/08/21	15.15748	76.63428	Grassland	44.27	51.67
01/08/21	15.15750	76.64598	Builtup	1.59	77.57
22/08/21	15.15754	76.63490	Scrub	3.02	78.20
22/08/21	15.15756	76.63718	Scrub	123.39	57.67
22/08/21	15.15756	76.63719	Scrub	123.05	59.63
14/08/21	15.15757	76.64508	Builtup	0.81	74.87
22/08/21	15.15759	76.63957	Scrub	89.62	63.40
31/07/21	15.15763	76.64677	Builtup	3.09	79.40
14/08/21	15.15763	76.64621	Builtup	13.64	75.97

17/08/21	15.15765	76.63616	Scrub	80.15	48.70
22/08/21	15.15767	76.63496	Scrub	2.76	71.30
14/08/21	15.15768	76.64572	Builtup	20.51	69.23
19/07/21	15.15769	76.64413	Builtup	1.67	74.70
22/08/21	15.15769	76.63501	Scrub	0.78	74.50
01/08/21	15.15771	76.64604	Builtup	24.45	72.50
17/08/21	15.15774	76.63376	Grassland	106.01	48.27
22/08/21	15.15774	76.63804	Scrub	94.09	64.70
19/07/21	15.15776	76.64406	Builtup	4.70	77.40
22/08/21	15.15778	76.63706	Scrub	96.50	62.40
14/08/21	15.15778	76.64519	Builtup	26.02	72.27
17/08/21	15.15779	76.63547	Scrub	23.62	63.00
22/08/21	15.15779	76.63805	Scrub	88.04	62.13
01/08/21	15.15781	76.64855	Builtup	38.20	68.33
19/07/21	15.15782	76.65501	Waterbody	235.36	57.30
22/08/21	15.15784	76.63510	Scrub	5.42	71.47
12/07/21	15.15786	76.63599		51.38	51.10
21/07/21	15.15787	76.64751	Builtup	6.00	72.60
17/08/21	15.15788	76.63587	Scrub	42.16	54.70
17/08/21	15.15797	76.63517	Scrub	11.91	61.07
01/08/21	15.15798	76.64821	Builtup	8.34	72.57
01/08/21	15.15803	76.64638	Builtup	55.42	64.37
14/08/21	15.15804	76.64270	Builtup	11.44	72.27
22/08/21	15.15809	76.63702	Scrub	62.07	69.53
14/08/21	15.15810	76.64643	Builtup	61.19	58.97
31/07/21	15.15810	76.64684	Builtup	51.70	72.60
14/08/21	15.15812	76.64799	Builtup	14.83	76.60
22/08/21	15.15812	76.63949	Scrub	32.86	64.93
22/08/21	15.15813	76.63953	Scrub	31.23	67.57
22/08/21	15.15813	76.63502	Scrub	36.34	58.63
14/08/21	15.15814	76.64445	Builtup	53.02	60.27
14/08/21	15.15815	76.64139	Builtup	0.50	73.63
14/08/21	15.15815	76.64188	Builtup	8.94	71.53
14/08/21	15.15818	76.64292	Builtup	30.28	66.40
30/07/21	15.15821	76.63431	Scrub	95.21	44.37
19/07/21	15.15823	76.65490	Waterbody	187.62	58.70
01/08/21	15.15824	76.64647	Builtup	76.46	54.67
22/08/21	15.15828	76.63958	Scrub	14.46	73.43
22/08/21	15.15832	76.63505	Scrub	50.37	63.17
22/08/21	15.15832	76.63503	Scrub	51.53	57.63
22/08/21	15.15834	76.63776	Scrub	31.09	67.43
22/08/21	15.15834	76.63684	Scrub	30.44	61.63
14/08/21	15.15838	76.63976	Builtup	0.37	71.43
22/08/21	15.15841	76.63686	Scrub	23.37	69.87
14/08/21	15.15845	76.64393	Builtup	77.42	64.60
22/08/21	15.15846	76.63957	Scrub	4.98	73.47
14/08/21	15.15846	76.64761	Builtup	64.55	67.17
22/08/21	15.15848	76.63476	Scrub	83.58	54.50
22/08/21	15.15848	76.63950	Scrub	6.54	71.67
22/08/21	15.15849	76.63709	Scrub	20.93	73.43

14/08/21	15.15849	76.64319	Builtup	68.65	60.63
14/08/21	15.15851	76.64824	Builtup	46.13	65.10
14/08/21	15.15853	76.64030	Builtup	24.60	71.10
01/08/21	15.15859	76.64638	Builtup	116.08	53.07
19/07/21	15.15860	76.65482	Waterbody	145.93	59.60
22/08/21	15.15862	76.63897	Scrub	12.63	70.53
22/08/21	15.15865	76.63677	Scrub	4.00	82.70
14/08/21	15.15865	76.64353	Builtup	92.09	59.70
14/08/21	15.15866	76.64655	Builtup	119.26	53.33
14/08/21	15.15866	76.64083	Builtup	46.77	62.67
22/08/21	15.15867	76.63894	Scrub	17.19	69.50
14/08/21	15.15867	76.64974	Builtup	10.02	75.73
22/08/21	15.15870	76.63461	Scrub	112.64	53.40
30/07/21	15.15870	76.63348	Scrub	196.21	37.67
14/08/21	15.15873	76.64013	Builtup	44.40	64.93
14/08/21	15.15875	76.64710	Builtup	112.73	57.10
19/07/21	15.15877	76.65422	Waterbody	111.98	60.50
22/08/21	15.15882	76.63468	Scrub	117.95	54.23
14/08/21	15.15886	76.64129	Builtup	76.98	59.63
22/08/21	15.15887	76.63957	Scrub	50.11	68.53
22/08/21	15.15892	76.63812	Scrub	37.31	71.63
22/08/21	15.15894	76.63835	Scrub	39.87	72.57
22/08/21	15.15895	76.63818	Scrub	40.34	72.70
31/07/21	15.15896	76.64746	Builtup	121.69	61.27
22/08/21	15.15897	76.63908	Scrub	51.88	65.90
22/08/21	15.15898	76.63960	Scrub	63.11	65.90
31/07/21	15.15900	76.64752	Builtup	123.89	53.27
19/07/21	15.15904	76.65480	Waterbody	98.88	64.10
31/07/21	15.15905	76.64744	Builtup	131.83	49.70
22/08/21	15.15907	76.63908	Scrub	63.81	68.13
14/08/21	15.15910	76.64843	Builtup	100.72	54.07
19/07/21	15.15917	76.65564	Waterbody	106.86	65.40
19/07/21	15.15918	76.65434	Waterbody	70.89	65.90
22/08/21	15.15920	76.63479	Scrub	144.79	53.60
14/08/21	15.15925	76.64938	Builtup	83.11	58.07
14/08/21	15.15927	76.65125	Builtup	24.91	68.27
22/08/21	15.15928	76.63963	Scrub	95.90	60.63
22/08/21	15.15932	76.63839	Scrub	82.16	68.17
14/08/21	15.15935	76.65012	Builtup	67.44	68.47
14/08/21	15.15936	76.65207	Builtup	10.26	76.67
14/08/21	15.15938	76.64861	Builtup	123.20	52.17
14/08/21	15.15942	76.64897	Builtup	115.06	53.37
14/08/21	15.15943	76.65100	Builtup	49.24	63.63
19/07/21	15.15944	76.65531	Waterbody	69.40	66.80
14/08/21	15.15948	76.65039	Builtup	73.55	62.70
22/08/21	15.15950	76.63459	Scrub	183.71	55.67
19/07/21	15.15951	76.65472	Waterbody	46.26	68.60
19/07/21	15.15956	76.65445	Waterbody	33.43	70.40
22/08/21	15.15957	76.63908	Scrub	118.41	62.43
22/08/21	15.15960	76.63556	Scrub	142.32	55.30

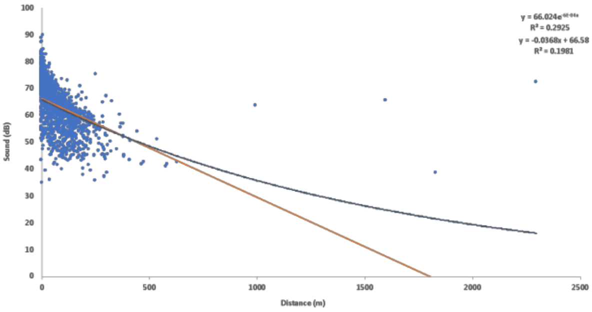
22/08/21	15.15964	76.63443	Scrub	206.41	55.73
22/08/21	15.15965	76.63448	Scrub	204.40	61.40
19/07/21	15.15967	76.65499	Waterbody	35.73	69.80
22/08/21	15.15968	76.63971	Scrub	141.26	61.50
14/08/21	15.15978	76.65329	Builtup	21.40	72.43
22/08/21	15.15978	76.63526	Scrub	174.32	57.17
22/08/21	15.15979	76.63987	Scrub	156.19	61.03
22/08/21	15.15981	76.63527	Scrub	176.62	67.00
22/08/21	15.15982	76.63613	Scrub	146.49	59.33
22/08/21	15.15983	76.63705	Scrub	126.81	64.77
22/08/21	15.15986	76.63501	Scrub	193.35	55.53
22/08/21	15.15987	76.63704	Scrub	130.35	58.60
22/08/21	15.15989	76.63770	Scrub	138.38	58.30
14/08/21	15.15989	76.65424	Builtup	7.90	72.33
19/07/21	15.15992	76.65462	Waterbody	0.86	74.40
04/08/21	15.15993	76.65584	Agriculture	31.18	70.23
04/08/21	15.15993	76.65652	Agriculture	50.91	72.63
04/08/21	15.15994	76.65583	Agriculture	29.84	69.43
22/08/21	15.15994	76.63899	Scrub	157.48	59.60
14/08/21	15.15999	76.65371	Builtup	32.94	70.00
22/08/21	15.16001	76.63551	Scrub	186.13	60.67
22/08/21	15.16005	76.63552	Scrub	189.99	58.40
22/08/21	15.16009	76.63669	Scrub	161.27	56.27
14/08/21	15.16010	76.65139	Builtup	108.01	54.63
14/08/21	15.16013	76.65114	Builtup	118.79	64.37
22/08/21	15.16013	76.63897	Scrub	177.48	60.70
14/08/21	15.16013	76.65509	Builtup	10.41	73.13
14/08/21	15.16014	76.65472	Builtup	21.28	74.20
14/08/21	15.16016	76.65438	Builtup	32.77	67.43
22/08/21	15.16022	76.63974	Scrub	200.79	60.60
22/08/21	15.16024	76.63973	Scrub	201.84	59.87
12/07/21	15.16030	76.65774		51.08	62.50
14/08/21	15.16032	76.65209	Builtup	113.03	57.67
04/08/21	15.16034	76.65743	Agriculture	36.34	69.17
06/08/21	15.16034	76.65623	Waterbody	1.63	79.03
14/08/21	15.16035	76.65588	Builtup	12.91	73.97
22/08/21	15.16036	76.63958	Scrub	212.60	58.43
22/08/21	15.16036	76.63917	Scrub	205.90	59.20
22/08/21	15.16040	76.63882	Scrub	205.07	58.03
14/08/21	15.16041	76.65538	Builtup	32.45	69.23
06/08/21	15.16044	76.65663	Waterbody	0.45	76.40
19/07/21	15.16045	76.65681	Builtup	5.09	74.10
22/08/21	15.16062	76.63870	Scrub	227.31	56.37
04/08/21	15.16062	76.65796	Agriculture	25.13	68.43
04/08/21	15.16064	76.65798	Agriculture	24.17	67.90
22/08/21	15.16067	76.63899	Scrub	236.95	57.33
06/08/21	15.16077	76.65716	Waterbody	17.67	69.57
06/08/21	15.16077	76.65683	Waterbody	28.12	71.83
06/08/21	15.16077	76.65716	Waterbody	17.67	75.50
14/08/21	15.16080	76.65626	Builtup	49.21	64.87

04/08/21	15.16089	76.65880	Agriculture	47.60	69.33
14/08/21	15.16131	76.65616	Builtup	106.41	54.53
04/08/21	15.16160	76.65934	Agriculture	32.97	75.23
04/08/21	15.16161	76.65933	Agriculture	31.43	74.47
06/08/21	15.16163	76.65819	Waterbody	57.28	68.20
06/08/21	15.16165	76.65866	Waterbody	25.79	69.63
14/08/21	15.16172	76.65654	Builtup	138.07	60.30
06/08/21	15.16186	76.65753	Waterbody	117.53	64.43
06/08/21	15.16192	76.65905	Waterbody	13.81	68.07
06/08/21	15.16192	76.65905	Waterbody	13.81	71.27
04/08/21	15.16201	76.65949	Agriculture	14.23	76.50
04/08/21	15.16218	76.65969	Agriculture	17.46	75.30
04/08/21	15.16218	76.65969	Agriculture	17.46	76.47
14/08/21	15.16221	76.65637	Builtup	194.58	52.27
19/07/21	15.16223	76.65953	Waterbody	0.59	76.20
06/08/21	15.16231	76.65881	Waterbody	62.04	71.40
04/08/21	15.16235	76.65992	Agriculture	24.08	72.03
19/07/21	15.16253	76.65915	Waterbody	51.59	65.30
06/08/21	15.16265	76.65978	Waterbody	8.92	77.10
14/08/21	15.16266	76.65677	Builtup	230.22	50.80
04/08/21	15.16277	76.66035	Agriculture	29.81	68.37
19/07/21	15.16277	76.65873	Waterbody	102.78	60.40
19/07/21	15.16278	76.65968	Builtup	26.43	70.05
06/08/21	15.16282	76.65942	Waterbody	50.58	71.20
06/08/21	15.16284	76.65943	Waterbody	51.20	68.17
19/07/21	15.16293	76.65847	Waterbody	135.67	59.70
06/08/21	15.16300	76.65847	Waterbody	140.68	61.67
06/08/21	15.16301	76.65846	Waterbody	142.22	66.47
22/08/21	15.16333	76.66036	JSW	8.47	69.83
20/07/21	15.16342	76.66097	Builtup	1.02	74.10
22/08/21	15.16348	76.66112	JSW	2.03	78.50
22/08/21	15.16363	76.66169	JSW	1.57	78.90
20/07/21	15.16371	76.66204	Builtup	1.25	88.80
22/08/21	15.16376	76.66217	JSW	2.61	79.63
22/08/21	15.16391	76.66252	JSW	10.21	74.23
22/08/21	15.16393	76.66280	JSW	5.75	79.40
20/07/21	15.16402	76.66323	Builtup	3.76	87.50
22/08/21	15.16412	76.66312	JSW	17.95	71.37
20/07/21	15.16415	76.66321	Builtup	18.94	74.60
22/08/21	15.16418	76.66372	JSW	7.92	77.47
22/08/21	15.16420	76.66358	JSW	13.95	74.37
20/07/21	15.16424	76.66398	Builtup	5.69	83.80
22/08/21	15.16427	76.66411	JSW	4.60	82.20
20/07/21	15.16437	76.66394	Builtup	21.31	77.90
22/08/21	15.16446	76.66475	JSW	1.73	79.73
22/08/21	15.16447	76.66445	JSW	11.96	74.17
20/07/21	15.16454	76.66486	Builtup	1.77	82.40
20/07/21	15.16467	76.66482	Builtup	16.46	75.70
22/08/21	15.16468	76.66520	JSW	1.63	79.17
22/08/21	15.16479	76.66552	JSW	1.93	83.73

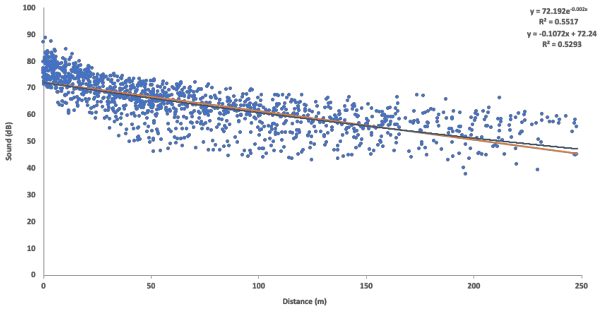
22/08/21	15.16506	76.66587	JSW	4.87	78.27
22/08/21	15.16535	76.67319	JSW	1.98	79.73
22/08/21	15.16537	76.67201	JSW	3.10	81.33
20/07/21	15.16539	76.67535	Builtup	0.23	87.10
22/08/21	15.16541	76.67420	JSW	6.77	79.23
22/08/21	15.16541	76.67514	JSW	3.10	79.50
20/07/21	15.16542	76.67160	Builtup	2.41	83.30
22/08/21	15.16542	76.67465	JSW	5.97	79.33
22/08/21	15.16545	76.67554	JSW	5.10	80.87
22/08/21	15.16547	76.67229	JSW	16.26	77.50
22/08/21	15.16547	76.66645	JSW	3.69	77.80
22/08/21	15.16550	76.67372	JSW	18.13	75.57
22/08/21	15.16553	76.67103	JSW	0.78	76.13
22/08/21	15.16554	76.67610	JSW	4.62	79.40
22/08/21	15.16556	76.67141	JSW	14.08	78.93
21/07/21	15.16560	76.67565	Builtup	19.50	68.20
22/08/21	15.16560	76.67051	JSW	7.15	75.40
22/08/21	15.16564	76.67170	JSW	28.40	73.97
22/08/21	15.16565	76.67626	JSW	11.95	75.30
22/08/21	15.16569	76.67666	JSW	5.17	78.67
22/08/21	15.16571	76.67019	JSW	5.17	76.50
20/07/21	15.16574	76.66698	Builtup	1.30	82.80
22/08/21	15.16578	76.66984	JSW	9.20	76.33
20/07/21	15.16580	76.66691	Builtup	10.15	78.50
22/08/21	15.16583	76.66707	JSW	5.82	80.63
22/08/21	15.16585	76.66964	JSW	8.55	76.80
22/08/21	15.16597	76.66749	JSW	4.55	79.73
22/08/21	15.16599	76.66906	JSW	5.40	77.67
22/08/21	15.16607	76.66881	JSW	0.47	71.77
22/08/21	15.16609	76.66816	JSW	4.54	81.43
21/07/21	15.17272	76.68375	JSW	10.88	74.10

Table 2.7b. Overall noise attenuation and noise attenuation in various land-uses.

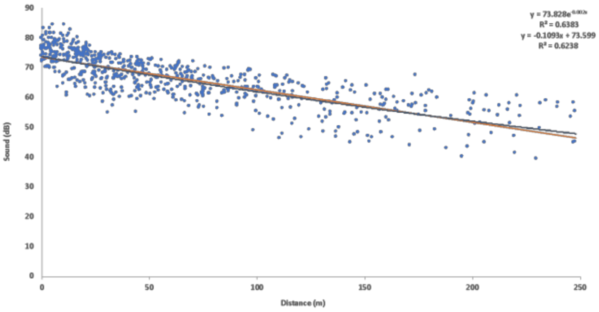
Land use	Points	Regression Equation	R^2	r (P)	Distance (m) Range	Sound (dB) Range
Total (Exponential)	**1587**	$y = 66.024e^{-6E-04x}$	**0.293**	**- 0.541**	**0.04 - 2297.74**	**34.9 – 89.77**
Total (Linear) A	**1587**	**y = -0.0368x + 66.58**	**0.198**	**- 0.445 <0.0001**	**0.04 - 2297.74**	**34.9 – 89.77**
Unique data (Exponential)	**1378**	$y = 72.192e^{-0.002x}$	**0.552**	**- 0.743**	**0.04 - 248.01**	**37.67 - 88.80**
Total (Linear) B	**1378**	**y = -0.1072x + 72.24**	**0.529**	**- 0.727 <0.0001**	**0.04 - 248.01**	**37.67 - 88.80**
Agriculture (Exponential)	**685**	$y = 73.828e^{-0.002x}$	**0.638**	**- 0.799**	**0.04 - 248.01**	**39.5 - 84.5**
Agriculture (Linear) C	**685**	**y = -0.1093x + 73.599**	**0.624**	**- 0.79 <0.0001**	**0.04 - 248.01**	**39.5 - 84.5**
Builtup (Exponential)	**97**	$y = 76.028e^{-0.002x}$	**0.794**	**- 0.891**	**0.23 – 230.22**	**49.7 – 88.8**
Builtup (Linear) D	**97**	**y = -0.1519x + 75.873**	**0.767**	**- 0.876 <0.0001**	**0.23 – 230.22**	**49.7 – 88.8**
Forest (Exponential)	**156**	$y = 70.149e^{-0.002x}$	**0.569**	**- 0.754**	**0.79 – 246.80**	**43.1 – 81.3**
Forest (Linear) E	**156**	**y = -0.1121x + 70**	**0.54**	**- 0.735 <0.0001**	**0.79 – 246.80**	**43.1 – 81.3**
Grassland (Exponential)	**25**	$y = 60.451e^{-0.003x}$	**0.715**	**- 0.846**	**22.38 – 136.99**	**43.6 – 62.3**
Grassland (Linear) F	**25**	**y = -0.1356x + 59.916**	**0.699**	**- 0.836 <0.0001**	**22.38 – 136.99**	**43.6 – 62.3**
JSW (Exponential)	**40**	$y = 79.527e^{-0.003x}$	**0.265**	**- 0.515**	**0.47 – 28.4**	**69.83 – 83.73**
JSW (Linear) G	**40**	**y = -0.2688x + 79.55**	**0.264**	**- 0.514 <0.0007**	**0.47 – 28.4**	**69.83 – 83.73**
Scrub (Exponential)	**214**	$y = 65.452e^{-0.001x}$	**0.265**	**- 0.515**	**0.78 – 246.84**	**37.67 – 82.7**
Scrub (Linear) H	**214**	**y = -0.0625x + 65.967**	**0.253**	**- 0.503 <0.0001**	**0.78 – 246.84**	**37.67 – 82.7**
Waterbody (Exponential)	**82**	$y = 70.412e^{-0.001x}$	**0.528**	**- 0.727**	**0.45 – 238.71**	**47.63 – 79.03**
Waterbody (Linear) I	**82**	**y = -0.0824x + 70.459**	**0.516**	**- 0.718 <0.0001**	**0.45 – 238.71**	**47.63 – 79.03**


y = 66.024e^-6E-04x
R² = 0.2925
y = -0.0368x + 66.58
R² = 0.1981
Sound (dB)
Distance (m)

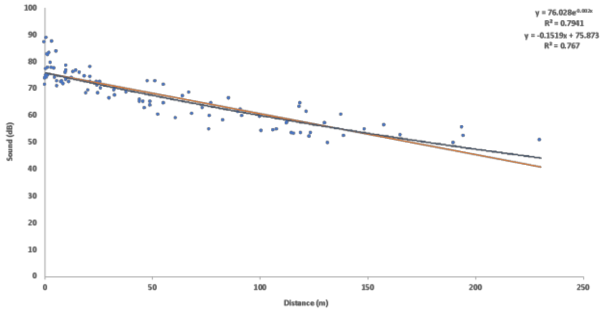
A


y = 72.192e^-0.002x
R² = 0.5517
y = -0.1072x + 72.24
R² = 0.5293
Sound (dB)
Distance (m)

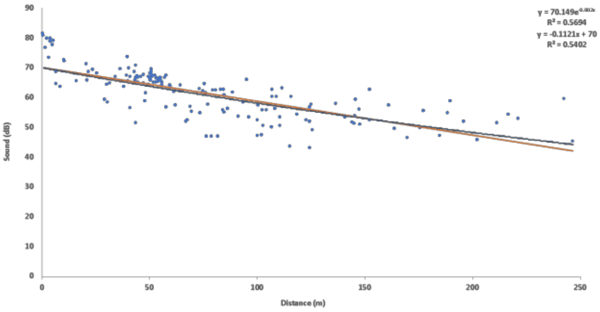
B


y = 73.828e^-0.002x
R² = 0.6383
y = -0.1093x + 73.599
R² = 0.6238
Sound (dB)
Distance (m)

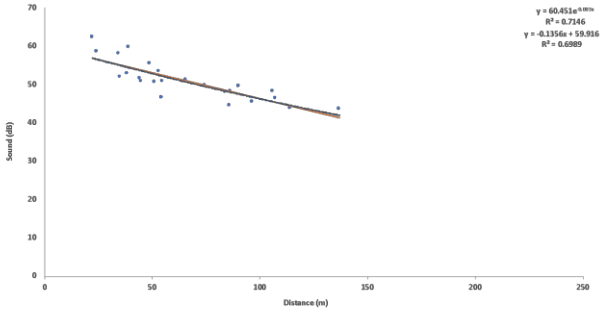
C


y = 76.028e^-0.002x
R² = 0.7941
y = -0.1519x + 75.873
R² = 0.767
Sound (dB)
Distance (m)

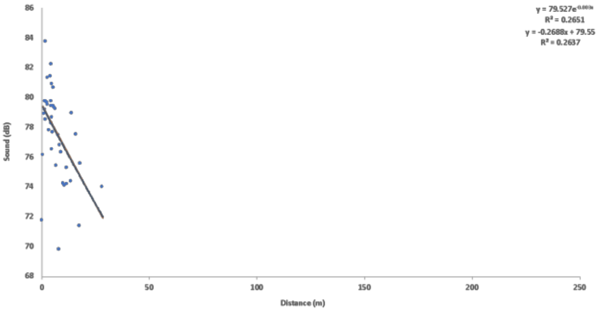
D


y = 70.149e^-0.002x
R² = 0.5694
y = -0.1121x + 70
R² = 0.5402
Sound (dB)
Distance (m)

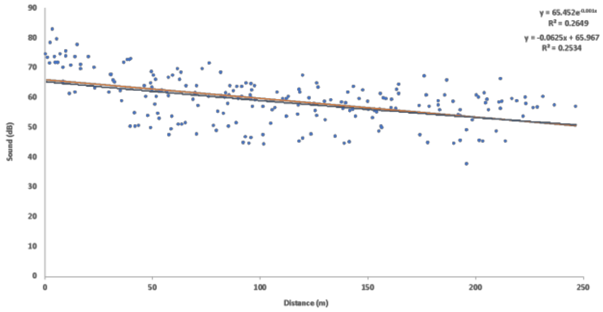
E


y = 60.451e^-0.003x
R² = 0.7146
y = -0.1356x + 59.916
R² = 0.6989
Sound (dB)
Distance (m)

F


y = 79.527e^-0.003x
R² = 0.2651
y = -0.2688x + 79.55
R² = 0.2637
Sound (dB)
Distance (m)

G


y = 65.452e^-0.001x
R² = 0.2649
y = -0.0625x + 65.967
R² = 0.2534
Sound (dB)
Distance (m)

H

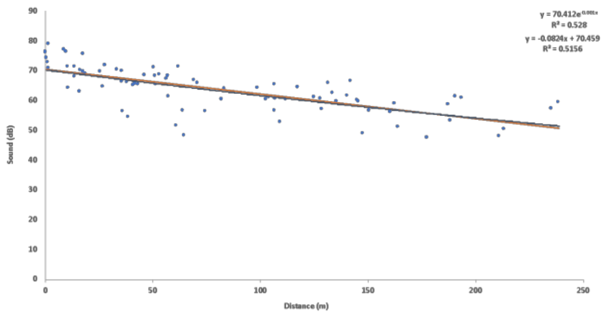


Figure 2.37. Regression analysis of the noise data. The orange trend line indicates linear regression and the blue trend line indicates exponential regression.

Noisescape map: Noisescape map is illustrated in Figure 2.34. The standard contour intervals used were 5dB with a minimum value of 35dB to a maximum value of 90dB (Figure 2.34 and 2.35). It is evident from the noise map that noise levels are higher near the MPC (70-90dB) and lower in the areas away from MPC. The places with HDPE idlers were relatively less noisy (40-60dB) compared to metal idlers in the other parts of MPC (Figure 2.36).

Noise attenuation: Perpendicular distance from MPC to observed noise were measured in QGIS and values were plotted to understand the noise attenuation. It is well known that sound levels decrease with distance, in an exponential manner. In the present study too, it was evident that noise levels decreased with distance. The overall datapoints plotted against distance showed a statistically significant negative relationship with distance (Exponential regression, $y = 72.192e^{-0.002x}$, $R^2 = 0.552$ and Linear regression, $y = -0.1072x + 72.24$, $R^2 = 0.529$). Table 2.7 and Figure 2.37 (A-I) details the regression equations calculated for varied land-uses in the study area.

Discussion and suggestions

This is the first-ever noisescape map of an active main pipe conveyor belt in India. This map visually represents the noise levels coming from the MPC along its length as well as at places with HDPE idlers. Karakula et al. (2007) and Parajuli (2018) indicate that the quality of a noise model can be improved with a high density of observation points. The present research had a large number of observation points (1378), the maps are of good accuracy as indicated by the statistical significance of regression analysis.

Suggestions: Planting a double row of trees along and on both sides of MPC can reduce the noise immission and propagation (Aksu and Yilmaz, 2021). In addition, HDPE idlers that reduce noise (by 10-50dB), can be used as alternatives to steel idlers along with the MPC.

Limitations: The inconsistent noise levels variations in the study could be due to a. Varied speed of the MPC, b. variation in the load inside MPC and c. variation in the sound meters used. The variation in the sound meters is at the level of 1 to 2 dB, while the variation due to speed and load of MPC is at the level of 20-40dB. The quality of the noise map thus would improve if the aforesaid limitations were considered in the long-term studies.

Vibration Map

Introduction

The process of change of physical quantities such as displacements, velocities, accelerations, and forces are may be vibration, It is well known that many of the human operations produce vibrations propagating in the ground which are perceptible in properties at certain distances, Vibrations in the frequency range relevant to the source and propagate parallel to the ground surface via Rayleigh wave modes with low rates of attenuation with distance (Jones, 2019).

The environmental impact of vibrations induced by the human activities like, construction, traffic, railway, etc. are in increasing concern in modern world specially among the developing countries. With the introduction of mass rapid transportations (Garg and Sharma, 2010) although the transportation facilities have much improved, yet their operation may result in an additional impact on environment and living nearby. Thus, it is indispensable to conduct the noise and vibration impact studies to assess the relative impact of the means of transportation to avoid any damage to surrounding and take precautionary measures for combating with it.

In nature, all the living beings must contend with the sound which may limit their ability to their activities such as detection of prey, communication signal, attracting the mates, and many others. Source of sound or the noise vary in the environment it may be by the animals or anthropogenic, a man made environmental changes were also introduced noise sources as well as artificial substrates that alter the vibratory noise profile, that may leading to mal adaptive behavioural responses in the animal community. In order to overlook to the anthropogenic vibratory effects we conducted field measurements of vibrations in all the habitats

Materials and Methods

Instrument and measurements: Seismograph Nomic Mini Supergraph-2 was used, a total of 115 vibration samples were collected all along the MPC a radial, transverse and vertical ground vibrations with frequencies s were documented, Samplings were done at all types of pillars consists of RCC, RCC and Steel and only the steel, at every pillar with a distance of 2m up to 8m during the peak activity of MPC.

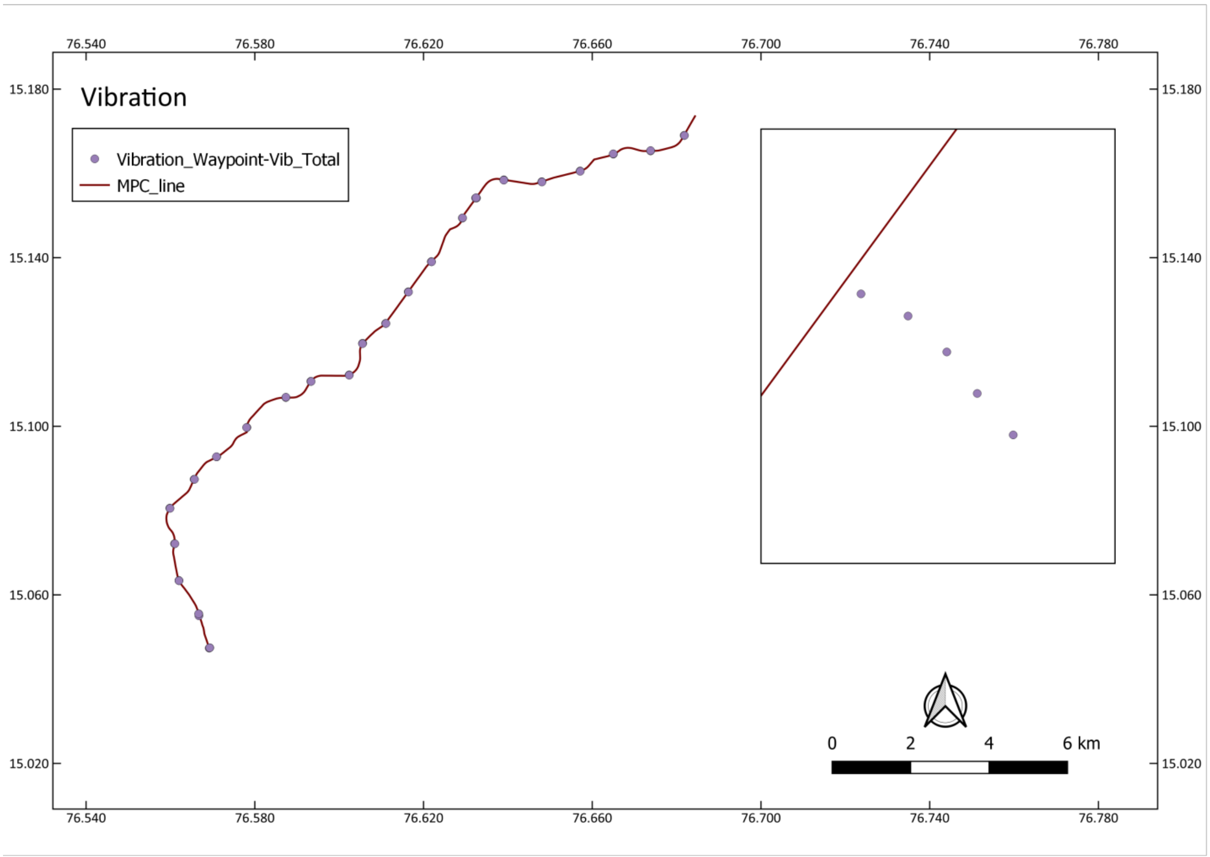


Figure 2.38. Vibration sampling Points along the MPC

Results

A total of 115 points of vibration data were collected near the pillars all along the MPC made up different materials, i.e., RCC, RCC+Steel, and steel pillars. At every 500m distance along MPC, vibration data was collected based on the type of pillar. The peak particle velocity (PVV) in three directions namely, radial (R), vertical (V) and transverse (T) documented along with radial, vertical and transverse frequency. Vibration data is provided in Table 2.8a. PVV is maximum (R, T and V) near the pillars and decreases while moving away from pillars, irrespective of type of material used for pillars. In contrast, frequencies increase while moving away from pillars. The regression analysis of all PVV and frequencies are given in the Figures 2.39 (RCC), 2.40 (RCC+Steel), 2.41 (Steel) and 2.42 (All kinds put together).

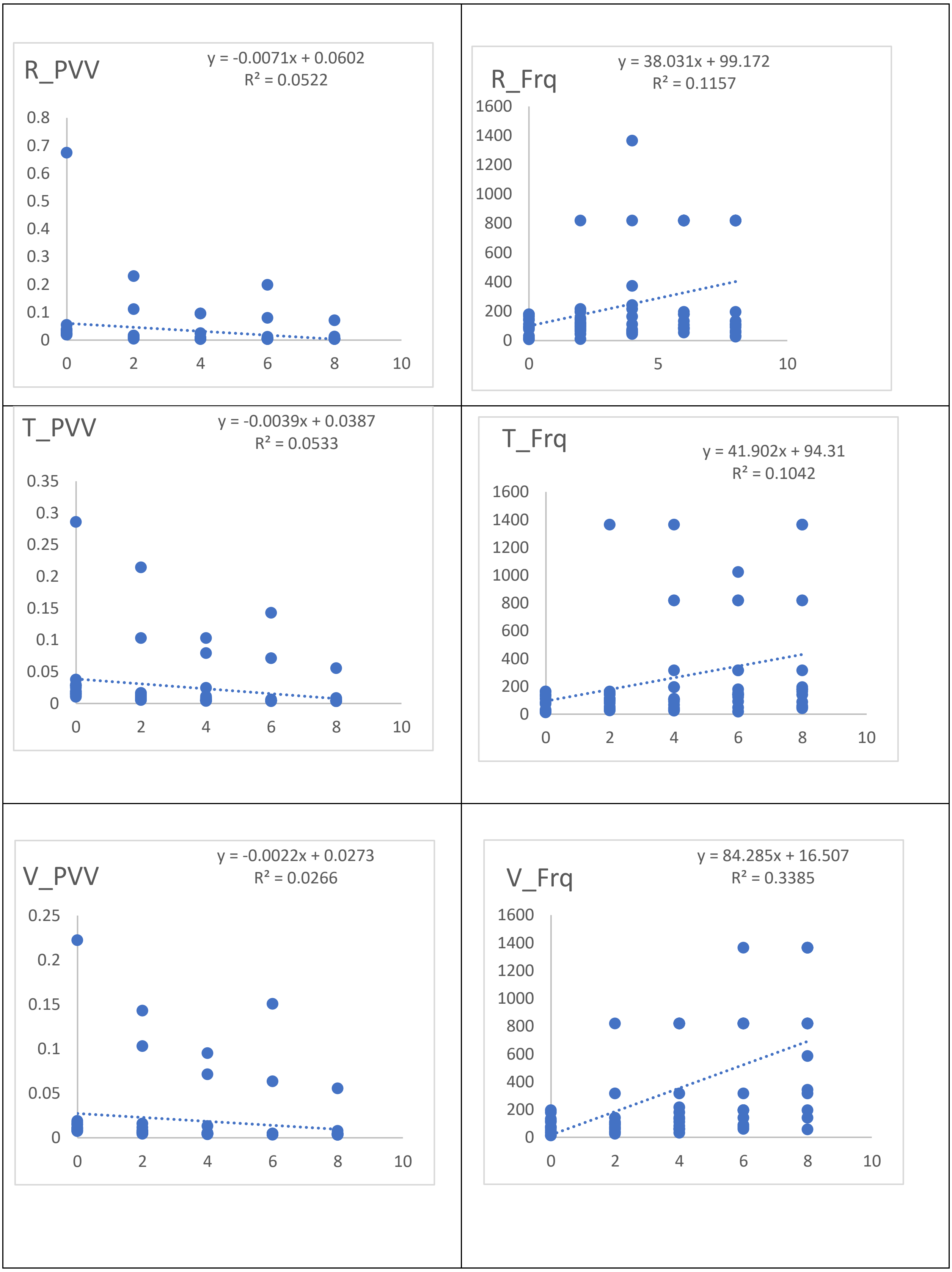


Figure 2.39. Regression analysis of vibration data for RCC Pillars.

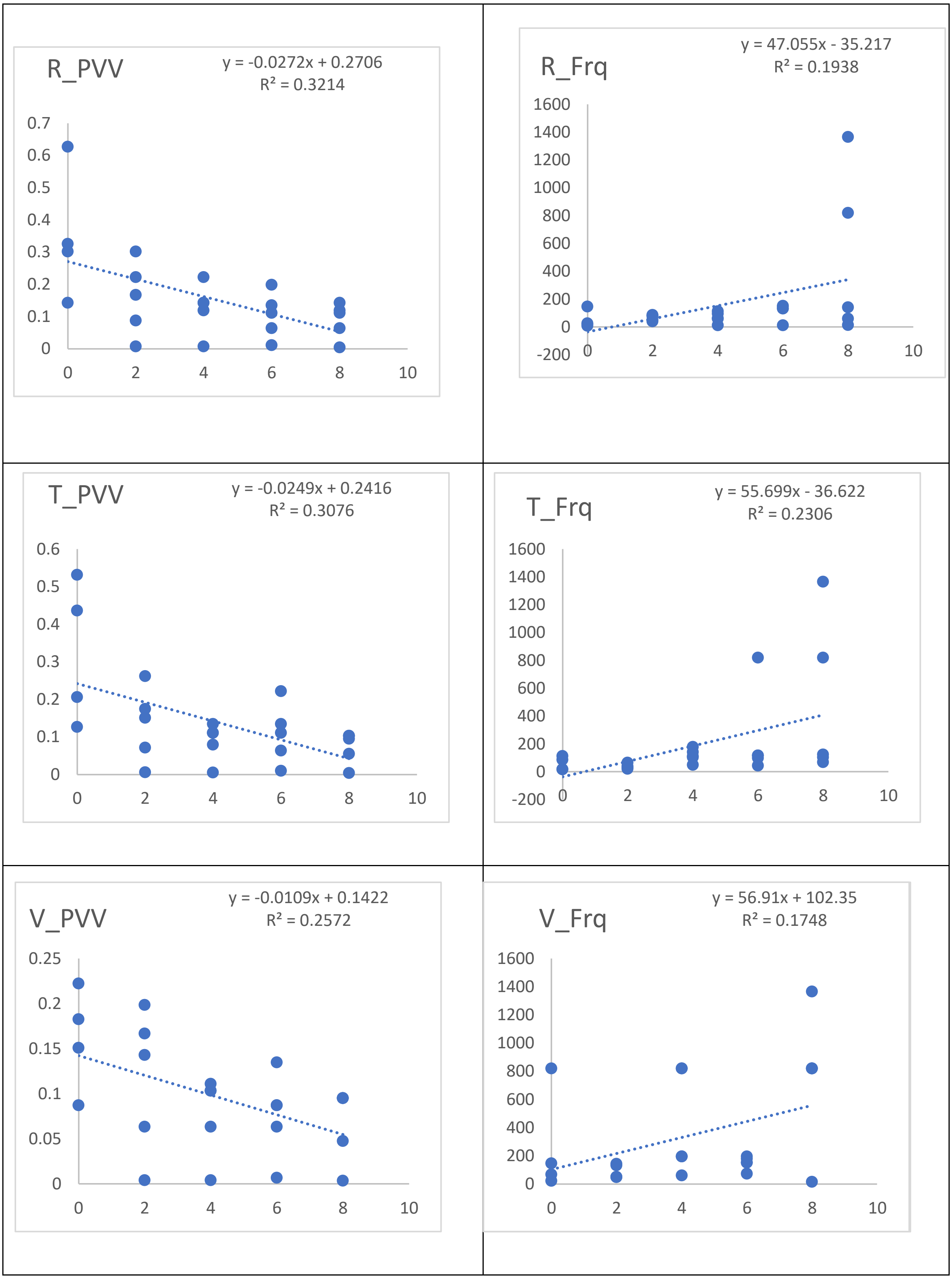


Figure 2.40. Regression analysis of vibration data for RCC+Steel Pillars.

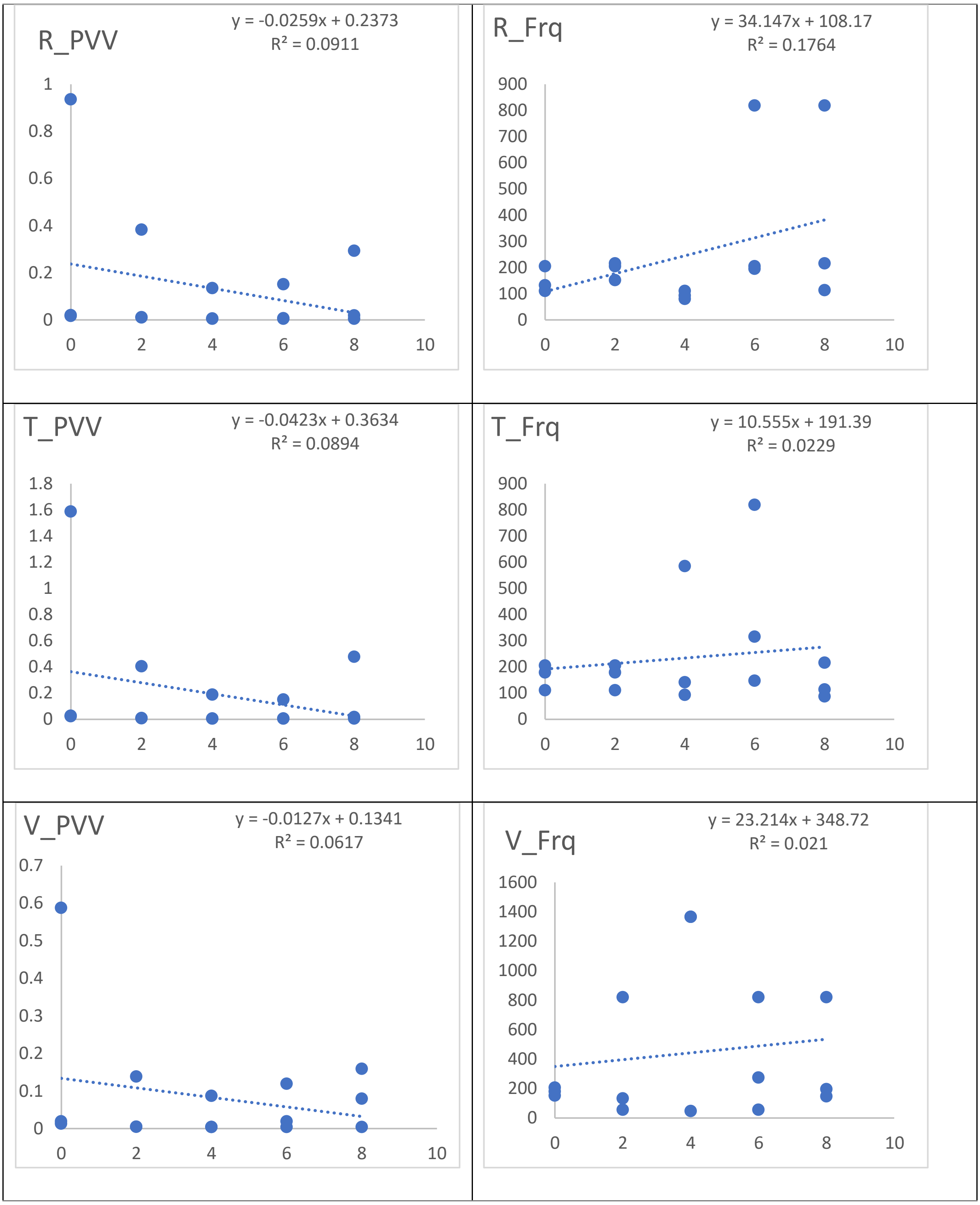


Figure 2.41. Regression analysis of vibration data for Steel Pillars.

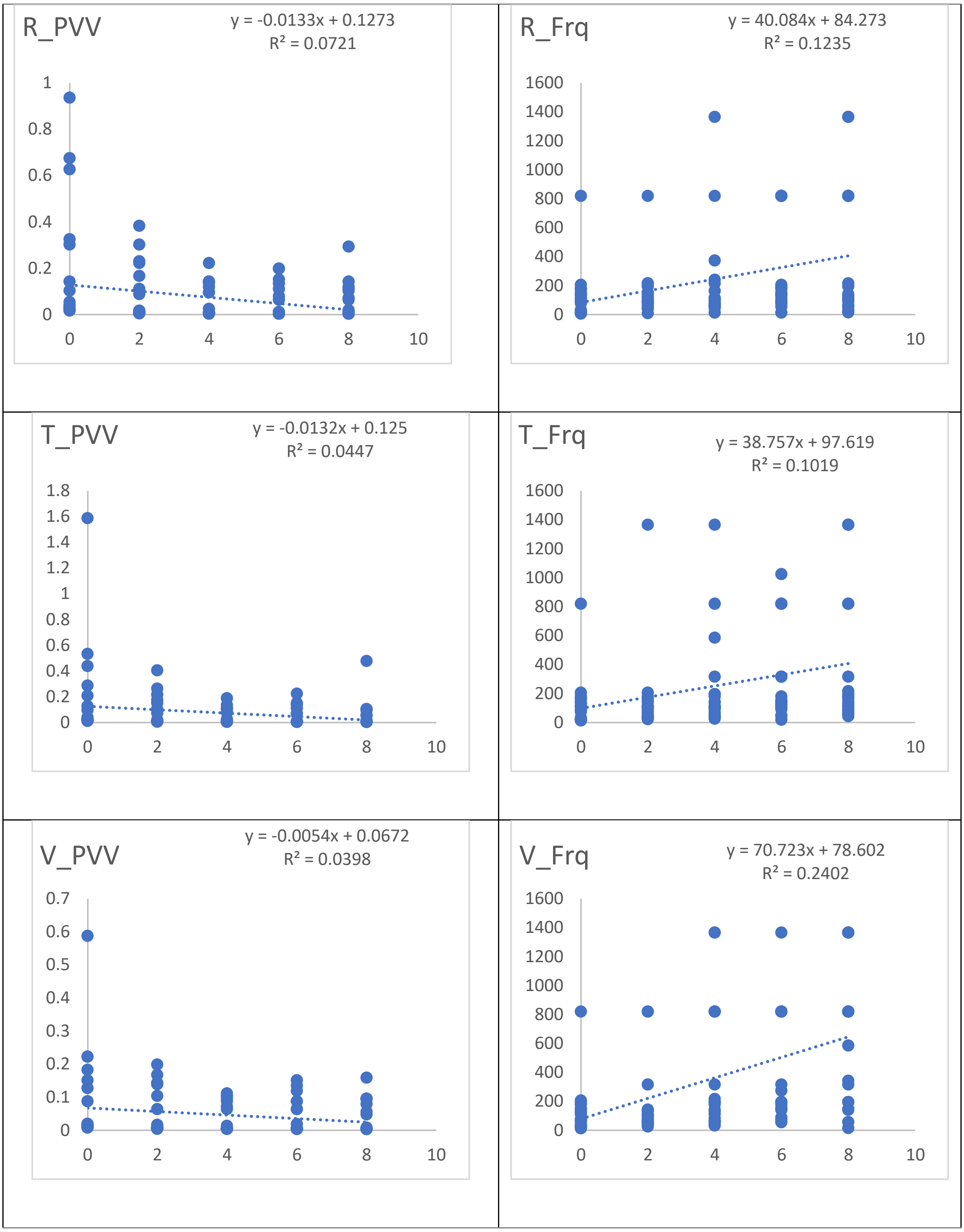


Figure 2.42. Regression analysis of vibration data for all pillars.

Table 2.8. Regression equation of vibration PVV and Frequency at various pillars along MPC.

Sampling		Peak particle velocity			Peak Frequency		Distance Range (m)
		Y	**R^2**		**Y**	**R^2**	
RCC	R_PPV	y = -0.007x + 0.060	R^2 = 0.052	R_Frq	y = 38.03x + 99.17	R^2 = 0.115	0-8
	T_PPV	y = -0.003x + 0.038	R^2 = 0.053	T_Frq	y = 41.90x + 94.31	R^2 = 0.104	0-8
	V_PPV	y = -0.002x + 0.027	R^2 = 0.026	V_Frq	y = 84.28x + 16.50	R^2 = 0.338	0-8
RCC+ Steel	R_PPV	y = -0.027x + 0.270	R^2 = 0.321	R_Frq	y = 47.05x - 35.21	R^2 = 0.193	0-8
	T_PPV	y = -0.024x + 0.241	R^2 = 0.307	T_Frq	y = 55.69x - 36.62	R^2 = 0.230	0-8
	V_PPV	y = -0.010x + 0.142	R^2 = 0.257	V_Frq	y = 56.91x + 102.3	R^2 = 0.174	0-8
Steel	R_PPV	y = -0.025x + 0.237	R^2 = 0.091	R_Frq	y = 34.14x + 108.1	R^2 = 0.176	0-8
	T_PPV	y = -0.042x + 0.363	R^2 = 0.089	T_Frq	y = 10.55x + 191.3	R^2 = 0.022	0-8
	V_PPV	y = -0.012x + 0.134	R^2 = 0.061	V_Frq	y = 23.21x + 348.7	R^2 = 0.021	0-8
All	R_PPV	y = -0.013x + 0.127	R^2 = 0.072	R_Frq	y = 40.08x + 84.27	R^2 = 0.123	0-8
	T_PPV	y = -0.013x + 0.125	R^2 = 0.044	T_Frq	y = 38.75x + 97.61	R^2 = 0.101	0-8
	V_PPV	y = -0.005x + 0.067	R^2 = 0.039	V_Frq	y = 70.72x + 78.60	R^2 = 0.240	0-8

Table 2.9. Vibration data collected from nearby pillars along MPC.

Sl_No	Reading	Distance_From_MPC (M)	Latitude	Longitude	Material	R_PVV	T_PVV	V_PVV	R_Frq	T_Frq	V_Frq
1	Vib_1	0	15.047347	76.56919	RCC	0.0544	0.0294	0.0169	6.57	12.92	13.43
2	Vib_1	2	15.047422	76.56928	RCC	0.0134	0.0084	0.0081	9.46	27.13	24.53
3	Vib_1	4	15.047453	76.56932	RCC	0.0059	0.005	0.005	57.69	105.03	61.13
4	Vib_1	6	15.047442	76.569336	RCC	0.0044	0.0044	0.0041	819.2	18.53	195.05
5	Vib_1	8	15.047444	76.569305	RCC	0.0044	0.0041	0.0038	24.82	43.12	819.2
6	Vib_2	0	15.05508	76.566757	RCC	0.0341	0.0144	0.0147	110.7	83.59	110.7
7	Vib_2	2	15.05503	76.566736	RCC	0.0163	0.0131	0.0116	124.12	151.7	141.24
8	Vib_2	4	15.055499	76.566718	RCC	0.0244	0.0244	0.0131	240.94	315.08	215.58
9	Vib_2	6	15.055495	76.566701	RCC	0.0047	0.0047	0.0041	132.13	141.24	1365.33
10	Vib_2	8	15.055491	76.566684	RCC	0.0047	0.0044	0.0034	105.03	178.09	819.2
11	Vib_3	0	15.063393	76.56203	RCC	0.0372	0.0281	0.0106	163.84	21.01	74.47
12	Vib_3	2	15.063403	76.56202	RCC	0.0072	0.0078	0.0059	63.02	30.34	37.58
13	Vib_3	4	15.063383	76.56201	RCC	0.0053	0.0044	0.0047	372.66	34.42	819.2
14	Vib_3	6	15.063356	76.56203	RCC	0.0047	0.005	0.0044	83.59	47.08	819.2
15	Vib_3	8	15.063355	76.56203	RCC	0.0041	0.0044	0.0041	819.2	57.69	585.14
16	Vib_4	0	15.072136	76.560974	RCC	0.0319	0.0375	0.0188	141.24	163.84	195.05
17	Vib_4	2	15.072132	76.560992	RCC	0.0116	0.0166	0.0069	151.7	163.84	110.7
18	Vib_4	4	15.072129	76.561012	RCC	0.0056	0.0047	0.0044	110.7	819.2	819.2
19	Vib_4	6	15.072126	76.56103	RCC	0.0047	0.0044	0.0038	178.09	819.2	819.2
20	Vib_4	8	15.072124	76.56105	RCC	0.0034	0.0034	0.0041	819.2	315.08	1365.33
21	Vib_5	0	15.08057	76.559846	RCC	0.0225	0.0194	0.0078	30.34	110.7	36.9
22	Vib_5	2	15.080559	76.559863	RCC	0.0066	0.0056	0.0047	195.05	99.9	59.36
23	Vib_5	4	15.080549	76.559876	RCC	0.0041	0.0041	0.0041	819.2	195.05	31.27

24	Vib_5	6	15.080537	76.559891	RCC	0.0041	0.0038	0.0041	819.2	315.08	87.15
25	Vib_5	8	15.080524	76.559903	RCC	0.0066	0.0044	0.0041	91.02	1365.33	195.05
26	Vib_6	0	15.087433	76.565626	RCC	0.0197	0.0166	0.0116	141.24	141.24	32.77
27	Vib_6	2	15.087428	76.565645	RCC	0.0159	0.0159	0.0159	43.12	54.61	57.69
28	Vib_6	4	15.087423	76.565666	RCC	0.0059	0.0088	0.0044	63.02	67.15	132.13
29	Vib_6	6	15.087418	76.565681	RCC	0.0041	0.0047	0.0038	819.2	315.08	819.2
30	Vib_6	8	15.087414	76.5657	RCC	0.0041	0.0038	0.0034	63.02	141.24	315.08
31	Vib_7	0	15.09275	76.570946	RCC	0.6747	0.2858	0.2222	10.78	14.03	13.65
32	Vib_7	2	15.092749	76.570946	RCC	0.2302	0.2143	0.1429	93.09	78.77	68.27
33	Vib_7	4	15.092759	76.570946	RCC	0.0952	0.0794	0.0714	53.89	24.98	60.24
34	Vib_7	6	15.092763	76.57094	RCC	0.0794	0.0714	0.0635	53.89	1024	60.24
35	Vib_7	8	15.092778	76.570915	RCC	0.0714	0.0556	0.0556	31.03	48.76	341.33
36	Vib_8	0	15.09972	76.578131	RCC	0.0197	0.015	0.0081	178.09	132.13	65.02
37	Vib_8	2	15.099721	76.578113	RCC	0.0072	0.0063	0.0053	117.03	110.7	91.02
38	Vib_8	4	15.099718	76.578094	RCC	0.0053	0.0044	0.0041	74.47	195.05	110.7
39	Vib_8	6	15.099719	76.578076	RCC	0.0038	0.0038	0.0038	819.2	819.2	819.2
40	Vib_8	8	15.099714	76.578057	RCC	0.0038	0.0034	0.0034	819.2	1365.33	1365.33
41	Vib_9	0	15.106826	76.587363	RCC	0.0241	0.025	0.0097	178.09	163.84	178.09
42	Vib_9	2	15.106844	76.587365	RCC	0.0084	0.0113	0.0059	110.7	141.24	99.9
43	Vib_9	4	15.106862	76.58737	RCC	0.0091	0.0059	0.0041	163.84	105.03	178.09
44	Vib_9	6	15.106879	76.587378	RCC	0.0069	0.0063	0.0041	178.09	141.24	195.05
45	Vib_9	8	15.106895	76.587386	RCC	0.0056	0.0041	0.0041	195.05	178.09	819.2
46	Vib_10	0	15.110673	76.593285	RCC	0.0384	0.0281	0.015	14.27	31.75	117.03
47	Vib_10	2	15.110663	76.593301	RCC	0.0116	0.0091	0.0075	99.9	95.26	105.03
48	Vib_10	4	15.110655	76.593315	RCC	0.0059	0.0081	0.0056	44.04	91.02	80.31
49	Vib_10	6	15.110645	76.593336	RCC	0.0053	0.0056	0.0047	87.15	141.24	315.08
50	Vib_10	8	15.110636	76.59335	RCC	0.0069	0.0084	0.0053	53.19	87.15	56.11

51	Vib_11	0	15.112195	76.602374	RCC	0.0194	0.0106	0.0075	91.02	26.43	49.35
52	Vib_11	2	15.112177	76.60238	RCC	0.0072	0.0078	0.0056	141.24	110.7	91.02
53	Vib_11	4	15.112162	76.602385	RCC	0.0047	0.0044	0.0041	67.15	819.2	315.08
54	Vib_11	6	15.112143	76.602392	RCC	0.0038	0.0038	0.0034	819.2	178.09	195.05
55	Vib_11	8	15.112126	76.602396	RCC	0.0034	0.0034	0.0034	819.2	819.2	1365.33
56	Vib_12	0	15.119658	76.60558	RCC	0.1032	0.0952	0.127	819	819.2	24.82
57	Vib_12	2	15.119677	76.605572	RCC	0.1111	0.1032	0.1032	215.58	1365.33	819.2
58	Vib_12	4	15.119689	76.605558	RCC	0.0952	0.1032	0.0952	215.58	1365.33	819.2
59	Vib_12	6	15.119685	76.605528	RCC	0.1984	0.1429	0.1508	77.28	91.02	74.47
60	Vib_12	8	15.119601	76.605535	RCC	0.1032	0.1032	0.0952	1365.33	819.2	819.2
61	Vib_13	0	15.124426	76.611031	RCC+STEEL	0.3254	0.2064	0.2222	8.52	18.2	21.67
62	Vib_13	2	15.124419	76.61105	RCC+STEEL	0.1667	0.1508	0.1429	83.59	21.9	132.13
63	Vib_13	4	15.12441	76.611066	RCC+STEEL	0.1429	0.1111	0.1032	12.68	141.24	819.2
64	Vib_13	6	15.124399	76.611079	RCC+STEEL	0.1349	0.1111	0.0873	13.17	819.2	195.05
65	Vib_13	8	15.124396	76.611098	RCC+STEEL	0.1429	0.1032	0.0952	14.08	819.2	819.2
66	Vib_14	0	15.131914	76.616384	RCC+STEEL	0.3016	0.4366	0.1826	25.76	18.2	67.15
67	Vib_14	2	15.131906	76.616401	RCC+STEEL	0.2222	0.1746	0.1667	51.85	29.05	47.08
68	Vib_14	4	15.131893	76.616415	RCC+STEEL	0.1191	0.1111	0.1032	59.36	178.09	819.2
69	Vib_14	6	15.131878	76.616426	RCC+STEEL	0.1111	0.1349	0.0873	132.13	117.03	151.7
70	Vib_14	8	15.131863	76.616439	RCC+STEEL	0.1111	0.0952	0.0952	819.2	105.03	819.2
71	Vib_15	0	15.139081	76.621862	RCC+STEEL	0.6271	0.5318	0.0873	18.88	87.15	819.2
72	Vib_15	2	15.139068	76.621876	RCC+STEEL	0.3016	0.2619	0.1984	41.27	65.02	49.35
73	Vib_15	4	15.139055	76.621889	RCC+STEEL	0.2222	0.1349	0.1111	95.26	105.03	195.05
74	Vib_15	6	15.139043	76.621902	RCC+STEEL	0.1984	0.2222	0.1349	151.7	117.03	151.7
75	Vib_15	8	15.139031	76.621916	RCC+STEEL	0.1191	0.1032	0.0952	141.24	124.12	1365.33
76	Vib_16	0			RCC+STEEL						
77	Vib_16	2	15.149416	76.62925	RCC+STEEL	0.0069	0.0063	0.0041	87.15	33.3	141.41

78	Vib_16	4	15.149417	76.62925	RCC+STEEL	0.0069	0.0053	0.0041	61.13	110.7	195.05
79	Vib_16	6	15.149444	76.62921	RCC+STEEL	0.0106	0.01	0.0069	132.13	99.9	178.09
80	Vib_16	8	15.149459	76.62926	RCC+STEEL	0.0041	0.0038	0.0034	1365.33	1365.33	819.2
81	Vib_17	0			RCC						
82	Vib_17	2	15.154156	76.632576	RCC	0.0063	0.0097	0.0063	74.47	39.77	36.9
83	Vib_17	4	15.154157	76.63234	RCC	0.0038	0.0113	0.005	1365.33	44.04	56.11
84	Vib_17	6	15.154253	76.632484	RCC	0.0041	0.0041	0.0038	195.05	819.2	819.2
85	Vib_17	8	15.154241	76.63247	RCC	0.0038	0.0038	0.0038	819.2	819.2	1365.33
86	Vib_18	0	15.158487	76.639058	RCC+STEEL	0.1429	0.127	0.1508	146.29	113.78	146.29
87	Vib_18	2	15.15847	76.639055	RCC+STEEL	0.0873	0.0714	0.0635	78.77	40.96	48.76
88	Vib_18	4	15.158453	76.639049	RCC+STEEL	0.1429	0.0794	0.0635	113.78	48.76	60.24
89	Vib_18	6	15.158436	76.639043	RCC+STEEL	0.0635	0.0635	0.0635	146.29	44.52	71.79
90	Vib_18	8	15.158418	76.63904	RCC+STEEL	0.0635	0.0556	0.0476	60.74	68.27	14.42
91	Vib_19	0	15.158048	76.648049	RCC	0.0256	0.0184	0.0106	91.02	19.6	132.13
92	Vib_19	2	15.15803	76.648057	RCC	0.0134	0.0109	0.0078	83.59	40.55	74.47
93	Vib_19	4	15.158014	76.648064	RCC	0.0078	0.0066	0.0053	56.11	110.7	141.24
94	Vib_19	6	15.157998	76.648073	RCC	0.0113	0.0044	0.0047	105.03	124.12	141.24
95	Vib_19	8	15.157981	76.64808	RCC	0.0128	0.0078	0.0078	132.13	163.84	141.24
96	Vib_20	0	15.16059	76.657138	RCC	0.0231	0.0119	0.0091	77.28	74.47	74.47
97	Vib_20	2	15.160572	76.657142	RCC	0.005	0.0053	0.0044	819.2	110.7	315.08
98	Vib_20	4	15.160554	76.657147	RCC	0.0038	0.0044	0.0038	57.69	195.05	819.2
99	Vib_20	6	15.160537	76.657156	RCC	0.0038	0.0034	0.0038	819.2	151.7	819.2
100	Vib_20	8	15.160521	76.657162	RCC	0.0056	0.0044	0.0034	110.7	195.05	819.2
101	Vib_21	0	15.164594	76.665021	STEEL	0.0166	0.0266	0.0131	132.13	110.7	151.7
102	Vib_21	2	15.164612	76.665014	STEEL	0.0116	0.0081	0.005	151.7	110.7	132.13
103	Vib_21	4	15.164629	76.665008	STEEL	0.0047	0.0047	0.0041	110.7	141.24	1365.33
104	Vib_21	6	15.164645	76.665002	STEEL	0.0047	0.005	0.0188	819.2	315.08	273.07

105	Vib_21	8	15.164662	76.664995	STEEL	0.0194	0.0169	0.0794	215.58	215.58	195.05
106	Vib_22	0	15.165352	76.673849	STEEL	0.0203	0.0231	0.0194	110.7	178.09	178.09
107	Vib_22	2	15.16537	76.673849	STEEL	0.0106	0.0066	0.005	215.58	178.09	819.2
108	Vib_22	4	15.165389	76.673849	STEEL	0.0056	0.0047	0.0044	80.31	585.14	1365.33
109	Vib_22	6	15.165406	76.673849	STEEL	0.0066	0.0044	0.0038	195.05	819.2	819.2
110	Vib_22	8	15.165424	76.673849	STEEL	0.0044	0.0038	0.0038	819.2	87.15	819.2
111	Vib_23	0	15.169046	76.681817	STEEL	0.9366	1.5875	0.5874	204.8	204.8	204.8
112	Vib_23	2	15.169038	76.681833	STEEL	0.3834	0.4048	0.1387	204.8	204.8	53.89
113	Vib_23	4	15.169032	76.681848	STEEL	0.1349	0.1876	0.0873	93.09	93.09	46.52
114	Vib_23	6	15.169024	76.681867	STEEL	0.1508	0.1508	0.1191	204.8	146.79	53.89
115	Vib_23	8	15.169018	76.681882	STEEL	0.2937	0.4763	0.1587	113.78	113.78	146.29

Discussions and suggestions

It is known that anthropogenic impacts, such as Vibrations, noise, light pollution have led to changes in the behaviour of the animal or they may be adopted to the changes (Philip and Rogerd 1979) many of the species may altered their activities like Detection of prey, mate attraction, and since communication is crucial to the survival and reproduction, of many species like anurans, arthropods which are acoustically communicating species. These species are the most affected due to the vibrations impact on the behavioural cycle (Caorsi et al, 2019) so the vibration may cause impact on the calling activity of these amphibians and affect the prey detections in the spiders (Chawng and Damain, 2013) In their natural habitat, our findings highlight the need to consider the vibratory sensory channel in assessing anthropogenic impacts on wildlife.

Luminescence

Introduction

Illumination is the amount of light incident per unit area. Ecological light pollution includes chronic or periodically increased illumination, unexpected changes in illumination, and direct glare which can experience increased orientation or disorientation of animals from additional illumination and are attracted to or repulsed by glare, which affects foraging, reproduction, communication, migration, and other critical behaviour. Artificial light disrupts interspecific interactions evolved in natural patterns of light and dark, with serious implications for community ecology (Longcore and Rich, 2004). The primary aims of luminescence map were (i) to determine and map luminescence along MPC in three different transfer points, (ii) to predict illumination attenuation with distance.

Materials and Methods

1. **Instrument and measurements**: Lux Light meter Android application was used to record the Luminescence. Light measurements were done in three different locations via; Bannihatti Transfer point, Jaffer Sheriff Mines and Devdari Down Hill Pipe Conveyor along Main Pipe Conveyor Belt during the operation time from 6PM to 2AM. Maximum Lux values were noted along with Longitude, Latitude and predominant land use of the place of recording.
2. QGIS 3.16.1 with plugin *contour* is used for mapping and creating Luminescence scape. PAST® and MS Excel are used for regression analysis.

Result

Luminescence Measurements: A total of 20 measurements were taken in a fixed interval of 0M, 50M in eight directions from the center point of light emission in which 9 measurements (Devdari down Hill Pipe Conveyor), 10 measurements (Bannihatti Transfer point) and 11 measurements (Jaffer Sheriff Mines).

Luminescence Map: Luminescence map is illustrated in Figure 2.43. The standard contour intervals used were Luminescence with a minimum value of 0 to a maximum value of 144 (Figure 2 and 3). It is evident from the Luminescence map that Luminescence levels are higher near the light source (129.6-144) and lower in the areas away from MPC.

Luminescence attenuation: Radial distance from Light sources along MPC to observed luminescence were measured and plotted to understand the noise attenuation. It is well known that luminescence levels decrease with distance, in a linear manner. In the present study too, it was evident that Luminescence levels decrease with distance. The overall data points plotted against distance showed a statistically significant negative relationship with distance (Linear regression y = -1.3837x + 134.22, R^2 = 0.6962). Table 2.9 and Figure 2.44 (A-I) details the regression equations calculated for varied land-uses in the study area.

Table 2.10. Luminescence attenuation of three transfer points.

Sampling Points	Points	Regression Equation	R2	Distance Range (m)	Luminescence Range (Lux)
Total (Linear)	20	y = -1.3837x + 134.22	0.6962	0-100	0-173
Bannihatti Transfer point (Linear)	10	y = -1.6055x + 160.1	0.66	0-100	0-173
Devdari down Hill Pipe Conveyor (Linear)	9	y = -1.1494x + 101.91	0.7527	0-100	0-141
Jaffer Sheriff Mines (Linear)	11	y = -1.3552x + 134.7	0.8506	0-100	0-144

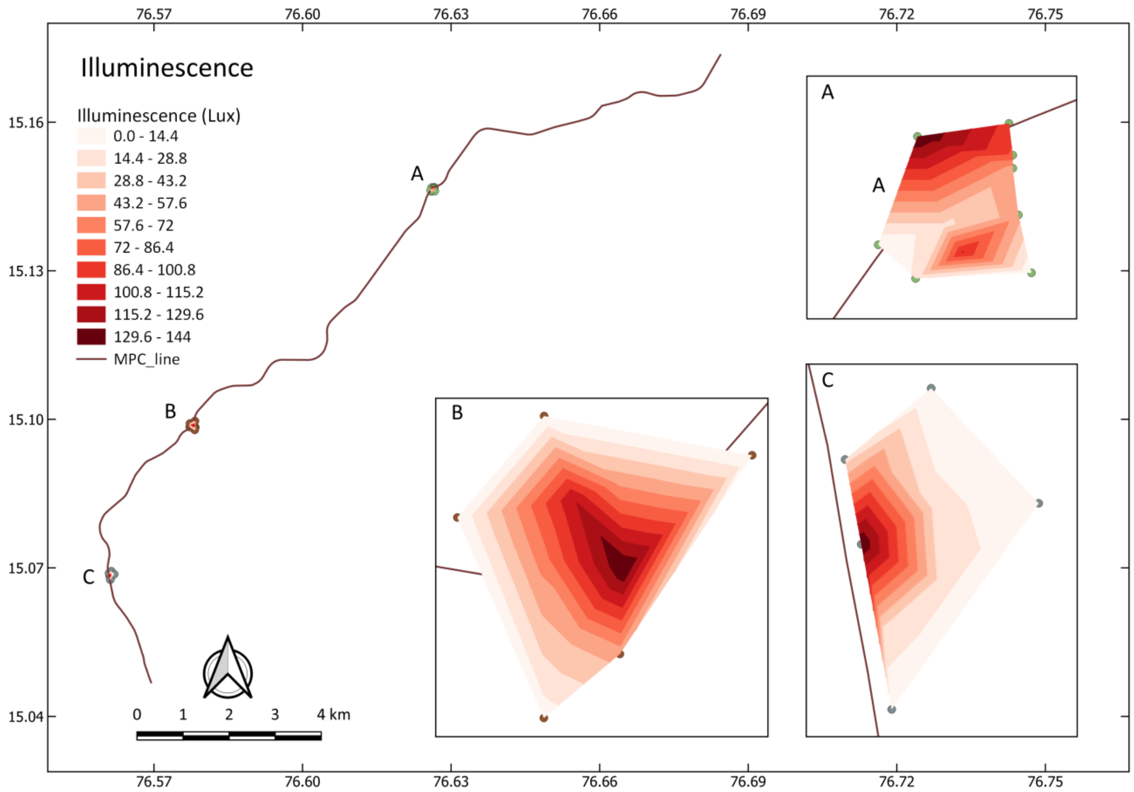


Figure 2.43. Luminescence mapping and contour along MPC. A. Bannihatti Transfer Point, B. Jaffer Sheriff Mines, and C. Devdari Down Hill Pipe Conveyor.

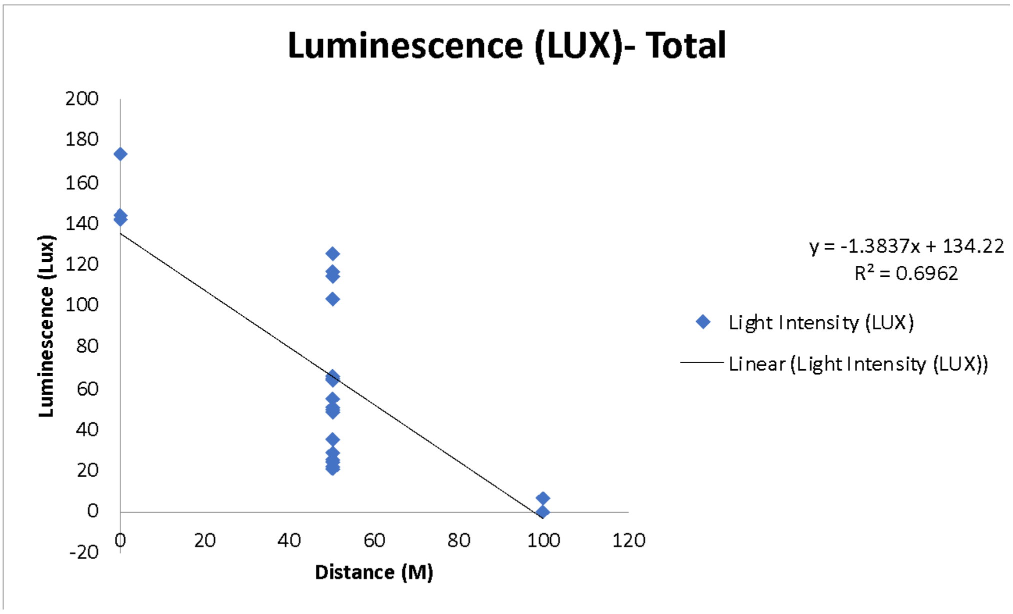


Figure 2.44A: Regression analysis of the luminescence data (Total).

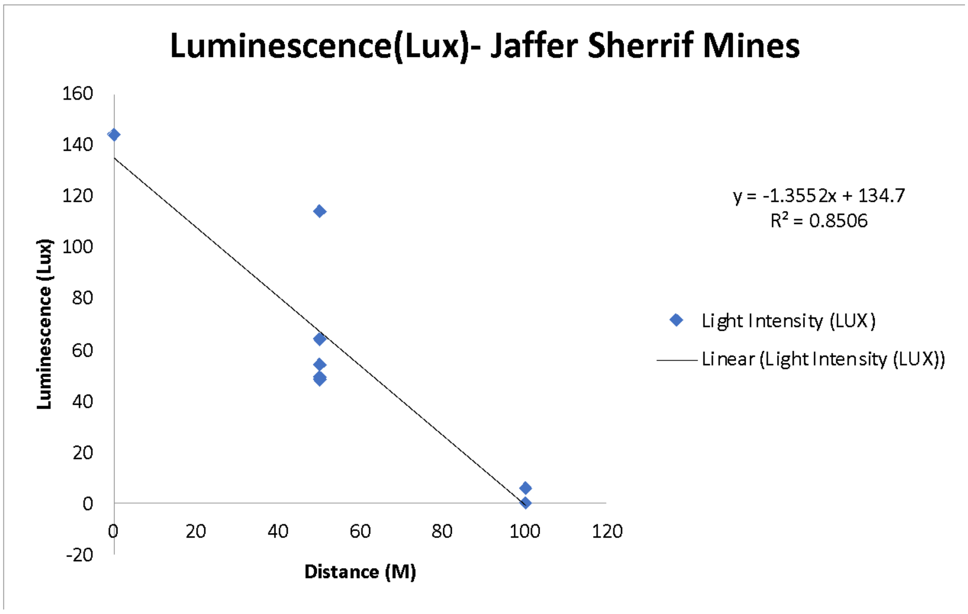


Figure 2.44B. Regression analysis of the luminescence data (Jaffer Sherri Mines).

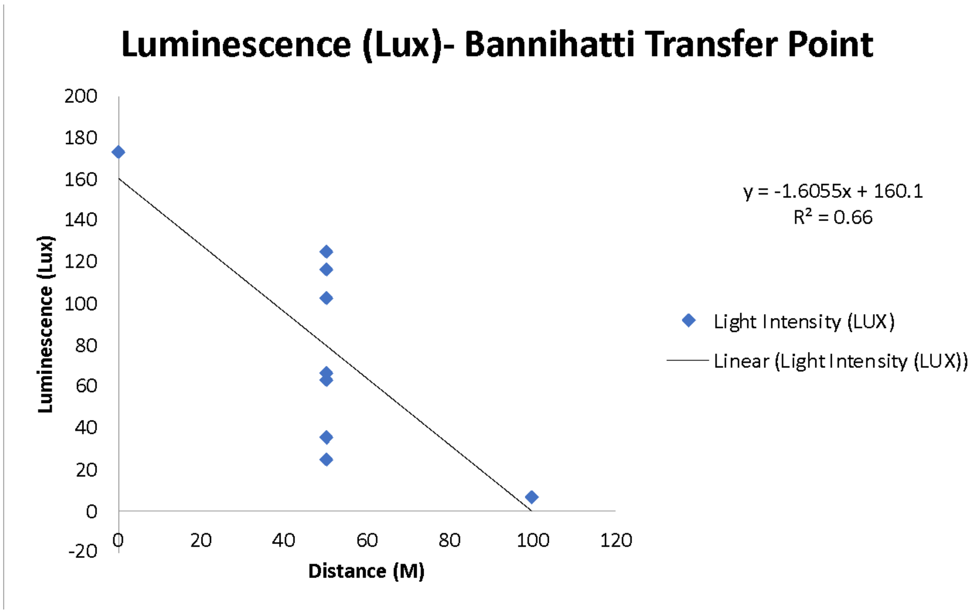


Figure 2.44C. Regression analysis of the luminescence data (Bannihatti TRnsfer Point).

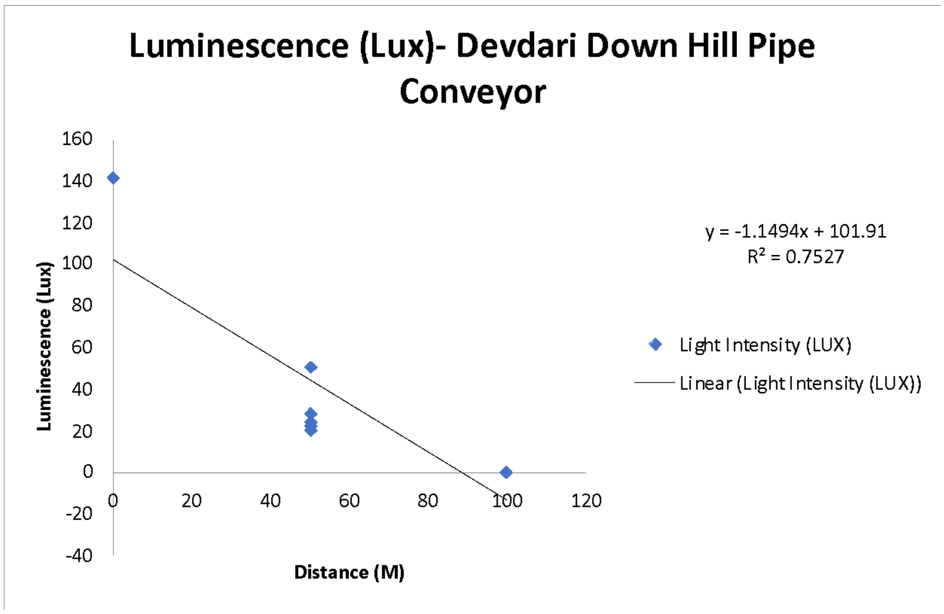


Figure 2.44D. Regression analysis of the luminescence data (Devdari down Hill Pipe Conveyor).

Discussion and Suggestions

The present study was focused on Mapping the Luminescence at three major transfer points (Bannihatti Transfer point, Devdari down Hill Pipe Conveyor and Jaffer Sheriff Mines) Along MPC (Main Pipe Conveyor Belt). This map visually represents how the light intensity is decreasing when moving away from the source.

It is known that anthropogenic impacts, such as light pollution have led to changes in the cycles of light and dark in the environment. This artificial light alters the spatial, temporal and spectral characteristics of the photic environment, creates a patchy light environment in illuminated areas, contributing to sky glow, resulting in illumination after sunset and creating spectra different from natural light. The responses to these stressors exist from the level of the individual to that of the entire ecosystem and include physiological and behavioural responses in individuals, altered patterns of predation and competition, restructuring of food webs and changes in natural nutrient cycling patterns (Megha Khanduri and Amita Saxena; 2020).

Limitations: The data collected for the present study was not robust enough to gauge the impact of the effect of luminescence on the ecology and ethology of wildlife. Hence the study needs to be reinvestigated in order to effectively measure the impact of luminescence on wildlife

Chapter III: Present Land Use Land Cover in the Main Conveyer Belt

CHAPTER III

PRESENT LAND USE LAND COVER IN THE MAIN CONVEYER BELT

Introduction

Land use/ land cover (LU/LC) analysis plays an important role in understanding the changes between human activities and nature. Land cover refers to how the earth surface is covered by different land patterns like agriculture, forest, water, wastelands and others. Land use refers to how humans use the land for developmental activities, built-ups, management and others. Due to the increase in the population, human activities on the earth surface are also increasing. And this would result in unexpected and abandoned changes in LU/LC such as landslides, and floods. Remote sensing and Geographic Information Systems (GIS) are powerful tools to derive exact and appropriate data on the spatial distribution of land use/land cover changes over large areas.

Land use and land cover change have become a central component in current strategies for managing natural resources and monitoring environmental changes and overcoming the problems of disorganized and uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, and destruction of important wetlands. Analysis of land use land cover change provides an estimation of the spread and health of the forest, grassland, and agricultural resources and is helpful in guiding future developments of policies. Land use data are needed in the analysis of environmental processes to understand the current conditions at different levels.

In the present study, remote sensing and GIS tools are used to analyse the LU/LC changes for the years 2012 and 2021. It is essential to understand the extent and trend of these changes both spatially and temporally to know about the changes in the regional environment. Different land-use types reflect different ecological sensitivity. Based on the landscape ecology, human activities tend to make the outline of a landscape patch. Since the study area includes mining and industrial area, it is facing environmental pressure and most of the regions are affected by mining activities. The mining activities impact the ecology and environment of the ecosystem.

This chapter deals with the study of LU/LC change analysis for the years 2012 and 2021. Satellite imageries from National Remote Sensing Application Centre (NRSC) were procured for the years 2012 and 2021, and interpretation for the imageries are done to analyse the change detection. Arc GIS software was used for the interpretation and ERDAS Imagine software was used for image processing.

Study Area

The study area extends from longitudes 76°20' E - 76°55' E and latitude 15°00 N - 15°15'0" N in Sandur taluk of Ballari district, Karnataka state. The Study area consists of 10 km and 2 km buffer zone on either side of the Main Pipe Conveyer Belt (MPC). The area of the 10 km buffer zone is 74002.71 hectares.

Different information layers were extracted from the 2011 District Census published handbook with taluk-village maps shows that the 10 km buffer zone encompasses parts of 75 villages (village boundaries) intersecting the buffer zone frontier. It is to be noted that some villages fall completely inside the buffer boundary and some village boundaries are having only a negligible area inside the buffer zone margin. Further, some of the intersecting village boundaries have settlements within the buffer zone and other village boundaries have settlements away from the buffer zone. The study area map of MPC with 2 km and 10 km buffer is created (Figure 3.1).

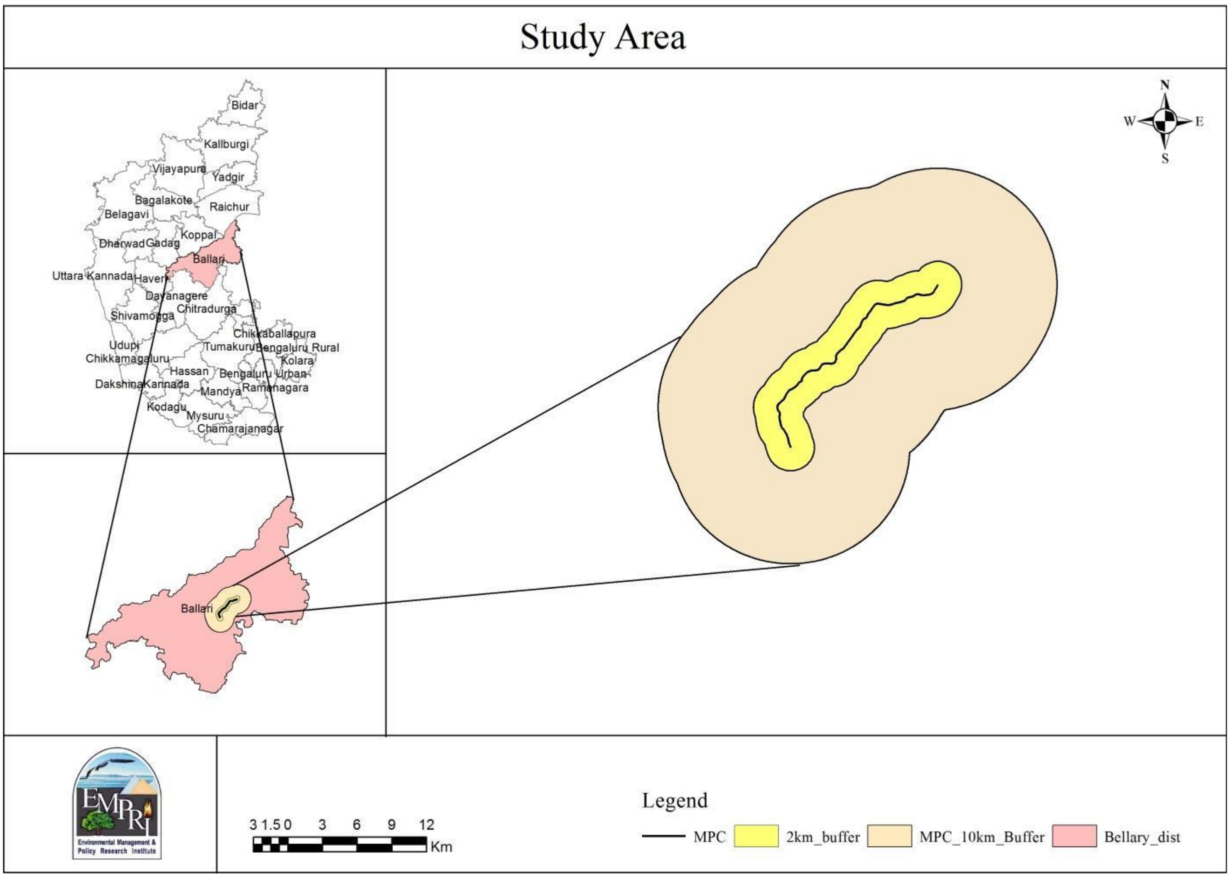


Figure 3.1. The main pipe conveyer belt and its buffer area are considered for assessing the land use and land cover

Datasets

Land Use/Land Cover (LU/LC) change detection studies are basically carried out by applying various remote sensing techniques using different spatial-temporal imageries. To execute the tasks of image classification and processing there are various Digital Interpretation (DIP) Techniques. In the current study, the Visual Interpretation technique was used to obtain the LU/LC patterns of the study area. In addition to the basic satellite imagery, other reference base data is necessary to achieve the objectives of image interpretation. This chapter provides the insight into the various data products used in this project.

Data products

For a comprehensive study of change detection in the Land use/Land cover, the following data sources were used,

1. Toposheets
2. Satellite imageries
3. Google earth reference
4. GPS based data from Ground truth verification

Toposheets

The Survey of India Toposheets has been taken as base maps for referring details of settlements, available administrative boundaries, reservoir FRL limits and others. There are 6 toposheets of 1:50,000 scale for the study area (Fig. 3.2). The toposheets also aid in geo-referencing the satellite imagery, identification of existing features such as forests, scrub regions, sheetrock areas and so on. The toposheets used in the study includes D43K05, D43E08, D43K09, D43E11, D43E12 and D43E16, and a toposheet grid map with 10 km and 2 km buffer is shown in Figure. 3.2.

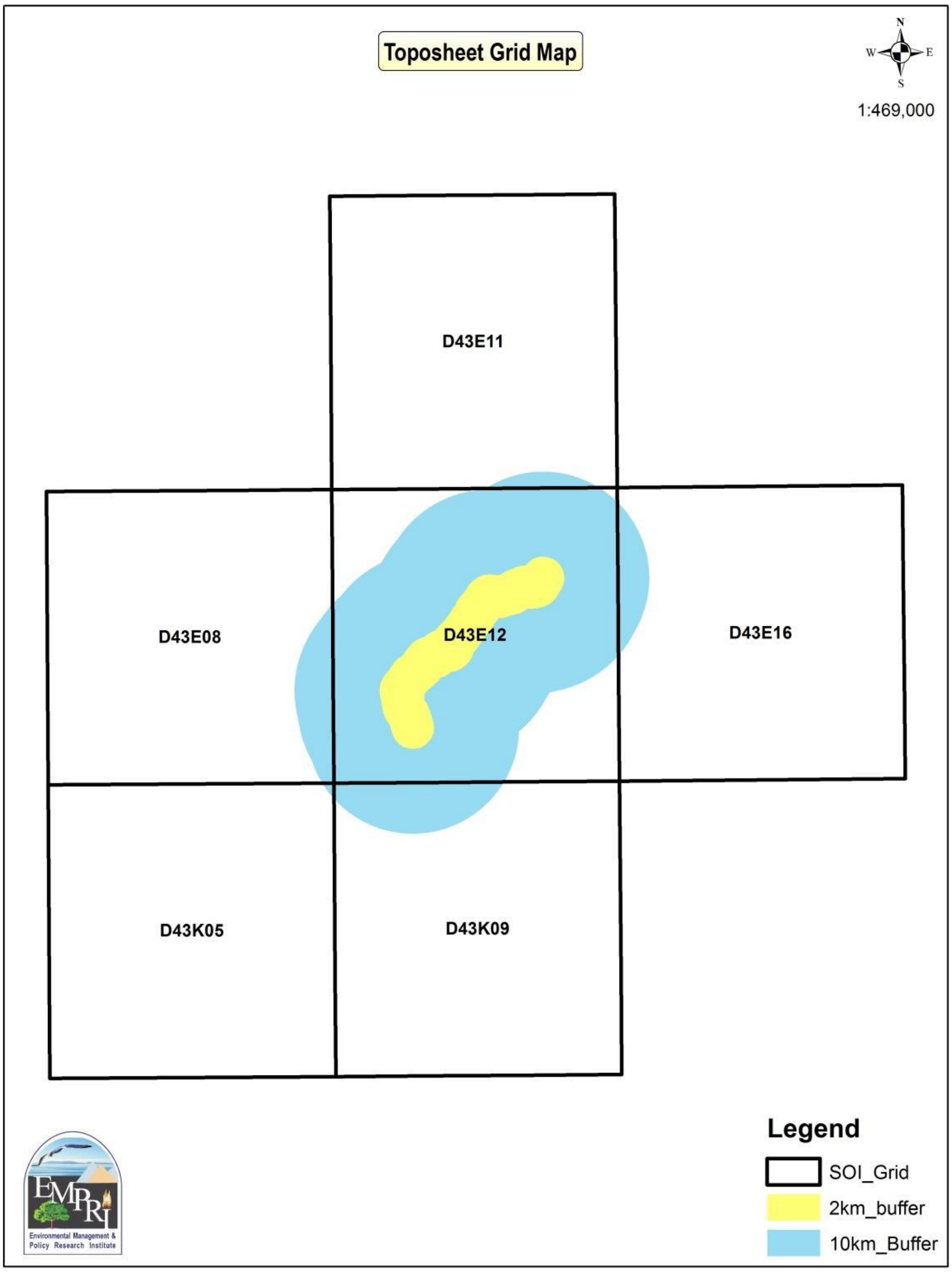


Figure 3.2. Toposheet Grid map

Satellite imagery

The Satellite imagery is the main data source that helps to delineate the LU/LC classification for the desired scale depending upon the resolution of the imagery. For the current study satellite imageries of the years, 2012 and 2021 have been used to detect the decadal changes in LU/LC features in the study area.

For the image classification, it is desired to have cloud-free imageries for clear visual interpretations. The cloud-free satellite imagery of the year is usually available during the winter season (December-March). Therefore, the satellite imageries during the winter season of the year 2012 and 2021 have been procured from the NRSC data centre for this study. There are in all 3 scenes of imagery for this study as shown (refer to Map no.3.3,3.4, 3.5 and 3.6).

LISS IV imagery from Resource Sat – 2 satellite of winter season is used. Image pre-processing operations such as layer stacking, geo-referencing, ortho-rectification, resolution merge have been done on the imageries to achieve high-resolution accuracy of 5.0 m.

Spectral resolution: Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength ranges for a particular channel or band. Hence, the features of different classes having different reflectance values in a channel or band are more clearly identified.

The sensors used in the current study have the below-described wavelength intervals in respective bands (Table 3.1).

Table 3.1. Details of spectral Bands of Satellite imagery considered for the study area.

Sensor	LISS IV
Band 1	0.52 – 0.59 µm
Band 2	0.62 – 0.68 µm
Band 3	0.76 – 0.86 µm

Spatial resolution: Spatial resolution describes the ability of a sensor to identify the smallest size detail of a pattern on an image (Table 3.2).

Table 3.2. Details of spatial resolution of Satellite imagery considered for the study area.

Sensor	Spatial resolution
LISS IV	5.8m

Swath: A swath is the area of the ground the satellite sees with each orbit, the wider the swath the greater the ground coverage. The swath of the LISS IV imagery is 23 – 70 km.

Path – Row: The path and row of each scene for the imagery used in this project is given in Table 3.3.

Table 3.3. Details pertaining to path and row of Satellite imagery considered for the study area.

Sl. No.	LISS IV
1.	98_62_d
2.	99_62_c
3.	99_63_a

Resampling: The level of detail (of features/phenomena) represented by a satellite image is often dependent on the cell (pixel) size, or spatial resolution, of the raster. The imagery products of LISS IV obtained from NRSC for the current project has a pixel resolution of 5.0 meters.

The scale of LULC dataset: The scale of the data prepared is given by the formula

$$0.25\ mm \times scale = resolution\ of\ imagery$$

$$\therefore Scale = \frac{resolution\ of\ imagery}{0.25\ mm}$$

$$Scale = \frac{5.0\ m}{0.25\ mm} = 20{,}000$$

Thus, the scale of the LU/LC classes obtained would be on a scale of 1:20,000.

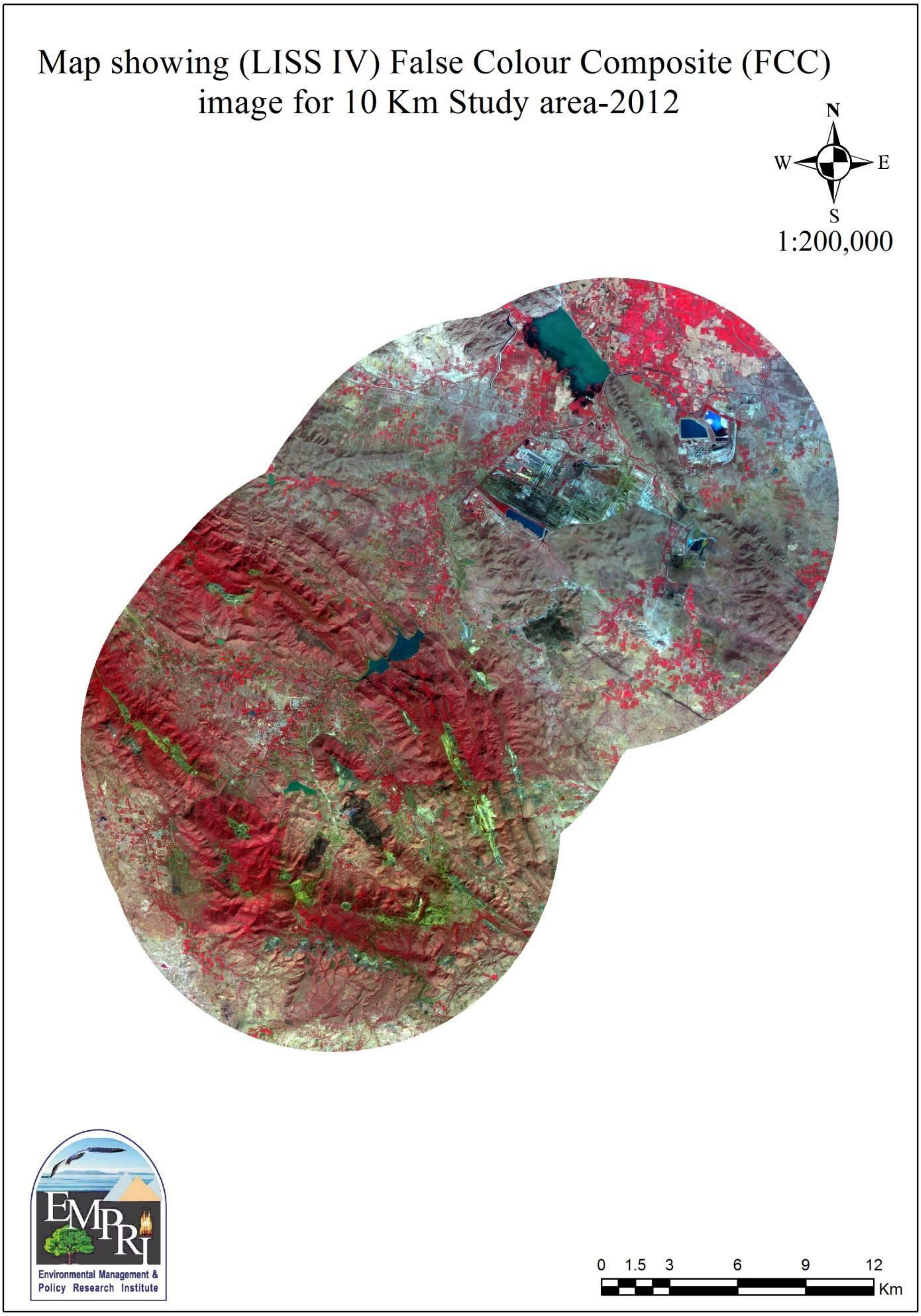


Figure 3.3. Satellite imagery map-2012 for 10 Km Buffer

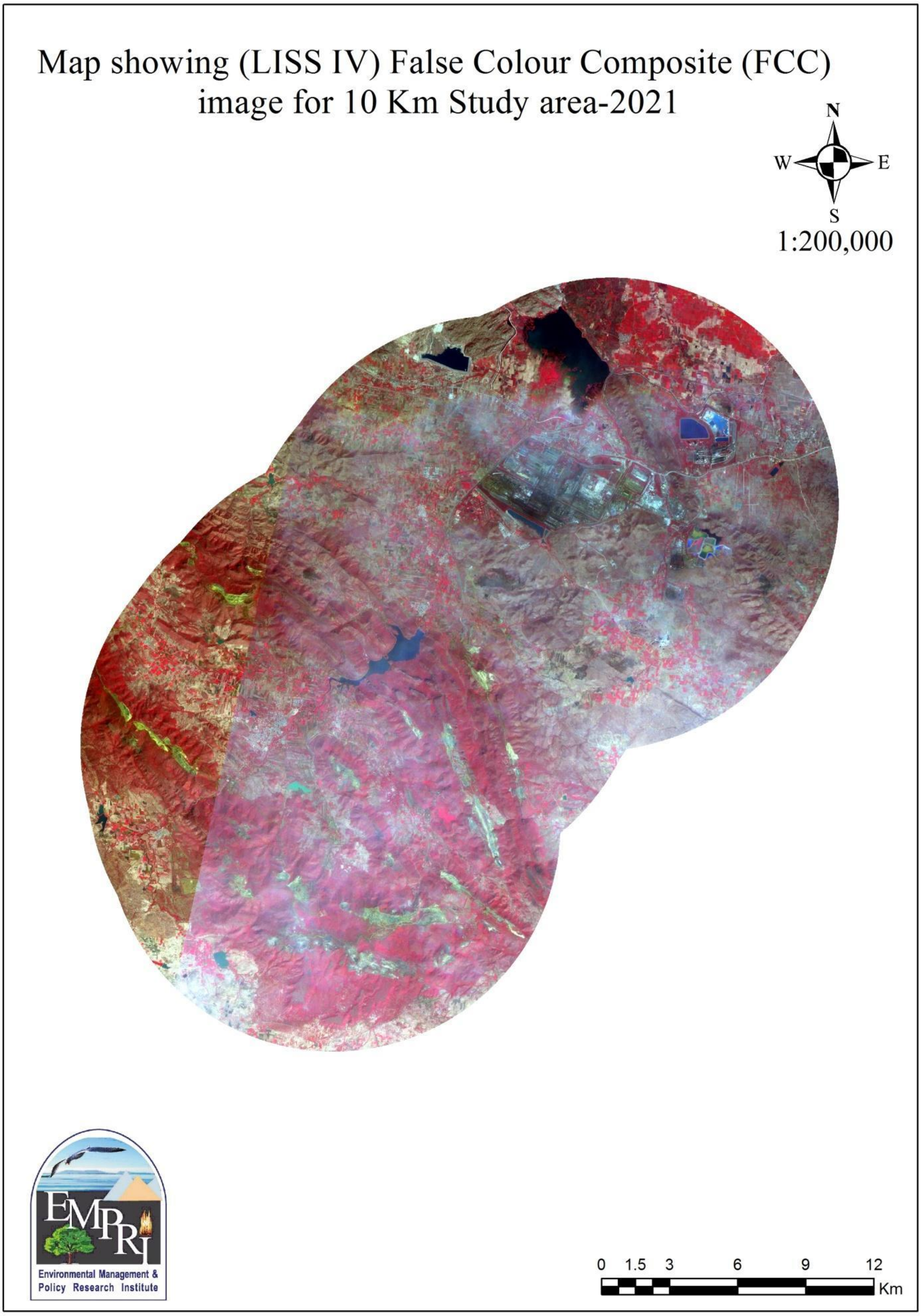


Figure 3.4. Satellite imagery map-2021 for 10 Km Buffer

Figure 3.5. Satellite imagery map-2012 for 2 Km Buffer

Figure 3.6. Satellite imagery map-2021 for 2 Km Buffer

Google Earth

Google Earth is a geographical information program that contains a virtual globe as well as maps of the entire globe. The maps are the resultant of the superimposition of satellite imagery, aerial photography and Geographical information system onto a 3D platform.

The satellite images displayed here are of different resolutions and can be zoomed to a finer level. The resolution varies from place to place with resolution ranging from 60 cm, 2.5 m, 15 m and so on based on the satellite sensor. Google Earth has the option to search addresses, places or even enter coordinates to check location. Google Earth maps can be used to visualize and verify the location details with respect to the surrounding environment. Google Earth can be used as base maps in the case of satellite image classification and also can be used for verifying sample image classification data. It has the option to view historical imagery acquired at different dates or years which can be used for change detection purposes.

GPS based data from Ground truth verification

Ground truth/field verification is an important component in mapping and its validation exercise. Utmost care and planning are taken while collecting ground data and its verification. To facilitate a good ground truth the following steps were followed

1. Identification and listing of all the doubtful areas for ground verification and all such areas with respect to toposheet were referred to know their geographical location and accessibility on the ground.
2. A field traverse plan was prepared to cover maximum doubtful areas in the field. It is also ensured that each traverse covers as many Land Use / Land Cover classes as possible, apart from the doubtful areas.
3. The number of points to be covered for each category is pre-determined before field visits. These observations are required both for quality checking as well as accuracy estimation, in addition, to use in interpretation.

The field verification for the doubtful areas was carried out using GPS instrument and the observations were reported and incorporated while preparing the LU/LC classification.

Methods

LU/LC is one of the basic information required for assessing the status of any region. The inventories of various LULC patterns which were existing before and are existing presently will aid in the assertion of changes which has occurred over time. This is the primary step for identifying, planning and management of the areas to be protected as eco-sensitive zones. In order to create LU/LC layer in GIS compatible manner and to provide an organized structure for future spatial analysis LU/LC layer data model is prepared. While creating the LU/LC database from Visual Interpretation Techniques. Further, Overlay analysis is carried out which helps in visualizing in-depth decadal changes that occurred in Land-Use patterns. The process flow followed for the LU/LC change detection is plotted in Figure 3.7.

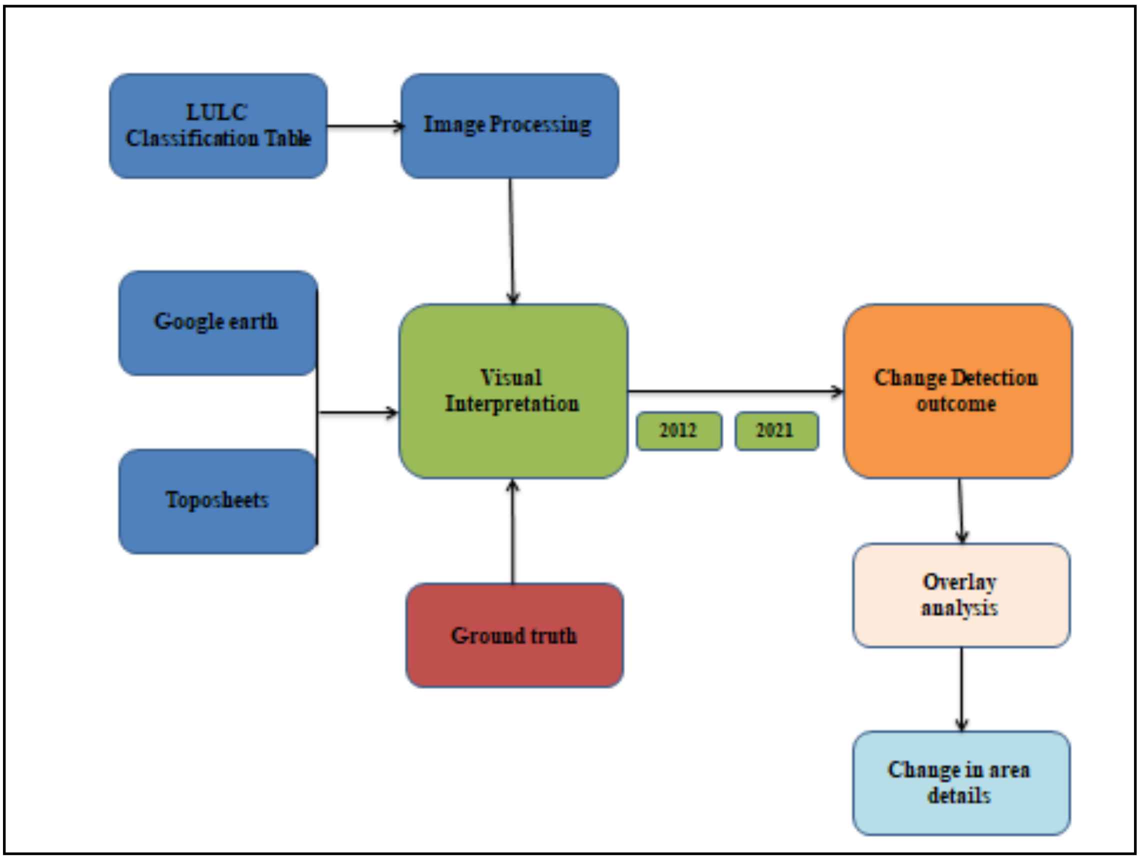


Figure 3.7. Flowchart for outline process steps followed in LU/LC change detection

Land-Use/ Land-Cover (LU/LC) layer data model

The geometrically corrected Resource Sat- 2 LISS IV and within the desired framework is the primary input for LU/LC classification and mapping. Survey of India topographic map layer on 1:50K scale is used as a base layer. A good amount of collateral data on themes like a wasteland, forest, and vegetation is used as an important source of reference for LU/LC classification (Table 3.4). These legacy layers are re-projected as per the current mapping specifications before using them. The projection system followed in this study is Projected Coordinate System: WGS 1984_UTM 43N.

To match the LU/LC classification and mapping on a best possible scale using the LISS IV, the following LU/LC layer data model table was derived from SIS- DP manual (NRSC, 2009) published by NRSC (ISRO). These LU/LC classes were followed in preparing the LULC dataset for the present project.

Based on the above-described inputs and the reference data visual interpretation is carried out on 2012, and 2021 imageries. From 2012 and 2021 LU/LC classification change detection analysis is carried out for quantifying the difference that has occurred over the period of 9 years. Apart from change detection analysis, overlay analysis is carried out, which is performed using the tools to overlay multiple feature classes to combine, erase, modify or update spatial features, resulting in a new feature class. Finally, the changes are tabulated and maps are generated.

Table 3.4. Land use/Land cover classification table for the project study area

Sl. No.	Level - I	Level - II	Level - III
1	Built-Up	Built-Up (Urban)	Built-Up (Urban)
		Built-Up (Rural)	Built-Up (Rural)
		Industrial/Mining	Industrial/Mining
		Transportation	Transportation
2	Agricultural Land	Cropland	Cropland
		Agriculture plantation	Agriculture plantation
3	Forest	Forest	Forest
4	Wastelands	Scrubland	Scrubland Dense
			Scrubland Open
		Sandy areas	Sandy areas
		Barren rocky	Barren rocky
		Waterlogged	Waterlogged
5	Water bodies	River / Stream / Drain	River / Stream / Drain
		Canal	Canal
		Lakes / Ponds	Lakes / Ponds
		Reservoir / Tanks	Reservoir / Tanks

Source: Contemplated table for (IRS 1D –PAN + LISS-III /LISS IV Mx) from SIS-DP manual, Preparation of Geo-Spatial Layers using High Resolution (Cartosat – 1 Pan + LISS- IV Mx) Orthorectified Satellite Imagery, NRSC(ISRO), DoS, GoI. Dec 2009

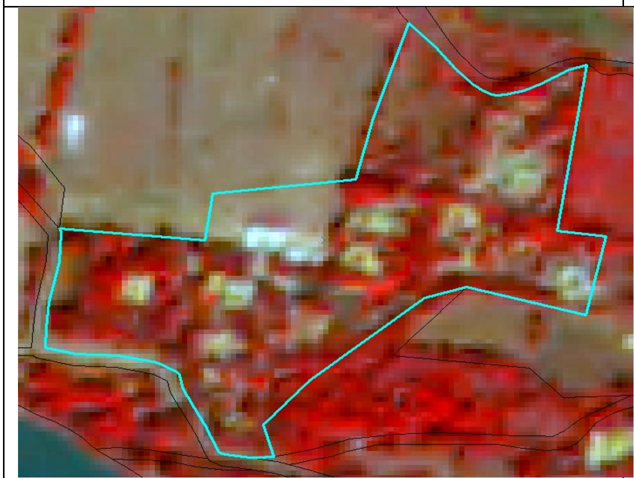
Visual Interpretation technique

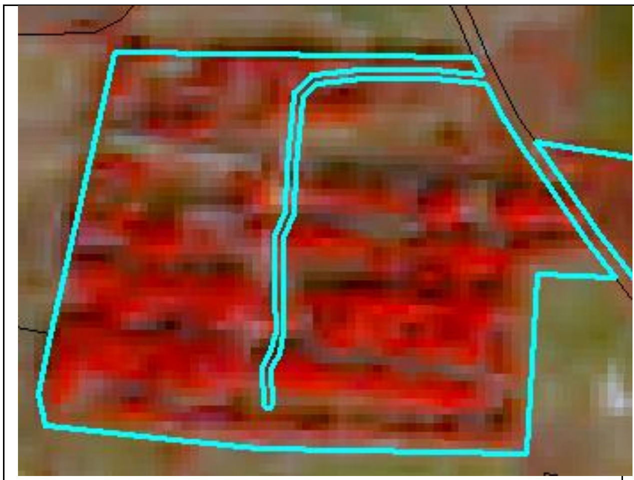
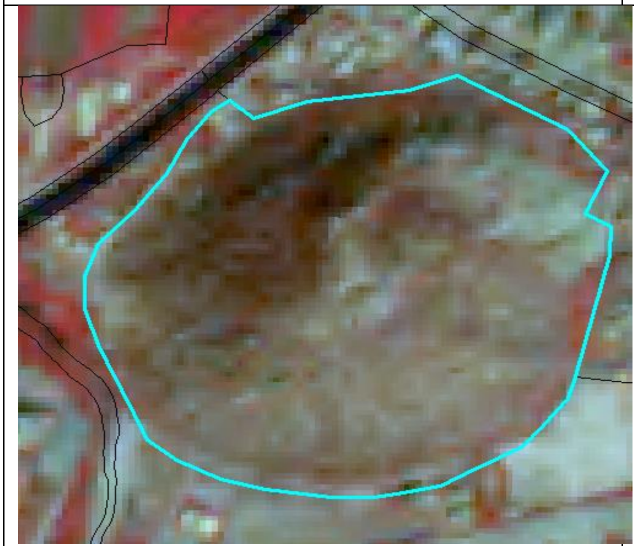
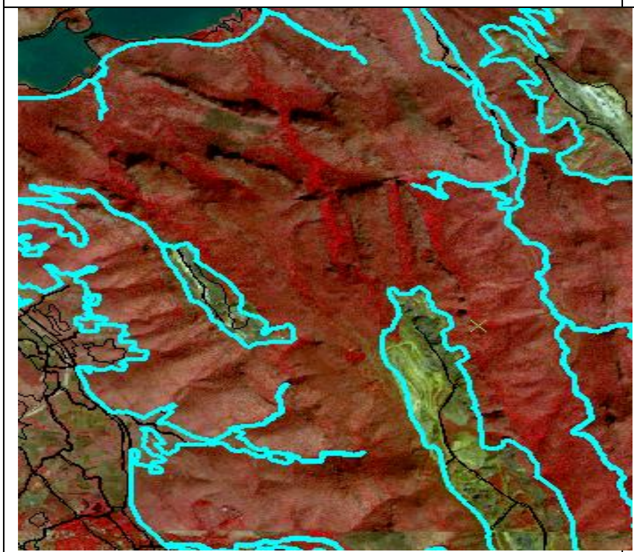
Image interpretation is a powerful technique that enables us to identify and distinguish various features of LU/LC in remote sensing images and allows gaining knowledge and information about them. These features are identified by the way they reflect or emit radiations and also by their association and location. These radiations are measured by satellite/Aerial sensors and ultimately depicted in the form of the satellite image. Identifying individual features from images is a key to interpretation and information extraction. Recognizing differences between a feature and its background are generally based on some of these visual interpretation keys known as visual interpretation elements, *viz*., shape, size, pattern, tone, texture, shadow and association. The procedure used in the identification of various LU/LC classes by means of visual interpretation techniques and their definitions is explained in Table 3.5.

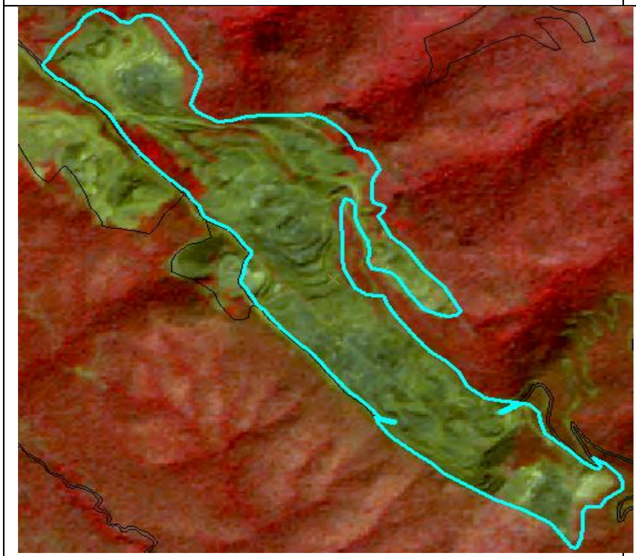
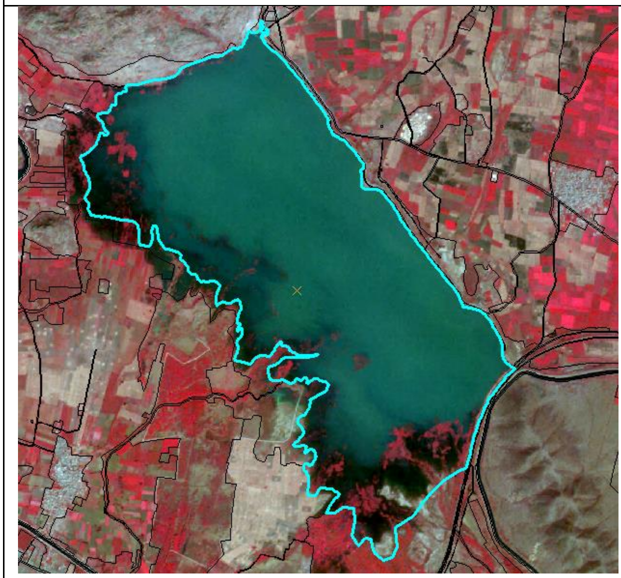
Classification algorithm

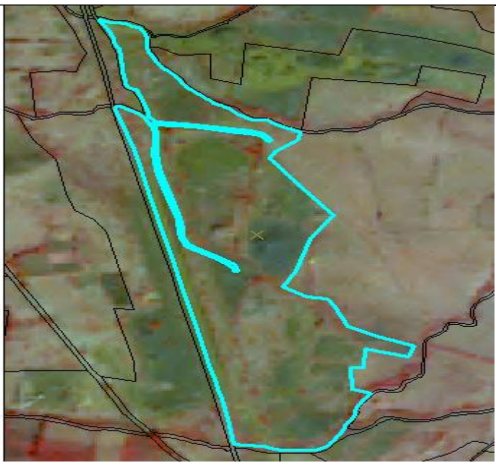
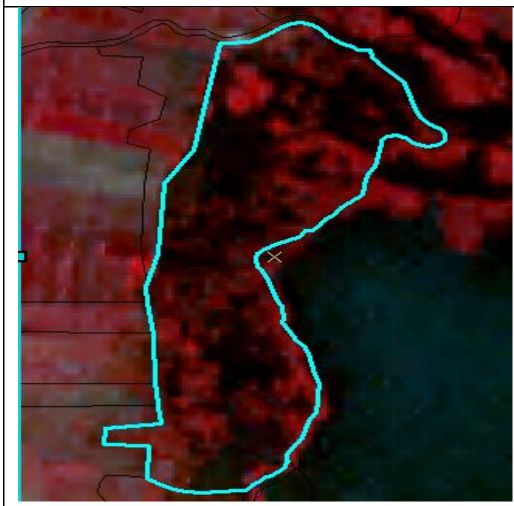
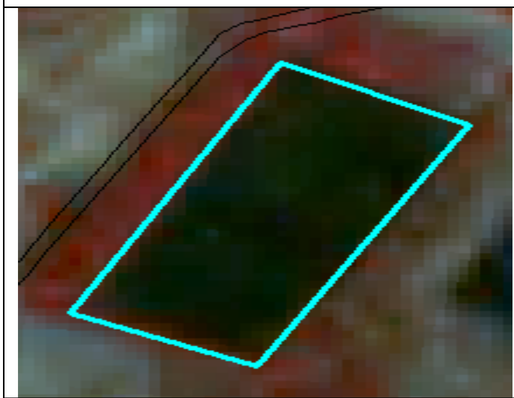
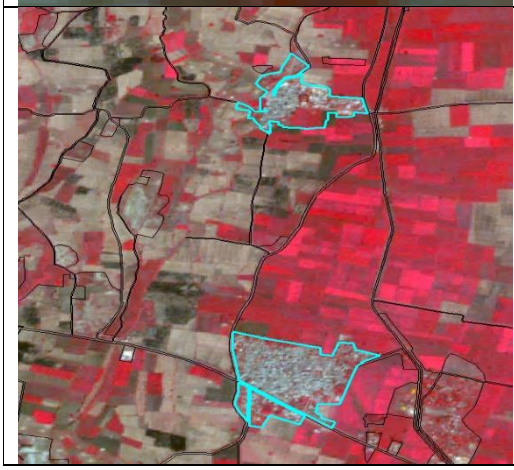
Land use refers to human activities and the various uses, which are carried out on land. Land cover refers to natural vegetation, water-bodies, rock/soil, etc. The following categories enlisted give a detailed description of characteristics of particular feature which is used in preparing the LU/LC feature dataset. As per the SIS-DP manual LU/LC is classified into 3 different levels. Level 1 is build-up is sub classified as Built Up (Urban), Built Up (Rural), Industrial/Mining and Transportation. Agricultural land is classified as crop land and Agriculture plantation. Waste lands are classifies as Scrub land Dense, Scrub land Open, Sandy areas, Barren rocky and Waterlogged areas. Water bodies are sub divided into River / Stream / Drain, Canal, Lakes / Ponds and Reservoir / Tanks. Few classes in which area prominently classified in the study area are briefed by taking the screen shots of the LISS IV images. Some examples showing the how each LU/LC classes are classified on the LISS IV satellite images are shown below to give the clarity on the visual interpretation technique.

Table 3.5. Identification key of various LU/LC classes by means of visual interpretation techniques and their definitions

	**Built-up (Urban)**: The Land used for human settlement of population more than 5000 of which more than 75% of the work forces are involved in non-agricultural activities. These settlements are usually larger in spatial extent than rural settlements and most of the land covered by building structures is parks, institutions, playgrounds and other open space within built up areas. **Sample location:** Sandur taluk
	**Built-up (Rural):** These are built up land in rural areas of size comparatively less than the urban settlement of which more than 80% of people are involved in agricultural activities and non-commercial activities generally limited support facilities that are unique to urban area like hospitals, industries, institutions. **Sample location:** Doulathapura Village
	**Crop Land:** These are the areas with standing crop as on the date of satellite overpass. Cropped areas appear in bright red to red in color with varying shape and size in a contiguous to non-contiguous pattern. They are widely distributed in different terrains; prominently appear in the irrigated areas irrespective the source of irrigation. **Sample location:** Doulathapura Village

	**Agricultural/Horticulture Plantation:** These are the areas under agricultural tree crops planted by adopting certain agricultural management techniques. This category includes the horticulture areas that refer to cultivation of coconut, areca nut, citrus fruits, orchards and other horticultural nurseries, herbs, shrubs, fruits, ornamental shrubs and trees, and vegetable gardens. **Sample location:** Sandur Taluk
	**Barren rocky:** These are rock exposures of varying lithology often barren and devoid of soil and vegetation cover. They occur amidst hill-forests as openings or as isolated exposures on plateau and plains. They appear in greenish blue to yellow to brownish in color depending on the rock type. They vary in size with irregular to discontinuous shape with a linear to contiguous or dispersed pattern. **Sample location:** Near Daroji lake
	**Forest:** These are the areas bearing an association predominantly of trees and other vegetation types (within the notified forest boundaries) capable of producing timber and other forest produce. **Sample location: Marutla extension**

	**Industrial:** Industrial area where the human activity is observed in the form of manufacturing along with other supporting establishments of maintenance, Engineering plants, petrochemical, thermal, cement industries are included under this. **Sample location:** JSW plant
	**Mining:** Mine / quarry are the areas subjected to removal of earth material (both surficial and sub- surficial) by manual and mechanized operations. Large scale quarrying and mechanization results in mining and mine dumps. It includes surface rocks and stone quarries, sand and gravel pits, brick kilns and associated features like mine dumps, abandoned mine pit etc. **Sample location:** Ramanmalai Forest area
	**Reservoir/ Tanks:** Reservoir is an artificial lake created by construction of a dam across the river specifically for hydel power generation, irrigation, and water supply for domestic/industrial needs, flood control, either Single or in combination. Tanks are small lakes of impounded water ways constructed on land surface for irrigation. They appear in light blue to dark blue depending on the depth from small to large sizes. They possess regular to irregular shape dispersed to linear, occupying lowlands, plains. **Sample location:** Daroji lake

	**Scrub land:** These areas possess shallow and skeletal soils, at times chemically degraded, extremes of slopes, severely eroded and lands subjected to excessive aridity with scrubs dominating the landscape. They have a tendency for intermixing with cropped areas. **Sample location:** BTP junction
	**Waterlogged:** Waterlogged land is that low lying land where the water is at/or near the surface and the water stands for most part of the year. **Sample location:** Near Daroji lake
	**Lakes / ponds:** Lakes / ponds are those that retain water in them either for one season or throughout the year and usually not subject to extreme fluctuation in water level. Ponds are body of water limited in size, either natural or artificial, regular in shape, smaller in size than a lake, generally located near settlements **Sample location:** Kuduthini Village
	**Villages:** These are built up areas in rural areas, smaller in size, mainly associated with agriculture and allied sectors and non-commercial activities with population size less than 5000, generally limited supporting facilities that are unique to urban areas like hospitals, industries, institutions**.** There are different types of rural settlements based on the extent of built-up area and inter-house distance. **Sample location:** Madapuram and hosadaroji village

Analysis and Results

The LU/LC classification is carried out for the year 2012 and 2021 by visual interpretation technique. This chapter briefs the results and outputs obtained from overlay analysis and change detection analysis.

LU/LC change detection analysis outcomes

LULC change between 2012 and 2021- 10 km buffer: The statistics generated from GIS analysis for the year 2012 to 2021 in 10 km buffer shows that Agricultural land is decreased by 260.30 hectares with the difference of 1.15%, whereas built up is increased by 689.50 hectares with the difference of 9.08%. Forest area is decreased by 396.96 hectares with a difference of 1.25%. Wasteland is decreased by 2.17% with 202.51 hectares. Water bodies are increased by 170.22 hectares with the difference of 6.55%. The detailed analysis LU/LC changes from 2012 to 2021 of level 1 and level 3 classifications is tabulated (Table 3.6; Fig. 3.8). The LU/LC map of level 3 classifications of 2012 and 2021 is shown in the Fig 3.10 and 3.11

LULC change between 2012 and 2021- 2 km buffer: The statistics generated from GIS analysis for the year 2012 to 2021 in 2km buffer shows that Agricultural land is decreased by 7.93 hectares with the difference of 0.33%, whereas built up is increased by 83.62 hectares with the difference of 4.18%. There are No changes in the forest area Wasteland is decreased by 4.44% with 104.12 hectares. Water bodies are increased by 28.43 hectares with the difference of 6.23%. The detailed analysis LU/LC changes from 2012 to 2021 of level 1 and level 3 classifications is tabulated (Table 3.7; Fig. 3.9). The LU/LC map of level 3 classifications of 2012 and 2021 is shown in the Fig 3.12 and 3.13.

Table 3.6. LU/LC change between 2012 and 2021 (10 km Buffer). Area given in hectares.

Land use – Land cover (Level-I and III) changes between 2012 and 2021					
LULC Category	**Area**		**difference**	**%**	**Remarks**
	2012	**2021**			
Agricultural land	**23071.88**	**22811.58**	**-260.30**	**-1.15**	**Decrease**
Agriculture plantation	212.09	212.09	-26.25	0	No Change
Crop land	22859.78	22599.49	-260.30	-1.15	Decrease
Built up	**6904.10**	**7593.60**	**689.50**	**9.08**	**Increase**
Built up (Rural)	140.87	187.42	46.55	24.84	Increase
Built up (Urban)	250.49	303.37	52.88	17.43	Increase
Hamlets and dispersed household	6.07	24.80	18.73	75.51	Increase
Mining / industrial	5180.72	5728.73	548.00	9.57	Increase
Mixed Settlement	1.33	1.33	0.00	0.00	No Change
Transportation	686.55	689.82	3.27	0.47	Increase
Village	638.06	658.13	20.07	3.05	Increase
Forest	**32045.88**	**31648.92**	**-396.96**	**-1.25**	**Decrease**
Forest	31970.43	31573.47	-396.96	-1.26	Decrease
Forest plantation	75.45	75.45	0.00	0.00	No Change
Wastelands	**9552.91**	**9350.40**	**-202.51**	**-2.17**	**Decrease**
Barren rocky	1172.31	1172.31	0.00	0.00	No Change
Salt affected	11.15	11.15	0.00	0.00	No Change
Sandy areas	18.39	18.39	0.00	0.00	No Change
Scrub land Dense	67.27	67.27	0.00	0.00	No Change
Scrub land Open	8064.85	7862.35	-202.50	-2.58	Decrease
Waterlogged	218.93	218.93	0	0	No Change
Water bodies	**2427.98**	**2598.20**	**170.22**	**6.55**	**Increase**
Canal	79.33	79.33	0.00	0.00	No Change
Lakes / Ponds	139.05	139.05	0.00	0.00	No Change
Reservoir / Tanks	1440.26	1601.75	161.49	10.08	Increase
River / Stream / Drain	769.30	769.30	0.00	0.00	No Change
Grand Total	**74002.71**	**74002.71**			

Table 3.7. LU/LC change between 2012 and 2021 (2 km Buffer)

Land use – Land cover (Level-I and III) changes between 2012 and 2021					
LULC Category	**Area**		**difference**	**%**	**Remarks**
	2012	**2021**			
Agricultural land	**2427.38**	**2419.45**	**-7.93**	**-0.33**	**Decrease**
Agriculture plantation	9.36	9.36	0.00	0.00	No Change
Crop land	2418.02	2410.09	-7.93	-0.33	Decrease
Built up	**1919.10**	**2002.72**	**83.62**	**4.18**	**Increase**
Built up (Rural)	6.42	14.35	7.93	55.26	Increase
Built up (Urban)	109.45	160.63	51.18	31.86	Increase
Hamlets and dispersed household	0.12	0.12	0.00	0.00	No Change
Mining / industrial	1579.77	1604.29	24.52	1.53	Increase
Transportation	98.30	98.30	0.00	0.00	No Change
Village	125.05	125.05	0.00	0.00	No Change
Forest	**2890.45**	**2890.45**	**0.00**	**0.00**	**No Change**
Forest	2890.45	2890.45	0.00	0.00	No Change
Wastelands	**2449.13**	**2345.01**	**-104.12**	**-4.44**	**Decrease**
Barren rocky	41.37	41.37	0.00	0.00	No Change
Scrub land Open	2387.90	2283.78	-104.12	-4.56	Decrease
Waterlogged	19.86	19.86	0.00	0.00	No Change
Water bodies	**427.54**	**455.96**	**28.43**	**6.23**	**Increase**
Canal	3.66	3.66	0.00	0.00	No Change
Lakes / Ponds	6.07	6.07	0.00	0.00	No Change

Reservoir / Tanks	320.97	349.39	28.43	8.14	Increase
River / Stream / Drain	96.84	96.84	0.00	0.00	No Change
Grand Total	**10113.59**	**10113.59**			

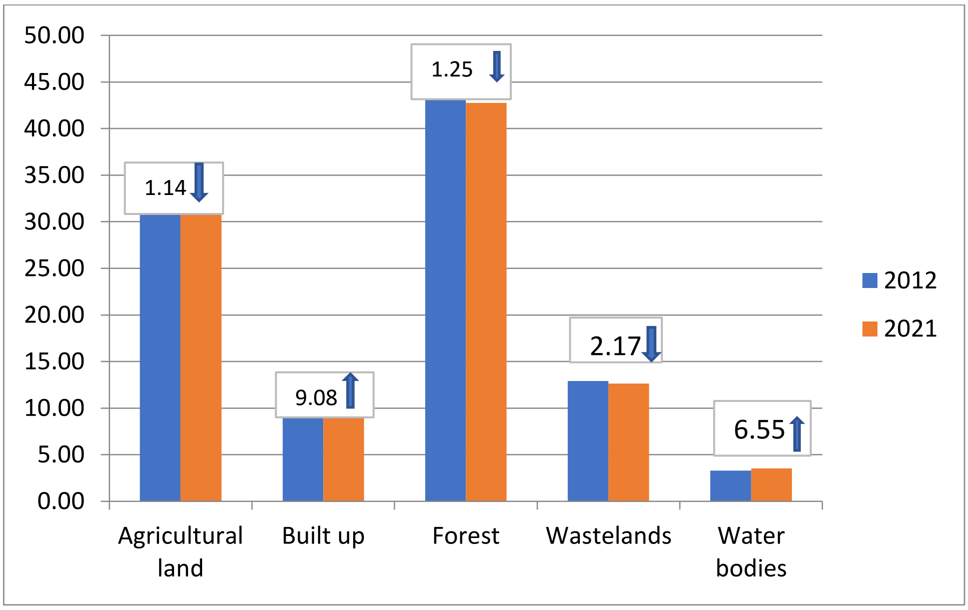


Figure 3.8. LU/LC change between 2012 and 2021 (10 km Buffer)

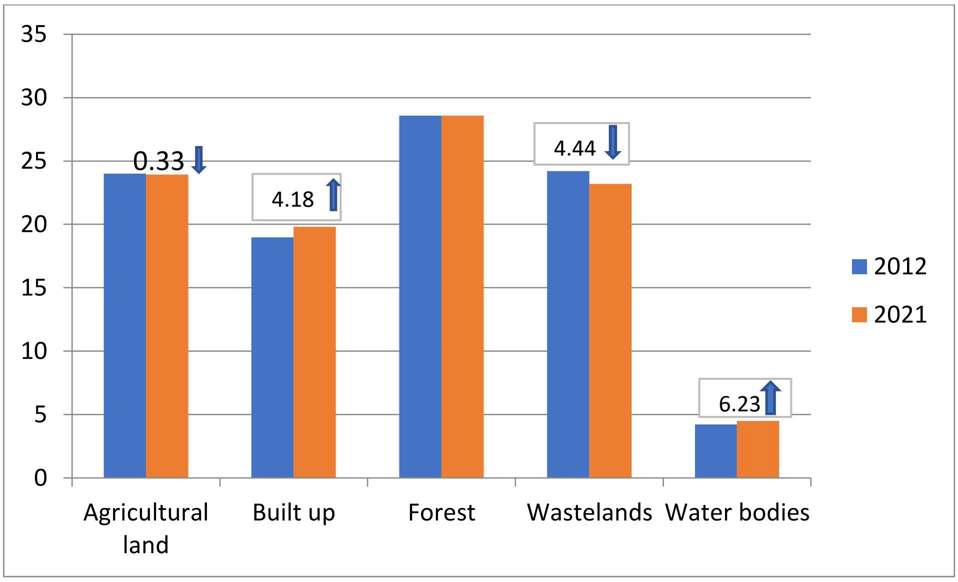


Figure 3.9. LU/LC change between 2012 and 2021 (2 km Buffer)

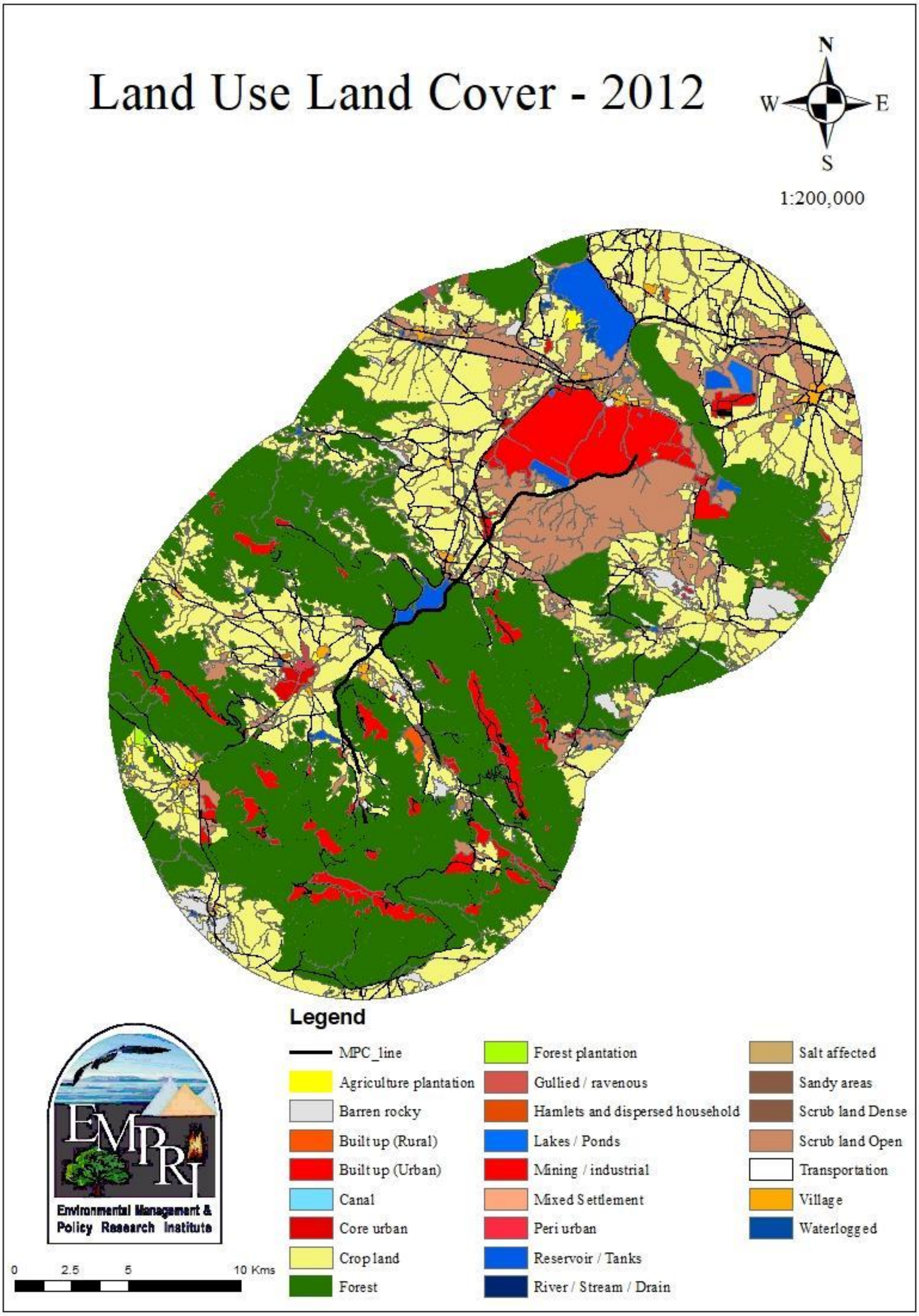


Figure 3.10. Land Use/ Land Cover – 2012 for 10 Km buffer

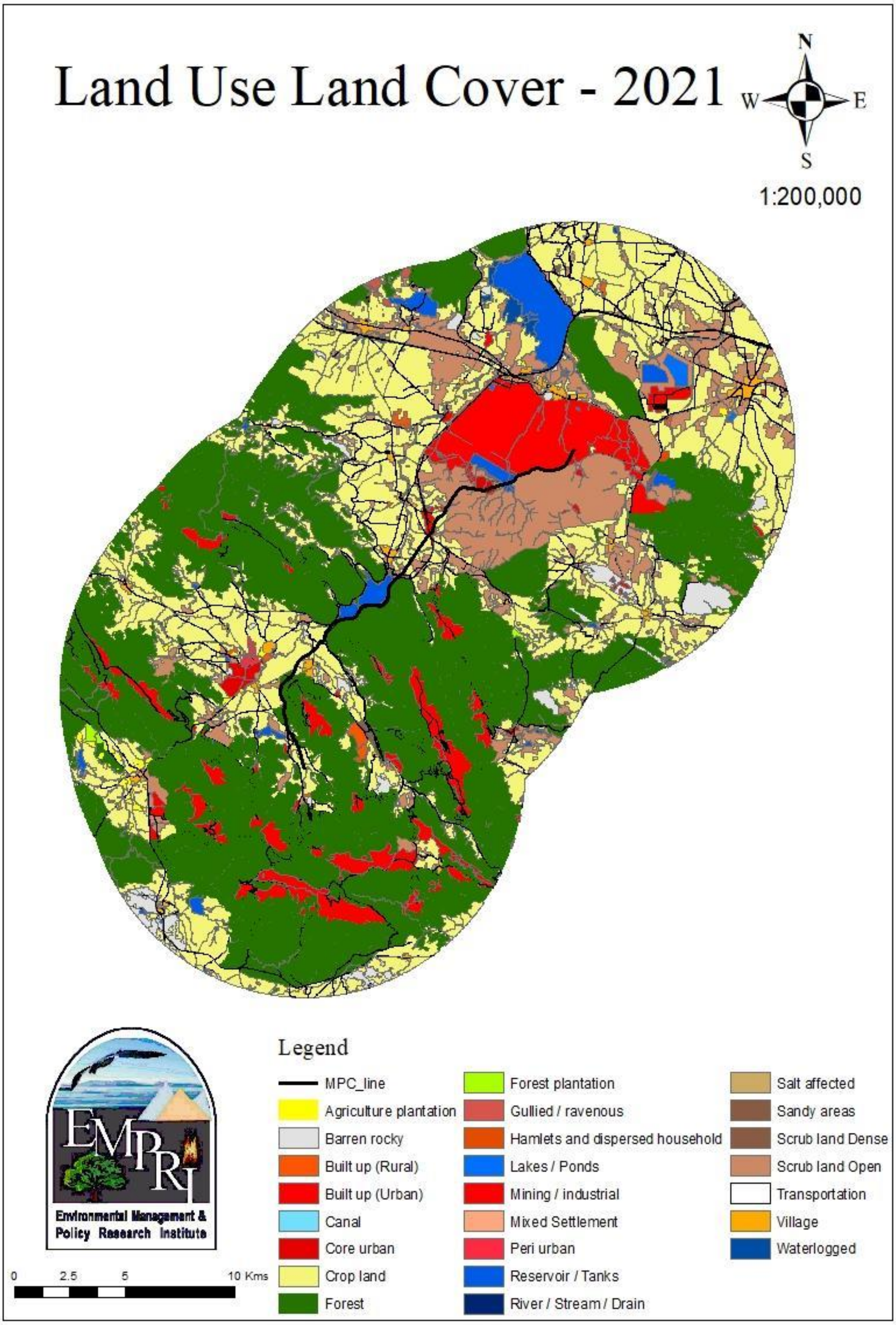


Figure 3.11. Land Use/Land Cover – 2021 for 10 Km Buffer

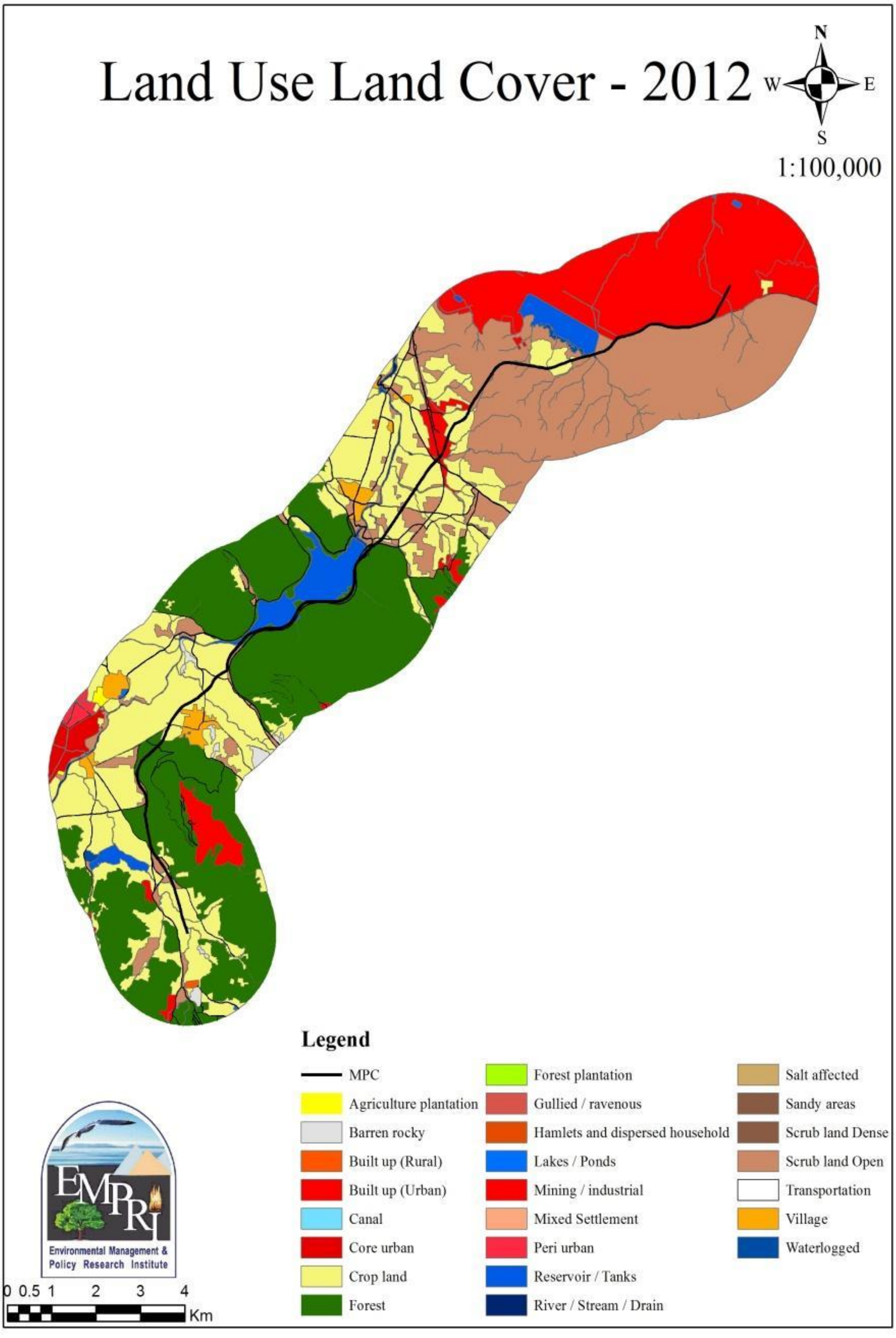


Figure 3.12. Land Use/ Land Cover – 2012 for 2 Km buffer

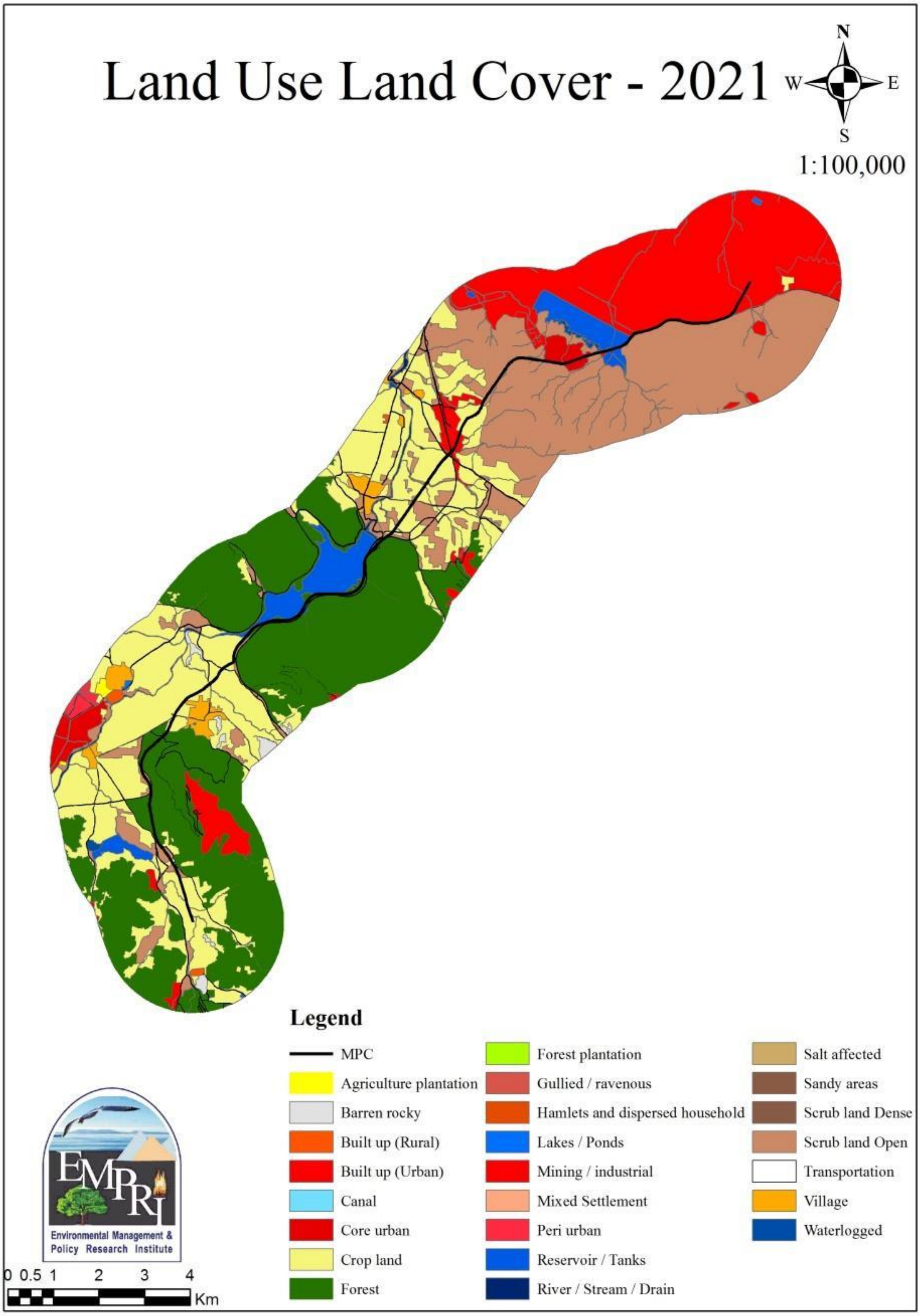


Figure 3.13. Land Use/ Land Cover – 2021 for 2 Km buffer

Accuracy Assessment

One of the most important steps at classification process is accuracy assessment. The aim of accuracy assessment is to quantitatively assess how effectively the interpretation of the images is classified. To analyse the accuracy assessment 1 km x 1 km grids are laid for entire study area. A total of 627 Points (locations) were created in the classified image of the study area by placing the point at the centre of each grid (Table 3.8). The points are verified on the high resolution google earth images and the LISS IV satellite imageries.

Table 3.8. Accuracy Assessment table

Sl. No	LU/LC classes	Sample points	Correct sampled
1	Agricultural Plantation	2	2
2	Barren rocky	5	5
3	Built-up(Rural)	6	6
4	Built-up(Urban)	1	1
5	Crop Land	202	196
6	forest	266	264
7	industry	24	24
8	mining	25	25
9	River/stream/Drain	27	27
10	Scrubland open	58	56
11	Transportation	3	3
12	village	2	2
13	waterlogged	6	6
	Total	**627**	**617**

- The overall accuracy percentage is calculated by the following formula
- **Classification accuracy percentage = (No. of correct sampled points/total number of sample points) *100**
- **Classification accuracy percentage = (617/627)*100**
- **Classification accuracy percentage=98.4%**
- The overall accuracy percentage obtained is 98.4%

Overlay analysis

To estimate the land transformation from one class to another class overlay analysis is carried out. In the current study two sets of vector feature classes such as 2012 and 2021 LU/LC are considered to analyse spatial relationship and change detection. Using the attribute information, the change detection was analysed to detect the transformation in LU/LC. The statistical representation of Individual class indicates the conversion of particular LU/LC to and from various other classes is detailed below.

1) **Agricultural Land:** Agricultural land has two major sub classes namely viz. Agricultural Plantation, Crop land.

With the observation the agricultural land has been decreased by conversion into other LU/LC classes:

a. **Agricultural Plantation:** There are no changes from agricultural plantation into other classes.
b. **Crop land:** The changes occurred in crop land are tabulated in Table 3.9 and 3.10 below that indicates the distribution in crop land to other LU/LC classes in 10km and 2 km buffer. 260.31 hectares of crop land is converted to other classes in 10 km buffer. 7.93 hectares of crop land is converted to other classes in 2 km buffer

Table 3.9. Distribution of LU/LC Classes in crop land in 10 km buffer

Year	LULC Classes	Area in ha	%
2012	**Crop land**	22859.78	100%
Unchanged Area			
2021	**Crop land**	22599.48	98.86
Crop land to other classes (Area lost)			
2021	Built up (Rural)	46.55	0.20
2021	Built up (Urban)	1.70	0.01
2021	Hamlets and dispersed household	18.73	0.08
2021	Reservoir / Tanks	131.61	0.58
2021	Scrub land Open	42.02	0.18
2021	Transportation	4.11	0.02
2021	Village	15.60	0.07
Total		260.31	1.14

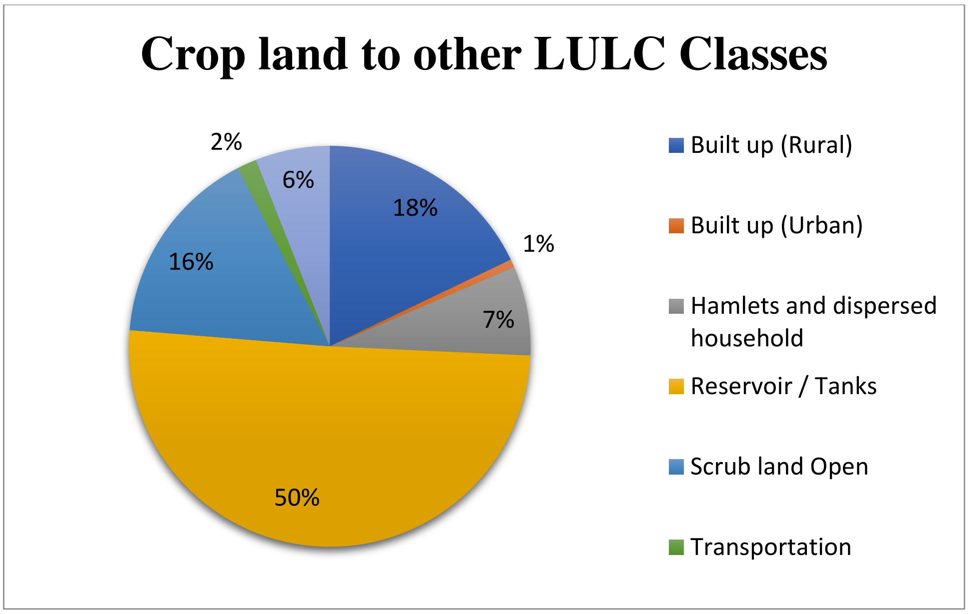


Figure 3.14. Graph showing crop land to other LU/LC classes (10 km buffer)

Table 3.10. Distribution of LU/LC Classes in Crop land in 2 km buffer

Year	LULC Class	Area in Ha	%
2012	Crop land	2418.02	100 %
Unchanged Area			
2021	Crop land	2410.09	99.67
Crop land to other classes (Area lost)			
2021	Built up (Rural)	7.93	0.33
Total		7.93	0.33

1) **Built-up:** Built-up has 7 major sub classes namely Built-up (Rural), Built up (Urban), Hamlets and dispersed household, Mining/ Industrial, Mixed Settlement, Transportation and Village but there are no changes from Built-up to other LU/LC classes

2) **Forest:** The changes observed in forest area are shown in the Table 3.11. An extent of 398.25 hectares of forest area is converted into various other LU/LC classes in 10 kms buffer. And no changes observed from forest land to other classes in 2 km buffer.

Table 3.11. Distribution of LU/LC Classes in forest 10 km buffer

Year	LULC class	Area In Ha	%
2012	Forest	31970.43	100 %
Unchanged Area			
2021	Forest	31572.18	98.754
Forest to other classes (Area lost)			
2021	Mining / industrial	380.85	1.191
2021	Reservoir / Tanks	10.24	0.022
2021	Scrub land Open	7.16	0.022
Total		**398.25**	1.246

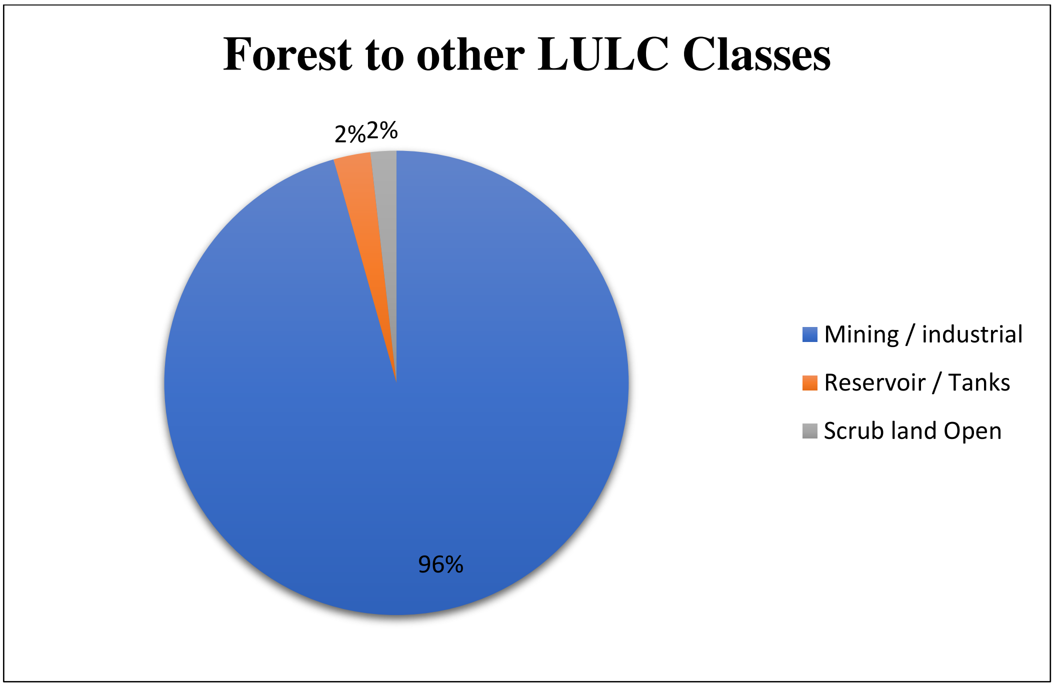


Figure 3.15. Graph showing forest to other LU/LC classes in 10 km buffer

3) **Water bodies:** There are four sub classes namely *viz*. Lakes / Ponds, Canals, River / Stream / Drain, Reservoir / Tanks. There are no changes in Lakes /Canals/ Ponds and River / Stream / Drain to various other LU/LC classes.
4) **Waste land:** There are six major sub classes *viz*. Barren rocky, Gullied / Ravenous, Salt affected, Sandy areas, Scrub land Dense, Scrub land Open, Waterlogged

Changes from waste land to various other LU/LC classes are identified only from Scrub land Open and Scrub land Dense. And no changes observed in other classes of waste land.

Scrub land Open: The changes occurred in Scrub land Open are tabulated in Table 3.12 and 3.13 below that indicates that 251.23 hectares of scrub land open is converted to other LU/LC classes mainly in build-up area in 10 km buffer and 104.12 hectares of scrub land open is converted to other classes in 2 km buffer.

Table 3.12. Distribution of LU/LC Classes in Scrub land Open in 10 km buffer

Year	LULC class	Area In Ha	%
2012	Scrub land Open	8064.85	100 %
Unchanged Area			
2021	Scrub land Open	7813.62	96.88
Scrub land Open to other classes (Area lost)			
2021	Built up (Urban)	51.18	0.63
2021	Crop land	0.01	0.00
2021	Mining / industrial	167.15	2.07
2021	Reservoir / Tanks	28.43	0.35
2021	Village	4.47	0.06
Total		**251.23**	3.12

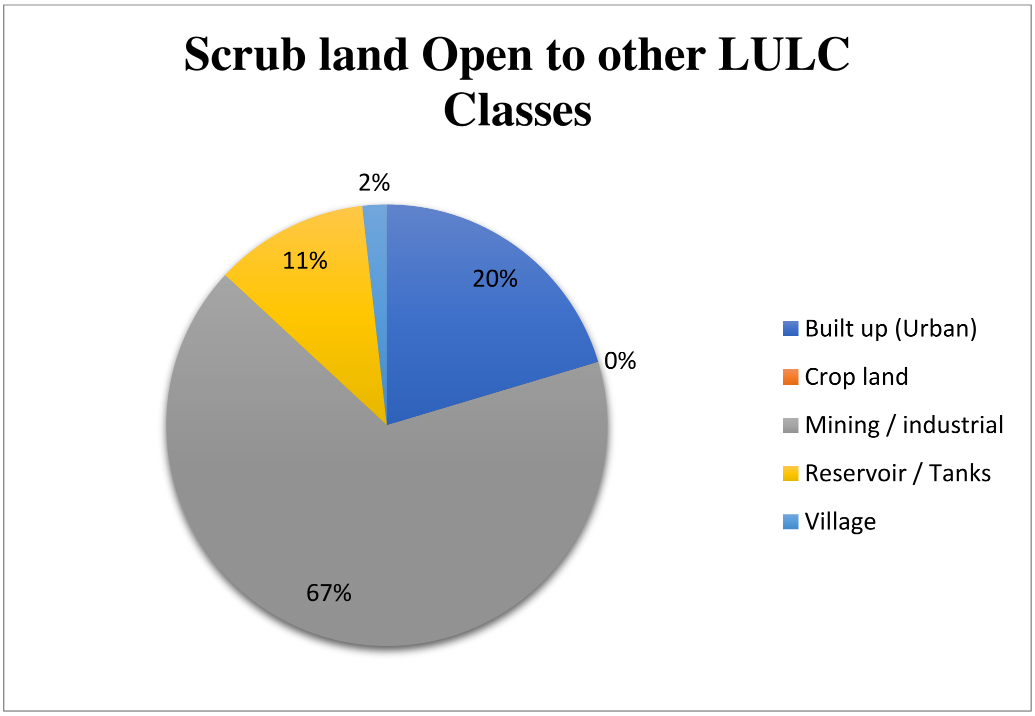


Figure 3.16. Graph showing scrub land open to other LULC classes in 10 km buffer

Table 3.13. Distribution of LU/LC Classes in Scrub land Open in 2 km buffer

Year	LULC Class	Area In Ha	%
2012	Scrub land Open	2387.90	100 %
Unchanged Area			
2021	Scrub land Open	2283.78	95.64
Scrub land Open to other classes (Area lost)			
2021	Built up (Urban)	51.18	2.14
2021	Mining / industrial	24.52	1.03
2021	Reservoir / Tanks	28.43	1.19
Total		104.12	4.36

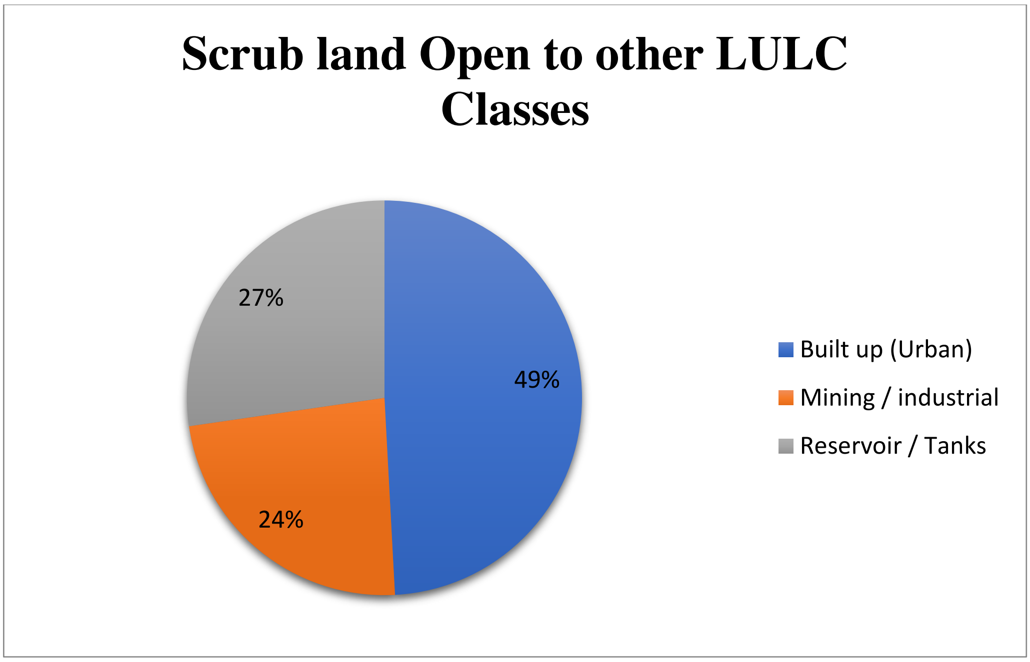


Figure 3.17. Graph showing scrub land open to other LU/LC classes in 2 km buffer

Conclusion

1. The assessment of LU/LC status in the study area and the change detection studies have been carried out on 1:20000 scales as per SIS-DP (Space Based Information Support for Decentralised Planning) guidelines prepared by Indian Space Research Organization (ISRO) published on 2011, there exists 6 major classes of LU/LC in study area. This analysis discusses various characteristics and vulnerable classes of the study area and details for each one of these are given above.
2. The study area mainly consists of forest land, followed by agriculture, built up, wasteland and water bodies.
3. Agricultural land and forest land are mainly affected LU/LC in the study area. An extent of 260.30 ha of agricultural land is decreased in 10 km buffer of main conveyor belt.

4. An extent of 396.96 ha of forest land are converted to other LU/LC classes mainly to mining/ industrial area and built-up due to these changes we lost natural resources and biodiversity in the ecosystem.
5. Apart from Agricultural land and Forest land, the major land use change observed in this study area is increase in mining/ industrial area by an extent of 548.00 ha. This change in LU/LC includes an extent of 380.85 ha of forest land getting converted to mining/industry.
6. In 251.23 ha of scrub land open, an extent of 167.15 ha is converted to Mining / industrial in 10 km buffer and in 2 km buffer out of 55.3 ha, 26.88 ha is converted to Mining / industrial.
7. 170.22 ha of water bodies are increased in the study area. This increase in the water bodies is due to construction of ponds for irrigation purpose and also a tank is constructed in agricultural land.

Chapter IV: Habitats of Conservation Significance within the area

CHAPTER IV
HABITATS OF CONSERVATION SIGNIFICANCE WITHIN THE AREA

Introduction

All organisms are involved in mutualistic and hostile interactions with other species (Thompson 2009). The interactions between the species form a multifaceted structure of ecological communities and manage important ecosystem functions, such as pollination, seed dispersal or biological control. 'Eat and eaten by' principal has driven the majority of interactions. There is a strong indication that the interaction between plants and insect pollinators is the chief driver of diversity in flowering plants and the insects involved in pollination (Simms 2013). The coexistence of the species, plant-animal interactions have a vast effect on plant and animal evolution. The selection by consumers has driven the evolution of numerous plant defence traits. For instance, the phytoconstituents are derived from plant evolutionary responses to consumers (Simms 2013).

The benefit that plants obtain from animals is mobility. Many of the plants depend on animals to carry pollen or seeds. The larvae of butterflies need a particular plant species to feed on for stepping up into its next life cycle. The frugivores depended on edible fruit-bearing plant species and in return plant gets the benefit of spreading its distribution. In several cases, the interactions between plants and animal interactions are extremely specialized and equally beneficial. These mutualisms can be vulnerable to extinction if the chain is disrupted, which is a vital issue in both animal and plant conservation. Plant communities are not only the species of the area but providers of habitats for other faunal biodiversity. The two core criteria for deciding the area of conservation significance are the high scale endemism and threat. The habitat should hold the richness of endemic species (irreplaceability) and also under threat (Vulnerability). In the current chapter, the crucial habitat or locations of biodiversity are identified using various criteria.

Methodology

For the identification of habitats of conservation significance within the MPC stretch, we consolidated the number of recorded species from all the taxonomic groups (Amphibians, Arthropoda, Aves, Mammals, Plants and Reptiles) in four different divisions of criteria. The details of the criteria are given in Table 4.1. The entire stretch of MPC is divided randomly into six fragments depending on the land uses such as Nandihalli, Devdari, Narihalla, Tharanagara, Bannihatti and JSW campus. The accumulated data among different sampling stations along the MPC stretch (Table 4.2) is then subjected to Inverse Distance Weighted (IDW) interpolation method using the GIS (Geographical Information System) technique to get the conservation significance area.

Table 4.1. Criteria for segregate number of species recorded in the MPC stretch

Criteria NO.	Differentiating criteria
1	Species richness of native species
2	Number of species under Schedule I- IV
3	Threatened species (as per IUCN)
4	Synanthropic/commensal (These species are highly generalists and aggressive species, they are quick in colonising and establishing their dominance, but they may be of native species).

Results

Narihalla forest stretch is the most species-rich area along MPC stretch in the perspective of native species richness (n= 259) and was followed by the Bannihatti region (n=179) (Table 4.1 andFig.4.1). All 8 endemic plant species such as *Dolichandrone atrovirens* of Bignoniaceae, *Cleome feline* of Capparaceae, *Cymbopogon martini* of Poaceae, *Gardenia gummifera* of Rubiaceae, *Grewia orbiculata* of Malvaceae, *Hardwickia binata* of Fabaceae, *Justicia glauca* of Acanthaceae and *Striga densiflora* of Orobanchaceae are recorded in Narihalla region.

For criteria-1 (Species richness of native species), Avi-fauna species accounted for the maximum (n=77) number of species richness and was followed by plants (n=69). Mammals including bat species accounted for 25 species in the Narihalla region. It includes Leopard, Sloth Bear, Four-horned Antelope, and Rusty Spotted Cat. The insect group accounted for 58 species while herpetofauna accounted for 30 species. Since, Narihalla forest region is associated with wetland and a dense dry deciduous forest habitat, the native species of flora and fauna are sheltered on a high scale.

Except, *Justicia glauca,* all other endemic plant species were also recorded in the Bannihatti location. Comparatively, the frequency and density of *Grewia orbiculata* are high in the Bannihatti location. *Grewia orbiculata* is an endemic species of the Peninsular region that bears an edible fruit being a prior species for various fruit-eating faunal and avifaunal species. The diversity of Arthropoda species were high in open scrub at the Bannihatti location which was followed by the forest at Narihalla. The presence of abundant larval host plants for Lepidoptera has driven the species richness and as well as abundance. The highest diversity of bat species has been recorded in the forest area followed by scrubland.

Table 4.2. The species data is used to identify an area of conservation significance along the MPC.

Taxa	**Nandihalli (Nandihalli to Devdari junction point)** **15.046710° 76.569450° To 15.068403° 76.560937°**				**Devdari (Devdari junction to Bheemagandi tunnel)** **15.068403° 76.560937° To 15.104085° 76.582205°**				**Narihalla (Tunnel to Pumphouse)** **15.104085° 76.582205° To 15.123065° 76.609291°**				**Tharanagara (Pumphouse to BTP Junction)** **15.123065° 76.609291° To 15.146653° 76.626363°**				**Bannihatti (BTP Junction to JSW Compound)** **15.146653° 76.626363° To 15.158515° 76.639626°**				**JSW (JSW Compound to starting point)** **15.158515° 76.639626° To 15.173425° 76.684412°**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Amphibians	**10**	**1**	**-**	**-**	**13**	**1**	**-**	**-**	**6**	**1**	**-**	**-**	**6**	**-**	**-**	**-**	**5**	**-**	**-**	**-**	**7**	**1**	**-**	**-**
Arthropod	**47**	**6**	**-**	**37**	**36**	**6**	**-**	**31**	**58**	**7**	**-**	**23**	**48**	**6**	**-**	**27**	**47**	**7**	**-**	**28**	**37**	**5**	**-**	**29**
Aves	**33**	**4**		**6**	**43**	**2**	**-**	**7**	**77**	**3**	**1**	**7**	**39**	**1**	**-**	**6**	**60**	**6**	**-**	**7**	**39**	**3**	**-**	**7**
Mammals-Bats	**7**	**-**	**-**	**-**	**8**	**-**	**-**	**-**	**13**	**-**	**-**	**-**	**11**	**2**	**-**	**-**	**9**	**1**	**-**	**-**	**5**	**-**	**-**	**-**
Mammals-large	**3**	**3**	**-**	**-**	**8**	**8**	**2**	**-**	**12**	**12**	**4**	**-**	**6**	**6**	**1**	**-**	**9**	**9**	**2**	**-**	**-**	**-**	**-**	**-**
Plants	**39**	**-**	**1**	**12**	**42**	**-**	**1**	**20**	**69**	**-**	**3**	**20**	**33**	**-**	**-**	**26**	**34**	**-**	**2**	**15**	**34**	**-**	**-**	**15**
Reptiles	**13**	**5**	**1**	**-**	**15**	**5**	**1**	**-**	**24**	**15**	**2**	**-**	**8**	**2**	**-**	**-**	**15**	**4**	**-**	**-**	**13**	**3**	**-**	**-**
Total	152	19	2	55	165	22	4	58	259	38	10	50	151	17	1	59	179	27	4	50	135	12	0	51

Criteria: 1-Species richness of native species (number), 2-Number of species under Schedule -I- IV, 3-Is it possible to have a number on IUCN threatened species (EN, VU, NT, DD), and 4-Synanthropic/commensal (these species are highly generalists and aggressive species, they are quick in colonising and establishing their dominance, but they may be of native species)

Frogs and Toads can be found in diverse habitats including inside the water, bushes, and the soil. Since their lifecycle is highly dependent on the water, they are mostly seen in areas associated with water bodies. The present study shows the diversity and density of frogs and toads are recorded in areas with water presence. Almost all the species recorded are mostly ground-dwelling or lives in a waterbody and one species was found to be resting and calling in the branches of bushes. The Locations like Narihalla, Bhimagandi tunnel are forest habitats with a water body on another side of MPC was recorded with 59 species of birds predominantly high for the habitat patch. In this habitat, forest specific species like Fantail flycatchers, Malkoha, insectivorous and frugivorous birds were recorded. Bannihatti (hilltop) to BTP junction, a large patch of open scrub forest area accounted for 57 species. The Open Scrublandmap concerning is also an easy foraging ground for Raptors like Black-shouldered Kite, Oriental Honey Buzzard, Short-toed Snake Eagle, Bonelli's Eagle, Indian Spotted Eagle which were recorded at Bannihatti. The diversity of the terrestrial mammals, both large and small mammals were higher in the forest area i.e., the Donimalai Forest Block, and the density of detections was found to be higher in the Open Scrublands and along the edges of the forest. Hence, a dry deciduous forest patch at Narihalla and an open scrub at Bannihatti are crucial habitats for conservation in the perspective of native species.

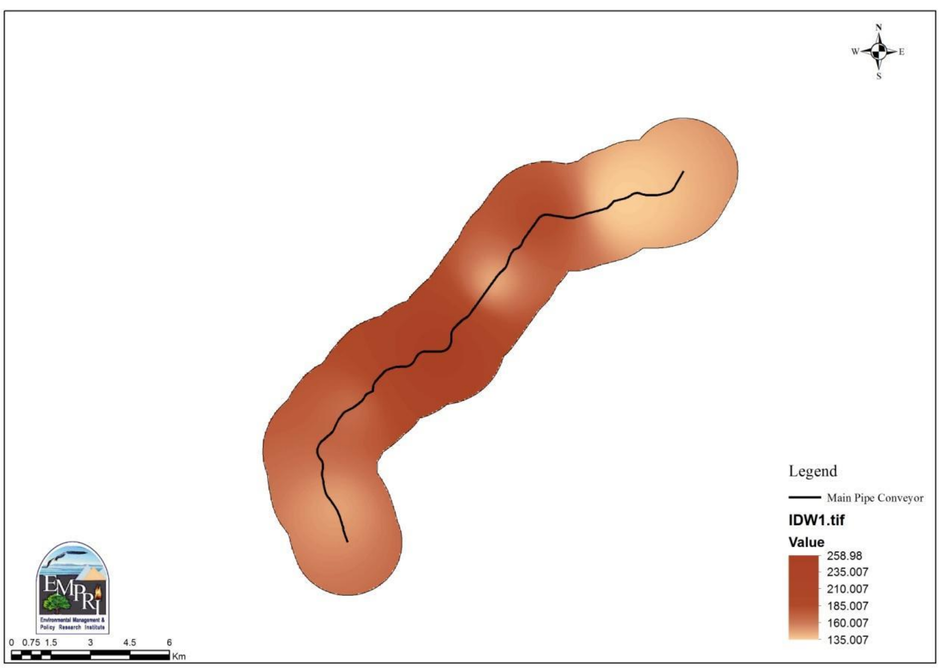


Figure 4.1. IDW interpolation map concerning the richness of native species**.**

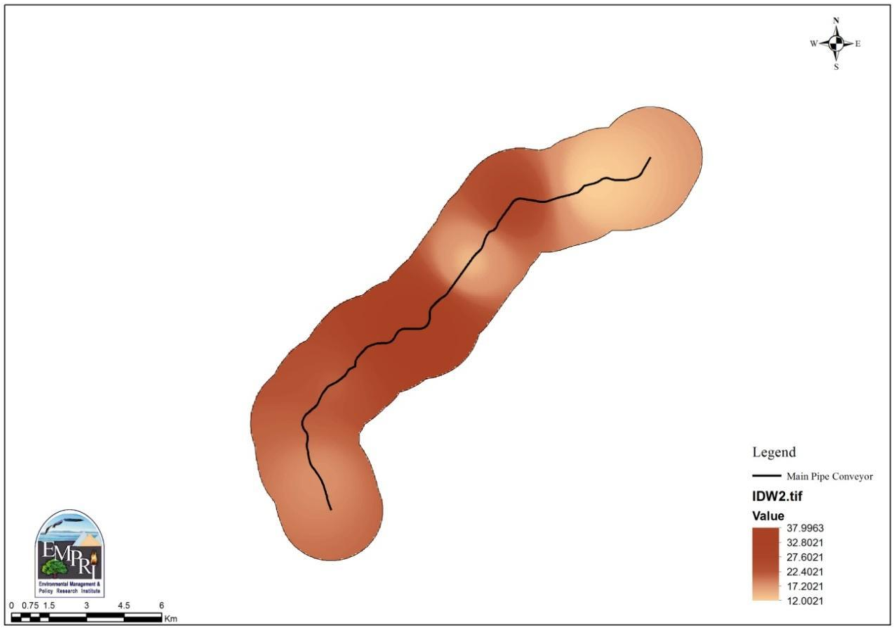


Figure 4.2. IDW interpolation mapconcerning richness of species under Schedule I- IV**.**

The forest stretches in Narihalla accounted for the maximum number of schedule species (n=38) (Fig. 4.2). Among 38 species, reptiles accounted for the maximum number of schedule species (n=19) which was followed by large mammals (n=15). Seven butterfly species, 3 species of birds and one species of amphibian were recorded in the Narihalla region. The open scrubland at Bannihatti is the second dominant habitat in holding a high number of schedule species (n=26).

Considering the threatened species, forests of Narihalla (Fig. 4.3) accounted for the maximum number of species (n=10), which was followed by Bannihatti open scrub and Devdari stretch equally with 4 threatened species. Among the different groups, Mammals accounted for a maximum number of threatened species in Narihalla but in Bannihatti, it shared its dominance rank equally with plants (n=2).

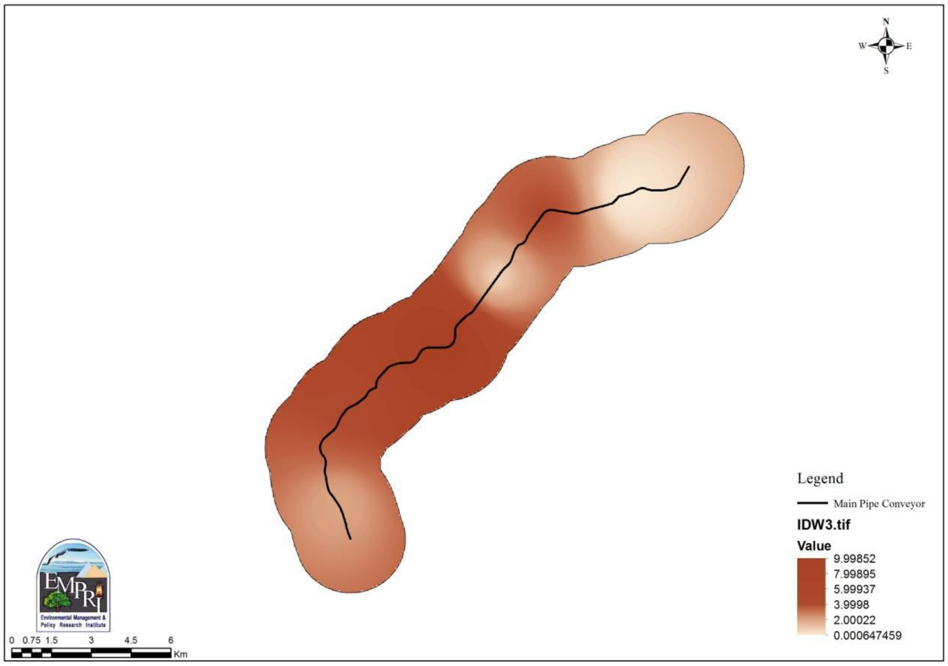


Figure 4.3. IDW interpolation map concerning the richness of threatened species

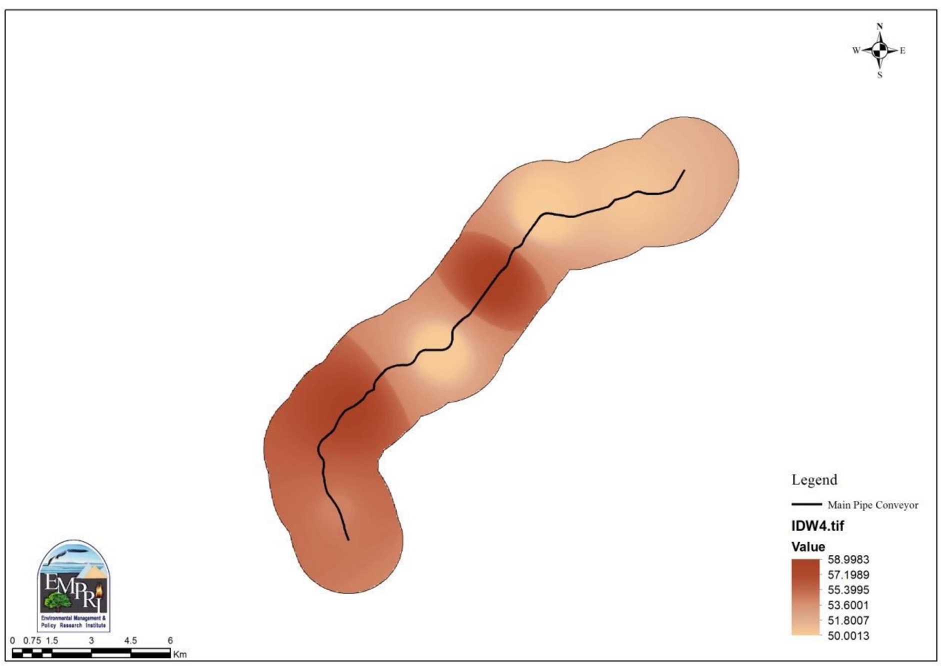


Figure 4.4. IDW interpolation map concerning the richness of generalist species.

The synanthropic and commensal species are highly generalists and aggressive that they are quick in colonising and establishing their dominance in the habitat, but some of them may be of native species. In the present study, such species are concentrated in an area that is already disturbed by various anthropogenic pressures (Fig. 4.4). The stretch of Taranagara is having agricultural land use accounted for a maximum number of generalist species which was followed by Devdari, Nandihalli and JSW campus. The Arthropoda group contributed more numbers (n=27) to the generalist species list of an area which was followed by plants (n=26). The area is full of pledged agricultural land and pest richness is relatively high.

Conclusion

Among six different areas along the MPC stretch, a dry deciduous forest patch at Narihalla and open scrubland at Bannihatti accounted for the maximum number of species richness regarding native species, schedule species and threatened species. Since all other stretches are already altered for anthropogenic activities like agriculture, built-up and mining activities, our study suggests Narihalla and Bannihatti stretch can be considered as 'source' for many of the taxa's, perhaps an area of conservation significance that underlines the need for conservation and management attention.

Chapter V: Diversity, Species Composition and Stand Structure of the Vegetation

CHAPTER V
DIVERSITY, SPECIES COMPOSITION AND STAND STRUCTURE OF THE VEGETATION

Introduction

Plant community assemblage of a region offering ground cover collectively is expressed with a term known as vegetation. The vegetation is general term with a broader expression than the term flora. It refers to a wide range of dimensions without exact reference to particular taxa, life forms, or any other specific botanical or geographic characteristics. There are many different regions with different climate regimes, ecology, geology etc., Due to these dimensions, there are types in vegetation and it is defined basically by characteristic dominant species, environmental conditions, and altitudinal gradients (Ornduff et al. 2003).

The production of oxygen and being a source continuously is the most important function of vegetation in the perspective of humans & all other faunal elements. Vegetation also regulates biogeochemical cycles like water, carbon, nitrogen. It serves as wildlife habitat and the energy source for measureless range of biodiversity. The global food production, wood, raw materials from natural origin, etc., are obtained by vegetation. The local climatic patterns, soil structures and ecology of an area shape the type of vegetation. The study of vegetation in defining the health of an ecosystem is a primary task indeed.

Karnataka is the seventh largest state of the country with a geographical area of 5.83% of total geographical area of India. The forest cover of the Karnataka is around 20.11% of the geographical area of the whole state. The density wise classification of the forests in Karnataka using the IRS Resourcesat-2 LISS III satellite data of the period Nov 2017 to Mar 2018 (FSI 2019) shows 10.97% of Moderately Dense Forest (MDF), 6.79% of Open Forest (OF), 2.35% of Very Dense Forest (VDF) of the total forest cover.

The forests in India are classified into different forest types by FSI. The Forest type map of2011 is recently refined by FSI and the percentage of forest types of Karnataka is presented as per the Champion & Seth (1968). The forests in Karnataka belong to 8 forest type groups that are further divided into 21 different forest types along with plantations/Trees outside forests (TOF). Among the 21 forest types, the West Coast Tropical Evergreen forest occupies 12.65% followed by Southern Moist Mixed Deciduous forests-11.70%, West Coast Semi-evergreen forest-10.52%, Southern Dry Mixed Deciduous forest-7.73%, Southern Thorn Scrub forest-7.49%, Dry

Deciduous Scrub forest-7.12%, & Dry Teak forest-6.07%. The plantations/TOF has the largest area with 19.57%; the other types of forests have less than 5% of the forest cover (FSI, 2019).
Ballari district with a geographical area of 8461 sq.km has the total forest cover of 739.22 sq.km (MDF & OF) accounting for 8.74% forest cover. The forest locations of the study area include vegetation of the southern tropical dry deciduous type.

Review of literature

Understanding plant bioacoustics

Many biological organisms use sound waves or vibrations for communication. The diverse organisms have evolved a diversity of sensory organs with adapted morphological structures and functions to perceive sound and or mechanical vibrations (Gagliano et al. 2012). Humans and most terrestrial mammals have evolved external auditory structures, the pinna, to collect airborne vibrations and transmit them to the eardrum, the first coupling stage of transformation of acoustical energy into mechanical energy. Yet, most auditory animals lack such external morphology, and many also have no eardrums. Birds and frogs have no outer ears, but their hearing can be more acute than humans (Hoy and Robert, 1996). Plants can produce relatively low frequencies of 50-120 Hz spontaneously (Hassanien et al. 2014). Sound waves can change the cell cycle (Bochu et al. 1998). Sound waves vibrate the plant leaves and speed up the protoplasmic movement in the cells (Godbole, 2013). Both sound energy and light energy could convert and store as chemical energy, which enhances the photosynthesis system (Meng et al.2012). Different plant species have various responses to sound stimulation at different growth stages. The optimal sound stimulation for seed germination of sound waves was at SPL of 100 dB and frequencies of 0.4-0.8 kHz every day for one hour (Hassanien et al. 2014).
Sound waves can affect cell cycle and the protoplasmic movement in the cells is speeded up by the vibrations of sound waves (Wang et al. 1998; Godbole, 2013). It has been reported that acoustic biology has become increasingly popular and more attention has been paid to the effects of environmental stresses on the growth and development of plants.
The sound travels readily and far in a dense substrate like soil.It can be surmised that those organisms that inhabit subterranean environments (e.g. fossorial mammals) or are indeed rooted within the ground (e.g. plants) benefit from some form of perception of substrate vibrations.

Methodology

Sampling methodology

The vegetation data were collected between June and August, 2021. A quadrat is a temporary frame/plot of specific size that is laid down for studying the diversity of the plant community. This method can also be used to quantify plant community in all types of vegetation. The number of quadrats/plots to be laid is based on the type of vegetation, terrain, and the objective of sampling. The plant community is assessed in the quadrat/plot based on the habit; trees are assessed in the whole plot whereas sub-plots of different dimensions are placed for sampling of shrubs and herbs (Table 5.1). The quadrats (Figure 5.1) are laid randomly to estimate the diversity. This type of sampling approach ensures representative sampling of the different physical and floristic features of the community and is called stratified random sampling. Once the sampling is completed, the data from all quadrats are added together and are considered to constitute an adequate sample of the community (Baxter 2014).

Plots were laid in all the land uses, the number of plots differed in different land uses/classes (Table 5.7). The land uses of the study area include Agriculture, built-up, forest, open scrub and wetland. Of these, forest accounted for maximum area cover (2890.45 ha) by 28.6% of land use/land cover of Main Pipe Conveyor (MPC) area in 2km buffer, followed by agriculture by 23.6%, open scrubland by 22.2%, built-up by 20.5% and water bodies by 4.5%.

Table 5.1. Quadrat size and shape.

Habit	Dimensions	Area (m^2)
Forest floor Herb	1 x 1 m	1
Shrub/Climbers	5 x 5 m	25
Forest/Tree	20 x 20 m	400

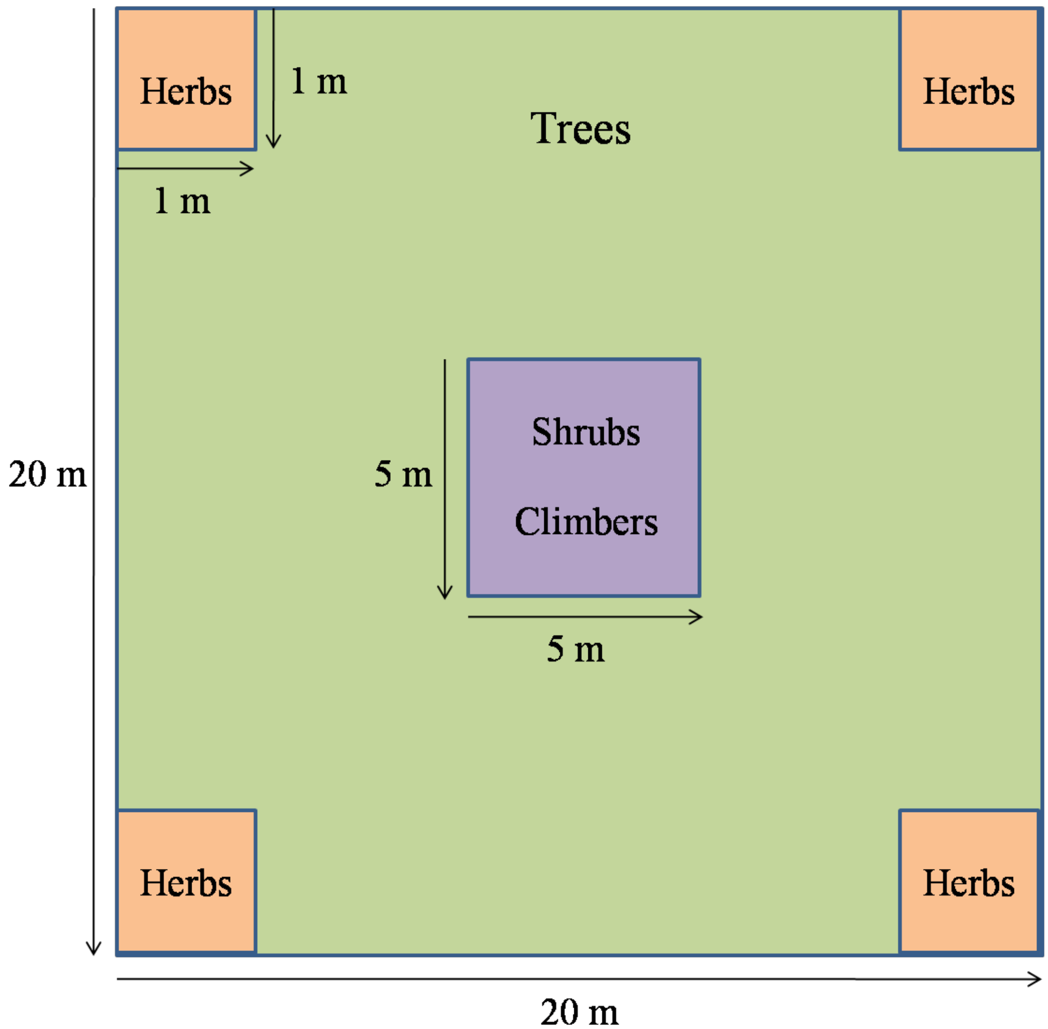


Figure 5.1. Design of quadrats in 20×20 m plot.

Pre-measured (20×20 m) rope is used to lay quadrate plot. The tree species inside the plot along with their regeneration was recorded. Girth at Breast Height (GBH) was measured using Freemans 20 m Measuring tape. Further, to quantify shrubs and climbers, 5×5 m quadrats were laid inside 20×20 m plot while 1×1 m quadrat was used for quantification of herbs (Figure 5.1). The data was collected using the format mentioned in the table 2.

Table 5.2. Data sheet format.

Quadrat /Plot number	Sub – quadrat number	Name of the species	Habit	Stem (S,D,T,F)	Counts (Number of individuals)	GBH (cm)	Remarks

(*S= Single, D=Double, T=Three, F=Four)

To check the differences in stand structure of vegetation, both MPC area (considered as noise impacted site) and undisturbed natural habitat (considered as control site) were sampled through quadrat method. A total of 35 quadrat (1.4 ha) was laid in MPC area while 10 quadrat (0.4 ha) was laid in control site randomly. The quadrats laid for control were at a distance beyond 500 m from MPC in forest and open scrub habitat.

Frequency, Abundance, Density, IVI, FIV, Basal area

The collected data were quantitatively analysed for frequency, abundance and density (Curtis and Mcintosh, 1950). Frequency denotes the homogeneity of distribution of various species in an ecosystem. The high frequency of a species indicates the high scale of repeated occurrence in a unit area/ecosystem.

Abundance of a species is determined as the occurrence of number of individuals per quadrat while density is defined as the number of individuals of a species in a unit area/ecosystem. The density of a species is an expression of the numerical strength of a species in a community.

The relative values of frequency, abundance and density were determined as per Philips (1959). Important Value Index (IVI), Family Importance Value (FIV) basal area was estimated only for tree species having Diameter at Breast Height (DBH) greater than 10cm.

Size class distribution

The size class distribution of all the individuals will provide an understanding of the structure of the forest community. The percent individuals in size classes 0-4.99 cm, 5-9.99 cm, 10-14.99 cm, 15-19.99 cm, 20-24.99 cm, 25-29.99 cm and >30 cm of DBH will be plotted against the percent basal area to obtain the Size class Vs Basal area graph. This will allow us to understand the nature of the forest in terms of its regeneration potential and the basal area.

Above Ground Biomass (AGB) and Carbon content

Above ground biomass (AGB) estimation is very important in assessing the carbon stored in a forest. Various methods of estimating biomass are available viz., Direct (Destructive) methods or Indirect (Non-destructive) methods. In case of the indirect/non-destructive method, the calculation of biomass is usually estimated using the values of DBH and height; where height is not available, biomass can be calculated by using only the DBH and is based on the type of vegetation. The estimation of the AGB is as per the regression equations of Chave et al.(2005) for dry deciduous forests. The carbon content of vegetation is constant over a wide variety of tissue types and species. The Food and Agriculture Organization (FAO) report on forestry

(Magnussen and Reed 2004) implies that the carbon content of biomass is almost always found to be between 45 and 50%. In our calculations the carbon content has been taken as 50% of the biomass. This allows us to estimate the carbon stored in the forest and the importance of these ecosystems for carbon storage and sequestration.

Diversity and dominance indices

For calculating diversity and dominance index of an area, only Shannon-weiner diversity index (Shannon and Weiner 1963) and Simpson dominance index (Simpson 1949) were taken into consideration using PAST (PAleontological STatistics) program. The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled.The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity.

Community similarity indices

To check the scale of community (MPC and Control site) similarities, Sorenson's and Jaccard coefficient index was used. Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common. Complete community overlap is equal to 1. Complete community dissimilarity is equal to 0. Jaccard index gives a percentage value for community similarity and by the obtained value, one can authentically portray how much of percentage similarity is there between two communities.

Table 5.3. Efforts put for the study

Particulars	Count
Number of Manpower involved	3
Number of working days	74
Number of field hours	1,332

Table 5.4. Calculating quantitative structure and composition of plant communities.

Parameters	Formula adopted	Analysis platform
Frequency (%)	(Total no. of quadrats in which species occurred / Total no. of quadrats studied) × 100	Microsoft Excel
Abundance	Total no. of individuals of a species / Total no. of quadrats in which species occurred.	Microsoft Excel
Density	Total Number of individuals of species occurring / Total number of quadrats studied.	Microsoft Excel
Relative density	(Density of a species / Sum of density of all the species) × 100	Microsoft Excel
Relative frequency	(Frequency of a species / Sum of frequency of all the species) × 100	Microsoft Excel
Basal area (m^2)	$(GBH)^2 / 4\pi$	Microsoft Excel
Relative basal area	(Total basal area of individuals / Total basal area of all the species) × 100	Microsoft Excel
Dominance	Basal area / Total area sampled	Microsoft Excel
Relative dominance	(Dominance of a species / Total dominance of all species) × 100	Microsoft Excel
Important value Index (IVI)	Relative density + Relative frequency + Relative dominance	Microsoft Excel
Family relative density (%)	(Number of trees in a family / total number of trees) × 100	Microsoft Excel
Family relative diversity (%)	(Number of species in a family / Total number of species) × 100	Microsoft Excel
Family relative dominance (%)	(Total basal area of all species in a family / Total basal area of all families) × 100	Microsoft Excel
Family Importance Value (FIV)	Σ of family relative density, diversity and dominance	Microsoft Excel
Simpson dominance index (SDI)	$1/\sum_{i=1}^{s} p_i^2$ (Where, **p** is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is the sum of the calculations, and **s** is the number of species)	PAST software
Shannon-Wiener's index	$-\sum_{i=1}^{s} p_i \ln p_i$ (Where, pis the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), lnis the natural log, Σ is the sum of the calculations, and **s** is the number of species)	PAST software
Sorenson's Coefficient (CC)	$2C / S_1+S_2$ (Where, C is the number of species of which two communities have in common S_1 is the total number of species found in community 1, S_2 is the total number of species found in community 2)	Microsoft Excel
Jaccard similarity Coefficient	(Number of common species in two communities / Number of total species) × 100	PAST software

Table 5.5. Materials used for the vegetation study.

SL. NO.	Materials	Quantity	Purpose
1	Boat ropes (20×20, 5×5 & 1×1)	1	To lay the measurements of the plots
2	Freemans 20 m Measuring tape	1	Measurements
3	Meter sticks	5	For accurate measurements
4	Clipboard	5	Used to hold data sheets in the field
5	Tent stakes	8	To tie rope
6	Pencils, pens, eraser, whitener, Gum tapes, Data sheets.	-	For data entry

Table 5.6. Electronic equipment used for the study.

SL. No.	Electronic equipment/Company/Model	Purpose
1	GPS device (Garmin etrex 10)	To record Latitude and longitude of the quadrate laid
2	DSLR Camera (Canon 1200D)	To record photographic evidences
3	Digital Altimeter	To record altitude of the quadrate laid
4	Noise meter	To record sound pressure level (dB)

Table 5.7. Location details of vegetation sampling points of MPC area.

Land use	Plot no.	Grid no.	Location	GPS Coordinates
Agriculture	P1	5	Nandihalli	N 15.051650° E 76.567800°
	P8	37	Bannihatti	N15.13534°E76.61923°
	P17	18	Bhujanganagara	N 15.097216° E 76.575683°
	P25	37	Tharanagara	N 15.129500° E 76.614662°
	P26	37	Tharanagara	N 15.132098° E 76.616379°
Built up	P9	42	BTP Junction	N15.145168°E76.625011°
	P13	54	Inside JSW	N 15.157690° E 76.644130°
	P15	57	Inside JSW	N 15.165420° E 76.675480°
	P27	42	BTP Junction	N 15.140616° E 76.623464°
	P35	17	Bhujanganagara	N 15.090794° E 76.568409°
Forest	P3	11	Devdari Junction	N 15.0689950°E 76.562310°
	P4	22	Bheemagandi tunnel	N 15.106050° E 76.585390°
	P5	29	Kothappana kolla	N 15.111450° E 76.602230°
	P7	33	Tharanagara	N15.123120°E76.609261°
	P16	29	Kothappana Kolla	N 15.111450° E 76.602230°
	P30	23	Shankarapura	N 15.106458° E 76.590230°
	P31	23	Shankarapura	N 15.107560° E 76.591840°
	P32	28	Shankarapura	N 15.111050° E 76.593390°

	P33	29	Shankarapura	N 15.111360° E 76.600170°
	P34	14	Devdari Junction	N 15.081350° E 76.562370°
Open scrub	P2	8	Thayamma temple	N 15.060000° E 76.564650°
	P10	46	Bannihatti	N 15.153100° E 76.631560°
	P11	46	Bannihatti	N 15.157526° E 76.634667°
	P12	53	Bannihatti	N 15.158340° E 76.636374°
	P18	46	Bannihatti	N 15.157400° E 76.635130°
	P19	46	Bannihatti	N 15.157016° E 76.634728°
	P20	53	Bannihatti	N 15.158617° E 76.636051°
	P21	53	Bannihatti	N 15.158365° E 76.638114°
	P22	46	Bannihatti	N 15.156156° E 76.633859°
	P23	46	Bannihatti	N 15.155270° E 76.633010°
Wetland	P6	33	Narihalla	N15.113310°E76.604460°
	P14	55	Inside JSW	N 15.160720° E 76.656950°
	P24	55	Inside JSW	N 15.159750° E 76.655300°
	P28	29	Shankharapura	N 15.113400° E 76.603370°
	P29	22	Jaffer Mines	N 15.103224° E 76.580434°

Table 5.8. Location details of vegetation sampling stations of Control area.

Land use	Plot no.	Grid no.	Location	GPS Coordinates
Forest	CP1	11		N 15.100220° E 76.583330°
	CP4	7	Bannihatti	N 15.078160° E 76.567710°
	CP5	16		N 15.111880° E 76.609160°
	CP6	12		N 15.108020° E 76.605620°
	CP10	16		N 15.122560° E 76.602490°
Open scrub	CP2	25		N 15.152550° E 76.637060°
	CP3	20		N 15.148760° E 76.638210°
	CP7	25	Narihalli	N 15.162640° E 76.627620°
	CP8	20		N 15.146480° E 76.633740°
	CP9	26		N 15.151520° E 76.659210°

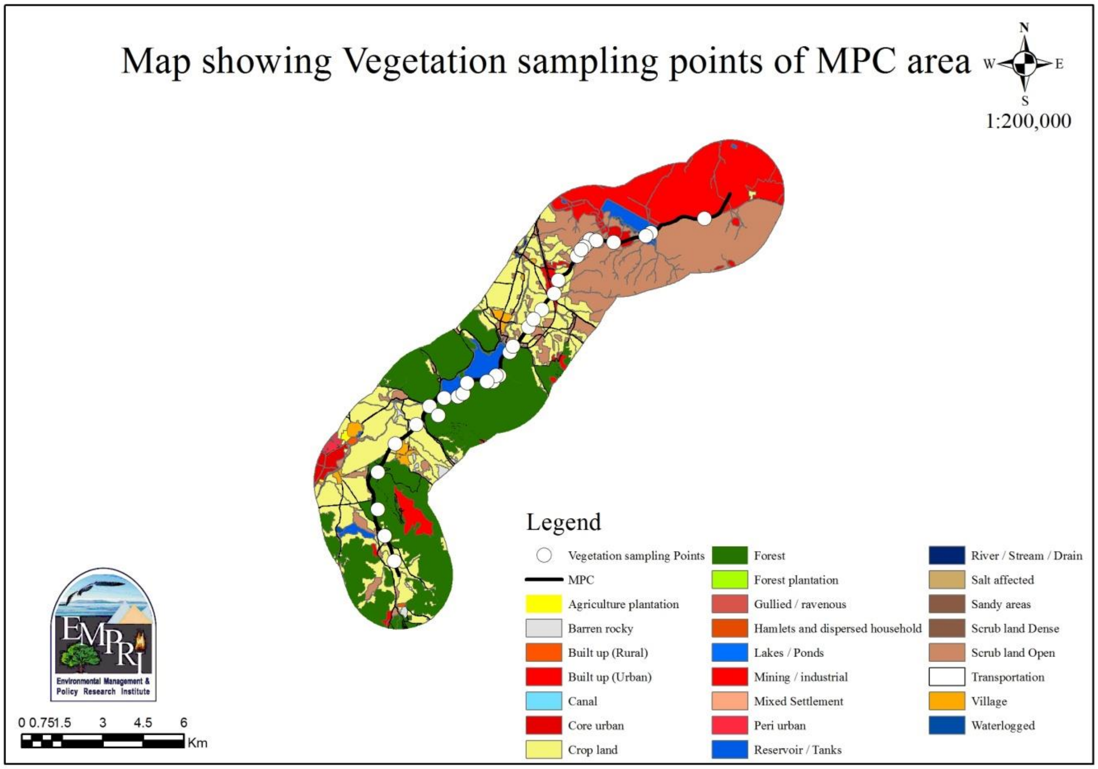


Figure 5.2. Vegetation sampling points of MPC area.

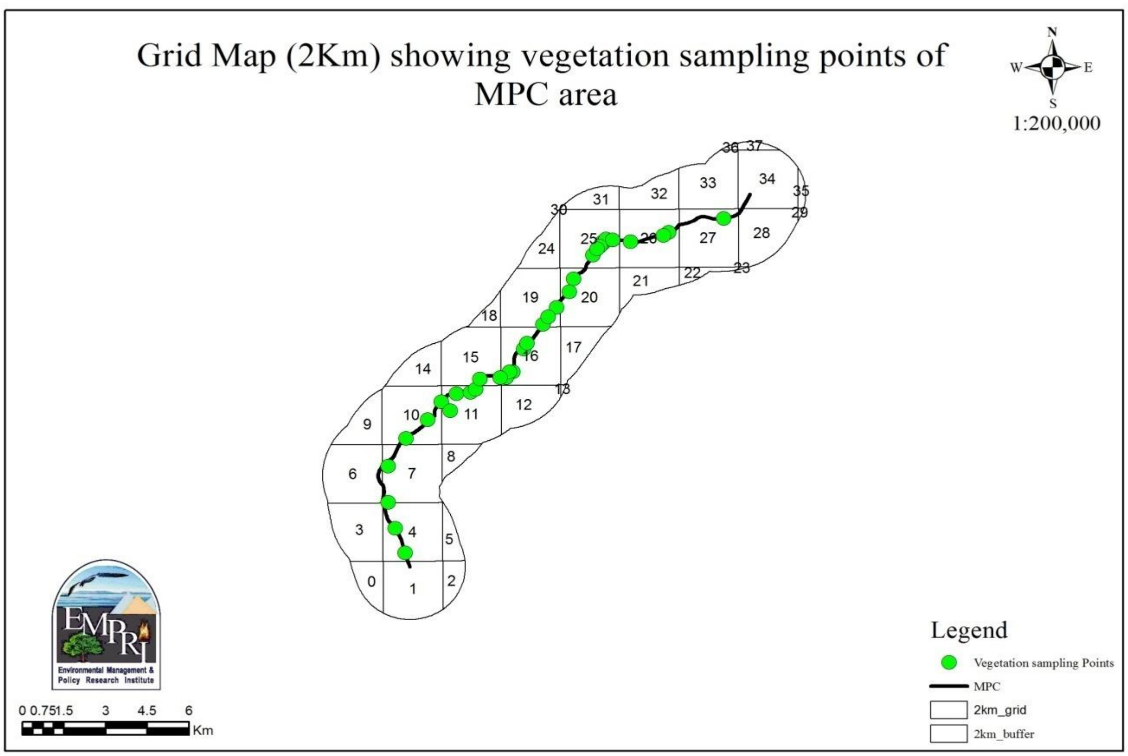


Figure 5.3. Vegetation sampling points of MPC area under 2km grid.

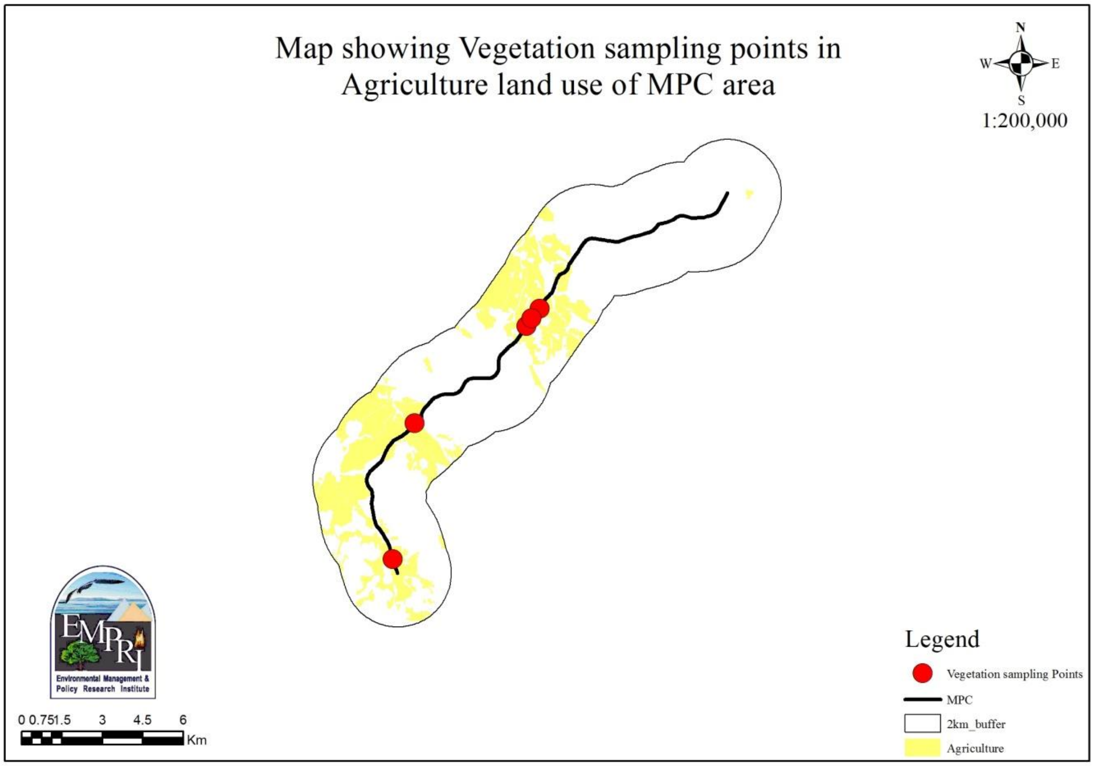


Figure 5.4. Vegetation sampling points of MPC area in agricultural land use.

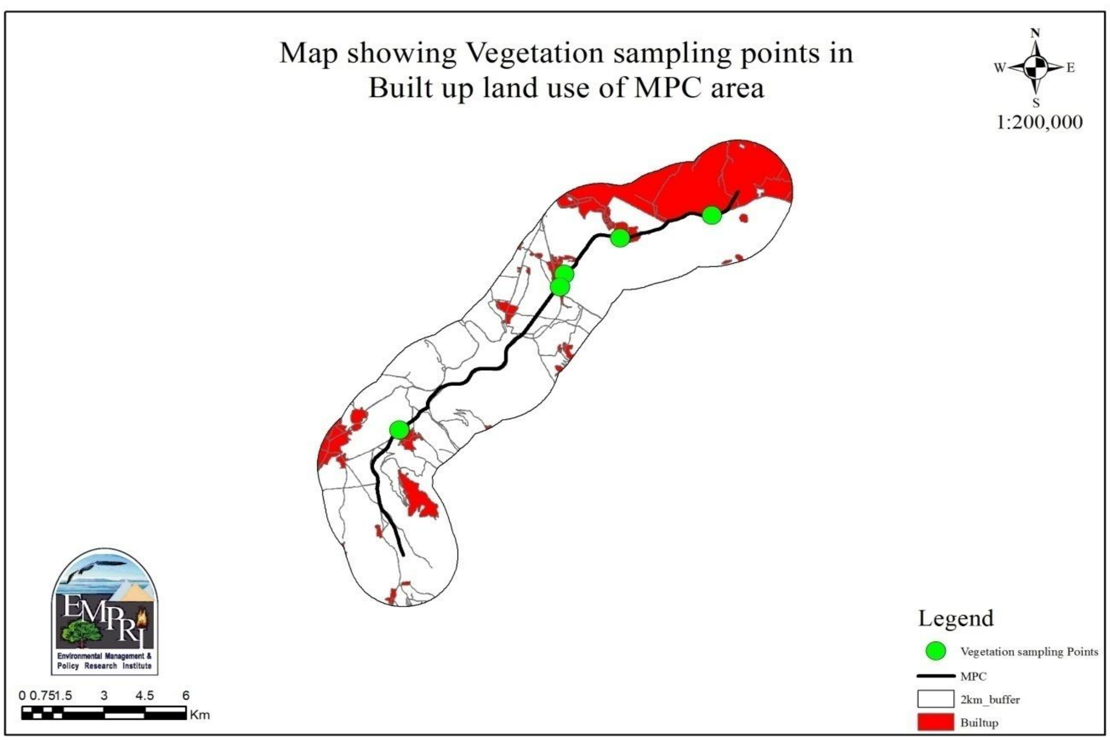


Figure 5.5. Vegetation sampling points of MPC area in built up land use.

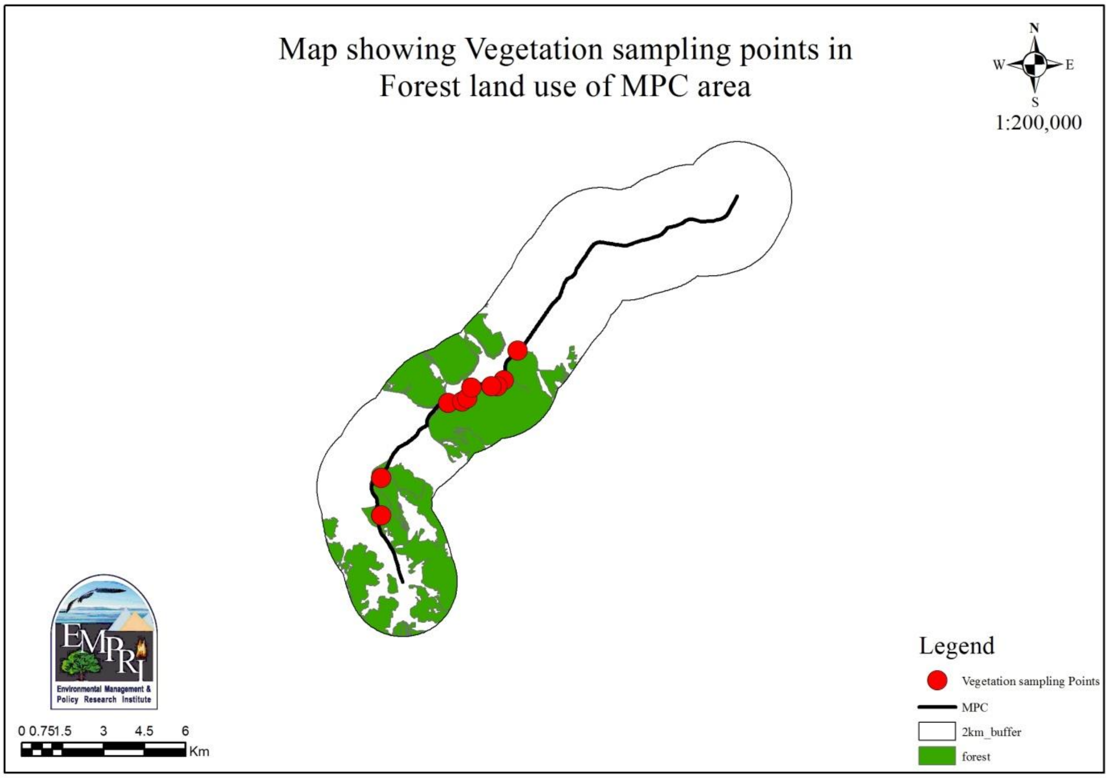


Figure 5.6. Vegetation sampling points of MPC area in forest land cover.

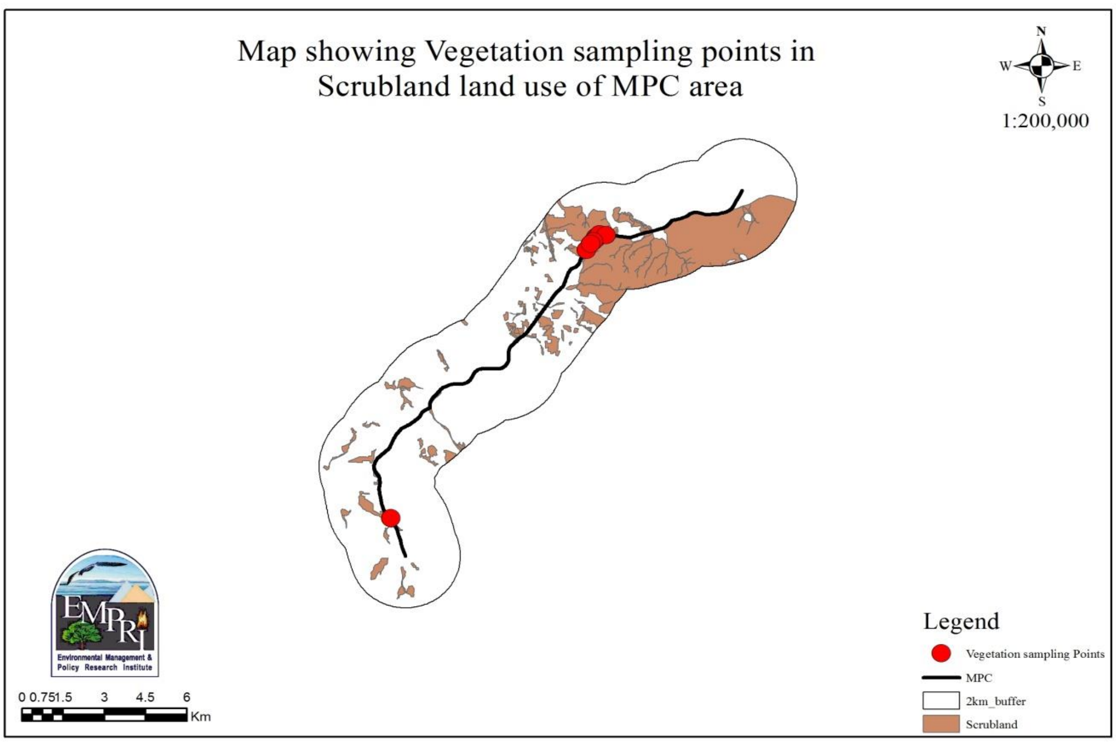


Figure 5.7. Vegetation sampling points of MPC area in open scrub land cover.

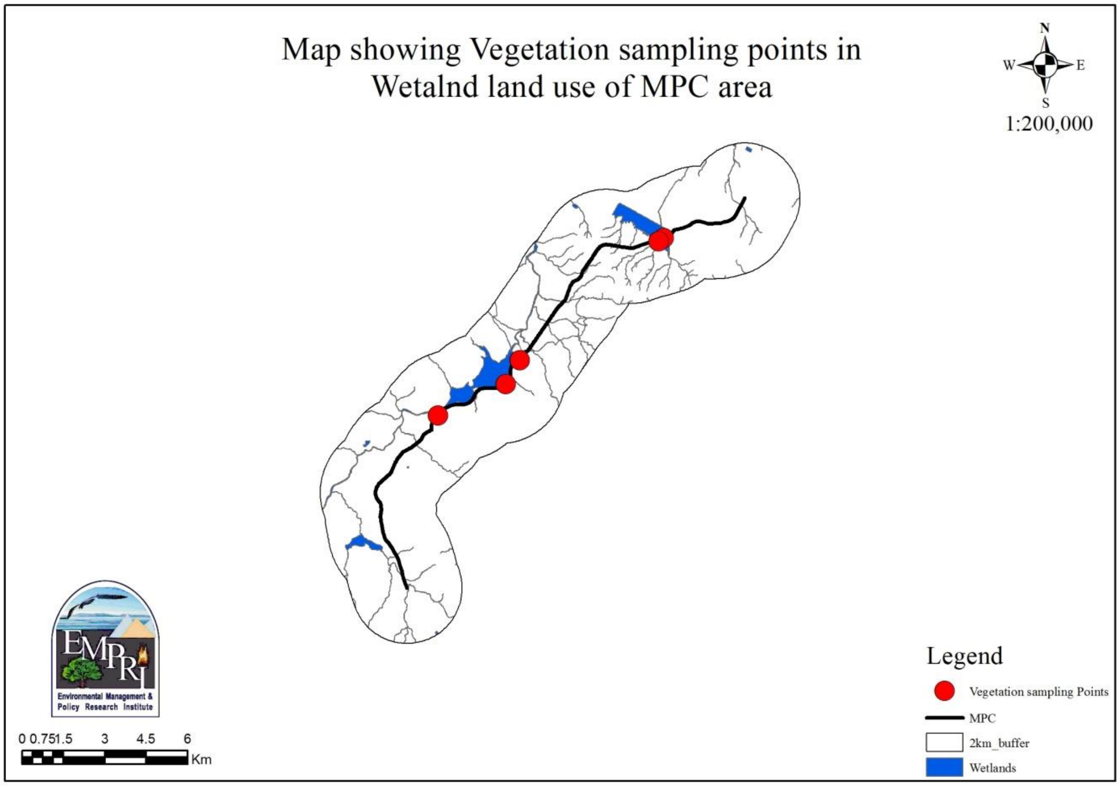


Figure 5.8. Vegetation sampling points of MPC area in wetland land cover.

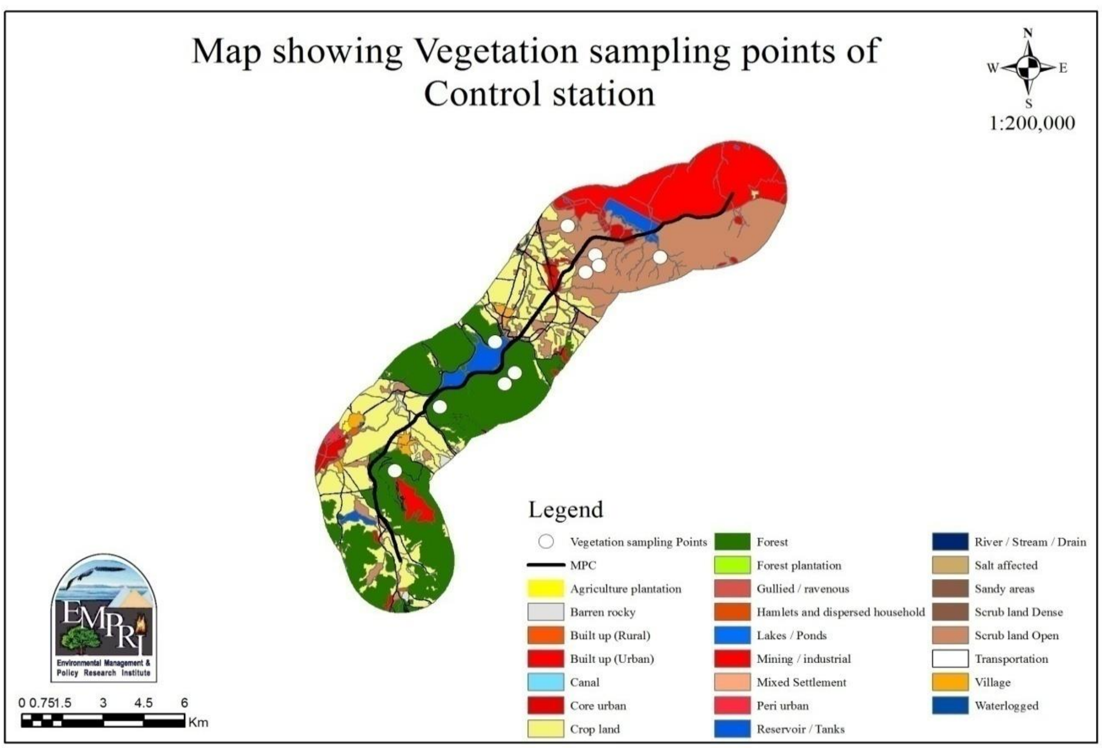


Figure 5.9. Vegetation sampling points of control site.

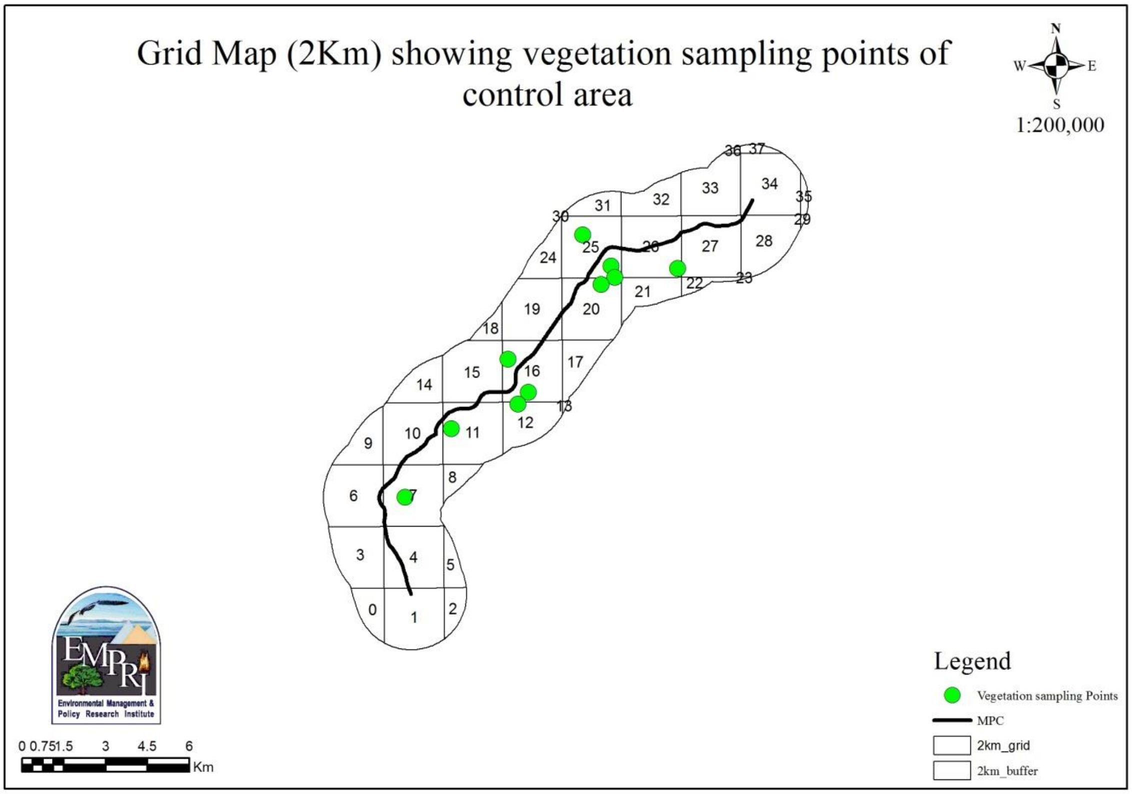


Figure 5.10. Vegetation sampling points of control site under 2km grid.

Results

Community structure

A total of 217 species of flowering plants in 167 genera belonging to 54 different families were recorded in the study area. The detailed checklist of recorded plant species and their occurrence in MPC and control site is given in the Annexure 5.1. A total of 4502 individuals were recorded from 35 quadrat plots (1.4 ha) in MPC area while 1300 individuals were recorded from 10 quadrat plots (0.4 ha) of control area. Among the tree species, *Prosopis juliflora* accounted for the maximum number of individuals (n=175) followed by *Morinda coreia* (n=108) and *Senegalia chundra* (n=107) in MPC area. While in the control area, *Grewia orbiculata*, an endemic species of Peninsular India accounted for the maximum number of individuals (n=101) followed by *Senegalia chundra* (n=92) and *Wrightia tinctoria* (n=54). However, *Senegalia chundra* (IVI - 44.78) was the dominant tree species followed by *Morinda coreia* (IVI - 32.63), *Grewia orbiculata* (IVI - 25.65) and *Albizia amara* (IVI - 24.43) in MPC area (Table 5.15). While in the control area, *Soymida febrifuga* (IVI - 33.26) is the dominant tree species followed by *Grewia orbiculata* (IVI - 31.43), *Albizia amara* (IVI - 29.56) and *Wrightia tinctoria* (IVI 29.15) (Table 5.16). The Shannon-Wiener index of the diversity of tree species in MPC area was 2.86 while in control area, it is 2.51 (Table 5.9). The presence of planted tree species in MPC area has driven up index in MPC area. The mean stand density was 268.57 individuals/ha while it is 767.5 individuals/ha in control site (Table 5.9). The habit wise contribution of genera, species and families by MPC and control area is portrayed in the table 5.9.

The widely used medicinal plants recorded in the study area are *Bacopa monnieri, Boerhavia diffusa*, *Cryptolepis buchananii, Eclipta prostrate, Hemidesmus indicus, Hybanthus enneaspermus,* and *Wrightia tinctoria,* while *Allium cepa*, *Capsicum spp*., *Zea mays* are the major crop along MPC area.

Table 5.9. Comparison of community structure of plant species in MPC area and control site.

Species composition variables	Value	
	MPC area	**Control site**
Herbs		
No. of species	58	31
No. of genus	47	27
No. of family	22	15
Density (individual/m^2)	15.50	15.65
Shannon-Wiener Diversity Index	3.173	2.526
Simpson Dominance Index	0.9321	0.8785
Under shrubs		
No. of species	6	2
No. of genus	6	2
No. of family	5	2
Density (individual/m^2)	2.4	0.25
Shannon-Wiener Diversity Index	0.5359	0.6931
Simpson Dominance Index	0.2171	0.5
Climbers		
No. of species	24	9
No. of genus	23	8
No. of family	10	5
Density (individual/m^2)	0.2	0.204
Shannon-Wiener Diversity Index	2.535	1.709
Simpson Dominance Index	0.8823	0.7559
Shrubs		
No. of species	25	13
No. of genus	22	12
No. of family	13	11
Density (individual/m^2)	0.753	0.352
Shannon-Wiener Diversity Index	2.586	2.287
Simpson Dominance Index	0.8996	0.8807
Trees (>10cm)		
No. of species	38	20
No. of genus	31	18
No. of family	16	12
Density (individual/ha)	268.57	767.5
Basal area (m^2/ha)	3.19	6.56
Carbon content (Tonnes/ha)	9.35	17.49
Shannon-Wiener Diversity Index	2.869	2.511
Simpson Dominance Index	0.9128	0.8992

Herbs are the dominant habit type recorded in both MPC and control sites. Among herbs, *Senna tora* accounted for the maximum number of individuals (n=409) followed by *Tridax procumbens* (n=158) and *Alternanthera tenella* (n=135) in MPC area while in control area, a native grass species *Cymbopogon martini* accounted for the maximum number of individuals (n=125) followed by *Indigofera cordifolia* (n=88), *Senna tora* (n=67) and *Urochloa panicoides* (n=27). Both, *Cymbopogon martini* & *Urochloa panicoides* are native grass species signifying undisturbed open scrub while in MPC area, the dominant herbs indicating physically disturbed edaphic factors. Among shrubs in MPC area, *Lantana camara* var. *aculeate*, an invasive species accounted for the maximum number of individuals (n=113) followed by *Chromolaena odorata* (n=99), *Hyptis suaveolens* (n=89) and *Dodonaea viscosa* (n=66) while in control sites, *Dodonaea viscosa* accounted for maximum number of individuals (n=18) followed by *Hyptis suaveolens* (n=13) and *Gymnosporia montana* (n=10). The mean stand density was 0.753 individualsm^{-2} in MPC area which is greater than the mean stand density in control area (0.352 individualsm^{-2}) which is because of abundant growth of invasive species like *Lantana camara* var. *aculeata* and *Chromolaena odorata* along MPC area. The habit wise comparison depicts the dominance of herbs in both MPC and control sites (Figure 5.11). In control site, native herb species from Fabaceae, Acanthaceae and Poaceae had driven herb community to top of the list.

Fabaceae is the dominant family with 33 species in 26 genera and was followed by Poaceae (13 species in 12 genera), Apocynaceae (12 species in 11 genera) & Malvaceae (9 species in 6 genera) in MPC area (Figure 5.12). In control area, Fabaceae accounts for dominant family (16 species in 12 genera) which was followed by Apocynaceae (6 species in 6 genera) and Acanthaceae (5 species in 3 genera).

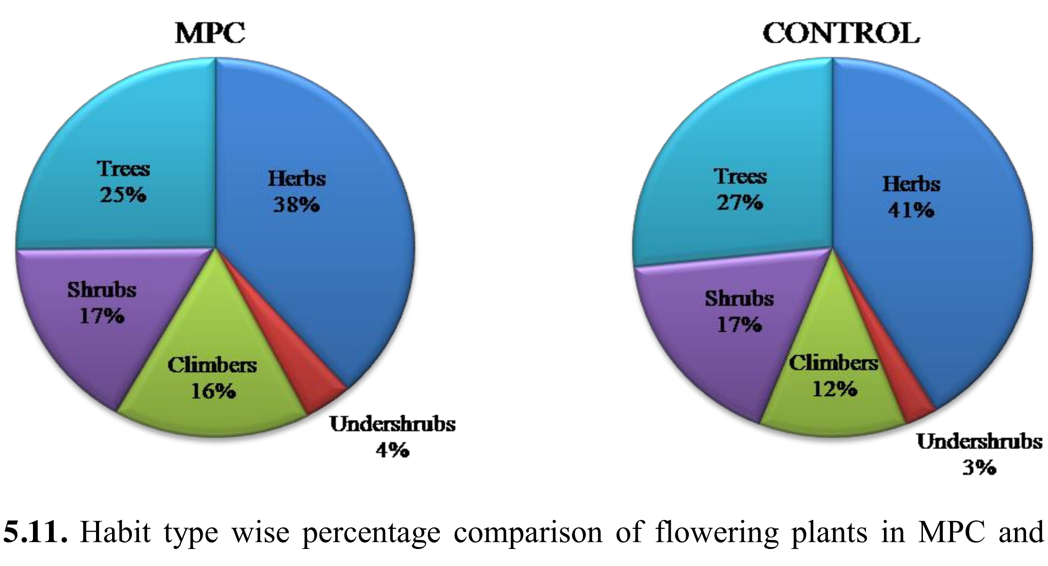


Figure 5.11. Habit type wise percentage comparison of flowering plants in MPC and control sites.

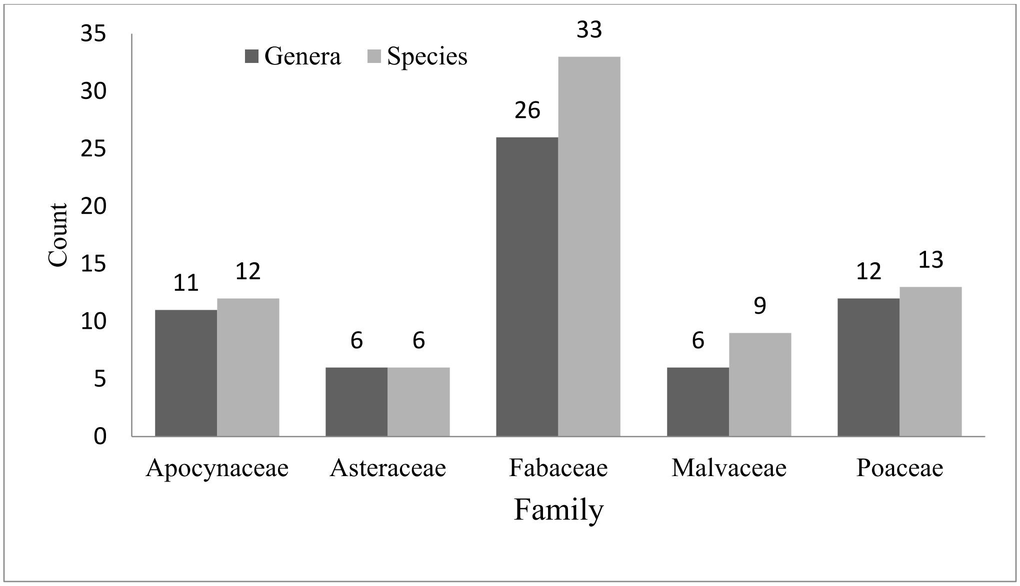


Figure 5.12. Genera and species contribution of five dominant families of MPC area.

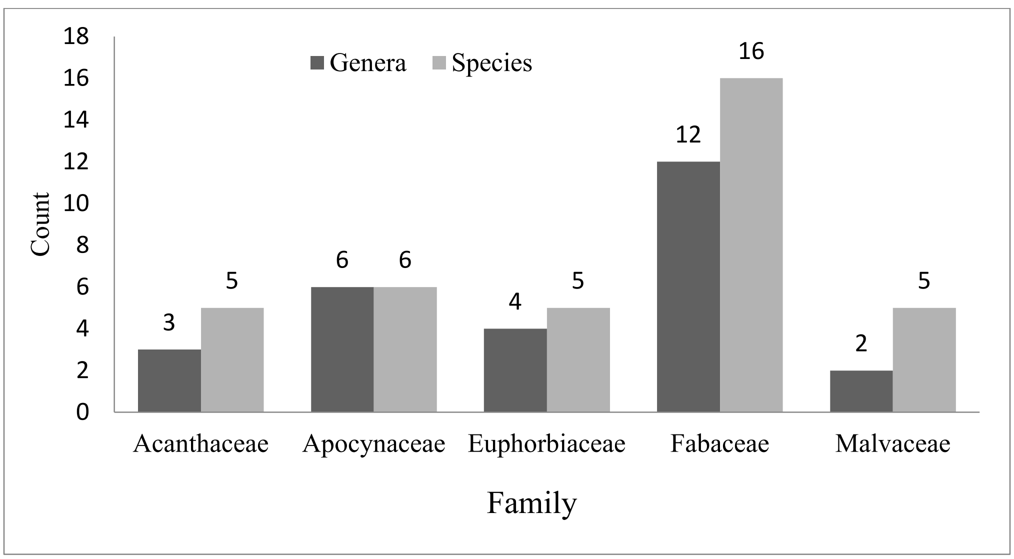


Figure 5.13. Genera and species contribution of five dominant families of Control site.

Invasive species infestation

Major invasive species recorded in the MPC area are *Argemone mexicana*, *Lantana camara* var. *aculeata*, *Parthenium hysteroph*orus, *Prosopis juliflora* and *Tridax procumbens*. The diversity, frequency and abundance of these invasive species are more in the MPC area when compared to natural habitat which remained undisturbed (Table 5.10). Among them, *Lantana camara* var. *aculeate* and *Parthenium hysteroph*orus are most frequently found invasive species along the stretch. *Prosopis juliflora* accounted for the maximum number of individuals (including regeneration). *Parthenium hysteroph*orus is a high density invasive species along MPC stretch while *Argemone Mexicana* accounted for least density. The forest land use has infested with high density of *Lantana camara* var. *aculeata* and *Chromolaena odorata* while built up and agricultural land has majorly infested with *Parthenium hysteroph*orus and *Tridax procumbens*. Like invasive species, a native species such as *Senna tora* and *Hyptis suaveolens* is also colonizing the MPC stretch indicating opened forest canopy.

Table 5.10. Comparison of Frequency (%), Abundance and Density of invasive species in MPC and control sites.

Botanical name	MPC area			Control		
	F (%)	A	D	F (%)	A	D
Argemone mexicana	8.57	7.67	0.66	-	-	-
Croton bonplandianus	22.86	6.63	1.51	20	4	0.8
Parthenium hysterophorus	45.71	18.38	8.40	20	2.5	0.5
Lantana camara var. *aculeata*	45.71	7.06	3.23	50	1.8	0.9
Prosopis juliflora	37.14	13.46	5.00	-	-	-
Chromolaena odorata	20.00	14.14	2.83	10	1	0.1
Tridax procumbens	31.43	14.36	4.51	20	5.5	1.1

Endemic and threatened species

Cleome felina of Capparaceae, *Cymbopogon martini* of Poaceae, *Dolichandrone atrovirens* of Bignoniaceae, *Hardwickia binata* of Fabaceae, *Gardenia gummifera* of Rubiaceae, *Grewia orbiculata* of Malvaceae and *Striga densiflora* of Orobanchaceae are endemic species recorded in the study area.

Chloroxylon swietenia of Rutaceae, *Dalbergia latifolia* of Fabaceae and *Santalum album* of Santalaceae are threatened species recorded in the study area. According to International Conservation of Nature and Natural resources (IUCN), these species falls under vulnerable class of threatened categories.

Table 5.11. Comparison of Frequency (%), Abundance and Density of endemic species in MPC and control sites.

Botanical name	MPC area			Control		
	F (%)	**A**	**D**	**F (%)**	**A**	**D**
Striga densiflora	14.29	1.40	0.20	20	2.5	0.5
Justicia glauca	-	-	-	10	1	0.1
Dolichandrone atrovirens	14.29	3.60	0.51	50	6	3
Dolichandrone falcata	-	-	-	10	1	0.1
Grewia orbiculata	51.43	5.50	2.83	90	11.22	2.83
Hardwickia binata	5.71	2.00	0.11	20	5	1

Diversity indices

In ecological studies, a diversity index is a general practice to disclose species richness and species evenness. The most common indices used are Shannon-Wiener and Simpson index. Shannon-wiener index is strongly influenced by species richness while Simpson depends on evenness and occurrence of common species. The higher the Shannon-wiener index in the community indicates higher diversity within it. The diversity indices for different land uses along MPC area is portrayed in the table 5.12. The forest habitat is accounted for maximum value of Shannon-wiener index followed by open scrub. The agricultural land has the least value of Shannon index indicating less diversified habitat among five land uses along the MPC stretch.

Table 5.12. Representation of diversity indices among five different land uses in the MPC area.

	Agricultural land	Built up	Forest	Open scrub	Wetland
Taxa_S	52	58	88	64	60
Individuals	743	893	1223	844	799
Dominance_D	0.092	0.063	0.030	0.062	0.067
Simpson_1-D	0.907	0.936	0.969	0.937	0.932
Shannon_H	2.903	3.247	3.828	3.384	3.173
Evenness_e^H/S	0.350	0.443	0.522	0.460	0.397

Basal area and size class distribution

The basal area cover of trees in MPC area is 3.19 m^2/ha from 376 individuals of 38 species while in the control area, it is 6.56 m^2/ha from 307 individuals of 20 species(Annexure 5.7). In MPC area, *Senegalia chundra* accounted for the maximum basal area cover (0.753 m^2/ha) by 70 individuals which was followed by *Dalbergia paniculata* (0.634 m^2/ha) by 16 individuals. In control area, *Albizia amara* accounted for maximum basal area cover (0.46m^2/ha) by only 15 individuals, followed by *Wrightia tinctoria* (0.36m^2/ha) by 21 individuals and *Terminalia anogeissiana* (0.355 m^2/ha) by 52 individuals. The invasive species *Prosopis juliflora* accounted for a basal area cover of 0.057m^2/ha by 11 individuals while in case of control site, it is absent. However, endemic species such as *Dolichandrone atrovirens, Grewia orbiculata* and *Hardwickia binata* accounted for a maximum basal area cover (Annexure 5.7) in control sites than in MPC area.

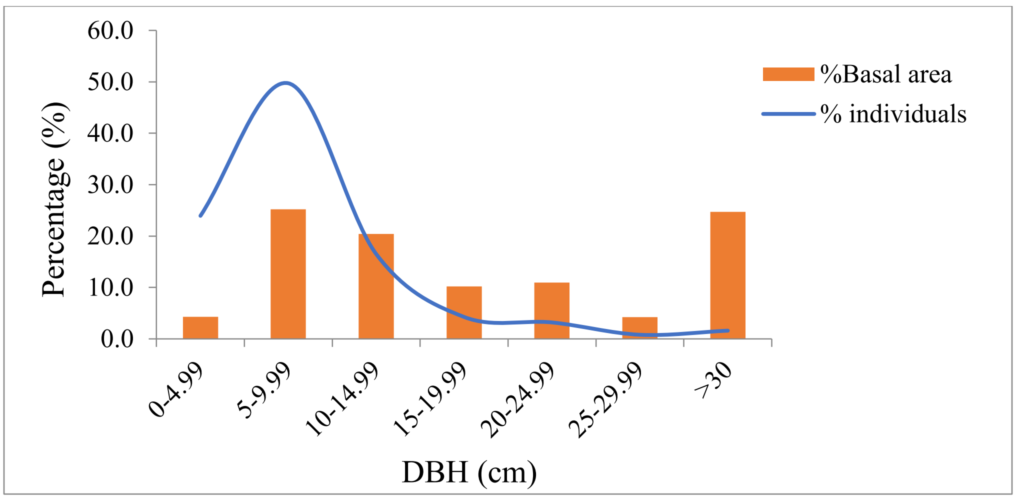


Figure 5.14. Size class distribution along MPC area in the perspective of percentage basal area and individuals.

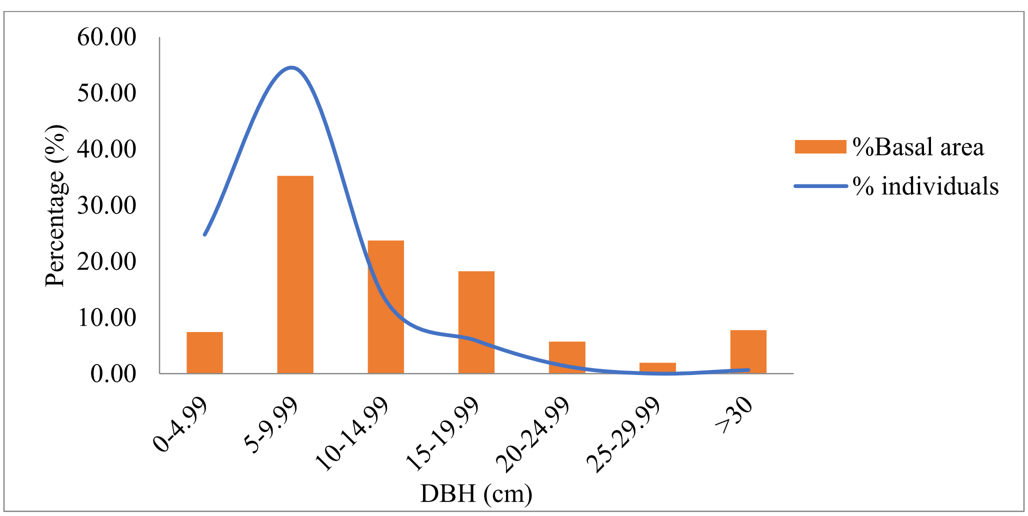


Figure 5.15. Size class distribution of control station in the perspective of percentage basal area and individuals.

Familial composition

The number of tree families in the MPC area was 16 where as in control sites, tree families were 12 (Table 5.13 & Table 5.14). Both in MPC and control area Fabaceae was the dominant family representing 15 species in MPC and 5 species in control sites. The Rubiaceae family represented by 3 species in MPC area was the second dominant family and was followed by Annonaceae, Combretaceae, Ebenaceae, Malvaceae, Rhamnaceae and Rutaceae representing 2 species. In control area, Bignoniaceae, Malvaceae, Meliaceae and Rubiaceae families had taken next dominant rank contributing 2 species.

At the genus level, the family Fabaceae was the dominant one with 13 genera & 5 genera in MPC area and control sites respectively. Based on density, family Fabaceae represents the highest number in MPC area with 1149 individuals from 33 species followed by Poaceae (n=592; 13 species), Asteraceae (n=572; 6 species) and Amaranthaceae (n=351; 5 species). In control sites, based on density, Fabaceae accounted for the highest number with 422 individuals from 16 species followed by Poaceae (n=303; 4 species), Malvaceae (n=116; 5species) and Apocynaceae (n=67; 6 species). The families Apocynaceae, Bignoniaceae, Boraginaceae, Lythraceae, Meliaceae, Moraceae, Ulmaceae and Zygophyllaceae are represented by single tree species in MPC area while in control sites Apocynaceae, Combretaceae, Ebenaceae, Euphorbiaceae, Lamiaceae, Rhamnaceae and Rutaceae are represented by single tree species.

The highest basal area recorded for the family Fabaceae (1.9 m^2/ha) followed by Rubiaceae (0.22m^2/ha) and Meliaceae (0.22m^2/ha) in MPC area (Table 5.13). In control sites, highest basal area (Table 5.14) recorded for the family Fabaceae (2.8m^2/ha) followed by Apocynaceae (0.9 m^2/ha) and Combretaceae (0.88 m^2/ha). Of these, Fabaceae was the densest family (25.52%), followed by Poaceae (13.14%) and Asteraceae (12.70%) in MPC area. In control area, Fabaceae was the densest family (32.41%), followed by Poaceae (23.30%), Malvaceae (8.92%) and Apocynaceae (5.15%). The family Fabaceae is the most diverse family (21.9%) in MPC area which was followed by Poaceae (8.61%) and Apocynaceae (7.95%). In control sites, the most diverse family is Fabaceae (21.3%), followed by Apocynaceae (8%).

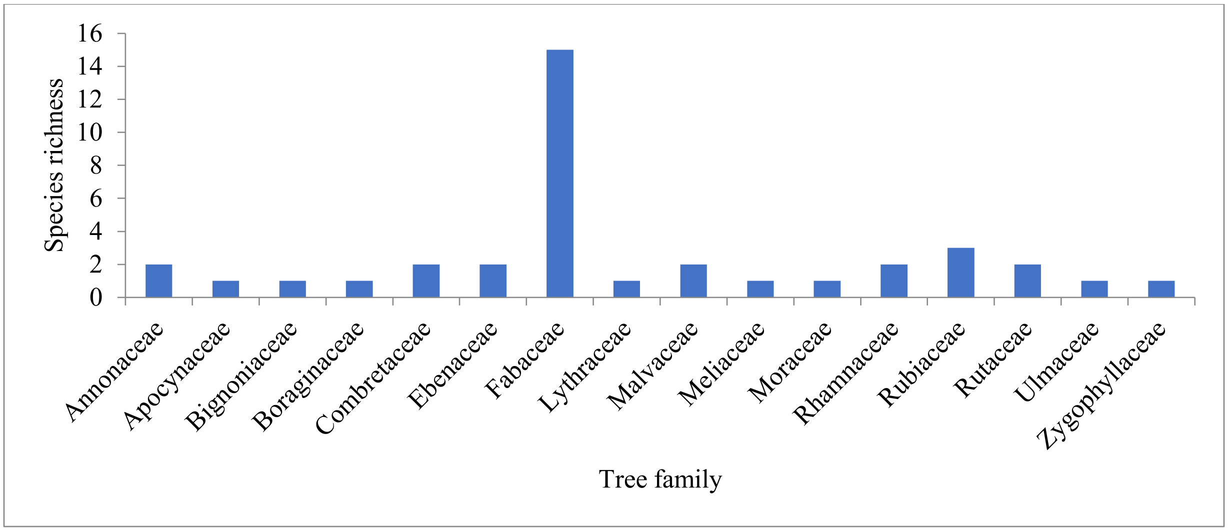


Figure 5.16. Species richness of tree families in MPC area.

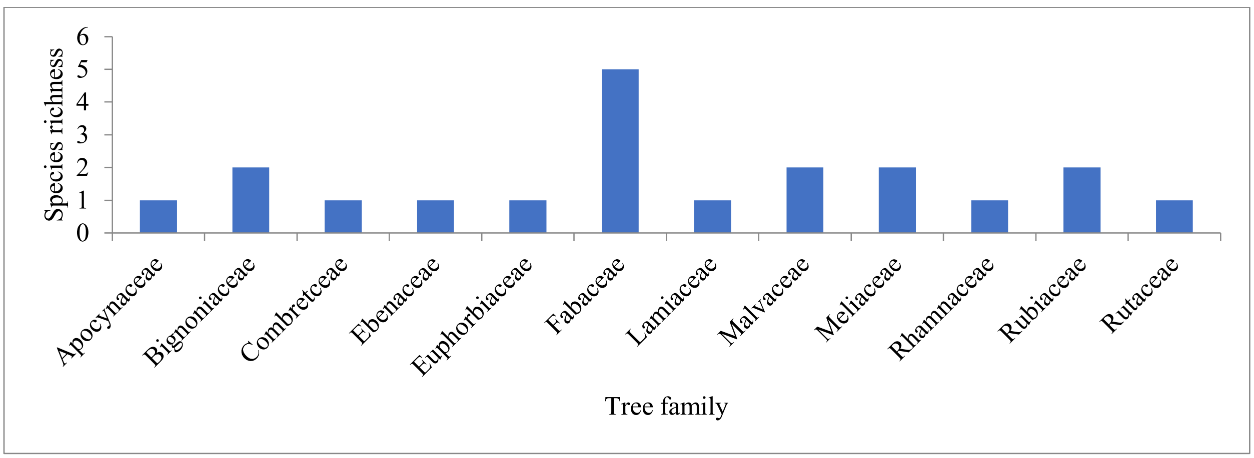


Figure 5.17. Species richness of tree families in Control sites.

Table 5.13. Contribution of tree families to species richness, genera richness, family relative density, family relative diversity, basal area, family relative dominance and family importance value (FIV) in MPC area.

Family	**Species richness**	**Generic diversity**	**No. of individuals**	**Basal area (m^2)**	**Family Relative density**	**Family Relative diversity**	**Family Relative dominance**	**FIV**
Annonaceae	2	2	12	0.08	3.19	5.26	1.85	10.30
Apocynaceae	1	1	7	0.20	1.86	2.63	4.41	8.91
Bignoniaceae	1	1	9	0.04	2.39	2.63	0.94	5.96
Boraginaceae	1	1	1	0.03	0.27	2.63	0.64	3.54

Combretaceae	2	1	5	0.03	1.33	5.26	0.74	7.34
Ebenaceae	2	1	19	0.07	5.05	5.26	1.65	11.96
Fabaceae	15	13	175	2.72	46.54	39.47	60.78	146.80
Lythraceae	1	1	3	0.01	0.80	2.63	0.19	3.62
Malvaceae	2	1	41	0.28	10.90	5.26	6.28	22.45
Meliaceae	1	1	10	0.31	2.66	2.63	7.05	12.34
Moraceae	1	1	2	0.06	0.53	2.63	1.27	4.43
Rhamnaceae	2	1	16	0.09	4.26	5.26	1.90	11.42
Rubiaceae	3	2	59	0.32	15.69	7.89	7.15	30.74
Rutaceae	2	2	14	0.21	3.72	5.26	4.69	13.68
Ulmaceae	1	1	2	0.01	0.53	2.63	0.26	3.43
Zygophyllaceae	1	1	1	0.01	0.27	2.63	0.17	3.07

Table 5.14. Contribution of tree families to species richness, genera richness, family relative density, family relative diversity, basal area, family relative dominance and family importance value (FIV) in control area.

Family	Species richness	Generic diversity	No. of individuals	Basal area (m^2)	Family Relative density	Family Relative diversity	Family Relative dominance	FIV
Apocynaceae	1	1	21	0.36	6.84	5	13.73	25.57
Bignoniaceae	2	1	19	0.11	6.18	10	4.54	20.73
Combretceae	1	1	35	0.35	11.40	5	13.53	29.93
Ebenaceae	1	1	6	0.034	1.95	5	1.31	8.269
Euphorbiaceae	1	1	3	0.050	0.97	5	1.93	7.91
Fabaceae	5	5	116	1.13	37.78	25	43.13	105.91
Lamiaceae	1	1	1	0.002	0.32	5	0.090	5.41
Malvaceae	2	1	52	0.35	16.93	10	13.45	40.39
Meliaceae	2	2	6	0.068	1.95	10	2.59	14.55

Rhamnaceae	1	1	4	0.007	1.30	5	0.27	6.57
Rubiaceae	2	2	22	0.072	7.16	10	2.76	19.93
Rutaceae	1	1	22	0.068	7.16	5	2.61	14.78

Table 5.15. Density and important value index of tree species in MPC area.

Tree species	**Family**	**TI**	**GBH**	**D**	**BA**	**Rel. BA**	**IVI**
Albizia amara (Roxb.) Boivin	Fabaceae	24	2028.8	0.68	0.52	11.68	24.43
Albizia lebbeck (L.) Benth.	Fabaceae	2	99	0.05	0.039	0.88	2.39
Annona squamosa L.	Annonaceae	2	41	0.05	0.004	0.11	1.62
Azadirachta indica A.Juss.	Meliaceae	10	551.3	0.28	0.31	7.05	14.61
Balanites roxburghii Planch.	Zygophyllaceae	1	44	0.02	0.007	0.17	0.93
Bauhinia racemosa Lam.	Fabaceae	1	48	0.02	0.018	0.41	1.66
Cassia fistula L.	Fabaceae	21	467.5	0.6	0.078	1.77	13.23
Chloroxylon swietenia DC.	Rutaceae	13	409.9	0.37	0.1	2.25	8.64
Cordia dichotoma G.Frost.	Boraginaceae	1	60	0.02	0.02	0.64	1.40
Dalbergia paniculata Roxb.	Fabaceae	17	967.8	0.48	0.63	14.19	22.15
Diospyros melanoxylon Roxb.	Ebenaceae	17	287.8	0.48	0.041	0.93	6.92
Diospyros montana Roxb.	Ebenaceae	2	84	0.05	0.032	0.72	2.72
Dolichandrone atrovirens (Roth) Sprague	Bignoniaceae	9	227.1	0.25	0.04	0.94	5.78
Ficus sp.	Moraceae	2	113.7	0.05	0.05	1.27	2.29
Grewia orbiculata Rottler	Malvaceae	40	1419.3	1.14	0.27	6.19	25.65
Grewia villosa Willd.	Malvaceae	1	40	0.02	0.004	0.10	1.34
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	2	65	0.05	0.011	0.26	1.29
Huberantha cerasoides (Roxb.) Chaowasku	Annonaceae	10	374.6	0.28	0.077	2.01	4.89
Ixora pavetta Andrews	Rubiaceae	1	16.4	0.02	0.002	0.05	2.27
Ixora sp	Rubiaceae	2	94.9	0.05	0.028	0.64	1.66
Lagerstroemia parviflora Roxb.	Lythraceae	3	55	0.08	0.008	0.19	1.97
Leucaena leucocephala (Lam.) de Wit	Fabaceae	4	97.3	0.11	0.016	0.38	3.40
Limonia acidissima L.	Rutaceae	1	117.2	0.02	0.109	2.45	3.20
Morinda coreia Buch.-Ham	Rubiaceae	56	1366	1.6	0.28	6.46	32.63

Parkinsonia aculeata L.	Fabaceae	2	45	0.05	0.009	0.22	1.24
Peltophorum pterocarpum (DC.) Backer ex K.Heyne	Fabaceae	4	94	0.11	0.019	0.44	1.99
Pongamia pinnata (L.) Pierre	Fabaceae	3	43	0.08	0.005	0.12	2.38
Prosopis juliflora (Sw.) DC.	Fabaceae	11	393	0.31	0.057	1.29	10.59
Senegalia chundra (Roxb. ex Rottler) Maslin	Fabaceae	70	2614.3	2	0.752	16.85	44.78
Senna surattensis (Burm. f.) H.S. Irwin & Barneby	Fabaceae	2	69	0.05	0.010	0.24	2.24
Tamarindus indica L.	Fabaceae	1	216	0.02	0.371	8.31	9.06
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	4	94	0.11	0.017	0.34	1.95
Terminalia alata Heyne ex Roth	Combretaceae	1	44	0.02	0.01	0.40	1.10
Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	Fabaceae	12	400.5	0.34	0.106	2.37	11.45
Vachellia nilotica (L.) P.J.H.Hurter & Mabb.	Fabaceae	1	96.2	0.02	0.073	1.65	2.40
Wrightia tinctoria (Roxb.) R.Br.	Apocynaceae	7	523.9	0.2	0.197	4.41	10.20
Ziziphus horrida Roth	Rhamnaceae	15	387	0.42	0.080	1.80	12.65
Ziziphus mauritiana Lam.	Rhamnaceae	1	24	0.02	0.004	0.10	0.86

Table 5.16. Density and important value index of tree species in control area.

Name of the species	**Family**	**TI**	**GBH**	**D**	**BA**	**Rel. BA**	**IVI**
Albizia amara (Roxb.) Boivin	Fabaceae	15	1159.1	1.5	0.460	17.53	29.56
Azadirachta indica A.Juss.	Meliaceae	35	1523	3.5	0.355	13.54	27.79
Cassia fistula L.	Fabaceae	4	86.4	0.4	0.015	0.58	11.88
Chloroxylon swietenia DC.	Rutaceae	12	297.9	1.2	0.059	2.25	10.45
Dalbergia paniculata Roxb.	Fabaceae	22	417.2	2.2	0.069	2.62	14.07
Diospyros melanoxylon Roxb.	Ebenaceae	27	657.9	2.7	0.136	5.20	15.42
Dolichandrone atrovirens (Roth) Sprague	Bignoniaceae	6	196.4	0.6	0.035	1.31	10.41
Dolichandrone falcata (Wall. ex DC.) Seem.	Bignoniaceae	18	452.2	1.8	0.088	3.34	10.63
Givotia moluccana (L.) Sreem.	Euphorbiaceae	1	63	0.1	0.032	1.20	2.96
Grewia tenax (Forssk.) Fiori	Malvaceae	3	132.4	0.3	0.051	1.94	15.77
Grewia orbiculata Rottler	Malvaceae	51	1708.6	5.1	0.351	13.39	31.43
Hardwickia binata Roxb.	Fabaceae	1	14.3	0.1	0.002	0.06	3.24

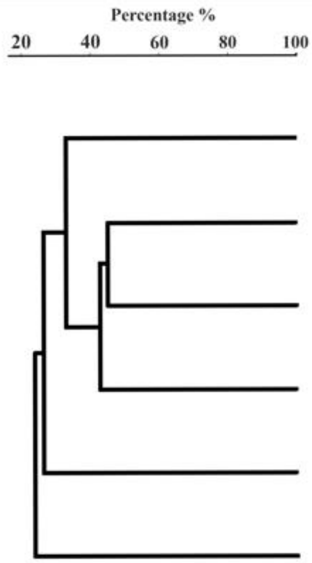
Ixora pavetta Andrews	Rubiaceae	10	345.2	1	0.123	4.69	9.37
Morinda coreia Buch.-Ham	Rubiaceae	1	67.8	0.1	0.012	0.47	9.37
Senegalia chundra (Roxb. ex Rottler) Maslin	Fabaceae	21	413.46	2.1	0.060	2.30	22.00
Soymida febrifuga (Roxb.) A.Juss.	Meliaceae	52	1676.9	5.2	0.353	13.46	33.26
Tectona grandis L.f.	Lamiaceae	2	146.9	0.2	0.053	2.01	4.09
Terminalia anogeissiana Gere & Boatwr.	Combretceae	1	17.3	0.1	0.002	0.09	1.85
Wrightia tinctoria (Roxb.) R.Br.	Apocynaceae	21	1345.3	2.1	0.361	13.74	29.15
Ziziphus horrida Roth	Rhamnaceae	4	59.5	0.4	0.007	0.27	7.29

Similarity indices

Jaccard index: The Jaccard index (Jaccard, 1901) is a well-known measurement of the similarity between two communities. It is defined as the size of the intersection divided by the size of the common species of the two communities. A good measure should be capable of differentiating high and low similarity of communities. In the present study, five different habitats along MPC area sampled for vegetation stand structure and that is compared with control station's sampling done 500m away from the MPC area in the natural habitat to portray the scale of similarity between two communities. The forest habitat of the MPC area and control sites accounted for high similarity (45%) followed by Open scrub of MPC area and control sites (44%) (Table. 5.17). Avery low similarity found between wetland and agriculture habitat(19%), Agriculture and control (21%) Agriculture and open scrub (22%), Wetland and control (24%). This pattern clearly projects the vegetation composition of forest and open scrub habitats along MPC are similar to control sites which need prior attention for conservation.

Sorenson's Coefficient (CC): The vegetation composition of five different habitats along MPC area is clubbed and compared it with control stations for checking Sorenson's similarity Coefficient. For the present study, the Sorenson's similarity coefficient is 0.48. The value is less than 0.5, which indicates low similarity of the two sets. The closer the value is to 1, the more the communities have in common. Complete community overlap is equal to 1. Complete community dissimilarity is equal to 0.

Table 5.17. Jaccard similarity index value and clustering sets.



	B	F	C	O	W	A
B		0.29	0.29	0.40	0.23	0.33
F	0.29		0.45	0.41	0.32	0.25
C	0.29	0.45		0.44	0.24	0.21
O	0.40	0.41	0.44		0.25	0.22
W	0.23	0.32	0.24	0.25		0.19
A	0.33	0.25	0.21	0.22	0.19	

B = **Built up**
F = **Forest**
C = **Control**
O = **Open scrub**
W = **Water bodies**
A = **Agriculture**

High similarity
Medium similarity
Low similarity

Discussion

Among the tree species, *Prosopis juliflora* accounted for the maximum number of individuals (n=175) and appears to be a dominant species in the MPC stretch. *Prosopis juliflora* is one of the 100 dominant invasive species and spreading at an alarming rate in tropical and sub-tropical areas of the World (Patnaik et al. 2017). Along with *Prosopis juliflora*, other invasive species like *Argemone mexicana*, *Lantana camara* var. *aculeate* and *Parthenium hysterophorus* abundantly covering the MPC stretch indicating disturbed forest canopy. As forest canopy opens, the opportunistic species occupies the area and dominate within a short span of time, there by suppressing native flora. The study by Kumar and Mathur (2014) in arid grasslands of Gujarat, India has discussed the adverse impacts of invasion of *Prosopis juliflora* on other plant communities with an evidence of decreased density of *Commiphora whitii* with the increasing density of *Prosopis juliflora*. The study by Mukherjee et al. (2017) in Keoladeo National Park (KNP), Bharatpur, Rajasthan, India reported the high invasibility of *Prosopis juliflora*. However, habitat specific faunal species associated to native vegetation also gets impacted due to the colonization of invasive species and struggle to adapt with the changing habitat which will ultimately lead to the local extinction of them.

With the dominance of invasive species, the habitat also tends to open up for their associated species suppressing previously present species community. The comparison of species dominance between MPC stretch and natural habitat (Control site) showed a significant outcome with a major gap in the richness, density and abundance of invasive species indicating disturbed vegetation structure along the stretch of MPC.

The mean stand density of shrubs was 0.753 individual m^{-2} in MPC area which is greater than the mean stand density in control area (0.352 individual m^{-2}). This is because of abundant growth of invasive species like *Lantana camara* var. *aculeata* and *Chromolaena odorata* along MPC area. These invasive species is thus dangerous because of its nature of colonizing neighbouring areas having native species. Bird species diversity and abundance were lower at high densities of *Lantana*. The foraging and microhabitat guilds of birds were impacted due to the increased density of *Lantana* in two different forest types of Male Mahadeshwara reserve forest, South India (Aravind et al. 2010).

The basal area cover by trees along MPC is half of the area covered by trees in control sites indicating the presence of lower number of tree species along MPC stretch. This confirms clearing of trees during the construction of MPC.

The amount of Carbon stored along MPC stretch is 9.35 tonnes/ha which is only a 50% of Carbon content stored in control area. In the perspective of climate change, trees are very important group which stores high carbon content comparatively. The tree layer of vegetation is cleared for constructions, making a highway for opportunistic invasive herb species. Hence, there is a record of more number of herb species along MPC stretch. The present study confirms a clear change in vegetation stand structure of MPC region with replacement of the native species over a period of time due to the construction of MPC.

The MPC stretch has five different habitats such as Agricultural land, Built up, Forest, Open scrubland and water bodies. The forest habitat accounted for maximum number of plant species, followed by open scrub and water bodies. The forest type is a southern mixed dry deciduous type associating mammals such as Leopard, Sloath Bear, Four Horned Antelope, Indian crested Porcupine, Jungle cat, Rusty-spotted cat, Small Indian civet and Asian palm civet, there by signifying the preference for forest conservation.

All organisms are involved in mutualistic and hostile interactions with other species (Thompson, 2009). The interactions between the species form a multifaceted structure of ecological communities and manage important ecosystem functions, such as pollination, seed dispersal or biological control. 'Eat and eaten by' principal has driven majority of interactions. There is a strong indication that the interaction between plants and insect pollinators is the chief driver of diversity in flowering plants and the insects involved in pollination (Simms, 2013). The coexistence of the species, plant-animal interactions has vast effect on plant and animal evolution. The selection by consumers has driven the evolution of numerous plant defence traits. For instance, the phyto-constituents are derived from plant evolutionary responses to consumers (Simms, 2013).

The benefit that plants obtain from animals is mobility. Many of the plants depend on animals to carry pollen, seeds. The larvae of butterflies need a particular plant species to feed on for stepping up into its next life cycle. The frugivores depended on edible fruit bearing plant species and in return plant gets benefit of spreading its distribution. In several cases, the interactions between plants and animal interactions are highly specialized and equally beneficial. These mutualisms may be highly vulnerable, which is a vital issue in both animal and plant conservation. Plant communities are not only the species of the area but provider of habitats for other faunal biodiversity. The small impact due to noise, vibrations on any animal may reflect in plant species composition as a chronic effect through various interrelations like pollination, seed dispersals, and pest infestation. This may ultimately lead to local extinction of native plant species which are specifically dependent on fauna for their range distribution. Hence, to assess the impacts induced by noise, vibrations on plant-animal relationship, a long term study is needed indeed.

The Narihalla forest patch and Bannihatti open scrub forest accounted for maximum number of forest native species diversity (refer chapter 4, Table 4.2). Hence, the two habitats along MPC stretch are identified as conservation significance area (Figure 5.18).

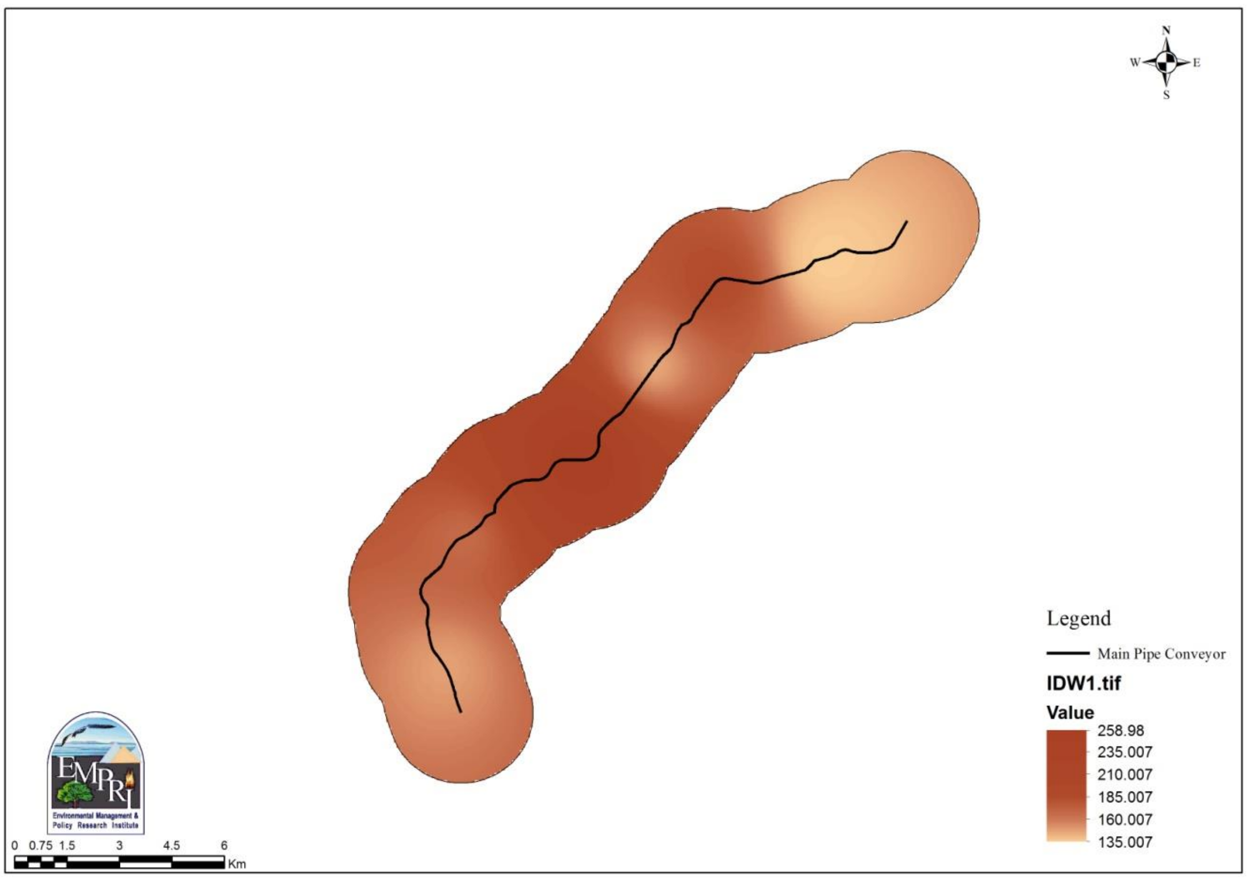


Figure 5.18. Interpolation map with respect to species richness of native species.

Conclusion

The vegetation stand structure is highly disturbed along MPC structure during the time of MPC construction as it is validated by our present study through the documentation of infestation of invasive species. The phenomenon of climate change is directly connected with amounts of carbon in the atmosphere. More the tree cover, large amount of carbon will sink there by balancing anthropogenic carbon emissions. In case of MPC stretch, comparatively, low tree basal area cover is recorded and hence the carbon storing capacity of a stretch decreased which is a major setback in the perspective of climate change. There will be less chances of colonization of invasive species, if the forest canopy is restored. Hence, the study suggests going for plantation of forest native species along MPC stretch to minimise the invasive species colonization. The ecosystem restoration is needed both in terms of biodiversity conservation and escalating carbon sink capacity to combat climate change.

Chapter VI: Diversity, Abundance and Activity Pattern of Arthropods

CHAPTER VI
DIVERSITY, ABUNDANCE AND ACTIVITY PATTERN OF ARTHROPODS

Introduction

Arthropods (Ancient Greek: arthro means 'joint', and pous means 'foot') are invertebrates having an exoskeleton, a segmented body, and paired jointed appendages. They are distinguished by their cuticle made of chitin, often mineralized with calcium carbonate. The Arthropod phylum includes over 85% of invertebrates such as insects, shrimps, millipedes, spiders and crabs. The number of known and described arthropods is about 30 million species. Over one million of the species are insects; arthropods have occupied all the habitats, perhaps the widest climatic extremes compared to any other taxa. Arthropods play a major role in the food web and ecosystem services like pollination, seed dispersal, decomposition and part of the food chains (Bunkley, 2017).

Communication efficacy is one of the most important factors to the animals, particularly for reproductive success as they communicate to defend territories, warn, approaching predators, and attract mates (Costello and Symes 2014). For the survival of species, changes in the communicational environment that render a signal unable to reach the receiver may negatively affect the individual or the group. Perhaps the artificial loud noise affects the animals including arthropods by disrupting their communication and natural perception (Morley et al. 2014). Anthropogenic noise currently is a growing form of pollution associated with the expansion of human infrastructure. However, quantifying the effects of anthropogenic noise on wildlife is challenging. Sensitivity to noise varies widely across taxa (Brumm and Slabbekoorn 2005; Morley et al. 2014; Slabbekoorn 2013), and may also vary depending upon the context, sex, and life history of the species (Ellison et al. 2012; Francis and Barber 2013). Noise can induce compound biological responses like shifts in vocalization and movement in certain species, (McLaughlin and Kunc 2013). Sound is rarely isolated from other forms of environmental disturbances such as habitat alteration and visual disturbance, leading to confounding interpretation of biological responses to noisy environments (Summers et al. 2011; Cunnington, 2013).

Arthropods play an important role in maintaining the health of ecosystems; provide livelihoods and nutrition to the human community. They are important indicators of environmental change.

Arthropods constitute a dominant group with 1.2 million species influencing the earth's biodiversity. Yet the population trends of several arthropod species show that they are on the decline.

Insects are an important class of creatures in any ecosystem, whether wild or man-made. A majority of the species on earth are insects. They have colonized every niche. The insect-plant relationship is the dominant biotic interaction. The insects have enormous functional significance, owing to the large numbers of individuals and great intra and interspecific variety. Because of their diversity, myriad life-history patterns, interactive functions and ecology, their influence on the environment, natural resources, agriculture and also on human health is immense. Insects play a major role as biomechanics in nature in developmental biology, evolution, ecology and climate change (Scudder, 2009).

The arthropods create a biological foundation for the entire terrestrial ecosystem. In nutrient cycles, pollinating the plants, seed dispersal, soil fertility and structure, provide food sources for other taxa. These insects are of great importance as a source of food for diverse predators (Carpenter 1928) like lizards, amphibians, carnivorous, anteaters. Many species of birds consume insects as their staple food, mammals like sloth bear use insects as food, aquatic insect larvae serve as food for fishes, and many stream fish appear to be limited by the availability or abundance of such prey. Under natural conditions, insects are a prime factor in regulating the abundance of all plants, especially as the flowering plants approximately 85% of angiosperms are pollinated by insects (Grimaldi and Engel 2005).

Determining the scale and extent of disturbance involves carefully measuring characteristics of the sound source such as duration (chronic, intermittent), frequency content and intensity (Nowacek et al. 2007; Southall et al. 2007; Francis and Barber 2013). Nevertheless, attempts to understand the impact of sound on animals is inevitable as they play an important role in the ecosystem. The effects of louder soundscapes on insects also conversely cause changes in other animals that are dependent on insects for their dietary requirements e.g., bats, birds and rodents. In the present context, one specific form of noise that concerns are that is produced by the main pipe conveyor (MPC) and associated noise. Thus, considering the ecological importance of arthropods, it is essential to determine the effects of noise generated due to the existing main pipe conveyor belt (MPC) running from 6:00 AM to 6:00 PM and also and its extended time till 2:00 AM on the arthropods.

Review of Literature

According to Bunkley et al. (2017), anthropogenic noise is a widespread and growing form of sensory pollution associated with the expansion of human infrastructure. A specific source of constant and intense noise produced by the source is transportation. Terrestrial arthropods play a central role in many ecosystems, and given that numerous species rely upon airborne sounds and substrate-borne vibrations, that may influence the distribution abundances of terrestrial arthropod families and community structure as a function of noise and sound. Methods used for this study were pitfall traps and transects in different land uses. Results of this study report differential effects on the abundances of some arthropods families.

A study conducted by Schmidt (2015) talks about the potentiality of long-distance acoustic signalling of arthropods in their natural habitat that plays a very important role in their bioecology. Acoustic signals are not only subjected to changes imposed by the physical structure of the habitat but also to masking interference from co-occurring signals of other acoustically communicating species. In natural habitats, when the noise level is high, a strong strategy to deal with and detect the relevant communication or signalling is required. To this issue, the ecological niche concept has been related and examined. Physiological mechanisms such as frequency tuning, spatial release from masking and gain control are useful strategies to counteract acoustic masking. Recent works on the effects of anthropogenic noise on insect acoustic communication and the importance of insect sounds as indicators of biodiversity and ecosystem health were also studied.

As per the study of Orci et al. (2015), noise pollution is a major issue in recent days. Its effects on animal behaviour have been investigated by numerous studies focusing mostly on vertebrates, as the insects are ecologically most important creatures; the workers have examined that whether the male crickets modified their calling sounds in response to the fluctuation of the external noise. This is done by collecting the noise level over a short period and paired with song parameters and measured the recording of males singing in their noise populated habitats. Another way is laboratory playback experiments results shows that a male recording which was done during the silent and noise time found that of these experiments the males shortened their calls and passed singing with a higher probability of increased noise level and Male did not modify the fundamental frequency. But did not adjust the duration of inter scheme intervals in response to the noise and reduction of masking was found during the study.

Duarte et al. (2019) assessed the effects of the truck- traffic on cricket calling activity. That is how the sound from the mining sector affects crickets' acoustic communication. Passive acoustic monitoring devices are used for the study. These devices are installed at different distances, at the distance of 500 m and another 2500 m from the mining site, these devices are conFig. to record the sound from 17:00 to 05:00 h during seven days in April 2013. After that, the spectral characters of the crickets were analysed. Mainly three types of crickets were analysed during the time of passing the trucks, before and after. Results showed a calling interruption for all the species during truck transit. This study revealed the insect acoustic behaviour varied between areas with different levels of noise. The authors stated that the acoustic variations in the insects may lead to interruption in their reproductive success also.

Wu et al. (2013) reported that animals must contend with the presence of noise, which may help to detect the prey, attract the mates and escape from the predator. In the study of anthropogenic effects, vibratory sensory modules play a major role in detecting the anthropogenic effects of noise on wildlife. These human-induced noises alter the vibratory noise profile which leads to maladaptive behavioural responses. Field measurement of vibratory noise in artificial substrate and analysis of the prey detection ability of European garden spider, it was tested whether the changes in the vibratory noise profiles consistent with anthropogenic alteration of vibratory habitats are sufficient to alter the spider's sensitivity to prey cues. The study results show that experimental levels of intermediate noise consistent with field measurements on natural substrates suggest that spiders' predatory performance is higher when webs are constructed on natural substrates. So, the anthropogenic sound and vibrations cause an effect on the prey detection of spiders.

Villet(1987) recorded the African cicada, *Brevisana brevis* (Homoptera: Cicadidae) producing a calling song with a mean sound pressure level of 106.7 decibels at a distance of 50 cm. *Brevisana brevis* is likely the loudest insect species on record. Cicada songs are species-specific and play a vital role in communication, reproduction and possibly defence.

Rashed et al. (2009) reported that it has long been recognized that many hoverfly species (Diptera: Syrphidae) mimic the morphological appearance of defended Hymenoptera, such as wasps and bees. However, it has also been repeatedly suggested that some mimetic hoverflies respond with sounds on the attack that resembles where at types the warning or startle sounds of their hymenopterans models.

Materials and Methods:

The study was conducted to evaluate the impacts of the existing MPC from Nandihalli Railway Yard to JSW Plant and its increased timing on wildlife in the Sandur Taluk, Ballari District of Karnataka between June and August 2021.

Including sweeping net, aspirator, glue cotton cloth, measuring tape, noise meter, sticky traps, poles, head torch, cell torch, solar LED light traps the materials used to conduct the study given in Table 6.1.

The methods followed for sampling the arthropods include sweeping for insects using the net, visual count method, foliage beating, sticky traps and solar traps for passive insects and soil arthropods were sampled using Tullgrens extractor(Table 6.2).

Table 6.1. The materials used for sampling arthropods

Sl. No	Materials	Quantity	Purpose
1	Measuring tape	1	To measure the perpendicular distance from MPC
2	Datasheets	-	To record the observed arthropod data
3	Solar traps	3	To trap the nocturnal insects
4	Sticky traps	16	To trap the air born insects
5	GPS Garmin	1	To record Latitude and longitude
6	DSLR Camera	1	To record photographic evidence
7	Noise meter	1	To record sound level (dB)

Table6.2. Methods adopted to sample different groups of arthropods

Sl. No.	Field technique	Target
1	Visual counting	To count the arthropods which are visible
2	Sticky traps	To capture and observe the air-born smaller insects which cannot be observed in the visual count method
3	Solar trap	To capture the nocturnal insects
4	Soil sampling	To sample the microarthropods, present in the soil
5	Bio acoustics	This method was used to record the arthropods that acoustically communicate and also record their activity

1. Visual counting:
   - The length of the MPC belt is about 24 km, within that; four major habitats were identified embracing scrub, forest, forest, agriculture and built-up area. The sampling was done in each habitat type.
   - The six perpendicular lines of 200 m were laid in each of the habitat type on either sides of the MPC (Fig 6.1a). Each line was walked for sampling the arthropods from 7:00 AM to 10:00 AM.
   - On each line transect, the sampling of 200 m was done in discrete transect line of 10 m each (0-10, 20-30, 40-50, 60-70, 80-90, 100-110, 120-130, 140-150, 160-170, 180-190 m) (Fig 6.1b). On each of these discrete lines, the arthropods were counted and also recorded the noise level using a handheld sound meter.
   - The visual counting was done only during the belt run of 12 hours.

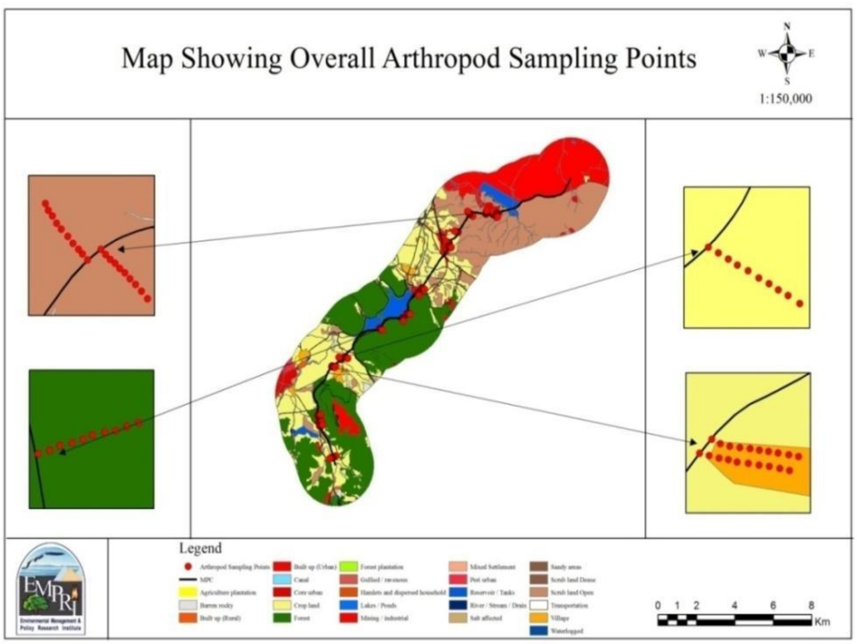


Fig.6.1a. Locations of transect lines for visual count sampling

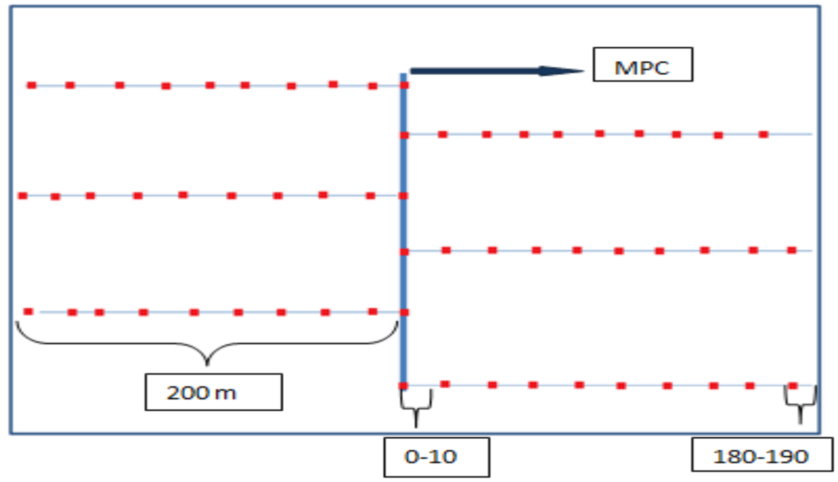


Fig. 6.1b. Study design for the visual count method for arthropod sampling

2. Sticky trap technique:

- A total of 16 blue and yellow sticky traps (10X12) inches were deployed at 1 m and 3 m height from the ground, at the distance of 20 m and 120 m away from the MPC (Fig. 6.1c).
- Sticky traps were deployed in all the habitats of the study area, and in each location each trap was kept for ten days.
- Observations were taken every two days on different insects trapped. Traps were cleaned and re-installed at every two days intervals.
- The traps were deployed during both 12 hours and 20 hours of belt run

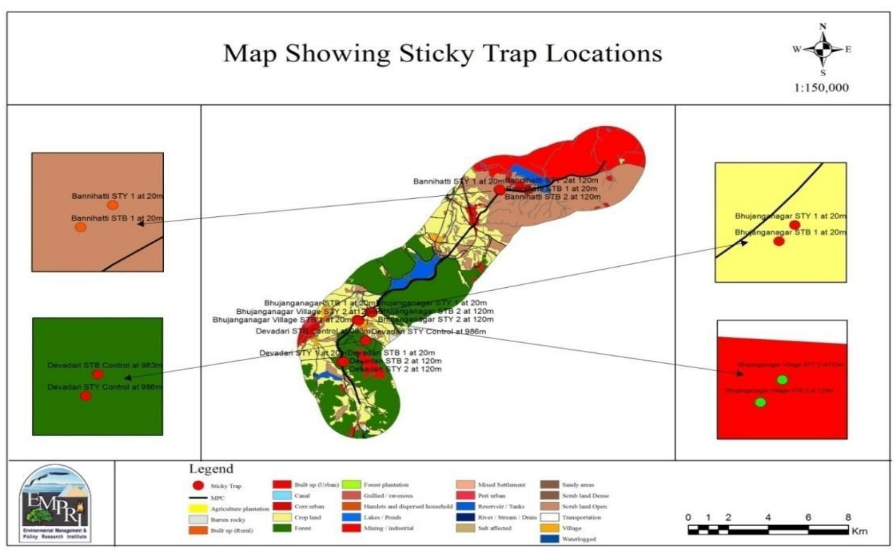


Fig.6.1c. Locations of sampling by deploying the sticky traps

3. LED Light trap:
   - Solar LED traps were deployed at the distance of 0m and 100 m from the MPC (Fig. 6.1d).
   - The traps were deployed at 0 m and 100 m distance from the MPC.
   - Each trap was kept in a sampling location for ten days and then shifted to another sampling location.
   - During the sampling, on alternative days, each trap was visited and collected all the species were, and cleaned the trap and redeployed in the same location.
   - The traps were deployed during both 12 hours and 20 hours of belt run.

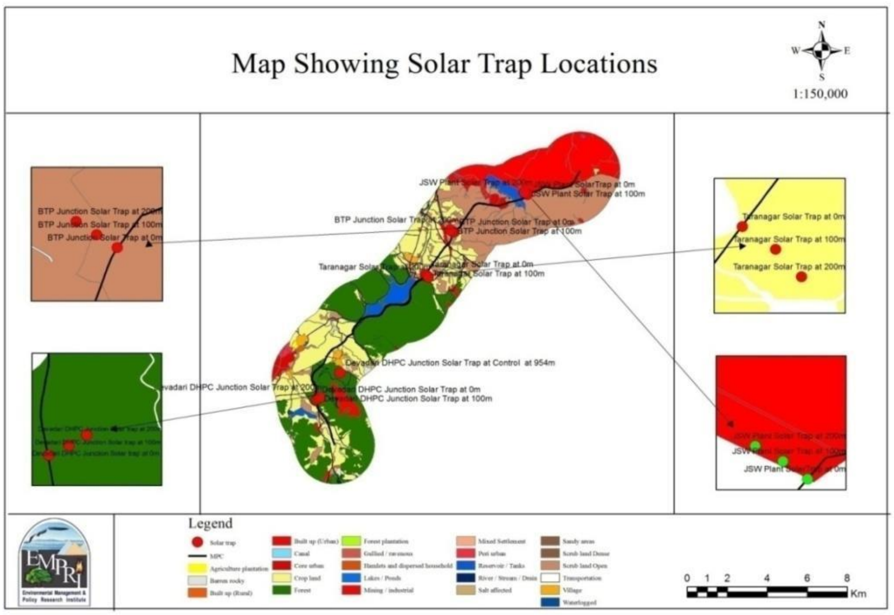


Fig.6.1d. Locations of solar traps deployed

4. Soil Sampling:
   - Soil samples were collected in all the habitats at 0m, 100m and 200m distance from the MPC (Fig. 6.1e).
   - Samplings were done at depth of 6 cm from the top soil layer and three samples were collected at every distance.
   - Arthropods were extracted using Tullgren's biota extractor method.

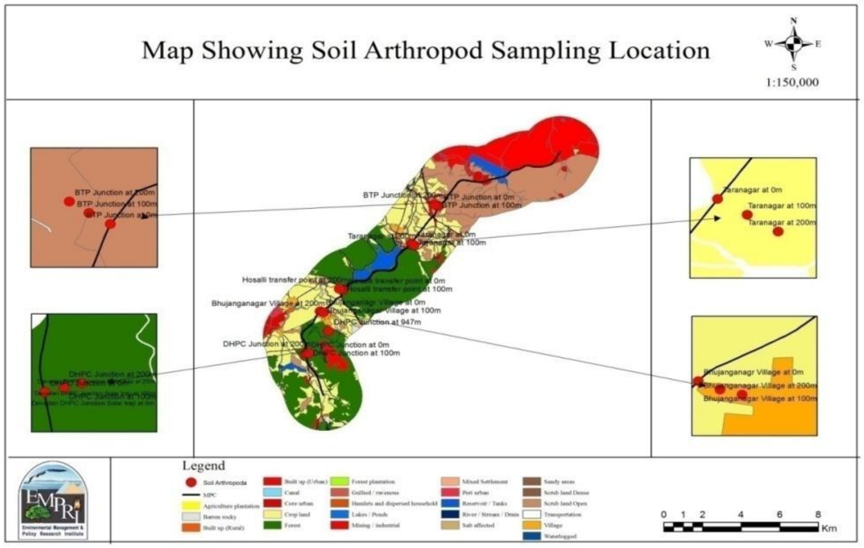


Fig.6.1e. Locations of sampling for soil arthropods

5. Recording the bio-acoustics:

- Passive Sound recorders like audio moths sound monitoring stations were deployed randomly in all the habitats. (Fig 6.1 f and 6.1 g).
- Sound recorders, Audio moths were kept in an on position to record the calls for 12hours from 6:00 PM to 6:00 AM. And the sound monitoring stations are kept for 30 days in each habitat, in the first Phase, and for 10 days in every habitat in the second Phase.
- After three days of deployments, the recorder was removed and downloaded all the recordings.
- The recorded calls were processed and analysed using Raven Pro 1.6 and Bat Explorer 2.1.9 software.

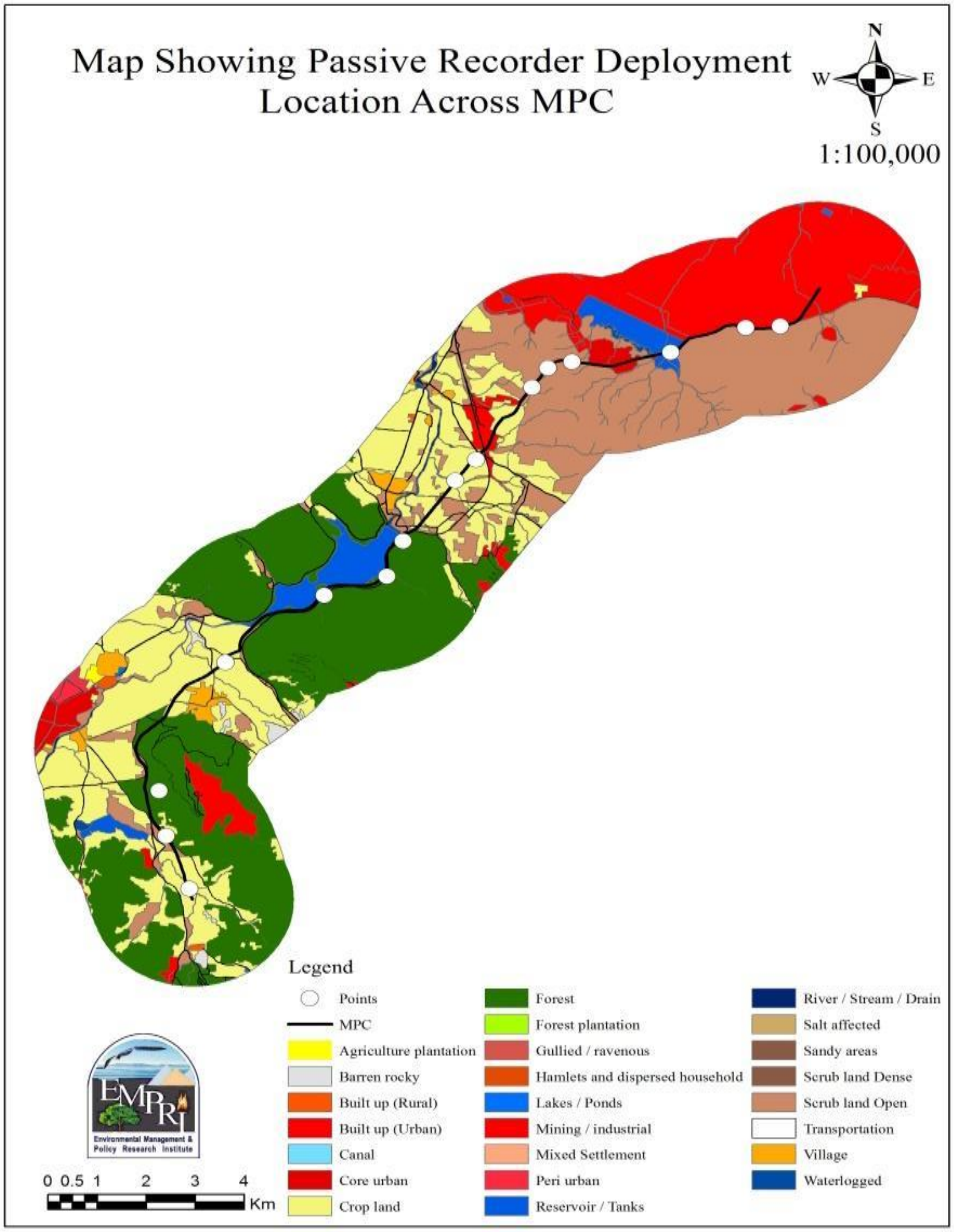


Fig.6.1f. Locations of passive recorders deployed

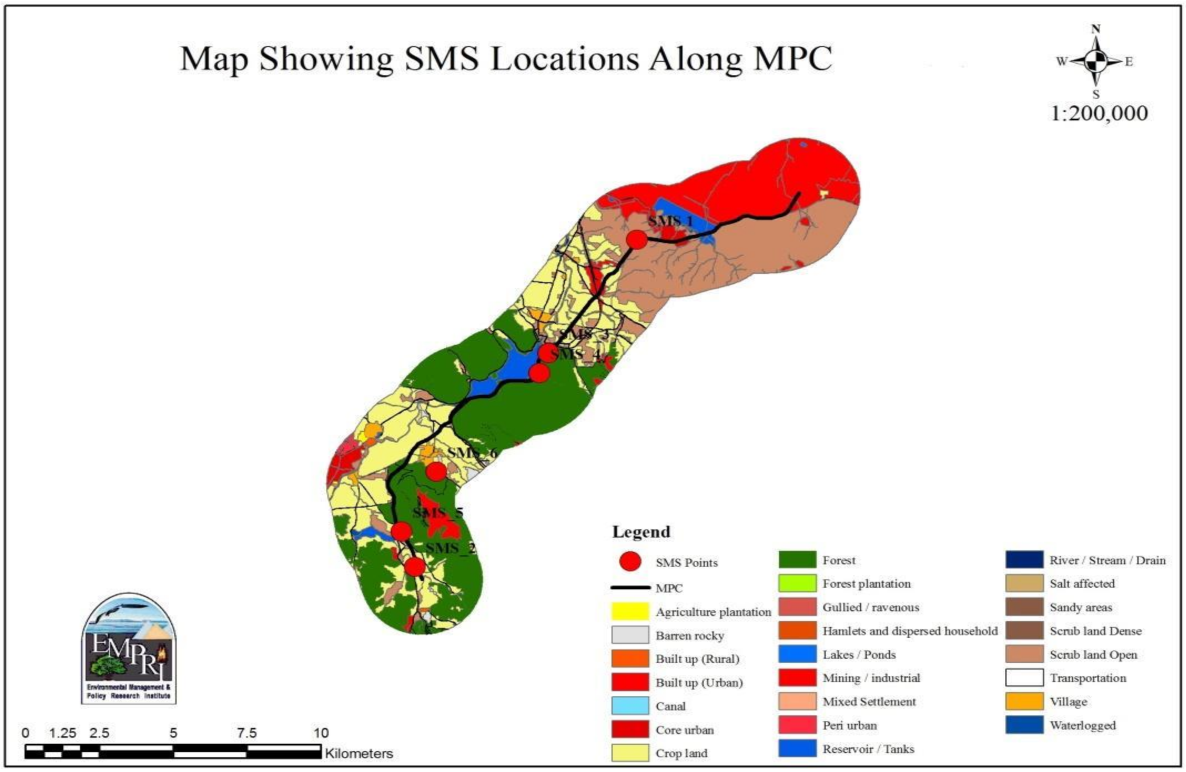


Fig.6.1g. Locations of Sound Monitoring Stations

Table 6.3. Efforts on all the methodologies

Visual count Method				
Habitat Type	Agriculture	Forest	Scrub	Built-up
No. of transect	6	6	6	6
No. of points on transect	10	10	10	10
Total sampling points	60	60	60	60

Sticky Trap method along MPC	12 hours of belt run	20 hours of belt run
No. of traps	16	16
No. of observation	5	5
Total	80	80

Solar Trap method along MPC	20 hours of belt run	20 hours of belt run
No. of traps	3	3
No. of observation	10	10
Total	30	30

Soil sampling					
Habitat type	Agriculture	Forest	Scrub	Builtup	Control
No. of soil sample points	3	3	3	3	3
No. of soil samples	1	1	1	1	1
Total	3	3	3	3	3
BioAcoustics	12 hours of belt run		20 hours of belt run		
No. of SMS	6		6		
No. of days	30		10		
Total number of Recordings	11266		5019		
No. of Audio moths/ passive recorders	7				
No. of days Deployed	36 days (432 hours/ 12 hours per day)				
Total No.Recordings	44,947				

Table 6.4. Data analysis for arthropods

Parameter	**Formula adopted**	**Analysis platform**
Abundance	Total no. of individual species / Total no. of points in which they occurred.	SPSS Software
Standard deviation	$\sigma = \frac{1}{N}\sqrt{\sum_{i=i}^{n} f_i x_i^2 - (\sum_{i=1}^{n} f_i x_i)^2}$	SPSS Software
ANOVA	$H_1 \neq H_0$ H_1(alternative hypothesis): rejects the null hypothesis and conclude that at least one of the population means is different from the others. H_0(null hypothesis): $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$ (all the population means are equal).	SPSS Software
Simpson dominance index (SDI)	$1/\sum_{i=1}^{s} p_i^2$ (Where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is the sum of the calculations, and is the number of species)	PAST Software
Shannon-Wiener's index	$-\sum_{i=1}^{s} p_i \ln p_i$ (Where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and is the number of species)	PAST Software

Pearson correlation	$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$ (Wh ere: r- *Pearson* correlation coefficient; n is the value of the measured inhibitory activity for compound i (i = 1, 2, ..., 67)	SPSS Software
t-test	$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{(s^2(\frac{1}{n_1} + \frac{1}{n_2}))}}$$ Where: x**1** is the mean of sample 1 s**1** is the standard deviation of sample 1 n**1** is the sample size of sample 1 x**2** is the mean of sample 2 s**2** is the standard deviation of sample 2 n**2** is the sample size in sample 2	SPSS Software
Overlap curves	-	**R-Studio**Version 1.4.1717.

Results

A total of 192 species of arthropods belonging to 15 orders, 46 families and73 genera were recorded during the study. Of them, 7 species are listed as 'Least Concern' under the IUCN list. A detailed checklist of arthropods recorded from all the methods and opportunistic sightings are given in Annexure1. Out of them, 43 species were predators/Parasites, 17 were pests, 9 were scavengers, 48 were pollinators, 8 were decomposers, 8 energy turnovers, 9 aquatic insects and 26 soil arthropods Table 6.6. The presence of insects at different distances perpendicular to MPC is given in Annexure 6.2. Lepidoptera was the major order recorded followed by orthoptera and Hymenoptera.

Solar trap method: A total of 30 species of insects were trapped in the solar trap installed at different distances from MPC. In phase one, 25 species and in phase two 30 species were trapped. Among them, Muscoid flies were the dominant group followed by the termites and *Hemiptera spp*. In phase 2, Termites were the dominant group followed by the muscoid flies and Treehoppers, few species of insects like European corn borer; *Sphingidae* moths were also trapped in Phase 2. The occurrence of the arthropods attracted to solar traps is given in Annexure 6.3.

Soil sampling: A total of 26micro and macro arthropods are identified in the soil samples collected from the MPC area and in the control area Annexure 6.4. Macro arthropods like soil mites, ants, cutworms and ground beetles were identified and microarthropods perpendicular distance like Protura, *Isotomurusbalteaus*, Pseudoscorpiones, *Acaronychus spp*. Silverfish are present in both the area. Diplura, Symphyla, *Cyphoderussp*, *Symphepleona*are present only in the control but not present in the MPC area.

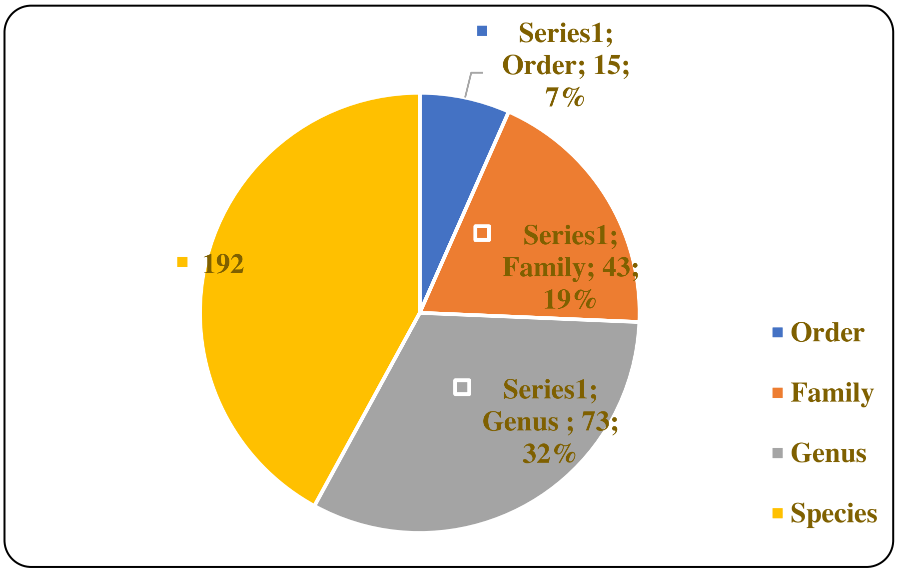


Fig.6.2. Arthropods recorded in the study area

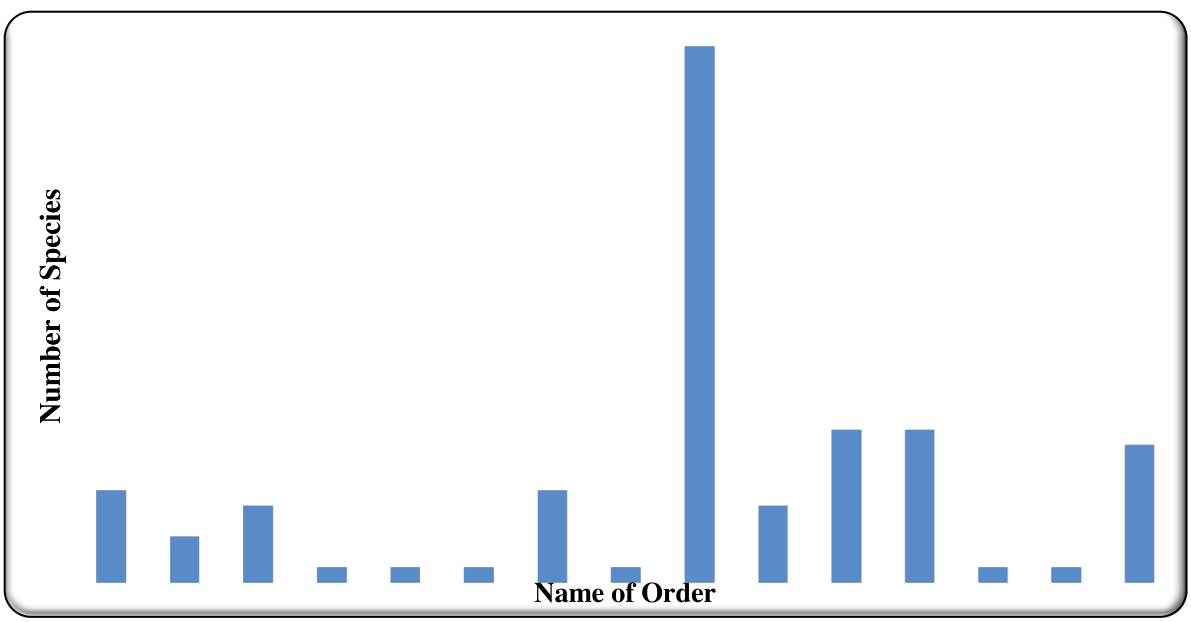


Fig.6.3. Order wise number of species in the study area

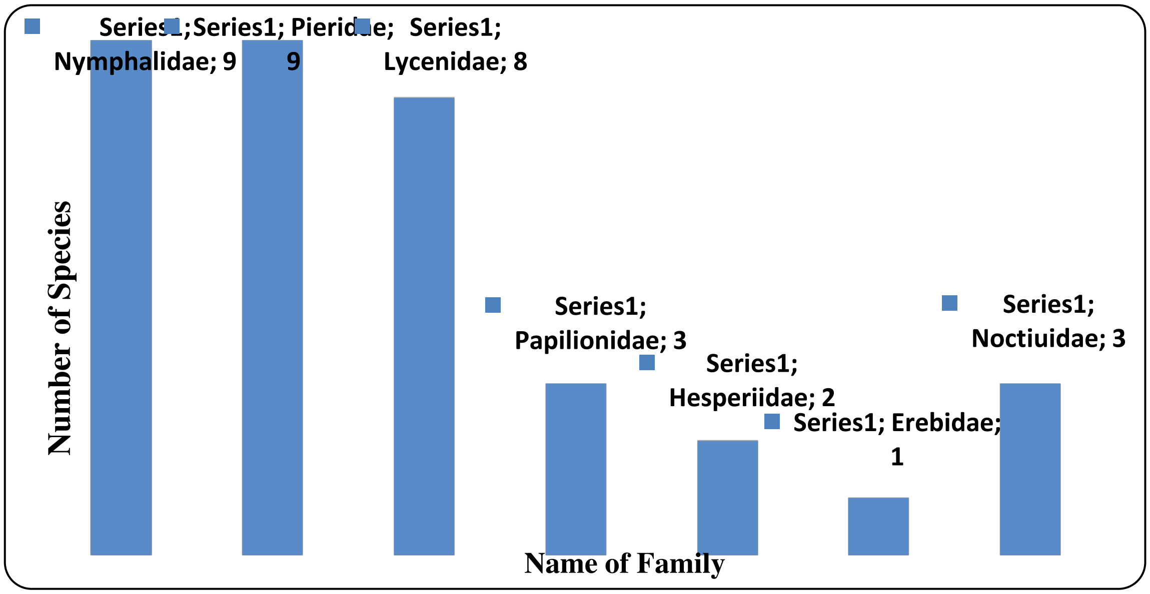


Fig. 6.4. Families recorded under the order Lepidoptera

Visual count method: About 95 species were recorded by the visual count method on transects line at different distances from the MPC at different habitats, occurrence of the species at perpendicular distance from 0m distance to 200 m. The Shannon-Wiener, Simpson index for species diversity of insect species at different distances MPC area is given in the Table 6.5.

Table 6.5. Species diversity indices (Visual counting) according to perpendicular distance from MPC

Species diversity indices										
Distance from MPC	0-10	20-30	40-50	60-70	80-90	100-110	120-130	140-150	160-170	180-190
Taxa_S	58	59	63	66	68	71	66	68	75	69
Individuals	607	593	523	612	634	673	684	566	689	791
Dominance_D	0.12	0.10	0.11	0.10	0.08	0.07	0.08	0.07	0.07	0.08
Simpson_1-D	0.88	0.90	0.89	0.90	0.92	0.93	0.92	0.93	0.93	0.92
Shannon_H	2.98	3.20	3.16	3.22	3.34	3.43	3.28	3.41	3.45	3.31
Evenness_e^H/S	0.34	0.41	0.38	0.38	0.41	0.43	0.40	0.45	0.42	0.40

The insect diversity indices were worked out at different distances from MPC (Table 6.5). The diversity of insect species varied from 0 m to 200 m Simpson diversity index value was 0.88 at 0 points and diversity in 160 points was high at 0.93. As Shannon index value at 0 m distance the diversity was2.99 and it varied little as we go away, at 160th point it records high diversity (3.447) and 3.31 at 180-190 m.

Ecological and economic significance:

In the study area, 192 species of arthropods were identified. The ecological status of 160 (90%) species has been determined. Of that, 30% of the species constituted predators, parasites and parasitoids. Scavengers, decomposers, nutrient and energy turnovers, and soil arthropods constituted 27% of the identified insect species ecological status of 32 insect species is yet to be determined. Details of the ecological categories of insects are present in Table 6.6 and Fig. 6.4. The broad categories of arthropods serving as a prey base for higher animals are listed in Table 6.7

Table 6.6. Broad ecological categories of identified insect species in the study area

Ecological categories	Proportion of species		Insect cohorts
	Number	%	
Predators/parasites/ parasitoids	43	30	Wasps, ants, reduvid bugs, coccinillidae
Pests	17	12	Lepidoptera, coleoptera,
Scavengers	9	2	Earwigs, beetles, Grasshoppers
Pollinators	48	31	Bees, Butterflies
Decomposers	8	2	Termites, Dung rollers caterpillars
Energy turnovers	8	1	Carabids, Tenibrionics, Chyisomelids
Aquatic insects	9	2	Water boatmen, skaters, swimmers
Soil arthropods	26	20	Columbolans, diplurans, proturans
Prey		< 90	
Undetermined	32	-	-

Table 6.7: Prey base of arthropods for higher taxa animals

Arthropods	Higher taxa animals
Odonata,	Birds, fishes
Dictyoptera	Lizards, small mammals
Orthoptera	Birds, bats, rodents,
Phasmida	Amphibians, birds
Isoptera	Birds, bats, rodents, amphibians, reptiles, mammals
Hemiptera	Birds and bats
Lepidoptera	Reptiles, amphibians, bats, mammals.
Hymenoptera	Birds, Bats,
Coleoptera	Bats, Birds, Rodents
Araneae	Amphibians, reptiles, Birds, Mammals
Scorpions	Birds of prey, Mammals

The intense activity of insects like pollination, foraging, and feeding was noticed in the scrub habitat, for example, Yucca moths (Tegeticula spp.) and dung beetles were noticed in the scrub. For instance, in the study area, bumblebees (Xylocopa spp.) formed the dominant species pollinating the Calotropis plants. Observations revealed that this pollinator spent less time (15-16 seconds per foraging bout per flower) near the MPC than at a faraway distance (50-55 seconds per foraging bout per flower). This observation was recorded at 5 m and 200 m away where the sound intensity was 70db and 45db, respectively. Frequencies of sightings were also less near the MPC. Similarly, on the Lantana blossoms, observations of piredae butterfly (n=11) the pierids spent less time (7-8 seconds per flower per foraging bout than at the MPC than at a distance where the sound was comparatively less (18-22 seconds per flower per foraging bout) Table 6.8.

Table 6.8. Observations on the Foraging activity of insects

Species	Habitat	Number of observations	Distance from the MPC (in m)	Duration of foraging (in sec)	Sound in dB
Bumblebees (*Xylocopa spp*.)	Forest	7	5	15-16	70
		9	200	50-55	48
Pieridae Butterfly	Scrub	6	5	7-8	67
		5	200	18-22	46

In the Light traps, on few days, dung rollers were the dominant species in the scrub and forest habitats. Pollinators several hymenopterous, dipterous, coleopterus and lepidopterous pollinators were found in the traps in the study area across the habitats. Their activity in the wild and cultivated habitats is crucial. Similarly, presence of mayflies, dragonflies and damselflies are an indication to the purity of water. These insects were abundantly sighted in the study area.

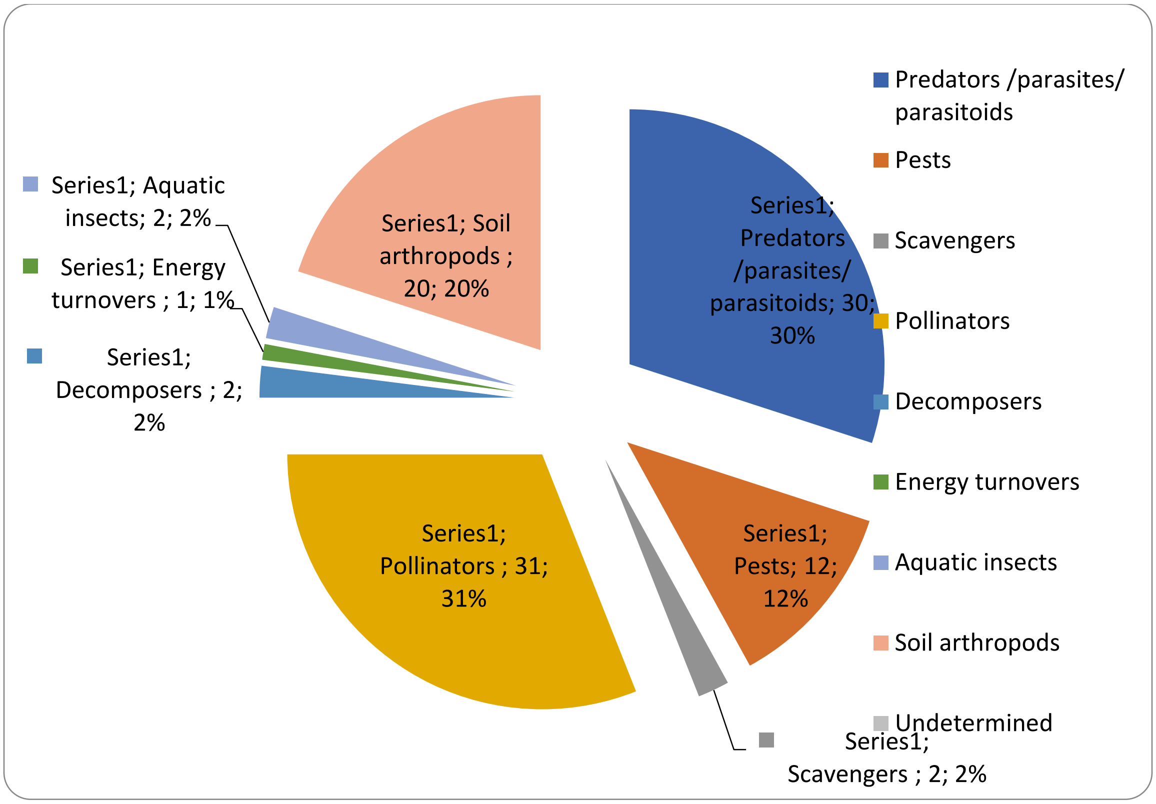


Fig.6.5. The Ecological characters of identified arthropods

Abundance: Mean number of insects species by visual count method

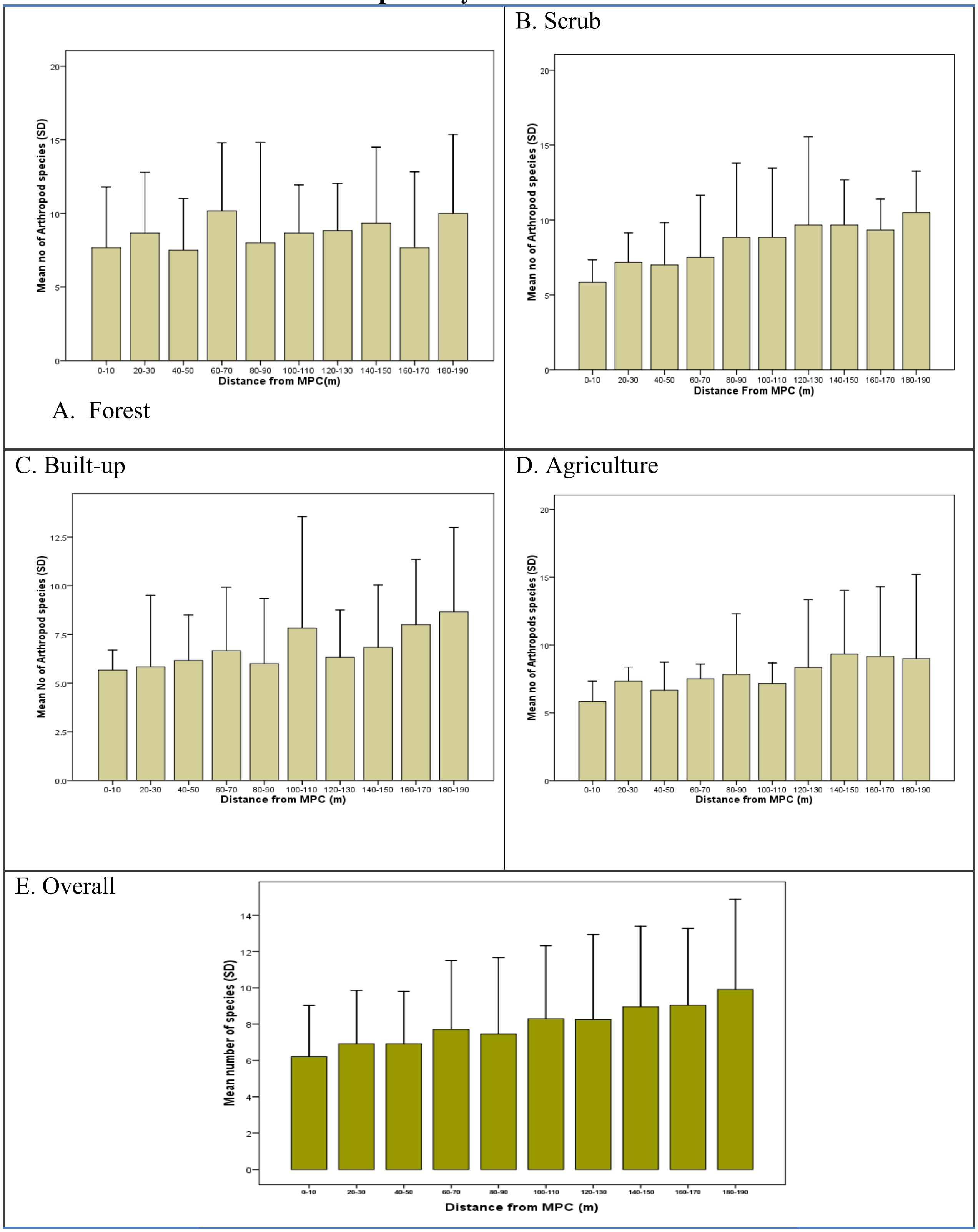


Fig. 6.6: The mean number of arthropods species from visual count at different distances from the MPC: A. Forest, B. Scrub Forest, C. Built-up area, D. Agriculture fields, and E. Overall.

The mean number of arthropods 'species varied between 20 and 35 (Fig. 6.6). The mean number of arthropods' species was higher at distances away from the MPC. The mean number of insect species varied significantly among different distances from the MPC. As given below in agriculture habitat ($F_{9,50}$= 2.208, $p < 0.01$) in scrub ($F_{9,50}$= 3.955, $p < 0.01$), built-up area ($F_{9,50}$= 2.099, $p < 0.01$), and did not varied in forest habitat ($F_{9,50}$ =2.853, $p = 0.09$) However, the overall mean number (samples pooled) of insect counts highly varied among the different distances from the MPC ($F_{9,230}$=8.813, $p < 0.01$). The differences between the mean numbers of arthropods were small in all the habitat types. But the overall mean number of insects species was much higher away from MPC.

The sound in decibels was recorded for every sector of sampling at the perpendicular distance to the MPC. The relationship of the mean number of insects with the mean sound in decibels was developed for all the habitat types (Fig. 4a) and also for the overall means (Fig. 4b). As the sound decreased away from the MPC the number of insects recorded increased in forest (r_p= - 0.723, df=9, p=0.01), scrub (rp= -0.937, df=9, p>0.01) is built up (r_p= - 0.783, df=9, p>0.00) and in agriculture field (r_p=-0.909,df=9, p>0.01)However, the overall mean number of species of arthropods increased at perpendicular distance to the MPC as the intensity sound decreased (Fig. 6.6 E: r_p= - 0.808, df=9, $p < 0.01$).

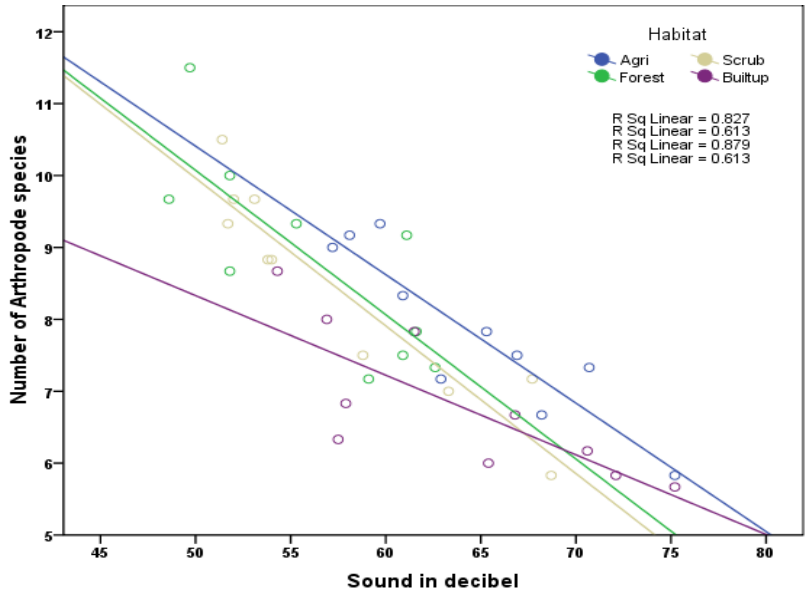


Fig 6.7. The relationship between the mean number of arthropod species and the sound in decibels
at a perpendicular distance to the MPC in different habitat type

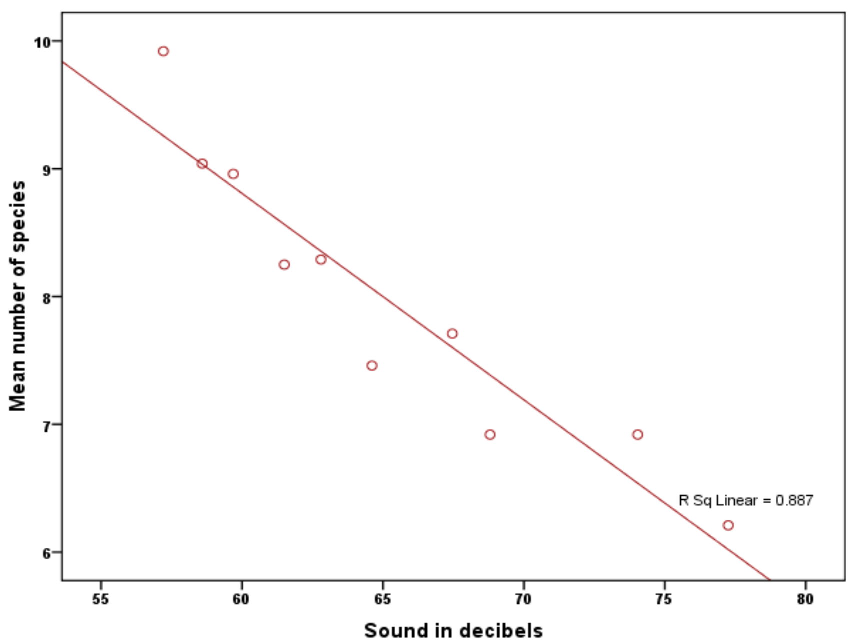


Fig.6.8. The relationship between the mean number of insect species (overall) and the sound in decibels at a perpendicular distance to the MPC

The abundance of Insect numbers at different distances from the MPC

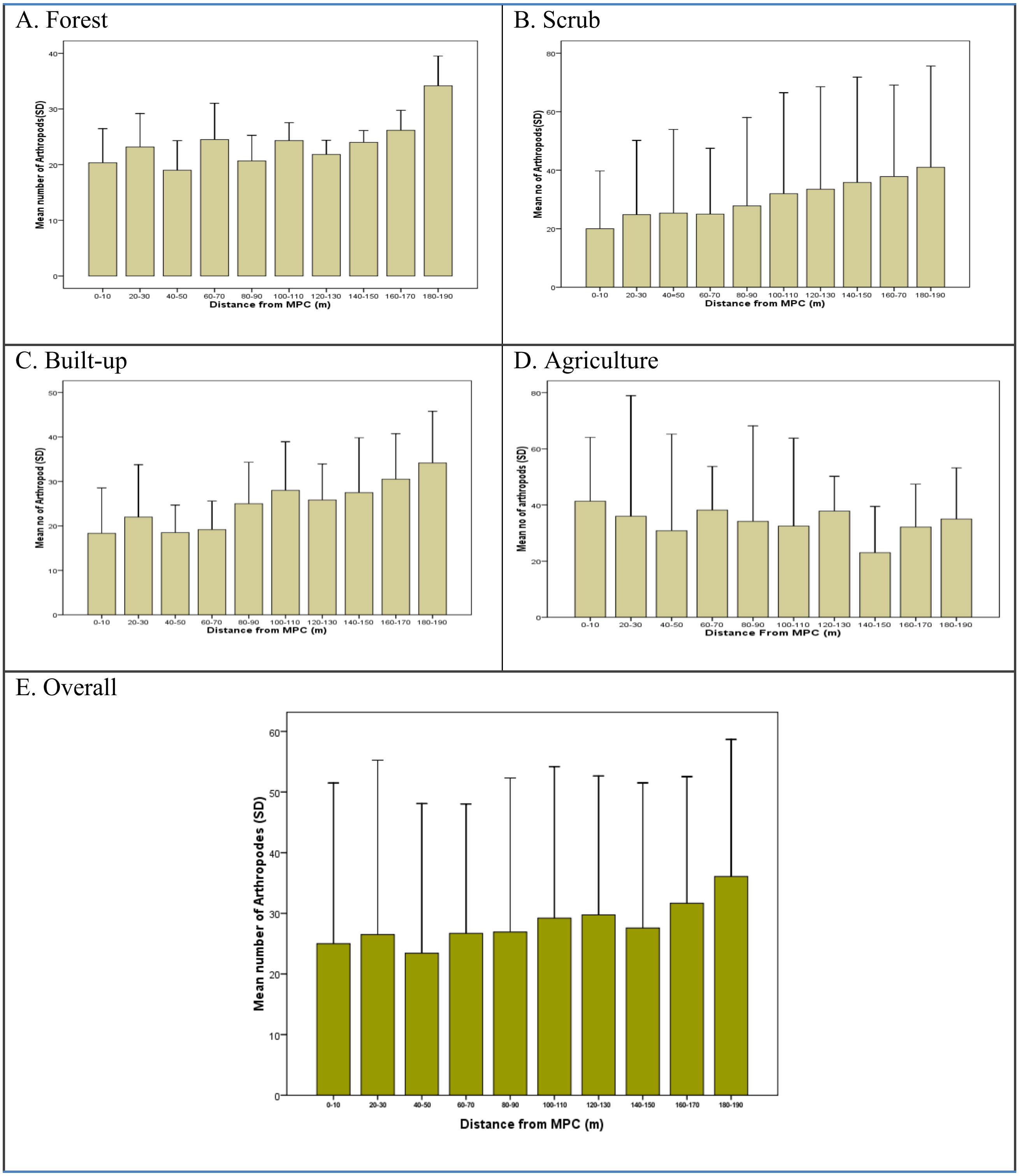


Fig.6.9. The mean number of arthropods from the visual count at different distances from the MPC: A. Forest, B. Scrub Forest, C. Built-up area, D. Agriculture fields, and E. Overall.

The mean number of insects was high at distances away from the MPC. Fig. 6.9.It varied significantly among the different distances from the MPC ,viz., in forest ($F_{9,50}$ =3.169, $p < 0.01$). But did not vary in scrub ($F_{9,50}$=1.193, $p = 0.320$), agriculture fields ($F_{9,50}$= 0.088 p =0.055), and built-up area ($F_{9,50}$= 1.937, $p = 0.068$). However, the overall mean number of insect counts highly varied between the different distances from the MPC ($F_{9,230}$=2.127, $p < 0.05$). Although the differences between the mean numbers of insects were small in all the habitat types, the overall mean number of arthropods was high away from MPC.

The sound in decibels was recorded for every sector of sampling at the perpendicular distance from the MPC. The relationship of the mean number of insects with the mean sound in decibels was developed for all the habitat types and the overall means (Fig. 6.9). As the sound decreased away from the MPC, the number of insects increased in forest (r_p= -0.723, df = 9, $p < 0.01$), in scrub (r_p= -0.870, df = 9, $p < 0.01$) and in built-up area (r_p= - 0.895, df=9, $p < 0.00$), while the relationship was reversed in agriculture field (r_p= 0.518, df = 9, $p = 0.130$). However, the overall mean number of insects increased at a perpendicular distance to the MPC as the sound decreased (Fig 6.9E: r_p= - 0.808, df=9, $p < 0.01$).

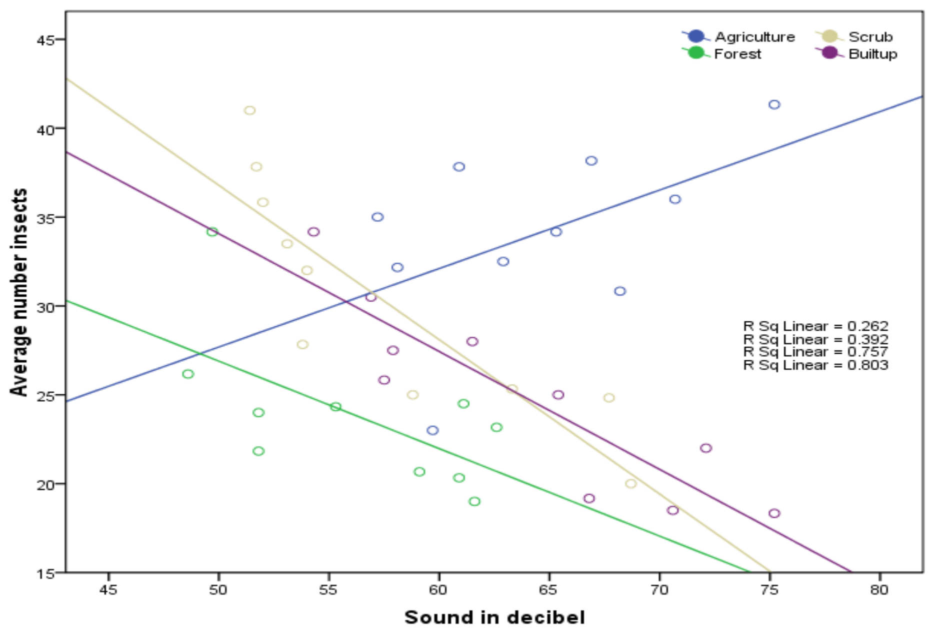


Fig. 6.10. The relationship between the mean number of insects and the sound in decibels at Perpendicular distance intervals from MPC in different habitat types

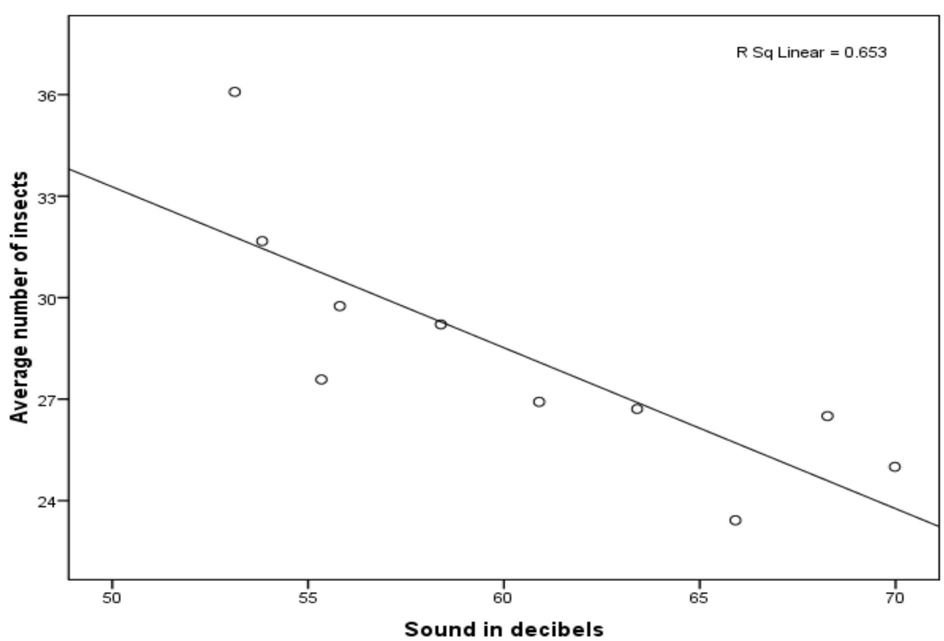
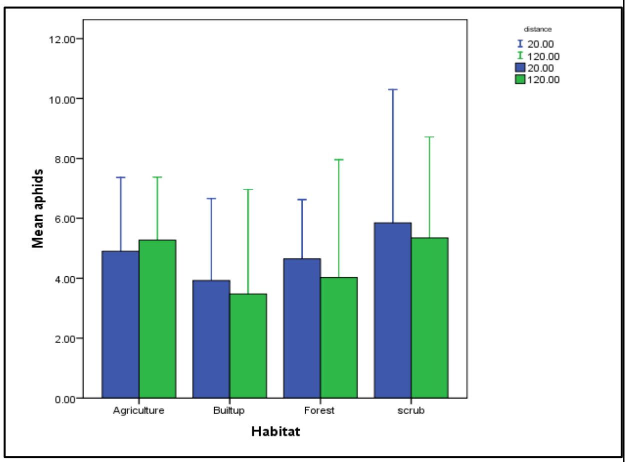
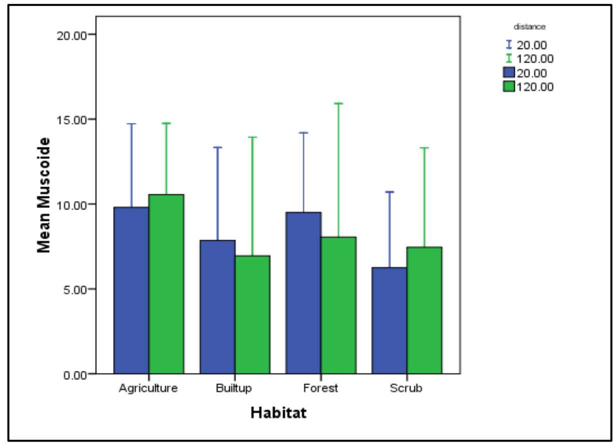


Fig. 6.11. The relationship between the mean number of insects (overall) and the sound in decibels at a erpendicular distance to the MPC.

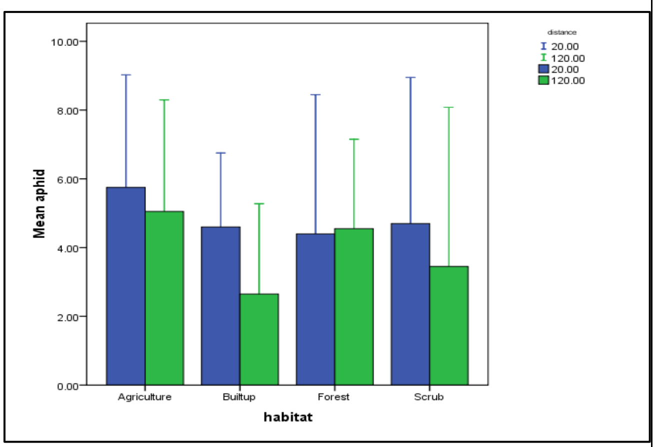
Sticky traps

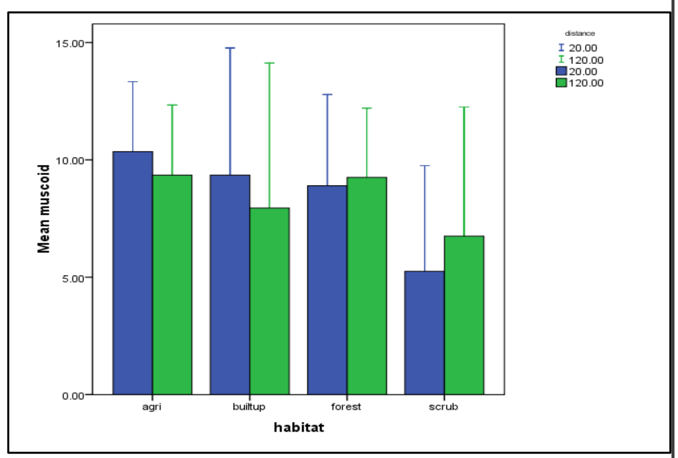
Phase 1



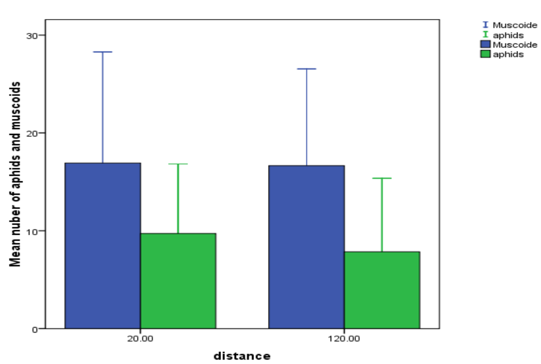


Phase 2 :





Phase 1, Phase 2 & Control



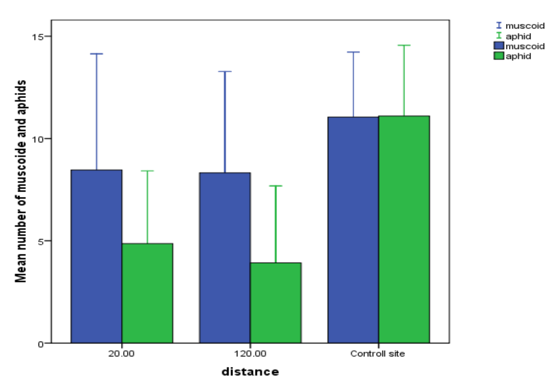


Fig 6.12 : Mean number of aphids and muscoid flies in Phase 1& Phase 2 and comparisons of Phase 1 Phase 2 and control site

Mean number of muscoid flies (t= 0.145, df=78, p=0.885)and aphids(t= 0.787, df = 78,p=0.433)did not vary between different habitats at the distance of 20 m and 120 m from the MPC in phase-1(Fig. 6.12).However, the mean number muscoid flies did not vary significantly (t= 0.231, df=78, p=0.818), but the Mean number of aphids varied significantly (t= 2.293, df= 78, p <0.01)in different distances in all the habitats in Phase 2. When the data were pooled, the mean number of muscoid flies and aphids during phase 1 and phase 2, at the distance of 20m and 120 m away from the MPC and in the control site, the mean number of muscoid flies were not varied significantly ($F_{2,167}$, =0.375,p=0.375) but the mean number of aphids varied significantly ($F_{2,167}$, =0.375,p <0.01).

Solar traps

The mean number of insects attracted to the solar traps was varied between 24 to 30, at 0 m and 100m distance from the MPC in Phase 1 (Table 6.9). The Root grub, Brown beetle, Black beetle, Snout Moth, Chiasmia moth, Mosquito, Treehopper, Leafhopper and European corn borer were not varied while other insects varied significantly at 0 m distance between Phase 1 and Phase 2. The solar trap data from 100 m distance from MPC during phase-1 and phase-2 is provided in Table 6.10. Except for Root grub, Brown beetle, Black beetle, Snout Moth, ameanae moth, Chiasmia moth, Mosquito, Treehopper, Leafhopper and European corn borer, other insects varied significantly at 100m distance between Phase 1 and Phase 2.

Table 6.9. Solar trap Statistical Analysis (at 0 pointsThe activity of both the phases)

Species	Phase 1	Phase 2	Statistical value
Termites	10.46+11.82	4.25+6.37	t= 8.73,df=34, p<0.01
Muscoid flies	13.40+5.84	0.43+1.03	t=9.70,df=34,p<0.01
Flesh flies	1.33+1.54	0.12+0.50	t=6.40,df=34,p<0.00
Root grub	1.60+1.68	1.06+1.61	t=1.24,df=34,p=0.22
Brown Beetle	0.00+0.00	0.06+0.06	t=5.98,df=34,p=3.93
Black Beetle	2.87+2.38	2.94+3.45	t=-.12,df=32,p=0.90
Silver moth	3.26+3.71	2.31+3.26	t=2.67,df=34,p< 0.01
Snout moth	1.13+1.18	3.31+3.26	t=.069,df=34,p=1.68
Geomitredea sp.	0.06+0.25	0.12+0.34	t=4.87,df=34,p<0.01
Aemene	1.46+1.18	0.25+0.77	t=4.20,df=34,p<0.01
Chiasmia moth	0.20+0.56	2.12+2.65	t=-1.74,df=34,p=0.09

Musquito	0.53+0.91	2.00+3.59	t=-1.89,df = 33,p =0.06
Brown stink bug	6.73+3.39	0.68+1.88	t=3.64,df = 34, p <0.01
Red cotton bug	0.00+0.00	1.12+2.06	t=2.41,df = 34, p <0.01
Horse fly	1.20+1.32	0.68+1.49	t=2.33,df = 34, p <0.01
Green stink bug	0.00+0.00	0.50+1.15	t=5.20,df=34,p<0.00
Saw fly	0.00+0.00	0.37+1.02	t=4.45,df=34,p<0.00
Water bugs	2.13+1.68	0.37+1.02	t=3.30,df=34,p<0.00
Honey bee	8.33+4.59	0.12+0.50	t=3.44,df=34,p<0.00
Potter wasp	0.26+0.59	1.93+3.39	t=3.30,df=34,p<0.00
Black wasp	0.06+0.25	0.56+0.96	t=3.44,df=34,p<0.00
Tree hopper	0.73+0.88	3.37+4.28	t=-1.82,df=34,p=0.07
leaf hopper	1.00+1.81	3.68+3.97	t=-1.01,df=34,p=0.31
Earwig	1.33+2.02	0.12+0.34	t=-3.29,df =34 p< 0.00
European corn borer	1.30+1.38	5.06+9.98	t=-1.38,df =34,p= 0.17
Aphids	0.00+0.00	0.00+0.00	t=-2.01, df =33,p< 0.01
Sphingidae moth	0.00+0.00	0.00+0.00	t=-2.33,df = 34,p<0.01
Green grasshopper	0.00+0.00	0.26+0.59	t=-2.01,df =33, p< 0.01
Long horned moth	0.00+0.00	0.31+0.60	t=-2.33, df =34,p<0.01
Water bugs	0.00+0.00	6.43+7.51	t=-3.84,df =34,p<.001

Table 6.10. Solar trap Statistical Analysis of phase 1 and Phase 2 at 100point

Species	Phase 1	Phase 2	Statistical value
Termites	34.95 +12.82	4.25+6.372	t= 8.73, df=34,p<0.00
Muscoid flies	15.65+6.18	0.44+1.03	t=9.70, df=3,p<0.00
Flesh flies	11.45+7.03	0.12+0.50	t=6.40, df=34,p<0.00
Root grub	2.25+3.53	1.06+1.61	t=1.24, df=34,p=0.22
Brown Beetle	4.00+2.61	0.06+0.25	t=5.98, df=34,p=3.93
Black Beetle	3.20+3.66	3.36+3.50	t=-0.12,df=32, p=0.90
Silver moth	5.90+4.50	2.31+3.26	t=2.67, df=34,p<0.01
Snout moth	5.00+2.10	3.31+3.26	t=0.069,df=34,p=1.68
Geomitredea sp.	2.75+2.12	0.12+.34	t=4.87, df=34,p<0.00
Aemene moth	2.85+2.36	0.25+0.77	t=4.20,df=34,p<0.00
Chiasmia moth	1.00+1.02	2.12+2.65	t=-1.74, df=34,p=0.09
Musquito	0.40+.68	2.00+3.72	t=-1.89, df = 33, p =0.06
Brown stink bug	3.25+2.24	0.69+1.88	t=3.64, df = 34,p<0.01
Red cotton bug	2.95+2.39	1.12+2.06	t=2.41, df = 34,p<0.02
Horse fly	1.80+1.36	0.69+1.49	t=2.33, df = 34,p<0.01
Green stink bug	5.35+3.57	0.50+1.15	t=5.20, df=34,p<0.00

Saw fly	3.50+2.64	0.38+1.02	t=4.4, df=34,p<0.00
Water bugs	2.80+2.78	0.38+1.02	t=3.30, df=34,p<0.00
Honey bee	5.25+5.91	0.12+0.50	t=3.44, df=34,p<0.00
Potter wasp	0.50+.88	1.94+3.39	t=3.30, df=34,p<0.01
Black wasp	0.30+.57	0.56+0.96	t=3.44, df=34,p<0.00
Tree hopper	0.20+.52	3.38+4.28	t=-1.82, df=34,p=0.07
Leaf hopper	2.55+1.76	3.93+3.99	t=-1.01,df=34,p= 0.31
Earwig	1.25+1.94	0.12+0.34	t=-3.29, df =34,p<0.00
European corn borer	1.25+1.94	0.12+0.34	t=-1.38,df =34 ,p=0.17
Aphids	1.30+1.38	5.06+9.98	t=-2.01,df =33,p=0.01
Sphingidae moth	0.00+0.00	0.00+0.00	t=-2.33, df = 34,p<0.01
Green grasshopper	0.00+0.00	0.26+0.59	t=-2.0, df =33 p=0.05
Long horned moth	0.00+0.00	0.31+0.60	t=-2.33,df =34,p<0.01
Water bugs	0.00+0.00	6.43+7.51	t=-3.84,df =34,p<0.00

Bioacoustic method:

Activity of crickets:

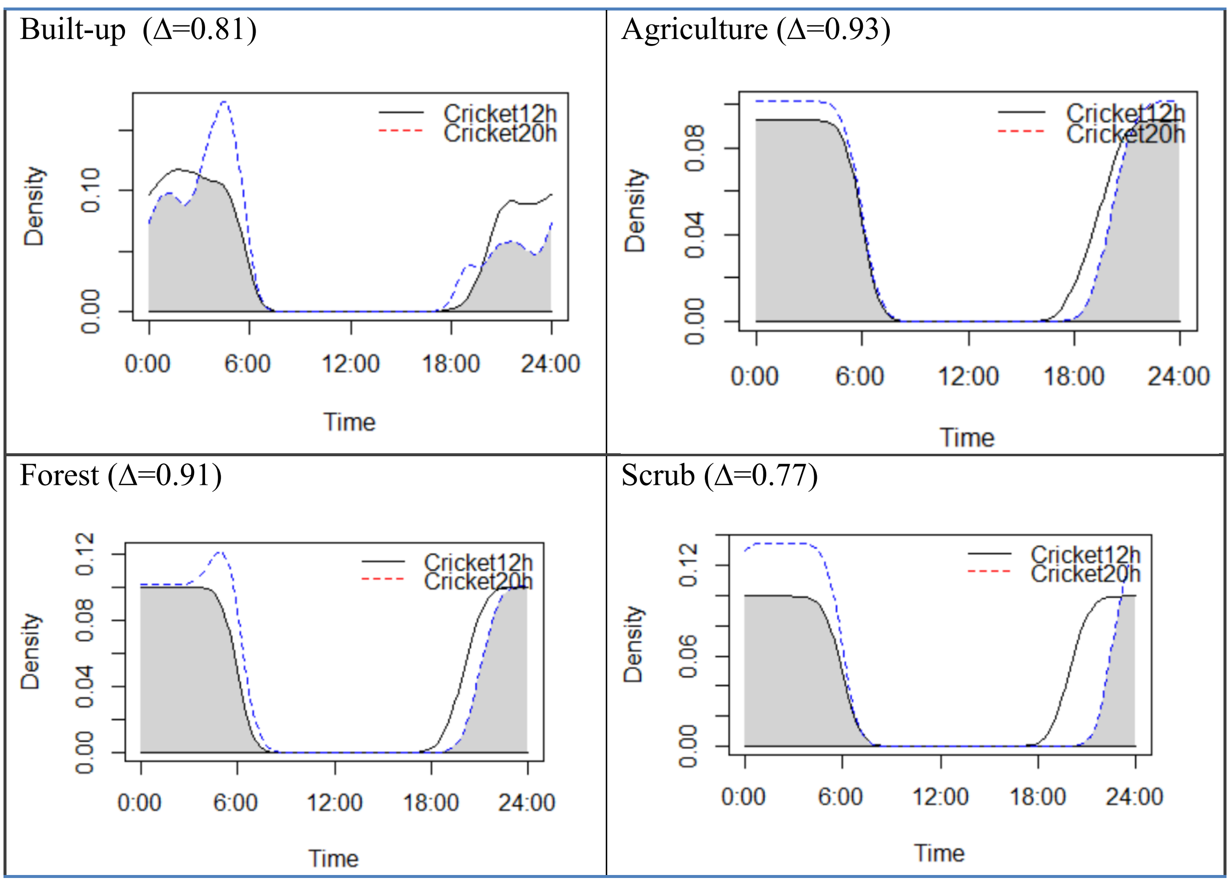


Fig.6.13: The density estimates in activity pattern of crickets during the operation of MPC

for both 12 hours and 20 hours. at different habitats A.Builtup, B. Agriculture, C. Forest, D. Open scrub.

Overlap in the calling activity pattern of crickets in four different habitats, viz Builtup, cultivated area, forest and scrub, habitat about 12 hours and 20 hours of belt run is showed in Fig. 6.13. The coefficient (Δ) of overlap in the built-up area was found to be (Δ=0.81) between 12 hours and 20 hours of operation of MPC. Similarly, the coefficient ($\hat{\Delta}$) of overlap in Agriculture habitat Δ=0.93, Forest Δ=0.91, Scrub Δ=0.77 respectively. Except in the built-up area, in all other habitat types, the activity of cricket started about 1 or 2 hours late during the 20-hours of the belt run. The density of their activity peaked after 01:00 hours during the 20-hours of the belt run.

Impact of MPC on cricket singing:

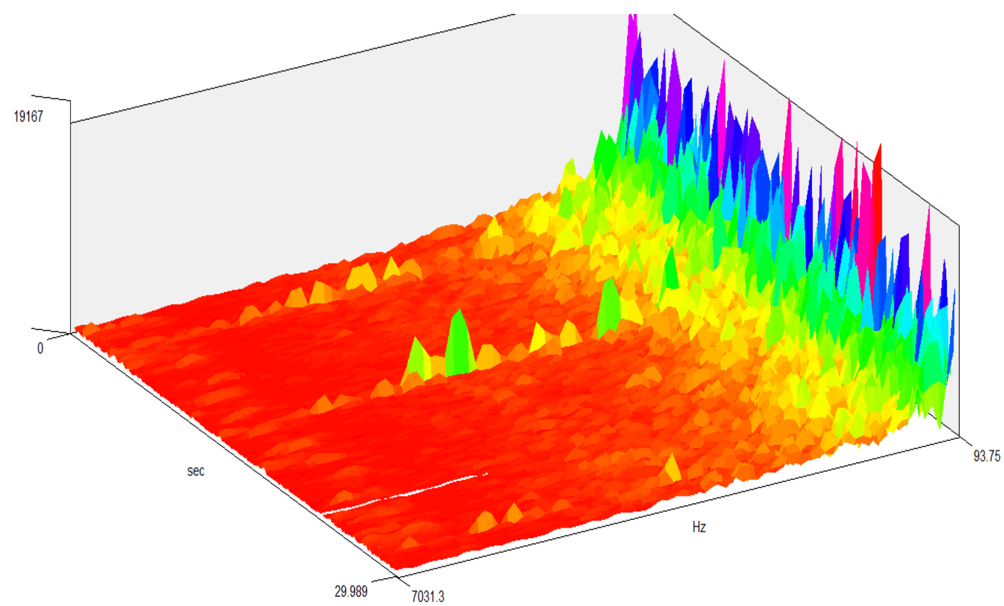


Fig.6.14: A 3D rendering of Fast Fourier Transform (FFT) of an orthoptera calls masked with the sound of MPCC.
The call of orthoptera sp is shown in green and the MPC sound is shown in yellow and orange. The X-axis indicates the frequency, Y-axis indicates the duration of the call and the Z-axis indicates the amplitude of the call.

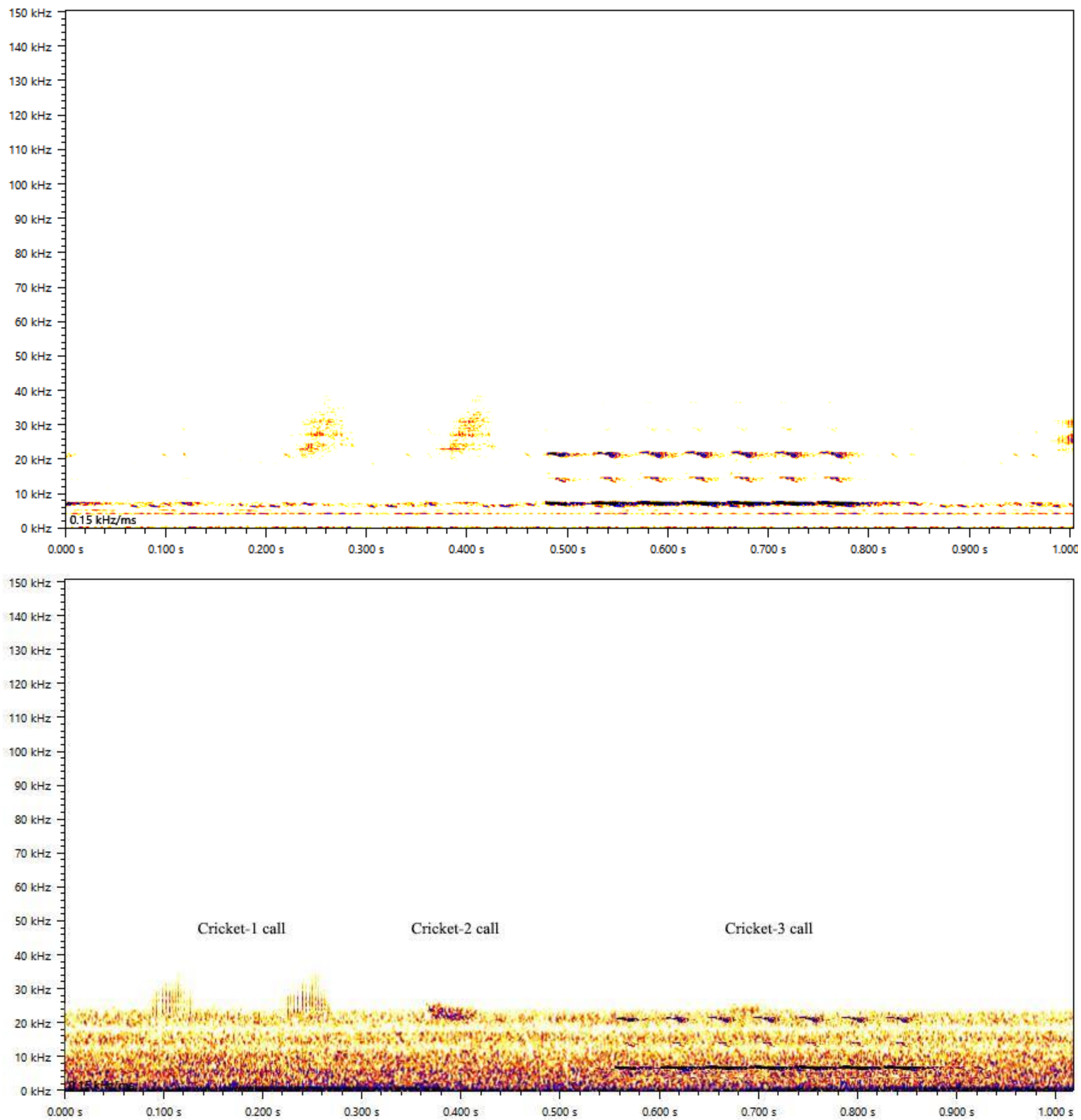


Fig. 6.15: A graphical representation of overlap of orthopterans calls on the noise from the MPC sound

The spectrogram resulting from the sound monitoring station is depicted in Fig. 6.14. The orthopterans including crickets and grasshoppers of having peak frequency 23.37 kHz and 21.64 kHz respectively are overlapping with the sound of MPC with the frequency 5.0 to 35.o kHz. This is represented graphically in Fig. 6.15. Further efforts are required to precisely identify the species and crickets of grasshoppers based on the sound recorders

Discussion

One hundred and ninety-two species of insects were identified and about 80% of them were beneficial to the ecosystem as they play many roles as Natural enemies, pollinators, scavengers, and many. This suggests that the study area is of high biological value considering the rich biodiversity. Most of the species are endemic to the Decan plaetue, regulating ecosystem function. Except in the agriculture field, both species richness and their abundance increased as the distance from the MPC increased. Although, the sound intensity gradually decreases perpendicular to MPC and also the relationship between the arthropod species richness and their abundance is negative that only indicates that some kind of avoidance of MPC area by them. However, this is difficult to provide a rationale for the same as the MPC is situated at the edge of the forest having the plant species composition is different. And further, agriculture practice also plays a role in determining the species richness and their abundance, thus concluding based on them from a single season data is incorrect. Thus, along-term observations and planned studies are required to develop the relationship between community turnover and sound as factors in determining the community composition and structure (Bunkley et al. 2017).

The species richness and the abundance of insects collected from the sticky trap showed no difference between phase-1 and phase-2, but variation in aphid numbers between both phases may be attributed to the diurnal activity of aphids (Broughton and Harrison 2012). However, the number of insect species trapped in the solar traps between phase-1 and phase-2 at 0 and 100 m distances from MPC difference in their abundance by few species. However, many of the insect species trapped were also diurnal and only a few were nocturnal.

Although, the cricket calling pattern remains the same in all the habitats, but the shift of few hours of late activity and also peaking of their activity after 1 AM during the 20-hours of belt run is of concern. There was a small period during peak calling activity when there was no overlap in the sound produced by the belt and the calling sound of the crickets (Slabbekoorn et al. 2007). Many studies have shown the impact of sound on acoustic communication of the animal however studies on the impact of MPC on the orthopterans is incipient here (Duarte et al. 2019). The masking and overlapping effects of cricket and grasshopper calls may manifest in differential impacts, ecologically. For instance, it may interfere with the mating and reproduction of crickets. The opposite sexes locate each other acoustically. If this medium of communication is disrupted, it will adversely affect the mating and reproduction of crickets. Similar would be the situation of other sound-producing insects which constitute the prey base for higher taxa animals. The amphibians, reptiles, birds and other mammal predators will be adversely affected as they will take more time to locate and search the prey. In the process, they will be exposed to harsh environmental situations. This in turn will affect adversely the top consumers in the ecosystem. This is because birds and small mammals serve as a prey base for these animals. Earlier studies conducted by (Schmidt and Balakrishnan2015) have also revealed similar consequences of sound produced by anthropogenic infrastructure in Austria. Thus, if the population of crickets and grasshoppers decline in the patch would lead to disruption in the ecosystem.

Conclusion

A total of One hundred and ninety-two species of arthropods was identified and documented in four different habitats in the study area in Sandbur taluk of Ballari, of that Lepidoptera was the dominant group of insects recorded. About 80% of insects identified were known to play a major role in the ecosystem as pollinators, predators, parasites decomposers scavengers and material and energy turnovers, thus, the study area is of high conservation and biodiversity value. As the distance from MPC increased, the sound decreased and the insect abundance and species richness increased. Cricket calls seem to be affected wherein their calls were masked by the sound produced by MPC. This might lead to different ecological and behavioural implications on the cricket and their predators. There was not much difference in the abundances and species richness of insects between phase-1 (12 hours of MPC operation) and Phase-2 (20 Hours of MPC operation) Since the study taken up was for a very short period, drawing any conclusion becomes difficult, thus, further, long term studies over different seasons would be appropriate to draw definite inferences on the impact of Noise and its associated factors produced by MPC on arthropods.

Chapter VII: Amphibian Study

CHAPTER VII

AMPHIBIAN STUDY

Introduction

Amphibians are the most threatened group of vertebrates in the world. They are composed of 3 orders, namely Anura (Frogs and Toads), Caudata (salamanders and newts) and Gymnophiona (caecilians). The word Amphibian comes from Greek (Amphi - dual or double, bios - life) for a tadpole and an adult lifestyle. The early life of an Amphibian is generally spent in water and it later metamorphoses into an adult, terrestrial form. There are 8365 known species of Amphibians world over (Frost, 2021). Global assessment carried out in the year 2004, shows that nearly one-third of the world's Amphibians are threatened with extinction (Baillie et al, 2004). India harbours over 465 species of Amphibians. Amphibians have evolved 360 million years ago; however, the last three decades have seen an alarming increase in extinction (nearly 168 species) and global decline in Amphibian populations (Stuart et al, 2004). Among many listed factors, habitat destruction is the most important factor leading to Amphibian population declines. An emerging disease called chytridiomycosis and global climate change are also causing threats to Amphibian population world over. Listed factors that influence negatively on Amphibian populations include habitat destruction, alteration and fragmentation (Marsh and Trenham, 2001), introduced species (Vredenburg 2004) and over-exploitation (Lannoo et al., 1994), climate change (Carey and Alexander 2003), increased UV-B radiation, chemical contaminants (Blaustein et al. 2003), emerging infectious diseases (Daszak et al. 2003) and deformities (or malformations).

Studies have shown that reproductive behaviour such as calling behaviour, calling plasticity and mate attraction are impacted by noise pollution in Amphibians. Vibrations had negative impacts on physiology and human presence changed the abundance of species, both in Amphibians and small mammals (Schaijk, 2013).

Review of Literature

A study by Simmons and Narins (2008) says Anurans are highly vocal species that rely on acoustic communication for social behaviours. The advertisement (mating) calls of many anurans contain considerable energy within the predominant spectral range of traffic and other anthropogenic-noise sources. Whether and how these noise sources affect reproductive success and species viability is unclear. Data that address how anthropogenic sources affect the spatial distribution of breeding ponds, production and propagation of males' vocal signals, and detection and discrimination of these signals by females are inconsistent. Anurans may respond to anthropogenic noise using many of the same strategies that they use to deal with biotic and abiotic noise. But there are considerable differences between species in their responses to noise, related to habitat and other variables.

Call frequencies of anuran species are partially constrained by body size (Kime et al., 2000). Snout–vent length is negatively correlated with dominant call frequency (Duellman and Pyles, 1983; Littlejohn, 1977; Morris, 1989; Richards, 2006; Ryan, 1980; Ryan and Brenowitz, 1985). Large frogs generally have larger larynxes and thus produce low-frequency calls. Sexual selection can affect the dominant frequency of mating calls as some females favour low-frequency signals (Ryan, 1980; Ryan and Keddy-Hector, 1992) as an indicator for larger body size (Morris, 1989; Morris and Yoon, 1989). Higher frequencies are easier to locate (Konishi, 1970) but suffer more attenuation than low frequencies (Kime et al., 2000; Ryan, 1986). Vocalizing in narrow frequency bands consequently includes a trade-off between detectability and long-distance transmission (Bosch and De la Riva, 2004). Selective forces not only act upon the production of signals but also on their transmission and detectability. Distinct, acoustic habitat properties (''melotops'') impose different selection pressures on animal vocalizations. Biotic and abiotic noise can influence the evolution of acoustic signals in a variety of ways such as spectral partitioning of acoustic signals of co-occurring species, noise-dependent vocal amplitude regulations and receiver's range of frequency sensitivity changes due to masking interference. Boeckle (2009) says dominant frequencies of call by Frog increase the signal-to-noise ratio in environments dominated by low-frequency noise. Troïanowski (2017) showed that noise exposure increased stress hormone levels and induced an immunosuppressive effect. Also, profound changes in sexual selection processes because the best quality males with initial attractive vocal sac colouration were the most impacted by noise.

This study was carried out

1. To study amphibian diversity, abundance and distribution along the MPC in different land-uses in existing and extended operations of the MPC belt.
2. To record and analyse anuran call records and to compare them with the frequency spectrum of MPC.

Materials and Methods

Maps of sampling sites

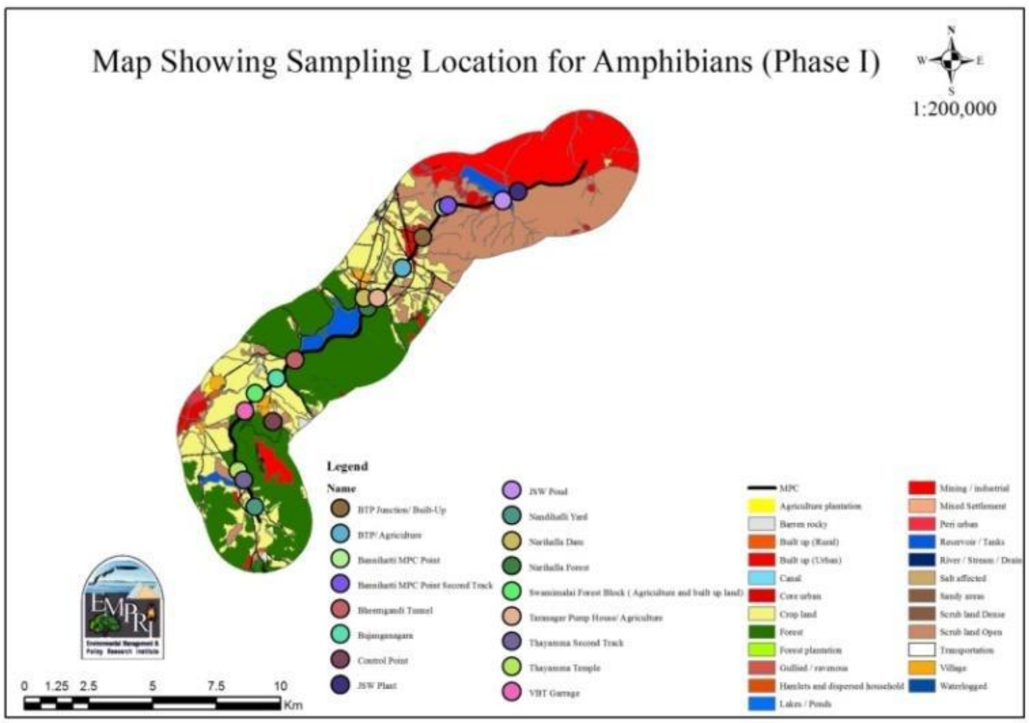


Figure 7.1: Map showing Sampling locations (Phase I)

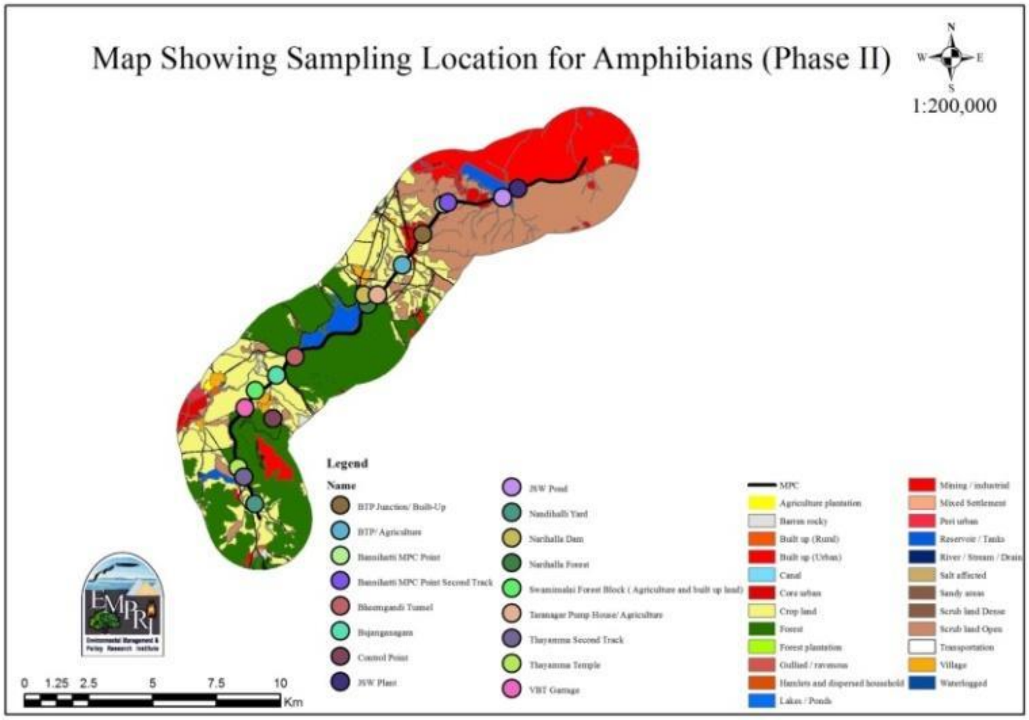


Figure 7.2: Map showing Sampling locations (Phase II)

Instruments Used

- Garmin e-Trex 10 GPS Instrument
- Zoom H1 Digital Voice Recorder
- SF-400 digital Weighing Machine
- 150mm 6" LCD Digital Carbon Fiber Vernier Caliper Gauge Micrometer

Amphibian survey methods

Visual Encounter Survey -Time Constrained Method: 6 habitats (Forest, Agriculture, Built-Up, Waterbody, Wasteland and Control Site) were selected and sampled. Nocturnal (18:30–20:30) surveys were carried out in each habitat.

Sound Recording

A 2-minute call of an individual frog species is recorded using Zoom H1 recorder, Cardioid Microphone and Earphone.

Total sampling effort in each phase

Phase I - 32h

Phase II - 32h

Result

Amphibian diversity in Phase I

A total of 12 species of anurans (frogs and toads) were sighted. This includes one Schedule IV species (IWP, 1972) and one unconfirmed species. All are least concern species according to IUCN Red List categories and no CITES species were sighted.

Table 7.1: Amphibian species list sighted during Phase_1

Common Name	Scientific_Name	IUCN*	#WPA
Common Indian Toad	*Duttaphrynus melanostictus*	LC	
Marbled Toad	*Duttaphrynus stomaticus*	LC	
Ferguson's Toad	*Duttaphrynus scaber*	LC	
Indian Burrowing Frog	*Sphaerotheca breviceps*	LC	
Ornate Narrow Mouthed Frog	*Microhyla ornata*	LC	
Red Narrow Mouthed Frog	*Microhyla rubra*	LC	
Common Skittering Frog	*Euphlyctis cyanophlyctis*	LC	
Common Cricket Frog	*Minervarya agricola*	LC	
Cricket Frog sp.	*Minervarya cf. agricola*		
Indian Tree Frog	*Polypedates maculatus*	LC	
Indian Bull Frog	*Hoplobatrachus tigerinus*	LC	Sch. IV
Marbled Balloon Frog	*Uperodon systoma*	LC	

Note: *IUCN: International Union for Conservation of Nature, NE: Not Evaluated, LC: Least Concern, NT: Near Threatened #WPA: Wildlife Protection Act, †CITES: Convention on International Trade in Endangered Species of Wild Flora and Fauna.

Amphibian Diversity Analysis Phase I

Control site shows high Shannon Index (H = 2.034) and while grasslands have lowest (without any species). Other habitats are more or less similar in diversity except in scrubland shows less Shannon Index (H = 1.055). Agriculture land had the highest amphibian richness and abundance (12 species and 261 individuals), followed by forest (9 species and 76 individuals). Shannon Index, richness and abundance are given in Table 7.2.

Table 7.2: Amphibians Diversity Analysis (Phase I)

Species	**Ag_01**	**BU_01**	**Ft_01**	**GL_01**	**Sb_01**	**WL_01**	**CN_01**
Duttaphrynus melanostictus (Schneider, 1799)	13	1	13		4	2	2
Duttaphrynus scaber (Schneider, 1799)	1					2	
Duttaphrynus stomaticus (Lütken, 1864)	1				4		1
Euphlyctis cyanophlyctis (Schneider, 1799)	46		32			2	7
Hoplobatrachus tigerinus (Daudin, 1802)	3		1			1	3
Microhyla ornata (Dumeril & Bibron, 1841)	14	1				1	4
Microhyla rubra (Jerdon, 1853)	3	1					
Minervarya agricola (Jerdon, 1853)	150	1	20		2	2	3
Minervarya cf. agricola	3						
Polypedates maculatus (Gray, 1830)	8	3	7			1	2
Sphaerotheca breviceps (Schneider, 1799)	17	1	3			5	3
Uperodon systoma (Schneider, 1799)	2						1
Shannon_H	1.449	1.667	1.422		1.055	1.923	**2.034**
Total Abundance	**261**	8	76	0	10	16	26
Total Richness	**12**	6	6	0	3	8	9

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL: Grass Land, Sb: Scrub Land, WL: Wetland, CN: Control

Figure 7.3 shows the species accumulation curve. A total of 12 species of amphibians were sighted and sampling plateaued by the callipers7th sampling effort.

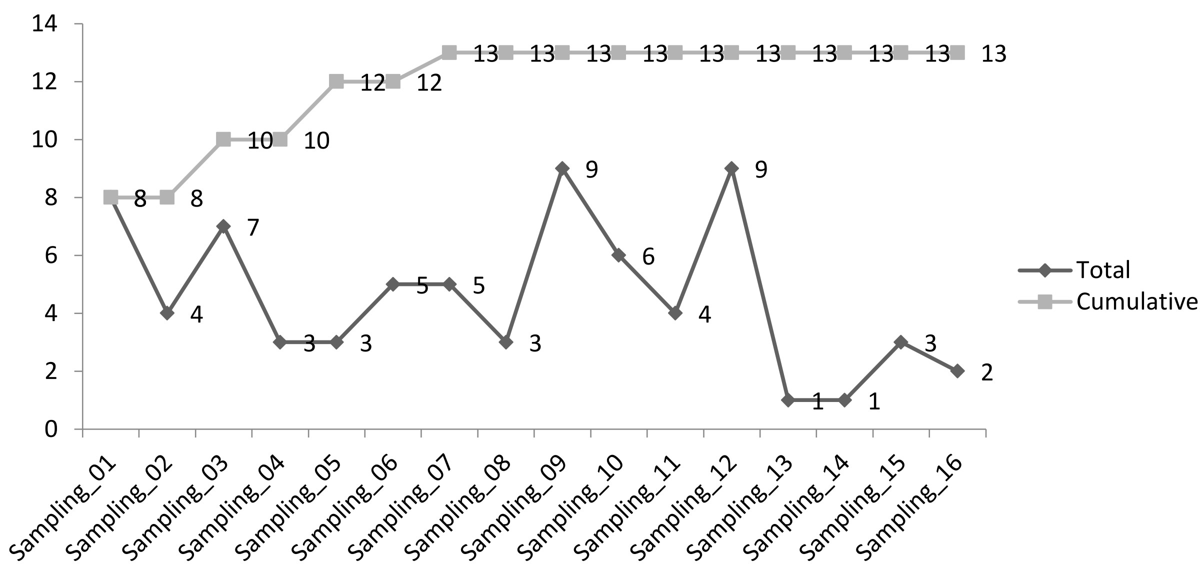


Figure 7.3: Amphibians Species Accumulation Curve (Phase I)

Amphibians Acoustic Analysis (Phase I)

Calls of 6 species were recorded during the sampling. Morphometric measurements were taken using Vernier callipers and a weighing machine. Calls were analyzed in Raven Pro software for annotation. It is found that peak frequencies of all calls were falling within 5000Hz. Indian tree Frog and Indian Bull Frog are found to be producing very low frequencies of sound (823.58±257.08Hz and 937.5Hz respectively) and Common cricket Frog and Ferguson's Toad produces higher frequency sound (3341.95±284.12Hz and 3222.38±43.7Hz respectively). Table 7.3 provides a list of species with male and female size, calls recorded, duration, and peak frequency. Figure 7.6 illustrates the 3D view of the call spectrum of a few annotated calls of frogs.

Table 7.3: Amphibians Acoustic Analysis (Phase I)

Species	***Duttaphrynus melanostictus***	***Duttaphrynus stomaticus***	***Duttaphrynus scaber***	***Sphaerotheca breviceps***	***Microhyla ornata***	***Microhyla rubra***	***Euphlyctis cyanophlyctis***	***Minervarya agricola***	***Polypedates maculatus***	***Hoplobatrachus tigerinus***	***Uperodon systoma***	***Uperodon taprobanicus***
No. of Individuals ♂	2	1	1	7	2	2	1	3	0	0	0	0
SVL♂(mm) ±SD	59.3±6.65	47.4	28.9	49±8.49	22±3.11	20.1±4.38	43	28.20±0.72				
Weight♂(g) ±SD	26.5±10.61	14	2	26.5±16.26	1.50±0.71	2.33±1.15	4	2.33±0.58				
No. Of Individuals ♀	2	2	2	4	1	1	3	4	1	1	1	1
SVL♀(mm) ±SD	93.6±10.75	59.55±4.88	36.55±5.30	41.00	21.2	27.20	51.2±13.86	33.58±1.90	47.00	39.6	33.20	49.9
Weight♀(g) ±SD	73.50±13.44	32±16.97	5.50±3.54	9	2	3	20±17.06	5	10	8	6	15
Number_of_calls	80		17		9			65	89.00	4		
Call_duration(s)	1.12±3.81		1.3±2.20		0.31±0.05			0.25±0.07	0.13±0.08	0.26±0.06		
Min_Freq(Hz)	580.30±82.06		2845.53±51.84		483.16±92.69			1128.77±103.56	144.41±63.21	686.71±26.90		
Max_Freq(Hz)	2478.05±84.03		4681.11±159.42		6207.03±234.09			5230.33±812.91	3732.41±145.24	1063.09±40.30		
Freq 25% (Hz)	1328.59±47.03		3100.78±86.13		2392.58±37.98			2777.45±602.55	700.68±66.45	937.5±0		
Freq 75% (Hz)	1452.41±32.84		3364.25±47.87		2698.82±43.06			3437.36±133.37	1420.71±253.17	1851.56±46.88		
Peak_Freq(Hz)	1399.66±42.24		3222.38±43.7		2603.12±37.98			3341.95±284.12	823.58±257.08	937.5		

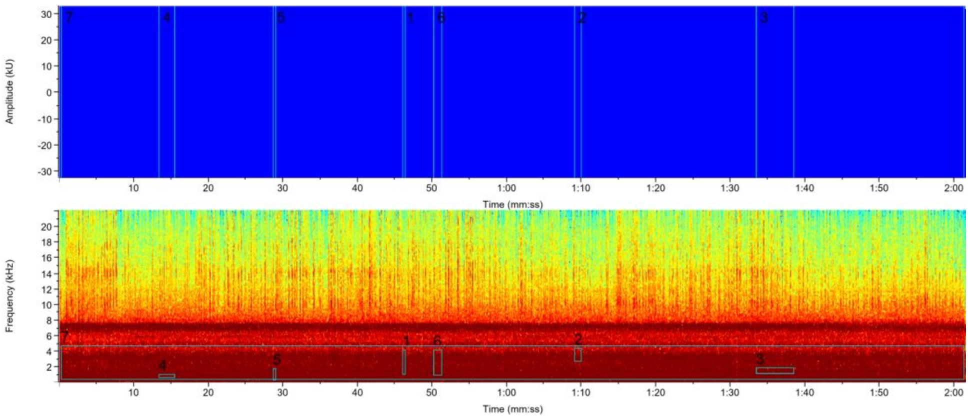


Figure 7.4: Fast Fourier Transform (FFT) of Frogs along with MPC

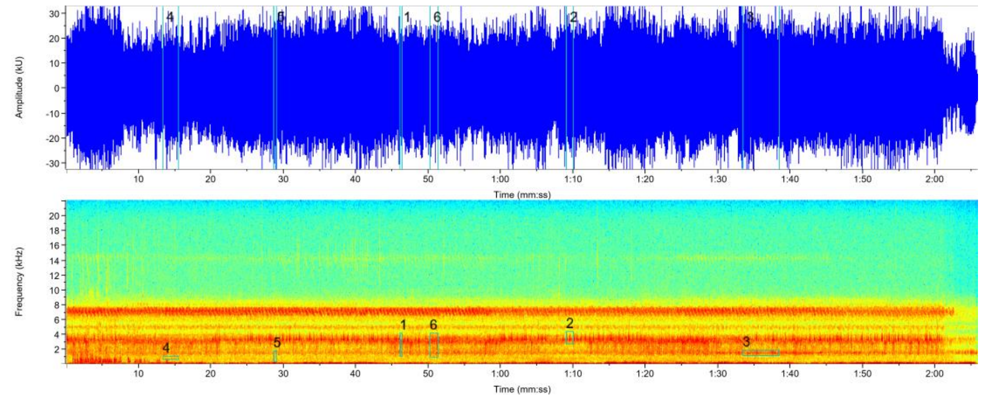


Figure 7.5: Fast Fourier Transform (FFT) of Frogs without MPC

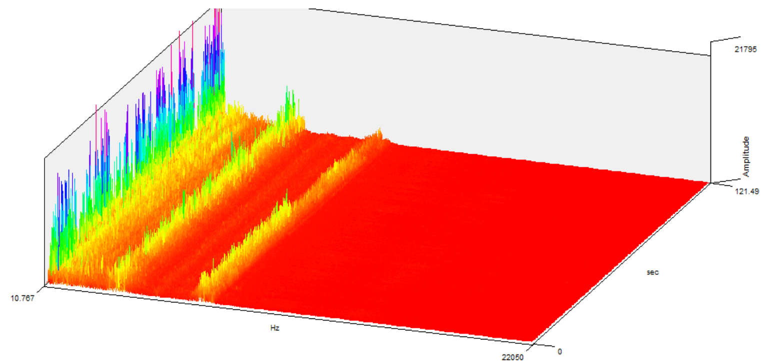


Figure 7.6: 3D rendering of Fast Fourier Transform (FFT) of Frogs along with MPC

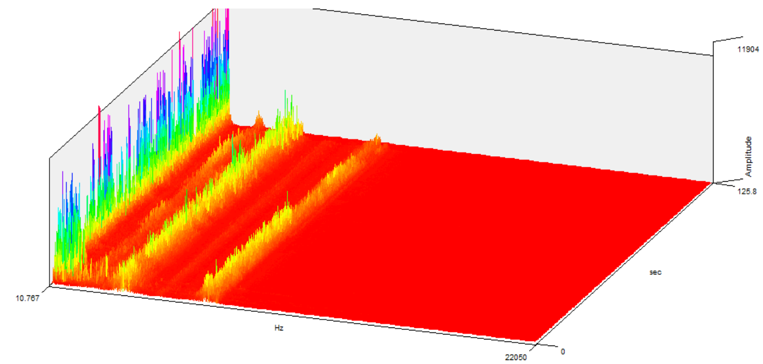


Figure 7.7: 3D rendering of Fast Fourier Transform (FFT) of Frogs without MPC

1: *Microhyla ornata*, 2: *Duttaphrynus scaber*, 3: *Duttaphrynus melanostictus*, 4: *Hoplobatrachus tigerinus*, 5: *Polypedates maculatus*, 6: *Minervarya agricola*, 7: Main Pipe Conveyor Belt (MPC)

Amphibian diversity in Phase II

A total of 12 species of amphibians were sighted. An additional species compared to Phase I was sighted during this period. The species recorded were the least concerned category according to IUCN.

Table 7.4: Amphibian species list sighted during Phase_2

Common Name	Scientific_Name	IUCN*	#WPA
Common Indian Toad	*Duttaphrynus melanostictus*	LC	
Marbled Toad	*Duttaphrynus stomaticus*	LC	
Ferguson's Toad	*Duttaphrynus scaber*	LC	
Indian Burrowing Frog	*Sphaerotheca breviceps*	LC	
Ornate Narrow Mouthed Frog	*Microhyla ornata*	LC	
Red Narrow Mouthed Frog	*Microhyla rubra*	LC	
Common Skittering Frog	*Euphlyctis cyanophlyctis*	LC	
Common Cricket Frog	*Minervarya agricola*	LC	
Indian Tree Frog	*Polypedates maculatus*	LC	
Indian Bull Frog	*Hoplobatrachus tigerinus*	LC	Sch IV
Marbled Balloon Frog	*Uperodon systoma*	LC	
Srilankan Painted Frog	*Uperodon taprobanicus*	LC	

*IUCN: International Union for Conservation of Nature, NE: Not Evaluated, LC: Least Concern, NT: Near Threatened #WPA: Wildlife Protection Act, †CITES: Convection on International Trade in Endangered Species of Wild Flora and Fauna

Amphibian Diversity Analysis (Phase II)

Shannon Index was again highest in Control (H=1.857) similar to that of Phase I. No amphibians were recorded from scrubland. Agriculture land had higher species richness as well as abundance compared to all the other land-uses (12 species and 212 individuals) followed by forest with higher abundance (126 individuals) and built-up with higher richness (9 species). Table 7.5 depicts the details of the Shannon Index, species richness and abundance of anurans in Phase II.

Table 7.5: Amphibian Diversity Analysis (Phase II)

Species	**Ag_02**	**BU_02**	**Ft_02**	**GL_02**	**Sb_02**	**WL_02**	**CN_02**
Duttaphrynus melanostictus (Schneider, 1799)	17	2	5			8	5
Duttaphrynus scaber (Schneider, 1799)	5						
Duttaphrynus stomaticus (Lütken, 1864)	1	1		2		1	
Euphlyctis cyanophlyctis (Schneider, 1799)	35	18	87			10	20

Hoplobatrachus tigerinus (Daudin, 1802)	3	2					11
Microhyla ornata (Dumeril & Bibron, 1841)	18	1					7
Microhyla rubra (Jerdon, 1853)	3	2					1
Minervarya agricola (Jerdon, 1853)	104	2	28				18
Polypedates maculatus (Gray, 1830)	2	2	1				17
Sphaerotheca breviceps (Schneider, 1799)	18	9	5	1			5
Uperodon systoma (Schneider, 1799)	1						
*Uperodon taprobanicus (*Parker, 1934)	5						
Shannon_H	1.66	1.645	0.8845	0.6365		0.857	**1.857**
Total Abundance	**212**	39	126	3	0	19	84
Total Richness	**12**	9	5	2	0	3	8

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL: Grass Land, Sb: Scrub Land, WL: Wetland, CN: Control

Amphibian Species Accumulation Curve (Phase II)

The species accumulation curve is depicted in Figure 7.8. A total of 12 species of amphibians were sighted during Phase II and the curve plateaued from the 4th sampling visit, but one species was added at the 9th and 15th visits.

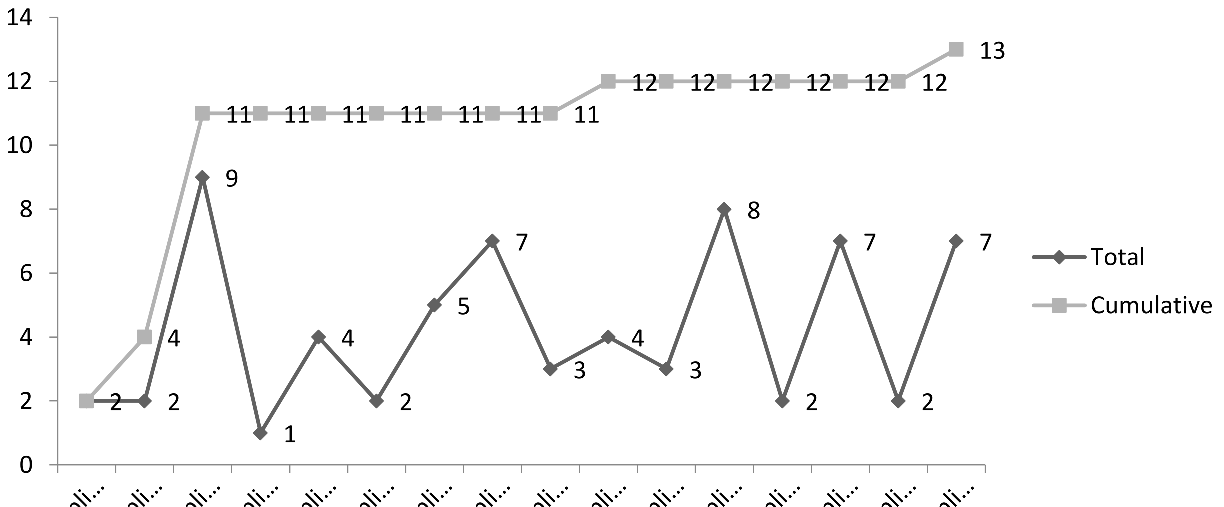


Figure 7.8: Amphibians Species Accumulation Curve (Phase II)

Habitatwise Diversity Comparison

Abundance values of amphibians were compared across different land-uses as well as control. Mann Whitney U test did not exhibit any significant difference between the sites, indicating a similarity between abundance irrespective of the habitats in which amphibians are found. Table 7.6 and 7.7 provides abundance values and Mann-Whitney U test values.

Table 7.6: Habitat Wise Diversity Comparison

Species	**Ag_01**	**Ag_02**	**BU_01**	**BU_02**	**Ft_01**	**Ft_02**	**GL_01**	**GL_02**	**Sb_01**	**Sb_02**	**WL_01**	**WL_02**	**CN_01**	**CN_02**
Duttaphrynus melanostictus **(Schneider, 1799)**	13	17	1	2	13	5			4		2	8	2	5
Duttaphrynus scaber **(Schneider, 1799)**	1	5									2			
Duttaphrynus stomaticus **(Lütken, 1864)**	1	1		1				2	4			1	1	
Euphlyctis cyanophlyctis **(Schneider, 1799)**	46	35		18	32	87					2	10	7	20
Hoplobatrachus tigerinus **(Daudin, 1802)**	3	3		2	1						1		3	11
Microhyla ornata **(Dumeril & Bibron, 1841)**	14	18	1	1							1		4	7
Microhyla rubra **(Jerdon, 1853)**	3	3	1	2										1
Minervarya agricola **(Jerdon, 1853)**	150	104	1	2	20	28			2		2		3	18
Minervarya cf. agricola	3													
Polypedates maculatus **(Gray, 1830)**	8	2	3	2	7	1					1		2	17
Sphaerotheca breviceps **(Schneider, 1799)**	17	18	1	9	3	5		1			5		3	5
Uperodon systoma **(Schneider, 1799)**	2	1											1	
Uperodon taprobanicus **(Parker, 1934)**		5												
Shannon_H	1.449	1.66	1.667	1.645	1.422	0.8845		0.6365	1.055		1.923	0.857	**2.034**	**1.857**
Total Abundance	261	212	8	39	76	126	0	3	10	0	16	19	26	84
Total Richness	12	12	6	9	6	5	0	2	3	0	8	3	9	8

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL: Grass Land, Sb: Scrub Land, WL: Wetland, CN: Control

Table 7.8: Habitat Wise Mann-Whitney U test. Values below diagonal are Mann-Whitney U values, above diagonal are P values.

Sites		Ag_01	BU_01	Ft_01	GL_01	Sb_01	WL_01	CN_01
		0.85						
Ag_02	80.5		0.07					
BU _02		50		0.75				
Ft_02			78.5		NA			
GL_02				NA		NA		
Sb_02					NA		0.12	
WL_02						57.5		0.33
CN_02							65.5	

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL: Grass Land, Sb: Scrub Land, WL: Wetland, CN: Control

Habitat Wise Mann-Whitney U test with Control

Except for forest area during phase I and control area in phase I, none of the land-uses differed with respect to amphibian abundance.

Table 7.9: Habitat Wise Mann-Whitney U test with Control. Values below diagonal are Mann-Whitney U values, above diagonal are P values.

		C1	C2	C1	C2	C1	C2	C1	C2	C1	C2	C1	C2
		0.07											
Ag_01	32.5		0.69										
Ag_02		42.5		0.12									
BU_01			16.5		0.06								
BU _02				16.5		**0.05**							
Ft_01					**12**		0.96						
Ft_02						19.5		NA					
GL_01							NA		NA				
GL_02								NA		0.34			
Sb_01									9		NA		
Sb_02										NA		0.27	
WL_01											31.5		0.53
WL_02												8.5	

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL: Grass Land, Sb: Scrub Land, WL: Wetland, C1: Control 1, C2: Control 2.

Changes in abundance of calling individuals

On comparing the number of calling individuals observed during Phase I with Phase II, there were differences between the two phases. This was to understand the impact of extended operations of MPC (20h). From 217 calling individuals in Phase I, they were reduced to 70 (nearly one third) during Phase II. However, the difference in their abundance was not statistically significant (U=0.212). Changes in abundance of calling individuals are given in Table 7.10

Table 7.10: Changes in abundance of calling individuals in Phase I and Phase II.

Species	No_Of_Calls_Phase I	No_Of_Calls_Phase II	Difference
Duttaphrynus melanostictus (Schneider, 1799)	9	5	-4
Duttaphrynus scaber (Schneider, 1799)		1	1
Euphlyctis cyanophlyctis (Schneider, 1799)	49	2	-47
Hoplobatrachus tigerinus (Daudin, 1802)	1	1	0
Microhyla ornata (Dumeril & Bibron, 1841)	6	10	4
Microhyla rubra (Jerdon, 1853)	2		-2
Minervarya agricola (Jerdon, 1853)	132	47	-85
Polypedates maculatus (Gray, 1830)	13	4	-9
Sphaerotheca breviceps (Schneider, 1799)	5		-5
Total Abundance	217	70	-147
Total Richness	8	7	-1

Habitat wise changes in abundance of calling individuals

To check the changes in abundance values from Phase I and II concerning land-uses, abundance data from different land-uses are given in Table 7.11. The abundance of calling individuals in agricultural areas changed from 166 in Phase I to 65 in Phase II. Similarly, it was reduced in forest habitat from 44 to 2 individuals. The reduction in abundance from forest area is statistically significant (U=18.5, p=0.04).

Table 7.11: Habitat Wise Call Analysis

Species/ Call	Ag_1	Ag_2	BU_1	BU_2	Ft_1	Ft_2	WL_1	WL_2	CN_1	CN_2
Duttaphrynus melanostictus (Schneider, 1799)	3	2			4	1	2	2		
Duttaphrynus scaber (Schneider, 1799)		1								
Euphlyctis cyanophlyctis (Schneider, 1799)	28	2			20		1			

Hoplobatrachus tigerinus (Daudin, 1802)		1			1					
Microhyla ornata (Dumeril & Bibron, 1841)	6	10							1	2
Microhyla rubra (Jerdon, 1853)	2									
Minervarya agricola (Jerdon, 1853)	120	47			11		1			1
Polypedates maculatus (Gray, 1830)	3	2	2	1	7	1	1			17
Sphaerotheca breviceps (Schneider, 1799)	4				1					
Total Abundance	**166**	**65**	2	1	44	2	5	2	1	20
Total Richness	**7**	**7**	1	1	6	2	4	1	1	3

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL: Grass Land, Sb: Scrub Land, WL: Wetland, CN: Control

Discussion

Thirteen species of anuran amphibians (frogs and toads) were recorded in this study. Except for grassland, all land-uses were similar in species richness. Species richness and total abundance of anurans did not differ statistically between Phase I and Phase II. However, the abundance of calling individuals differed considerably from Phase I to Phase II, with a reduction of about a third of individuals. The reduction in the abundance of calling individuals can be attributed to the extended hours of operation of MPC and sound frequency emanating from it. Sun and Narins (2005) have discussed similar reductions in their study. MPC frequency spectrum may further influence the call modulations in anurans of the region; however, this needs long-term study and a large sample size to substantiate.

The call records of anurans and sound records of MPC are subjected to Fast Fourier Transformation (FFT) analysis using Raven Pro 1.6. As shown in Figures 7.4 and 7.5, the call spectrum of frogs is masked by the spectrum of MPC, which is about 5000Hz. It is evident from Table 7.3, all the calling species of frogs and toads from this region have a call spectrum below 3500Hz. Species like *Polypedates maculates* and *Hoplobarachus tigerinus* have peak frequencies at 823.58±257.08 Hz and 937.5 Hz respectively. *Duttaphrynus melanostictus* also had a low frequency around 1399.66±42.24 Hz. These frequencies are masked by the MPC frequency spectrum very well.

Anurans are highly vocal species that rely on acoustic communication for social and reproductive behaviours. Their reproductive success depends on the male advertisement call and the female's detection of the potential male (Sun and Narins, 2005). An increase in the noise in the environment such as noise from MPC can mask the calls of male Frogs which fail advertisement and they may be pushed to increase the frequency of their calls (Higham et al. 2020). Studies show that male Frogs in noisy environments tend to acquire certain adaptations to overcome the call masking. A study by Boeckle (2009) quoted various adaptations as follows; (1) changing calling patterns (in rate, duration, frequency, or amplitude), (2) shifting the timing of calls, (3) calling at times of day when another noise is not present, (4) varying the complexity of the type of call produced, and (5) maintaining specific spatial locations within choruses to minimize call overlap with noise. Changing the calling pattern is a costly adaptation where individuals have to spend more energy to overcome the masking by other noise. Since the MPC noise is dynamic, shifting time and calling at day is also may not be possible for them. Female receptors are sensitive to the male frequencies. This may be a constrain when increasing the calling pattern. The mate may not be recognizing the advertisement of the male (Boeckle, 2009). In addition to this, studies proved that the frequency is inversely proportional to the body size, especially the snout to vent length. This implies a future reduction in the body mass of male Frogs when they are forced to call in higher frequencies. In addition to this, as suggested by Grace and Noss (2017), Amphibians tend to avoid the noisy environment, which may lead to the reduction in richness and abundance of Amphibians. Our diversity analysis was also showing the same. Even though it was not statistically significant, the diversity indices show little variations in both phases. This can be experimented with by increasing the sampling in a long term study. Also, noise exposure can trigger physiological stress (Tennessen et al. 2018).

Apart from these, some other parameters like vibration and luminescence are also needed to be addressed. We have collected the vibration produced by MPC during its operational time and Illuminescence from three different transfer points along MPC. The data was not able to correlate with the species data collected. Even though these issues can also be flagged and suggested for future studies. Light pollution is poorly studied and is of concern for Amphibians. Adult Frogs conduct the majority of their foraging and reproductive activities under twilight or nocturnal conditions. Increased luminescence may be affected their reproductive biology and physiology. Also, night lighting may increase the predation risk. Eggs and larvae typically develop in aquatic environments, where they may be exposed to artificial illumination. Studies by Gutierrez et al. (1984), Delgado et al. (1987), Edwards and Pivorun (1991) and Eichler and Gray (1976) shows artificial night lighting has the potential to affect time to metamorphosis or size at metamorphosis. The behaviour and physiology of tadpoles may also be affected by night lighting. However, the consequences of lights for the Amphibian population remains poorly studied and immediate attention is needed in this area. Amphibians comprise the terrestrial vertebrates most sensitive to vibrations (Caorsi et al. 2019). A study by Caorsi et al. (2019) shows that anthropogenically derived substrate-borne vibrations could reduce individual reproductive success. The amphibian ear is known to detect both airborne sounds and substrate born vibrations. And their study shows that anthropogenic vibratory stimuli caused a strong reduction in the calling activity in focal males, decreasing their mean call rate by 50%. In the present study also the MPC is causing vibration to the ground through pillars during its operational time, which may harm their calling activity and physiology (Schaijk, 2013).

In the present study, the sampling was mainly focused on the adults, thus the impacts of noise and vibration in tadpoles (dependent on water) is not addressed. Since the transmission of acoustic signals is much higher in denser mediums like water (McGregor et al. 2013), a long-term study of both adult and tadpoles is needed to understand the impact better. Creating more ecologically functional waterbodies, sound barriers (natural as well as artificial), change in MPC operational procedures (steel idlers to HDPE, reduced MPC function during breeding season and time of amphibians, to reduce frequency and sound emanating from MPC) can be implemented to reduce the impact on amphibians.

Chapter VIII: Reptile Study

CHAPTER VIII
REPTILE STUDY

Introduction to Reptiles

Reptiles of India are one of the most diverse and poorly known taxa in terms of their ecology (Vijayakumar et al., 2006). Studies on the population and ecology of reptiles are scanty in India. There have been several efforts to create inventories of Indian reptiles which are collations of documentation, findings and records of herpetologists (Ahmed et al. 2009, Daniel 2002, Das 2002, Das & Das 2018, Gururaja 2012, Ganesh 2015, Vasudevan & Sondhi 2010; Whitaker and Captain 2004). In India, reptiles have three representative orders – Crocodylia (Crocodiles), Testudines (Turtles and Tortoises) and Squamata (Lizards and Snakes). Reptiles found in almost all parts of the world except the very cold regions. The diversified climate, varying vegetation and different types of soil in the country form a wide range of biotopes that support a highly diversified herpetofauna. A total of 572 species of reptiles which includes 3 species of crocodiles, 34 species of turtles and tortoises, 231 species of lizards and 304 species of snakes belonging to 36 families recorded till date from India (Aegnals et al. 2018) .

Unlike birds and mammals, reptiles are ectotherms, requiring enough complexity in their habitat to move from areas of higher or lower temperatures as needed. This may make them more strongly affected by the habitat of reclaimed areas than birds and mammals (Walton, 2012). factors caused by mining activities, such as pollution of rivers and aquifers, polluting debris, acid drainage, gas and dust emissions, and local removal of all vegetation, could increase the impact of mining over species and further increase species extinction risks (Fernando Mayani-Parás; 2019).

Noise and Reptiles

Noise has been acknowledged as a major stressor with the capability to mask and alter calls between conspecifics, hamper the detection of predators, change the hearing thresholds of individuals and alter animals' distribution. Noise exposure has negative physiological effects on animals, including hearing impairment and deafness, disrupted responses of the hypothalamic- pituitary-adrenal axis, reproductive problems, immunosuppression and stress, (Kight and Swaddle, 2011; Mancera, 2017). Moreover, even less is known about how anthropogenic noise impacts the acoustic behaviours of reptiles. Knowing how some species have adapted to noise is important for understanding and modelling potential population and ecosystem consequences.

Review of Literature:

Tennessen *et. al*. (2014) suggested that Human-generated noise has profoundly changed natural soundscapes in aquatic and terrestrial ecosystems, imposing novel pressures on ecological processes. Despite interest in identifying the ecological consequences of these altered soundscapes, little is known about the sub lethal impacts on wildlife population health and individual fitness.

Some species of reptiles are also vocal, but data on the effects of anthropogenic noise on reptile social behaviours are severely lacking. The most vocal reptiles include the geckos (squamata) and the crocodilians and are sensitive to sounds. These animals are amphibious and so could be impacted by anthropogenic noise both on land and in the water. Various studies shown that Tokay Geckos (*Gekko gecko*) are sensitive to sounds in the frequency range from about 200 to 5000 Hz, with the best sensitivity in the range around 2000 Hz (Brittan-Powell et al. 2010). Hearing has also been assessed in several species of turtles (Testudines). The first study in which the auditory system of a turtle was studied by Crawford and Fettiplace (1980) in detail revealed that auditory nerve fibres of the Red-Eared Slider (*Pseudemys scripta elegans*) were tuned to the range of 70–700 Hz. Sea turtles [Green Sea Turtle (*Chelonia mydas)* and loggerhead turtles (*Caretta caretta*)] can detect sounds in the frequency range from <100 Hz to about 2000 Hz, with the best sensitivity between 100 and 400 Hz (Martin et al. 2012; Popper et al. 2014).

Mancera et al. (2017) analysed the reactions of the Blue-Tongued Lizard (*Tiliqua scincoides*) to playbacks of synthetic mining machinery noise (bulldozer, coal truck, and drill, filtered to comprise frequencies less than or greater than 2000 Hz) at mean levels of 74 dB SPL and 63 dB SPL A-weighting. Lizards exposed to high-frequency high-amplitude noise spent more time freezing, with their heads oriented downward compared with lizards exposed to other noise combinations which is the reactions as indicative of fear or stress. The authors Simmons and Narins (2018) interpreted these reactions as indicative of fear or stress. Thus it is possible that the high frequency component of mining noise was misinterpreted as an alarm call or predation risk due to the similarity of frequencies from both acoustic stimuli. Frequency appeared to have a greater effect than amplitude, suggesting the possibility of frequency dependent sound mimicking, which generates stress-related behaviours when frequencies overlap with important acoustic cues for lizards.

Sounds used by reptiles to convey aggression and stress are in the high frequency range. Hissing is one of the most representative distress calls, and it has been defined as white noise of several types produced by the massive expulsion of air (Gans & Maderson 1973). Many lizards produce this vocalization when afraid, being handled or during escape attempts, accompanied by aggression and the deliberate inflation of the body (Warwick et al 2013). According to Simmons and Narins (2018) Reptiles including tortoises, turtles, alligators, crocodiles, caimans, snakes, skinks, geckos and lizards, are showing sensitivity to various sounds. Some squamates, consisting geckos and crocodiles, have extensive vocal repertoires, whereas others, including the rhynchocephalids and some other squamates, have not been found to use sounds for intra-conspecific communication. Dooling et al. 2000 studied that Most of the reptiles hear to some extent.

This study was carried out

1. To study reptile diversity, abundance and distribution along the MPC in different land-uses in existing and extended operations of MPC belt.
2. To enlist the possible impact of vibration and sound from MPC on them

Materials and Methods

Maps of Sampling Site

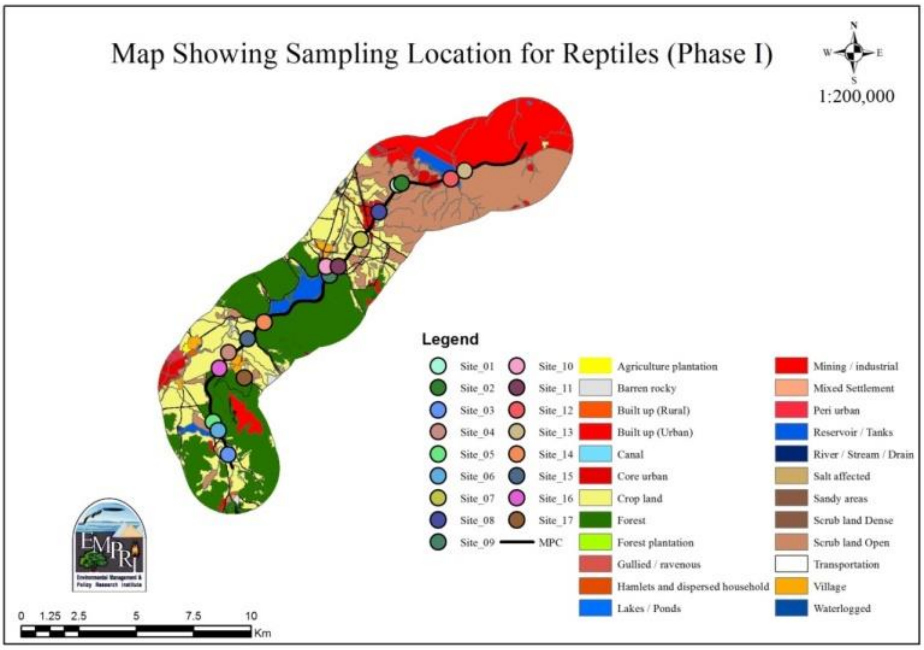


Figure 8.1: Reptile Sampling Locations (Phase I)

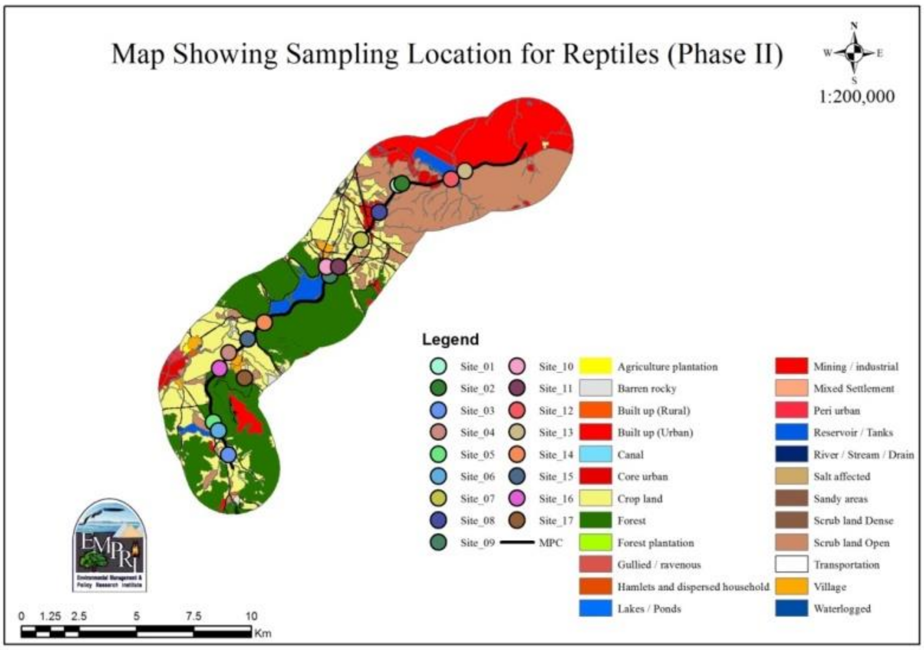


Figure 8.2: Reptile Sampling Locations (Phase II)

Instruments Used

Snake Hook, Field gears, Head and Cell Torch, Camera, GPS Instrument.

Methods used for reptile sampling

We may adopt various methods while sampling for reptiles. Since the study period is very short, we adhered to simple and less man power required method.

Time constrained search method: Following methods of Campbell and Christman, (1982); Vogt and Hine, (1982); Karns (1986), Heyer et al (1994), Daniels, (1994); Addoor (2001, 2020); Sukumar et al (2001); Rödel and Ernst (2004), reptiles were sampled in the study area.

Due to the short study period, the best method for inventorying reptiles will be the time constrained search. This method involves the selection of a suitable habitat of the study area and without defining its limits thoroughly searched for reptiles over a fixed period of time. Between site and habitat comparisons of reptile richness can be made if the following are kept constant: 1) the total area searched, 2) the number of hours spent, 3) the sampling time, 4) the sampling season, 5) the expertise/man-power. Time constrained search is a simple form of sampling method. The result obtained through such sampling are often more reliable than that from less standardised large scale surveys. Diurnal (06:30–08:30) and nocturnal (18:30–20:30) surveys was carried out in each habitats.

Opportunistic sampling method

Apart from systematic sampling, opportunistic sampling is done both during early hours of the day and late night in all study sites. This helped while compiling a species list for the area.

All the reptiles seen are recorded on completion of the search. Micro habitat descriptions are noted where the reptiles first observed. The place of observation may be on the ground, different types of vegetation, on logs, stones etc. They are closely examined, photographed and identification is done based on the field guides, literatures, books, and websites and also with the help of experts. The assessments of reptiles are based on sightings, tracks, dead specimens and other evidences. Observational information was collected from the field staff of forest department personnel and also from the people familiar with the area.

6 habitats (Forest, Agriculture, Built-Up, Waterbody, Grassland and Control site) were selected and sampled.

Efforts

Phase I – 16 Morning hours and 30 Night hours

Phase II- 34 hours

Data Analysis

A diversity index, Shannon index (H) is calculated considering species richness and abundance values. In this study, the number of individuals across five different habitats was considered to calculate the diversity index. Also the comparison of diversity across habitats were done using Mann-Whitney U test. All diversity indices analysis was calculated using PAST software.

Results

Reptiles Sighted During the Study

A total of 38 species of reptile were recorded during the studyin which six species are listed under CITES and eighteen under WPA. Table 8.1 and 8.2 gives the list of species observed during the study.

Table 8.1: Reptiles Sighted during the Study

Sl. No	Common Name	Scientific Name	IUCN*	WPA#	CITES†
1	Indian Black Turtle	*Melanochelys trijuga*	NT		App. II
2	Geoemydinae sp.	-			
3	Oriental Garden Lizard	*Calotes versicolor*	NE		
4	Peninsular Rock Agama	*Psammophilus dorsalis*	LC		
5		*Sitana cf. lanticeps*			
6	Brook's House Gecko	*Hemidactylus brookii*	NE		
7		*Hemidactylus cf. brookii*			
8		*Hemidactylus cf. murray*			
9		*Hemidactylus cf. parvimaculatus*			
10	Asian House Gecko	*Hemidactylus frenatus*	NE		
11	Giant Leaf-Toed Gecko	*Hemidactylus giganteus*	NE		
12	Bark gecko	*Hemidactylus leschenaultii*	LC		
13	Spotted House Gecko	*Hemidactylus parvimaculatus*	LC		
14	Reticulate Gecko	*Hemidactylus reticulatus*	LC		
15	Southern Termite Hill Gecko	*Hemidactylus triedrus*	NE		
16	Beddomie's Snake-eyed Lizard	*Ophisops beddomi*	LC		
17	Common Keeled Skink	*Eutropis carinata*	LC		
18		*Lygosoma cf. albopunctata*			
19	Russel's Viper	*Daboia russelii*	NE	Sch. II	App. III
20	Spectacled Cobra	*Naja naja*		Sch. IV	
21	Common Trinket Snake	*Coelognathus helena helena*	NE	Sch. IV	
22	Common Wolf Snake	*Lycodon aulicus*	NE	Sch. IV	
23	Barred Wolf Snake	*Lycodon striatus*	NE	Sch. IV	
24	Banded Kukri Snake	*Oligodon arnensis*	NE	Sch. IV	
25		*Boiga f. trigonata*			
26	Checkered Keelback Water Snake	*Xenochrophis piscator*	NE	Sch. II	App. III
27	Russel's Kukri	*Oligodon taeniolatus*		Sch. IV	
28	Brahminy Blind Snake	*Indotyphlops braminus*	NE	Sch. IV	
29	Colubridae sp.	-			

*IUCN: International Union for Conservation of Nature, NE: Not Evaluated, LC : Least Concern, NT: Near Threatened #WPA: Wildlife Protection Act, †CITES: Convention on International Trade in Endangered Species of Wild Flora and Fauna.

Reptiles Sighted During Opportunistic Sampling

Table 8.2: Reptiles Sighted during Opportunistic Sampling

Sl. No	Common Name	Scientific Name	IUCN*	WPA#	CITES†
1	Star Tortoise	*Geochelone elegans*	VU	Sch. IV	
2	Indian Flapshell Turtle	*Lissemys punctata*	LC	Sch. I	App. II
3	Indian Chameleon	*Chamaeleo zeylanicus*	NE	Sch. II	
4	Indian Monitor Lizard	*Varanus bengalensis*	LC	Sch. I	App. I
5	Common Indian Krait	*Bungarus caeruleus*	NE	Sch. IV	
6	Saw Scaled Viper	*Echis carinatus*	NE	Sch. IV	
7	Indian Rock Python	*Python molurus*	NE	Sch. I (Part II)	App. I
8	Bronzeback Tree Snake	*Dendrelaphis cf. tristis*	LC	Sch. IV	
9	Green Keelback	*Macropisthodon plumbicolor*	NE	Sch. IV	

*IUCN: International Union for Conservation of Nature, NE: Not Evaluated, LC: Least Concern, NT: Near Threatened #WPA: Wildlife Protection Act, †CITES: Convention on International Trade in Endangered Species of Wild Flora and Fauna.

A total of 28 Species of reptiles were recorded during the Phase I Sampling in which 7 species were unidentified at the species level.

Diversity Analysis of Reptiles (Phase I- Total)

The diversity analysis of Reptiles of Phase I (Total) was carried out using PAST. The diversity analysis of Reptiles of Phase I (Total) shows a high diversity in Wetland with a Shannon H Index value 2.262 with slight variation from Agriculture land and Forest areas. Lowest is in Control Site with Shannon H index 0. Abundance is found more in Agriculture Land (76n) followed by Wetland (37n) and Species richness is found higher in Agriculture land (18n) followed by Built-Up (14n).

Table 8.3: Species diversity Phase I (Total)

Species	Ag_01	Ft_01	GL/Sb_01	BU_01	WL_01
Melanochelys trijuga	1				1
Geoemydinae sp.	2				
Calotes versicolor	2	3	2		1
Psammophilus dorsalis					1
Sitana cf. lanticeps	1				
Hemidactylus brookii	7	3	11		5
Hemidactylus cf. brookii	1				

Hemidactylus cf. murray	4				1
Hemidactylus cf. parvimaculatus		1			
Hemidactylus frenatus	10	1			5
Hemidactylus giganteus		4			1
Hemidactylus leschenaultii	9	4	5	1	7
Hemidactylus parvimaculatus	20	4	3	1	5
Hemidactylus reticulatus					1
Hemidactylus triedrus	11	8			6
Ophisops beddomi			5		
Lygosoma cf. albopunctata	1				
Eutropis carinata		1	3		
Daboia russelii	1				
Naja naja		1			
Coelognathus helena helena	1				2
Lycodon aulicus	1	1			
Lycodon striatus	1				
Oligodon arnensis				1	
Oligodon taeneolatus		1			
Colubridae sp.		1	1		
Xenochrophis piscator	2	2			1
Indotyphlops braminus	1		1		
Total Abundance	76	35	31	3	37
Species Richness	18	14	8	3	13
Shannon_H	2.325	2.377	1.807	1.099	2.262

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL/Sb: Grass Land/ Scrub Land, WL: Wetland

Diversity Analysis of Reptiles (Phase I- Night)

The diversity analysis of Reptiles of Phase I (Night) shows a high diversity in Agriculture Land with a Shannon H Index value 2.247 with slight variation from Wetland and Forest areas. Lowest is in Built-Up with Shannon H index 1.099. Abundance is found more in Agriculture Land (64n) followed by Wetland and Forest (30n) and Species richness is found higher in Agriculture land (16) followed by Forest and Wetland (10).

Table 8.4: Species diversity Phase I (Night)

Species	Ag_01	Ft_01	BU_01	GL/Sb_01	WL_01
Melanochelys trijuga	1				1
Geoemydinae sp.	1				
Calotes versicolor	1	2		1	
Psammophilus dorsalis					1
Hemidactylus brookii	7	3		10	5
Hemidactylus cf. brookii	1				
Hemidactylus cf. murray	4				1
Hemidactylus frenatus	10				3
Hemidactylus giganteus		4			
Hemidactylus leschenaultii	5	4	1	5	6
Hemidactylus parvimaculatus	16	4	1	3	5
Hemidactylus triedrus	11	8			6
Lygosoma cf. albopunctata	1				
Naja naja		1			
Daboia russelii	1				
Lycodon aulicus	1	1			
Coelognathus helena Helena	1				1
Oligodon arnensis			1		
Oligodon taeneolatus		1			
Xenochrophis piscator	2	2			1
Indotyphlops braminus	1			1	
Total Abundance	64	30	3	20	30
Total Richness	16	10	3	5	10
Shannon_H	2.247	2.09	1.099	1.277	2.038

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL/Sb: Grass Land/ Scrub Land, WL: Wetland

Species accumulation Curve of Reptiles Phase I (Total)

A total of 28 species of Reptiles were recorded during Phase I (Total). Maximum diversity achieved during 21st Sampling

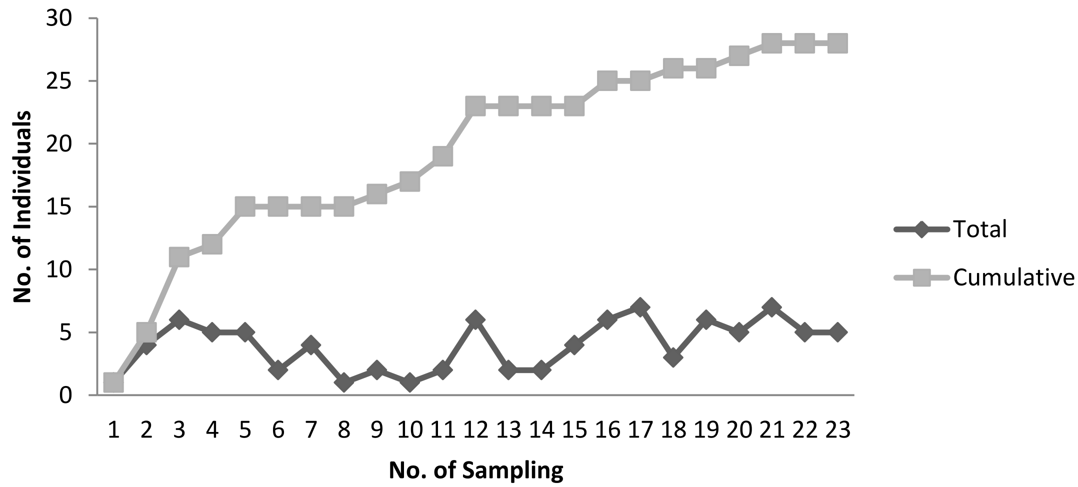


Figure 8.3: Species accumulation Curve of Reptiles Phase I (Total)

Species accumulation Curve of Reptiles Phase I (Total)

A total of 21 species of Reptiles were recorded during Phase I (Night). Maximum diversity achieved during 13th Sampling.

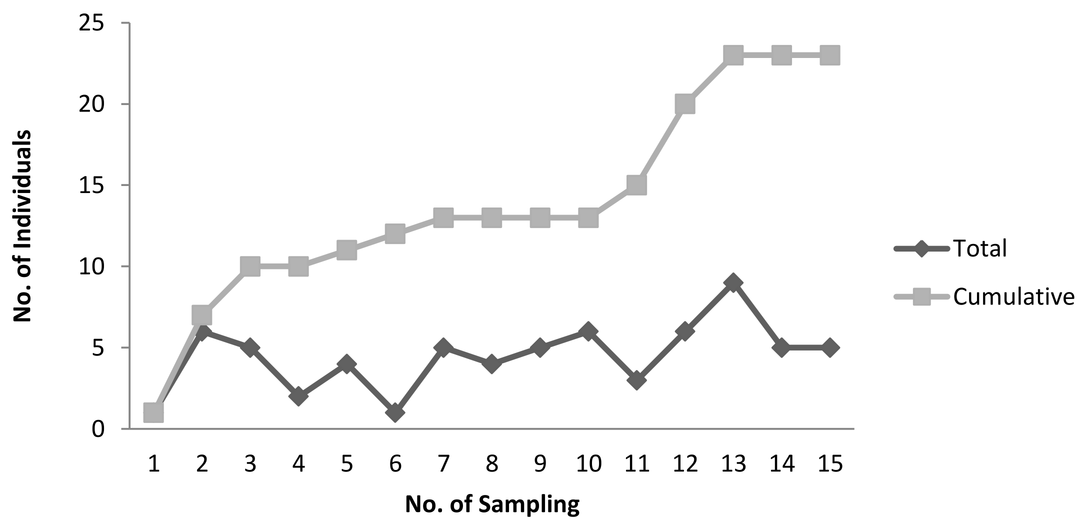


Figure 8.4: Species accumulation Curve of Reptiles Phase I (Night)

Diversity Analysis of Reptiles (Phase II)

The diversity analysis of Reptiles of Phase II shows a high diversity in Wetland with a Shannon H Index value 1.987 with slight variation from Agriculture land and Built up areas. Lowest is in Grassland/ Scrub land with Shannon H index 0.9882. Abundance is found more in Built-Up (55n) followed by Agriculture (37n) and Species richness is found higher in Agriculture land (11) and Built-Up (11) followed by Wetland (8).

Table 8.5: Species diversity Phase II

Species	Ag_02	Ft_02	BU_02	GL/Sb_02	WL_02
Melanochelys trijuga	1				
Boiga cf. trigonata		1			
Calotes versicolor	3		1	2	2
Psammophilus dorsalis	1				1
Sitana cf. ponticeriana	1				
Hemidactylus brookii	8		12		
Hemidactylus frenatus	2	1	6		2
Hemidactylus giganteus		4	7		1
Hemidactylus leschenaultii	2		3		4
Hemidactylus parvimaculatus	13	9	18	1	2
Hemidactylus reticulatus				2	
Hemidactylus triedrus	4	2	4	10	3
Lycodon aulicus		1			
Oligodon taeneolatus			1		
Xenochrophis piscator			1		2
Indotyphlops braminus	1		1		
Colubridae sp.	1		1		
Total Abundance	37	18	55	15	17
Total Richness	11	6	11	4	8
Shannon_H	1.946	1.407	1.915	0.9882	1.987

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL/Sb: Grass Land/ Scrub Land, WL: Wetland

Species Accumulation Curve of Reptile Sampling (Phase II)

A total of 25 species of reptiles were sighted during the phase 02 and the maximum diversity obtained during the 13th Sampling.

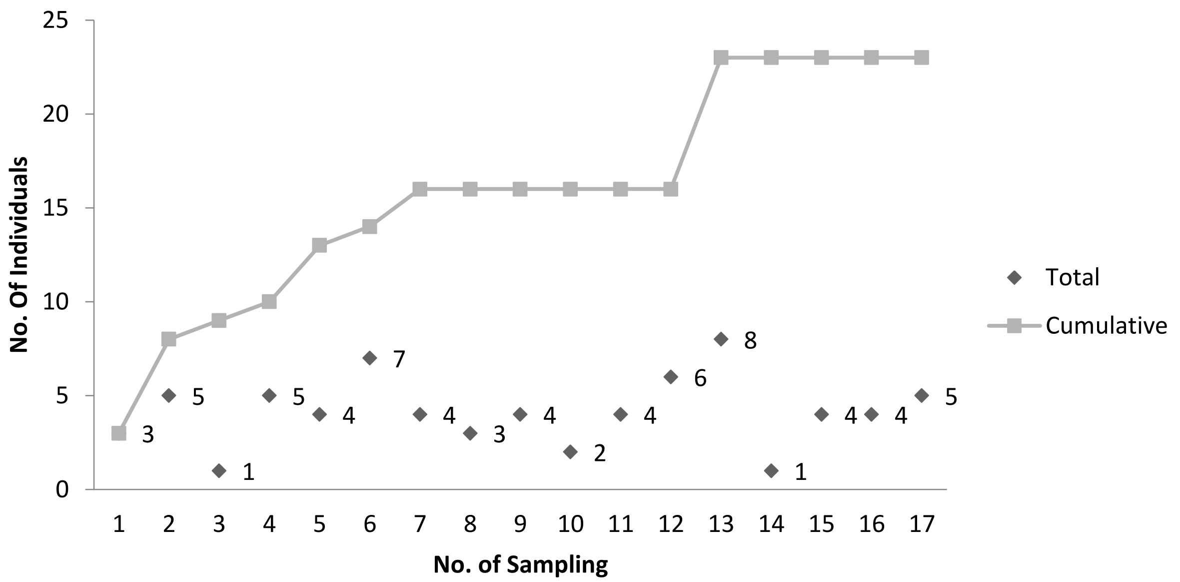


Figure 8.5: Species Accumulation Curve of Reptile Sampling (Phase II)

Habitat Wise Diversity Comparison of Reptiles

Table 8.6: Habitat Wise Diversity Comparison

Species	**Ag_01**	**Ag_02**	**Ft_01**	**Ft_02**	**BU_01**	**BU_02**	**GL/Sb_01**	**GL/Sb_02**	**WL_01**	**WL_02**
Melanochelys trijuga	1	1							1	
Geoemydinae sp.	1									
Calotes versicolor	1	3	2			1	1	2		2
Psammophilus dorsalis		1							1	1
Sitana cf. ponticeriana		1								
Hemidactylus brookii	7	8	3			12	10		5	
Hemidactylus cf. brookii	1									
Hemidactylus cf. murray	4								1	
Hemidactylus frenatus	10	2		1		6			3	2

Hemidactylus giganteus			4	4		7				1
Hemidactylus leschenaultii	5	2	4		1	3	5		6	4
Hemidactylus parvimaculatus	16	13	4	9	1	18	3	1	5	2
Hemidactylus reticulatus								2		
Hemidactylus triedrus	11	4	8	2		4		10	6	3
Lygosoma cf. albopunctata	1									
Naja naja			1							
Daboia russelii	1									
Coelognathus helena helena	1								1	
Boiga cf. trigonata				1						
Oligodon arnensis					1					
Oligodon taeneolatus			1			1				
Lycodon aulicus	1		1	1						
Xenochrophis piscator	2		2			1			1	2
Indotyphlops braminus	1	1				1	1			
Colubridae sp.		1				1				
Total Abundance	64	37	30	18	3	55	20	15	30	17
Total Richness	16	11	10	6	3	11	5	4	10	8
Shannon_H	2.247	1.946	2.09	1.407	1.099	1.915	1.277	0.988	2.038	1.987

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL/Sb: Grass Land/ Scrub Land, WL: Wetland, CN: Control

Table 8.7: Habitat wise Diversity analysis of Reptiles using Mann-Whitney U test

		Ag_01	BU_01	Ft_01	GL/ Sb_01	WL_01
		0.9249				
Ag_02	86		0.22527			
BU_02		7.5		0.69343		
Ft_02			26		1	
GL/ Sb_02				9.5		0.7626
WL_02					36.5	

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL/Sb: Grass Land/ Scrub Land, WL: Wetland, CN: Control

Habitat wise activity analysis of Reptiles

Habitat wise activity analysis were done in which each habitat from Phase 01 is compared with Phase 02. Mann-Whitney U test couldn't be done since number of recordings was not more than 3 in phase wise.

Table 8.8: Habitat wise activity analysis of Reptiles

Activity	Ag_01	Ag_02	BU_01	BU_02	Ft_01	Ft_02	GL/Sb_01	GL/Sb_02	WL_01	WL_02
Basking		1					1			4
Moving	14	28	32	3	11	15	12	14	8	14
Resting	21	20	22		7	13	2	5	9	11
Foraging		14				1				1
Total Abundance	37	64	55	3	18	30	15	20	17	30

Ag: Agriculture, BU: Built_Up, Ft: Forest, GL/Sb: Grass Land/ Scrub Land, WL: Wetland, CN: Control

Discussion

The study resulted in recording 29 species of reptiles during the sampling and 9 species of reptiles during opportunistic survey. Out of 38 species recorded, 8 were unidentified at species level. The diversity of species across different habitats was compared among Phase I and Phase II. For this diversity analysis, night sampling data was taken from both phases since the MPC operation was already there from morning 6 to evening 6. The extended period operation of MPC was during evening 6 to morning 2. Shannon H index shows that diversity of reptiles in higher in agriculture during Phase I and Built_Up during Phase II. Since the data was not a normally distributed one, Mann-Whitney U test was done for diversity comparison and it was not statistically significant. Even though it was not statistically significant, there was an observed decrease in the abundance and richness of species from Phase I to Phase II. This may be due to the sudden exposure to certain parameters like noise and vibration during the increased operational time of MPC. We did a comparison of various activities done by reptiles during sampling across Phase I and Phase II. There was an observed increase in activities such as moving and resting across different habitats. Even though the Mann-Whitney U test shows no significance, it was observed that the change in activity was accountable. Various studies also state the same. Mancera et al. (2017) analysed the reactions of the blue-tongued lizard to mining machinery noise and found that lizards exposed to high-frequency high-amplitude noise spent more time freezing, with their heads oriented downward compared with lizards exposed to other noise combinations which is the reactions as indicative of fear or stress. This may be having similar to the present study where the reptiles show more time on resting.

As per the chapter by Simmons and Narins (2018) Reptiles including tortoises, turtles, alligators, crocodiles, caimans, snakes, skinks, geckos and lizards, are showing sensitivity to various sounds. Some squamates, consisting geckos and crocodiles, have extensive vocal repertoires. These reptiles may have an impact associated with the sound of MPC during its increased operational time. Since reptiles are mostly nocturnal or more or less dusk active animals, the increased operation of MPC may affect the various behaviour and physiology of reptiles.

Apart from noise, other important parameters that can impact on reptiles are Vibration and Illuminescence. Field data on both vibration and Illuminescence was collected but couldn't correlate with the reptile assemblage and activity. The Vibration data collected shows a complete depletion and merging into natural vibration when moving away from MPC around 4-6m in length. Also during the 12 hour operational period of MPC, it is observed reptiles, especially Geckos resting on the pillars of MPC. But when comes to the extended operational period of MPC, reptiles observed to be moved away from MPC and there were no sightings of reptiles resting in the MPC. This could be due to the sensitivity of reptiles towards the vibrations. Even though this is observed, we couldn't collect data to prove its significance.

In the present study iluminescence data was collected in three different transfer points along MPC, but the data was not able to correlate with the species data collected. Increase in the night lighting have several impacts on reptiles and are flagged in various studies also. Reptiles have evolved with natural lighting cycle. Alteration of natural variation in diurnal and nocturnal light intensities and spectral properties has the potential to disrupt their physiology, behaviour and ecology (Perry et al. 2008). Negative influences of light pollution on sea turtles, especially those of artificial lights near beaches on the seaward locomotion of hatchlings, have been well-studied (Witherington and Martin 1996). Similarly Perry and Fisher (2006) discussed possible positive predator-prey interactions between snakes and their prey, such as geckos, that are attracted to artificial lights. They also reviewed the probable negative predator-prey interactions associated with prey, such as the apparent decline of hetero-myid rodents due to artificial lights, and increased exposure to snake predators. These kinds of interactions of reptiles in presence of increased night lighting may also be addressed for future studies for better understanding of the impact of illuminescence on Reptiles.

Reptiles are important components of the food webs in most ecosystems. They can be listed as follows; The function of reptiles as ecosystem linkers and their involvement in the transport of nutrients from freshwater and marine ecosystems to terrestrial ones; (3) Reptiles as trophic agents through the exertion of top-down pressure on prey or vegetation, and by acting as prey themselves; (4) Reptiles as ecosystem engineers that can increase biodiversity in providing refuges or reproduction sites to other species.

Although seed dispersal is key to maintaining plant diversity, seed dispersal by reptiles (saurochory) is sometimes regarded as a rare phenomenon (Valido and Olesen, 2007). This notion is challenged by growing evidence of reptiles as seed dispersers (González-Castro et al., 2015), especially because of the tendency for most reptiles to gulp fruits whole, which provides little opportunity for seed damage. Large reptiles can act as nutrient transporters in two main ways: (a) through reproduction, when aquatic reptiles lay eggs in terrestrial environments (Bouchard and Bjorndal, 2000), and (b) through predation, when aquatic reptiles are killed and dragged onto land by terrestrial predators (Veríssimo et al., 2012). Reptiles can act as top predators in aquatic and terrestrial ecosystems. Crocodilians are conspicuously present as predators in aquatic-terrestrial interfaces in the tropical regions of all continents. Squamate reptiles, like snakes, are capable of overpowering bird and mammalian prey. They are also capable of strongly impacting avian prey populations (Patten and Bolger, 2003), and intense declines have been recorded where exotic snakes species have been introduced, as, for instance, on the island of Guam (Richmond et al., 2014). Some herbivorous reptiles can have a profound effect on vegetation. The grazing and browsing impact of large tortoises, for example, can intensely impact vegetation composition and structure (Hamann, 1993). Another means by which reptiles can act as ecosystem engineers is via their burrows, which can provide shelter for other species. In a nutshell one can conclude the ecological importance as in Reptiles impose an important check on insect and rodent populations. Some of the most venomous snakes in the world such as the Indian cobra actually prevent the spread of disease-carrying rodents, even in urban centres, so their usefulness often outweighs their danger. However, far more benign reptiles also act to control populations of pests. According to the website Animal Bytes from Busch Gardens, crocodiles and alligators also prevent overpopulation of fish species in coastal regions and wetlands, which is pivotal in keeping these aquatic ecosystems healthy and balanced. A healthy aquatic ecosystem is instrumental for fisheries that make their living in these environments. Many reptiles lead very indolent lifestyles, so they attempt to strike quickly to subdue their prey. For any reptile a rotting carcass, which is called carrion, is an easy meal, so reptiles such as the Indian Monitor Lizard are one of many organisms that play a role in clearing dead animals from the environment. Reptiles themselves are often used for food. Birds of prey will eat anything from boas to lizards.

Conclusion

The reptiles have a major role in the food chain. In most ecosystems, reptiles are the vital part of food chains and they play an important role both as the prey species and as the Predators. The pests like insects and rodent populations are controlled by the reptiles and the snake's venom are used in manufacturing modern life saving medicines. When the prey species of reptiles such as insects, amphibians, birds, mammals are affected by the noise, it will have a direct impact on the reptile population too. This can be ascertained only through a long-term study. The study on reptiles would be more reliable if it is done across the season as reptiles are elusive in nature. The habitat specialist and those which are cryptic in nature may easily be overlooked. Some species of reptiles tend to shift with the seasons as well as according to the changes in the surrounding temperature, relative humidity and other environmental conditions. Hence the long-term detailed study of the area is very essential.

Chapter IX: Diversity, Abundance, and Activity Pattern of Aves

CHAPTER IX
DIVERSITY, ABUNDANCE, AND ACTIVITY PATTERN OF AVES

Introduction

The birds are the warm-blooded creatures that evolved from dinosaurs around 160 million years ago and the first known transitional stage bird is the 'Archeopteryx' which shows the initial adaptations of birds started as back as 170 million years ago. They are a large group of warm-blooded vertebrates constituting the class Aves characterized by having feathers, the major characteristic that distinguishes them from all other animals, is toothless beaked jaws, the laying of hard-shelled eggs, a four-chambered heart, and a strong yet lightweight skeleton. They have wings that are modified forelimbs, which have enabled them to survive through the years. They have adapted to a wide range of habitats due to which they are seen across all the seven continents, even in the remotest islands on our planet.

The main adaptation was their hollow pockets in their skeletal system called '**pneumatic bones**' which gave them the ability to fly long distances by reducing their body weight. A varied type of special beak and foot adaptations can be observed in every individual species which makes them perch, feed, eat, hunt, or scavenge depending on the type of habitat they live in and the food they consume. A large diversity of bird species varying in size from the smallest Bee Hummingbird of 5cm to the largest Ostrich of 9Feet occurs on earth. In Ballari, Karnataka the smallest bird, **'Pale-billed Flowerpecker'** (smallest in India) to the heaviest **'Indian Peafowl'** (largest and heaviest representatives of the Phasianidae (jungle fowls, partridges)) were found to occur.

Birds occupy a wide range of positions in providing ecosystem services like some nectar-feeding birds are important pollinators, and many frugivorous birds play a key role in seed dispersal and are called farmers of the forest. Insectivorous birds are also known as the friend of farmers, as they assist through biological control of agricultural pests. They have also inspired us to fly and many of today's complex aircraft are imitations of birds. Many painters and poets have used various birds in their creative work which are famous even today. The occurrence of bird species is dependent on the abundance of the food available in habitats such as a forest, the niches occupied by different species of birds vary, with some species feeding in the forest canopy, others beneath the canopy, and still others on the forest floor. Forest birds may be insectivores, frugivorous, and nectarivores. Aquatic birds generally feed by fishing, plant-eating, and kleptoparasitic activities (where one bird steals food from another bird). Birds of prey specialize in hunting mammals or other birds, while vultures are specialized scavengers. Birds are specific to the habitat and microhabitat for roosting and breeding. The high species richness also signifies a low rate of disturbance in their habitat.

Birds make up the largest vertebrate group when compared to others and are more related to reptiles than to mammals. They have a four-chambered heart (as do mammals) and keen vision. Their sense of smell is not highly developed, and their auditory range is limited. Most of them give parental care except a few species like Asian Koel which are brood-parasitic (laying eggs in other bird's nests). There are about eighteen thousand living species, more than half of which are passerine, or "perching" birds.

Birds are social, communicating with visual signals, calls, and songs, and participating in such behaviors as cooperative breeding and hunting, flocking, and mobbing off or escaping from predators.

Review of Literature

Avifaunal diversity of Ballari district

A total of 5176 individual birds representing **132 species**, 50 families were observed in Gudekote Sloth Bear Sanctuary through line Transect count and point count methods. The maximum (8.19%) of species were recorded in the Columbidae family, followed by Muscicapidae (7.65%), Charadriidae (6.91%), and so on. Terrestrial habitat contributed much in terms of family composition (78%) than aquatic habitat (22%). Red-vented Bulbul had the highest relative frequency. The higher relative frequency of birds could be contributed by the high frequency of occurrences to some of the birds. Shannon’s diversity index indicates that terrestrial habitat had higher species diversity (H’ = 3.9996) than aquatic habitat (H’ = 3.0717). The overall bird diversity in both terrestrial and aquatic was H’=4.2669 (Reegan et al. 2017).

Kotangale et al. (2020) studied bird diversity in the mining area of the Ballari-Hospet region. The birds were studied by direct observations with Binoculars. The study revealed the presence of 77 species of birds, of which 15 species were aquatic/semi-aquatic. They were found along or near the water bodies. House crow emerged as the most dominant species with a dominance index value of 14.32%, followed by laughing dove (11.85%) and house sparrow (10.32%). However, very few birds were encountered in the active mining zones. The density of birds was generally more where feeding and nesting sites were more. The species diversity index was calculated as 9.98. The birds were found to avoid the core zone of iron ore mines.

Basavarajappa and Kanamadi (2002) identified a total of 121 bird species of 44 families. Of these 23 were aquatic Species in Thavaragundi village of Ballari district. Species number is lower in July-August-September months (for about 50). Species number is high in October and Maximum between December and April-May. Meadow region and Agricultural Fields show maximum populations of birds. The highest density and Species richness witnessed between December and April may be due to better availability of food.

Impacts of mining and other industrial activities on avifauna

The mining activities in Brazil affected 8 endemic bird species of that region. 2.04% and 26.76% of the potential range of median proportions of bird species were affected directly or indirectly by mining. Ecological niche model (ENM) study showed more than 30% of the area considered as suitable for bird species are currently under pressure by mining activities through destroying, fragmenting, and degrading natural habitats, releasing toxic wastes, and altering land-use dynamics in mined regions (Pena et al. 2017).

Saha and Padhy (2011) studied and suggested that the high volume of noise in Lalpahari forest (West Bengal) due to Stone mining and crushing may be one of the factors responsible for thin distribution and reduced diversity of birds. Also, excessive load of air pollution in this area has led to degradation of the forest. However, Tree canopies contain a major portion of the diversity of birds. They also observed that vegetation variables have a direct relationship with the abundance and richness of bird species.

The study around four Non-ferrous smelters in Russia (Eeva et al. 2012) indicated the decreased bird densities, biomass, and the number of bird species observed towards smelters. The SO_2 and metal emissions (Litter Copper) have been very high in this area which creates an industrial barren of about 10km distance. Shannon index showed the species number, values decreasing strongly with increasing copper load. Reduction in species diversity seems to be accelerated when litter copper concentrations exceed 1000 µg/g. Decreased population densities of breeding birds in polluted sites may be an outcome of inferior reproductive success, increased mortality, or lack of suitable resources (food and/or habitat) for breeding. Poor breeding success may be due to a lack of suitable invertebrate food (Snails etc.) for birds, and especially the scarcity of calcium-rich food items necessary for the needs of breeding females. Heavily damaged ground vegetation shows a strong impact on bird population by reduction of food sources, suitable shelter, and protection from predators.

Salovarov and Kuznetsova (2006) compared the systems of industrially affected habitats (coal mining and ash dump areas) of the upper Angara region of Russia to demonstrate the different bird species diversity. Ash dumps and neighboring areas showed higher numbers of bird species, for about 1.2 times more compared to coal mining areas. Less availability of food and lower fitness of area for the nesting considerably influenced the distribution of species. In the case of coal mining areas, completely transformed landscape elements (fresh pits) attract fewer bird species compared to any ash dumps.

Large-scale denudation of forest cover, scarcity of water, pollution of air, water, and soil, degradation of agricultural lands, and disturbed and fragmented natural habitats of birds are some of the conspicuous environmental implications of mining of minerals including limestone, bentonite, and lignite in western Kachchh. Results revealed that the species diversity, richness, and abundance were less in the zones which are close to the mines within a 4 km radius to mines. Whereas, found highest in areas which were located in between 8 km to 18 km from the mines. Due to the opencast type of mining birds of certain habitats receive more threats from the activities (Gajera et al. 2013).

Smith et al. (2005) conducted a study to determine the effect of diamond mines on Tundra-breeding birds at the Ekati Diamond Mine in Canada. Overall, the monitoring data collected around the mine suggests that the mine had a relatively limited impact on the breeding bird community within 1 km of the footprint. The mine plots showed changes in the relative densities of nine individual species and slightly higher species diversity when analyzed with an index more sensitive to richness than to evenness. The differences in individual species density may be directly related to mining disturbance or indirectly related to mining through changes in habitat from mining activity.

Artisanal and small-scale gold mining (ASM) is becoming a significant cause of environmental degradation in tropical ecosystems in Tambopata Natural Reserve, Peru. Rapid assessment using seven audio recorders (three near an active mine, two in an abandoned mine, and two in an adjacent forest), collecting 2900 recordings, identified 56 bird species. Bird species richness was similar between the forest (28 bird species), the abandoned mine (25 species), and the active mine (24 species). There were considerable differences in species composition. Species richness was found high in the periphery of active mines, which may be due to the birds being sensitive to disturbance of active mining due to habitat degradation and noise pollution by the machinery. This may also have long-term effects given the absence of natural regeneration (Alvarez-Berríos et al. 2016).

Wells et al. (2008) reported the impacts of Tar Sands Oil Development on birds of Canada's boreal forest. Tar sands oil development creates open-pit mines, habitat fragmentation, toxic waste holding ponds, air, and water pollution, upgraders and refineries, and pipelines spreading far beyond the Boreal Forest. Which result in the loss of breeding habitat, bird mortality from landing and drowning in the oily water in current tar sands tailing ponds, air and water pollution, which causes the accumulation of toxins in tissues, and from acid rain and nitrogen deposition, air pollution, and heavy metals which often leads to eventual death.

It is found from the study that light pollution causes birds to begin nesting up to a month earlier than normal in open environments such as grasslands and wetlands, and 18 days earlier in forested environments. The consequence could be a mismatch in timing – hungry chicks may hatch before their food is available. When considering noise pollution, results showed that birds living in forested environments tend to be more sensitive to noise than birds in open environments. Noise pollution delayed nesting for birds whose songs are at a lower frequency and thus more difficult to hear through low-frequency human noise (Senzaki et al. 2020).

Kleist et al. (2018) studied the impact of high noise caused by compressors in natural gas fields of New Mexico. Noise exposure decreases baseline corticosterone in adults and nestlings and, conversely, increases acute stressor-induced corticosterone in nestlings and also documented fitness consequences with increased noise in the form of reduced hatching success in the western bluebird. A 10-decibel increase in noise above natural levels can shrink an animal's listening area by 90 percent. This study also shows that noise pollution reduces animal habitat and directly influences their fitness and ultimately their numbers.

Consistent evidence for adverse health impacts on birds attributable to exposure to gas-phase and particulate air pollutants, including carbon monoxide (CO), ozone (O3), sulfur dioxide (SO2), smoke, and heavy metals, as well as mixtures of urban and industrial emissions (Sanderfoot and Holloway, 2017). Avian responses to air pollution include respiratory distress and illness, increased detoxification effort, elevated stress levels, immunosuppression, behavioral changes, and impaired reproductive success. Exposure to air pollution may furthermore reduce population density, species diversity, and species richness in bird communities.

The coal mining activity results in major disturbances in core bird diversity due to large amounts of sound pollution by blasting, air pollution by mining dust, habitat degradation due to tree felling and ground digging, vehicle movement, and anthropogenic pressure. Bird diversity of the core is lesser than the buffer. Species richness is higher (1.02) in buffer and lesser (0.36) in core and abundance is greater (26) in core and lesser (15) in buffer, this is due to the core area is disturbed with mining activity. Shannon diversity showed high in buffer 2.771 and low in core 2.288. Due to said disturbances, birds prefer buffers rather than core mining areas (Vishwakarma et al. 2018).

Fine sediments of diamond mining are released into the waters caused the decline of prey fishes and oysters. Due to the decline of food, the density and diversity of species of birds were reduced over the period in the mining area in Namibia (Simmons, 2005).

Costa et al. (2011) reported no evidence of direct toxic effects on the 'Great Tit' from paper industry emissions in Portugal. However, pollution from the industry has been directly related to variability in food availability, indirectly affecting the 'breeding performance' of the 'Great Tit'.

Francis et al. (2009) showed from their study that noise alone from the natural gas compressors reduces nesting species richness and leads to different avian communities. Noise indirectly facilitates the reproductive success of individuals (i.e., Noise tolerant) nesting in noisy areas as a result of the disruption of predator-prey interactions. Whereas findings also suggest that noise can have cascading consequences for communities through altered species interactions.

Methodology

During phase-I, avifaunal studies were conducted to sample both diurnal and nocturnal birds.

1. Point intercept line transect / Point Count Method: In this method, the observer recorded the bird species sighted around and along with the MPC with the radial and angular distance from the transact for 10 minutes. Later, the observer moves to the next location at a fixed distance (100m) and repeats the same method of observation to record avian fauna present in the surrounding environs (Wheater et al. 2011)

The Point counts are temporally perpendicular to the MPC with an interval of 100m for a distance of 300m with a spatial replicate of 6 per habitat and 3 temporal replicates (**Figure 9.1**).

2. Nocturnal Bird Survey: Field studies has been conducted to estimate the densities of owls, nightjars, Indian Thick-knee, and Lapwings following the **Intercept Line transect Method**. In this method, the bird species sighted on both sides and along the length of the transact will be observed and recorded continuously. **Length of transect:** The length of the main pipeline conveyor (MPC) belt acts as the line of the transect. The length of MPC is equally divided to form 8 transacts, (24 km length of MPC/ 3km Transact length) and the Length of one transect is 3km. At every 500m, the

change in habitat type is recorded.

Following are certain nocturnal bird survey methods (Babu et al. 2019), used to record the nocturnal birds of the study area.

a. Spontaneous listening: The birds were identified through listening to the bird calls in the sampling locations.

b. Spotlight searches: Search for non-responsive owls and floaters within 100 m in four cardinal directions for five minutes from the sampling point using handheld spotlights and headlamps were used. The visual sightings of the species were identified and recorded their presence.

c. Broadcasting of conspecific calls: Prefer to use an audio lure to attract conspecific individuals and potentially congeneric species as well (Zuberogoitia and Campos, 1998). Calls will be played in a pre-determined multispecies sequence based on body size, starting with the smallest owl to larger species (30 seconds of call play + 2 minutes observation).

Sampling time and number of Samples: Sampling was conducted from evening 7:00 PM to 10:00 PM. Bird survey was carried out on all the weekdays for three temporal replicates i.e., all the transects were walked thrice.

During the phase-II period, avifaunal studies were conducted on all the weekdays focusing on nocturnal sampling. We used the nocturnal bird surveys as mentioned above were adopted.

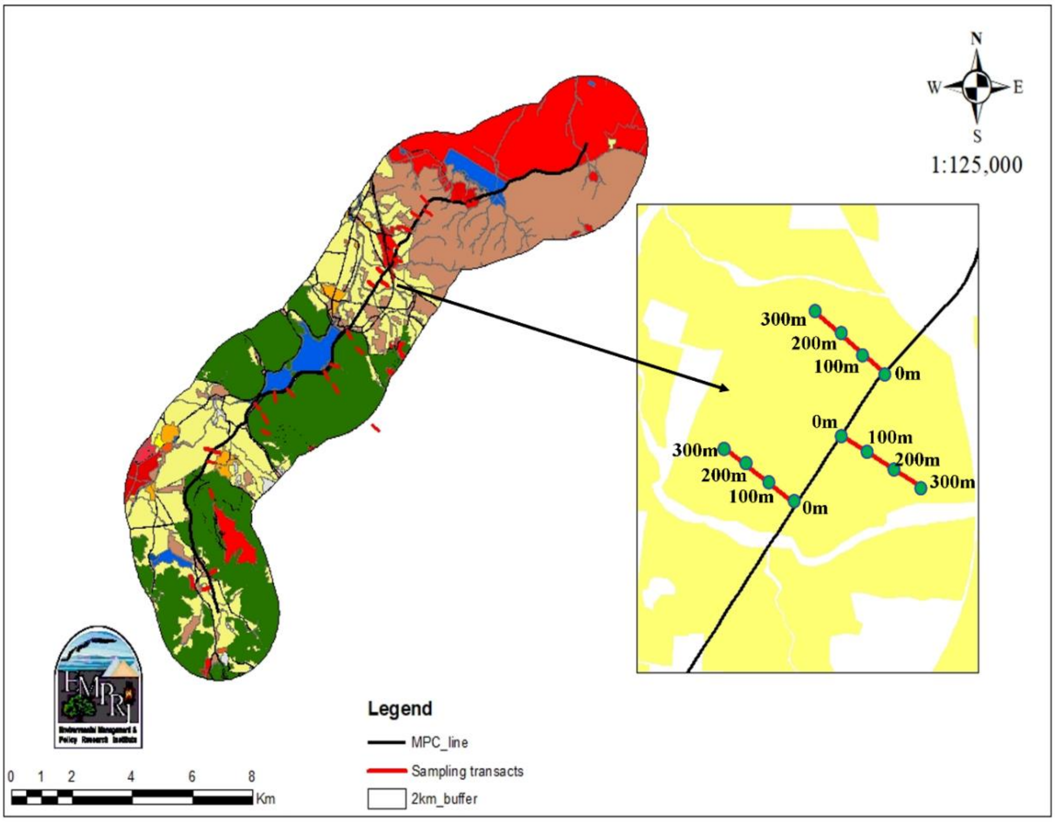


Figure 9.1: Point transects laid in different habitats of the study area. Inset: Intercept line transects in agricultural habitat

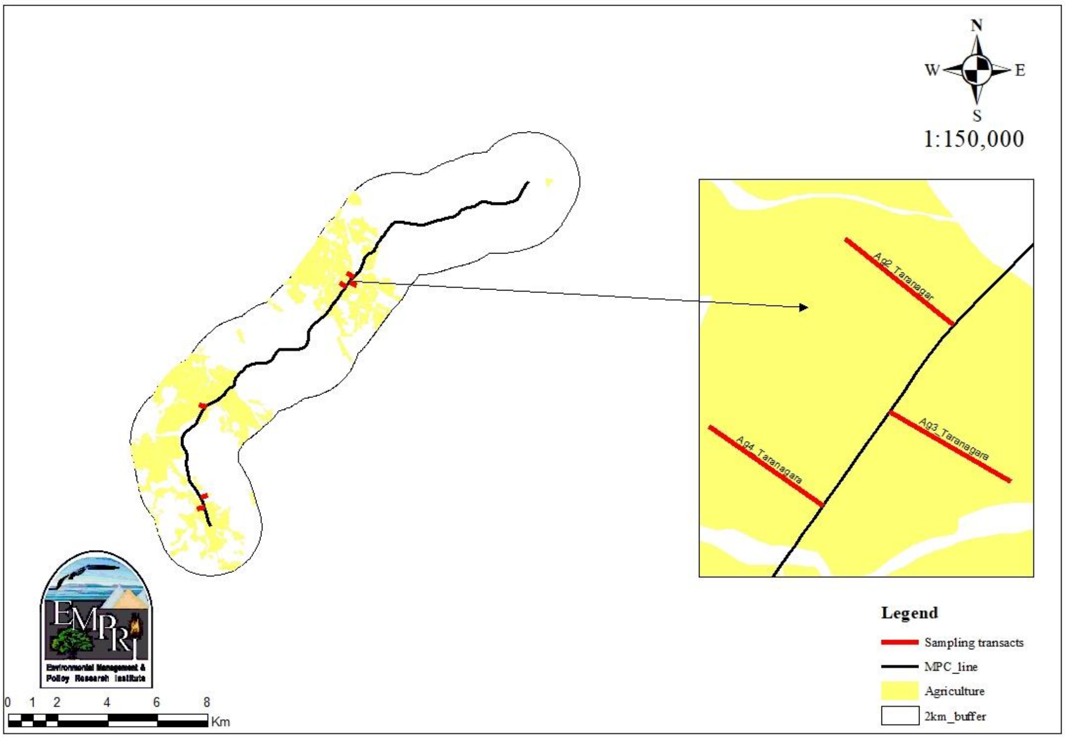


Figure 9.1a: Point transects laid in the agriculture habitats of the study area.

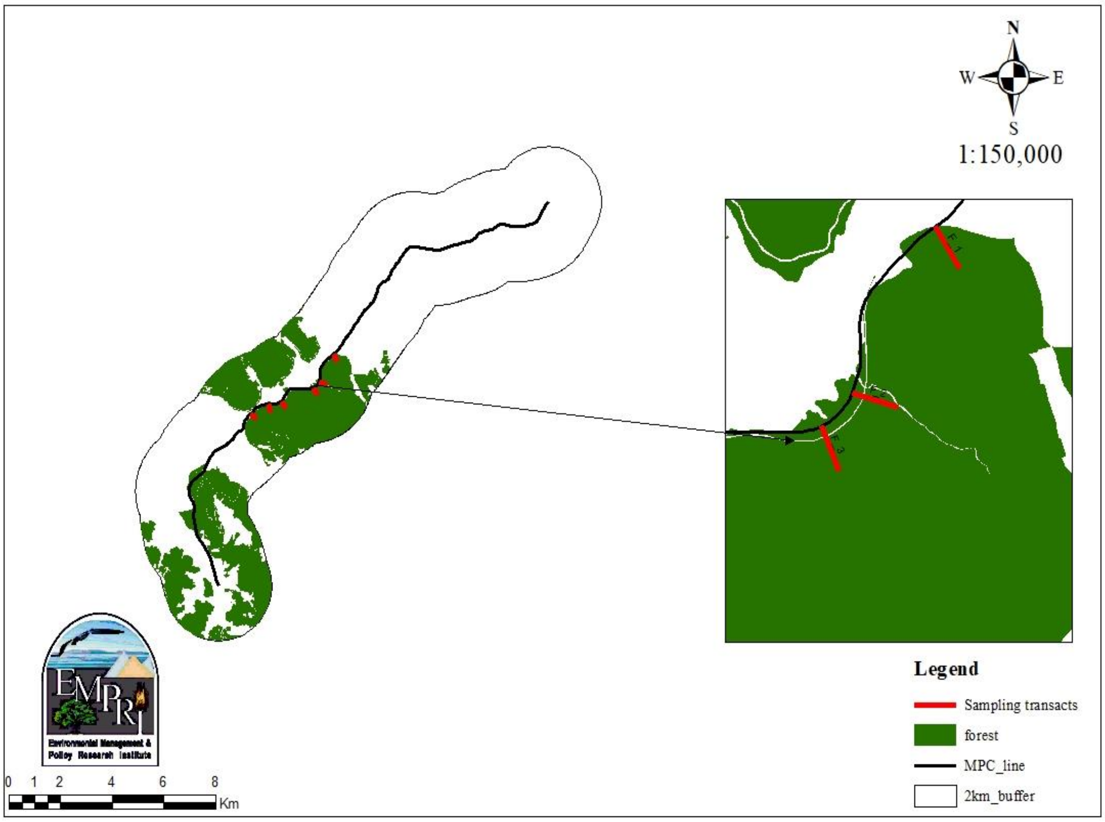


Figure 9.1b: Point transects laid in Forest habitats of the study area.

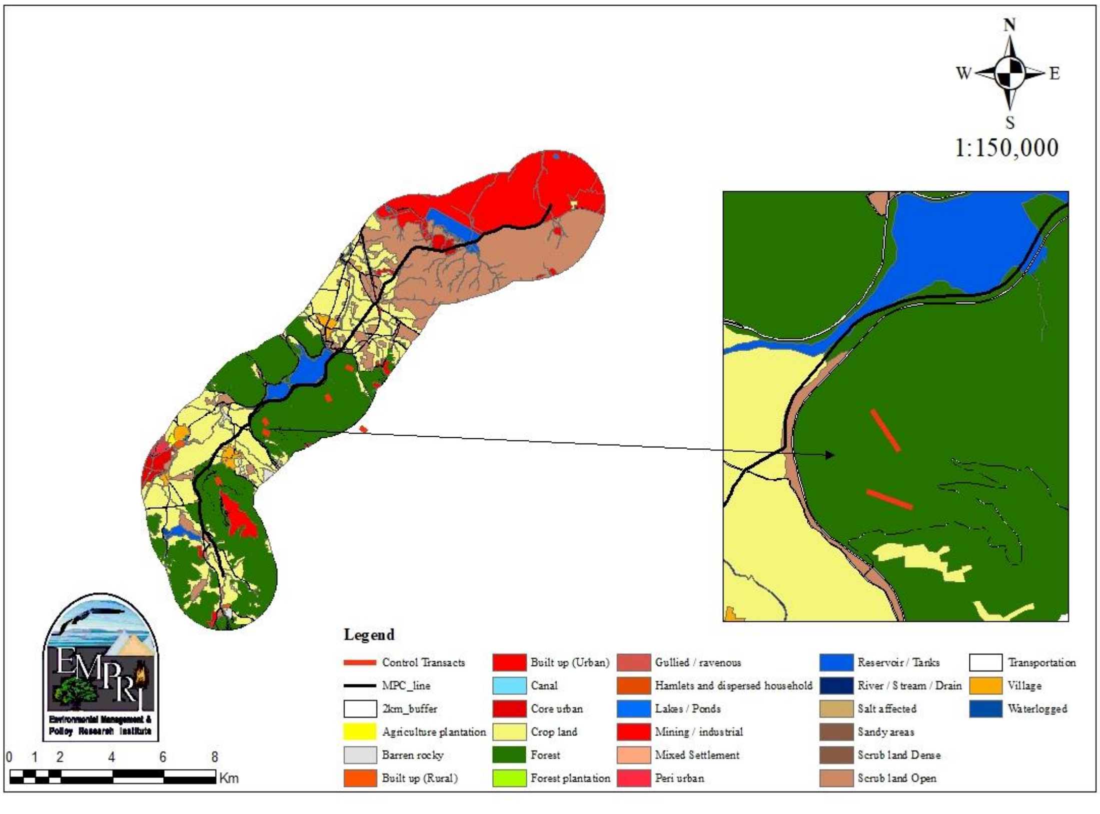


Figure 9.1c: Point transects laid in control locations.

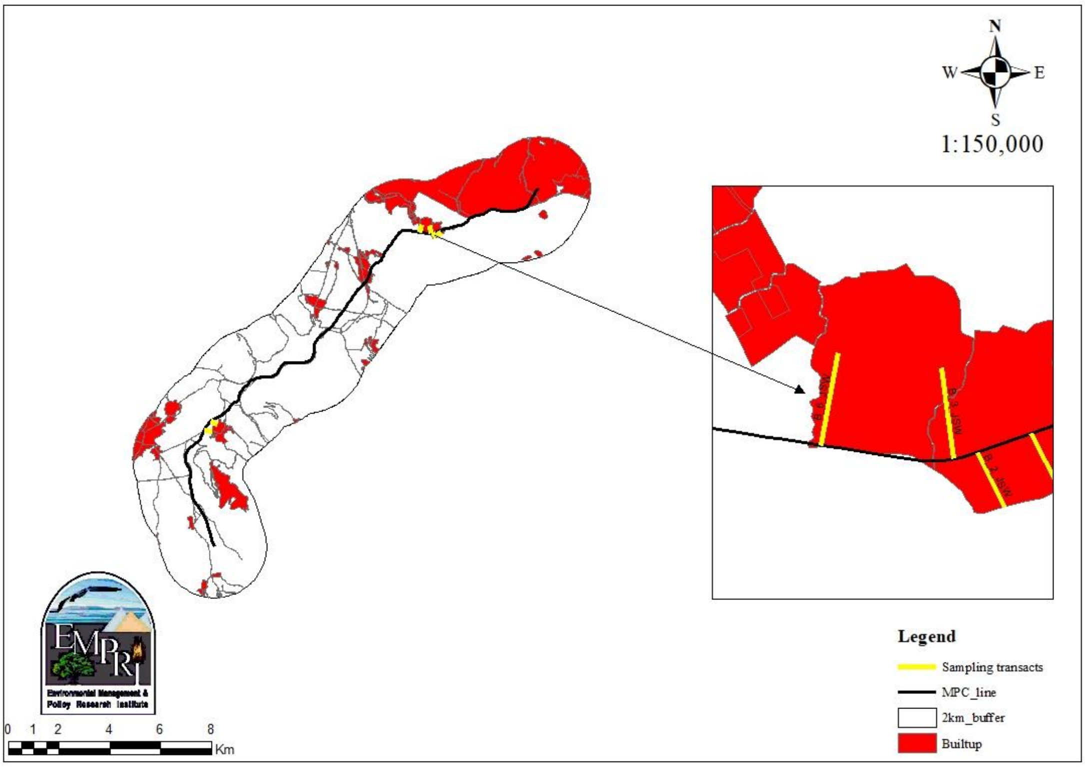


Figure 9.1d: Point transects laid in Built-up habitats of the study area.

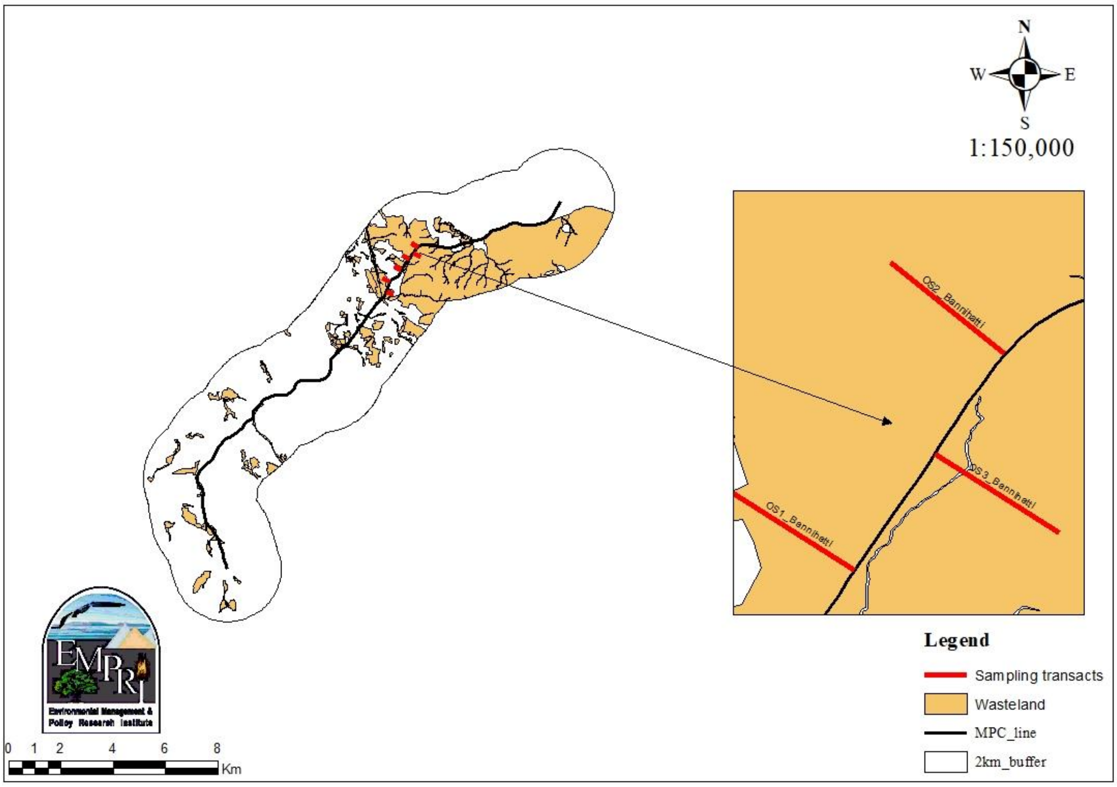


Figure 9.1e: Point transects laid in Open Scrub habitats of the study area.

Table 9.1: Equipment details, used in the field

Equipment	Usage
Noise Meter	Recording the noise generated from MPC
Pocket Weather Meter (Kestrel 3000)	Record the different environmental attributes/ weather parameters like temperature, wind speed, average wind speed, maximum wind speed, relative humidity, and the dew point
GPS (Garmin *e*Trex 10 and 20) GPS essentials (Mobile App)	Mark waypoints and field tracks during sampling and data collection
Binocular (Nikon 10x50)	were used to spot the birds and identify
Camera (DSLR: Nikon D810A), aided with 150mm-600mm telescopic Lens	For photo documentation of Avi-faunal species

Table 9.2: Efforts on all the methodologies

I. Point Intercept line transect

Habitat Type	Agri	Forest	Scrub	Built-up	Wetland	Control
No. of transects (Spatial replications)	6	6	6	6	6	6
No. of points on transect	4	4	4	4	1	4
Total sampling points	24	24	24	24	6	24
Temporal Replications	3	3	3	3	3	3

II. Nocturnal survey

	Phase 1	Phase 2
No. of Transects	8	8
Temporal Replications	3	3

Table 9.3: Data analysis

Parameter	Formula adopted	Analysis platform
Abundance	Total no. of individual species / Total no. of points in which they occurred.	SPSS Software
Relative abundance	Total no. of individuals of Species/ Total no. of individuals of all the species recorded in the study area	Excel spreadsheet
Mean and Standard deviation	$\sigma = \frac{1}{N}\sqrt{\sum_{i=i}^{n} f_i x_i^2 - (\sum_{i=1}^{n} f_i x_i)^2}$	SPSS Software
ANOVA	$H_1 \neq H_0$ H_1 (alternative hypothesis): rejects the null hypothesis and concludes that at least one of the population means is different from the others. H_0(null hypothesis): $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$ (all the population means are equal).	SPSS Software
Simpson dominance index (SDI)	$1/\sum_{i=1}^{s} p_i^2$ (Where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is the sum of the calculations, and is the number of species)	PAST Software
Shannon-Wiener's index	$-\sum_{i=1}^{s} p_i \ln p_i$ (Where p is the proportion (n/N) of individuals of one species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and is the number of species)	PAST Software
Pearson correlation	$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$ Determined by dividing the covariance by the product of the two variables' standard deviations	SPSS Software
Density estimation: Distance-wise, habitat wise, and individual species wise	$\hat{N} = \hat{E}(s)\sum_{i=1}^{n}\frac{1}{\hat{P}_i}$ Estimation of density of individual or group of birds with sample size, mean cluster size, coefficient of variation, and associated confidence intervals per unit area (Kumara et al. 2012)	DISTANCE Software

This checklist is a collective of bird species recorded from the Point counts/ intercept line transect studies, nocturnal surveys as well as opportunistic sightings of birds that occurred in the study area. The checklist of birds recorded from the study area with IUCN Status, Migratory status, Habit, habitat, feeding guild, and status of them in Indian Wildlife Protection Act-1972 was prepared.

Birds that do not migrate are known as resident birds. These residents' birds make few habitats as their permanent homes for their feeding and breeding grounds. One of the most fascinating reasons for the flight of birds is their migration, and these birds are known as migratory birds. There are different migratory patterns; few major ways are Nocturnal Migration, Long-distance migration, Diurnal migration, Short-distance migration, and Altitudinal migrations. We classified them accordingly.

Birds are often considered to be outstanding indicators of the health of the overall environment. The population of Birds is threatened due to various reasons. One of the main reasons being the loss of habitat, deforestation, the draining of wetlands, planting of non-native trees, the loss of areas due to urban developments, and intensive agriculture are major threats to birds. International Union for Conservation of Nature (IUCN) has given the following categories for species that are globally threatened.

It is highly important to monitor the birds and to understand the feeding guild of birds present in the area. A varied type of special beak and foot adaptations can be observed in each species depending on the type of habitat they live in and the type of food they consume. The diverse avifauna in the study area may be because of the presence of a wide spectrum of food sources ranging from the scrub jungle to agricultural, horticultural crop fields. The different species of birds that occupy a particular feeding guild and space have evolved specialized foraging strategies to explore and obtain food resources efficiently and thus to reduce competition among diverse species (Nudds and Bowlby 1984; Jose and Zacharias 2003).

The Wildlife (Protection) Act, 1972 is an Act of the Parliament of India enacted for the protection of wild animals, birds, and plants. It has six schedules that give varying degrees of protection. Schedule I and part II of Schedule II provide absolute protection - offenses under these are prescribed the highest penalties. Species listed in Schedule III and Schedule IV are also protected, but the penalties are much lower. In India except for crows and pigeons, all the other species are protected either in schedule I or Schedule IV. Indian Peafowl, Raptors (Eagles and Kites) are listed in Schedule-I.
Birds are habitat-specific; thus, we classified the birds species according to habitat wise. The variation in vegetation structure influences the species distribution within a habitat (Pearman 2002). Wetland characteristics like size, water depth, quality of water, trophic structure, and presence of suitable roosting and nursery sites influence the abundance and diversity of birds (Mukherjee et al. 2002; Ma et al. 2010).

The relation between the species occurrence and the frequency of noise generated in different habitats and distances from MPC was established by correlating the noise (dB) with the number of bird species recorded and the abundance of birds recorded at different distances from MPC. The sound in decibels was recorded for every area of sampling at the perpendicular distance to the MPC. The relationship of the mean number of bird species with the mean sound in decibels was developed for all the habitat types and the overall means.

The data was analyzed using DISTANCE statistical software for estimating the density of birds. The sampling size was maintained the same from all the habitats and distances. The data from temporal replicates were considered as a single sample (Sample size= 126). The farthest sightings of the birds at sampling points were truncated for a reliable density estimate. The density estimation for all the species was presented from the truncating and untruncated data which fits well. The birds with good detection probability (>20 detections) at different distances of sampling (zero (0 m), 100 m, 200 m, and 300 m) point clusters from MPC were considered for density estimation of individual species and concerning distance along with sample size, mean cluster size, coefficient of variation and associated confidence intervals

Studies were conducted in enumerating the nocturnal birds all along the length of MPC during the nocturnal hours to know the occurrence of species diversity, and abundance of nocturnal birds, and their utility pattern of the type of habitat. The study area (length of MPC) has been split up into 8 transects of 3 km each and at every 500 m the habitat features were recorded along with the sound (dB) and the details of birds sighted. Survey efforts were equal in conducting studies for both phases -I and II (Table 1).

Results:
Occurrence

A total of 125 species of birds belonging to 20 orders, 53 families were recorded from the study site (Annexure 9.1). Order Passeriformes with 49 species is the highest, followed by Accipitriformes with 11 species of birds of prey which includes kites, hawks, and eagles (Fig. 9.2). The dominant family was Family Accipitridae that is the bird of prey with eleven species. Family Cisticolidae (Prinias), Family Cuculidae (Cuckoos and Koels), were represented with six species in each family (Fig. 9.3).

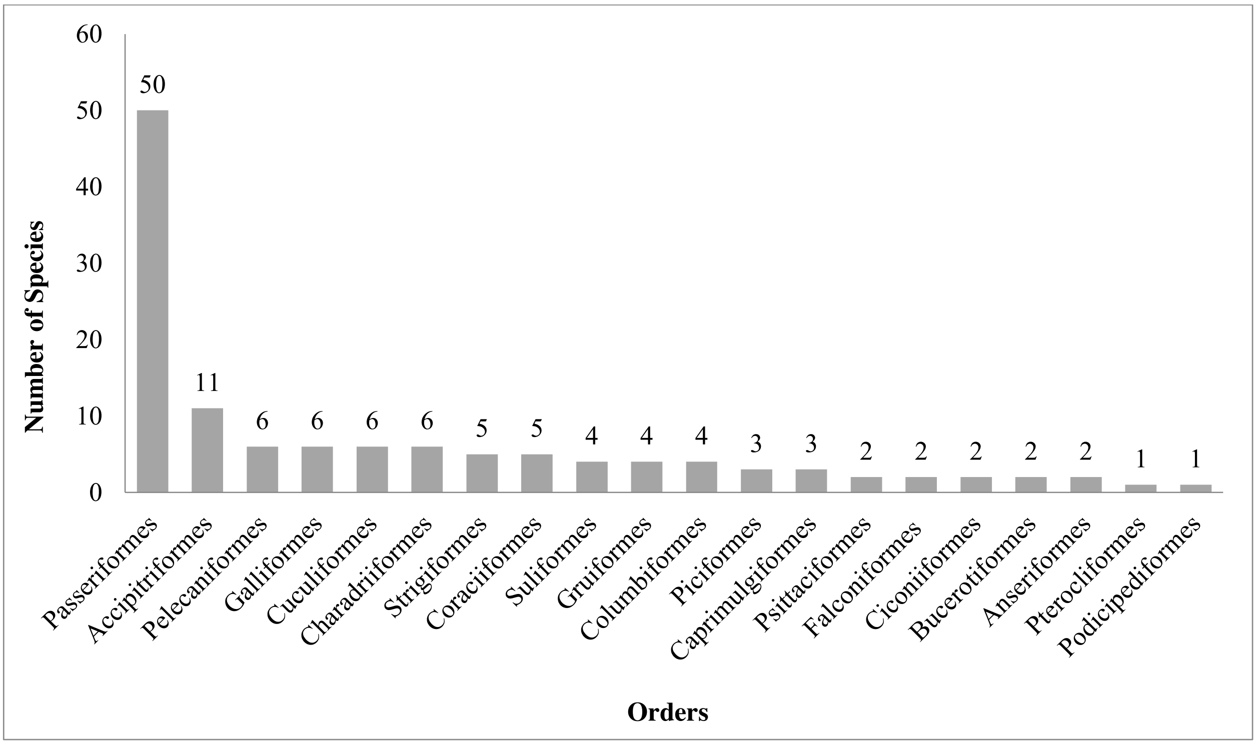


Figure 9.2. Order wise distribution of birds

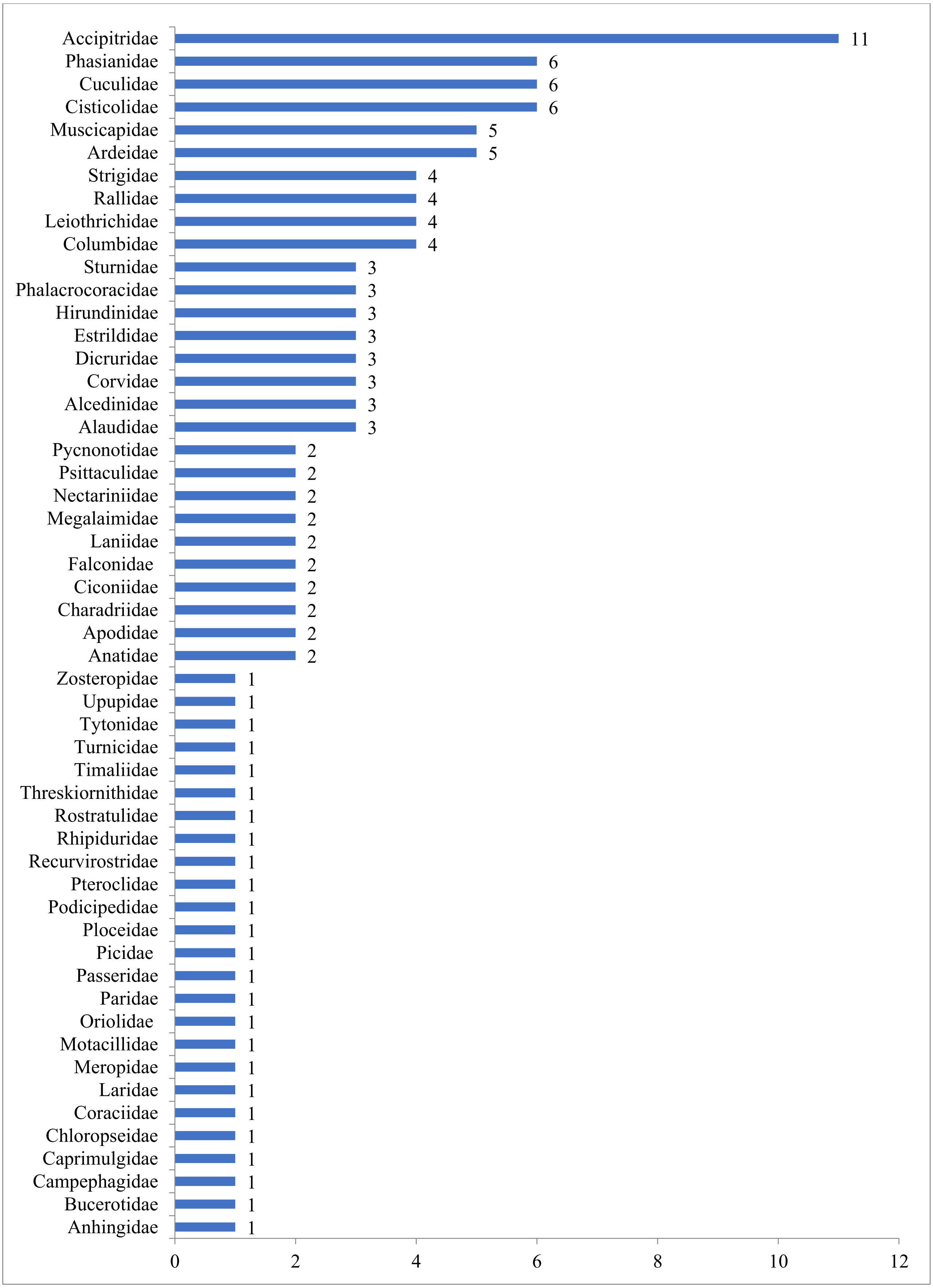


Figure 9.3: Family wise number of species occur in the study area

Of 125 species, 124 species are residents, and only one species is found to be migratory, which is a local migrant that is 'Barn Swallow' (Fig. 9.4). Of 125 species, six species are threatened. Four being 'Near Threatened' (Rufous-bellied Eagle, Painted Stork, Oriental Darter, and Black-headed Ibis) and two 'Vulnerable' species that is (Indian Spotted Eagle and River Tern) (Birdlife International 2016; IUCN 2021). Table 9.4 represents the percent of globally threatened species of birds from the study area.

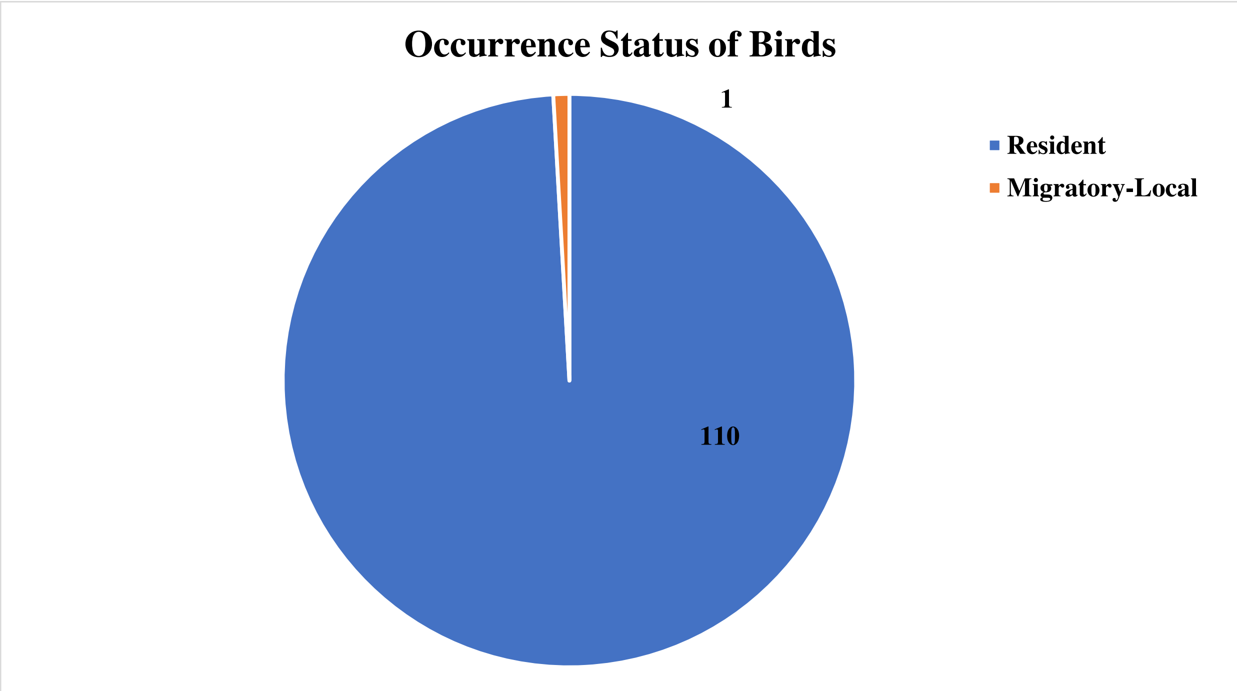


Figure 9.4: Occurrence status of birds recorded from the study area

Table 9.4: Classification of birds under IUCN protection categories

IUCN Status	No. of Species
Least Concern	119
Near Threatened	4
Vulnerable	2
Total	**125**

In the present study, 33% (40 species) were insectivorous, (Figure 9.5) 5% (6 species) are Insectivore and Frugivore, 5% (5 species) are Insectivore and Granivore, 18% (15 species) were Carnivorous, 16% (19 species) were Omnivorous, 8% (10 species) were Granivore mainly pigeons, doves, and munias. 5% (6 species) were Frugivorous, 2% (2 species) were Nectarivores (only sunbirds), 5% (6 species) were Piscivore (fish-eating) and 7% (8 species) were Piscivore and Insectivore and (fish-eating and insect-eating like egrets, herons). Only 2% (2 species) were found to be herbivorous that is Indian Spot-billed Duck and Lesser Whistling Duck which feeds mainly on aquatic plants and algae. Occurrence of a significant number of insectivorous bird communities indicates that the area consists rich insect diversity (Gregory et al. 2001) and also play a major role as important bio-control agents of insect pest of agriculture, horticulture, and forest ecosystem. From the present study, out of 125 species, 13 species are protected under Schedule –I, 111 species are under Schedule-IV and only one species is in Schedule-V (Table 9.5). Out of 125 species documented, 98 species (78%) were associated with terrestrial habitat and 27 species (22%) were wetland-associated. During the survey, wetland birds such as ducks, herons, egrets, cormorants, and kingfishers were observed near Narihalla backwaters, Bhimagundi Tunnel. Other terrestrial birds are distributed and categorized as Grasslands, Scrubland, Forests, and those which are present in many habitats like human habitations, adjoining agriculture fields and other marshy areas are termed as Widespread. Crows, mynas, pigeons, kites are the best example for these categories (Table 9.6).

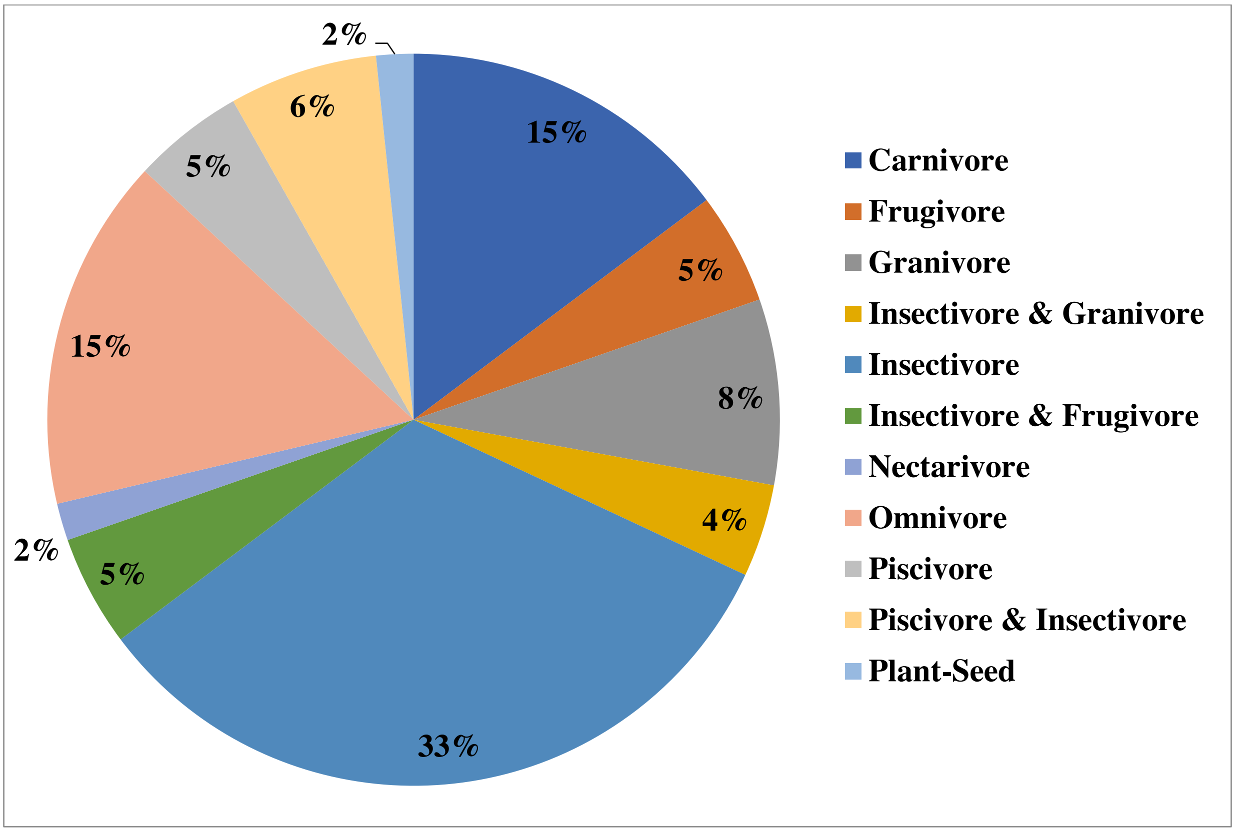


Figure 9.5: Feeding guild of birds recorded from the study area

Table 9.5: Protection status of birds under IWPA, 1972.

IWPA Schedule	No. of Species
Schedule-I	**13**
Schedule-IV	**111**
Schedule-V	**1**
Total	**125**

Table 9.6: Distribution of birds by the type of Habitats

Habitat Type	No. of Species	Percentage of Species
Forest	12	9%
Open Scrubland	20	16%
Wetland	27	22%
Widespread	66	53%
Total	**125**	**100**

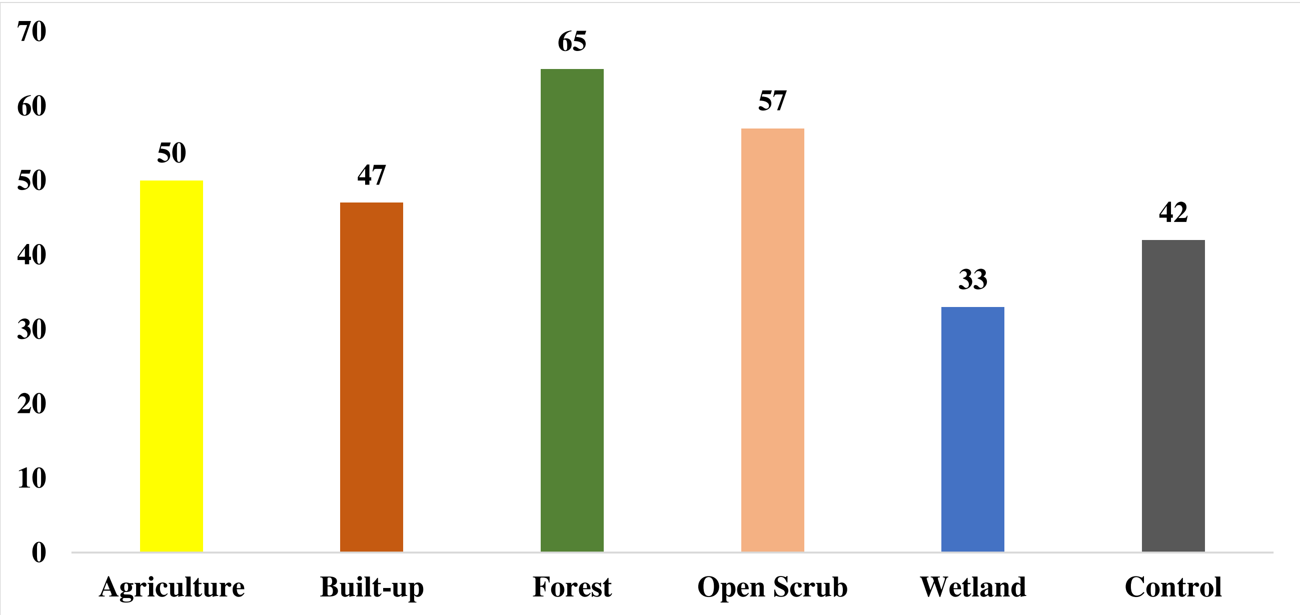


Figure 9.6: Occurrence of number of avifaunal species in different habitats

Occurrence of avifaunal species in the study area

Out of 125 species recorded from the locality, only 97 bird species were observed to utilize different habitats of the study area all along with the MPC. Habitat-wise, Forest type of habitat is predominant with 65 species, followed by Open scrub with 57 species, 50 species in Agriculture, 47 species in Built-up, followed by Control area with 42 species, and least in wetland habitat with 33 species

(Figure 9.6). According to the distance from the MPC, 77 species were recorded from 300 m distance from MPC followed by 75 species from 0 m, and 70 species from 200 m and 42 species were recorded from the Control area (Annexure 9.2) (Figure 9.7).

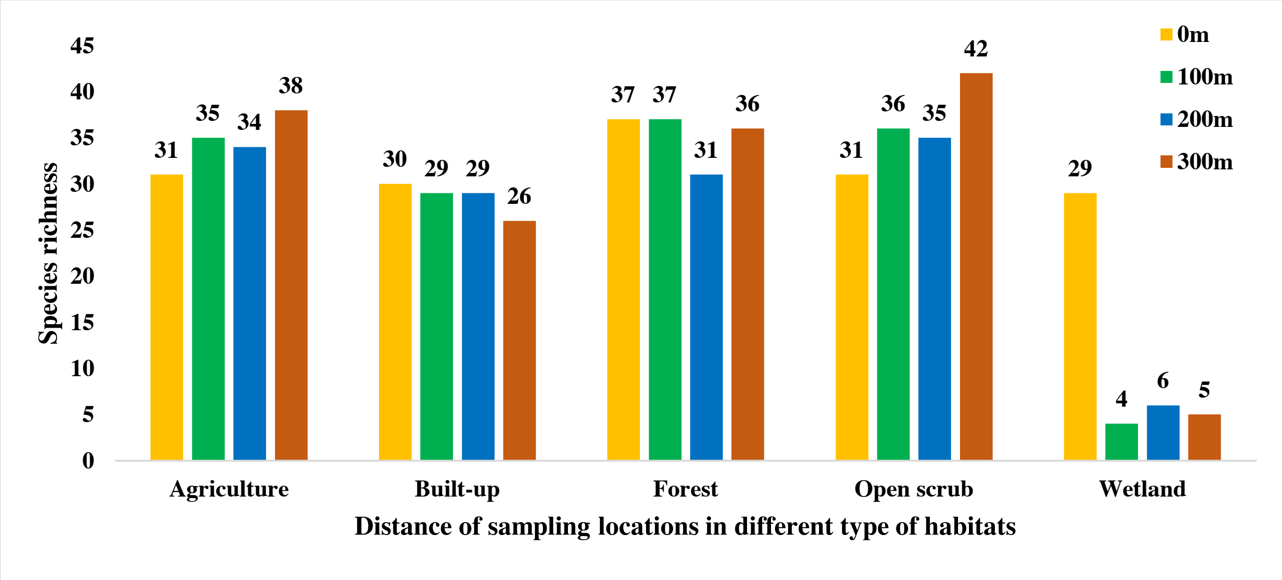


Figure 9.7: Avi-faunal species richness recorded at a different distance of sampling locations at different habitats.

Diversity indices:

Diversity indices were calculated for the sampling distances and habitats, and it shows an almost similar pattern. In all the habitats at different distances from MPC, the species richness was almost similar but slightly increasing in agricultural and Open Scrub habitats. Shannon and Simpson's values reveal the homogeneity in species diversity among the sampling locations of the habitats (Table 9.7, 9.8, 9.9, 9.10).

Table 9.7: Diversity indices of sampling locations in Agricultural habitat.

Distance	Richness	Abundance	Simpson_1-D	Shannon_H	Evenness
0 m	31	302	0.90	2.80	0.53
100 m	35	260	0.93	3.01	0.58
200 m	34	221	0.93	2.97	0.57
300 m	**38**	406	0.91	2.89	0.47
Control	**42**	**980**	**0.94**	**3.11**	**0.54**

Species richness in the control site was higher than along MPC. The Overall sampling locations at distances from MPC show a similar pattern of species richness among zero meters to 200 m, Shannon-Weiner index, and Simpson index but at the 300 m shows increased species richness than the control sites. The abundance at zero meters is high, but the evenness value is more in control sites followed by at 200 m distance from MPC (Table 9.11).

Table 9.8: Diversity indices of sampling locations at Built-up area.

Distance	Richness	Abundance	Simpson_1-D	Shannon_H	Evenness
0 m	**30**	218	0.91	2.79	0.54
100 m	29	241	0.93	2.90	0.63
200 m	29	314	0.86	2.57	0.45
300 m	26	164	**0.93**	2.93	0.72
Control	**42**	**980**	**0.94**	**3.11**	**0.54**

Table 9.9: Diversity indices of sampling locations at Forest habitat.

Distance	Richness	Abundance	Simpson_1-D	Shannon_H	Evenness
0 m	37	290	0.92	2.95	0.52
100 m	37	190	0.91	2.97	0.53
200 m	31	210	0.92	2.94	0.61
300 m	36	165	0.93	3.05	0.59
Control	**42**	**980**	**0.94**	**3.11**	**0.54**

Table 9.10: Diversity indices of sampling locations at Open scrub habitat.

Distance	Richness	Abundance	Simpson_1-D	Shannon_H	Evenness
0 m	31	201	0.90	2.75	0.50
100 m	36	233	0.87	2.76	0.44
200 m	35	219	0.92	2.96	0.55
300 m	42	241	0.94	3.19	0.58
Control	**42**	**980**	**0.94**	**3.11**	**0.54**

Table 9.11: Overall diversity indices of sampling locations of the study area.

Distance	Richness	Abundance	Simpson_1-D	Shannon_H	Evenness
0 m	65	**1280**	0.95	3.30	0.42
100 m	67	939	0.94	3.38	0.44
200 m	65	977	0.95	3.42	**0.47**
300 m	72	988	0.95	3.48	0.45
Control	**42**	**980**	**0.94**	**3.11**	**0.54**

Overall habitat-wise, Shannon and Simpson's indices show a similar pattern of diversity and species distribution other than at wetland habitat. Habitats wise the species richness is more in forest habitat and less in wetland habitat (Table 9.12).

Table 9.12: Overall diversity indices of habitats in the study area.

Habitat	Richness	Abundance	Simpson_1-D	Shannon_H	Evenness
Agriculture	50	**1189**	0.94	3.18	0.48
Built-up	47	954	0.94	3.09	0.47
Forest	**65**	858	0.93	3.26	0.40
Open Scrub	57	894	0.93	3.16	0.41
Wetland	**33**	289	0.92	2.84	0.52
Control	42	980	0.94	3.11	0.54

The mean numbers of bird species were high at distances away from the MPC. It is not varied significantly among the different distances from the MPC, viz., agriculture fields ($F_{3,20}$= 1.039 p =0.39), Built-up ($F_{3,20}$ =1.078, p=0.38), Forest area ($F_{3,20}$= 0.335 p = 0.800) and Scrub ($F_{3,20}$=1.085, p= 0.378). The overall mean number of species were not significantly varied between the different distances from the MPC ($F_{3,20}$=0.214, p = 0.885) (Figure 9.8).

The mean number of birds were high at distances away from the MPC, however did not vary between different distances from the MPC, viz., agriculture fields ($F_{3,20}$= 144. p = 0.26), Built-up ($F_{3,20}$ =0.68, p = 0.57), Forest area ($F_{3,20}$= 1.91p = 0.16) and scrub ($F_{3,20}$=1.08, p = 0.908). The overall mean number of birds also did not differ between the distance points from the MPC ($F_{3,20}$=0. 579, p = 0.636) (Figure 9.9).

As the sound decreased away from the MPC the number of bird species has increased in agriculture field (r_p= -0.607, df = 4, p = 0.393) followed by built-up area (r_p= - 0.186, df=4, p =0.81), forest (r_p= 0.882, df = 4, p <0.11), and in open scrub (r_p= -0.99, df = 4, p =0.09) (Figure 9.10). Similarly, as the sound decreased away from the MPC the population of birds increased in agriculture field (r_p= - 0.225, df = 4, p = 0.775). Built-up area (r_p= - 0.013, df=4, p =0.98), forest (r_p= 0.758, df = 4, p =0.242), in scrub (r_p= -0.798, df = 4, p =0.20) (Figure 9.11). However, the relationship among bird species and mean number of birds against the sound in decibels are not significant.

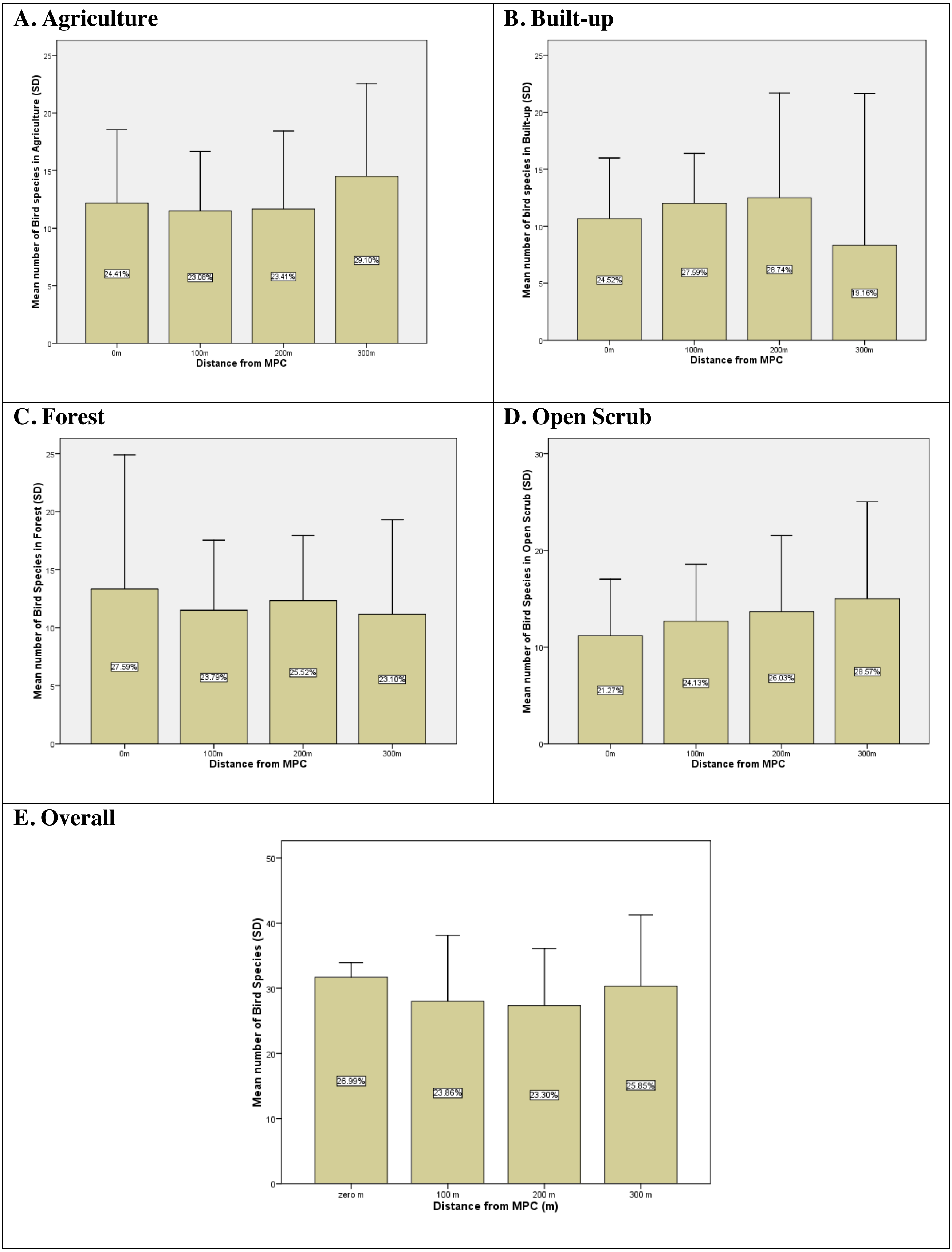


Figure 9.8: The mean number of bird species at different distances from the MPC.

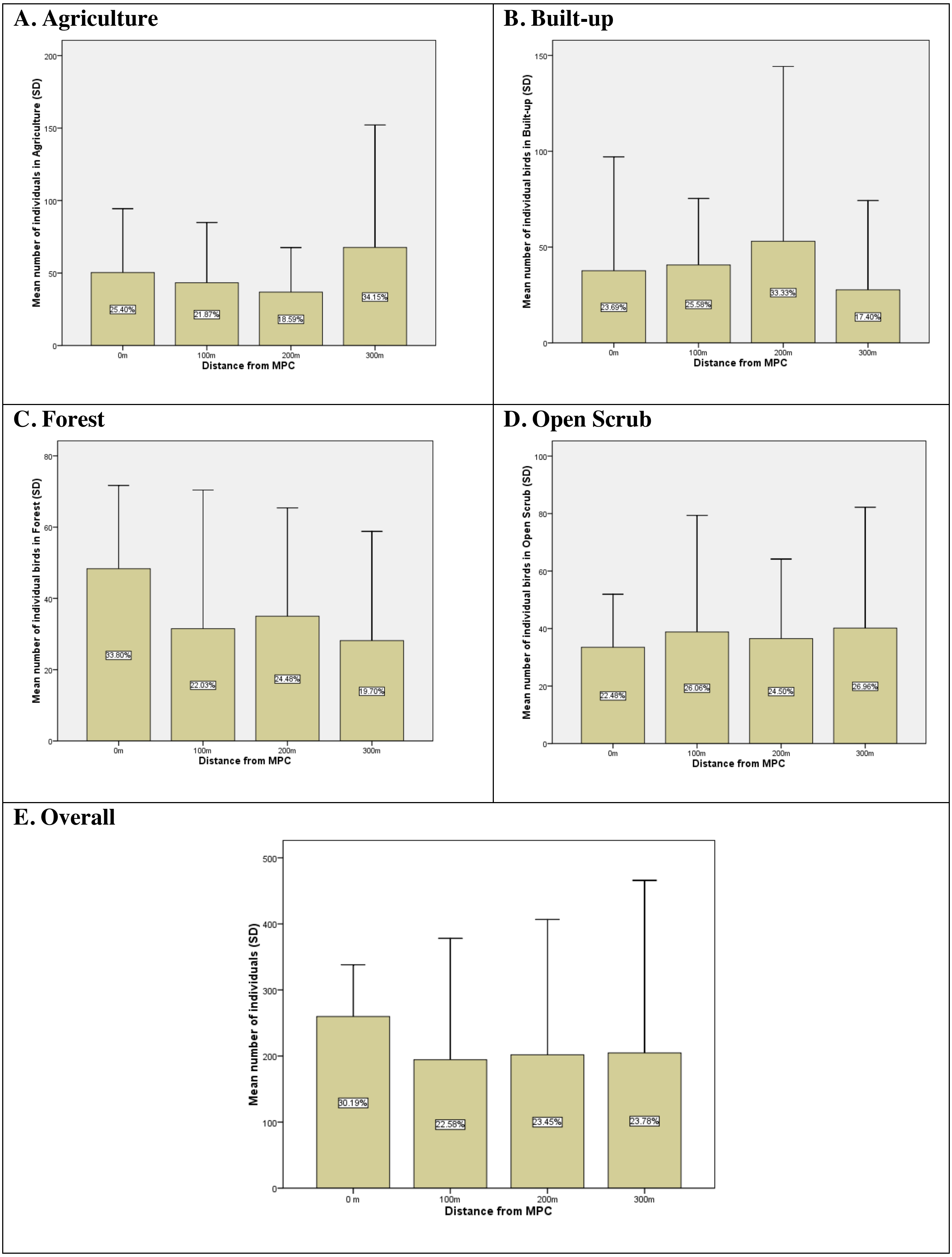


Figure 9.9: The mean number of the abundance of birds at different distances from the MPC.

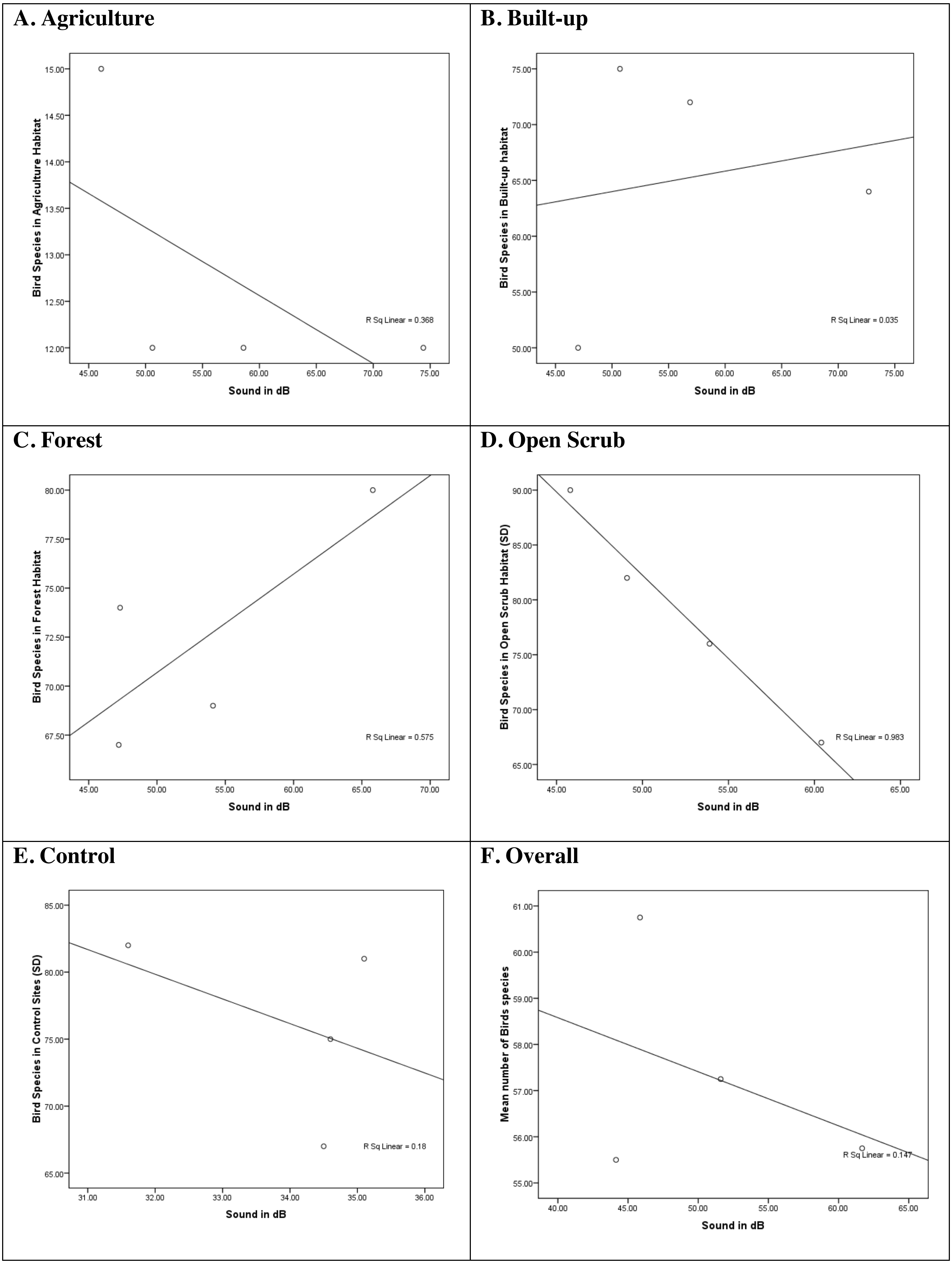


Figure 9.10: Correlation of Bird species with sound intensity (dB)

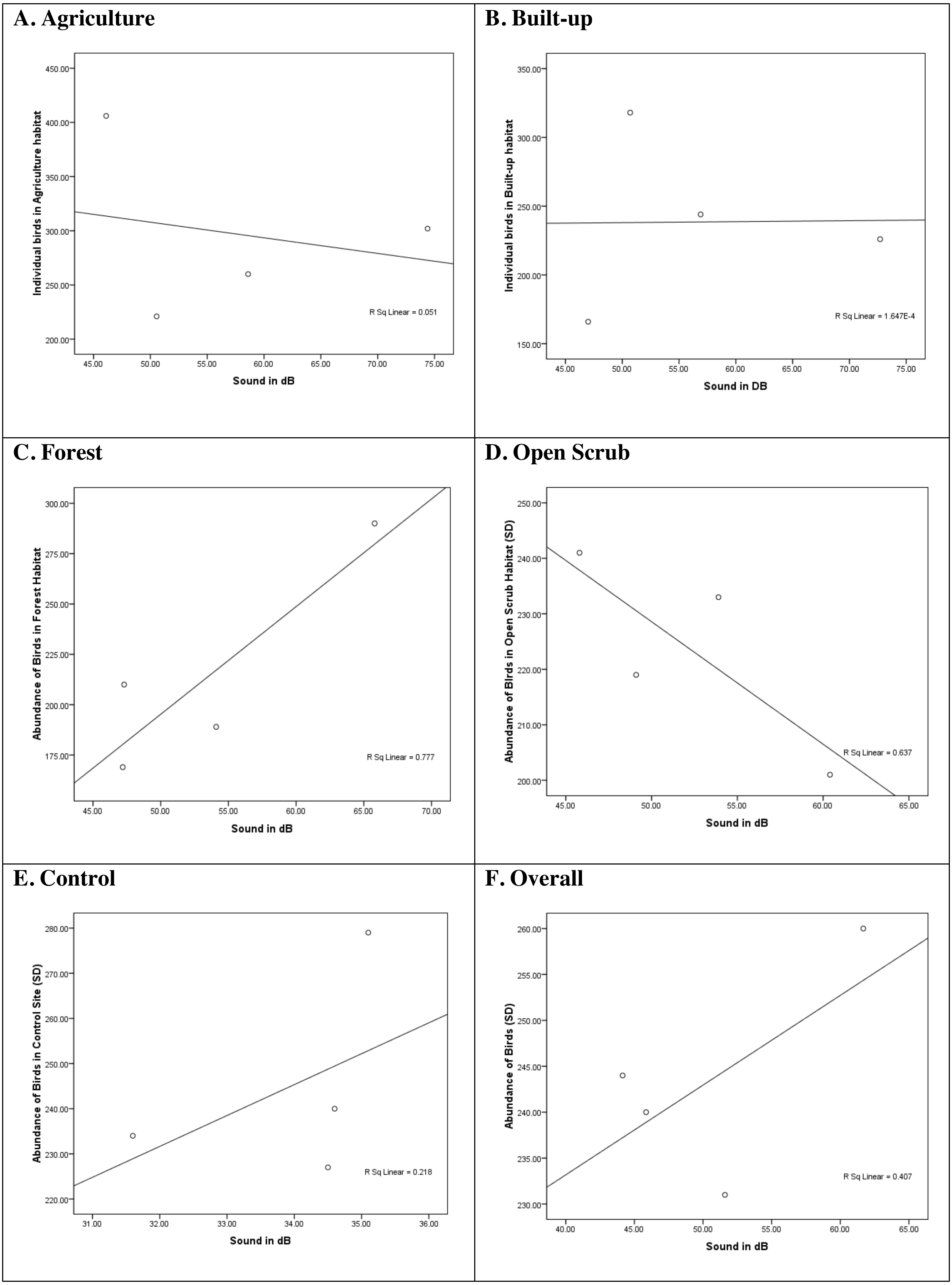


Figure 9.11: Correlation of bird abundance with sound intensity (dB)

Abundance:

Relative abundance, of the top 10 species at a different distance from MPC was calculated, in terms of species, 20 species were listed to be found abundant throughout all the distance of sampling from MPC. And it was found Red-vented Bulbul, Laughing Dove, and Ashy Prinia were found to occur at all the distances and were the most abundantly occurring, however, except 0 m and 100 m from MPC, all other distances from MPC the most abundant species was different, while White-browed Bulbul is the most abundant species in the control site (Table 9.13). Species-wise relative abundance of all the species of occurrence was also calculated in terms of their occurrence in different habitats and distance of sampling locations from MPC (Annexures 9.3, 9.4).

Table 9.13: Top 10 abundant bird species in different distances from MPC.

Top 10 abundant species of birds at Zero (0 m) from MPC					
S. No	**Species Name**	**Distance**	**Count**	**Rel. Abound**	**% Abund**
1	Red-vented Bulbul	Zero	134	0.10	10.47
2	Blue Rock Pigeon	Zero	129	0.10	10.08
3	Common Myna	Zero	128	0.10	10.00
4	Red-rumped Swallow	Zero	80	0.06	6.25
5	Ashy Prinia	Zero	76	0.06	5.94
6	Laughing Dove	Zero	74	0.06	5.78
7	Rose-ringed Parakeet	Zero	63	0.05	4.92
8	Little Swift	Zero	55	0.04	4.30
9	Indian Silverbill	Zero	54	0.04	4.22
10	Plain Prinia	Zero	43	0.03	3.36
Top 10 abundant species of birds at 100 m distance from MPC					
1	Red-vented Bulbul	100	168	0.18	17.89
2	Laughing Dove	100	57	0.06	6.07
3	Blue Rock Pigeon	100	55	0.06	5.86
4	Common Myna	100	55	0.06	5.86
5	Ashy Prinia	100	51	0.05	5.43
6	Large Grey Babbler	100	48	0.05	5.11
7	Little Swift	100	39	0.04	4.15
8	Plain Prinia	100	39	0.04	4.15
9	Baya Weaver	100	28	0.03	2.98
10	House Crow	100	27	0.03	2.88
Top 10 abundant species of birds at 200 m distance from MPC					
1	House Sparrow	200	101	0.10	10.34

Top 10 abundant species of birds at 200 m distance from MPC					
2	Red-vented Bulbul	200	93	0.10	9.52
3	Plain Prinia	200	66	0.07	6.76
4	Ashy Prinia	200	60	0.06	6.14
5	Large Grey Babbler	200	56	0.06	5.73
6	Laughing Dove	200	52	0.05	5.32
7	Blue Rock Pigeon	200	41	0.04	4.20
8	House Crow	200	40	0.04	4.09
9	Little Swift	200	38	0.04	3.89
10	Indian Silverbill	200	34	0.03	3.48
Top 10 abundant species of birds at 300 m distance from MPC					
1	Little Swift	300	104	0.11	10.53
2	Red-vented Bulbul	300	88	0.09	8.91
3	Rose-ringed Parakeet	300	85	0.09	8.60
4	Common Myna	300	60	0.06	6.07
5	Ashy Prinia	300	51	0.05	5.16
6	Laughing Dove	300	43	0.04	4.35
7	Plain Prinia	300	42	0.04	4.25
8	Large Grey Babbler	300	39	0.04	3.95
9	Green Bee-eater	300	30	0.03	3.04
10	House Crow	300	30	0.03	3.04
Top 10 abundant species of birds at Control sites of the study area					
1	White-browed Bulbul	Control	129	0.13	13.16
2	Red-vented Bulbul	Control	127	0.13	12.96
3	Purple Sunbird	Control	80	0.08	8.16
4	Common Iora	Control	71	0.07	7.24
5	Laughing Dove	Control	60	0.06	6.12
6	Rose-ringed Parakeet	Control	54	0.06	5.51
7	Grey-breasted Prinia	Control	46	0.05	4.69
8	Plain Prinia	Control	44	0.04	4.49
9	Indian Peafowl	Control	38	0.04	3.88
10	Ashy Prinia	Control	35	0.04	3.57

Density:

The density of birds at Control sites (41.86/Sq.km, 19.17 %CV) is close to that at zero (0m) (41.46/Sq.km, 13.5 %CV) distance has high density of birds, followed by distance 200m (36.72 Sq.km, 29.16 %CV), 100m (32.9 Sq.km, 16.01 %CV) and least in 300m (25.82/ Sq.km, 19.45 %CV) (Table 9.14). Habitat wise, bird density was estimated to be high in Forest habitat (51.02/ Sq.km, 18.53%CV) followed by Built-up area (50.86/ Sq.km, 20.8% CV), control sites (41.86/sq. km, 19.17 %CV), Open scrub (34.41/ Sq.km, 17.08) and observed less in Agricultural habitat with density of 17.21/ Sq. km, 7.28% CV. (Table 9.15). The density of highly detected species is summarized in Table 9.16.

Table 9.14: Overall bird density occurrence at distance wise from MPC

Distance	n	Dg (Sq. km	Y (Cluster size)	D (Sq. km)	SE	CV (D) (%)	95% CI (Sq.km)
Zero	562	22.37	4.3	**41.46**	±5.59	13.5	31.64-54.34
100 m	452	18.65	3.2	32.9	±5.2	16.01	23.92-45.26
200 m	212	22.79	1.6	36.72	±10.70	29.16	20.52-65.69
300 m	460	15.74	2.5	25.82	±5.02	19.45	17.40-38.32
Control	543	26.52	1.3	**41.86**	±8.02	19.17	28.36-61.76

Table 9.15: Overall bird density in different habitats of the study area.

Habitat	n	Dg (Sq. km)	Y (Cluster size)	D (Sq. km)	CV (D) (%)	95% CI (Sq.km)
Agricultural	514	9.22	3.5	17.21	17.28	12.10-24.47
Built-up	436	26.99	2.4	**50.86**	20.8	33.36-77.53
Forest	503	30.12	1.7	**51.02**	18.53	35.13-74.11
Open Scrub	499	20.78	2.4	34.41	17.08	24.39-48.56
Control	543	26.52	1.3	41.86	19.17	28.36-61.76

Table 9.16: Species wise density estimation of birds at different distances from MPC

Distance from MPC	Species	n	Dg (Sq. km)	Y (Cluster size)	D (Sq. km)	% C V	95% C. I (Sq.km)
0(Zero) m	Ashy Prinia	60	2.38	1.27	3.02	10.87	2.43-3.75
	Common Myna	46	111.10	2.25	**250.55**	37.41	121.3-517.4
	House Crow	26	0.40	38.9	0.60	16.71	0.43-0.84
	Laughing Dove	29	1.83	18.5	2.76	16.61	1.97-3.85
	Plain Prinia	34	1.59	35.2	1.57	7.76	1.34-1.83
	Red-vented Bulbul	79	3.58	8.6	6.09	16.78	4.37-8.47
	Rose-ringed Parakeet	15	1.45	31.9	**7.25**	35.04	3.59-14.63

Distance from MPC	Species	n	Dg (Sq. km)	Y (Cluster size)	D (Sq. km)	% C V	95% C. I (Sq.km)
100 m	Ashy Prinia	40	1.43	1.25	1.8	33.53	0.93-3.47
	Common Myna	22	0.32	1.7	**0.55**	15.75	0.40-0.75
	Laughing Dove	38	1.00	1.34	1.34	17.23	0.95-1.89
	Plain Prinia	31	1.32	1.24	1.65	19.97	1.10-2.46
	Red-vented Bulbul	78	2.47	2.01	**4.98**	13.62	3.81-6.51
200 m	Ashy Prinia	45	2.16	4.4	**3**	22.66	1.92-4.69
	Laughing Dove	35	1.7	5.6	2.19	25.18	1.32-3.63
	Plain Prinia	50	2.14	7.2	2.82	17.26	1.99-3.98
	Red-vented Bulbul	53	1.51	8.8	2.41	20.68	1.59-3.64
300 m	Ashy Prinia	40	2.01	5.7	**2.47**	21.33	1.61-3.78
	Common Iora	23	0.57	2.8	0.65	33.37	0.34-1.26
	Laughing Dove	27	0.85	5.8	1.35	34.64	0.68-2.65
	Plain Prinia	36	1.28	1.7	1.57	24.45	0.97- 2.55
	Purple Sunbird	18	1.66	42.4	**2.63**	15.05	1.94-3.57
	Red-vented Bulbul	53	1.55	8.3	**2.64**	21.8	1.72-4.07
	Rose-ringed Parakeet	18	0.22	70.3	0.7	24.67	0.42-1.16
Control	Ashy Prinia	32	1.45	6.5	1.69	15.47	1.24-2.31
	Common Iora	55	2	6.9	2.55	18.6	1.76-3.69
	Grey-breasted Prinia	35	1.72	21.9	2.19	12.21	1.71-2.79
	Indian Peafowl	29	0.16	27.6	0.19	12.62	0.15-0.24
	Laughing Dove	32	1.54	19.7	1.91	16.01	1.39-2.63
	Plain Prinia	38	1.65	1.1	1.6	25.13	0.97-2.65
	Purple Sunbird	43	3.61	46.2	**5.17**	11.01	4.16-6.43
	Red-vented Bulbul	63	3.53	46.1	**6.28**	8.62	5.29-7.44
	White-browed Bulbul	48	1.72	27.9	**3.57**	11.65	2.83-4.50

Nocturnal Studies

A total of 18 species were recorded (Table 9.17) of which Spotted Owlet and Indian Nightjar were nocturnal in habit and were frequently recorded for their activeness/ alert. During Phase-I, the frequency of sighting of Spotted Owlets and Indian Nightjar and their abundance were high when compared to Phase-II (Fig. 9.12, 9.13).

During phase-I survey, the occurrence of Spotted Owlets was more in the agricultural area, and in Phase-II, only two individual Spotted Owlets were sighted and only once in the agricultural habitat, i.e., there is a considerable decrease in the number of sightings and abundance during the phase-II and no sightings in other habitats (Figure 9.14, 9.15, 9.16).

Indian Nightjar a ground-nesting and nocturnal bird also had decent sightings during the Phase-I survey, this bird species was sighted mainly in agriculture, open scrub, and less in forest habitats. During Phase-II, there is a significant decrease in the abundance at agricultural habitat and in Open Scrub. But there is an increased sighting in the forest habitat (Fig. 9.17, 9.18, 9.19).

Table 9.17: List of Bird species recorded during Nocturnal survey

S. No	Order/ Family	Scientific Name	Species Name	Phase-I	Phase-II
I	**Anseriformes**				
1	Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck		*
II	**Caprimulgiformes**				
2	Caprimulgidae	*Caprimulgus asiaticus*	Indian Nightjar	*	*
III	**Charadriiformes**				
3	Rostratulidae	*Rostratula benghalensis*	Greater Painted Snipe		*
4	Turnicidae	*Turnix suscitator*	Barred Buttonquail	*	
5	Chadriidae	*Vanellus indicus*	Red-Wattled Lapwing	*	
6	Chadriidae	*Vanellus malabaricus*	Yellow-wattled Lapwing		*
IV	**Columbiformes**				
7	Columbidae	*Columba livia*	Blue Rock pigeon	*	
8	Columbidae	*Streptopelia decaoct*	Eurasian Collared-Dove	*	
V	**Cuculiformes**				
9	Cuculidae	*Hierococcyx varius*	Common Hawk Cuckoo	*	
VI	**Galliformes**				
10	Phasianidae	*Ortygornis pondicerianus*	Grey Francolin	*	
11	Phasianidae	*Pavo cristus*	Indian Peafowl		*
VII	**Passeriformes**				
12	Motacillidae	*Motacilla maderaspatensis*	White-browed Wagtail		*
13	Muscicapidae	*Copsychus fulicatus*	Indian Robin	*	*
VIII	**Pelecaniformes**				
14	Ardeidae	*Ardea cinerea*	Grey heron	*	
IX	**Strigiformes**				
15	Strigidae	*Bubo bengalensis*	Indian Eagle Owl	*	
16	Strigidae	*Athene brama*	Spotted Owlet	*	*
17	Strigidae	*Ketupa zeylonensis*	Brown Fish Owl		*
18	Strigidae	*Otus bakkamoena*	Indian Scops Owl		*

***= Occurrence / sighting of the species**

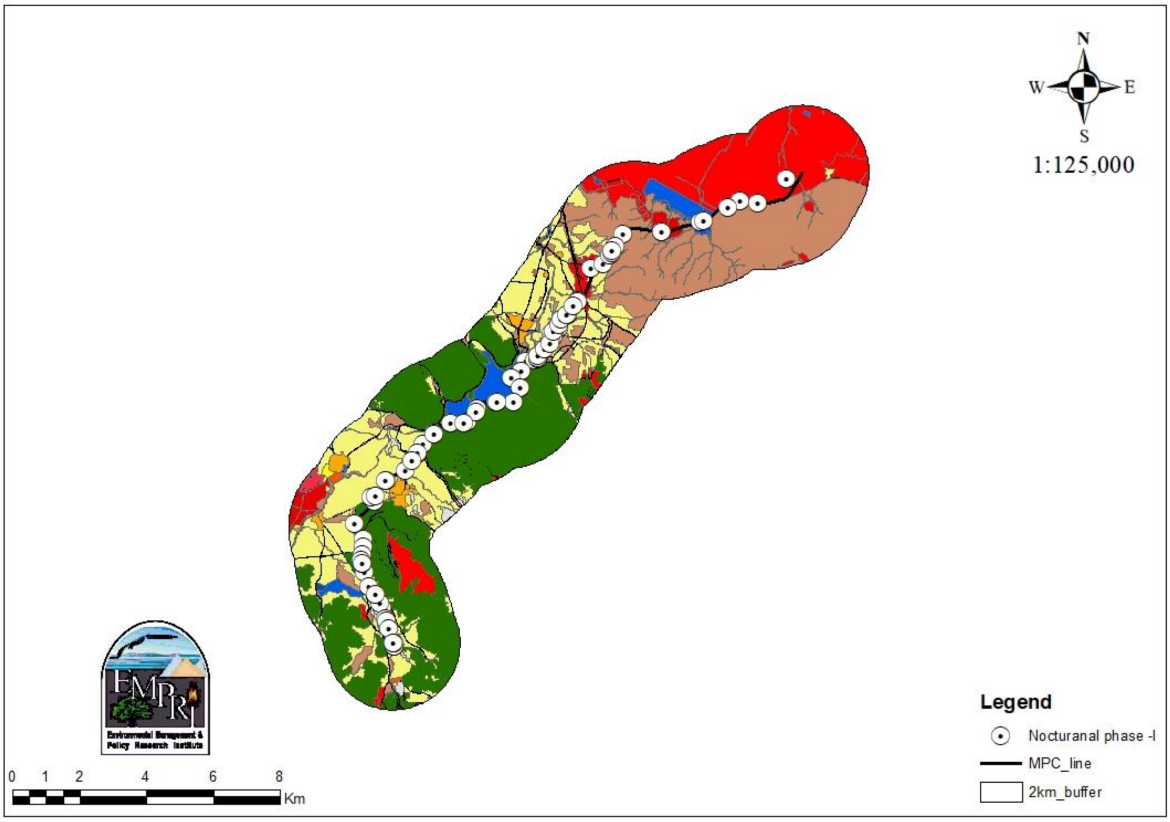


Figure 9.12: Bird sighting locations during Nocturnal survey Phase-I

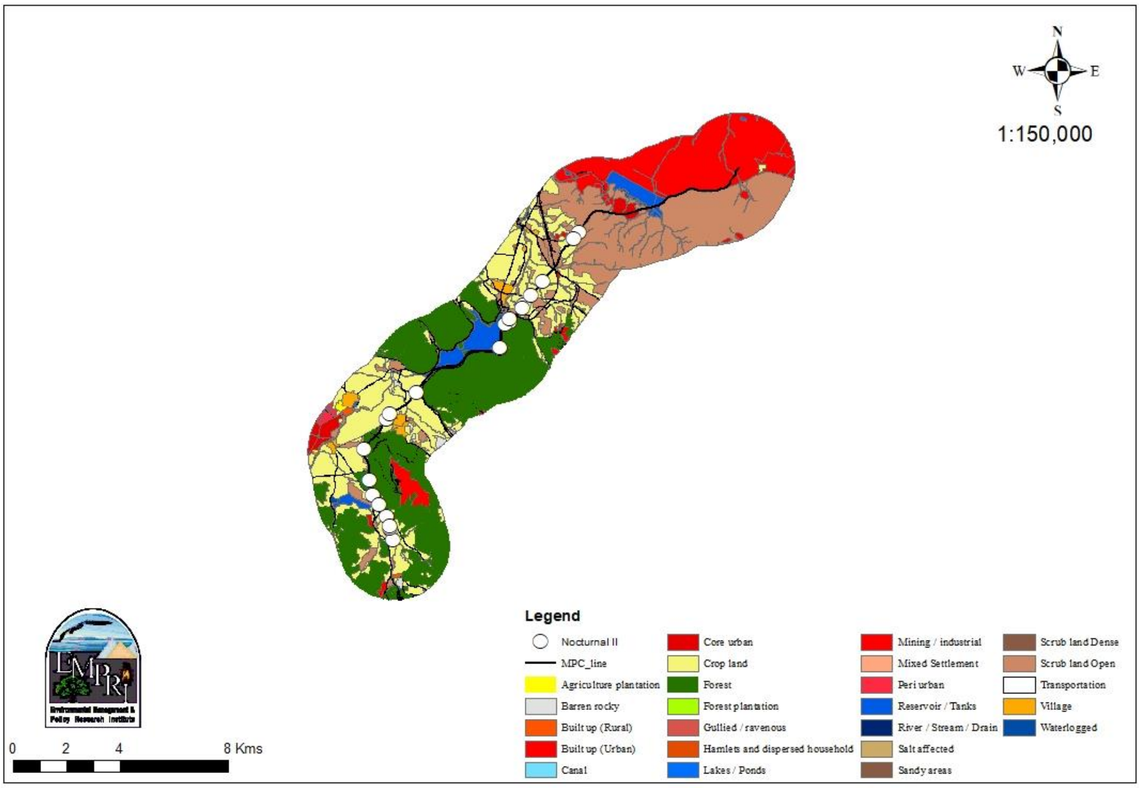


Figure 9.13: Bird sighting locations during Nocturnal survey Phase- II

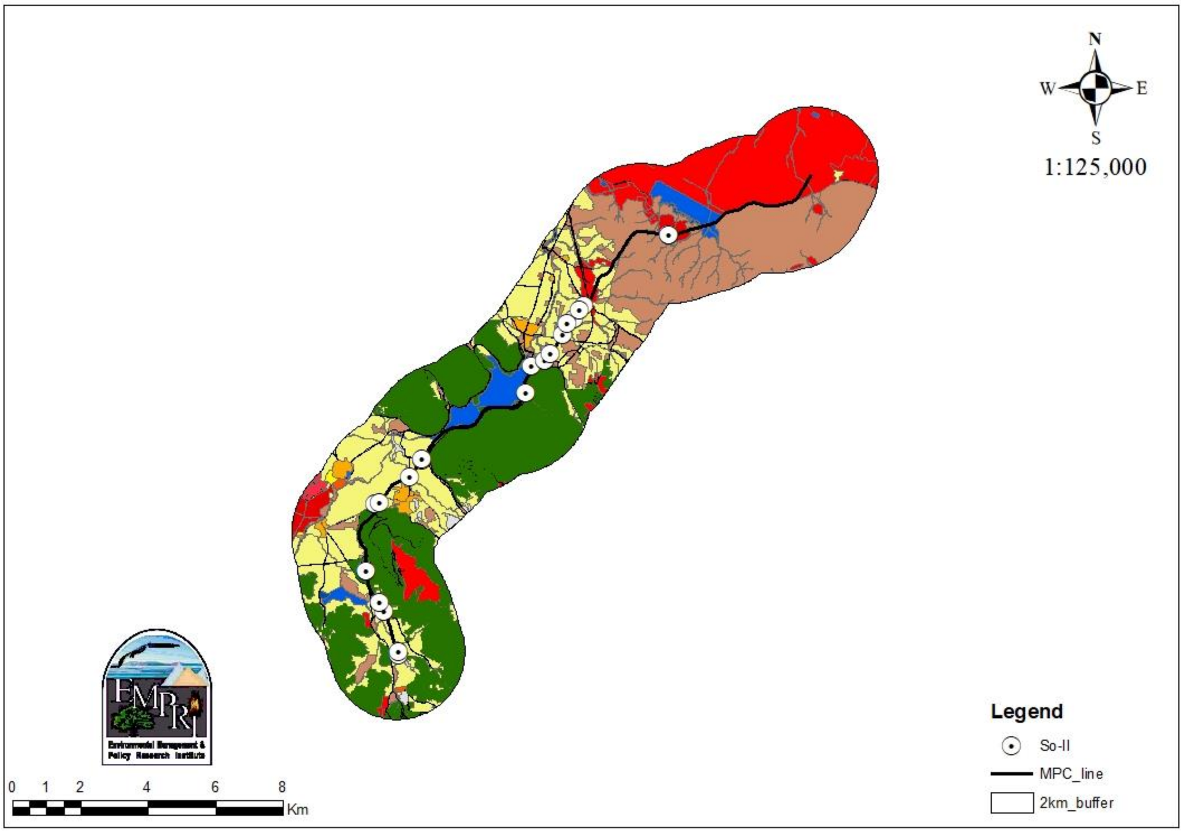


Figure 9.14: Distribution of Spotted Owlet during Phase-I

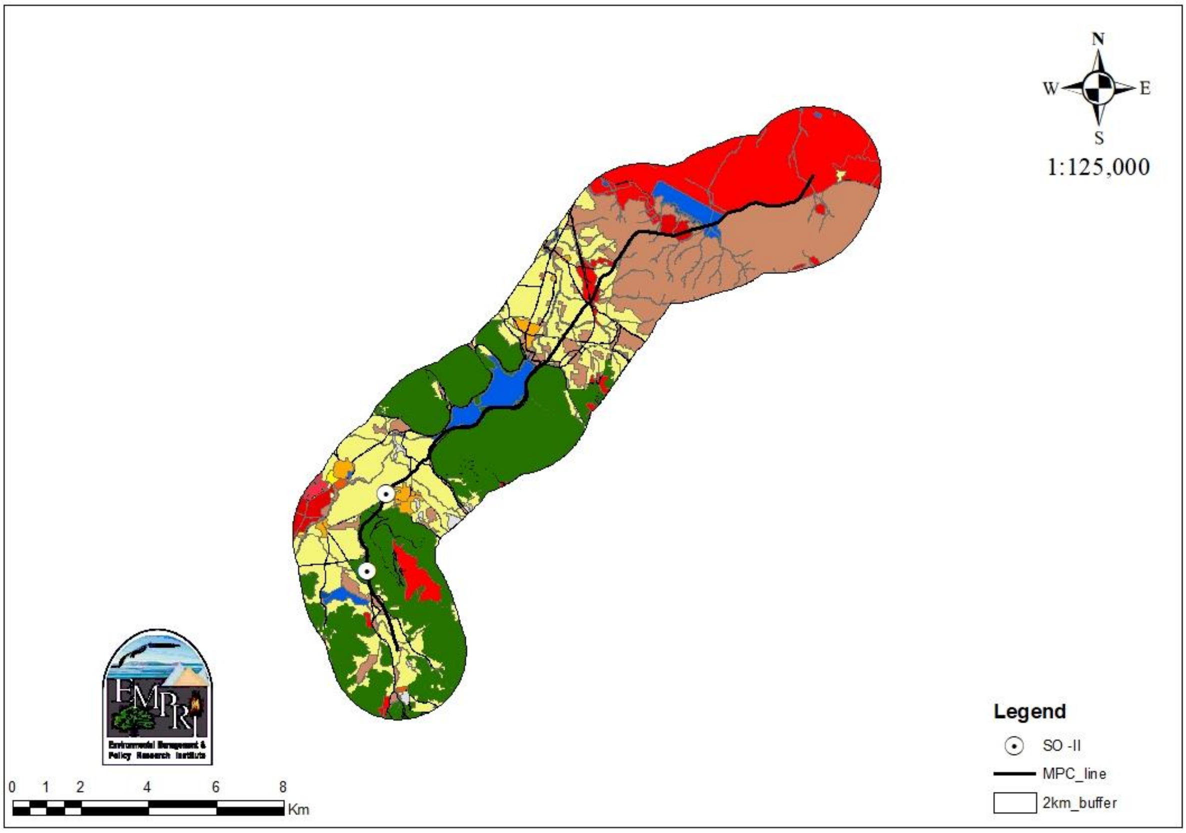


Figure 9.15: Distribution of Spotted Owlet during Phase-II

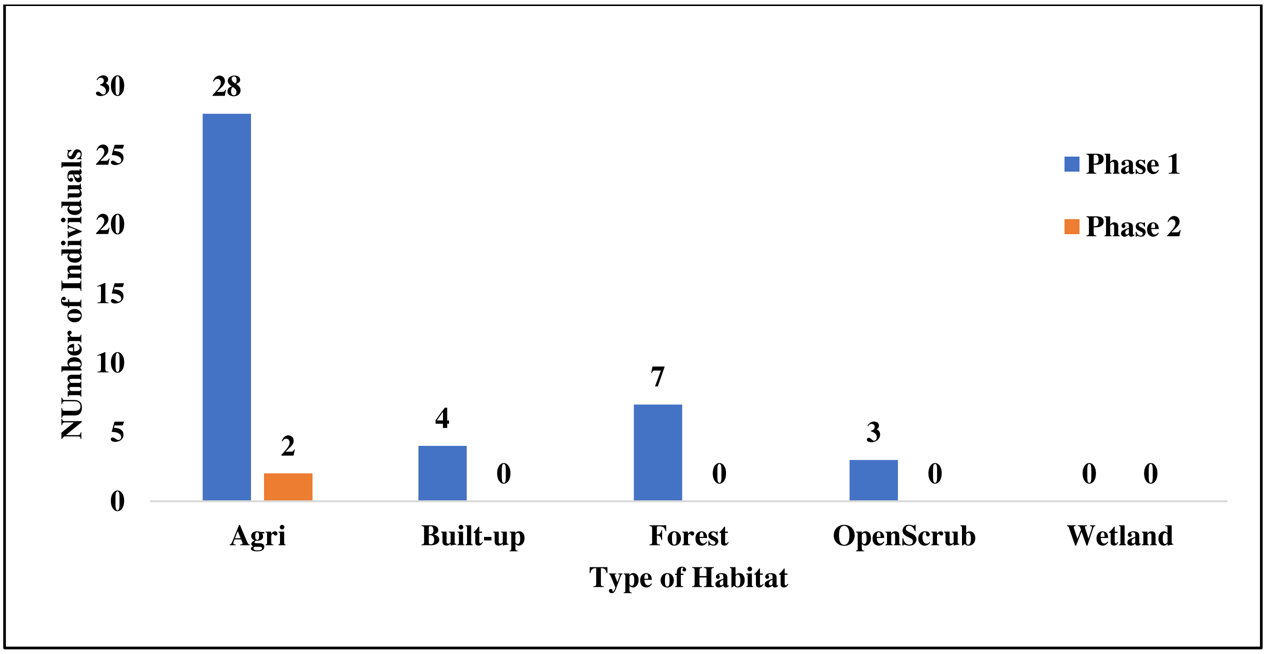


Figure 9.16: Occurrence of Spotted Owlet in different habitats along with MPC

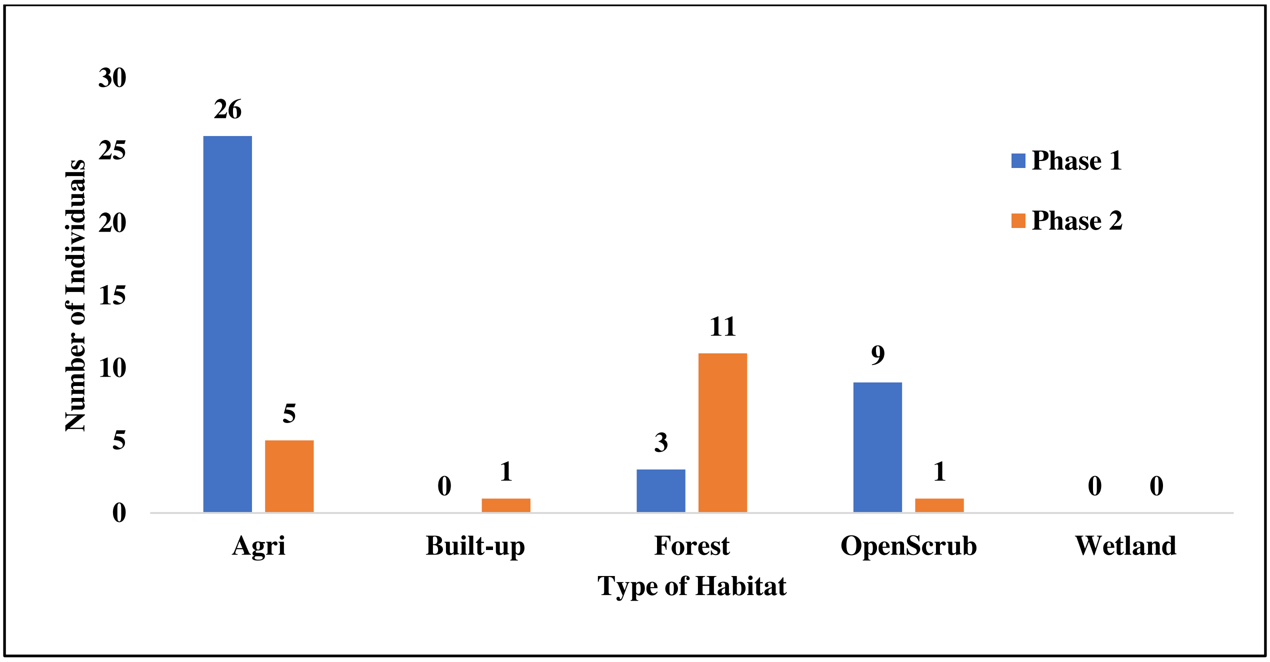


Figure 9.17: Occurrence of Indian Nightjar in different habitats along MPC

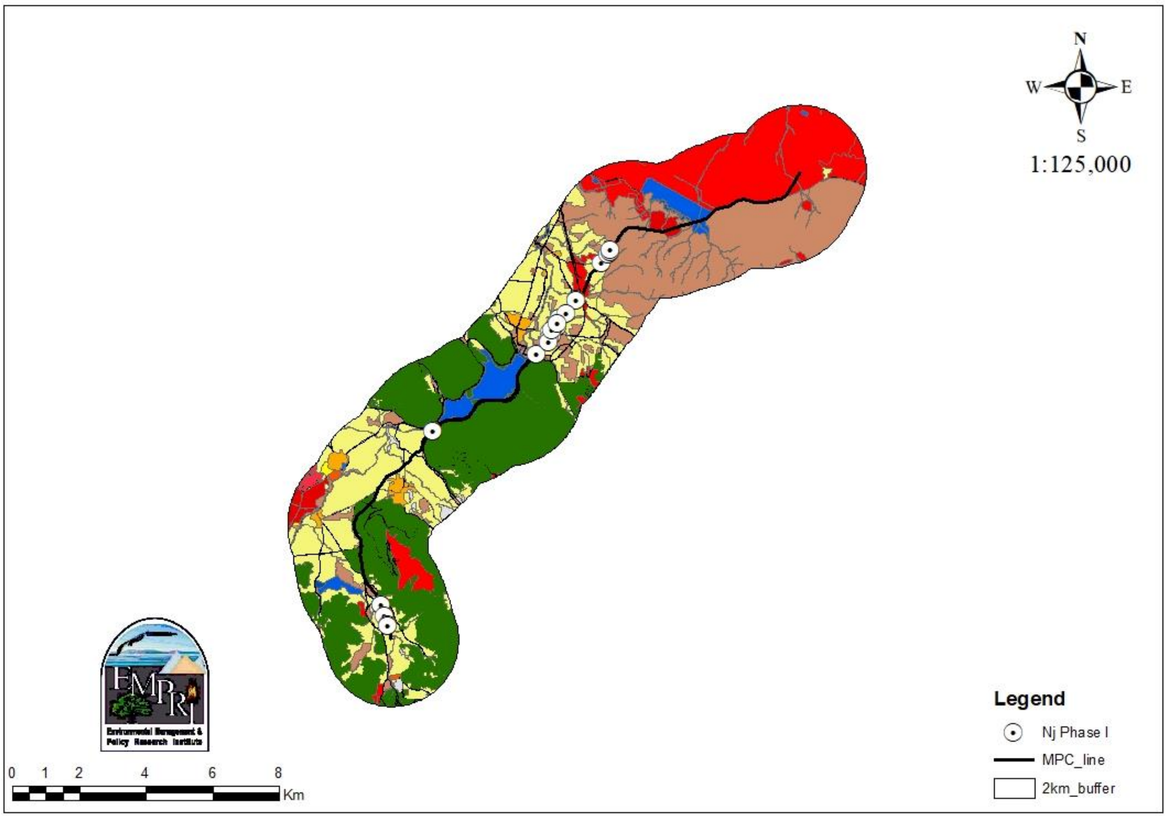


Figure 9.18: Distribution of Indian Nightjar during Phase-I

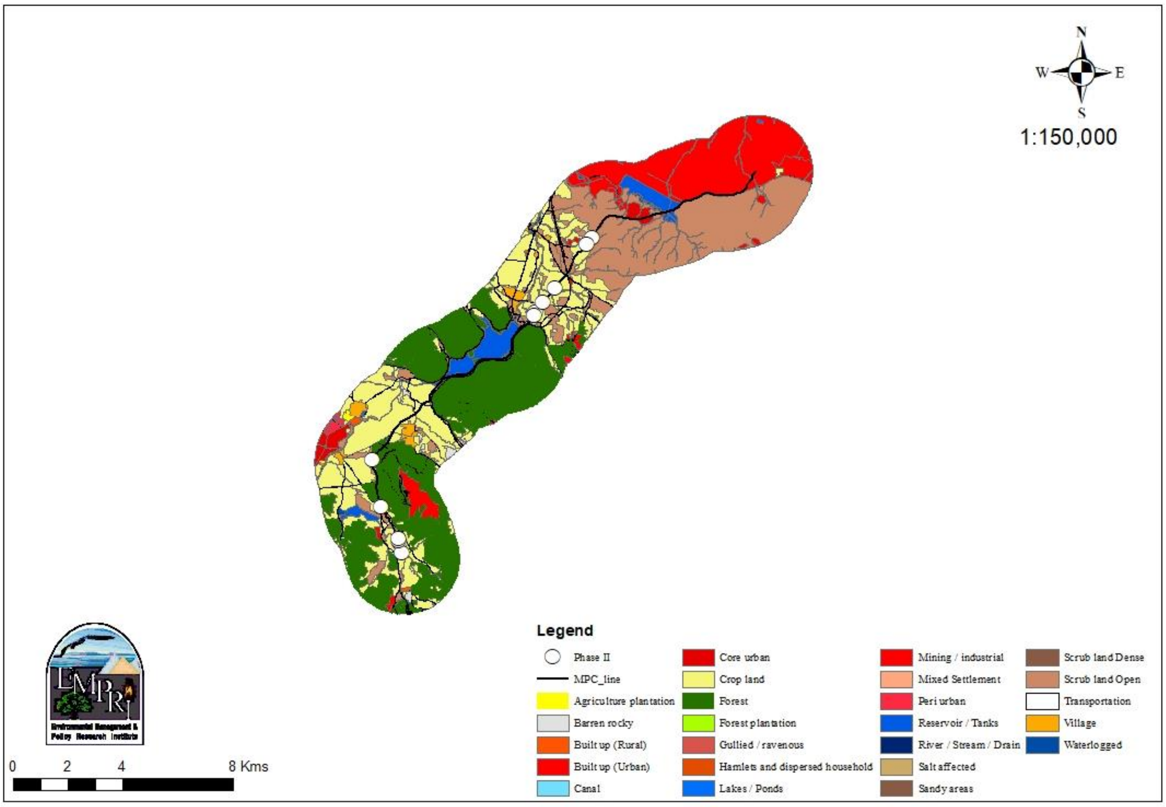


Figure 9.19: Distribution of Indian Nightjar during Phase-II

Discussion

Globally there are 36 orders in the class Aves. Passeriformes is the largest order of birds and among the most diverse orders of terrestrial vertebrates, representing 60% of birds. The systematic backbone and nomenclature as well as common names of birds used for this study are based on the 'International Ornithologists Union's World Bird List, with names updated as of 2020'. Donsker, and Rasmussen (2020). India is represented by 26 orders, out of which, Order Passeriformes dominates the avifauna.

The relationship between bird richness and their abundance against different distances from the MPC and also corresponding sound shows the contrasting pattern in different habitat types. However, the abundant species in each habitat type are also different. Further, the abundance of synanthropic bird species and their abundance along MPC make all the difference in the relationship. Thus, it is difficult to provide the rationale for the different types of relationships that emerged in the study.

The results of the nocturnal studies conducted in different phases of MPC working hours, shows a smaller number of detection of owls and nightjars when the belt run was increased to 20 hour that too extended hours in the night. Although, it appears that the increased sound in the night has driven away these birds, but due to the smaller number of Spatio-temporal replication resulted in a small sample size and effort with very less in number detection.

Despite a short study, the record of the occurrence of 125 avifaunal species in the region, of which 119 species are under Least Concerned and four (4) species are under Near threatened and two (2) species under Vulnerable status of IUCN categories, increase the biodiversity value of the area. Since the study was also confined to MPC and its buffer area of about a kilometer, the area of forest in the landscape is much more. The landscape further has the scope to record more avifaunal species concerning seasonal variations. Hence, further, it is suggested for the need to conduct long-term studies across different seasons to get a better understanding of birds. Further, the short-term study may not reveal the real impact of any changes in the habitat, thus, it would be appropriate to study the associated factors of noise produced by the Conveyor Belt, like Vibration, Light (Lumen), and types of Idlers used for a long time.

Chapter X: Diversity, Abundance, and Activity Pattern of Mammals

CHAPTER X
DIVERSITY, ABUNDANCE, AND ACTIVITY PATTERN OF MAMMALS

Introduction

Mammals are considered the dominant animals in terrestrial and non-terrestrial ecosystems. Indian mammals are the coalescence of Oriental, Palaearctic, and Ethiopian biogeographical realms, as India is located at the confluence of these three realms. A total of 5416 species of mammal belonging to 154 families and 29 orders have been reported from the globe (Wilson and Reeder 2005). Out of these, a total of 427 species are known from India, which is about 7. 8% of the global mammalian species, representing 48 families and 14 orders (Sharma et al. 2015). Due to various anthropogenic pressures, about 50% of mammalian fauna have shrunk in their distributional range.

Acoustic communication is crucial for the survival of many species as they use such signals to communicate, to select mating partners (Brumm et al. 2009), to inform others of their location, and to warn about the presence of a predator (Chan et al. 2010; Casar et al. 2012). Anthropogenic noise can mask the animal sounds by interfering with the detection of signals and thus, prevent effective communication (Foote et al. 2004; Bee and Swanson, 2007). Anthropogenic noise is a major stress for wildlife and many studies have reported how noise pollution affects the physiology and behavior of many animal species (Warren et al. 2006; Kight and Swaddle, 2011). Schaub et al. (2008) studied how and why foraging bats avoid noisy areas. Duarte et al. (2011) studied the impact of noise from mining on animals and reported that they select quiet areas to perform their daily activities. Chan et al. (2010) showed that animals can be distracted by noise and that the noise can increase the risk of predation. Noise can also cause physiological stress (Kight and Swaddle, 2011) and impact on ecological aspects of the lives of animals such as population distribution (Bejder et al. 2006), species abundance (Bayne et al. 2008), and diversity (Proppe et al. 2013). Various studies reported that animals use a range of vocal adjustments to minimize the immediate impact of noise on communication systems. These adjustments like frequency shifts, changes in amplitude, calling rate, number of notes, timing, and duration of calls (Slabbekoorn and Peet 2003; Brumm 2004; Sun and Narins 2005; Slabbekoorn and Boer-Visser 2006; Fuller et al. 2007; Parks et al. 2007; Nemeth and Brumm 2009; Hage et al. 2013). Continuous noise exposure may elicit stereotypical behaviors in primates (Patterson-Kane and Farnworth 2006), rodents (Anthony et al. 1959) and pandas (Powell et al. 2006).

Among mammals, bats are one of the perfect model organisms to study the impact of noise, as they depend on echolocation for prey detection. The anthropogenic noise associated with infrastructure could affect the habitat usage by bats (Barberet et al. 2010; Francis and Barber 2013; Bonsenet al. 2015). Bats hunt using echolocation and to detect prey based on the sound emitted from them, these sounds could be masked by anthropogenic noise. Such noise could compromise foraging efficiency thus reducing the activity in the noisy areas (Senzaki et al. 2016). Some laboratory experiments demonstrated that gleaning bats exposed to certain kinds of noise reduce the foraging efficiency and avoid hunting in noise (Siemers and Schaub 2011; Schaub et al. 2008). Identification of bat species is challenging as acoustic signals contain a lot of intra and inter-specific variation (Fenton and Bell 1981; Hughes et al. 2011; Walters et al. 2013). Echolocation is often shaped by ecological demands than phylogeny (Jones and Teeling 2006). In addition, there is no robust documentation, tools, and database supporting trouble-free identification (Brigham et al. 2004; Walters et al. 2013). Bat detectors help in detecting bats where they may go undetected in case of capturing (MacSwiney et al. 2008). Ultrasonic call detection also helps in avoiding problems and bias oriented with capturing or direct observation and a large sample size can be collected (Thomas 1989).

Technophony, which is the sound produced by human-made machinery, has become omnipresent in natural soundscapes (Barber et al. 2011), and despite evidence demonstrating negative impacts on animals, there is still a lack of official regulation of the noise produced by industrial and exploratory activities in terrestrial natural areas. In many countries, noise monitoring from industrial activities is required only concerning its impacts on human health. Consequently, the effects of noise on wildlife that are already known should drive efforts to develop environmental legislation to protect wildlife (Brown et al. 2013).

Review of literature

Owusu et al. (2017) assessed the impact of mining on medium to large mammals in the Western Region of Ghana, comparisons of effects between before and after the commencement of mines were being done and they found that there were drastic declines in mammalian species richness and abundance in the area to high noise levels from the mining and machinery used in the process, Habitat degradation and hunting also played a minor role along with the noise.

Rabin et al. (2006) studied the antipredation behavior in California ground squirrels (*Spermophilus beecheyi*) where squirrels live near wind turbines. The turbines generated average sound levels of 110 dB where the average ambient noise level was 76 dB, with turbines producing peak levels of 118 dB SPL. Playback of conspecific alarm calls was associated with increased vigilance and excessive cautionary behavior among animals at the turbine farm compared with those at control sites. The authors concluded that the wind turbine noise caused enhanced antipredator behavior to the alarm calls.

A study evaluating behavioral and hormonal responses of a captive female giant panda (*Ailuropoda melanoleuca*) found that stress level due to noise has a strong influence on the reproductive state. The animal demonstrated increases in agitation behaviors and urine cortisol levels on days with a louder average amplitude of ambient noise (60.9-84.2 dB), those outcomes were especially reported in the course of oestrus and lactation (Owen et al. 2004).

Duarte et al. (2011) studied the effects of man-made noise on spatial behavior of the black-tufted marmoset (*Callithrix penicillata*) and reported that the monkeys spent more time in the central and quiet areas of the park than in areas close to the park edges that were noisy due to road traffic, especially during weekdays. The animals were shown to adjust this spatial pattern during weekends when the roads were relatively quiet and the central areas were noisier due to the increased presence of park visitors. The authors argued that traffic noise led the animals to occupy non-optimal, less than desirable spatial patterns.

Weisenberger et al. (1996) reported elevated heart rate and sense organs being oriented by physiological changes indicating increased readiness to respond among Desert Ungulates due to 92.5-112.2 dB of noise produced by Jet Aircraft indicating a disturbance in their regular activities like foraging by false alarms.

The histological data of domestic cats born and raised in a quiet environment and cats raised in a noisy laboratory environment were compared. Noise-induced hearing threshold changes are related to the loss or damage of hair cells in the cochlea of cats exposed to noise. In every animal exposed to noise, the hair cells in at least one cochlear region appeared to be more disordered than the hair cells in the cochlea of cats that were not exposed to noise (Liberman and Beil 1979).

Munawar et al. (2020), Burrow baiting and bait stations were employed at the early flowering stages of the respective crops, and continued through three growth stages (germination, peg formation/flowering, and maturity). The treatment efficacy of the trials was assessed through counts of active rodent burrows before and after treatments at the three growth stages of these crops. The results indicated variable degrees of reduction in burrow activities following the three bait applications.

Krohn et al. (2003) conducted studies using rats, reveals that some sounds have been shown to induce an increase in blood pressure. After a long-term sound exposure, hypertension persists weeks after the exposure has been terminated, in the same way as it is observed in rats exposed to grid floor housing or other stressors. Sound exposure to the mother within a narrow time window during pregnancy may result in off-spring being malformed at birth. In other cases, sound exposure of the pregnant female may have physiological or behavioral consequences for the offspring later in life.

The effects of sound on animal physiology and behavior depend not only on intensity (dB), its frequency, which is measured in hertz (Hz), and its duration and pattern (including vibration potential), but also on the hearing ability of the animal species and strain, the age and physiological state of the animal at the time of exposure, to what sounds the animal has been exposed to during its lifetime (noise exposure history of the animal) and to the predictability of the acoustic stimulus (Burn 2008).

Methods and Analysis

Methodology

The study was conducted along the 24 Km stretch of the MPC from June 2021-August 2021. The baseline data for the 12-hour operation (Phase 1) were collected between June 28th to August 12th, 2021. The data for 20-hour operations (Phase 2) were collected between August 13th and August 31st, 2021, during the trial run of the MPC.To determine the presence of terrestrial small and large mammals, we followed – Belt Transect, Line Transect, and Camera Trapping method, along with Opportunistic surveys. The field techniques followed to quantify different mammals are provided in Table 10.1a.

Table 10.1a. Different field techniques adopted to conduct study on mammals

Sl. No.	**Method**	**Species of target**	**Sampling**
1	Camera Trapping	Photo capturing of terrestrial mammals	Sampled on 24 hours cycle along MPC and Control site (during Phase-I, Phase-II)
2	Line Transect	Direct sightings of terrestrial mammals, and arboreal mammals	Sampled along MPC and Control site (during Phase-I)
3	Belt Transect	Sign survey of different mammals	Sampled along MPC and Control site (during Phase-I)
4	Records from the Forest Department	Data on human-wildlife conflict	Records from the year 2013-14 to 2021
5	Burrow Count Method	Secondary evidence of presence of rodents	Sampled along MPC and Control site (during Phase-I)
6	Sherman Trap	To capture the rodents	Sampled along MPC and Control site (during Phase-II)
7	Audiomoth and Echo Meter	Acoustic Monitoring of bats	Sampled along MPC (during Phase-I and Phase-II)
8	Visual count	Counting of bats in the night	Sampled along MPC (during Phase-I and Phase-II)

Camera trapping: The study design for camera trapping is depicted in Fig. 10.1. A total of 51 passive infrared motion-sensor camera-traps were used for sampling (Cuddeback and KeepGuard), which remained continuously active during the period of study. A total of 29 camera traps were deployed all along the MPC and 19 traps were deployed at the control sites (Fig. 10.2a, 10.2b). Among the 29 traps, 14 were deployed in the Thorn Scrub Forest areas, 7 in the Open Scrub Land region, 6 in the Agricultural land and 2 in the Built-up area. The mean distance between the Camera Trap points and the MPC stretch was about 57.5m and the mean noise level at the trap points was about 59.2db (Fig. 10.3a and 10.3b). The camera trapping along the MPC was done during 12 h and 20 h of belt run. In the second phase, during the 20 h of belt run, 19 camera traps were installed along the MPC stretch, out of which 8 were deployed in the Thorn Scrub Forest areas, 6 traps in the Open Scrub Land region, 3 in Agricultural land, and 2 in the Built-up area. A total of 22 Camera traps were deployed at the control sites, majorly in the Thorn Scrub Forest and Open Scrub Land region. The mean distance between the camera trap points in control sites and the MPC stretch was about 431 m and the mean noise level at the trap points was about 46.6 db (Fig. 10.3a and 10.3b).

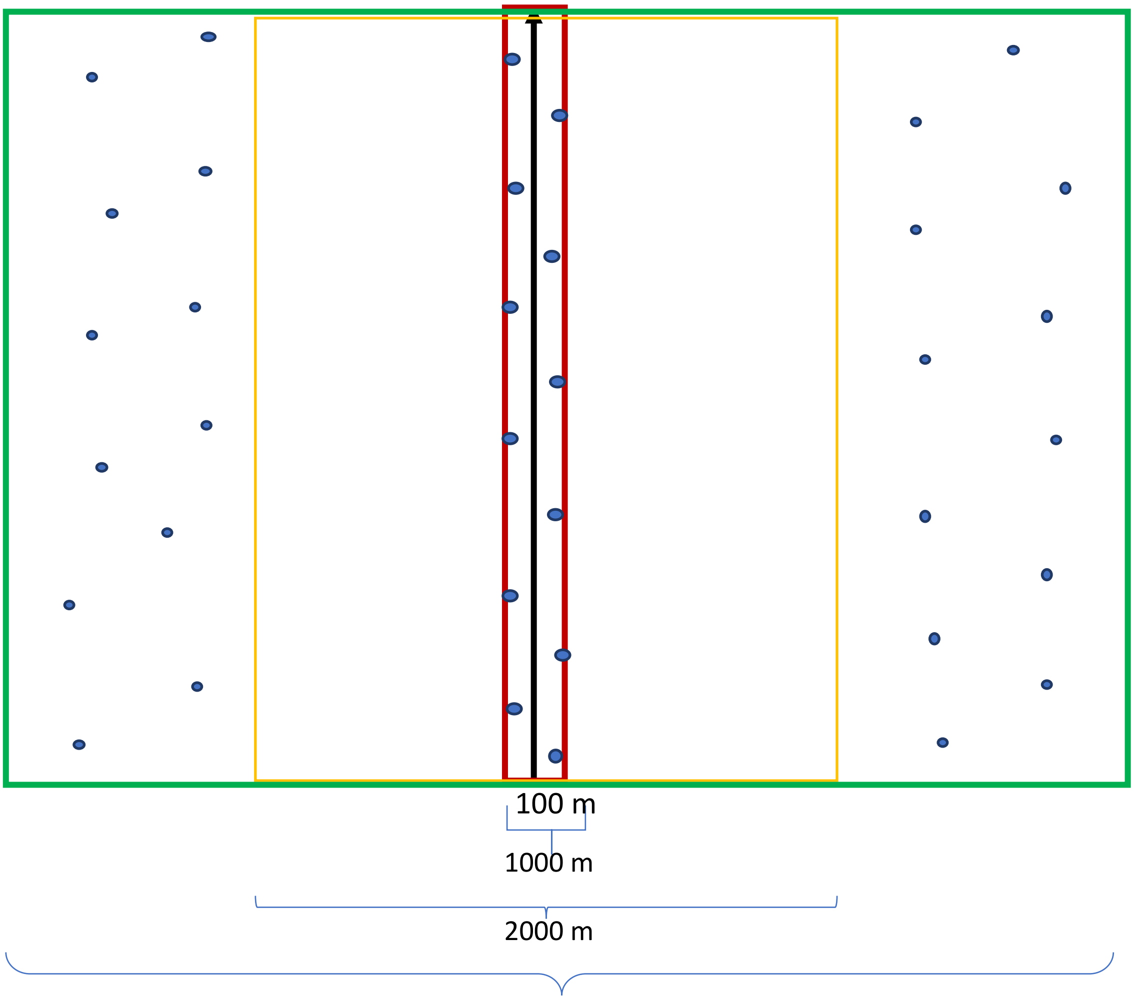


Figure10.1. Design for the camera trapping

At the select point location, the search was made for the high activity areas or animal paths to deploy the camera trap. In that location, the suitable tree was identified and the camera trap was fixed at the height of 60 cm from the ground (to capture small mammals). The camera trap was set for three snaps and 10 sec-videos for each trigger. Each camera-trap trigger captured a set of three pictures with the date and time registered. The traps were regularly monitored and the batteries were checked at regular intervals. The trap photographs were downloaded every 5th day and saved with the CameraID, Trap location, and the date. The amount of recording per trap varied because of malfunctioning and theft of some of the camera traps. The trapping efforts per location ranged from 18 camera trap days to 47 days, totaling 1711 camera-trap days combining all the sites.

Line transect: The line transects were established along the MPC (n = 7) and also in the control site (n = 9). Along MPC, a two-kilometer straight line was selected alternate side of the belt, while the transect length in the control site was the one-kilometer length (Fig. 10.2d and 10.2e). Each selected line was walked between 06:00 h and 09:00 h, and 16:00 h and 18:00 h. The walk was made at the slow speed of 1 km/ hour. The geocoordinates of the start and endpoint of the transect were recorded. The bearing of the transect was recorded. The time of the sighting of the animal, species name, number of individuals, angle of the species to the transect line (animal bearing) and animal-to-observer distance was recorded. The angle was recorded using a designed compass and distance has to be recorded using a range finder. The total effort of the transect walk was 37 km.

Belt transect: The belt transects were established on the fixed-line - belt transects of 500 m for every one kilometer on the alternative side of the belt were considered and sampling was done on 2.5+2.5 m of strips on either side of the MPC (Fig. 10.2c). A total of 15 belt transects were laid along the MPC and 9 belt transects at the control site. The belt transect was walked in a day. All along the belt transect, the search was made to find the animal signs like a footprint, droppings, and other markings. The geocoordinates of each detection i.e., signs were recorded using handheld GPS.

Opportunistic records: All the field efforts apart from the transect walks were kept in record. During these, all the sightings of mammals were recorded with details of species, geocoordinates, number of individuals and status of the animal. During the study period, a total of about 320 km of the opportunistic walk was made in the study area.

Records from the Forest Department: We collected the data on Human-Wildlife Conflict Incidents from the Forest Department to understand if there were any emerging patterns in the study area. The data was collected from the year 2013-14 to the present, which comprised of the information on species, year of conflict, location of conflict, and the type of conflict.

Burrow count method: The burrow count method was followed to search and record the burrows near the bunds and under the bushes, present in that habitat up to a distance of 200 m perpendicular to the MPC. The same procedure was followed in all the habitats.

Sherman trap: Twenty Sherman traps were deployed to capture rodents in a grid format at a distance of 10 m from each other in a select site. Two sites along the MPC and one site in the control site. The trapped rodents were recorded, marked, photographed, and released. (Fig. 10.2g, 10.2h, and 10.2i)

Ultrasonic recorders: Ultrasonic recorders were used to record the ultrasonic sound emitting from the rollers/idlers of the conveyor belt. The recordings were carried out during the regular operational time i.e., 06:00 hrs to 18:00 hrs at different sections and height. The recording of ultrasonic sound emitting from the MPC with metal rollers/idlers as well as HDPE rollers/idlers were recorded (Bortnowski et al. 2020). Calls were recorded at the transfer points to detect and record any ultrasonic sound emitting from the electric motors driving the conveyor belts.

Table 10.1b. Effort of all the methods to assess the mammals using different field techniques

	Methods	**Efforts**		
		12 h	**20 h**	**Control Site**
Terrestrial mammals	Camera Trap Nights	889	361	461
	Opportunistic survey	Total distance covered = 320 Km		
	Belt Transect	Total area covered = 9.75 Ha		
	Line Transect	Total distance covered = 37 Km		
Rodents	Burrow count	Total area covered = 0.6 Ha		
	Sherman Trap	300 trap days		
Bats	**Ultrasonic Recorders**	**Number of calls recorded**		
	Echo Meter Touch 2 Pro	14,601		-
	EM3+	9,440		-
	Song Meter 4 Mini Bat	9,880		-
	Audiomoth 1.2	44,947		-

Audiomoth (Passive Recording Stations): Audiomoth1.2.0 (Table 10.1b, c)an open-source and affordable ultrasonic recorders (https://www.openacousticdevices.info/audiomoth) were deployed (Hill et al. 2018) across all the habitats and at 15 sites (Fig. 10.2f) close to the conveyor system to detect and record ultrasonic bat calls. The calls were recorded overnight from 06:00 pm to 06:00 am. The ultrasonic calls were recorded from free-flying bats within 10-25 ft distance from the Audiomoths depending on the ultrasound frequency of bats. The Audiomoths were deployed between 3 ft to 20 ft height depending on feasibility and potential species in the habitat and their foraging niches (Strata). The recorders were deployed at an average of 1.5 Km distance from each other.

Echo meter on the line transect: The ultrasonic calls of free-flying bats were recorded along the MPC (within 50 meters except for places covered in waterbody) in each habitat using handheld ultrasonic recorders (Table 10.1b, c) like Echo Meter Touch 2 Pro with

Android-phone, EM3+ and Song Meter 4 Mini Bat all developed by Wildlife Acoustics (https://www.wildlifeacoustics.com/) (Unger 2019).

Visual counting: We also carried out physical overnight observations to track any movement of bats in each of the habitats. We searched for signs (guano droppings) of any permanent and temporary roosts, like caves, abandoned buildings, culverts, bridges, and water pipes under railway lines/roads.

Table 10.1c. List of equipment used to conduct the study

Devices	Nos.	Purpose
Camera Trap (CuddeBack and KeepGuard)	51	Continuous sampling for obtaining photocaptures of species
Garmin eTrex 20x GPS	8	To record Geo-coordinates
Range Finder (Nikon Forestry)	2	To measure distance of animal from observer
Sherman Trap	20	To sample Rodents in the study area
Ultrasonic Recorders		
Echo Meter Touch 2 Pro	3	Active recorder, Transect
EM3+	1	Active recorder, Transect
Song Meter 4 Mini Bat	1	Active/ Passive recorder
Audiomoth 1.2	7	Passive recorder

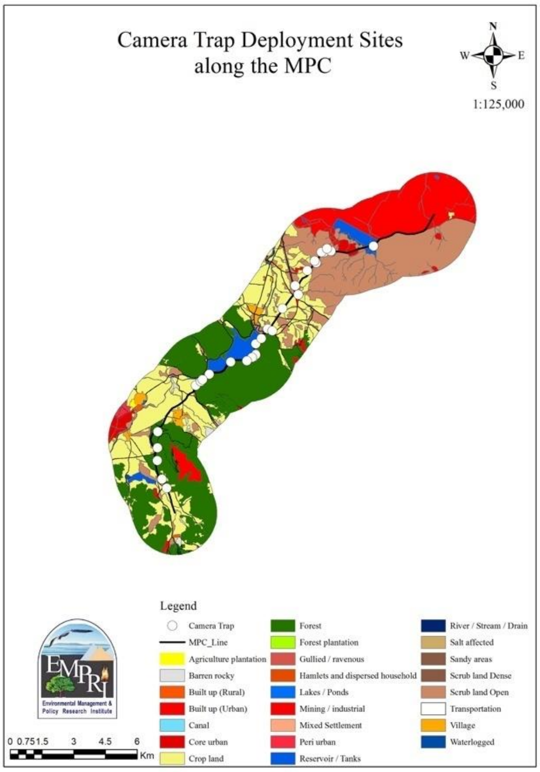


Figure 10.2a. Camera Trap deployment sites along MPC

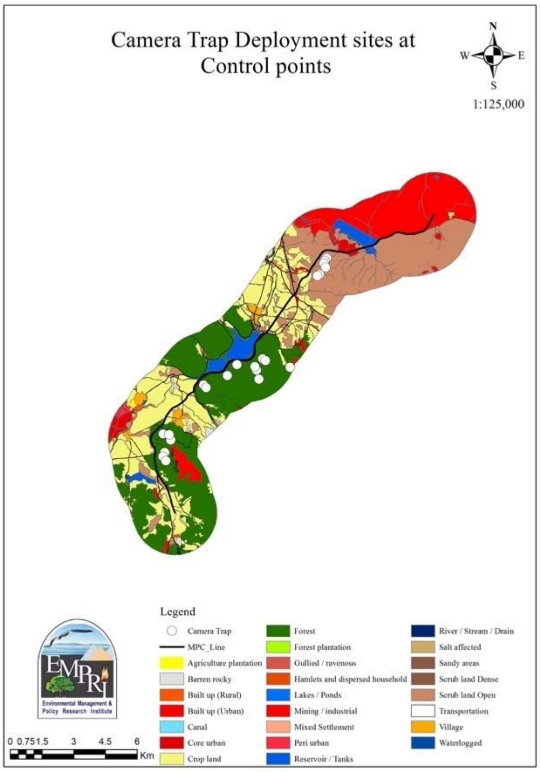


Figure 10.2b. Camera Trap deployment sites at Control Points

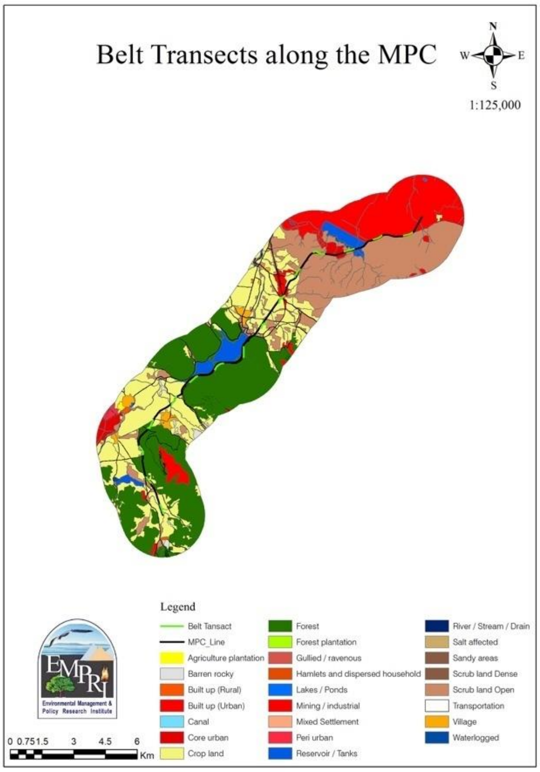


Figure10.2c. Belt Transects along MPC

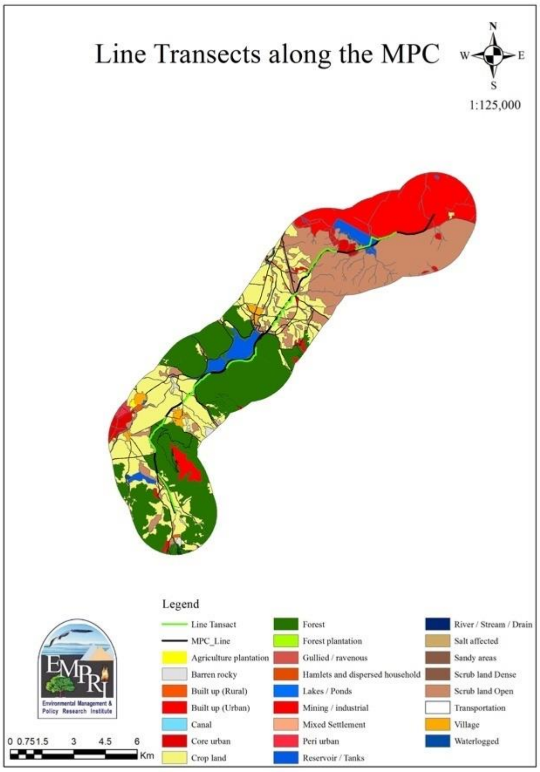


Figure10.2d. Line Transects along MPC

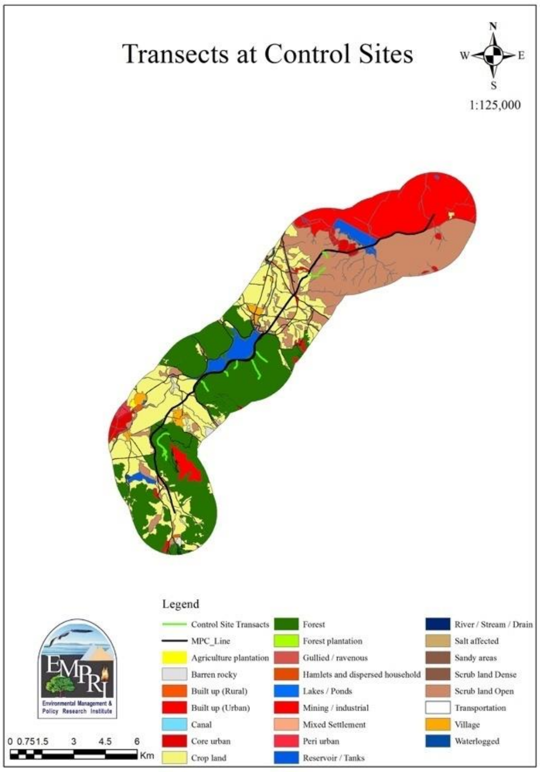


Figure10.2e. Transects in Control Sites

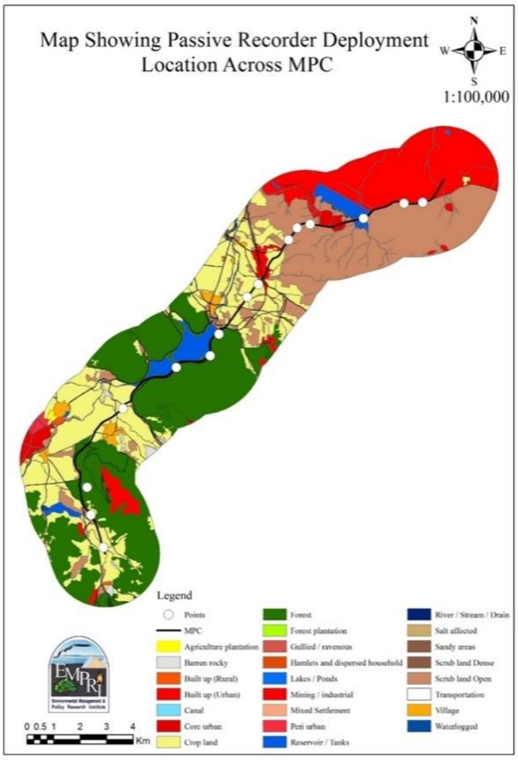


Figure10.2f. Passive Recorders Deployment sites along the MPC

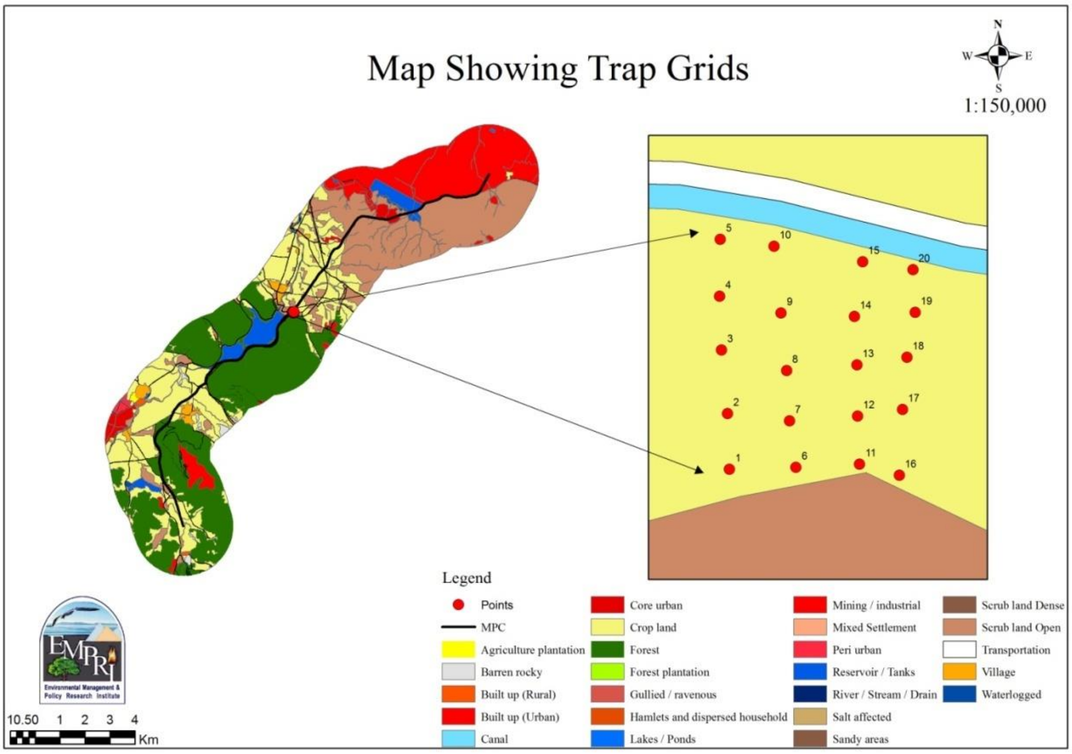


Figure10.2g. Rodent Trap Grids in agricultural land near MPC area

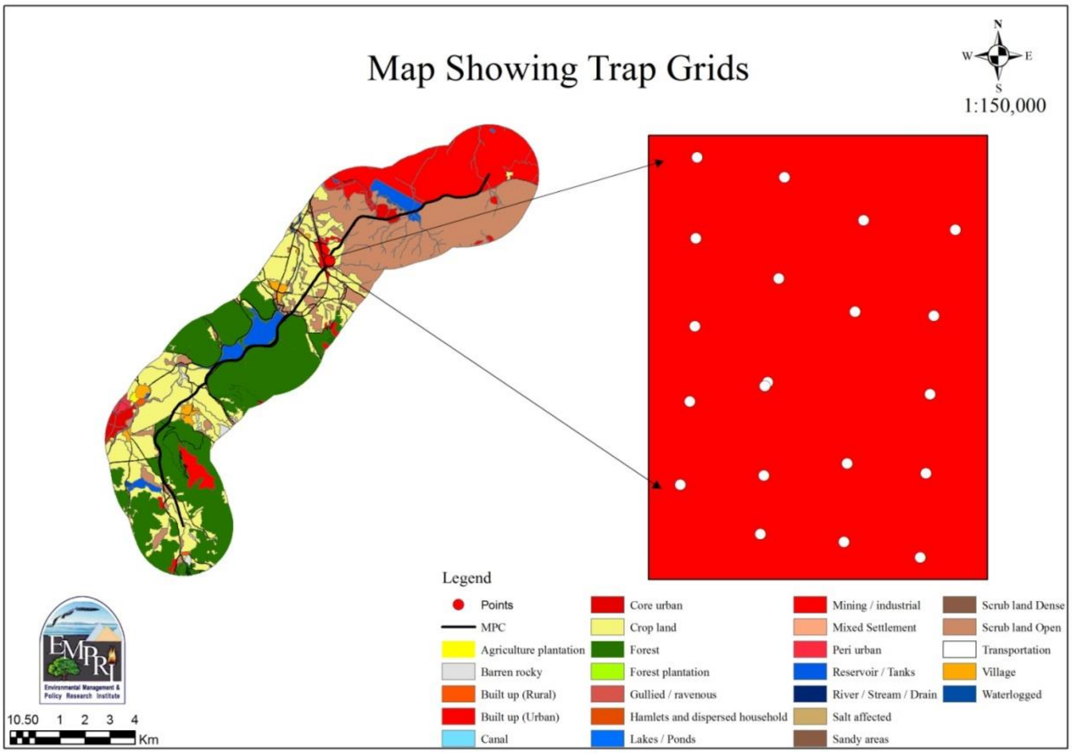


Figure 10.2h. Rodent Trap Grids in built-up near MPC area

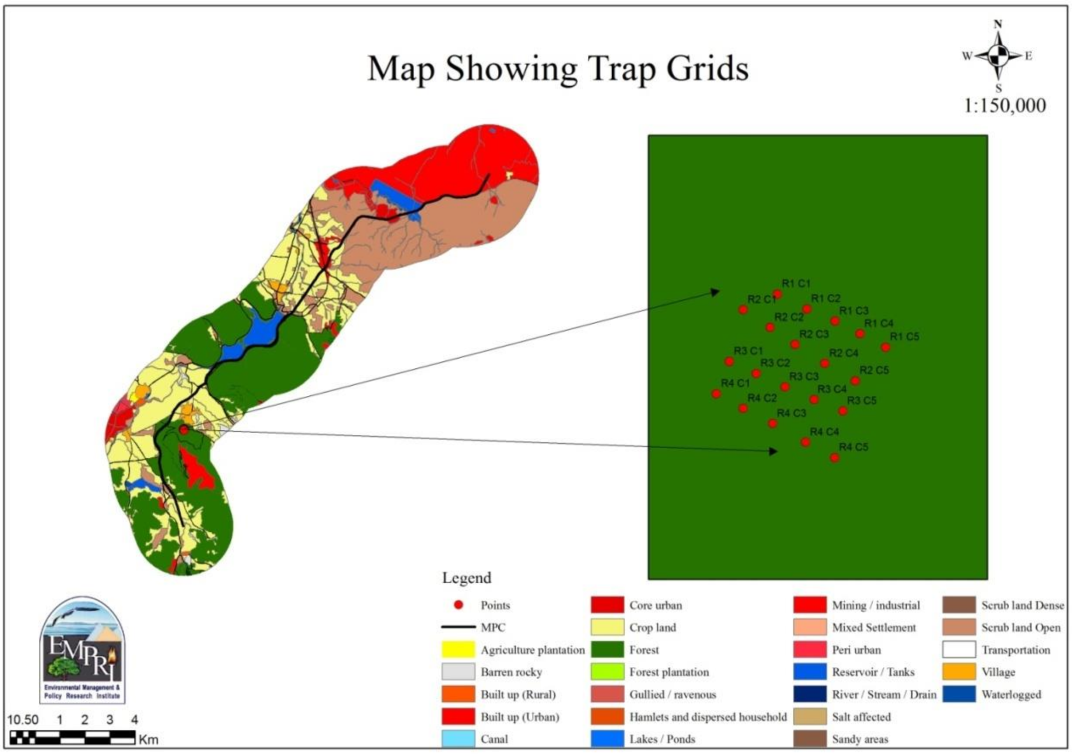


Figure10.2i. Rodent Trap Grids in Control site

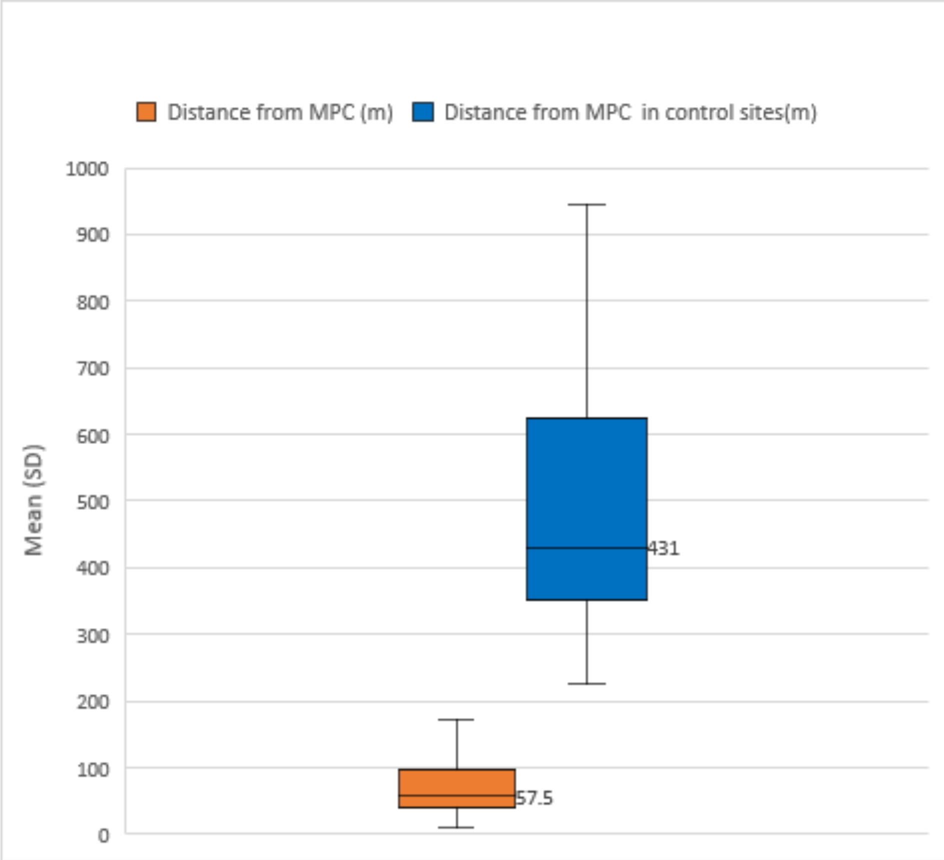


Figure10.3a. Distance (mean+SD) of camera traps from MPC

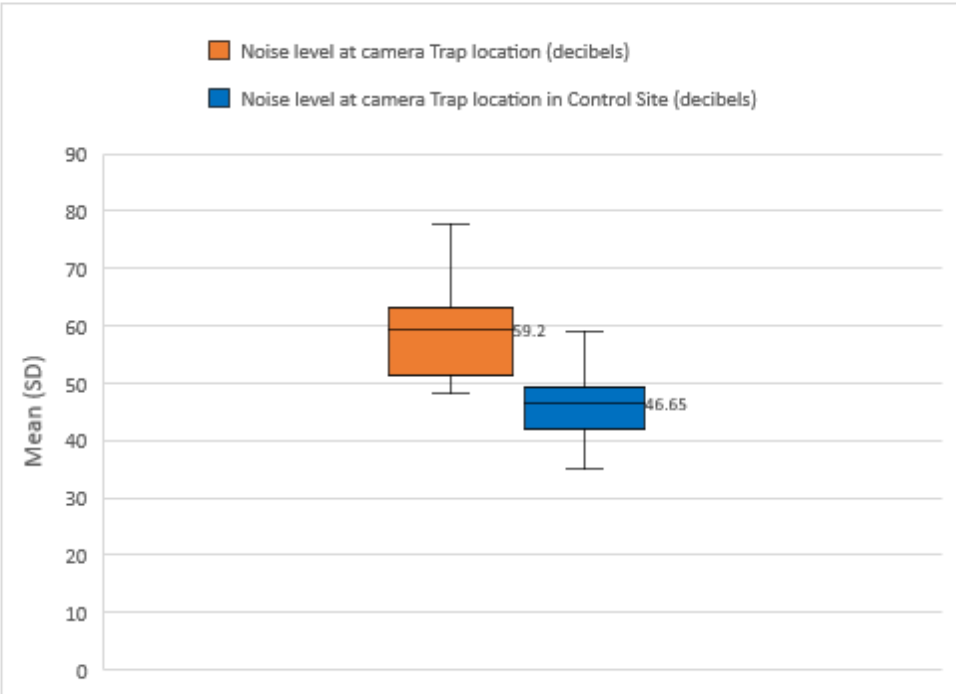


Figure10.3b. Noise Level (MPC and control) at camera trap locations

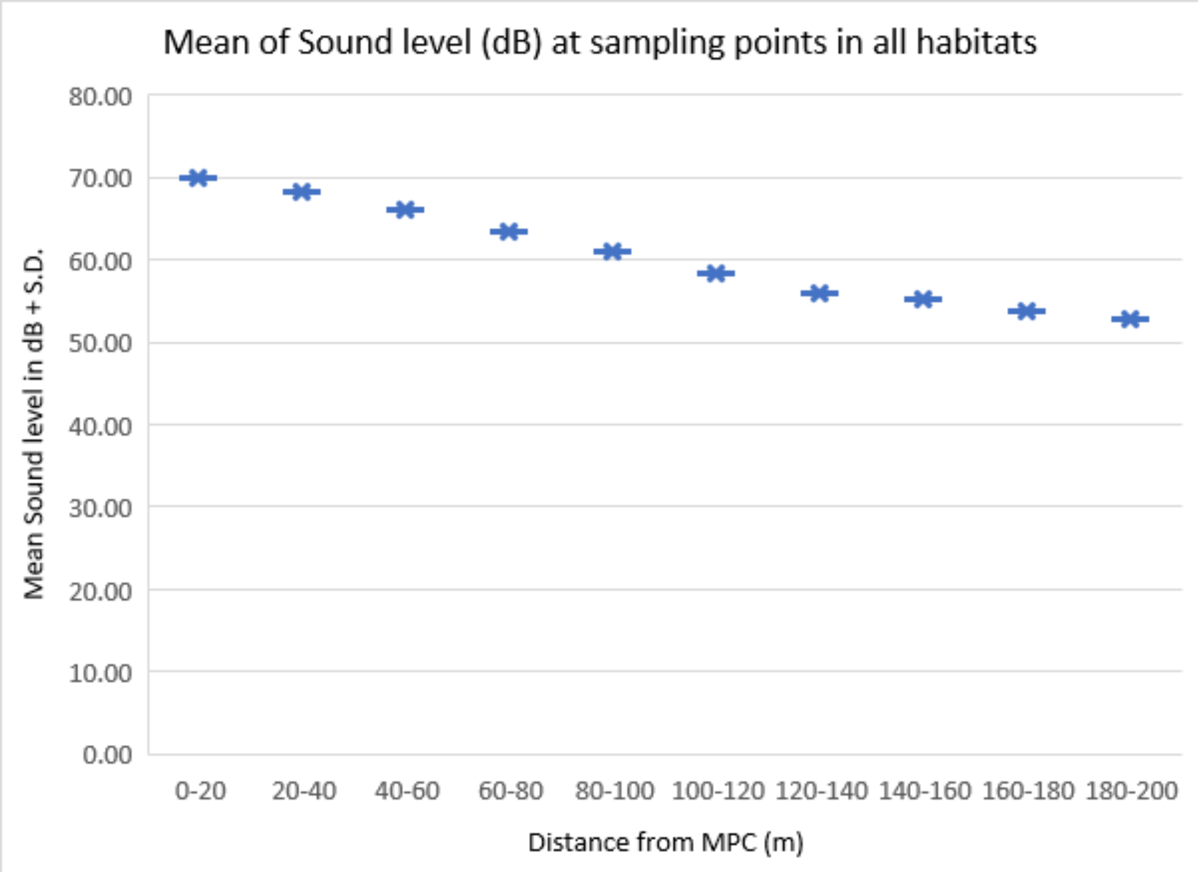


Figure10.3c. Noise Level (in dB) at Burrow sampling points in all habitats

Analysis

Camera Trap data analysis: The camera trap photographs were downloaded on every 5th day and the Images were saved with the CameraID and the date. Subsequently, the capture details were entered including the Camera ID, Date, Camera Trap Geo-coordinates, Species captured, and the Time of capture, later this information was used to plot the Activity graphs and Activity Overlap curves of the species.

Checklist of mammals: A checklist of mammals that were recorded from all possible methods in the study area was prepared. The checklist includes the common name of the species, its scientific name, the order it belongs to, IUCN status (International Union for Conservation of Nature and Natural Resources), the schedule under Indian Wildlife Protection Act, 1972 (IWLPA), the habitat type where the species was detected or sighted from and the source of information or detection. (Table 10.3)

Relative Abundance Index (RAI): Relative Abundance Indices i.e., the number of trap days required to capture a single photo of a particular species were calculated, based on the photo capture rates of terrestrial large and small mammalian species (Carbone et al. 2001). The RAI calculated for the terrestrial small and large mammals, derived from the Camera Trap survey, during both 12 and 20 hours of belt run and also at the control sites are in Table 10.7. Only independent pictures of a particular species were counted as valid to estimate RAI. Each photo was identified to a species and was rated as "dependant" or "independent capture events" (O'Brien et al. 2003, where independent capture events are defined as (a) consecutive photographs of different individuals of the same or different species, (b) consecutive photographs of individuals of the same species taken more than 0.5 h apart and (c) non-consecutive photos of individuals of the same species). Relative abundance values from phase one (12 hours belt run) were compared with phase two (20 hours belt run) and the values obtained from control sites. RAI is negatively correlated to species abundance (Carbone et al. 2001; O'Brien et al. 2003) and is a useful tool to compare relative abundances of species.

Diversity Indices Analysis: Shannon and Simpson diversity indices are usually measured for the number of individuals in ecological studies, but in our study, for terrestrial mammals, we have considered the number of captures, for rodents we have taken the number of individuals, and for bats, the number of call records was considered because taking individual counts are not recommended with acoustic study for bats. The species richness indices were calculated using the Software PAST 4.0.

Estimation of activity pattern of mammals: The time of bat call recordings and the time of capture of mammals in the camera traps were used for each species to investigate the activity pattern. The activity patterns for each species at respective habitat for both phases (12 h and 20h of operations of MPC) of the study were analyzed using an overlap package (Mukherjee et al. 2019) in RStudio Version 1.4.1717. The Overlap coefficient (Δ) is the area under the curve formed by considering two density functions at the same period (Schmid and Schmidt 2006).

Acoustic analysis: The ultrasonic calls recorded were analyzed both from passive and active recorders to identify the bat species. The acoustic call libraries published across various literature were referred to identify the species. About 2-3 nights some Audiomoths had few recordings only and had stopped recording after few hours or had very few intermittent recordings (Britzke et al. 2013). Such recordings were ignored from the data set to avoid biases. The Audiomoths were able to detect, and record calls for only 8 of the 12 Microchiroptera in the region (Adams et al. 2012).

The ultrasonic calls recorded were processed and analyzed using Bat Explorer 2.1.9 software (https://www.batlogger.com/en/news/20210726_batexplorer2.1/). The species of bats were identified based on the reference data from various literature (Raman and Hughes 2020; Raghuram et al. 2014; Deshpande and Kelkar 2015; Chakravarty et al. 2020; Wordley et al. 2014; Shah and Srinivasulu 2020). The following parameters Start frequency (Fstart), End frequency (Fend), Maximum frequency (Fmax), and Minimum frequency (Fmin) were determined using spectrograms, and frequency of Maximum energy (FmaxE) also referred to as Peak Frequency (kHz) was determined from determining the peak power in the power spectrum (FFT size 1024, Hanning window) (Colony 2014); to identify the species. The luminance of the spectrogram was increased to 0.50 for few calls to evaluate and interpret the spectrogram shape and to validate the species identified.

For each species 10 calls were selected from different locations and devices and those that had the highest signal-to-noise ratio. Mean values and standard deviations were calculated for each species and across all the calls analyzed. The GPS locations for respective species were exported from the software to determine the distribution across the MPC line.

There is no exhaustive call library for bats of India and the limited studies carried out so far across India indicate variations in call frequencies. The acoustic calls of many species of bats especially that of the Vespertilionidae family overlap and have variations, which make automated identification challenging (Adams 2013; Aldridge and Rautenbach 1987). As a result, relying on only acoustic analysis of identifying a species has its own limitations and the results could have room for errors (+/-5%) (Walters et al. 2013).

Results

Hanuman Langur, Golden Jackal, Indian Fox, Sloth Bear, Black-Naped Hare, Jungle Cat, and Rusty Spotted cat were opportunistically recorded. The signs such as droppings and tracks of Leopard, Sloth Bear, Indian Wild Pig, and Black-Naped Hare were also documented. Through Belt Transect survey, we recorded signs of species such as Sloth Bear (scat and pugmark), Indian Crested Porcupine(droppings), Indian Wild Pig (scat), Black-Naped Hare (pellets), Bonnet Macaque (droppings), and Hanuman Langur (droppings) (Table 10.2). Line Transects were walked to quantify the abundance of mammals, however, only one detection of Black-naped Hare was recorded, due to the poor encounter rate the density could not be estimated.

Checklist of mammals

The study revealed the presence of a total of 33 species of mammals (Table 10.3), out of which 10 belong to the order Carnivora, two belong to Artiodactyla, two belong to Primates, four belongs to Rodentia, one belongs to Lagomorpha, and 14 belongs to the order Chiroptera.

Table10.2. Animal Signs documented during the Opportunistic survey, Belt Transect and Line Transect walk

Species				Sloth bear	Bonnet Macaque	Hanuman Langur	Black Naped Hare	Indian Wild Pig	Indian Crested Porcupine	Golden Jackal	Indian Fox	Rusty Spotted Cat	Jungle Cat	Leopard
Belt Transect (Detection/Ha)	**AL**	S/Pl		0.1	0.1	-	-	-	-	-	-	-	-	-
		Pg		-	-	-	-	-	-	-	-	-	-	-
	TSF	S/Pl		0.21	-	0.21	0.51	0.21	0.21	-	-	-	-	-
		Pg		-	-	-	-	-	-	-	-	-	-	-
	OSL	S/Pl		-	-	-	0.82	-	-	-	-	-	-	-
		Pg		0.1	-	-	-	-	-	-	-	-	-	-
	BU	S/Pl		-	0.1	-	-	-	-	-	-	-	-	-
		Pg		-	-	-	-	-	-	-	-	-	-	-
Opportunistic Survey and Line Transect (Total number of Detection)	**AL**	LT		-	-	-	-	-	-	-	-	-	-	-
		OS	S/Pl	-	-	-	5	-	-	-	-	-	-	-
			Pg	-	-	-	-	-	-	-	-	-	-	-
			D	-	10	-	-	-	-	-	-	-	-	-
	TSF	LT		-	-	-	1	-	-	-	-	-	-	-
		OS	S/Pl	-	-	-	12	5	-	-	-	-	-	2
			Pg	-	-	-	-	-	-	-	-	-	-	-
			D	-	-	7	5	1	-	-	-	1	-	-
	OSL	LT		-	-	-	3	-	-	-	-	-	-	-
		OS	S/Pl	-	-	-	-	-	-	-	-	-	-	-
			Pg	-	-	-	-	-	-	-	-	-	-	-
			D	2	-	-	8	-	-	2	1	-	1	-
	BU	LT		-	2	2	-	-	-	-	-	-	-	-
		OS	S/Pl	-	-	-	-	-	-	-	-	-	-	-
			Pg	-	-	-	-	-	-	-	-	-	-	-
			D	-	-	-	-	-	-	-	-	-	-	-

Agricultural Land (AL) , Thorn Scrub Forest (TSF), Open Scrub Land (OSL), Built Up (BU); Scat (S),Pellet (Pl), Pugmark (Pg), Direct (D); Line Transect (LT), Opportunistic Survey (OS)

The camera trap study reported the presence of Sloth Bear *Melursus ursinus*, Leopard *Panthera pardus*, Four Horned Antelope *Tetracerus quadricornis*, Rusty Spotted Cat *Prionailurus rubiginosus,* which are under Schedule I of Indian Wildlife Protection Act, 1972 and are listed as Vulnerable in the IUCN Red List of Threatened Species, except for Leopard which is listed as NT in the IUCN Red List of Threatened Species.

The Sherman Trap method recorded four species of rodents in the study area. Among them, three species were rats and one species was a squirrel. The recorded three species were House rat *Rattus rattus*, Little Indian field mouse *Mus booduga*, Indian gerbil *Tatera indica*, and Squirrel *Funambulus palmerum*. All three rat species fall under Schedule IV as in Indian Wildlife Protection Act, 1972.

The 14 species of bats recorded belonging to five families and spread across four habitats. Of them, all are listed as Least Concern (LC) under IUCN status, and only two species i.e., Indian Flying Fox *Pteropus medius* and Short Nosed Fruit Bat *Cynopterus sphinx* fall under Schedule IV of Indian Wildlife Protection Act, 1972.

Among 15 terrestrial small and large mammals and 14 species of bats recorded in the study area, about 13 terrestrial small and large mammals and all 14 species of bats were detected near the MPC area during 12 h belt run (Four species of rodents were not sampled during 12 h belt run). Whereas during 20 h belt run, among a total of 33 mammals in the study area, only 29 species were detected in the MPC area (Table 10.4).

Table 10.3. Checklist of Mammals recorded in the study area

Species	Order	IUCN Status	IWLPA Schedule	Habitat				Source of Detection						
				TSF	OS	AL	BU	DR	CT	ST	AM	SM4	EMT	EM3
Bonnet Macaque (*Macaca radiata*)	Primates	LC	Schedule II	✓		✓		✓						
Hanuman Langur (*Semnopithecus hypoleucos*)	Primates	VU	Schedule II	✓		✓		✓	✓					
Leopard (*Panthera pardus*)	Carnivora	NT	Schedule I	✓	✓				✓					
Jungle cat (*Felis chaus*)	Carnivora	LC	Schedule II	✓		✓			✓					
Rusty Spotted Cat (*Prionailurus rubiginosus*)	Carnivora	VU	Schedule I	✓	✓			✓	✓					
Golden Jackal (*Canis aureus*)	Carnivora	LC	Schedule II		✓			✓	✓					
Bengal Fox (*Vulpes bengalensis*)	Carnivora	LC	Schedule II			✓		✓	✓					
Small Indian Civet (*Viverricula indica*)	Carnivora	LC	Schedule II	✓	✓				✓					
Asian Palm Civet (*Paradoxurus hermophroditus*)	Carnivora	LC	Schedule II	✓					✓					
Common Mongoose (*Herpestes edwardsi*)	Carnivora	LC	Schedule II	✓	✓	✓		✓	✓					
Ruddy Mongoose (*Herpestes smithii*)	Carnivora	LC	Schedule II	✓	✓			✓	✓					
Sloth Bear (*Melursus ursinus*)	Carnivora	VU	Schedule I	✓	✓			✓	✓					
Four Horned Antelope (*Tetracerus quadricornis*)	Artiodactyla	VU	Schedule I	✓	✓				✓					
Indian Wild pig (*Sus scrofa*)	Artiodactyla	LC	Schedule III	✓	✓			✓	✓					
Indian Crested Porcupine (*Hystrix indica*)	Rodentia	LC	Schedule IV	✓					✓					
Black Naped Hare (*Lepus nigricollis*)	Lagomorpha	LC	Schedule IV	✓	✓	✓		✓	✓					
Black Rat or House Rat (*Rattus rattus*)	Rodentia	-	Schedule IV			✓				✓				
Indian Gerbil *(Tatera indica)*	Rodentia	-	Schedule IV			✓				✓				
Little Indian Field Mouse (*Mus booduga*)	Rodentia	-	-			✓				✓				

Palm Squirrel (*Funambulus palmarum*)	Rodentia	-	Schedule IV			✓				✓				
Least Pipistrelle Bat (*Pipistrellus tenuis*)	Chiroptera	LC	-	✓		✓							✓	✓
Indian Pipistrelle (*Pipistrellus coromandra*)	Chiroptera	LC	-	✓	✓	✓	✓				✓	✓	✓	✓
Kelaart's Pipistrelle (*Pipistrellus ceylonicus*)	Chiroptera	LC	-	✓	✓	✓	✓				✓	✓	✓	✓
Greater Asiatic house bat (*Scotophilus heathii*)	Chiroptera	LC	-	✓	✓	✓	✓				✓	✓	✓	✓
Lesser Asiatic house bat (*Scotophilus kuhlii*)	Chiroptera	LC	-	✓										✓
Bent-wing bat (*Miniopterus fuliginosus*)	Chiroptera	LC	-	✓										✓
Blyth's Horseshoe bat (*Rhinolophus lepidus*)	Chiroptera	LC	-	✓	✓	✓					✓	✓		✓
Schneiders Leaf-nosed bat (*Hipposideros speoris*)	Chiroptera	LC	-	✓	✓	✓					✓	✓	✓	✓
Indian roundleaf bat (*Hipposideros lankadiva*)	Chiroptera	LC	-	✓		✓					✓		✓	✓
Cantor's roundleaf bat (*Hipposideros galeritus*)	Chiroptera	LC	-	✓										✓
Egyptian Free-tailed bat (*Tadarida aegyptiaca*)	Chiroptera	LC	-	✓	✓	✓	✓				✓	✓	✓	✓
Wrinkle-lipped Free-tailed Bat (*Chaerephon. plicatus*)	Chiroptera	LC	-		✓	✓	✓				✓	✓	✓	✓
Indian Flying Fox (*Pteropus medius*)	Chiroptera	LC	Schedule IV	✓		✓					Visual Detection			
Short Nosed Fruit Bat (*Cynopterus sphinx*)	Chiroptera	LC	Schedule IV		✓	✓					Visual Detection			

Habitat	Thorn Scrub Forest (TSF), Open Scrub (OS), Agricultural Land (AL), Built Up (BU)
Source of Detection	Direct, (DR), Camera Trap (CT), Sherman Trap (ST), Audiomoth (AM), Song Meter 4 Mini Bat (SM4),Echo Meter Touch 2 Pro (EMT), Echo Meter 3+(EM3)
IUCN Status	Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in The Wild (EW), Extinct (EX)

Table 10.4. Occurrence of mammals along MPC and control sites

Species	MPC Operation			Control Sites
	12 h	20 h	Total MPC	
Sloth Bear	1	1	1	1
Black-Naped Hare	1	1	1	1
Indian Wild Pig	1	1	1	1
Indian Crested Porcupine	1	1	1	1
Common Grey Mongoose	1	1	1	1
Ruddy Mongoose	1	1	1	1
Jungle Cat	1	0	1	1
Rusty Spotted Cat	1	1	1	1
Leopard	1	1	1	1
Four Horned Antelope	1	0	1	1
Asian Palm Civet	0	1	1	1
Small Indian Civet	1	1	1	1
Hanuman Langur	1	1	1	1
Golden Jackal	0	1	1	0
Indian Fox	1	0	1	0
Palm Squirrel	-	1	1	0
Black Rat or House Rat	-	1	1	1
Indian Gerbil	-	1	1	1
Little Indian Field Mouse	-	1	1	0
Least Pipistrelle Bat	1	0	1	-
Indian Pipistrelle	1	1	1	-
Kelaart’s Pipistrelle	1	1	1	-
Greater Asiatic house bat	1	1	1	-
Lesser Asiatic house bat	1	1	1	-
Bent-wing bat	1	1	1	-
Blyth’s Horseshoe bat	1	1	1	-
Schneider’s Leaf-nosed bat	1	1	1	-
Indian roundleaf bat	1	1	1	-
Cantor's roundleaf bat	1	1	1	-
Egyptian Free-tailed bat	1	1	1	-
Wrinkle-lipped Free-tailed Bat	1	1	1	-
Indian Flying Fox	1	1	1	-
Short Nosed Fruit Bat	1	1	1	-

*Present=1; Absent=0

Diversity of Mammals

Among terrestrial mammals, although the number of species recorded was almost the same except one species less recorded during the 20 hours of belt run along the MPC, the diversity indices varied near MPC during both 12 h and 20 h operation and in the control sites. Shannon diversity index, being high (H=2.10) in the control site and the least along the MPC during 12-hour belt run (H=1.41) and 20-hour of belt run (H=1.59) (Table 10.5).

Table10.5. Diversity Indices of terrestrial Mammals, Rodents and Bats

Terrestrial mammals	12 h	20 h	Control	
Taxa_S	13	12	13	
Number of captures	234	101	98	
Dominance_D	0.43	0.37	0.19	
Simpson_1-D	0.57	0.63	0.81	
Shannon_H	**1.41**	**1.59**	**2.10**	
Evenness_e^H/S	0.31	0.41	0.63	
Rodents	**12 h**	**20 h**	**Control**	
Taxa_S	-	4	2	
Number of call recordings	-	10	4	
Dominance_D	-	0.30	0.63	
Simpson_1-D	-	0.70	0.38	
Shannon_H	-	1.28	0.56	
Evenness_e^H/S	-	0.90	0.88	
Bats	**Agriculture**	**Scrub**	**Forest**	**Built - up**
Taxa_S	11	9	14	5
Number of call recordings	3403	3169	4039	1602
Dominance_D	0.29	0.24	0.23	0.33
Simpson_1-D	0.71	0.76	0.77	0.67
Shannon_H	1.48	1.55	1.71	1.29
Evenness_e^H/S	0.40	0.52	0.39	0.73

Among bats, a greater number of species were found in the forest area (Taxa, S=12), followed by agricultural land (S=11), scrubland (S=6), and the least was in a built-up area (S=5). For the overall species recorded during the study period, diversity indices vary from habitat to habitat. Shannon diversity index, being high (H=**1.71**) in the forest habitat shows more diversity and the least diversity (H=**1.29**) in the built-up area. Scrubland possesses the second-highest diversity with a 1.551 Shannon index (Table 10.5). In the forest area species are more evenly distributed (1-D=**0.77**), followed by scrubland (1-D=**0.76**) and agriculture land (1-D=**0.71**), whereas built-up area has less evenly distributed (1-D=**0.67**) faunal diversity (Table 10.5).

Abundance of Mammals

The RAI was calculated for the terrestrial small and large mammals, derived from the Camera Trap survey during both 12 and 20 hours of belt run and also at the control (Table 10.6). Among 15 camera-trapped species, the RAI values of most of the species, i.e., seven species were lower in the Control site, except for Common Grey Mongoose and Jungle Cat. The lower value of RAI indicates the higher abundance of these species in the control sites, than compared to their abundance near the MPC area. The RAI value of Sloth bear is RAI=40 during the 12 h belt run and RAI=181 during the 20 h belt run. Hence there was a higher abundance of sloth bears during 12 h belt run than compared to 20 h belt run. In Control Site, the RAI of the bear was RAI=77, which indicated that their abundance in the Control site is higher. Similarly, leopards showed the difference in RAI values during 12 h (RAI=445), 20 h (RAI=90), and in the control site (RAI=42). Four Horned Antelope was captured during 12 h MPC operation (RAI=889) and was not captured during 20 h belt run. However, Four Horned Antelopes were captured several times in the Control sites (RAI=46), indicating that the species is abundant in the control site). The overall abundance of mammals was relatively higher along the MPC over the control site.

Table 10.6. Relative abundance of mammals from capture data (12 and 20 hours MPC data and control sites)

Species	12h		20h		Control Site	
	No. of Captures	RAI	No. of Captures	RAI	No. of Captures	RAI
Sloth Bear	22	**40**	2	**181**	4	**77**
Black-Naped Hare	149	6	60	6	38	9
Indian Wild Pig	19	47	6	60	7	42
Indian Crested Porcupine	10	89	6	60	9	42
Common Grey Mongoose	3	296	6	60	1	461
Ruddy Mongoose	9	99	6	60	7	27
Jungle Cat	6	148	0	-	3	154
Rusty Spotted Cat	1	889	2	181	4	92
Leopard	2	**445**	4	**90**	8	**42**
Four Horned Antelope	1	**889**	0	-	7	**46**
Asian Palm Civet	0	-	1	361	6	77
Small Indian Civet	7	127	4	90	2	154
Hanuman Langur	4	222	1	361	2	154
Golden Jackal	0	-	3	120	0	-
Indian Fox	1	889	0	-	0	-
Mammal	234	3.8	101	3.6	98	4.7

*RAI = Relative Abundance Index

Rodent abundance near MPC and control sites: The highest number of burrows were recorded in the agriculture habitat, i.e., twenty-eight; followed by forest and open scrub habitat which recorded 19 and 16 burrows, respectively. The lowest number of burrows (11) was noticed in built-up habitat (Table 10.7a). The density of rodents recorded in the study area is shown in Table 10.7b. The rodent's species trapped were T. Indica, R. rattus, and M. booduga. The highest number of rodents recorded near the MPC area is Palm Squirrel (4), followed by Indian Gerbil (3), Little Indian Field Mouse (2), and Black Rat (1). In Control Site, 3 Black Rats and 1 Indian Gerbil were recorded. During 12 h MPC operation (RAI=889) and was not captured during 20 h belt run. However, Four Horned Antelopes were captured several times in the Control sites (RAI=46), indicating that the species is abundant in the control site). The overall abundance of mammals was relatively higher along the MPC over the control site.

Table 10.7a. Burrow Count findings

Habitat Type	Number of Burrows recorded
Agricultural Land	28
Open Scrub Land	16
Thorn Scrub Forest	19
Built-up	11
Total	**74**

Table 10.7b. Density of rodents recorded in the study area

Species	MPC area		Control Site	
	Total no.of Individuals in 0.6 ha (N_1)	No.of individuals per hectare	Total no. of Individuals in 0.3 ha (N_2)	No.of individuals per hectare
Palm Squirrel (*Funambulus palmarum)*	4	2.4	0	0
Black Rat or House Rat (*Rattus rattus)*	1	0.6	3	0.9
Indian Gerbil (*Tatera indica)*	3	1.8	1	0.3
Little Indian Field Mouse (*Mus booduga)*	2	1.2	0	0

Acoustic Analysis

From the acoustics data gathered from all possible detectors during the study period, 12 species of insectivore bats were identified (Table 10.3) by analyzing their call parameters (Table 10.9, Fig 10.5). A total of 78,404 call recordings were gathered from all ultrasonic devices, out of which 44,947 recordings were from passive recorders and the remaining is from active recorders (Table 10.1b).

All 14 species of bats were recorded during the line transect method, including both visual observation and acoustic analysis and 8 species were recorded in passive recorders. The number of calls recorded differed in different habitats (Fig. 10.4).

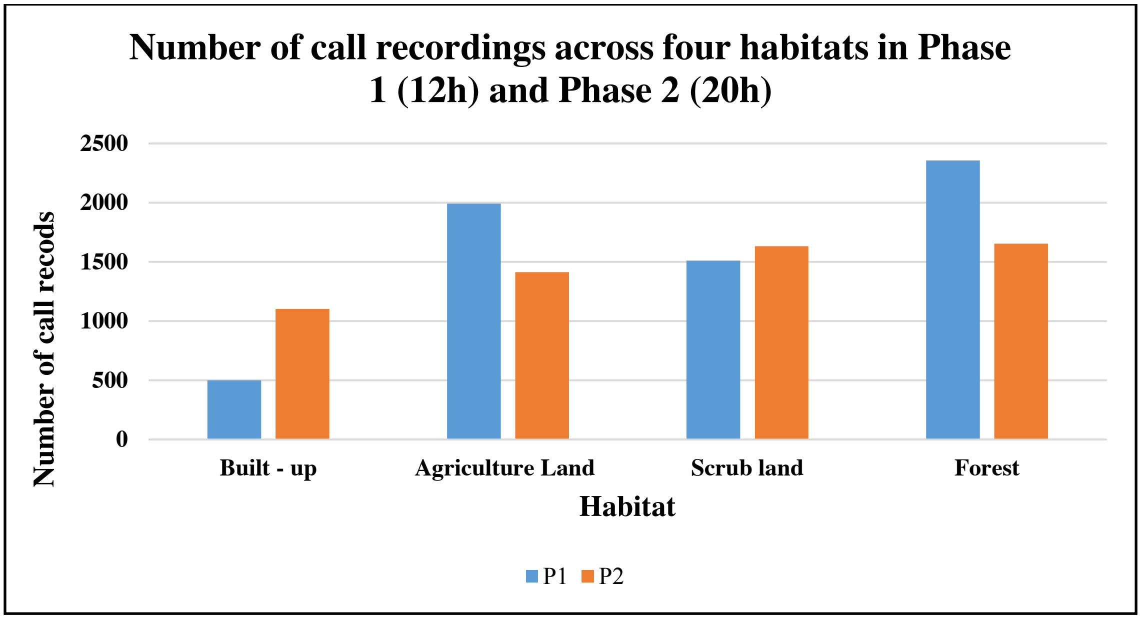


Figure 10.4. Number of calls recorded across habitat during study period.

Table 10.8. No. of call records of all bat species in different study areas in Phase 1 and Phase 2.

HABITAT	Phase 1/ 12h	Phase 2/ 20h
Built - up	499	1103
Agriculture Land	1983	**1413**
Scrub land	1511	1628
Forest	2351	**1655**
TOTAL	**6344**	**5799**

In the current study, the maximum number of bat calls were recorded in the forest area, during phase-1 (2351 call records), and the least is from the built-up area during phase-1 (499). The total number of calls from agricultural land and forest area has considerably decreased from phase-1 to phase-2, i.e., 1983 to 1413 and 2351 to 1655 respectively. In the other two habitats, there has been an increase in the number of call recordings. However, the overall call recordings were more in phase-1 (**6344**) compared to phase-2 (**5799**) (Table 10.8, Fig. 10.4).

During Visual observations, one small colony (15-20) of *Hipposideroslankadiva'*s under the bridge of a railway line which was a night roost used during foraging was recorded. Few bats were observed and identified at the family level during their flight around the MPC. We observed *Pteropus medius* (Indian Flying Fox) foraging on the fruits of neem and fig trees around the agricultural landscape. The *Cynopterus sphinx* (Lesser Short Nosed Fruit bat) was observed in Fig plantation and in scrubland foraging on the fruits of *Muntingia calabura* (Singapore cherry tree). A single Lesser Mouse Tailed Bat (*Rhinopoma hardwickii*) was observed in a rock crevice in the region but almost a kilometer away from the MPC. However, we did not record any acoustic calls of this species anywhere within the MPC line. Hence the same has not been accounted for in the list of species identified.

Table 10.9. Acoustic parameters (mean ± SD) of various echolocating bat species recorded from the study area

SL	Common Name	Scientific Name	Start (kHz)	End (kHz)	Peak (kHz)	Duration (ms)
1	Least Pipistrelle-Indian Pygmy Bat	*Pipistrellus tenuis*	55.89±7.45	40.4±1.13	40.72±0.93	5.45±0.67
2	Indian Pipistrelle	*Pipistrellus coromandra*	67.25±6.08	50.9±0.90	50.98±0.87	3.79±0.90
3	Kelaart's Pipistrelle	*Pipistrellus ceylonicus*	40.44±2.33	33.74±1.05	34.24±1.04	8.65±2.02
4	Greater Asiatic house bat	*Scotophilus heathii*	51.88±3.68	48.09±0.69	48.57±0.81	6.42±1.43
5	Lesser Asiatic house Bat	*Scotophilus kuhlii*	75.54±8.76	49.4±1.20	49.65±1.43	7.43±1.41
6	Bent-wing Bat	*Miniopterus fuliginosus*	88.12±6.60	50.34±0.43	50.27±0.43	8.27±4.90
7	Blyth's Horseshoe Bat	*Rhinolophus lepidus*	96.5±2.31	97.72±2.08	100.15±1.26	48.71±6.62
8	Schneider's Leaf-nosed Bat	*Hipposideros speoris*	125.83±0.73	119.42 ±2.95	127.04±0.72	8.22 ± 0.80
9	Indian Roundleaf Bat	*Hipposideros lankadiva*	78.22 ±1.05	73.57±2.41	78.8±0.88	13.79±2.17

10	Cantor's roundleaf bat	*Hipposideros galeritus*	106±4.31	108.39±3.07	110.91±0.49	9.43±1.17
11	Egyptian Free-tailed bat	*Tadarida aegyptiaca*	28.97±3.75	22.1±1.22	22.47±0.36	13.99±4.94
12	Wrinkle-lipped Free-tailed Bat	*Chaerephon plicatus*	30.91±2.38	20.83±1.40	22.64±0.75	15.34±3.21

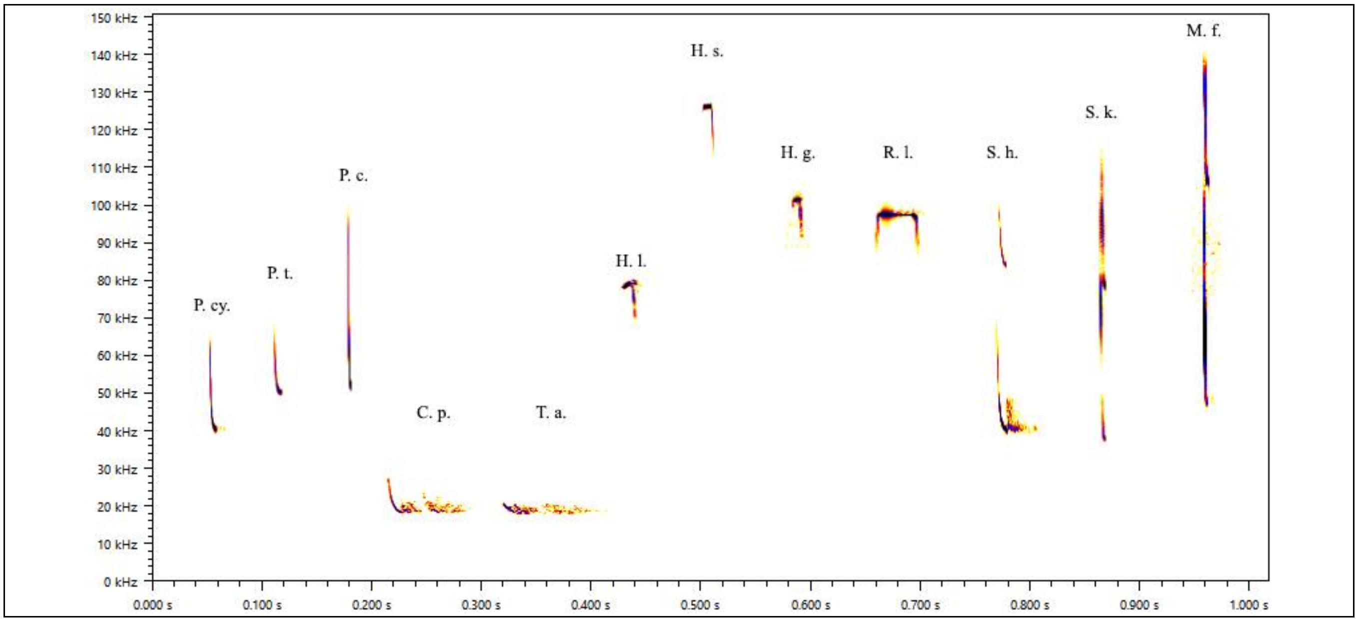


Figure 10.5. Spectrograms of representative species emitting echolocation calls, (FFT size of 1024 in a Hann window). P.cy. = *Pipistrellus ceylonicus*, P.t. = *Pipistrellus tenuis*, P.c. = *Pipistrellus coromandra*, C.p.= *Chaerephonplicatus*, T.a. = *Tadarida aegyptiaca*, H.l. = *Hipposideroslankadiva*, H.s. = *Hipposiderosspeoris*, H.g. = *Hipposiderosgaleritus*, R.l. = *Rhinolophus lepidus*, S.h. = *Scotophilusheathii*, S.k. = *Scotophiluskuhlii*, M.f. = *Miniopterus fuliginosus*

Impact of sound from MPC on bat echolocation

Two of the bats identified in the study area belong to the genus Mollasidae (Free-tailed bats) namely, *Tadarida aegyptiaca* (Egyptian Free-tailed Bat) and *Chaerephon plicatus* (Wrinkle-lipped Free-tailed Bat). The echolocation calls of *Tadarida aegyptiaca* showed a mean peak frequency of 22.47 kHz and *Chaerephon plicatus* showed about 22.64 kHz. The masking of echolocation calls can result in lesser capture of prey leading to starvation of bats if they do not avoid the MPC area and shift to other foraging grounds (Jones 2008; Bunkley et al. 2015). Even if the bats try to adapt to the increased anthropogenic sound, by increasing their echolocating frequencies this might result in excessive stress to the bats (Bednarz 2021).

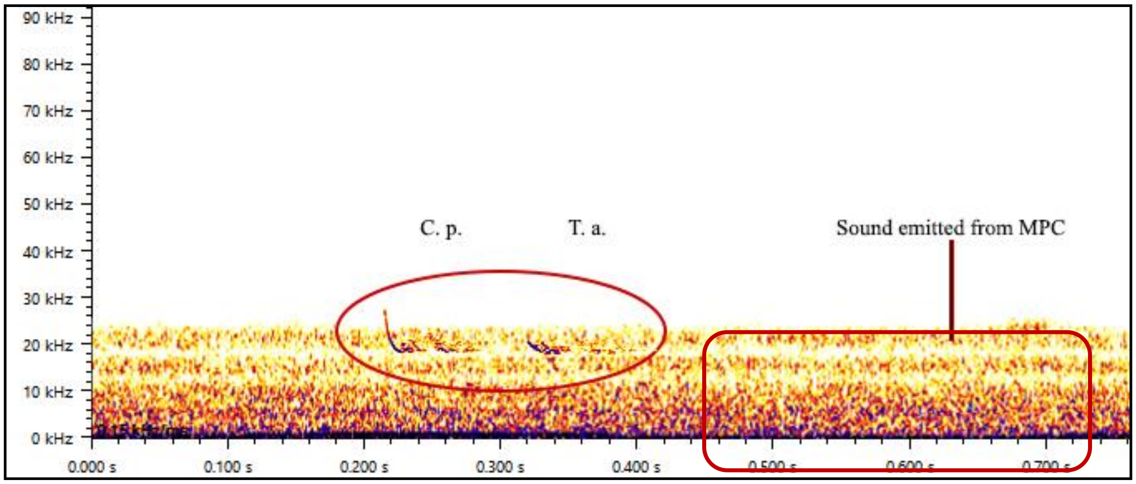


Figure 10.6. A graphical representation of overlap of echolocation calls of *Tadarida aegyptiaca* on the noise from the MPC idlers. Note the masking of echolocation calls due to the noise.

A 2D spectrogram may not provide a detailed pictorial view of sound getting masked. However, with 3D imaging, we can identify an audio call with multiple calls of the same frequency (Fig. 10.7). The calls of *Chaerephon plicatus* are shown in green and the MPC sound is shown in yellow and orange. The X-axis indicates the frequency of the call, Y-axis indicates the duration of the call, and Z-axis indicates the amplitude at which the call is.

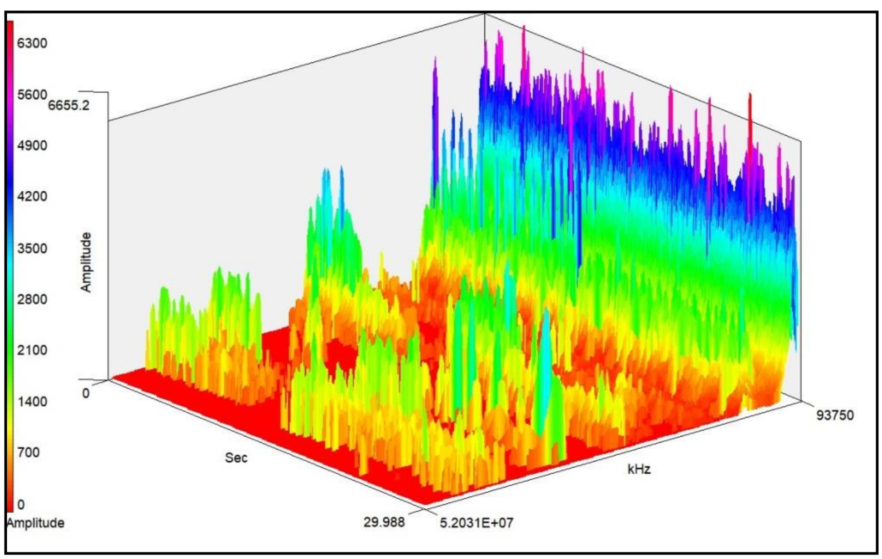


Figure 10.7. A 3D rendering of Fast Fourier Transform (FFT) of a Wrinkle-lipped Free-tailed Bat (*Chaerephon plicatus*) call masked with the sound from MPC. The calls of *Chaerephon plicatus* is shown in green and the MPC sound is shown in yellow and orange. X axis indicates the frequency, Y axis indicates the duration of the call and Z axis indicates the amplitude at which the call is at.

Impact of MPC on Activity pattern of mammals

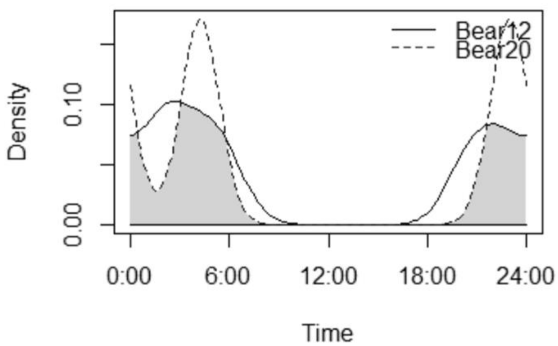
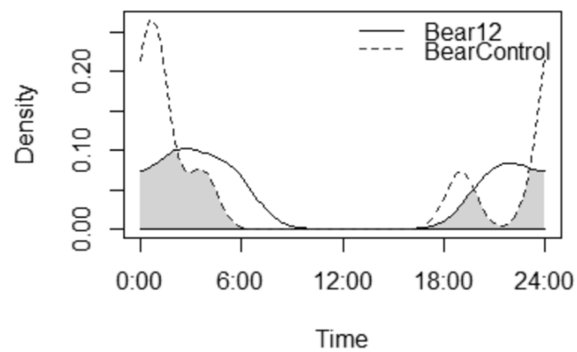
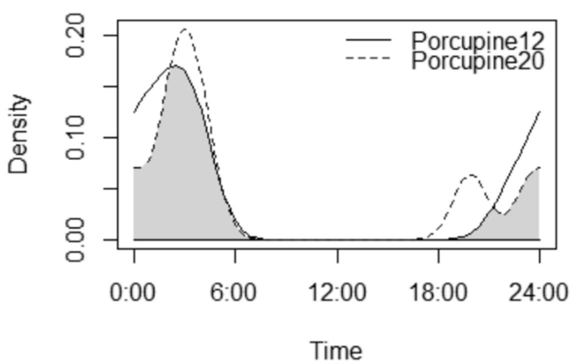
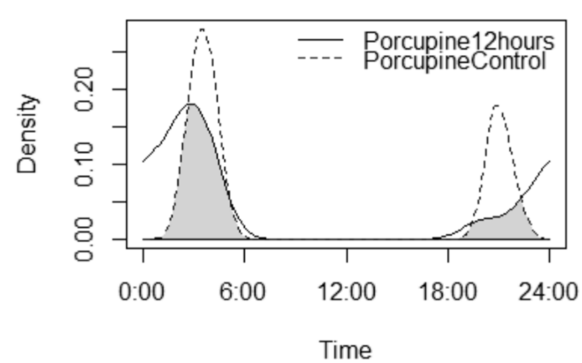
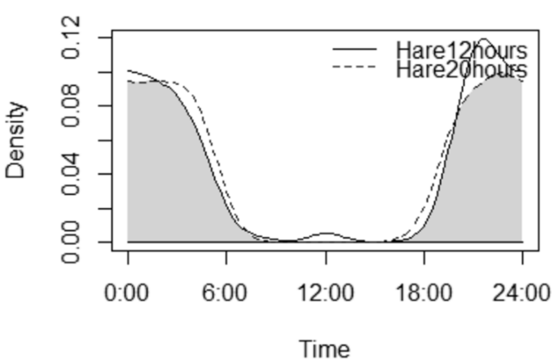
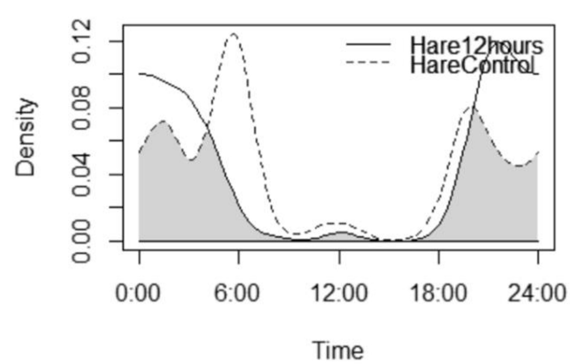
To assess the impact of MPC on the activity of mammals, Activity overlap curves were developed and Overlap in the activity of Sloth Bears between 12 hours and 20 Hours of belt run and between 12 Hours of belt run and in the Control Sites is shown in Fig. 10.8a, b, the True Coefficient of Overlap (Δ) was found to be 0.62 between 12 Hours and 20 Hours of belt run and 0.50 between 12 Hours of belt run and Control Site. During 12 Hours of belt run, the Sloth Bears remained active from 18:00 to 06:00, with a peak in activity at 22:00, 2:00, and 5:00. Whereas, during 20 Hours of belt run, the activity was comparatively lesser and was found to be active only at 22:00 and 04:00, hence very little activity was seen post 18:00. However, in Control sites, the bears were active from 19:00 to 03:00 and the peak in activity was seen at 24:00.

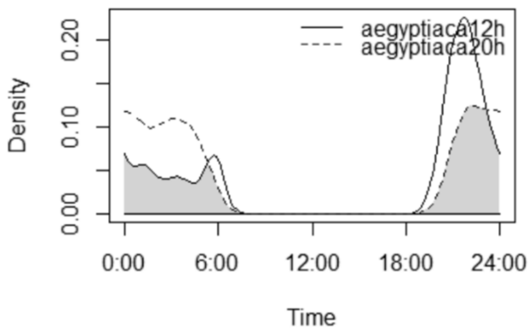
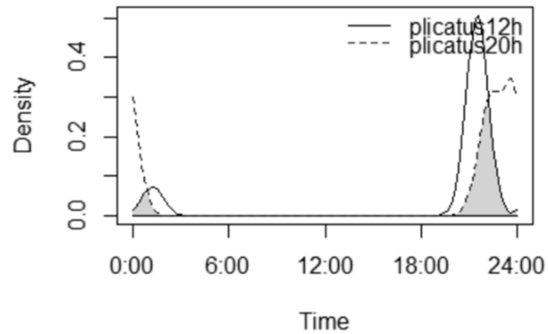
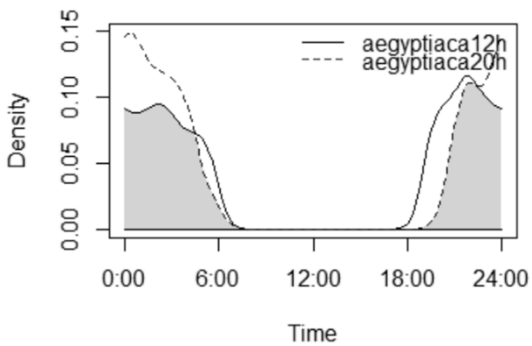
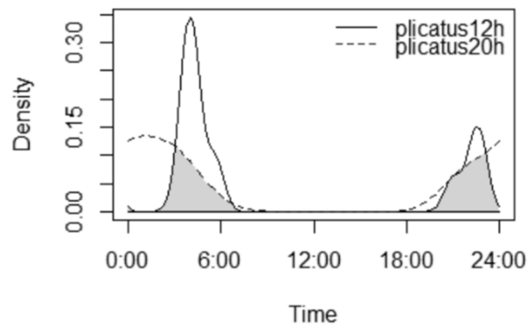
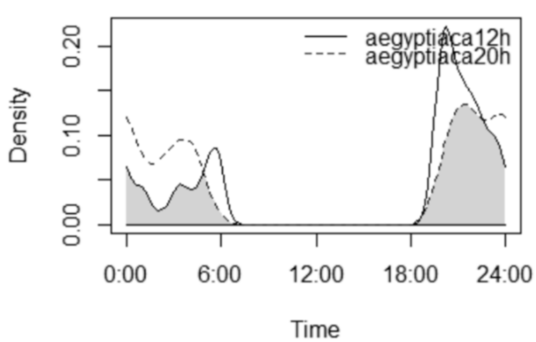
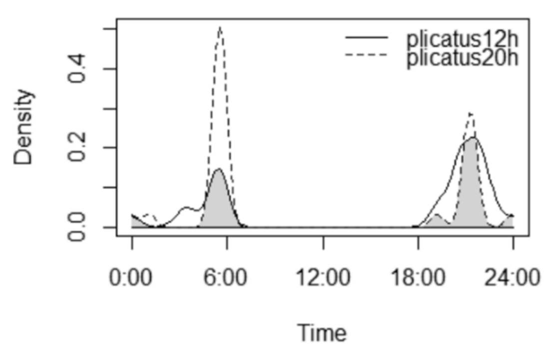
Overlap in the activity of Indian Crested Porcupine between 12 hours and 20 Hours of belt run and between 12 Hours of belt run and in the Control Sites is shown in Fig. 10.8c, d, the True Coefficient of Overlap (Δ) was found to be 0.67 between 12 Hours and 20 Hours of belt run and 0.58 between 12 Hours of belt run and Control Site. During 12 Hours of belt run, the Porcupines remained active from 22:00 to 03:00, with a peak in activity at 03:00. Whereas, during 20 Hours of belt run, interestingly the activity was comparatively higher and the porcupines were found to be active 19:00 to 04:00, with a peak in activity at 02:00. However, in Control sites, the Porcupines were active from 20:00 to 04:00 and the peak in activity was seen at 03:00.

Overlap in the activity of Black Naped Hare between 12 hours and 20 Hours of belt run and between 12 Hours of belt run and in the Control Sites is shown in Fig.10.8e, f, the True Coefficient of Overlap (Δ) was found to be 0.93 between 12 Hours and 20 Hours of belt run and 0.66 between 12 Hours of belt run and Control Site. During 12 Hours of belt run, the hares remained active from 18:00 to 05:00, with a peak in activity at 21:00, and the minimal activity was also seen at 12:00 and 07:00. Whereas, during 20 Hours of belt run, the Hares were found to be active from 18:00 and 05:00, with a peak in activity at 20:00 and 22:00. Hence during both 12 hours and 20 hours of belt run, a maximum of overlap was shown. However, in Control sites, the Hares were active from 18:00 to 06:00 with the peak in activity was seen at 05:00 and the minimal activity was also seen at 07:00 and 10:00 and 12:00.

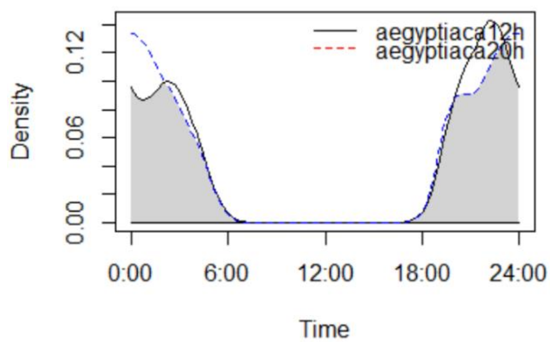
The activity pattern of two of the bat species *Tadarida aegyptiaca* and *Chaerephon plicatus* which have a peak frequency (22.47 kHz and 22.64 kHz respectively) (Deshpande and Kelkar 2015) that overlap with the frequency range from the MPC (5.0 kHz to 45.0 kHz) is assessed for each habitat and depicted below(Fig. 10.8; Table10.10). The activity pattern of both *Tadarida aegyptiaca* and *Chaerephon plicatus* shows significant variation across each habitat. The actual variation defers from one habitat to another habitat and one species to another species.

In the built-up land, *Tadarida aegyptiaca* shows a coefficient value of Δ=0.67. The Overlap ( ) curve indicates a delayed start in its activity by almost an hour from 18:00 hr to 19:00 hrs and the density of activity is reduced by half (0.20 to 0.10). The density of activity which would reduce gradually after 24:00 hrs until early hours has now seen an increase in activity after 23:30 hrs. The peak activity has shifted from the evening and has got spread across the night. Similarly, the *Chaerephon plicatus* shows a coefficient value of Δ=0.35 and indicates not only a delayed start in its activity but also early closure (Fig. 10.8; Table10.10).

Overlap Curves between 12 h and 20 h	Overlap Curves between 20 h and Control
 (a) Sloth Bear 12h and 20h(Δ=0.62)	 (b) Sloth Bear 20h and Control(Δ=0.50)
 (c) Porcupine 12h and 20h(Δ=0.67)	 (d) Porcupine 20h and Control(Δ=0.58)
 (e) Hare 12h and 20h(Δ=0.93)	 (f) Hare 20h and Control(Δ=0.66)

<table>
<tr><th colspan="2">Overlap Curves between 12 h and 20 h</th></tr>
<tr><th colspan="2">Habitat: Built-up land</th></tr>
<tr><td>Tadarida aegyptiaca (Δ=0.67)</td><td>Chaerephon plicatus (Δ = 0.35)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Habitat: Forest Land</th></tr>
<tr><td>Tadarida aegyptiaca (Δ=0.81)</td><td>Chaerephon plicatus (Δ = 0.52)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">Habitat: Agricultural Land</th></tr>
<tr><td>Species:Tadarida aegyptiaca (Δ=0.72)</td><td>Species:Chaerephon plicatus (Δ = 0.58)</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Habitat: Scrub Land	
Species: *Tadarida aegyptiaca* (Δ=0.91)	**Species:** *Chaerephon plicatus* (Δ = 0.83)



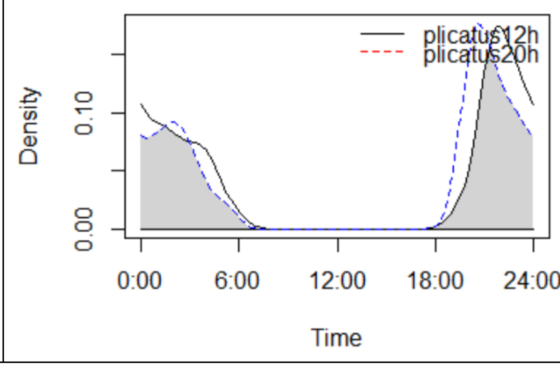


Figure 10.8. Density estimates in activity patterns of various species during 12 hrs and 20hrs of operat ion of MPC and in Control Sites

Table10.10. ($\hat{\Delta}$) Overlap of activity pattern of various mammalian species.

Species	**$\hat{\Delta}$ (True Co-efficient of Overlap)**				
	Between 12 h and 20 h				**Between 12 h and Control Site**
Sloth Bear	0.62				0.50
Indian Crested Porcupine	0.67				0.58
Black Naped Hare	0.93				0.66
	TSF	**AL**	**OS**	**BU**	
Tadarida aegyptiaca	0.81	0.72	0.91	0.67	-
Chaerephon plicatus	0.52	0.58	0.83	0.35	-
Thorn Scrub Forest (TSF), Agricultural Land (AL), Open Scrub (OS), Built Up (BU)					

Impact of sound from MPC on bat's prey detection

We have recorded different species of crickets (unidentified) which have the call frequency in the range of 5 kHz to 30 kHz (Figure 10.9). These calls overlap with the noise emanating from the MPC which at times has been as high as 45 kHz (Figure 10.10).

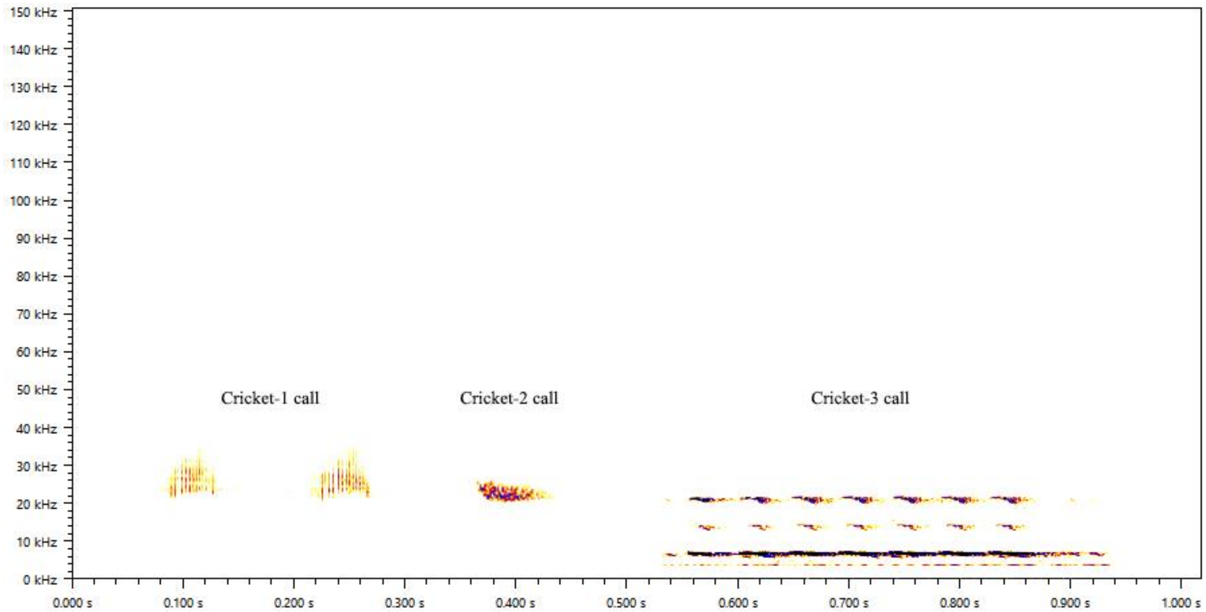


Figure 10.9. A collage of spectrogram depecting the call frequencies of three species of Crickets (Orthopteran).

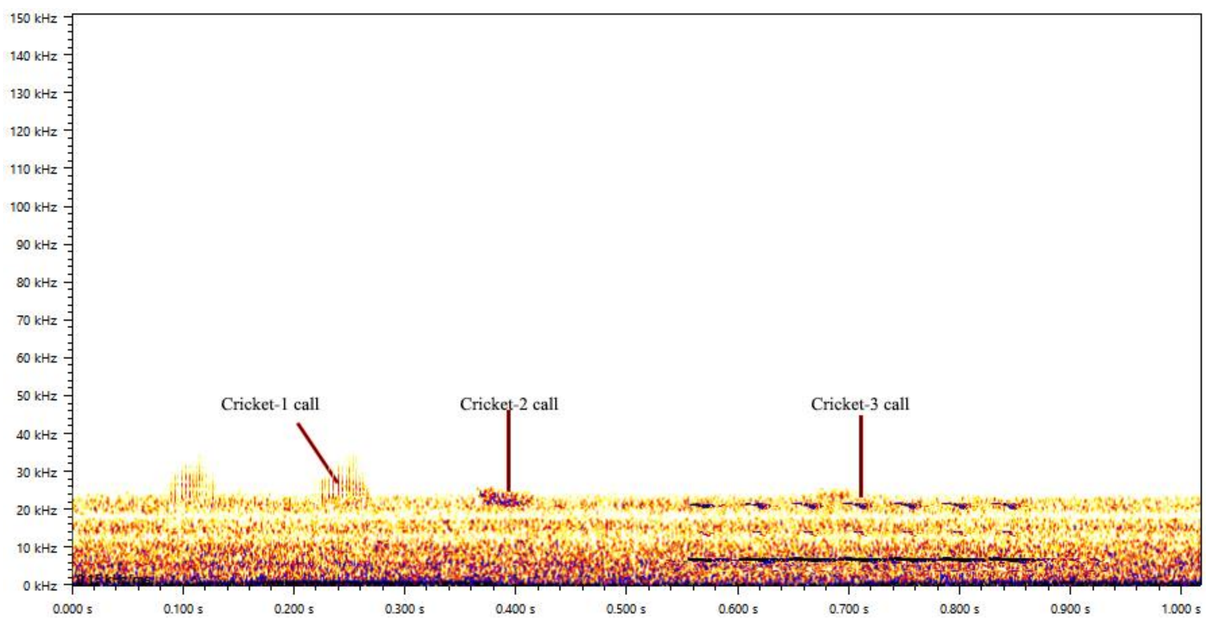


Figure 10.10. A collage of spectrogram depicting the call frequencies of three species of Crickets (Orthopteran) masked with MPC sound.

Data on Human-Wildlife Conflict (HWC)

The data on Human-Wildlife conflict incidents in the study area, over 8 years was mapped. Two of the incidents involving the species Indian wild pig (crop damage) in the year 2021-21 and a leopard (livestock depredation) in the year 2018-19, were reported from the MPC Belt region near Taranagar. The rest of the incidents were reported at least 1 Km away from the MPC area (Fig. 10.11a, b).

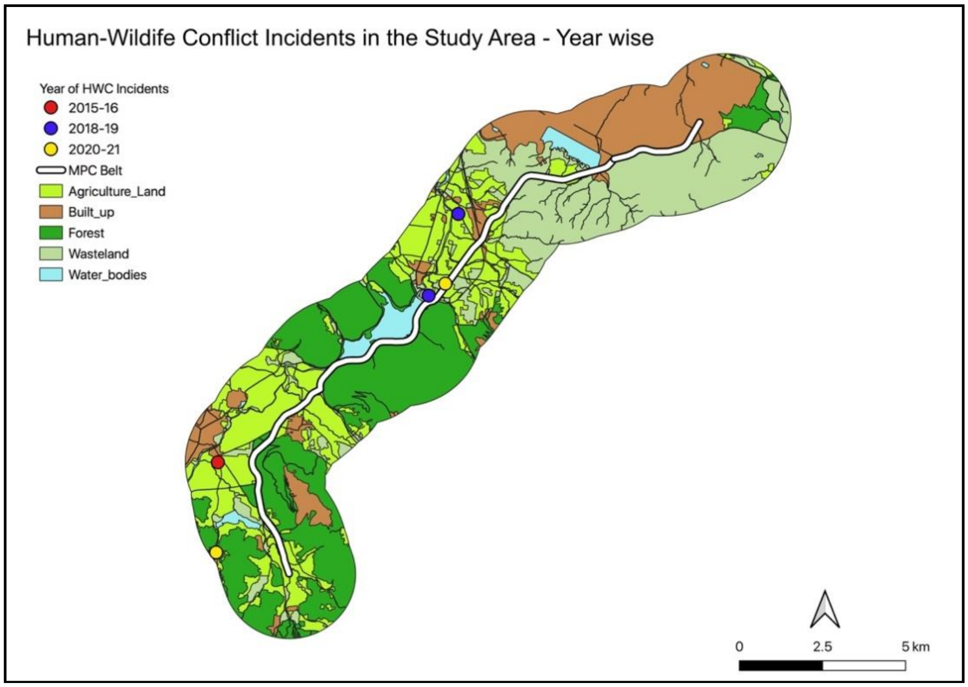


Figure10.11a. HWC incidents in the study area – Year wise

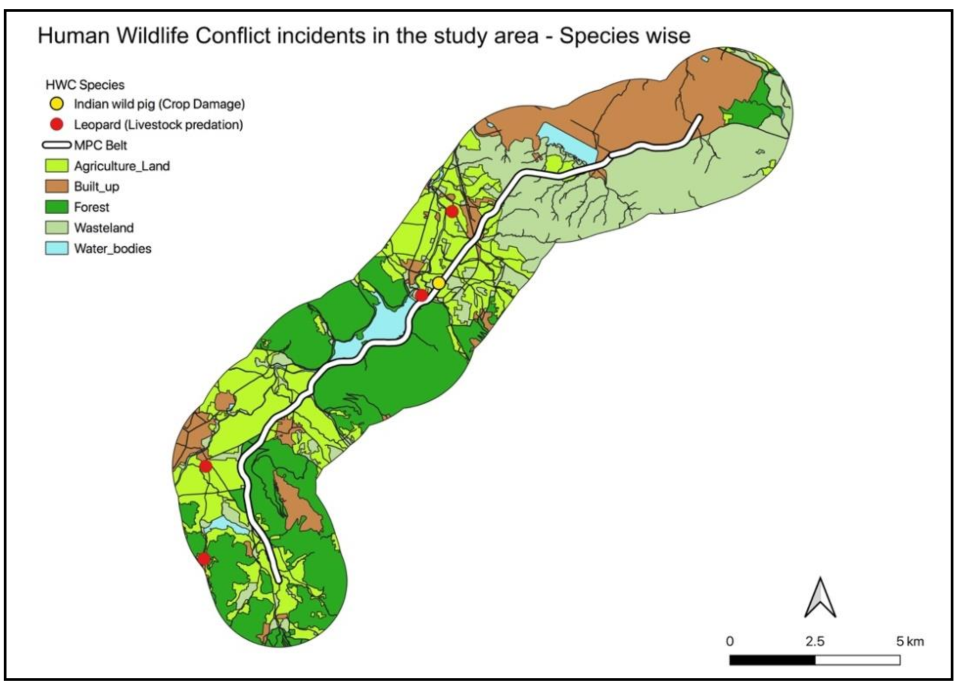


Figure 10.11b. HWC incidents in the study area – Species wise

Discussion

The present study provides a comprehensive account of the occurrence and abundance of terrestrial small, large mammals, bats, and little information on rodents. This is the first report documents persistence of many mammal species (33 species of mammals) in the study area. Further recordings of five threatened species and four species having high priority in protection that increase the importance of the study site.

Across all habitat types, the diversity of the terrestrial mammals, both large and small mammals was relatively higher in the forest area i.e., the Donimalai Forest Block, and the density of detections was found to be higher in the Open Scrublands and along the edges of the forest. Among large mammals, Black-Naped Hare was the most abundant species, which was followed by Sloth Bear. The number of detections of Leopard was found to be higher in the Thorn Scrub Forest area along the forest edges and the streams of the Donimalai Forest Block, and was also reported from the Swamymalai Forest Block and the Open Scrub land region of Bannihatti. Four Horned Antelope was reported from the Open Scrub land region of Swamymalai Forest Block. Species such as Rusty Spotted cat, Indian Crested Porcupine, Small Indian Civet, were reported majorly from the Forest areas of both Donimalai and Swamymalai Forest Block. Other taxa such as Indian Wild Pig, Golden Jackal, Indian Fox, Ruddy Mongoose, Common Grey Mongoose, were reported from the Open Scrubland and at the interface of Agricultural land and Scrub Forest areas. The RAI values of mammals were relatively higher in control sites, compared to that of MPC area, which indicates that species were more abundant in along the MPC. The probable, reason for this is the certain species of mammals are known to live along the forest edge and also commensal with the humans e.g., Indian Wild Pig, Golden Jackal, Indian Fox, Ruddy Mongoose, Common Grey Mongoose, and Black-Naped Hare (Kumara and Singh 2007, 2012). Often, they forage in the human-dominated landscape, thus they may have occurred along MPC which is located at the edge of the forest. Although, many of these species are known to use human-dominated landscape, but the required forest areas to roost and breed, thus, some of the species are largely recorded only in the forested areas. Among all the mammal species, Four Horned Antelope is a complete forest-dwelling (open scrub) species (Krishna et al. 2008; Kumara et al. 2012), thus recorded only in the forest than along MPC.

Among Rodents, the squirrels were the dominant species followed by *Ratus rattus* most of the rodents were recorded foraging in the cultivated habitat compared to that in scrub and forest habitat. In the

Built-up habitat, the predominant species was *Rattus rattus*. Interestingly systematic observations throughout the cultivated track revealed that rodent burrows were found only at 250 m away from MPC and the spot recorded 42.6 dB sounds. As only four species were recorded, that was due to less effort, thus further studies are required on large landscapes with a greater number of traps to derive inferences on rodent community characters and relate their habitat selection and impact of vibration created by the MPC.

Among bats, the sound emitted from the MPC can result in a different type of impact for various bat species depending on various factors. The activity pattern of both *Tadarida aegyptiaca* and *Chaerephon plicatus* show significant variation across each habitat. These bats forage in the open sky and catch their prey by gleaning in the air and detect their prey by echolocation (Arlettaz et al. 2001). This indicates their hunting performance was significantly reduced and their search times increased. This change in behavior especially for these two species could be either due to the masking effect or a distraction from the ambient noise resulting in their inability to detect prey (Hage and Metzner 2013).

While the Pipistrelle species belonging to Vespertilionidae were found to be more generalist and found across the MPC line irrespective of habitat, the *Miniopterus fuliginosus* was recorded only from forest patch and near streams running across agricultural land. The forest land had the highest diversity with 13 species while the agricultural land interspersed with stream accounted for the second-highest diversity at 11 species. We also observed that the activity of bats was less on few nights and at different habitats due to rain. Bats have been known to delay their emergence and foraging time to avoid the rain (Geipel et al. 2019) and this could be one of the factors affecting the activity period.

Bats listen to low-frequency sounds, which is having greater importance in feeding, as prey like crickets generates low-frequency sound. Listening to prey-generated sound in silence help bats to locate their prey. A wide variety of prey-generated sounds are used by bats to locate them, such as prey movement and fluttering sounds of moths (Bell 1982; Anderson and Racey 1993; Neuweiler 1989; Fenton et al. 1983). While hunting prey that is producing sound, bats do not echolocate (Fuzessery et al. 1993). The main approach for foraging in the clutter in few bats is performed by passive listening to prey-generated noises rather than echolocation detection of prey movement (Arlettaz et al. 2001). As observed in the study the cricket calls are getting masked by the sound from

MPC (Figure 10.9, 10.10), and this could have a significant impact on the bat's ability to detect and hunt its prey. It is known that bats approach crickets where there is an aggregation of calls than an individual call (Prakash et al. 2021). So, if the population of cricket declines, then that would have a direct impact on the bat's source of food. Prey abundance also drives bats' habitat selection, such as forest patches which provide favorable habitat for insectivorous bats (Prakash et al, 2021).

We hypothesized that the animal activity does not change in a short period unless some external factor affected their activity. In that case, the co-efficient of overlap should be very close to 100 % or at least 90 %. Further, the direction of shift and the peaks also indicates the change in the activity pattern that may be related to the causing factor. Currently, some of the species of mammals showed high variation in the co-efficient value of Δ (overlap in the activity) between 12-hours and 24 hours of belt run, control site, and also shift pattern e.g., Sloth Bear (12 h and 20 h belt run: Δ=0.62; MPC and control:Δ=0.50). The overlap curve indicates the delayed start in activity at post 18:00 and early retreat i.e., by 06:00 in both 12 h and 20 h. However, porcupines showed a shift in the start and started early i.e., around 17:00 during the 20 h belt run and the start was delayed by an hour at the control sites. Studies have shown that at higher noise levels mammals tend to evade the habitat or show decreased movement rates (Drolet et al. 2016). Thus, such a contrasting pattern does not properly reflect the change in the pattern. However, long term monitoring of the activity pattern of mammals needs to be carried out in the study area, and various covariates such as ecological parameters of the study area, seasonality, livestock movement, and other anthropogenic disturbances required to be assessed in addition to sound to effectively relate the changes in activity patterns and sound generated by MPC.

The MPC during its operations generates sound and the frequency emitted can reach up to 30 kHz based on speed, the material of idlers, load, and other factors (Brown 2004). It's been proven through similar studies that anthropogenic noise can have a direct and immediate impact on bats as it affects their ability to detect prey due to masking (Bunkley et al. 2015). Our observations and call records indicate similar findings where the noise from MPC can be as high as 45 kHz. Most free-tailed bats (Mollasidae's) found in India have a peak call frequency ranging from 12 kHz to 30 kHz. We recorded the presence of at least two species of mollasidae's namely *Tadarida aegyptiaca* and *Chaerephon plicatus* in the study area. Few other bat species under Vespertillionidae family (Table 10.9) which have a peak frequency ranging up to 45 kHz could also get impacted due to masking (Refer chapter 2, Figure 2.7b). The overlap analysis carried out for *Tadarida aegyptiaca* and *Chaerephon plicatus*across different habitats indicate a change in their activity timing and frequency of activities across all habitats except for scrubland.

The anthropogenic noise can also act as a stress for the bats leading to a decrease in foraging efficiency (Luo et al. 2015). Diversity and activity of bats reduce with raising human activity like roads, traffics and other urbanization activities. Bats use prey-generated sounds as cues while hunting (gleaning bats), masking of prey-generated sounds affects the bat foraging (Jones 2008). Bats' foraging ability is impacted by traffic noise up to 60m distance from the highway (Finch et al. 2020; Siemers et al. 2010). Bunkley et al. (2015) conducted a study on *Tadarida brasiliensis* and documented a reduction in call bandwidth at the 85% confidence level and the duration of the call also increased at 95% confidence level. They also found that low frequency (<35 kHz) echolocating bat species reduce activity levels in increased noise in general. Allen et al. (2021) reported a decline in the successful foraging attempts and efficiency of foraging in noisy conditions arising from wind turbines in *Antrozous pallidu*s. In our study, the shift in the pattern of their activity in *Tadarida aegyptiaca* and *Chaerephon plicatus* may be due to the noise. Anthropogenic noise is a potential threat to bat populations and needs to be considered when managing habitat (Bunkley et al. 2015).

Chapter XI: Aquatic Flora and Fauna

CHAPTER XI
AQUATIC FLORA AND FAUNA

Environmental Management & Policy Research Institute (EMPRI), Government of Karnataka vide its letter No. EMPRI/CR-64/Admin/2020-21/327 dated 02.08.2021 requested the Professor and the Dean College of Fisheries, Mangalore to undertake the study on “Impact of Noise and Vibrations of Main Pipe Conveyor (MPC) from Nandihalli Railway yard at JSW plant, Toranagallu, Ballari District on Aquatic Fauna at Narihalla Dam”.

Accordingly, a team comprising professors and scientists of the College of Fisheries, Mangalore visited the site and has reported vide letter no FCM/Dean/JSW Plant Visit/2021-22/58 dated 31/08/2021of Dean (Fisheries), College of Fisheries, Mangalore that noise and vibrations do have potential to cause an impact on the wildlife in general.

The noise was recorded at different stations and it was suggested to reduce the noise in the said area in the interest of wildlife.

They have observed that the metallic idlers cause more noise compared to HDPE Idlers, especially when they are not properly lubricated and also due to wear and tear. A water sample from the site was analyzed for various parameters they felt that the vibrations are harmful to the biorhythm of wildlife as it disturbs the life cycle of the animals. Further, they suggested that the vibrations on the ground could be reduced by digging concentric circular trenches below the stilts/pillars with 1 m gaps between each concentric circle and these concentric circles can be brick pitched with sand between the gaps which will reduce the transmission of the vibrations at the ground level, thereby not disturbing the wildlife and their habitats. Another measure suggested to reduce vibrations is to only use HDPE idlers and to calibrate the speed of the conveyor belt.

The qualitative and quantitative analysis report of Phytoplankton and Zooplanktons at different locations in Naarihalla dam was documented and enclosed as an annexure in the report. The report emphasized that detailed studies about noise and sound pollution need to be taken up for its impact on wildlife.

The complete report is enclosed as an annexure (Annexure 11.1 to 11.5).

Chapter XII: Synthesis and Conclusion

CHAPTER XII
SYNTHESIS AND CONCLUSION

Deccan plateau is relatively more arid, least studied and least concerned (Rawat 1997). However, in the last one or two decades as the unfolding of information on many species confined to plains started flowing, more attention was given to the biodiversity and their conservation. Even in Karnataka, more then ten protected areas were notified keeping species or habitat in the center in the last 15 years, this emphasizes the importance of the remnant forests as refuge for several habitat specific species and unique biodiversity. Singh and Kumara (2006) emphasized the importance of remote forest area available playing a role in the retaining of the animal like Indian Gray Wolves; similarly it may be true for many species in the plains as they require a forest or remote area for roosting and breeding.

Using of natural resources is essential part of the developmental activity for the human needs. The government demarcate the potential areas for various minerals and provide the lease to extact, process and use. In this process, various companies get the lease and mine the given source for the minerals and transport the same to the processing units. Thus, the transportation is essential part of the entire process of using of the minerals. JSW the steel company is located at Thoranagallu in Sandur Taluk of Ballari District. They have been used to get the iron ore from road transportation by truck and railways, however, in 2019 JSW implemented the conveyer belt project to transport the iron ore from the mining area to the processing unit. JSW established 24 km Main Pipe Conveyer Belt for the same. However, it passes through/ adjoining to forest area that has become a concern as these forest patches are remanent refuge for the unexplored biodiversity. In addition to that, the MPC, which was running between 6 AM to 6 PM, is being proposed for extension of the running time in the night i.e. from 6AM to 2 AM. In the view of this concern the study on impact of noise, vibrations and other associated factors on biodiversity was conducted between May and August 2021.

The advantages of the pipe conveyor as given by JSW:

1. Out of 24 km of Main Pipe Conveyor, 1.60 km stretch is in forest area. In order to reduce the noise levels, JSW has taken the steps by replacing the metal idlers to HDPE idlers to reduce the noise level and also kept the height of the belt at 7 to 8 m to facilitate the animal movement,
2. Reduction in carbon emission due to road transportation by trucks, thus the transportation by MPC is environmentally friendly,
3. Reduction in truck movement there by ensuring safety and health of man and animals,
4. Reduction in air, dust and noise pollution,
5. En-route spilling are avoided there by ensuring complete usage of the natural resources,
6. Reduction in consumption of HSD, thereby reducing the Forex,
7. Prevention of environmental degradation due to formation of roads/ rails for iron ore movement,
8. Ensuring security of wild animal moving on road while crossing

Current study:

The study was conducted keeping the wildlife and ecological aspects of ecosystem in view:

1. Impact of noise, vibrations, loss of habitat and other associated disturbances caused due to MPC on wildlife,
2. Compare the biodiversity along MPC and the control forest area, and
3. To assess the responses of wildlife belt run in the night time.

Findings, Caveats and Conclusion:

The study developed a noisescape keeping the MPC in the center, to understand the spatial extant of the sound levels. Meanwhile, it documented the level of vibration from the MPC, and light spread due to flood light from the loading station of the iron ore, and recorded the ultrasonic sound created by the MPC (Table 12.1). The noise level near the MPC with steel idlers was around 70 to 90 dB, and near the HDPE idlers it gets reduced to 40-60 dB. The extent of its impact may be up to 250 m away from the MPC where the noise level gets reduced to ~40-50 dB. This has become a baseline data to understand the responses of animals in and around the MPC. We also noticed that the Steel idlers were replaced by HDPE idlers only at few stretches of the MPC at each stretch and not the entire forest stretch.

Table 12.1. Recordings of noise, vibration and light from MPC and its uploading stations

Source	Readings		Remarks
Noise from MPC- up to 80 m from MPC	Audible Noise	Non-Audible (Ultrasonic)	
Metal idlers	70 to 90 dB	25 kHz to 45 kHz	Acceptable range for audible noise -40 dB, non-auditable frequency ≥20 kHz
HDPE idlers	40-60 dB	15 kHz to 25 kHz	
Pillar - from 8 m from MPC	Peak particle velocity (R^2)	Peak Frequency (R^2)	This documents the range of readings, which require long term study
Radial	0.072	0.123	
Transverse	0.044	0.101	
Vertical	0.039	0.240	
Luminance levels at 100 m from MPC	**Luminescence Range (Lux)**		
Light at Bannihatti Transfer point	0-173		This documents the range of readings, which require long term study
Light at Devdari down Hill Pipe Conveyor	0-141		
Light at Jaffer Sheriff Mines	0-144		

The study documents the persistence of high biodiversity in the target habitat that includes 217 species of plants, 192 species of arthropods, 13 species of amphibians, 38 species of reptiles, 125 species of birds, 33 species mammals (Table 12.2). Of the total 624 species, 23 species are of high important species (Schedule-I) in Indian Wildlife (Protection) Act 1972 and 16 species are of highly threatened (Vulnerable and Near Threatened) species as listed by IUCN Red List. This documentation of high biodiversity and also occurrence of many threatened and scheduled species demonstrates the importance of the area as an important habitat.

Table 12.2. List flora and fauna under The Wildlife Protection Act 1972 and IUCN

Flora and Fauna	Total Species	Wildlife Protection Act-1972 (WPA) Schedule -I to V					International Union for Conservation of Nature (IUCN)		
		I	II	III	IV	V	Vulnerable	Near Threatened	Least Concerned
Plants	217						3		18
Arthropods	192	3	2						7
Amphibians	13				1				10
Reptiles	38	3	3		11		1	1	9
Aves	125	13			111	1	2	4	119
Mammals	33	4	9	1	7		4	1	27
Total	605	23	14	1	130	1	10	6	197

The responses of flora and fauna in relation to the MPC and its running time are summarized in the Table 12.3. Due to removal of the vegetation and disturbance caused while erecting the MPC, it has led to loss of old treegrowth and native tress, while many invasive alien species especially of weed species have invaded. This has changed the species composition along MPC, in turn affected the dependent wildlife species also.

Table 12.3. Summarizes the responses of flora and fauna in relation to the MPC and its running time.

Flora/Fauna	**Taxa/group of animals**	**Observed pattern**	**Conclusion**
Loss of habitat and other disturbance caused due to MPC			
Plants	*Prosopis juliflora*	Accounted for maximum number of individuals (n=175) while in the control it is absent.	Absence of *Prosopis juliflora*in control site just 500m away from MPC indicating the invasive species has entered physically disturbed MPC stretch
	Parthenium hysterophorus	High frequency (45.71%), density (8.40) and abundance (18.38) in MPC are compare to control site	Invasive species infestation along MPC stretch
	Endemic species *(Grewia orbiculata, Dolichandrone atrovirens, Justicia glauca,Dolichandrone falcata)*	Comparatively low density along MPC, *Justicia glauca andDolichandrone falcate* are absent	Endemic species distribution is below average along MPC stretch
	Tree	Low basal area cover along MPC than control.Carbon content (9.35 tonnes/ha) stored is below the half of carbon content of control area (17.49 tonnes/ha).	Trees are important in balancing atmospheric carbon emissions and its sink. More number of trees help in sinking more carbon emissions there by decreasing the impact on climate.
Mammals	Sloth Bear	Higher RAI along MPC area and lesser in Control site. The	Higher abundance and increased activity were seen in Control sites, indicating a

		overlap curve indicates the delayed start in their activity early retreat, whereas in control sites, started earlyand retreated late.	possible loss of habitat along MPC.
	Four-Horned Antelope	Recorded only from forest area.	Strict forest dwelling species. Indicating that the MPC area is unsuitable
	Asian Palm Civet	Recorded only from Control Sites	Absent near MPC region, indicating a possible loss in habitat.
	Indian Crested Porcupine	RAI was higher near MPC area and lesser in Control site.	Higher abundance seen in Control sites than at the MPC region.
	Leopard	RAI was higher near MPC area and lesser in Control site.	Higher abundance and increased activity in Control sites.
	Overall terrestrial mammals	Species richness near MPC was comparatively lower (H=1.41 at 12h, H=1.59 at 20h) than that of Control site (H=2.10)	Higher Species richness at Control Sites, indicates that some species have avoided MPC and confined to the forest.
Birds	Common Myna	Abundantly was observed using the MPC structure as a congregation spot and as a perch.	Generalist species were observed to be habituated to the MPC operations.
	Indian Roller	The insectivorous bird species in the agricultural habitats was observed to use the MPC structure as perching heights for screening crops for foraging insects	Generalist species were observed to be habituated to the MPC operations.
	Blue-faced Malkoha	Species occurrence was recorded only from the forest habitats	This shy species forage on insects and fruits from the thick canopies where it can also hide from the predators.
	Sirkeer Malkoha	Species occurrence was recorded only from the control site forest habitats	The occurrence of species wasaway from MPC noise.
		Increased sightings of insectivorous birds in the open areas around MPC and in the scrub habitats	In the open and the scrub areas, species like Ashy Prinia, Plain Prinia were observed to occur in high numbers
Arthropoda	Butterflies	Host plants for the Lepidoptera were less (Swallow tails, skippers)	Many species were not found near MPC and extensive growth of invasive species
Existing sound (including ultrasonic sound)12-hours of MPC run and its impact Between MPC and Control sites, Or Increase in the perpendicular distance from the MPC			
Mammals	Indian Crested Porcupine	There was about 58% of overlap in the activity (Δ=0.58) seen between 12 hours of belt run and Control sites. During 12 Hours of belt run, the Porcupines remained active from 22:00 to 03:00, with a peak in activity at 03:00.	Difference in the activity pattern of the porcupines during 12 h belt run and at Control sites.
	Sloth Bear	There was about 50% of overlap in the activity (Δ=0.50) seen between 12 hours of belt run and Control sites. The	Difference in the activity pattern of the bears during 12 h belt run and at Control sites.

		overlap curve indicates the delayed start in activity and early retreat in 12 h whereas in control sites, they started early and retreated late.	
	Overall Terrestrial mammals	Species Richness near MPC was comparatively lower H=1.41 during 12h belt run than that of Control site H=2.10	Higher Species richness at Control Sites.
Birds	Aves	Species diversity was observed to be different and decreased in the MPC sampling sites. Forest habitat shows decrease in the species diversity.	The shy and canopy dwelling species like Blue-faced Malkoha, Sirkeer Malkoha, spot-breasted Fantail flycatchers, Tickell’s Blue flycatcher were sighted away from MPC and in Control sites
Extended time of MPC belt run for 20 hours			
Amphibians	*Duttaphrynus melanostictus*	Decreased number of calling individuals. Abundance decreased	Masking by frequency spectrum of MPC may have impacted calling activity.
	Duttaphrynus scaber	Decreased number of individuals Calling. Abundance increased	Masking by frequency spectrum of MPC may have impacted calling activity
	Microhyla ornata	Increased number of individuals Calling. Abundance decreased	Perhaps to overcome the masking, individuals are increasing the number of calls. Needs long term study to understand the impact better
	Minervarya agricola	No change in number of individuals Calling. Abundance decreased	Individuals may have moved away from the habitat. Needs long term study to understand the impact better
	Polypedates maculatus	Decreased number of individuals Calling. Abundance decreased	Masking by frequency spectrum of MPC may have impacted calling activity
Reptiles	*Calotes versicolor*	Basking, Resting and moving activities are increased. Abundance increased	The activities increased may be due to the disturbance which made them spend more time in resting. Also the movement increase can also be due to the disturbance since they tend to avoid noise or vibration disturbance.
	Hemidactylus frenatus	Basking, Foraging activities decreased. Resting is increased. Abundance decreased	The activities increased may be due to the disturbance which made them spend more time in resting.
	Hemidactylus leschenaultii	Moving and resting activities decreased. Abundance decreased	The resulted decrease in the activities may be due to the decreased detection of the individuals. The abundance may be decreased as an effect of MPC.
	Hemidactylus parvimacculatus	Basking activity decreased. Moving and Resting activities decreased. Abundanceincreased	The activities increased may be due to the disturbance which made them spend more time in resting. Also the movement increase can also be due to the disturbance since they tend to avoid noise or vibration disturbance.
	Hemidactylus triedrus	Moving activity increased and resting increased. Abundance decreased	The activities increased may be due to the disturbance which made them spend more time in resting. Also the movement

			increase can also be due to the disturbance since they tend to avoid noise or vibration disturbance.
	Melanochelys trijuga	Activities decreased. Abundance didn't change.	
	Psamophilus dorsalis	Activities increased. Abundance also increased	
	Xenochrophis piscator	Foraging and moving activities decreased. Abundance also decreased	
Mammal (Bats)	*Tadarida aegyptiaca*	Most common species recorded across habitats. Highest abundance was found in Forest followed by Scrub land. The activity pattern changed during the 20 hours operating resulting in delayed start as well as extended hours of activity.	The delayed start could deprive it from foraging its prey and extend its foraging time. This could result in stress and reduced food source.
	Chaerephon plicatus	Most common species recorded across habitats. Highest abundance was found in Forest followed by Scrub land. The activity pattern changed during the 20 hours operating resulting in delayed start as well as extended hours of activity.	The delayed start could deprive it from foraging its prey and extend its foraging time. This could result in stress and reduced food source.
	Pipistrellus ceylonicus	Found consistently all along the MPC irrespective of the habitat. The foraging activity was reduced at built-up area during the extended hours of operation	Having a peak frequency of about 35 kHz the sound will have an impact in the built-up area like the plant, but may not have significant impact in other habitats if the MPC sound is within 20-25 kHz.
Large Mammals	Indian Crested Porcupine	There was about 67% of overlap in the activity (Δ=0.67) seen between 12 hours and 20 hours of belt run.	During 20 h of belt run, interestingly the activity was comparatively higher.
	Sloth Bear	There was about 62% of overlap in the activity (Δ=0.62) seen between 12 hours and 20 hours of belt run.	The activity was comparatively lower during 20 h of belt run.
	Overall Terrestrial mammals	Species Richness near MPC was comparatively lower H=1.59 during 20h belt run than that of Control site H=2.10	Higher Species richness at Control Sites.
Birds	Spotted Owlet	Decreased frequency of sightings	There is a considerable impact of extended operation of MPC (Totally 20 hours run) on nocturnal birds
	Indian Nightjar	Decreased frequency of sightings	There is a considerable impact of extended operation of MPC (Totally 20 hours run) on nocturnal birds
Arthropoda	Orthopterans	Shifts in the Calling activity of the crickets and grasshoppers, delay in the calling activity of the grasshoppers and crickets	Orthopterans calls may masked by the MPC sound or some species of crickets may change their calling frequency,
	Pollinators	Foraging bout of pollinators is less	Avoidance of disturbed habitat by the pollinators as they are most sensitive

Some of the arthropods show that the species richness and their abundance increase perpendicularly away from the MPC that too in forest area. Similarly, although some of the mammal species have abundance along the MPC, but certain species are highly confined to forest and away from the MPC. However, seeing the pattern of these animals' distribution in relation to the MPC and the noise generated it is difficult to draw any conclusion without understanding the seasonality of animal movement in the landscape. In contrast to this, some of the mammals and also birds showed their abundance along the MPC, but those species are synanthropic or commensal which are adapted to live in a human dominated landscape. They are highly adaptable and colonizers. Such species dominated the MPC.

Some of the nocturnal mammals e.g., Sloth Bear, few bat species, birds e.g., Spotted Owlet, arthropods e.g., cricket species, amphibians e.g., many frog species, showed decreased activity and also shift in their activity (2 to 3 hours of delay in starting of their activity), and some of their activity peaked after 1 AM by many of these nocturnal creatures. Further, masking of their calls due to the noise from the MPC is also observed in bats and frogs. However, though there will be an immediate impact on certain species, some of the species will be able to cope-up with up to a certain level of noise, while some of the species may get really affected.

The soundscape developed in the study indeed reveals that there is a band of sound (up to 80-100 m from the MPC that can be considered as noise which is more than the permissible range for wildlife. As established in chapters of different faunal elements, the initial responses as a decrease in their number and shift in their activity by many especially the nocturnal animals (Table 12.3), such noise band might create a population fragmentation for some species of animals and even also arial fragmentation of the habitat for some sensitive species which is of management concern.

The study conducted is a standalone study focusing only on MPC and adjoining landscape areas from the MPC. Further the study was conducted to understand the impact of extended time of the belt on the animals. However, when the earlier baseline data on occurrence and abundance of animals are not available for the entire landscape, conducting a study in a smaller part of the landscape will provide highly biased information as the impact is already created due to two years of belt run from 2019.

Further, in such small forests or forest fragment in the Deccan plateau where the targeted habitat may have importance in a certain season for certain species of animals since many animals have a much larger home ranges, e.g., Wolves and leopards. Thus, a long-term study in larger landscape keeping the MPC in the center is indeed required to understand the impact due to MPC.

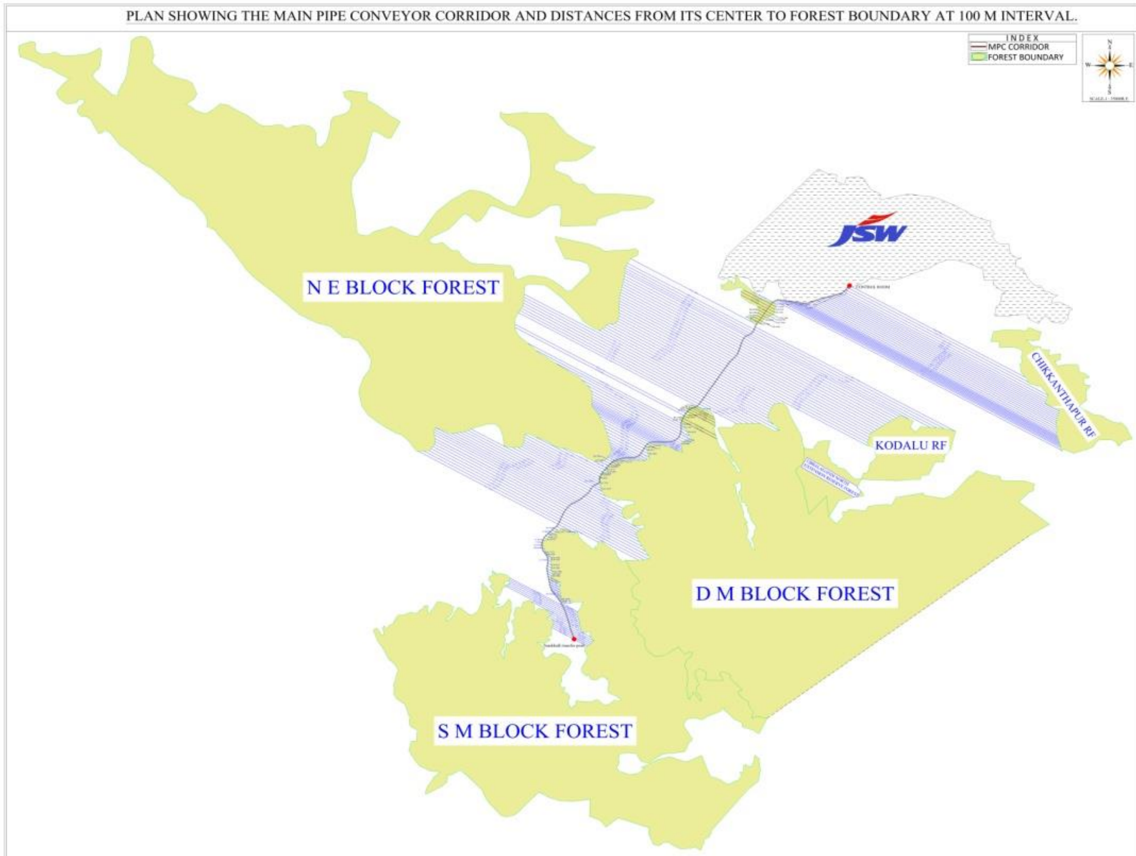
As given by JSW, out of 24 km length of MPC, 1.6 km is in forest. But available wild habitat is several folds high including scrub forest and plantations of Bannihatti and a long stretch of Narihalla. Further, these areas have emerged as an important habitat with high biodiversity. Thus, the issue has to be seen from the point of the requirement of wildlife ecology and at the level of the ecosystem.

MPC is projected as a linear feature for the transit through the landscape (especially in the forest area, e.g., 1.6 km). However, the MPC operations in this study clearly indicated the interaction and impact of MPCs are dynamic, multidimensional and complex in nature with the existing landscape, vegetation and wildlife.

The study also identified the area of conservation significance i.e., dry deciduous forest patch at Narihalla and open scrub land at Bannihatti accounted for maximum number of species richness regarding native species, schedule species and threatened species. Since all other stretches are already altered for anthropogenic activities like agriculture, built-up and mining activities, our study suggests Narihalla and Bannihatti stretch can be considered as 'source' for many of the taxa's, perhaps area of conservation significance. Thus, the fewer disturbances in those sites and also proper protection of those patches would help in protecting the source population to ensure a sustainable ecosystem by avoiding detrimental impact on wildlife and its ecology and ethology.

In addition to the noise generated by the MPC, there is a need to consider the impact of vibrations and the flood light at the loading stations on the wildlife. Therefore, besides the environmental factors, it is extremely important to keep in view, the wildlife and ecological aspects of ecosystem as well.

Annexure 1. 1 Forest boundary Map



Annexure 5.1. Detailed checklist of flowering plant species recorded in the study area along with their occurrence in MPC area and control site.

SL NO.	Family/Botanical name	Habit/Nature of presence/ Endemism/IUCN status	MPC area	Control area
	Acanthaceae			
1	*Andrographis echioides* (L.) Nees	H/W/NE/NE	+	-
2	*Barleria prionitis* L.	US/In/NE/NE	+	-
3	*Justicia glauca*Rottl.	H/W/PI/NE	-	+
4	*Justicia procumbens* L.	H/W/NE/NE	-	+
5	*Justicia spp*.	H/W	+	+
6	*Ruellia patula* Jacq.	H/W/NE/NE	+	+
7	*Ruellia pseudopatula* Ensermu	H/W/NE/NE	+	-
8	*Blepharis maderaspatensis* (L.) Roth.	H/W/NE/NE	+	+
	Amaranthaceae			
9	*Aerva javanica* (Burm.f.) Juss. exSchult.	S/W/NE/NE	+	-
10	*Aerva lanata* (L.) Juss. exSchult.	H/W/NE/NE	+	+
11	*Alternanthera tenella*	H/Wd/NE/NE	+	-
12	*Alternanthera ficoidea*	H/Wd/NE/NE	+	-
13	*Alternanthera paronychioides* A.St.-Hil.	H/Wd/NE/NE	+	-
14	*Alternanthera pungens*	H/Wd/NE/NE	+	-
15	*Alternanthera sessilis* (L.) R.Br. ex DC.	H/Wd/NE/LC	+	-
16	*Celosia argentea* L.	H/Wd/NE	+	-
	Amaryllidaceae			
17	*Allium cepa* L.	H/AC/NE/LC	+	-
	Anacardiaceae			
18	*Buchanania lanzan* Spreng	T/W/NE/NE	+	-
	Annonaceae			
19	*Annona squamosa* L.	T/In/NE/NE	+	-
20	*Huberantha cerasoides* (Roxb.) Chaowasku	T/W/NE/NE	+	+
	Apocynaceae			
21	*Gymnema sylvestre (*Retz.) R.Br. ex Schult.	L/W/NE/NE	+	+

22	*Hemidesmus indicus* (L.) R.Br.	C/W/NE/NE	+	-
23	*Holarrhena pubescens* Wall. ex G.Don	T/W/NE/LC	+	+
24	*Ichnocarpus frutescens* (L.) R.Br.	L/W/NE/NE	+	+
25	*Calotropis gigantea* (L.) W.T.Aiton	T/Wd/NE/NE	+	-
26	*Calotropis procera* (Aiton) W.T.Aiton	T/Wd/NE/NE	+	-
27	*Caralluma adscendens* var. *fimbriata* (Wall.) Gravely &Mayur			
	Carissa spinarum L.	H/W/PI/NE	+	+
28	*Cryptolepis buchananii* R.Br. ex Roem. &Schult.	S/W/NE/NE	+	+
29	*Cryptostegia grandiflora* R.Br.	CS/W/NE/NE	+	+
30	*Pergularia daemia* (Forssk.) Chiov.	L/In/NE/NE	+	-
31	*Tylophora indica* (Burm.f.) Merr.	C/W/NE/NE	+	+
32	*Wattakaka volubilis* (L.f.) Stapf	C/W/NE/NE	-	+
33	*Wrightia tinctoria* (Roxb.) R.Br.	L/W/NE/NE	+	+
34		T/W/NE/LC	+	+
	Arecaceae			
35	*Cocos nucifera* L.	Pm/C/NE/NE	+	-
	Asparagaceae			
36	*Asparagus racemosus* Willd.	CS/W/NE/NE	+	+
37	*Asparagus spp*.	CS/W	+	+
	Asteraceae			
38	*Ageratum conyzoides* L.	H/Wd/NE/NE	+	-
39	*Chromolaena odorata* (L.) R.M.King&H.Rob.	US/I/NE/NE	+	+
40	*Eclipta prostrata* (L.) L	H/W/NE/NE	+	-
41	*Grangea maderaspatana* (L.) Poir.	H/W/NE/LC	+	-
42	*Lagascea mollis* Cav.	H/Wd/NE/NE	+	-
43	*Parthenium hysterophorus* L.	US/I/NE/NE	+	+
44	*Tridax procumbens* L.	H/Wd/NE/NE	+	+
45	*Vernonia spp*.	H/W	-	+
	Basellaceae			
46	*Basella alba* L.	C/C/NE/NE	+	-
	Bignoniaceae			
47	*Dolichandrone atrovirens* (Roth) Sprague	T/W/PI/NE	+	+
48	*Dolichandrone falcata* (Wall. ex. DC.) Seem.	T/W/NE/NE	-	+
	Boraginaceae			

49	*Cordia dichotoma* G.Frost.	T/W/NE/NE	+	-
50	*Trichodesma indicum* (L.) Lehmann	H/Wd/NE/NE	+	-
	Cactaceae			
51	*Opuntia dillenii* (Ker Gawl.) Haw.	S/In/NE/NE	+	-
	Capparaceae			
52	*Cadaba fruticosa* (L.) Druce	S/W/NE/NE	+	+
53	*Cleome felina* L.f.	H/W/PI/NE	+	-
54	*Cleome viscosa* L.	H/Wd/NE/NE	+	-
	Celastraceae			
55	*Gymnosporia montana* Benth.	S/W/NE/NE	+	+
	Combretceae			
56	*Terminalia alata* Heyne ex Roth	T/P/NE/NE	+	-
57	*Terminalia arjuna* (Roxb. ex DC.) Wight &Arn.	T/P/NE/NE	+	-
58	*Terminalia bellirica* (Gaertn.) Roxb.	T/W/NE/NE	+	-
59	*Terminalia catappa* L.	T/P/NE/NE	+	-
60	*Terminalia anogeissiana* Gere &Boatwr.	T/W/NE/NE	-	+
	Commelinaceae			
61	*Cyanotis spp*.	H/W/NE/NE	+	+
62	*Commelina benghalensis* L.	H/W/NE/LC	+	+
	Convolvulaceae			
63	*Argyreia nervosa* (Burm.f.) Bojer	CS/In/NE/NE	+	-
64	*Evolvulus alsinoides* (L.) L.	H/W/NE/NE	+	+
65	*Ipomoea cairica* (L.) Sweet	L/In/NE/NE	+	-
66	*Ipomoea obscura* (L.) Ker Gawl.	C/In/NE/NE	+	-
	Cucurbitaceae			
67	*Cucumis prophetarum* L.	C/Wd/NE/NE	+	-
68	*Coccinia grandis* (L.) Voigt	C/C/NE/NE	+	-
	Ebenaceae			
69	*Diospyros melanoxylon* Roxb.	T/W/NE/NE	+	+
70	*Diospyros montana* Roxb.	T/W/NE/NE	+	+
	Euphorbiaceae			
71	*Acalypha ciliata* Forssk.	H/W/NE/NE	+	-
72	*Croton bonplandianus* Baill.	H/I/NE/NE	+	+
73	*Euphorbia hirta* L.	H/Wd/NE/NE	+	+

74	*Euphorbia heterophylla* L.	H/Wd/NE/NE	+	-
75	*Euphorbia hypericifolia L.*	H/Wd/NE/NE	+	-
76	*Euphorbia caducifolia* Haines	S/W/NE/NE	+	+
77	*Euphorbia serpens* Kunth	H/W/NE/NE	+	-
78	*Euphorbia tirucalli* L.	T/In/NE/LC	+	-
79	*Givotia moluccana* (L.) Sreem.	T/W/NE/NE	-	+
80	*Jatropha curcas* L.	T/In/NE/NE	+	-
81	*Jatropha gossypiifolia* L.	US/In/NE/NE	+	+
82	*Tragia plukenetii* Radcl.-Sm.	US/W/NE/NE	+	-
	Fabaceae			
83	*Acacia auriculiformis* Benth.	T/In/NE/LC	+	-
84	*Abrus precatorius* L.	CS/W/NE/NE	+	+
85	*Albizia amara* (Roxb.) Boivin	T/W/NE/LC	+	+
86	*Albizia lebbeck* (L.) Benth.	T/W/NE/NE	+	-
87	*Alysicarpus vaginalis* (L.) DC.	H/W/NE/NE	+	-
88	*Bauhinia racemosa* Lam.	T/W/NE/NE	+	-
89	*Cajanus cajan* (L.) Huth	S/AC/NE/NE	+	-
90	*Cassia fistula* L.	T/W/NE/NE	+	+
91	*Crotalaria hebecarpa* (DC.) Rudd	H/W/NE/NE	+	+
92	*Crotalaria pallida* Aiton	US/Wd/NE/NE	+	-
93	*Cyamopsis tetragonoloba* (L.) Taub.	US/C/NE/NE	+	-
94	*Dalbergia latifolia* Roxb.	T/W/NE/VU	+	+
95	*Dalbergia paniculata* Roxb.	T/W/NE/NE	+	+
96	*Hardwickia binata* Roxb.	T/W/I/NE	+	+
97	*Indigofera cordifolia*Heyne ex Roth	H/W/NE/NE	+	+
98	*Indigofera linnaei* Ali	H/W/NE/NE	+	+
99	*Leucaena leucocephala* (Lam.) de Wit	T/In/NE/NE	+	-
100	*Mimosa hamata* Willd.	S/W/NE/NE	+	-
101	*Mucuna pruriens* (L.) DC.	L/W/NE/NE	+	-
102	*Paracalyx scariosus* (Roxb.) Ali	L/W/NE/NE	+	-
103	*Parkinsonia aculeata* L.	T/In/NE/NE	+	-
104	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	T/P/NE/NE	-	-
105	*Pongamia pinnata* (L.) Pierre	T/W/NE/LC	+	-
106	*Prosopis juliflora* (Sw.) DC.	T/I/NE/NE	+	-

107	*Rhynchosia aurea* DC.	H/W/NE/NE	+	+
108	*Rhynchosia minima* (L.) DC.	C/W/NE/LC	+	+
109	*Senegalia chundra* (Roxb. ex Rottler) Maslin	T/W/NE/NE	+	+
110	*Senegalia pennata* (L.) Maslin	CS/W/NE/LC	+	-
111	*Senna auriculata* (L.) Roxb.	S/W/NE/NE	+	+
112	*Senna occidentalis* (L.) Link	S/C/NE/NE	+	-
113	*Senna siamea* (Lam.) H.S.Irwin&Barneby	T/C/NE/NE	+	-
114	*Senna surattensis* (Burm. f.) H.S. Irwin &Barneby	T/W/NE/NE	+	-
115	*Senna tora* (L.) Roxb.	H/W/NE/NE	+	+
116	*Sesbania bispinosa* (Jacq.) W.Wight	S/W/NE/LC	+	-
117	*Stylosanthes guianensis* (Aubl.) Sw.	H/Wd/NE/NE	+	+
118	*Tamarindus indica* L.	T/In/NE/NE	+	-
119	*Tephrosia purpurea* (L.) Pers.	US/W/NE/NE	+	-
120	*Vachellia horrida* (L.) Kyal. &Boatwr.	T/W/NE/NE	+	+
121	*Vachellia leucophloea* (Roxb.) Maslin, Seigler&Ebinger	T/W/NE/NE	+	+
122	*Vachellia nilotica* (L.) P.J.H.Hurter&Mabb.	T/In/NE/NE	+	-
	Lamiaceae			
123	*Anisomeles malabarica* (L.) R.Br.	US/W/NE/NE	+	-
124	*Hyptis suaveolens* (L.) Poit.	S/Wd/NE/NE	+	+
125	*Leucas aspera* (Willd.) Link	H/Wd/NE/NE	+	-
126	*Leucas nutans* (Roth) Spreng.	H/W/NE/NE	+	-
127	*Ocimum sanctum* L.	US/C/NE/NE	+	-
128	*Rotheca serrata* (L.) Steane&Mabb.	S/W/NE/NE	+	-
129	*Tectona grandis*L.f.	T/W/NE/NE	-	+
130	*Vitex negundo* L.	S/W/NE/NE	+	-
	Loranthaceae			
131	*Dendrophthoe spp*.	P/W	+	-
	Lythraceae			
132	*Lagerstroemia parviflora* Roxb.	T/W/NE/NE	+	+
	Malvaceae			
133	*Abutilon indicum* (L.) Sweet	S/W/NE/NE	+	-
134	*Grewia flavescens* Juss.	S/W/NE/NE	+	+
135	*Grewia hirsuta* Vahl	S/W/NE/NE	+	+
136	*Grewia orbiculata* Rottler	T/W/PI/NE	+	+

137	*Grewia tenax* (Forssk.) Fiori	CS/W/NE/NE	-	+
138	*Grewia villosa* Willd.	T/W/NE/NE	+	-
139	*Gossypium arboreum* L.	S/AC/NE/NE	+	-
140	*Hibiscus vitifolius* L.	US/W/NE/NE	+	-
141	*Pavonia zeylonica* (L.) Cav.	US/Wd/NE/NE	+	+
142	*Sida acuta* Burm.f	US/W/NE/NE	+	-
143	*Melhania incana* Heyne ex Wight &Arn.	H/Wd/NE/NE	+	-
	Martyniaceae			
144	*Martynia annua* L.	US/Wd/NE/NE	+	-
	Meliaceae			
145	*Azadirachta indica* A.Juss.	T/W/NE/NE	+	+
146	*Soymida febrifuga* (Roxb.) A.Juss.	T/W/NE/NE	+	+
	Menispermaceae			
147	*Cocculus hirsutus* (L.) Diels	CS/W/NE/NE	+	-
148	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	CS/W/NE/NE	+	-
	Molluginaceae			
149	*Glinus lotoides* L.	H/W/NE/NE	+_	-
	Moraceae			
150	*Ficus arnottiana* (Miq.) Miq.	T/W/NE/NE	-	+
151	*Ficus benghalensis* L.	T/W/NE/NE	+	-
152	*Ficus carica*L.	T/C/NE/NE	+	-
153	*Ficus racemosa* L.	T/W/NE/NE	+	-
154	*Ficus religiosa* L.	T/W/NE/NE	+	-
155	*Ficus spp*.	T/W/NE/NE	+	+
	Moringaceae			
156	*Moringa oleifera* Lam.	T/C/NE/NE	+	-
	Muntangiaceae			
157	*Muntingia calabura*L.	T/C/NE/NE	+	-
	Musaceae			
158	*Musa paradisiaca* L.	H/C/NE/NE	+	-
	Myrtaceae			
159	*Eucalyptus tereticornis* Sm	T/C/NE/NE	+	-
	Nyctaginaceae			
160	*Boerhavia diffusa* L.	H/W/NE/LC	+	+

	Oleaceae			
161	*Jasminum roxburghianum*Wall. ex. C.B.Clarke	CS/W/NE/NE	+	-
	Orobanchaceae			
162	*Striga densiflora* (Benth.) Benth.	H/W/I/NE	+	+
	Passifloraceae			
163	*Passiflora foetida* L.	C/W/NE/NE	+	-
	Papaveraceae			
164	*Argemone mexicana* L.	H/I/NE/NE	+	-
	Phyllanthaceae			
165	*Flueggea leucopyrus* Willd.	S/W/NE/NE	+	+
166	*Phyllanthus amarus*Schumacher &Thonn.	H/W/NE/NE	+	-
167	*Phyllanthus maderaspatensis* L.	H/W/NE/NE	+	+
168	*Phyllanthus reticulatus* Poir.	S/W/NE/NE	+	-
169	*Phyllanthus virgatus* G. Forster	H/W/NE/NE	+	+
	Plantaginaceae			
170	*Scoparia dulcis* L.	H/W/NE/NE	+	-
171	*Bacopa monnieri* (L.) Wettstein	H/W/NE/LC	+	-
	Poaceae			
172	*Bambusa arundinacea* Willd.	S/W/NE/NE	+	-
173	Bannihatti grass	H/W	+	+
174	*Chloris barbata* Sw.	H/W/NE/NE	+	-
175	*Cymbopogon martini* (Roxb.) Wats.	H/W/PI/NE	+	+
176	*Cynodondactylon* (L.) Pers.	H/W/NE/NE	+	-
177	*Cynodon sp*.	H/W	+	-
178	*Dactyloctenium aegyptium* (L.) P.Beauv.	H/W/NE/NE	+	-
179	*Digitaria bicornis* (Lam.) Roem. &Schult.	H/W/NE/NE	+	-
180	*Pennisetum pedicellatum* Trin.	H/W/NE/NE	+	-
181	*Setaria italica* (L.) Beauv.	H/AC/NE/NE	+	-
182	*Tragus roxburghii* Panigrahi	H/W/NE/NE	+	+
183	*Urochloa panicoides* P.Beauv.	H/W/NE/LC	+	+
184	*Zea mays* L.	H/AC/NE/NE	+	-
	Rhamnaceae			
185	*Ventilago maderaspatana* Gaertner	L/W/NE/NE	+	-
186	*Ziziphus horrida* Roth	T/W/NE/NE	+	+

187	*Ziziphus mauritiana* Lam.	T/In/NE/NE	+	+
188	*Ziziphus oenopolia* (L.) Mill.	CS/W/NE/NE	+	+
	Rubiaceae			
189	*Borreria stricta* (L.f.) K.Schum.	H/Wd/NE/NE	+	-
190	*Canthium coromandelicum* (Burm.f.) Alston	S/W/NE/NE	+	+
191	*Catunaregam spinosa* (Thunb.) Tirveng.	S/W/NE/NE	+	+
192	*Gardenia gummifera* L.f.	T/W/PI/LC	+	+
193	*Ixora pavetta* Andrews	T/W/NE/NE	+	+
194	*Ixora spp*.	T/W	+	+
195	*Meyna laxiflora* Robyns	T/W/NE/NE	-	+
196	*Morinda coreia* Buch.-Ham	T/W/NE/NE	+	+
197	*Oldenlandia sp*.	H/W	-	+
	Rutaceae			
198	*Chloroxylon swietenia* DC.	T/W/NE/VU	+	+
199	*Limonia acidissima* L.	T/W/NE/NE	+	+
	Santalaceae			
200	*Santalum album* L.	T/W/NE/VU	+	+
	Solanaceae			
201	*Capsicum spp*.	S/AC/NE/NE	+	-
202	*Datura innoxia* Mill.	US/In/NE/NE	+	-
203	*Datura stramonium* L.	S/In/NE/NE	+	-
204	*Solanum virginianum* L.	H/W/NE/NE	+	-
205	*Solanum torvum* Sw.	S/In/NE/NE	+	-
	Sapindaceae			
206	*Cardiospermum halicacabum* L.	C/W/NE/NE	+	-
207	*Dodonaea viscosa* N. Jacq.	S/W/NE/NE	+	+
	Simaroubaceae			
208	*Ailanthus excelsa* Roxb.	T/C/NE/NE	+	-
	Ulmaceae			
209	*Holoptelea integrifolia* (Roxb.) Planch.	T/W/NE/NE	+	+
	Verbenaceae			
210	*Lantana camara* var. *aculeata* (L.) Moldenke	S/I/NE/NE	+	+
211	*Phyla nodiflora* (L.) Greene	H/W/NE/LC	+	-

212	*Priva cordifolia* (L.f.) Druce	H/W/NE/NE	+	-
213	*Stachytarpheta indica* (L.) Vahl	US/Wd/NE/NE	+	-
	Violiaceae			
214	*Hybanthus enneaspermus* (L.)	H/W/NE/NE	+	-
	Zygophyllaceae			
215	*Balanites roxburghii* Planch.	T/W/NE/NE	+	+
216	*Tribulus terrestris* L.	H/W/NE/NE	+	-
217	*Zygophyllum indicum* (Burm.f.) Christenh. & Byng	S/Wd/NE/NE	+	+

Species : 217 Genera : 162 Family : 54

(H = Herb, US = Under shrub, S = Shrub, CS = Climbing Shrub, C = Climber, L = Liana, T = Tree, Pm = Palm.
W = Wild, Wd = Weed, C = Cultivated, I = Invasive, In = Introduced, AC = Agricultural Crop.
NE = Non Endemic, PI = Peninsular India, I = India.
NE = Not evaluated, VU = Vulnerable, LC = Least concern)

Annexure 5.2. Comparison of Frequency, Abundance and density of recorded herb species in MPC area and control site.

Botanical name	Frequency (%)		Abundance		Density	
	MPC	Control	MPC	Control	MPC	Control
Aerva lanata (L.) Juss. ex Schult.	-	10	-	06	-	0.6
Allium cepa L.	2.86	-	30.00	-	0.86	-
Alternanthera ficoidea (L.) Sm	28.57	-	9.60	-	2.74	-
Alternanthera paronychioides A.St.-Hil.	5.71	-	55.50	-	3.17	-
Alternanthera sessilis (L.) R.Br. ex DC.	2.86	-	5.00	-	0.14	-
Alternanthera tenella Colla	37.14	-	10.38	-	3.86	-
Alysicarpus vaginalis (L.) DC.	5.71	-	4.00	-	0.23	-
Andrographis echioides (L.) Nees	5.71	-	2.50	-	0.14	-
Argemone mexicana L.	8.57	-	7.67	-	0.66	-
Bacopa monnieri (L.) Wettstein	2.86	-	8.00	-	0.23	-
Bannihatti grass	25.71	60	21.33	21.33	5.49	12.8
Blepharis maderaspatensis (L.) Roth.	5.71	10	2.00	25	0.11	2.5
Boerhavia diffusa L.	20.00	10	5.57	1	1.11	0.1
Caralluma adscendens var. *fimbriata* (Wall.) Gravely & Mayur	2.86	10	1.00	1	0.03	0.1
Chloris barbata Sw.	5.71	-	5.50	-	0.31	-
Cleome felina L.f.	5.71	-	1.00	-	0.06	-
Commelina sp.	2.86	-	1.00	-	0.03	-
Commelina benghalensis L.	8.57	10	2.67	1	0.23	0.1
*Crotalaria hebecarpa (*DC.) Rudd	-	20	-	8	-	1.6
Croton bonplandianus Baill.	22.86	20	6.63	4	1.51	0.8
Cynodon dactylon (L.) Pers.	20.00	-	15.14	-	3.03	-
Cymbopogon martini (Roxb.) Wats.	42.86	70	7.93	17.85	3.40	12.5
Cynadon spp.	11.43	-	29.00	-	3.31	-
Cynotis spp.	8.57	30	2.00	2.33	0.17	0.7
Dactyloctenium aegyptium (L.) P.Beauv.	2.86	-	6.00	-	0.17	-
Dichanthium annulatum (Forssk.) Stapf	2.86	-	2.00	-	0.06	-
Digitaria bicornis (Lam.) Roem. &Schult.	8.57	-	4.33	-	0.37	-
Eclipta prostrata (L.) L	5.71	-	2.50	-	0.14	-
Euphorbia heterophylla L.	8.57	-	3.33	-	0.29	-
Euphorbia hirta L.	25.71	10	6.56	1	1.69	0.1
Euphorbia hypericifolia L.	2.86	-	2.00	-	0.06	-
Euphorbia serpens Kunth	8.57	-	16.67	-	1.43	-
Evolvulus alsinoides (L.) L.	17.14	10	4.17	1	0.71	0.1
Zygophyllum indicum (Burm.f.) Christenh. & Byng	2.86	10	2.00	2	0.06	0.2
Glinus lotoides L.	5.71	-	3.00	-	0.17	-

Grangea maderaspatana (L.) Poir.	5.71	-	2.00	-	0.11	-
Indigofera cordifolia Heyne ex Roth	31.43	60	5.82	14.66	1.83	8.8
Indigofera linnaei Ali	-	20	-	5	-	1
Justicia glauca Rottl.	-	10	-	1	-	0.1
Justicia procumbens L.	-	10	-	3	-	0.3
Justicia spp.	14.29	40	4.40	2.75	0.63	1.1
Lagascea mollis Cav.	2.86	-	12.00	-	0.34	-
Leucas nutans (Roth) Spreng.	2.86	-	1.00	-	0.03	-
Melhania incana Heyne ex Wight &Arn.	2.86	-	5.00	-	0.14	-
Oldenlandia sp.	-	10	-	1	-	0.1
Pavonia zeylonica (L.) Cav.	-	10	-	7	-	0.7
Pennisetum pedicellatum Trin.	2.86	-	6.00	-	0.17	-
Phyla nodiflora (L.) Greene	5.71	-	4.50	-	0.26	-
Phyllanthus amarus Schumacher &Thonn.	2.86	-	2.00	-	0.06	-
Phyllanthus maderaspatensis L.	28.57	20	8.40	3.5	2.40	0.7
Phyllanthus reticulatus Poir.	5.71	-	2.50	-	0.14	-
Phyllanthus virgatus G. Forster	17.14	10	2.00	1	0.34	0.1
Ruellia patula Jacq.	11.43	10	11.00	2	1.26	0.2
Ruellia pseudopatula Ensermu	2.86	-	4.00	-	0.11	-
Senna tora (L.) Roxb.	51.43	30	22.72	22.33	11.69	6.7
Striga densiflora (Benth.) Benth.	14.29	20	1.40	2.5	0.20	0.5
Stylosanthes guianensis (Aubl.) Sw.	20.00	20	2.43	8.5	0.49	1.7
Tragus roxburghii Panigrahi	2.86	10	5.00	23	0.14	2.3
Tribulus terrestris L.	2.86	-	4.00	-	0.11	-
Trichodesma indicum (L.) Lehmann	5.71	-	4.00	-	0.23	-
Tridax procumbens L.	31.43	20	14.36	5.5	4.51	1.1
Urochloa panicoides P.Beauv.	20.00	10	8.86	27	1.77	2.7
Wetland grass	5.71	-	5.50	-	0.31	-
Zea mays L.	11.43	-	32.75	-	3.74	-

Annexure 5.3. Comparison of Frequency, Abundance and density of recorded under shrub species in MPC area and control site.

Botanical name	Frequency (%)		Abundance		Density	
	MPC	Control	MPC	Control	MPC	Control
Abutilon indicum (L.) Sweet	5.71	-	4.5	-	0.25	-
Jathropha gossyppifolia	8.57	10	1.66	5	0.14	0.5
Parthenium hysterophorous	45.71	20	18.37	2.5	8.4	0.5
Pavonia odorata	8.57	-	1	-	0.08	-
Stachytarpheta indica	8.57	-	4.66	-	0.4	-
Tephrosia purpurea	11.42	-	2	-	0.22	-

Annexure 5.4. Comparison of Frequency, Abundance and density of recorded climber species in MPC area and control site.

Botanical name	Frequency (%)		Abundance		Density	
	MPC	Control	MPC	Control	MPC	Control
Abrus precatorius L.	2.85	10	1	1	0.028	0.1
Argyreia nervosa (Burm.f.) Bojer	2.85	-	1	-	0.028	-
Asparagus racemosus Willd.	11.42	20	3	1.5	0.342	0.3
Asparagus sp.	34.28	60	2.25	2.5	0.771	1.5
Cardiospermum halicacabum L.	8.57	-	2.33	-	0.2	-
Clitoria ternatea	2.85	-	2	-	0.057	-
Coccinia grandis (L.) Voigt	2.85	-	1	-	0.028	-
Cocculus hirsutus (L.) Diels	2.85	-	1	-	0.028	-
Cryptolepis buchananii R.Br. ex Roem. &Schult.	17.14	-	2	-	0.342	-
Cucumis prophetarum L.	5.71	-	1	-	0.057	-
Desmodium species	2.85	-	2	-	0.057	-
Gymnema sylvestre (Retz.) R.Br. ex Schult.	2.85	20	1	1.5	0.028	0.3
Hemidesmus indicus (L.) R.Br.	2.85	-	4	-	0.114	-
Ichnocarpus frutescens (L.) R.Br.	14.28	10	3	1	0.428	0.1
Ipomoea obscura (L.) Ker Gawl.	2.85	-	1	-	0.028	-
Mucuna pruriens (L.) DC.	2.85	-	1	-	0.028	-
Paracalyx scariosus (Roxb.) Ali	2.85	-	1	-	0.028	-
Passiflora foetida L.	8.57	-	2.66	-	0.228	-
Pergularia daemia (Forssk.) Chiov.	11.42	10	1.5	3	0.171	0.3
Rhynchosia aurea DC	20	60	2.28	2.5	0.457	1.5
Rhynchosia minima (L.) DC.	40	50	3.28	3.8	1.314	1.9
Rivea hypocrateriformis (Desr.) Choisy	-	20	-	1	-	0.2
Senegalia pennata (L.) Maslin	5.71	-	2	-	0.114	-
Wattakaka volubilis (L.f.) Stapf	11.42	-	2	-	0.228	-
Ziziphus oenopolia (L.) Mill.	17.14	20	2.5	2	0.428	0.4

Annexure 5.5. Comparison of Frequency, Abundance and density of recorded shrub species in MPC area and control site.

Botanical name	Frequency (%)		Abundance		Density	
	MPC	**Control**	**MPC**	**Control**	**MPC**	**Control**
Aerva javanica (Burm.f.) Juss. ex Schult.	8.57	-	1.33	-	0.11	-
Bambusa arundinacea Willd.	5.71	-	2.00	-	0.11	-
Canthium coromandelicum (Burm.f.) Alston	17.14	20	4.33	4	0.74	0.8
Capsicum spp.	5.71	-	18.00	-	1.03	-
Carissa spinarum L.	28.57	30	2.80	1.66	0.80	0.5
Catunaregam spinosa (Thunb.) Tirveng.	14.29	10	1.80	2	0.26	0.2
Chromolaena odorata (L.) R.M.King&H.Rob.	20.00	10	14.14	1	2.83	0.1
Datura innoxia Mill.	5.71	-	3.50	-	0.20	-
Dodonaea viscosa N. Jacq.	34.29	40	5.50	4.5	1.89	1.8
Euphorbia caducifolia Haines	-	10	-	1	-	0.1
Flueggea leucopyrus Willd.	37.14	50	2.77	2.2	1.03	1.1
Gossypium arboreum L.	5.71	-	7.50	-	0.43	-
Grewia flavescens Juss.	2.86	20	1.00	2	0.03	0.4
Grewia hirsuta Vahl	5.71	20	2.50	1.5	0.14	0.3
Gymnosporia montana Benth.	22.86	50	1.88	2	0.43	1
Hyptis suaveolens (L.) Poit.	25.71	10	9.89	13	2.54	1.3
Lantana camara var. *aculeata* (L.) Moldenke	45.71	50	7.06	1.8	3.23	0.9
Ocimum sanctum L.	5.71	-	5.00	-	0.29	-
Priva cordifolia (L.f.) Druce	2.86	-	11.00	-	0.31	-
Rotheca serrata (L.) Steane&Mabb.	5.71	-	2.00	-	0.11	-
Senna auriculata (L.) Roxb.	31.43	10	5.55	3	1.74	0.3
Senna occidentalis (L.) Link	5.71	-	1.50	-	0.09	-
Sida acuta Burm.f	2.86	-	1.00	-	0.03	-
Solanum stramoniifolium Jacq.	11.43	-	1.25	-	0.14	-
Solanum virginianum L.	5.71	-	4.50	-	0.26	-
Vitex negundo L.	2.86	-	2.00	-	0.06	-

Annexure 5.6. Comparison of Frequency, Abundance and density of recorded tree species in MPC area and control site.

Botanical name	Frequency (%)		Abundance		Density	
	MPC	Control	MPC	Control	MPC	Control
Acacia auriculiformis Benth.	2.86	-	13.00	-	0.37	-
Albizia amara (Roxb.) Boivin	37.14	50	2.69	3.8	1.00	1.9
Albizia lebbeck (L.) Benth.	5.71	-	1.00	-	0.06	-
Annona squamosa L.	5.71	-	2.00	-	0.11	-
Azadirachta indica A.Juss.	28.57	20	1.80	6	0.51	1.2
Bauhinia racemosa Lam.	5.71	-	1.00	-	0.06	-
Balanites roxburghii Planch.	2.86	-	1.00	-	0.03	-
Calotropis gigantea (L.) W.T.Aiton	8.57	-	1.67	-	0.14	-
Calotropis procera (Aiton) W.T.Aiton	5.71	-	1.50	-	0.09	-
Cassia fistula L.	34.29	70	3.17	4	1.09	2.8
Chloroxylon swietenia DC.	17.14	30	4.67	10.66	0.80	3.2
Cordia dichotoma G.Frost.	2.86	-	1.00	-	0.03	-
Dalbergia paniculata Roxb.	20.00	30	7.00	11.33	1.40	3.4
Diospyros melanoxylon Roxb.	8.57	10	7.67	6	0.66	0.6
Diospyros montana Roxb.	8.57	-	1.33	-	0.11	-
Dolichandrone atrovirens (Roth) Sprague	14.29	50	3.60	6	0.51	3
Dolichandrone falcata (Wall. ex DC.) Seem.	-	10	-	1	-	0.1
Ficus arnottiana (Miq.) Miq.	-	10	-	2	-	0.2
Ficus sp.	2.86	-	2.00	-	0.06	-
Gardenia gummifera L.f.	2.86	-	5.00	-	0.14	-
Givotia moluccana (L.) Sreem.	-	10	-	3	-	0.3
Grewia orbiculata Rottler	51.43	90	5.50	11.22	2.83	10.1
Grewia tenax (Forssk.) Fiori	-	10	-	1	-	0.1
Grewia villosa Willd.	5.71	-	1.00	-	0.06	-
Hardwickia binata Roxb.	5.71	20	2.00	5	0.11	1
Holarrhena pubescens Wall. ex G.Don	5.71	-	1.00	-	0.06	-
Holoptelea integrifolia (Roxb.) Planch.	2.86	-	2.00	-	0.06	-
Huberantha cerasoides (Roxb.) Chaowasku	2.86	10	43.00	2	1.23	0.2
Ixora sp	2.86	-	1.00	-	0.03	-
Ixora pavetta Andrews	11.43	10	5.50	1	0.63	0.1
Lagerstroemia parviflora Roxb.	5.71	-	1.50	-	0.09	-
Leucaena leucocephala (Lam.) de Wit	11.43	-	1.00	-	0.11	-

Limonia acidissima L.	2.86	-	1.00	-	0.03	-
Morinda coreia Buch.-Ham	65.71	60	4.70	7.33	3.09	4.4
Parkinsonia aculeata L.	2.86	-	17.00	-	0.49	-
Peltophorum pterocarpum (DC.) Backer ex K.Heyne	2.86	-	4.00	-	0.11	-
Pongamia pinnata (L.) Pierre	8.57	-	1.33		0.11	
Prosopis juliflora (Sw.) DC.	37.14	-	13.46		5.00	
Santalum album L.	-	10	-	1	-	0.1
Senegalia chundra (Roxb. ex Rottler) Maslin	54.29	90	5.63	10.22	3.06	9.2
Senna surattensis (Burm. f.) H.S. Irwin &Barneby	8.57	-	7.67	-	0.66	-
Soymida febrifuga (Roxb.) A.Juss.	2.86	20	1.00	1	0.03	0.2
Tamarindus indica L.	2.86	-	1.00	-	0.03	-
Tectona grandis L.f.	-	10	-	1	-	0.1
Terminalia anogeissiana Gere &Boatwr.	-	10	-	41	-	4.1
Terminalia bellirica (Gaertn.) Roxb.	2.86	-	1.00	-	0.03	-
Terminalia alata Heyne ex Roth	2.86	-	7.00	-	0.20	-
Vachellia horrida (L.) Kyal. &Boatwr.	-	10	-	1	-	0.1
Vachellia leucophloea (Roxb.) Maslin, Seigler&Ebinger	34.29	10	2.17	2	0.74	0.2
Vachellia nilotica (L.) P.J.H.Hurter&Mabb.	2.86	-	1.00	-	0.03	-
Wrightia tinctoria (Roxb.) R.Br.	22.86	60	3.63	9	0.83	5.4
Ziziphus horrida Roth	40.00	40	2.07	1.25	0.83	0.5
Ziziphus mauritiana Lam.	2.86	-	1.00	-	0.03	-

Annexure 5.7. Comparison of basal area cover of tree species in MPC area and control sites.

Name of the Species	MPC		Control	
	No. of individuals	**Basal area (m^2)**	**No. of individuals**	**Basal area (m^2)**
Albizia amara (Roxb.) Boivin	24	0.522	15	0.46
Albizia lebbeck (L.) Benth.	2	0.039	-	-
Annona squamosa L.	2	0.005	-	-
Azadirachta indica A.Juss.	10	0.315	4	0.01
Balanites roxburghii Planch.	1	0.008	-	-
Bauhinia racemosa Lam.	1	0.018	-	-
Cassia fistula L.	21	0.079	12	0.05
Chloroxylon swietenia DC.	13	0.100	22	0.06
Cordia dichotoma G.Frost.	1	0.029	-	-
Dalbergia paniculata Roxb.	17	0.634	27	0.13
Diospyros melanoxylon Roxb.	17	0.042	6	0.03
Diospyros montana Roxb.	2	0.032	-	-
Dolichandrone atrovirens (Roth) Sprague	9	0.042	18	0.08
Dolichandrone falcata (Wall. ex DC.) Seem.	-	-	1	0.03
Ficus spp.	2	0.057	-	-
Givotia moluccana (L.) Sreem.	-	-	3	0.05
Grewia orbiculata Rottler	40	0.276	51	0.35
Grewia tenax (Forssk.) Fiori	-	-	1	0.001
Grewia villosa Willd.	1	0.004	-	-
Holoptelea integrifolia (Roxb.) Planch.	2	0.012	-	-
Hardwickia binata Roxb.	-	-	10	0.123
Huberantha cerasoides (Roxb.) Chaowasku	10	0.078	-	-
Ixora pavetta Andrews	1	0.002	1	0.012
Ixora spp.	2	0.029	-	-
Lagerstroemia parviflora Roxb.	3	0.009	-	-
Leucaena leucocephala (Lam.) de Wit	4	0.017	-	-
Limonia acidissima L.	1	0.109	-	-
Morinda coreia Buch.-Ham	56	0.289	21	0.06
Parkinsonia aculeata L.	2	0.010	-	-
Peltophorum pterocarpum (DC.) Backer ex K.Heyne	4	0.020	-	-
Pongamia pinnata (L.) Pierre	3	0.005	-	-
Prosopis juliflora (Sw.) DC.	11	0.057	-	-
Senegalia chundra (Roxb. ex Rottler) Maslin	70	0.753	52	0.353
Senna surattensis (Burm. f.) H.S. Irwin &Barneby	2	0.011		
Soymida febrifuga (Roxb.) A.Juss.	-	-	2	0.052

Tamarindus indica L.	1	0.371	-	-
Tectona grandis L.f.	-	-	1	0.002
Terminalia alata Heyne ex Roth	4	0.018	-	-
Terminalia anogeissiana Gere &Boatwr.	-	-	35	0.355
Terminalia bellirica (Gaertn.) Roxb.	1	0.015	-	-
Vachellia leucophloea (Roxb.) Maslin, Seigler&Ebinger	12	0.106	-	-
Vachellia nilotica (L.) P.J.H.Hurter&Mabb.	1	0.074	-	-
Wrightia tinctoria (Roxb.) R.Br.	7	0.197	21	0.36
Ziziphus horrida Roth	15	0.080	4	0.007
Ziziphus mauritiana Lam.	1	0.005	-	-
Total	**376**	**3.19/ha**	**307**	**6.56/ha**

Annexure 6.1: Arthropods recorded in the study area

Sl. No	Order	Family	Common Name	Scientific Name	IWPA status	IUCN status	Habitat			
							A	F	B	S
1	Odonata	Coenagrionidae	Senegal Golden Dartlet	*Ischnurarubilio*		NE	✓		✓	
2		Libellulidae	Crimson Marsh Glider	*Trithemis aurora*		NE		✓		✓
3			Long legged Marsh Glider	*Trithemis pallidinervis*		NE	✓		✓	
4			Ditch Jewel	*Brachythemis contaminate*		NE			✓	✓
5			Picture Wing	*Rhyothemis variegata*		NE	✓		✓	
6		Platycnemidiae	Black winged Bambootail	*Disparoneura quadrimaculata*		NE		✓		
7	Dictyoptera	Mantidae	Grass Mantis	*Archimantislatistyla*		NE	✓	✓	✓	✓
8		Blattidae	American Cockroach	*Periplanata Americana*		NE			✓	
9		Corydiiae	Seven spotted cockroach	*Thereapetiveriana*		NE	✓	✓		✓
10	Orthoptera	Acridinae	Brown Grasshopper	*Gomphocerippus sp*.			✓	✓	✓	✓
11			Short Horned Grasshopper	*Neortha crissimulans*			✓	✓	✓	✓
12			Spur throated grass hopper	*Melanoplus sp*.			✓	✓	✓	✓
13			Green Grass hopper	*Omocestussimulans*			✓	✓	✓	✓
14		Grylidae	Cricket	*Gryllus sp*.			✓	✓	✓	✓
15	Phasmida	Phyllidae	Stick Insect	*Phasmatodea sp*.			✓	✓		✓
16	Dermoptera	Forficulidae	Earwig	*Forfocula auricularia*			✓	✓	✓	✓

17	Isoptera	Rhinotermitidae	Formosa termite	*Coptotermes formosanus*			✓	✓	✓	✓
18	Hemiptera	Chrysomelidae	Parthenium Bug	*Zygogramma bicolorta*			✓		✓	✓
19		Coreidae	Leaf footed bug	*Acanthocephaliniter minalis*			✓	✓		✓
20		Eurybrachidae	Plant Hopper	*Eurybrachys tomentosa*						✓
21		Lygaeidae	Seed bug	*Spilostethus pandurus*			✓		✓	✓
22		Reduviidae	Assassin Bug	*Platymeris biguttatus*				✓		✓
23		Scutelleridae	Jewel bug	*Chrysocoris stolli*			✓	✓	✓	✓
24	Neuroptera	Myrmeleontidae	Ant lion	*Myrmeleonitade sp.*				✓		✓
25	Lepidoptera	Nymphalidae	Angled Castor	*Ariadne ariadne*				✓	✓	
26			Blue Pansy	*Junonia orithiya*			✓	✓		
27			Blue tiger	*Tirumala limniace*				✓		✓
28			Common Crow	*Euploea core*	Sch I (Part IV)	LC	✓	✓	✓	✓
29			Common four ring	*Ypthima huebneri*			✓	✓		✓
30			Lemon pansy	*Junonia lemonias*			✓	✓		✓
31			Plain tiger	*Danaus chrysippus*	Sch I (Part IV)	LC	✓	✓	✓	✓
32			Striped tiger	*Danaus genutia*				✓		
33			Twany Castor	*Acraea terpsicore*				✓	✓	✓
34		Pieridae	Common emigrant	*Catposila pomona*			✓	✓	✓	✓
35			Grass yellow	*Eurema hecabe*			✓	✓	✓	✓
36			Indian Crimson tip	*Calotis danae*			✓	✓	✓	✓

37			Jezebel	*Delias eucharis*	Sch I (Part IV)			✓		
38			Salmon Arab	*Colotis fausta*				✓		
39			Pioneer White	*Belenois aurota*			✓	✓	✓	
40			Orange Tip	*Colotis aurora*			✓	✓	✓	✓
41			Yellow orange tip	*Ixias pyrene*				✓		✓
42			White orange tip	*Ixias marianne*			✓	✓		
43		Lycaenidae	Bright bubul blue	*Azanus ubaldus*					✓	✓
44			Common silver line	*Ciggaratis vulcanus*	Sch I (Part IV)		✓		✓	✓
45			Gram Blue	*Euchrysops cnejus*	Sch II (Part II)	NE	✓	✓	✓	✓
46			Orange spotted grass jewel	*Freyeri atrochylus*				✓		
47			Pierrot	*Tarucus sp*.			✓	✓	✓	✓
48			StipedPierrot	*Tarucus nara*				✓	✓	✓
49			Tiny Grass Blue	*Zizula hylax*			✓	✓	✓	
50			Zebra blue	*Leptotes plinus*			✓	✓	✓	✓
51		Papilionidae	Common Mormon	*Papilio polytes*	Sch II (Part II)		✓	✓		
52			Crimson Rose	*Pachliopta hector*		LC	✓	✓		✓
52			Common Lime	*Papilio demoleus*			✓	✓	✓	
54		Hesperridae	Grizzled Skipper	*Pyrgus malvae*			✓		✓	
55			Marbled Skipper	*Gomalia elma*				✓		

56		Erebidae	Indian Wasp moth	*Amta passalis*			✓	✓	✓	✓
57		Noctiuidae	Passenger moth	*Dysgonia algira*			✓	✓	✓	✓
58			Owlet Moth	*Spirama retorta*			✓	✓	✓	✓
59			Silver Moth	*Micromia aculeate*			✓	✓		
60	Diptera	Asilidae	Robber fly	*Cyrtopogon sp*.			✓	✓	✓	✓
61		Syrphidae	Hover fly	*Ischiodons cutellaris*			✓	✓	✓	✓
62		Culicidae	Mosquito	*Anopheles sp*.			✓	✓	✓	✓
63		Muscidae	House fly	*Musca domestica*					✓	✓
64		Sarcophagidae	Flesh Fly	*Sacrophaga carnaria*			✓	✓	✓	✓
65	Hymenoptera	Apidae	Honey Bee	*Apis cerana*			✓	✓	✓	✓
66			Wood Bee	*Xylocopa latreille*			✓	✓	✓	✓
67			Blue banded bee	*Amegilla cingulata*			✓	✓	✓	✓
68			Honey bee	*Apis dorsata*			✓	✓	✓	✓
69		Formicidae	Red Ant	*Solenopsis sp*.			✓	✓	✓	✓
70			Black Ant	*Lasius niger*			✓	✓	✓	✓
71		Pompilidae	Black orange Wasp	*Cryptocheilus bicolor*				✓	✓	✓
72		Vaspidae	Hornet	*Vaspa orientails*			✓	✓	✓	✓
73			Red paper wasp	*Polistes Carolina*			✓	✓	✓	✓
74			Yellow paper wasp	*Polistes versicolor*			✓	✓	✓	✓
75	Coleoptera	Carabidae	Six spot ground beetle	*Anthiasex guttata*			✓			✓
76			Yellow spotted ground beetle	*Eudema angulatus*				✓		
77		Chrysomelidae	Leaf Beetle	*Calligrapha philadelphica*			✓			✓
78			Pumpkin Beetle	*Raphidopalpa foveicollis*			✓			
79			Tortise shell	*Charidotella sp*.			✓	✓		

			beetle							
80		Lycidae	Net winged beetle	*Lycostomus* sp.			✓	✓	✓	✓
81		Meloidae	Blister Beetle	*Hycleus plymorphus*			✓	✓	✓	✓
82			Striped beetle	*Hycleus sp*.			✓	✓		✓
83		Scarabaeida	Dung beetle	*Scarabaeida sp*.			✓	✓	✓	✓
84		Tenebrionidae	Black Darkling beetle	*Tenebrionidae sp*.			✓	✓	✓	✓
85	Julida	Julidae	Julus	*Julus scandinavius*			✓	✓	✓	✓
86	Polydesmida	Polydesmidae	Yellow spotted millipede	*Harpaphe haydeniana*			✓	✓	✓	✓
87	Araneae	Araneidae	Signature spider	*Argiope sp*.			✓	✓	✓	✓
88			Garden Spider	*Araneus sp*.					✓	✓
89		Lycosidae	Wolf spider	*Lycosidae sp*.			✓	✓	✓	✓
90		Oxyopidae	Ornge Lynx spider	*Oxyopes salticus*			✓		✓	
91			Green Lynx spider	*Peucetia viridans*			✓	✓		✓
92		Tetragnatidae	Decorative silver orb spider	*Leucauge decorate*					✓	✓
93		Thomisidae	Crab spider	*Ozyptila practcola*			✓	✓	✓	✓
94		Salticidae	Jumping Spider	*Hasarius sp*.			✓	✓	✓	✓
95		Sparcidae	Huntsman spider	*Sparassidae sp*.			✓	✓	✓	✓
Opportunistic sighting										
96	Odonata	Aeshnidae	Blue Darner	*Anaximma culifrons*						✓
97	Dictyoptera	Gonypetidae	Indian Bark Mantis	*Humbertiella sp*.				✓		
98	Orthoptera	Acridinae	Grass hopper	*Acridaexa latata*						✓
99			Grass hopper	*Aulacobothrus sp*.			✓			
100	Phasmida	Phasmatidae	Stick Insect	*Ctenomorpha sp*.				✓		

101	Hemiptera	Cicadellidae	Leaf Hopper	*Cicadellidae* sp.						✓
102		Pyrrhocoridae	Red Cotton Bug	*Dysdercu scingulatus*				✓		
103		Pentatomidae	Brown Stink Bug	*Halyomorpha halys*			✓			
104	Lepidoptera	Nymphalidae	Joker	*Byblia ilithyia*				✓		
105		Pieridae	Mottled Emigrant	*Catopsilia pyranthe*				✓		
106			Psyche	*Leptosianina*				✓		
107			Albatross	*Appias albina*				✓		
108			Small Salmon Arab	*Colotis fausta*				✓		✓
109		Lycaenidae	Dark Cerulean	*Jamides bochus*				✓		
110			Pale Grass Blue	*Pseudozizeeria maha*			✓			
111	Diptera	Dolichopodiae	Long legged fly	*Dolichopodidae sp*.				✓		
112		Tephritidae	Fruit fly	*Drosophila melanogaster*					✓	
113			Uzi fly	*Exorista sorbillans*					✓	
114	Hymenoptera	Sphecidae	Thread waisted wasp	*Sphecidae sp*.				✓		
115		Vespidae	Red potter wasp	*Delta dimidiatipenne*					✓	
116		Apidae	Apisflorea	*Apis florea*						✓
117	Coleoptera	Carabidae	Ground beetle	*Carabidae sp*.			✓			
118		Curculionidae	Weevil	*Tanymecus indicus*					✓	
119	Araneae	Araneidae	Cyclosa	Cyclosa sp.					✓	
120		Tetragnathidae	Silver orb spider	*Leucaugede corata*						
121			Green Crab Spider	Thomisidae sp.				✓		
122	Scorpiones	Buthidae	Indian Red Scorpion	*Hottentotta tamulus*					✓	
123		Scorpionidae	Gaint forest scorpion	*Heterometrus sp*.				✓		
124	Spirobolida	Trigoninulidae	Common	*Trigoniulus sp*.					✓	

			millipede							
125	Trombidiformes	Trombidiidae	Red valvet mites	*Trombidiidae sp.*						✓
Sticky Trap Arthropods										
126	Hemiptera	Aphidoidea	Aphids	*Aphidoidea sp.*			✓	✓	✓	✓
127	Diptera		Flies	Dipterasp			✓	✓	✓	✓
Soil Arthropods										
128			Pseudoscorpiones	**Pseudoscorpion Sp.**				✓	✓	✓
129	Opisthopora		Earthworm	Lumbricina sp.					✓	✓
130			Snails	Gastropod sp.					✓	
131			Cutworms	-					✓	
132	Aranea		Spiders	-				✓		✓
133			Nematodes	*Nematoda sp.*			✓	✓	✓	✓
134			Soil mites	-			✓			✓
135			Coccinellids	*Coccinellidae sp.*					✓	
136			Spring tail	*Collembola sp.*			✓	✓		
137	Aranea		Spider Mites	*Tetranychidae sp.*					✓	
138	Isoptera		Termites	*Isoptera sp.*				✓	✓	✓
139			Millipede	*Diplopoda sp.*				✓		
140	Diptera		Diptera flies	*Diptera sp.*						✓
141	Hymenoptera		Ants	*Formicidae.*			✓	✓		✓
142	Orthoptera		Cricket	*Grylloidea sp.*				✓		
143	Orthoptera		Grass hopper	*Caelifera sp.*				✓		
144	Coleoptera		Ground beetle	*Carabidae sp.*				✓		
145			Protura	*Protura sp.*						
Solar trap Arthropods										
146	Coleoptera		Dung rollers	-			✓	✓	✓	✓
147	Lepidoptera	Noctuidae	Silver Moth	*Autographa gamma*			✓		✓	✓
148	Hymenoptera		Ants	*Formicidae sp.*			✓	✓	✓	✓

149	Isoptera		Termites	*Isoptera sp.*			✓	✓	✓	✓
150	Diptera		Flies	*Diptera sp.*			✓	✓	✓	✓
151	Hymenoptera		Wasp	*Vespula germanica*			✓	✓	✓	✓
152	Lepidoptera	Geomitridae	Moth	*Geomitridae sp.*			✓	✓	✓	✓
153	Coleoptera		Horned Beetle	-			✓	✓	✓	✓
154	Lepidoptera	Pyraloidea	Snout Moth	*Pyralidae sp.*			✓	✓	✓	
155	Coleoptra	Carabidae	Ground Beetle	*Carabidae sp.*			✓	✓	✓	✓
156	Hemiptera	Cicadellidae	Leaf hoppers	*Cicadellidae sp.*			✓	✓		
157	Dermoptera		Earwig	*Dermaptera sp.*			✓	✓	✓	✓
158	Diptera	Tenthredinoidea	sawflies	*Symphyta sp.*			✓	✓		✓
159	Hemiptera	Eurybrachidae	Plant hopper	*Fulgoromorpha sp.*						✓
160	Coleoptera		Weevils	*Curculionoidea sp.*			✓	✓		✓
161	Hemiptera		Water Bug	*Lethocerus americanus*			✓	✓	✓	✓
162	Lepiodoptera	Geometridae	Chaismia moth	*Chiasmia sp.*			✓		✓	✓
163		Erebidae	Aemene moth	*Aemeneta probanis*			✓			✓
164			Euprocits moth	*Erebidae sp.*			✓			
165		Erebidae	Moth	*Spirama sp.*				✓		✓
166		Noctuidae	Scopariae	*Scopariae sp.*			✓		✓	✓
167			Aphids	*Aphidoidea sp.*			✓	✓	✓	
168			Crockroach	*Blattodea sp.*				✓	✓	✓
opportunistic sightings										
169	Odonata	Coenagrionida e	Coromandel Marsh Dart	*Ceriagrion coromandelianum*				✓		
170		Libellulidae	Chalky Percher	*Diplacodes trivialis*			✓			✓
171			Granite Ghost	*Bradino pygageminata*				✓		
172	Dictyoptera	Ectobiidae	Wood Cockroach	*Parco blatta*				✓		
173	Orthoptera	Tettigoniidae	Green Bush Cricket	*Tettigonia viridissima*			✓			

174		Pyrgomorphinae	Grass hopper	*Chrotogonus sp.*			✓			
175	Lepiodptera	Lycaenidae	Lesser Grass Blue	*Zizina otis*				✓		✓
176			Small Cupid	*Chilades parrhasius*						
177		Papilionidae	Common Rose	*Pachliopta aristolochiae*				✓		
178		Crambidae	Beet webworm Moth	*Hymenia perspectalis*			✓			
179		Erebidae	Maiden Moth	*Syntomoides imaon*						✓
180	Diptera	Calliphoridae	Blue Bottle fly	*Calliphora vomitoria*				✓		
181		Culicidae	Asian Tiger mosquito	*Aedes taemiorhyncus*				✓		
182		Bombyliidae	Bee fly	*Bombylius sp.*						✓
183		Stratiomyidae	Black Soldier fly	*Hermetia illucens*						✓
184			Common Green Colonel	*Oplodontha viridula*				✓		
185	Coleoptera	Buprestidae	Jewel Beetle	*Buprestidae sp.*				✓		
186		Chrysomelidae	Leaf beetle	*Chrysomelinae sp.*			✓			
187	Arenea	Hersilidae	Bark Spider	*Caerostris darwini*				✓		
188		Salticidae	Plexipus							✓
Aquatic Arthropods										
189	Odonata		Dragonfly larvae	*Anisoptera sp.*						
190	Hemiptera		Water Skeeters	*Gerridae sp.*						
191			Water Boatmen	*Corixidae sp.*						
192	Decapoda		Crab	*Brachyura sp.*						

* NE- Not evaluated. LC-Least concerned. IWPA- Indian wildlife Protection act. IUCN- International Union for Conservation Nature. A-Agriculture. F- Forest B- Built S-Scrub

Annexures 6.2: Occurrence of arthropods at different perpendiculardistances from the MPC

Sl No.	Taxa	Distance from MPC(m)									
		0-10	20-30	40-50	60-70	80-90	100-110	120-130	140-150	160-170	180-190
1	Senegal Golden Dartlet	✓	-	-	✓	✓	✓	✓	-	-	-
2	Crimson Marsh Glider	✓	✓	-	-	-	-	-	-	-	✓
3	Long legged Marsh Glider	-	✓	✓	✓	✓	✓	-	✓	✓	✓
4	Ditch Jewel	-	-	-	✓	-	-	✓	-	✓	✓
5	Picture Wing	-	✓	✓	✓	-	✓	-	-	✓	-
6	Black winged Bambootail	-	-	-	✓	✓	✓	✓	✓	✓	✓
7	Grass Mantis	-	✓	✓	-	✓	✓	✓	✓	✓	✓
8	American Cockroach	✓	✓	-	✓	✓	-	✓	✓	✓	-
9	Seven spotted cockroach	-	✓	-	-	✓	✓	✓	✓	-	✓
10	Brown Grasshopper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	Short Horned Grasshopper	✓	✓	✓	-	✓	✓	✓	✓	✓	✓
12	Spur throated grass hopper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
13	Green Grass hopper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
14	Cricket	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15	Stick Insect	-	-	-	✓	-	✓	✓	✓	✓	✓
16	Earwig	-	✓	-	✓	✓	✓	✓	✓	✓	✓
17	Formosa termite	✓	✓	-	✓	✓	✓	✓	✓	✓	✓
18	Parthenium Bug	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
19	Leaf footed bug	-	✓	✓	✓	✓	-	-	✓	✓	✓

20	Plant Hopper	✓	✓	-	-	✓	✓	✓	✓	✓	✓
21	Seed bug	✓	-	✓	-	✓	✓	✓	-	✓	✓
22	Assassin Bug	-	-	✓	✓	✓	✓	✓	-	✓	-
23	Jewel bug	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
24	Ant lion	-	-	✓	✓	✓	✓	✓	✓	-	-
25	Angled Castor	-	✓	-	✓	-	✓	-	✓	✓	✓
26	Blue Pansy	✓	-	-	-	-	-	-	-	✓	-
27	Blue tiger	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
28	Common Crow	✓	-	-	-	✓	-	✓	✓	-	✓
29	Common four ring	✓	✓	✓	-	-	-	-	-	✓	-
30	Lemon pansy	-	-	✓	✓	✓	✓	✓	-	✓	-
31	Plain tiger	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
32	Striped tiger	✓	-	✓	-	✓	-	✓	-	✓	✓
33	Twany Castor	✓	-	✓	✓	✓	✓	-	-	-	✓
34	Common emigrant	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
35	Grass yellow	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
36	Indian Crimson tip	✓	✓	✓	✓	✓	✓	-	-	✓	✓
37	Jezebel	✓	✓	-	-	-	-	-	✓	✓	-
38	Salmon Arab	-	-	✓	-	-	-	✓	✓	✓	✓
39	Pioneer White	✓	-	-	-	-	-	-	✓	✓	✓
40	Orange Tip	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
41	Yellow orange tip	✓	✓	-	✓	-	✓	✓	-	-	-

42	White orange tip	-	✓	✓	-	✓	✓	✓	-	✓	-
43	Bright bubul blue	-	-	-	✓	✓	-	-	-	-	✓
44	Common silver line	-	-	✓	✓	-	-	-	-	-	-
45	Gram Blue	-	✓	✓	✓	✓	✓	✓	✓	-	✓
46	Orange spotted grass jewel	✓	-	-	-	-	✓	-	-	✓	✓
47	Pierrot	-	✓	-	✓	✓	✓	-	✓	✓	✓
48	Striped Pierrot	✓	-	✓	✓	-	✓	-	✓	-	-
49	Tiny Grass Blue	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
50	Zebra blue	✓	✓	-	✓	✓	✓	-	✓	✓	-
51	Common Mormon	✓	-	-	✓	-	-	-	✓	-	✓
52	Crimson Rose	✓	✓	✓	✓	✓	✓	-	-	✓	-
53	Common Lime	✓	✓	✓	✓	✓	-	✓	-	✓	✓
54	Grizzled Skipper	-	-	✓	-	✓	✓	-	✓	-	✓
55	Marbled Skipper	✓	-	-	-	✓	-	✓	-	✓	-
56	Indian Wasp moth	-	✓	✓	✓	-	✓	✓	✓	✓	-
57	Passenger moth	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
58	Owlet Moth	✓	-	✓	✓	-	✓	-	✓	✓	✓
59	Silver Moth	✓	-	✓	-	-	-	✓	-	✓	-
60	Robber fly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
61	Yellow shoulderd Hover fly	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
62	Mosquito	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

63	House fly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
64	Flesh Fly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
65	Apisdorsata	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
66	Wood Bee	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
67	Blue banded bee	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
68	hornet	-	✓	✓	-	✓	-	✓	✓	✓	✓
69	Red Ant	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
70	Black Ant	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
71	Black orange Wasp	-	-	✓	✓	✓	-	-	✓	✓	-
72	Apiscerana	-	-	✓	✓	✓	✓	✓	✓	✓	✓
73	Red paper wasp	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
74	Yellow paper wasp	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
75	Six spot ground beetle	-	✓	-	-	-	-	✓	✓	✓	✓
76	Yellow spotted ground beetle	-	-	-	✓	✓	✓	✓	✓	✓	✓
77	Leaf Beetle	-	✓	✓	-	-	✓	✓	-	✓	✓
78	Pumpkin Beetle	-	-	-	-	✓	-	-	-	-	✓
79	Tortoise shell beetle	-	-	✓	✓	✓	✓	✓	-	-	✓
80	Net winged beetle	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
81	Blister Beetle	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
82	Striped beetle	-	✓	✓	-	✓	-	-	✓	✓	✓
83	Dung beetle	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
84	Black Darkling beetle	-	-	-	-	✓	-	✓	✓	-	-

85	Julus	-	-	-	-	✓	✓	✓	✓	✓	✓
86	Yellow spotted millipede	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
87	Signature spider	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
88	Garden Spider	-	✓	✓	✓	-	-	✓	✓	✓	✓
89	Wolf spider	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
90	Orange Lynx spider	-	-	-	-	-	✓	-	-	-	-
91	Green Lynx spider	-	-	-	✓	-	✓	-	✓	✓	-
92	Decorative silver orb spider	✓	-	-	-	✓	✓	✓	-	✓	-
93	Crab spider	✓	✓	-	-	✓	✓	-	✓	-	✓
94	Jumping Spider	✓	-	-	-	-	✓	✓	✓	-	-
95	Huntsman spider	-	-	✓	✓	-	✓	✓	✓	✓	✓

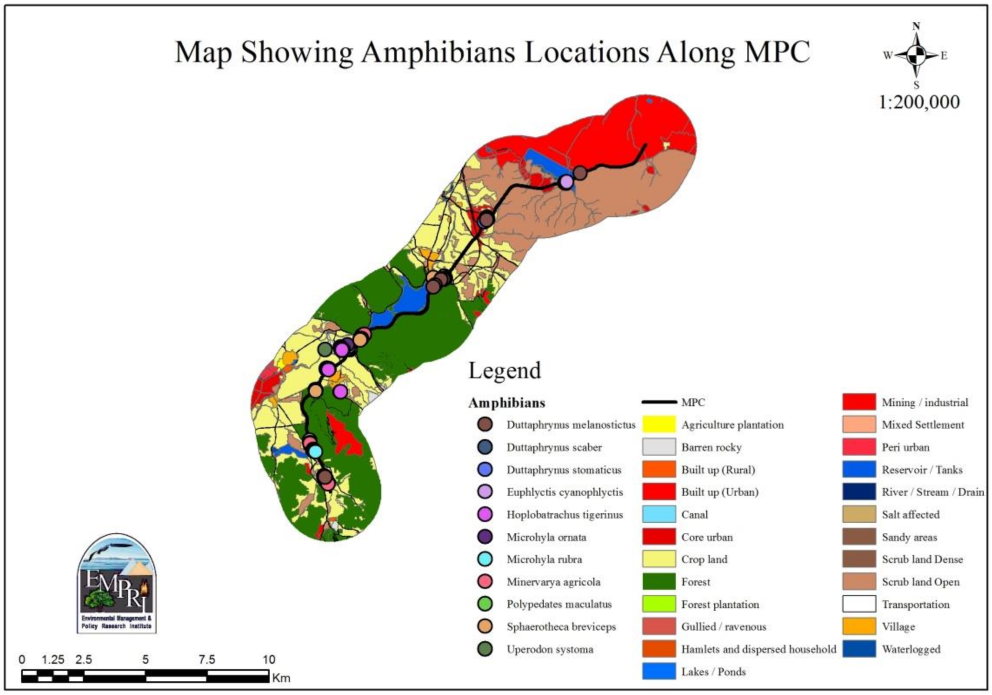
Annexure 6.3: Species attracted to solar traps

Species	Phase 1	Phase 2
Termites	✓	✓
Muscoid flies	✓	✓
Flesh flies	✓	✓
Root grub	✓	✓
Brown Beetle	✓	✓
Black Beetle	✓	✓
Silver moth	✓	✓
Snout moth	✓	✓
Geomitredea sp.	✓	✓
Aemene	✓	✓
Chiasmia moth	✓	✓
Musquito	✓	✓
Brown stink bug	✓	✓
Red cotton bug	✓	✓
Horse fly	✓	✓
Green stink bug	✓	✓
Saw fly	✓	✓
Water bugs	✓	✓
Honey bee	✓	✓
Potter wasp	✓	✓
Black wasp	✓	✓
Tree hopper	✓	✓
Leaf hopper	✓	✓
Earwig	✓	✓
European corn borer	-	✓
Aphids	-	✓
Sphingidae moth	-	✓
Green grasshopper	-	✓
Long horned moth	✓	-
Water bugs	✓	✓

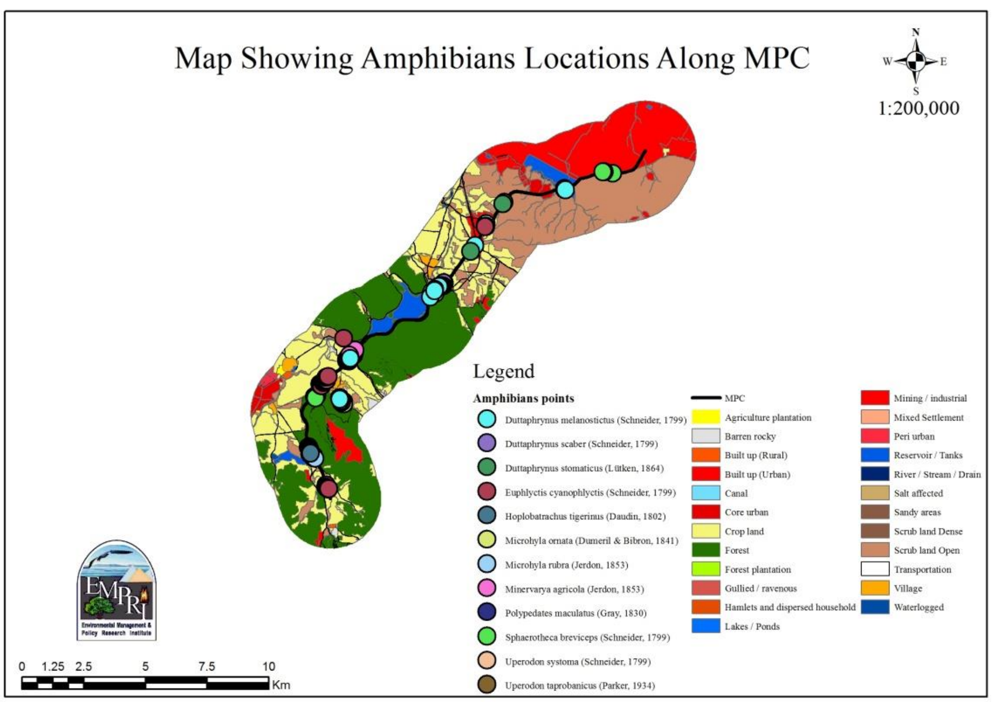
Annexure 6. 4: Micro and macro arthropods identified in soil samples

Species	MPC	Control
Protura	✓	✓
Isotomurusbalteaus	✓	✓
Entomobryaindica	✓	-
Cyphoderussp	-	✓
Silverfish	-	✓
Zachvatkinella sp.	✓	✓
Pseudoscorpiones		
Acaronychus spp.	✓	✓
Diplura	-	✓
Symphyla	-	✓
Earthworm	-	✓
Cutworms	✓	✓
Spiders	✓	✓
Nematodes	✓	✓
Soil mites	✓	✓
Coccinellids	✓	✓
Nilipliona (spring tail)	✓	✓
Symphepleona	-	✓
Puduromorpha	✓	✓
Spider Mites	✓	
Formosa Termites	✓	✓
Millipede	✓	✓
Diptera flies	✓	✓
Ants	✓	✓
Ground beetle	✓	✓

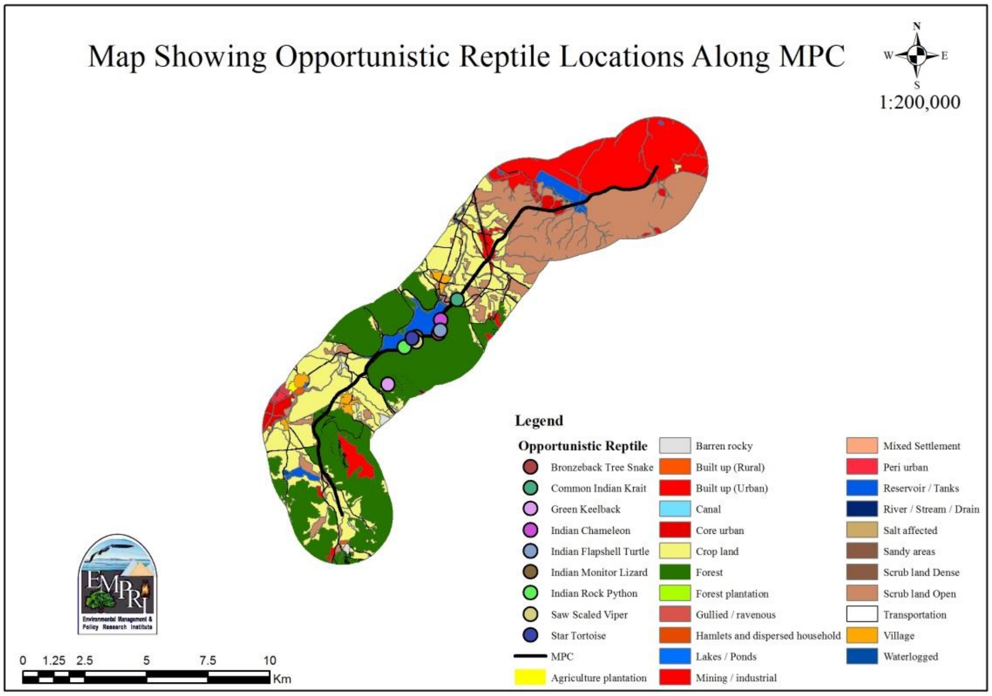
Annexure 7.1: Amphibian sightings along MPC ({Phase I)



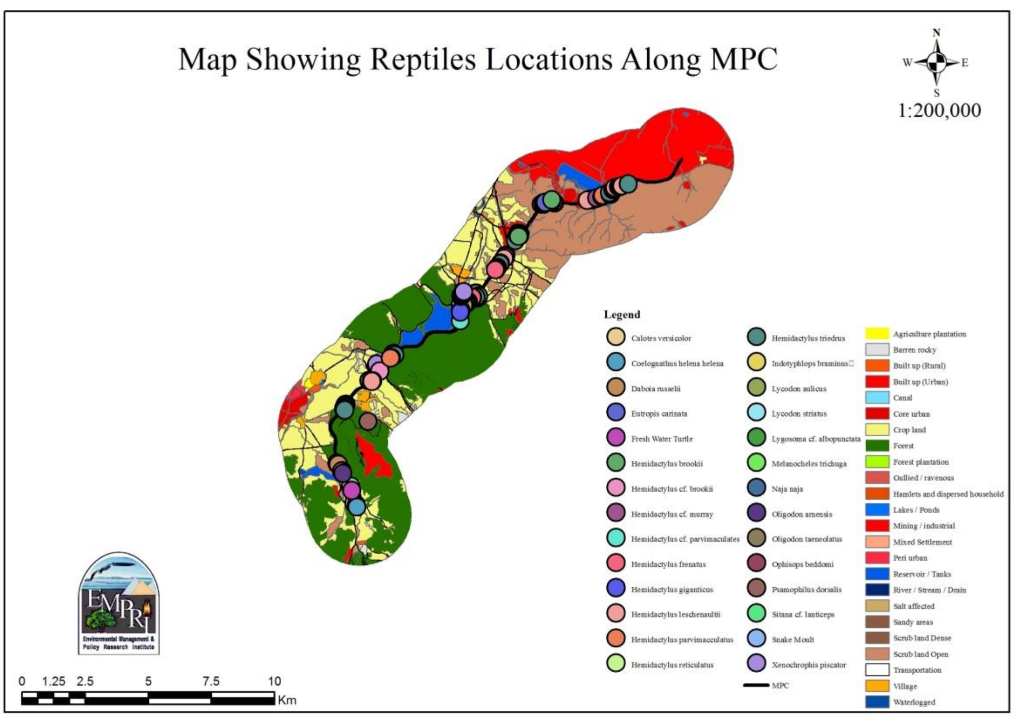
Annexure 7.2: Amphibian sightings along MPC ({Phase II)



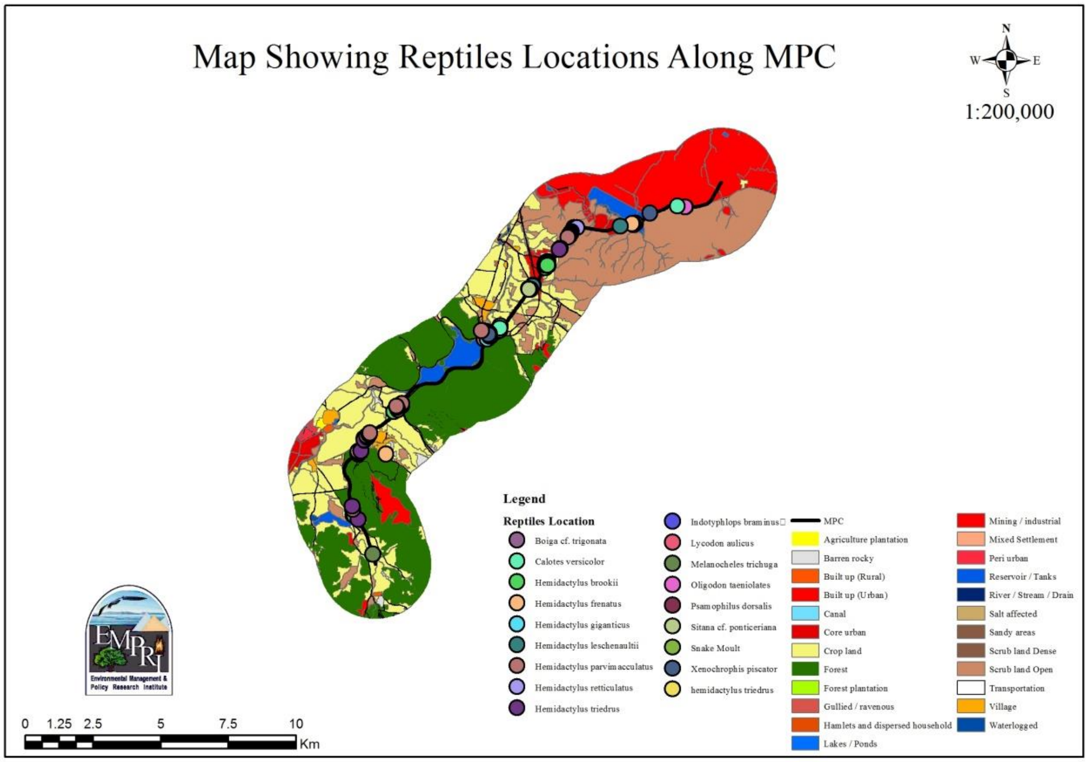
Annexure 8.1: Opportunistic sightings of Reptile



Annexure 8.2: Reptile sightings ({Phase_I)



Annexure 8.2: Reptile sightings ({Phase_II)



Annexure 9.1: Checklist of bird species recorded from the study area, their habitat of occurrence and conservation status

S. No	Order:	Scientific Name	Common Name	Habitat of Occurrence						FG	Status			GH
	Family			AG	B	F	OS	W	C		IUCN	IWPA	Occ	
I.	**Accipitriformes:**													
1	Accipitridae	*Accipiter badius*	Shikra	*	*	*	*			C	L C	Sch-I	R	W S
2	Accipitridae	*Aquila fasciata*	Bonelli's Eagle	*						C	L C	Sch-I	R	F
3	Accipitridae	*Circaetus gallicus*	Short-toed Snake Eagle	*		*	*			C	L C	Sch-I	R	G and S
4	Accipitridae	*Clanga hastata*	Indian Spotted Eagle			*				C	V	Sch-I	R	F
5	Accipitridae	*Elanus caeruleus*	Black-winged Kite	*	*	*	*			C	L C	Sch-I	R	G and S
6	Accipitridae	*Haliastur indus*	Brahminy Kite			*				C	L C	Sch-I	R	W S
7	Accipitridae	*Ictinaetus malaiensis*	Black Eagle			*	*			C	L C	Sch-I	R	F
8	Accipitridae	*Lophotriorchis kienerii*	Rufous-bellied Eagle				*			C	N T	Sch-I	R	G and S
9	Accipitridae	*Milvus migrans*	Black Kite		*					C	L C	Sch-I	R	W S
10	Accipitridae	*Nisaetus cirrhatus*	Changeable Hawk Eagle			*				C	L C	Sch-I	R	F
11	Accipitridae	*Pernis ptilorhynchus*	Oriental Honey Buzzard			*				C	L C	Sch-I	R	W S
II.	**Anseriformes:**													
12	Anatidae	*Anas poecilorhyncha*	Indian Spot-billed Duck			*		*		P-S	L C	Sch-IV	R	W L
13	Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck					*		P-S	L C	Sch-IV	R	W L
III.	**Bucerotiformes:**													
14	Bucerotidae	*Ocyceros birostris*	Indian Grey Hornbill	*		*	*		*	F	L C	Sch-IV	R	W S
15	Upupidae	*Upupa epops*	Common Hoopoe				*			I	L C	Sch-IV	R	G and S
IV.	**Caprimulgiformes:**													
16	Apodidae	*Apus affinis*	Indian House Swift	*	*	*	*	*	*	I	L C	Sch-IV	R	W S
17	Apodidae	*Cypsiurus balasiensis*	Asian Palm Swift	*	*		*			I	L C	Sch-IV	R	W S

18	Caprimulgidae	*Caprimulgus asiaticus*	Indian Nightjar	*		*	*			I	L C	Sch-IV	R	W S
V.	**Charadriiformes:**													
19	Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	*		*	*			O	L C	Sch-IV	R	W L
20	Charadriidae	*Vanellus malabaricus*	Yellow-wattled Lapwing				*			O	L C	Sch-IV	R	G and S
21	Laridae	*Sterna aurantia*	River Tern					*		O	V	Sch-IV	R	W L
22	Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	*				*		I	L C	Sch-IV	R	W L
23	Rostratulidae	*Rostratula benghalensis*	Greater Painted-snipe	*						P and I	L C	Sch-IV	R	W L
24	Turnicidae	*Turnix suscitator*	Barred Buttonquail	*						G and I	L C	Sch-IV	R	G and S
VI.	**Ciconiiformes:**													
25	Ciconiidae	*Anastomus oscitans*	Asian Openbill					*		P	L C	Sch-IV	R	W L
26	Ciconiidae	*Mycteria leucocephala*	Painted Stork					*		P	N T	Sch-IV	R	W L
VII.	**Columbiformes:**													
27	Columbidae	*Columba livia*	Rock Pigeon	*	*	*	*		*	G	L C	Sch-IV	R	W S
28	Columbidae	*Streptopelia chinensis*	Spotted Dove	*	*	*	*		*	G	L C	Sch-IV	R	W S
29	Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	*	*	*	*		*	G	L C	Sch-IV	R	W S
30	Columbidae	*Streptopelia senegalensis*	Laughing Dove	*	*	*	*	*	*	G	L C	Sch-IV	R	W S
VIII.	**Coraciiformes:**													
31	Alcedinidae	*Alcedo atthis*	Common Kingfisher			*		*		P	L C	Sch-IV	R	W L
32	Alcedinidae	*Ceryle rudis*	Pied Kingfisher					*		P and I	L C	Sch-IV	R	W L
33	Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	*	*	*	*	*	*	P and I	L C	Sch-IV	R	W L
34	Coraciidae	*Coracias benghalensis*	Indian Roller	*	*		*			I	L C	Sch-IV	R	G and S
35	Meropidae	*Merops orientalis*	Green Bee-eater	*	*	*	*	*	*	I	L C	Sch-IV	R	W S

IX.	**Cuculiformes:**													
36	Cuculidae	*Centropus sinensis*	Greater Coucal	*	*	*	*	*	*	I and F	L C	Sch-IV	R	W S
37	Cuculidae	*Clamator jacobinus*	Pied Cuckoo				*			I and F	L C	Sch-IV	R	W S
38	Cuculidae	*Eudynamys scolopaceus*	Asian Koel	*	*	*	*			I and F	L C	Sch-IV	R	W S
39	Cuculidae	*Hierococcyx varius*	Common Hawk Cuckoo				*		*	I and F	L C	Sch-IV	R	W S
40	Cuculidae	*Phaenicophaeus viridirostris*	Blue-faced Malkoha		*	*		*		I	L C	Sch-IV	R	W S
41	Cuculidae	*Taccocua leschenaultii*	Sirkeer Malkoha						*	I	L C	Sch-IV	R	W S
X.	**Falconiformes:**													
42	Falconidae	*Falco peregrinus*	Shaheen Falcon				*			C	L C	Sch-I	R	F
43	Falconidae	*Falco tinnunculus*	Common Kestrel		*					C	LC	Sch-IV	R	W S
XI.	**Galliformes:**													
44	Phasianidae	*Francolinus pondicerianus*	Grey Francolin	*	*		*		*	G and I	L C	Sch-IV	R	G and S
45	Phasianidae	*Galloperdix spadicea*	Red Spurfowl			*			*	O	L C	Sch-IV	R	F
46	Phasianidae	*Gallus sonneratii*	Grey Jungle Fowl			*								
47	Phasianidae	*Pavo cristatus*	Indian Peafowl	*	*	*	*	*	*	O	L C	Sch-I	R	W S
48	Phasianidae	*Perdiculaar goondah*	Rock Bush Quail				*			G and I	L C	Sch-IV	R	G and S
49	Phasianidae	*Perdicula asiatica*	Jungle Bush Quail		*	*	*			G and I	L C	Sch-IV	R	G and S
XII.	**Gruiformes:**													
50	Rallidae	*Amaurorni sphoenicurus*	White-breasted Waterhen		*					O	L C	Sch-IV	R	W L
51	Rallidae	*Fulica atra*	Common Coot		*					O	L C	Sch-IV	R	W L
52	Rallidae	*Gallinula chloropus*	Common Moorhen		*					O	L C	Sch-IV	R	W L

53	Rallidae	*Porphyrio porphyrio*	Purple Swamphen		*					O	L C	Sch-IV	R	W L
XIII.	**Passeriformes:**													
54	Aegithinidae	*Aegithina tiphia*	Common Iora	*	*	*	*		*	I and F	L C	Sch-IV	R	W S
55	Alaudidae	*Alauda gulgula*	Oriental Skylark				*		*	I	L C	Sch-IV	R	W S
56	Alaudidae	*Ammomanes phoenicura*	Rufous-tailed Lark				*			I	L C	Sch-IV	R	G and S
57	Alaudidae	*Eremopterix griseus*	Ashy-crowned Sparrow Lark		*	*	*			I	L C	Sch-IV	R	G and S
58	Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet			*			*	G	L C	Sch-IV	R	F
59	Chloropseidae	*Chloropsis jerdoni*	Jerdon's Leafbird			*				I and F	L C	Sch-IV	R	W S
60	Cisticolidae	*Cisticola juncidis*	Zitting Cisticola		*					I	L C	Sch-IV	R	G and S
61	Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	*	*	*	*	*	*	I	L C	Sch-IV	R	W S
62	Cisticolidae	*Prinia buchanani*	Rufous-fronted Prinia				*			I	L C	Sch-IV	R	G and S
63	Cisticolidae	*Prinia hodgsonii*	Grey-breasted Prinia			*	*	*	*	I	L C	Sch-IV	R	W S
64	Cisticolidae	*Prinia inornata*	Plain Prinia	*	*	*	*	*	*	I	L C	Sch-IV	R	W S
65	Cisticolidae	*Prinia socialis*	Ashy Prinia	*	*	*	*	*	*	I	L C	Sch-IV	R	W S
66	Corvidae	*Corvus macrorhynchos*	Indian Jungle Crow		*		*			O	L C	Sch-IV	R	W S
67	Corvidae	*Corvus splendens*	House Crow	*	*	*	*			O	L C	Sch-V	R	W S
68	Corvidae	*Dendrocitta vagabunda*	Rufous Treepie			*	*		*	O	L C	Sch-IV	R	W S
69	Dicruridae	*Dicaeumerythro rhynchos*	Pale-billed Flowerpecker	*	*	*			*	F	L C	Sch-IV	R	W S
70	Dicruridae	*Dicrurus caerulescens*	White-bellied Drongo			*			*	I	L C	Sch-IV	R	W S
71	Dicruridae	*Dicrurus macrocercus*	Black Drongo	*	*	*		*		I	L C	Sch-IV	R	G and S
72	Estrildidae	*Euodice malabarica*	Indian Silverbill	*	*	*	*	*		G	L C	Sch-IV	R	G and S
73	Estrildidae	*Lonchura malacca*	Tricoloured Munia	*			*			G	L C	Sch-IV	R	W S
74	Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	*	*	*	*	*	*	G	L C	Sch-IV	R	W S

75	Hirundinidae	*Cecropis daurica*	Red-rumped Swallow	*	*	*	*	*		I	L C	Sch-IV	R	W S
76	Hirundinidae	*Hirundo rustica*	Barn Swallow	*		*				I	L C	Sch-IV	M-L	W S
77	Hirundinidae	*Ptyonoprogne concolor*	Dusky Crag Martin		*	*				I	L C	Sch-IV	R	W S
78	Laniidae	*Laniuss chach*	Long-tailed Shrike			*	*			I	L C	Sch-IV	R	G and S
79	Laniidae	*Lanius vittatus*	Bay-backed Shrike		*	*	*			I	L C	Sch-IV	R	G and S
80	Leiothrichidae	*Argyama lcolmi*	Large Grey Babbler	*	*	*	*		*	I	L C	Sch-IV	R	W S
81	Leiothrichidae	*Chrysomma sinense*	Yellow-eyed Babbler		*		*			I	L C	Sch-IV	R	G and S
82	Leiothrichidae	*Turdoides affinis*	Yellow-billed Babbler	*		*	*	*	*	I	L C	Sch-IV	R	W S
83	Leiothrichidae	*Turdoides striata*	Jungle Babbler			*		*	*	I	L C	Sch-IV	R	W S
84	Motacillidae	*Motacilla maderaspatensis*	White-browed Wagtail	*	*	*		*		I	L C	Sch-IV	R	W L
85	Muscicapidae	*Copsychu ssaularis*	Oriental Magpie Robin	*		*			*	I	L C	Sch-IV	R	W S
86	Muscicapidae	*Cyornis tickelliae*	Tickell's Blue Flycatcher	*		*		*	*	I	L C	Sch-IV	R	W S
87	Muscicapidae	*Muscica padauurica*	Asian Brown Flycatcher			*			*	I	L C	Sch-IV	R	W S
88	Muscicapidae	*Saxicola caprata*	Pied Bushchat	*	*	*	*			I	L C	Sch-IV	R	W S
89	Muscicapidae	*Saxicoloides fulicatus*	Indian Robin	*	*	*	*	*	*	I	L C	Sch-IV	R	W S
90	Nectariniidae	*Cinnyris asiaticus*	Purple Sunbird	*	*	*	*	*	*	N	L C	Sch-IV	R	W S
91	Nectariniidae	*Leptocoma zeylonica*	Purple-rumped Sunbird	*	*	*	*		*	N	L C	Sch-IV	R	W S
92	Oriolidae	*Oriolus kundoo*	Indian Golden Oriole			*				F	LC	Sch-IV	R	
93	Paridae	*Parus cinereus*	Cinereous Tit			*				I	L C	Sch-IV	R	W S
94	Passeridae	*Passer domesticus*	House Sparrow		*					G	L C	Sch-IV	R	W S
95	Ploceidae	*Ploceus philippinus*	Baya Weaver	*		*	*			G	L C	Sch-IV	R	W S
96	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	*	*	*	*	*	*	O	L C	Sch-IV	R	W S
97	Pycnonotidae	*Pycnonotus luteolus*	White-browed Bulbul	*		*	*	*	*	O	L C	Sch-IV	R	W S

98	Rhipiduridae	*Rhipidura albogularis*	White-spotted Fantail			*			*	I	L C	Sch-IV	R	W S
99	Sturnidae	*Acridotheres fuscus*	Jungle Myna	*		*	*			O	L C	Sch-IV	R	W S
100	Sturnidae	*Acridotheres tristis*	Common Myna	*	*	*	*	*		O	L C	Sch-IV	R	W S
101	Sturnidae	*Sturnia pagodarum*	Brahminy Starling	*	*		*			O	L C	Sch-IV	R	W S
102	Timaliidae	*Dumetia hyperythra*	Tawny-bellied Babbler			*				I	L C	Sch-IV	R	W S
103	Zosteropidae	*Zosterops palpebrosus*	Oriental White-eye			*				I	L C	Sch-IV	R	W S
XIV.	**Pelecaniformes:**													
104	Ardeidae	*Ardea cinerea*	Grey Heron					*		P and I	L C	Sch-IV	R	W L
105	Ardeidae	*Ardea purpurea*	Purple Heron					*		P and I	L C	Sch-IV	R	W L
106	Ardeidae	*Ardeola grayii*	Indian Pond Heron	*				*		P and I	L C	Sch-IV	R	W L
107	Ardeidae	*Bubulcus ibis*	Cattle Egret					*		P and I	L C	Sch-IV	R	W L
108	Ardeidae	*Egretta garzetta*	Little Egret					*		P and I	L C	Sch-IV	R	W L
109	Threskiornithidae	*Threskiornis melanocephalus*	Black-headed Ibis					*		O	N T	Sch-IV	R	W L
XV.	**Piciformes:**													
110	Megalaimidae	*Psilopogon haemacephalus*	Coppersmith Barbet		*	*			*	F	L C	Sch-IV	R	W S
111	Megalaimidae	*Psilopogon viridis*	White-cheeked Barbet	*					*	F	L C	Sch-IV	R	W S
112	Picidae	*Dinopium benghalense*	Lesser Golden-backed Woodpecker						*	I	L C	Sch-IV	R	W S
XVI.	**Podicipediformes:**													
113	Podicipedidae	*Tachybaptus ruficollis*	Little Grebe					*		O	L C	Sch-IV	R	W L
XVII.	**Psittaciformes:**													
114	Psittaculidae	*Psittacula cyanocephala*	Plum-headed Parakeet			*			*	F	L C	Sch-IV	R	F

115	Psittaculidae	*Psittacula krameri*	Rose-ringed Parakeet	*	*	*		*	*	F	L C	Sch-IV	R	W S
XVIII.	**Pterocliformes:**													
116	Pteroclidae	*Pterocles indicus*	Painted Sandgrouse		*		*			G and I	L C	Sch-IV	R	G and S
XIX.	**Strigiformes:**													
117	Strigidae	*Athene brama*	Spotted Owlet	*			*			C	L C	Sch-IV	R	W S
118	Strigidae	*Bubo bengalensis*	Indian Eagle Owl			*	*			C	L C	Sch-IV	R	F
119	Strigidae	*Ketupa zeylonensis*	Brown Fish Owl			*				C	L C	Sch-IV	R	F
120	Strigidae	*Otus bakkamoena*	Indian Scops Owl			*				C	L C	Sch-IV	R	F
121	Tytonidae	*Tyto alba*	Common Barn Owl		*					C	L C	Sch-IV	R	W S
XX.	**Suliformes:**													
122	Anhingidae	*Anhinga melanogaster*	Oriental Darter					*		C	N T	Sch-IV	R	W L
123	Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	*		*		*		P	L C	Sch-IV	R	W L
124	Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant					*		P	L C	Sch-IV	R	W L
125	Phalacrocoracidae	*Phalacrocorax fuscicollis*	Indian Cormorant					*		P	L C	Sch-IV	R	W L

*, Species occurrence in Habitat; A, Agriculture; B, Built-up; F, Forest; OS, Open Scrub; W, Wetland; C, Control; FG, Feeding guild; Occ, Occurrence; GH, General Habitat; LC, Least Concerned; V, Vulnerable; NT, Near Threatened; F, Frugivore; N, Nectarivore; P, Piscivore; C, Carnivore/ Flesh eating; I, Insectivore; G, Granivore; O, Omnivore; Sch, Schedule; R, Resident; M-L, Local Migratory; WL, Wet-lands; WS, Wide spread F, Forest; G, Grassland; S, Scrub land.

Annexure 9.2: Occurrence of Bird species at different distances from the MPC.

S No	Order: Family	Scientific Name	Common Name	Distance from MPC				
				0m	100m	200m	300m	Control
I	**Accipitriformes:**							
1	Accipitridae	*Accipiter badius*	Shikra	*	*	*	*	
2	Accipitridae	*Aquila fasciata*	Bonelli's Eagle				*	
3	Accipitridae	*Circaetus gallicus*	Short-toed Snake Eagle	*	*			
4	Accipitridae	*Clanga hastata*	Indian Spotted Eagle		*			
5	Accipitridae	*Elanus caeruleus*	Black-winged Kite	*	*	*	*	
6	Accipitridae	*Haliastur indus*	Brahminy Kite	*				
7	Accipitridae	*Ictinaetus malaiensis*	Black Eagle	*	*		*	
II	**Anseriformes:**							
8	Anatidae	*Anas poecilorhyncha*	Indian Spot-billed Duck	*	*			
III	**Bucerotiformes:**							
9	Bucerotidae	*Ocyceros birostris*	Indian Grey Hornbill	*	*	*	*	*
10	Upupidae	*Upupa epops*	Common Hoopoe				*	
IV	**Caprimulgiformes:**							
11	Apodidae	*Apus affinis*	Indian House Swift	*	*	*	*	*
12	Apodidae	*Cypsiurus balasiensis*	Asian Palm Swift	*	*	*	*	
V	**Charadriiformes:**							
13	Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	*		*	*	
14	Charadriidae	*Vanellus malabaricus*	Yellow-wattled Lapwing		*		*	
15	Turnicidae	*Turnixsus citator*	Barred Buttonquail		*	*		
VI	**Columbiformes:**							
16	Columbidae	*Columba livia*	Rock Pigeon	*	*	*	*	*
17	Columbidae	*Streptopelia chinensis*	Spotted Dove	*	*	*	*	*
18	Columbidae	*Streptopelia decaocto*	Eurasian Collared Dove	*	*	*	*	*
19	Columbidae	*Streptopelia senegalensis*	Laughing Dove	*	*	*	*	*
VII	**Coraciiformes:**							
20	Alcedinidae	*Alcedo atthis*	Common Kingfisher	*				
21	Alcedinidae	*Ceryl erudis*	Pied Kingfisher			*		
22	Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	*	*	*	*	*

23	Coraciidae	*Coracias benghalensis*	Indian Roller	*		*	*	
24	Meropidae	*Merops orientalis*	Green Bee-eater	*	*	*	*	*
VIII	**Cuculiformes:**							
25	Cuculidae	*Centropus sinensis*	Greater Coucal	*	*	*	*	*
26	Cuculidae	*Clamator jacobinus*	Pied Cuckoo	*	*	*		
27	Cuculidae	*Eudynamys scolopaceus*	Asian Koel	*	*	*	*	
28	Cuculidae	*Hierococcyx varius*	Common Hawk Cuckoo	*	*	*	*	*
29	Cuculidae	*Phaenicophaeus viridirostris*	Blue-faced Malkoha	*	*	*	*	
30	Cuculidae	*Taccocua leschenaultii*	Sirkeer Malkoha			*	*	*
IX	**Falconiformes:**							
31	Falconidae	*Falco peregrinus*	Shaheen Falcon	*			*	
X	**Galliformes:**							
32	Phasianidae	*Francolinus pondicerianus*	Grey Francolin	*	*	*	*	*
33	Phasianidae	*Galloperdix spadicea*	Red Spurfowl	*			*	*
34	Phasianidae	*Gallus sonneratii*	Grey Jungle Fowl		*			
35	Phasianidae	*Pavo cristatus*	Indian Peafowl	*	*	*	*	*
36	Phasianidae	*Perdiculaar goondah*	Rock Bush Quail				*	
37	Phasianidae	*Perdicula asiatica*	Jungle Bush Quail		*		*	
XI	**Gruiformes:**							
38	Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	*				
XII	**Passeriformes:**							
39	Aegithinidae	*Aegithina tiphia*	Common Iora	*	*	*	*	*
40	Alaudidae	*Alauda gulgula*	Oriental Skylark		*	*	*	*
41	Alaudidae	*Ammomanes phoenicura*	Rufous-tailed Lark	*		*	*	
42	Alaudidae	*Eremopterix griseus*	Ashy-crowned Sparrow Lark	*	*	*	*	
43	Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet	*	*	*	*	*
44	Chloropseidae	*Chloropsis jerdoni*	Jerdon's Leafbird				*	
45	Cisticolidae	*Cisticola juncidis*	Zitting Cisticola				*	
46	Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	*	*	*	*	*
47	Cisticolidae	*Prinia buchanani*	Rufous-fronted Prinia	*		*	*	
48	Cisticolidae	*Prinia hodgsonii*	Grey-breasted Prinia	*	*	*	*	*
49	Cisticolidae	*Prinia inornata*	Plain Prinia	*	*	*	*	*
50	Cisticolidae	*Prinia socialis*	Ashy Prinia	*	*	*	*	*

51	Corvidae	*Corvus macrorhynchos*	Large-billed Crow		*		*	
52	Corvidae	*Corvus splendens*	House Crow	*	*	*	*	
53	Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	*	*	*	*	*
54	Dicruridae	*Dicaeum erythrorhynchos*	Pale-billed Flowerpecker	*	*	*	*	*
55	Dicruridae	*Dicrurus caerulescens*	White-bellied Drongo	*		*		*
56	Dicruridae	*Dicrurus macrocercus*	Black Drongo	*	*			
57	Estrildidae	*Euodice malabarica*	Indian Silverbill	*	*	*	*	
58	Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	*	*	*	*	*
59	Hirundinidae	*Cecropis daurica*	Red-rumped Swallow	*	*	*	*	
60	Hirundinidae	*Hirundo rustica*	Barn Swallow	*	*			
61	Hirundinidae	*Ptyonoprogne concolor*	Dusky Crag Martin		*	*	*	
62	Laniidae	*Lanius schach*	Long-tailed Shrike		*	*	*	
63	Laniidae	*Lanius vittatus*	Bay-backed Shrike		*	*	*	
64	Leiothrichidae	*Argya malcolmi*	Large Grey Babbler	*	*	*	*	*
65	Leiothrichidae	*Chrysomma sinense*	Yellow-eyed Babbler	*	*			
66	Leiothrichidae	*Turdoides affinis*	Yellow-billed Babbler	*	*	*	*	*
67	Leiothrichidae	*Turdoides striata*	Jungle Babbler	*	*	*	*	*
68	Motacillidae	*Motacilla maderaspatensis*	White-browed Wagtail	*	*	*		
69	Muscicapidae	*Copsychus saularis*	Oriental Magpie Robin	*	*	*	*	*
70	Muscicapidae	*Cyornis tickelliae*	Tickell's Blue Flycatcher	*	*	*	*	*
71	Muscicapidae	*Muscicapa dauurica*	Asian Brown Flycatcher	*	*			*
72	Muscicapidae	*Saxicola caprata*	Pied Bushchat	*	*	*	*	
73	Muscicapidae	*Saxicoloides fulicatus*	Indian Robin	*	*	*	*	*
74	Nectariniidae	*Cinnyris asiaticus*	Purple Sunbird	*	*	*	*	*
75	Nectariniidae	*Leptocoma zeylonica*	Purple-rumped Sunbird	*	*	*	*	*
76	Passeridae	*Passer domesticus*	House Sparrow	*	*	*	*	
77	Ploceidae	*Ploceus philippinus*	Baya Weaver	*	*	*	*	
78	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	*	*	*	*	*
79	Pycnonotidae	*Pycnonotus luteolus*	White-browed Bulbul	*	*	*	*	*
80	Rhipiduridae	*Rhipidura albogularis*	White-spotted Fantail	*	*			*
81	Sturnidae	*Acridotheres tristis*	Common Myna	*	*	*	*	
82	Sturnidae	*Sturnia pagodarum*	Brahminy Starling	*	*	*	*	
83	Zosteropidae	*Zosterops palpebrosus*	Oriental White-eye		*	*		

84	Oriolidae	*Oriolus kundoo*	Indian Golden Oriole			*		
XIII	**Pelecaniformes:**							
85	Ardeidae	*Ardea cinerea*	Grey Heron	*			*	
86	Ardeidae	*Ardea purpurea*	Purple Heron			*		
87	Ardeidae	*Ardeola grayii*	Indian Pond Heron	*	*	*	*	
88	Ardeidae	*Bubulcus ibis*	Cattle Egret	*			*	
89	Ardeidae	*Egretta garzetta*	Little Egret	*			*	
XIV	**Piciformes:**							
90	Megalaimidae	*Psilopogon haemacephalus*	Coppersmith Barbet	*	*	*	*	*
91	Megalaimidae	*Psilopogon viridis*	White-cheeked Barbet	*	*	*	*	*
92	Picidae	*Dinopium benghalense*	Lesser Golden-backed Woodpecker	*	*		*	*
XV	**Psittaciformes:**							
93	Psittaculidae	*Psittacula cyanocephala*	Plum-headed Parakeet			*	*	*
94	Psittaculidae	*Psittacula krameri*	Rose-ringed Parakeet	*	*	*	*	*
XVI	**Pterocliformes:**							
95	Pteroclidae	*Pterocles indicus*	Painted Sandgrouse			*	*	
XVII	**Strigiformes:**							
96	Strigidae	*Athene brama*	Spotted Owlet			*	*	
XVIII	**Suliformes:**							
97	Phalacrocoracidae	*Microcarboniger*	Little Cormorant	*	*	*	*	

*, Occurrence of species in the study area.

Annexure 9.3: Relative abundance and Percent abundance of all bird species in different habitat

S. No	Habitat	Agriculture			Built-up			Forest			Open Scrub			Wetland			Control		
	Species Name	**Count**	**Rel. Abun**	**% Abundance**	**Count**	**Rel. Abun**	**% Abundance**	**Count**	**Rel. Abun**	**% Abundance**	**Count**	**Rel. Abun**	**% Abundance**	**Count**	**Rel. Abun**	**% Abundance**	**Count**	**Rel. Abun**	**% Abundance**
1	Ashy Prinia	110	0.09	9.25	33	0.04	3.46	58	0.07	6.76	25	0.03	2.80	12	0.04	4.15	35	0.04	3.57
2	Ashy-crowned Sparrow Lark	0	0.00	0.00	39	0.04	4.09	2	0	0.23	10	0.01	1.12	0	0.00	0.00	0	0.00	0.00
3	Asian Brown Flycatcher	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10
4	Asian Koel	9	0.01	0.76	9	0.01	0.94	3	0	0.35	6	0.01	0.67	0	0.00	0.00	0	0.00	0.00
5	Asian Palm Swift	6	0.01	0.51	3	0.00	0.31	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
6	Barn Swallow	13	0.01	1.09	0	0.00	0.00	3	0	0.35	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
7	Barred Buttonquail	7	0.01	0.59	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
8	Baya Weaver	92	0.08	7.74	0	0.00	0.00	2	0	0.23	6	0.01	0.67	0	0.00	0.00	0	0.00	0.00
9	Bay-backed Shrike	0	0.00	0.00	4	0.00	0.42	2	0	0.23	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
10	Black Drongo	1	0.00	0.08	4	0.00	0.42	1	0	0.12	0	0.00	0.00	1	0.00	0.35	0	0.00	0.00
11	Black Eagle	0	0.00	0.00	0	0.00	0.00	1	0	0.12	3	0.00	0.34	0	0.00	0.00	0	0.00	0.00
12	Black-winged Kite	3	0.00	0.25	23	0.02	2.41	1	0	0.12	2	0.00	0.22	0	0.00	0.00	0	0.00	0.00
13	Blue Rock Pigeon	91	0.08	7.65	57	0.06	5.98	29	0.03	3.38	69	0.08	7.72	0	0.00	0.00	10	0.01	1.02
14	Blue-faced Malkoha	0	0.00	0.00	3	0.00	0.31	4	0	0.47	0	0.00	0.00	1	0.00	0.35	0	0.00	0.00
15	Bonneli's Eagle	1	0.00	0.08	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
16	Brahminy Kite	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
17	Brahminy Starling	11	0.01	0.93	2	0.00	0.21	0	0	0	7	0.01	0.78	0	0.00	0.00	0	0.00	0.00
18	Cattle Egret	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	2	0.01	0.69	0	0.00	0.00
19	Common Hawk Cuckoo	0	0.00	0.00	0	0.00	0.00	0	0	0	1	0.00	0.11	0	0.00	0.00	6	0.01	0.61
20	Common Hoopoe	0	0.00	0.00	0	0.00	0.00	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
21	Common Iora	8	0.01	0.67	5	0.01	0.52	53	0.06	6.18	12	0.01	1.34	0	0.00	0.00	71	0.07	7.25
22	Common Kingfisher	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
23	Common Myna	119	0.10	10.01	80	0.08	8.39	2	0	0.23	63	0.07	7.05	3	0.01	1.04	0	0.00	0.00

24	Common Tailorbird	3	0.00	0.25	7	0.01	0.73	13	0.02	1.52	4	0.00	0.45	1	0.00	0.35	16	0.02	1.63
25	Coppersmith Barbet	0	0.00	0.00	1	0.00	0.11	3	0	0.35	0	0.00	0.00	0	0.00	0.00	12	0.01	1.22
26	Dusky Crag Marten	0	0.00	0.00	1	0.00	0.11	7	0.01	0.82	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
27	Eurasian Collared Dove	34	0.03	2.86	4	0.00	0.42	2	0	0.23	26	0.03	2.91	0	0.00	0.00	3	0.00	0.31
28	Greater Coucal	5	0.00	0.42	1	0.00	0.11	9	0.01	1.05	9	0.01	1.01	1	0.00	0.35	12	0.01	1.22
29	Green Bee-eater	24	0.02	2.02	10	0.01	1.05	8	0.01	0.93	17	0.02	1.90	4	0.01	1.38	10	0.01	1.02
30	Grey Francolin	8	0.01	0.67	3	0.00	0.31	0	0	0	17	0.02	1.90	0	0.00	0.00	9	0.01	0.92
31	Grey Heron	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	4	0.01	1.38	0	0.00	0.00
32	Grey Jungle Fowl	0	0.00	0.00	0	0.00	0.00	2	0	0.23	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
33	Grey-breasted Prinia	0	0.00	0.00	0	0.00	0.00	5	0.01	0.58	3	0.00	0.34	2	0.01	0.69	46	0.05	4.69
34	House Crow	22	0.02	1.85	97	0.10	10.17	6	0.01	0.7	14	0.02	1.57	0	0.00	0.00	0	0.00	0.00
35	House Sparrow	0	0.00	0.00	130	0.14	13.63	0	0	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
36	Indian Golden Oriole	0	0.00	0.00	0	0.00	0.00	2	0	0.23	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
37	Indian Grey Hornbill	8	0.01	0.67	0	0.00	0.00	7	0.01	0.82	1	0.00	0.11	0	0.00	0.00	10	0.01	1.02
38	Indian Jungle Crow	0	0.00	0.00	11	0.01	1.15	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
39	Indian Peafowl	13	0.01	1.09	5	0.01	0.52	20	0.02	2.33	7	0.01	0.78	3	0.01	1.04	38	0.04	3.88
40	Indian Pond Heron	1	0.00	0.08	0	0.00	0.00	0	0	0	0	0.00	0.00	6	0.02	2.08	0	0.00	0.00
41	Indian Robin	14	0.01	1.18	23	0.02	2.41	9	0.01	1.05	17	0.02	1.90	5	0.02	1.73	17	0.02	1.74
42	Indian Roller	6	0.01	0.51	1	0.00	0.11	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
43	Indian Silverbill	40	0.03	3.36	57	0.06	5.98	2	0	0.23	16	0.02	1.79	11	0.04	3.81	0	0.00	0.00
44	Indian Spot-billed Duck	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	11	0.04	3.81	0	0.00	0.00
45	Indian Spotted Eagle	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
46	Jerdon's Leafbird	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
47	Jungle Babbler	0	0.00	0.00	0	0.00	0.00	12	0.01	1.4	0	0.00	0.00	16	0.06	5.54	29	0.03	2.96
48	Jungle Bush Quail	0	0.00	0.00	1	0.00	0.11	1	0	0.12	6	0.01	0.67	0	0.00	0.00	0	0.00	0.00
49	Large Grey Babbler	34	0.03	2.86	27	0.03	2.83	5	0.01	0.58	101	0.11	11.30	0	0.00	0.00	5	0.01	0.51
50	Laughing Dove	37	0.03	3.11	80	0.08	8.39	28	0.03	3.26	68	0.08	7.61	13	0.05	4.50	60	0.06	6.12
51	Lesser Goldenback	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	3	0.00	0.31
52	Little Cormorant	1	0.00	0.08	0	0.00	0.00	4	0	0.47	0	0.00	0.00	49	0.17	16.96	0	0.00	0.00
53	Little Egret	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	2	0.01	0.69	0	0.00	0.00

54	Little Swift	71	0.06	5.97	34	0.04	3.56	56	0.07	6.53	38	0.04	4.25	37	0.13	12.80	9	0.01	0.92
55	Long-tailed Shrike	0	0.00	0.00	0	0.00	0.00	3	0	0.35	6	0.01	0.67	0	0.00	0.00	0	0.00	0.00
56	Oriental Magpie Robin	1	0.00	0.08	0	0.00	0.00	7	0.01	0.82	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10
57	Oriental Skylark	0	0.00	0.00	0	0.00	0.00	0	0	0	6	0.01	0.67	0	0.00	0.00	2	0.00	0.20
58	Oriental White-eye	0	0.00	0.00	0	0.00	0.00	6	0.01	0.7	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
59	Painted Sandgrouse	0	0.00	0.00	1	0.00	0.11	0	0	0	2	0.00	0.22	0	0.00	0.00	0	0.00	0.00
60	Pale-billed Flowerpecker	1	0.00	0.08	1	0.00	0.11	2	0	0.23	0	0.00	0.00	0	0.00	0.00	17	0.02	1.74
61	Pied Bushchat	14	0.01	1.18	14	0.02	1.47	12	0.01	1.4	9	0.01	1.01	0	0.00	0.00	0	0.00	0.00
62	Pied Kingfisher	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	1	0.00	0.35	0	0.00	0.00
63	Pied-crested Cuckoo	0	0.00	0.00	0	0.00	0.00	0	0	0	3	0.00	0.34	0	0.00	0.00	0	0.00	0.00
64	Plain Prinia	37	0.03	3.11	46	0.05	4.82	49	0.06	5.71	49	0.06	5.48	9	0.03	3.11	44	0.05	4.49
65	Plum-headed Parakeet	0	0.00	0.00	0	0.00	0.00	5	0.01	0.58	0	0.00	0.00	0	0.00	0.00	3	0.00	0.31
66	Purple Heron	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	1	0.00	0.35	0	0.00	0.00
67	Purple Sunbird	6	0.01	0.51	18	0.02	1.89	16	0.02	1.86	16	0.02	1.79	1	0.00	0.35	80	0.08	8.16
68	Purple-rumped Sunbird	24	0.02	2.02	9	0.01	0.94	42	0.05	4.9	19	0.02	2.13	0	0.00	0.00	23	0.02	2.35
69	Red Spurfowl	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	6	0.01	0.61
70	Red-rumped Swallow	20	0.02	1.68	7	0.01	0.73	33	0.04	3.85	4	0.00	0.45	38	0.13	13.15	0	0.00	0.00
71	Red-vented Bulbul	90	0.08	7.57	55	0.06	5.77	162	0.19	18.88	153	0.17	17.11	23	0.08	7.96	127	0.13	12.96
72	Red-wattled Lapwing	10	0.01	0.84	0	0.00	0.00	1	0	0.12	2	0.00	0.22	0	0.00	0.00	0	0.00	0.00
73	Rock Bush Quail	0	0.00	0.00	0	0.00	0.00	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
74	Rose-ringed Parakeet	117	0.10	9.84	14	0.02	1.47	53	0.06	6.18	0	0.00	0.00	13	0.05	4.50	54	0.06	5.51
75	Rufous Treepie	0	0.00	0.00	0	0.00	0.00	4	0	0.47	1	0.00	0.11	0	0.00	0.00	13	0.01	1.33
76	Rufous-fronted Prinia	0	0.00	0.00	0	0.00	0.00	0	0	0	7	0.01	0.78	0	0.00	0.00	0	0.00	0.00
77	Rufous-tailed Lark	0	0.00	0.00	0	0.00	0.00	0	0	0	10	0.01	1.12	0	0.00	0.00	0	0.00	0.00
78	Scally-breasted Munia	13	0.01	1.09	15	0.02	1.57	7	0.01	0.82	22	0.03	2.46	1	0.00	0.35	4	0.00	0.41
79	Shaheen Falcon	0	0.00	0.00	0	0.00	0.00	0	0	0	2	0.00	0.22	0	0.00	0.00	0	0.00	0.00
80	Shikra	2	0.00	0.17	1	0.00	0.11	2	0	0.23	3	0.00	0.34	0	0.00	0.00	0	0.00	0.00
81	Short-toed Snake Eagle	1	0.00	0.08	0	0.00	0.00	1	0	0.12	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
82	Sirkeer Malkoha	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	2	0.00	0.20

83	Small Minivet	0	0.00	0.00	0	0.00	0.00	6	0.01	0.7	0	0.00	0.00	0	0.00	0.00	19	0.02	1.94
84	Spotted Dove	32	0.03	2.69	2	0.00	0.21	6	0.01	0.7	13	0.02	1.45	0	0.00	0.00	5	0.01	0.51
85	Spotted Owlet	2	0.00	0.17	0	0.00	0.00	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
86	Streaked-fantail Warbler	0	0.00	0.00	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
87	Tickell's Blue Flycatcher	1	0.00	0.08	0	0.00	0.00	5	0.01	0.58	0	0.00	0.00	1	0.00	0.35	11	0.01	1.12
88	White-bellied Drongo	0	0.00	0.00	0	0.00	0.00	2	0	0.23	0	0.00	0.00	0	0.00	0.00	17	0.02	1.74
89	White-breasted Waterhen	0	0.00	0.00	2	0.00	0.21	0	0	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
90	White-browed Bulbul	1	0.00	0.08	0	0.00	0.00	28	0.03	3.26	3	0.00	0.34	5	0.02	1.73	129	0.13	13.16
91	White-browed Wagtail	3	0.00	0.25	6	0.01	0.63	3	0	0.35	0	0.00	0.00	7	0.02	2.42	0	0.00	0.00
92	White-cheeked Barbet	1	0.00	0.08	0	0.00	0.00	0	0	0	0	0.00	0.00	0	0.00	0.00	9	0.01	0.92
93	White-spotted Fantail	0	0.00	0.00	0	0.00	0.00	1	0	0.12	0	0.00	0.00	0	0.00	0.00	3	0.00	0.31
94	White-throated Kingfisher	4	0.00	0.34	5	0.01	0.52	3	0	0.35	1	0.00	0.11	4	0.01	1.38	1	0.00	0.10
95	Yellow-billed Babbler	17	0.01	1.43	0	0.00	0.00	31	0.04	3.61	4	0.00	0.45	1	0.00	0.35	8	0.01	0.82
96	Yellow-eyed Babbler	0	0.00	0.00	1	0.00	0.11	0	0	0	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00
97	Yellow-wattled Lapwing	0	0.00	0.00	0	0.00	0.00	0	0	0	2	0.00	0.22	0	0.00	0.00	0	0.00	0.00

Annexure 9.4: Abundance of all birdspecies in relation to distance from MPC and Control area

S. No	Distance from MPC	Zero (0m)			100m			200m			300m			Control		
	Species Name	Count	Rel. Abund	% Abundance	Count	Rel. Abund	% Abundance	Count	Rel. Abund	% Abundance	Count	Rel. Abund	% Abundance	Count	Rel. Abund	% Abundance
1	Ashy Prinia	76	0.059	5.938	51	0.05	5.43	60	0.06	6.14	51	0.05	5.16	35	0.04	3.57
2	Ashy-crowned Sparrow Lark	18	0.014	1.406	12	0.01	1.28	11	0.01	1.13	10	0.01	1.01	0	0.00	0.00
3	Asian Brown Flycatcher	0	0.000	0.000	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10
4	Asian Koel	4	0.003	0.313	3	0.00	0.32	6	0.01	0.61	14	0.01	1.42	0	0.00	0.00
5	Asian Palm Swift	2	0.002	0.156	3	0.00	0.32	1	0.00	0.10	4	0.00	0.40	0	0.00	0.00
6	Barn Swallow	3	0.002	0.234	13	0.01	1.38	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
7	Barred Buttonquail	0	0.000	0.000	3	0.00	0.32	4	0.00	0.41	0	0.00	0.00	0	0.00	0.00
8	Baya Weaver	17	0.013	1.328	28	0.03	2.98	33	0.03	3.38	22	0.02	2.23	0	0.00	0.00
9	Bay-backed Shrike	0	0.000	0.000	1	0.00	0.11	4	0.00	0.41	2	0.00	0.20	0	0.00	0.00
10	Black Drongo	1	0.001	0.078	6	0.01	0.64	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
11	Black Eagle	1	0.001	0.078	1	0.00	0.11	0	0.00	0.00	2	0.00	0.20	0	0.00	0.00
12	Black-winged Kite	1	0.001	0.078	3	0.00	0.32	2	0.00	0.20	23	0.02	2.33	0	0.00	0.00
13	Blue Rock Pigeon	129	0.101	10.078	55	0.06	5.86	41	0.04	4.20	21	0.02	2.13	10	0.01	1.02
14	Blue-faced Malkoha	4	0.003	0.313	2	0.00	0.21	1	0.00	0.10	1	0.00	0.10	0	0.00	0.00
15	Bonneli's Eagle	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00
16	Brahminy Kite	1	0.001	0.078	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
17	Brahminy Starling	4	0.003	0.313	3	0.00	0.32	2	0.00	0.20	11	0.01	1.11	0	0.00	0.00
18	Cattle Egret	1	0.001	0.078	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00
19	Common Hawk Cuckoo	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	6	0.01	0.61
20	Common Hoopoe	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00
21	Common Iora	9	0.007	0.703	21	0.02	2.24	22	0.02	2.25	26	0.03	2.63	71	0.07	7.24
22	Common Kingfisher	1	0.001	0.078	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
23	Common Myna	128	0.100	10.000	55	0.06	5.86	24	0.02	2.46	60	0.06	6.07	0	0.00	0.00

24	Common Tailorbird	5	0.004	0.391	6	0.01	0.64	10	0.01	1.02	7	0.01	0.71	16	0.02	1.63
25	Coppersmith Barbet	2	0.002	0.156	0	0.00	0.00	0	0.00	0.00	2	0.00	0.20	12	0.01	1.22
26	Dusky Crag Marten	0	0.000	0.000	6	0.01	0.64	1	0.00	0.10	1	0.00	0.10	0	0.00	0.00
27	Eurasian Collared Dove	20	0.016	1.563	12	0.01	1.28	16	0.02	1.64	18	0.02	1.82	3	0.00	0.31
28	Greater Coucal	8	0.006	0.625	4	0.00	0.43	6	0.01	0.61	7	0.01	0.71	12	0.01	1.22
29	Green Bee-eater	14	0.011	1.094	9	0.01	0.96	10	0.01	1.02	30	0.03	3.04	10	0.01	1.02
30	Grey Francolin	7	0.005	0.547	2	0.00	0.21	9	0.01	0.92	10	0.01	1.01	9	0.01	0.92
31	Grey Heron	2	0.002	0.156	0	0.00	0.00	0	0.00	0.00	2	0.00	0.20	0	0.00	0.00
32	Grey Jungle Fowl	0	0.000	0.000	2	0.00	0.21	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
33	Grey-breasted Prinia	3	0.002	0.234	2	0.00	0.21	0	0.00	0.00	5	0.01	0.51	46	0.05	4.69
34	House Crow	42	0.033	3.281	27	0.03	2.88	40	0.04	4.09	30	0.03	3.04	0	0.00	0.00
35	House Sparrow	5	0.004	0.391	22	0.02	2.34	101	0.10	10.34	2	0.00	0.20	0	0.00	0.00
36	Indian Golden Oriole	0	0.000	0.000	0	0.00	0.00	2	0.00	0.20	0	0.00	0.00	0	0.00	0.00
37	Indian Grey Hornbill	3	0.002	0.234	3	0.00	0.32	4	0.00	0.41	6	0.01	0.61	10	0.01	1.02
38	Indian Jungle Crow	0	0.000	0.000	4	0.00	0.43	0	0.00	0.00	8	0.01	0.81	0	0.00	0.00
39	Indian Peafowl	6	0.005	0.469	6	0.01	0.64	12	0.01	1.23	24	0.02	2.43	38	0.04	3.88
40	Indian Pond Heron	3	0.002	0.234	1	0.00	0.11	2	0.00	0.20	1	0.00	0.10	0	0.00	0.00
41	Indian Robin	21	0.016	1.641	23	0.02	2.45	20	0.02	2.05	4	0.00	0.40	17	0.02	1.73
42	Indian Roller	5	0.004	0.391	0	0.00	0.00	2	0.00	0.20	1	0.00	0.10	0	0.00	0.00
43	Indian Silverbill	54	0.042	4.219	22	0.02	2.34	34	0.03	3.48	16	0.02	1.62	0	0.00	0.00
44	Indian Spot-billed Duck	11	0.009	0.859	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
45	Indian Spotted Eagle	0	0.000	0.000	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
46	Jerdon's Leafbird	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00
47	Jungle Babbler	16	0.013	1.250	5	0.01	0.53	1	0.00	0.10	6	0.01	0.61	29	0.03	2.96
48	Jungle Bush Quail	0	0.000	0.000	1	0.00	0.11	0	0.00	0.00	7	0.01	0.71	0	0.00	0.00
49	Large Grey Babbler	24	0.019	1.875	48	0.05	5.11	56	0.06	5.73	39	0.04	3.95	5	0.01	0.51
50	Laughing Dove	74	0.058	5.781	57	0.06	6.07	52	0.05	5.32	43	0.04	4.35	60	0.06	6.12
51	Lesser Goldenback	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	3	0.00	0.31
52	Little Cormorant	42	0.033	3.281	10	0.01	1.06	1	0.00	0.10	1	0.00	0.10	0	0.00	0.00
53	Little Egret	1	0.001	0.078	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00

54	Little Swift	55	0.043	4.297	39	0.04	4.15	38	0.04	3.89	104	0.11	10.53	9	0.01	0.92
55	Long-tailed Shrike	0	0.000	0.000	4	0.00	0.43	1	0.00	0.10	4	0.00	0.40	0	0.00	0.00
56	Oriental Magpie Robin	1	0.001	0.078	5	0.01	0.53	2	0.00	0.20	0	0.00	0.00	1	0.00	0.10
57	Oriental Skylark	0	0.000	0.000	1	0.00	0.11	3	0.00	0.31	2	0.00	0.20	2	0.00	0.20
58	Oriental White-eye	0	0.000	0.000	3	0.00	0.32	3	0.00	0.31	0	0.00	0.00	0	0.00	0.00
59	Painted Sandgrouse	0	0.000	0.000	0	0.00	0.00	2	0.00	0.20	1	0.00	0.10	0	0.00	0.00
60	Pale-billed Flowerpecker	0	0.000	0.000	1	0.00	0.11	2	0.00	0.20	1	0.00	0.10	17	0.02	1.73
61	Pied Bushchat	8	0.006	0.625	13	0.01	1.38	25	0.03	2.56	3	0.00	0.30	0	0.00	0.00
62	Pied Kingfisher	0	0.000	0.000	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00	0	0.00	0.00
63	Pied-crested Cuckoo	1	0.001	0.078	1	0.00	0.11	1	0.00	0.10	0	0.00	0.00	0	0.00	0.00
64	Plain Prinia	43	0.034	3.359	39	0.04	4.15	66	0.07	6.76	42	0.04	4.25	44	0.04	4.49
65	Plum-headed Parakeet	0	0.000	0.000	0	0.00	0.00	2	0.00	0.20	3	0.00	0.30	3	0.00	0.31
66	Purple Heron	0	0.000	0.000	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00	0	0.00	0.00
67	Purple Sunbird	9	0.007	0.703	12	0.01	1.28	21	0.02	2.15	15	0.02	1.52	80	0.08	8.16
68	Purple-rumped Sunbird	21	0.016	1.641	24	0.03	2.56	20	0.02	2.05	29	0.03	2.94	23	0.02	2.35
69	Red Spurfowl	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	6	0.01	0.61
70	Red-rumped Swallow	80	0.063	6.250	9	0.01	0.96	6	0.01	0.61	7	0.01	0.71	0	0.00	0.00
71	Red-vented Bulbul	134	0.105	10.469	168	0.18	17.89	93	0.10	9.52	88	0.09	8.91	127	0.13	12.96
72	Red-wattled Lapwing	4	0.003	0.313	0	0.00	0.00	3	0.00	0.31	6	0.01	0.61	0	0.00	0.00
73	Rock Bush Quail	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00
74	Rose-ringed Parakeet	63	0.049	4.922	25	0.03	2.66	24	0.02	2.46	85	0.09	8.60	54	0.06	5.51
75	Rufous Treepie	1	0.001	0.078	2	0.00	0.21	0	0.00	0.00	2	0.00	0.20	13	0.01	1.33
76	Rufous-fronted Prinia	1	0.001	0.078	0	0.00	0.00	3	0.00	0.31	3	0.00	0.30	0	0.00	0.00
77	Rufous-tailed Lark	1	0.001	0.078	0	0.00	0.00	7	0.01	0.72	2	0.00	0.20	0	0.00	0.00
78	Scally-breasted Munia	25	0.020	1.953	6	0.01	0.64	14	0.01	1.43	13	0.01	1.32	4	0.00	0.41
79	Shaheen Falcon	1	0.001	0.078	0	0.00	0.00	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00
80	Shikra	1	0.001	0.078	3	0.00	0.32	1	0.00	0.10	3	0.00	0.30	0	0.00	0.00
81	Short-toed Snake Eagle	1	0.001	0.078	2	0.00	0.21	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
82	Sirkeer Malkoha	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	2	0.00	0.20
83	Small Minivet	0	0.000	0.000	0	0.00	0.00	4	0.00	0.41	2	0.00	0.20	19	0.02	1.94
84	Spotted Dove	12	0.009	0.938	10	0.01	1.06	15	0.02	1.54	16	0.02	1.62	5	0.01	0.51

85	Spotted Owlet	0	0.000	0.000	0	0.00	0.00	2	0.00	0.20	1	0.00	0.10	0	0.00	0.00
86	Streaked-fantail Warbler	0	0.000	0.000	0	0.00	0.00	0	0.00	0.00	2	0.00	0.20	0	0.00	0.00
87	Tickell's Blue Flycatcher	1	0.001	0.078	2	0.00	0.21	3	0.00	0.31	1	0.00	0.10	11	0.01	1.12
88	White-bellied Drongo	0	0.000	0.000	0	0.00	0.00	2	0.00	0.20	0	0.00	0.00	17	0.02	1.73
89	White-breasted Waterhen	2	0.002	0.156	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
90	White-browed Bulbul	8	0.006	0.625	5	0.01	0.53	15	0.02	1.54	9	0.01	0.91	129	0.13	13.16
91	White-browed Wagtail	13	0.010	1.016	5	0.01	0.53	1	0.00	0.10	0	0.00	0.00	0	0.00	0.00
92	White-cheeked Barbet	0	0.000	0.000	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00	9	0.01	0.92
93	White-spotted Fantail	0	0.000	0.000	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00	3	0.00	0.31
94	White-throated Kingfisher	10	0.008	0.781	3	0.00	0.32	2	0.00	0.20	2	0.00	0.20	1	0.00	0.10
95	Yellow-billed Babbler	15	0.012	1.172	19	0.02	2.02	3	0.00	0.31	16	0.02	1.62	8	0.01	0.82
96	Yellow-eyed Babbler	1	0.001	0.078	1	0.00	0.11	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
97	Yellow-wattled Lapwing	0	0.000	0.000	1	0.00	0.11	0	0.00	0.00	1	0.00	0.10	0	0.00	0.00

Annexure10.1. Camera trap ID, geocoordinates, habitat type, distance from MPC and sound dB values.

Camera Trap ID	Latitude	Longitude	Habitat Type	Distance from MPC (m)	Sound in dB
CAM01	15.11447	76.60557	Thorn Scrub Forest	52	60.4
CAM02	15.15786	76.63599	Open Scrub Land	50	51.1
CAM03	15.15787	76.63476	Open Scrub Land	38	50.1
CAM04	15.11324	76.60458	Thorn Scrub Forest	58	48.4
CAM05	15.06916	76.56194	Built-up	70	51.5
CAM06	15.05739	76.56594	Agricultural Land	10	77.9
CAM07	15.11417	76.60556	Thorn Scrub Forest	40	61.2
CAM08	15.12517	76.61083	Agricultural Land	62	62.9
CAM09	15.15326	76.63247	Open Scrub Land	50	54.6
CAM10	15.15417	76.63172	Open Scrub Land	60	49.3
CAM11	15.10125	76.57902	Thorn Scrub Forest	62.5	52.1
CAM12	15.11302	76.60387	Thorn Scrub Forest	30	72.1
CAM13	15.11164	76.60156	Thorn Scrub Forest	53	64.3
CAM14	15.11116	76.59446	Thorn Scrub Forest	45	51.2
CAM15	15.10594	76.58501	Thorn Scrub Forest	62	54.5
CAM16	15.11886	76.60558	Thorn Scrub Forest	40	63.1
CAM17	15.0815	76.56223	Open Scrub Land	108	53.5
CAM18	15.07465	76.56205	Open Scrub Land	102	63.2
CAM19	15.1397	76.62447	Open Scrub Land	150	58.4
CAM20	15.13388	76.6174	Agricultural Land	31	64.5
CAM21	15.15832	76.63893	Open Scrub Land	18	79.5
CAM22	15.15937	76.63722	Open Scrub Land	76	61.5
CAM23	15.12429	76.61289	Agricultural Land	171	50.1
CAM25	15.15007	76.6285	Agricultural Land	98	61.2

CAM26	15.14355	76.62311	Open Scrub Land	57	56.6
CAM27	15.12111	76.60806	Thorn Scrub Forest	65	55.6
CAM28	15.10297	76.58122	Thorn Scrub Forest	99	61.8
CAM29	15.10374	76.58203	Thorn Scrub Forest	119	60
CAM30	15.06123	76.56392	Built-up	31	72.4
CAM31	15.1603	76.65774	Open Scrub Land	48.4	82.5
Control Site					
CAM24	15.10864	76.62056	Thorny Scrub Patch	1790	38.5
CAM32	15.15532	76.63707	Open Scrub Land	331	39.8
CAM33	15.14833	76.63389	Open Scrub Land	411	49.2
CAM34	15.08055	76.56459	Thorny Scrub Patch	359	59.1
CAM35	15.07266	76.56518	Thorny Scrub Patch	461	54.6
CAM36	15.11244	76.60857	Thorny Scrub Patch	473	42.5
CAM37	15.10367	76.60688	Thorny Scrub Patch	1060	42.1
CAM38	15.10761	76.60582	Thorny Scrub Patch	623	42.4
CAM39	15.10536	76.59302	Thorny Scrub Patch	321	47.1
CAM40	15.10138	76.58253	Thorny Scrub Patch	341	47.6
CAM41	15.1541	76.63619	Open Scrub Land	354	49.1
CAM42	15.15306	76.63583	Open Scrub Land	354	41.5
CAM43	15.15132	76.63658	Open Scrub Land	570	54.2
CAM44	15.14775	76.63288	Open Scrub Land	424	49.2
CAM45	15.07095	76.56434	Thorny Scrub Patch	380	46.2
CAM46	15.06908	76.56567	Thorny Scrub Patch	513	55.8
CAM47	15.07797	76.56786	Thorny Scrub Patch	945	47.4
CAM48	15.08024	76.56715	Thorny Scrub Patch	798	45.9
CAM49	15.10028	76.58361	Thorny Scrub Patch	327	35
CAM50	15.11	76.59722	Thorny Scrub Patch	226	49.2

CAM51	15.10913	76.6051	Thorny Scrub Patch	438	35.9
CAM52	15.11167	76.60972	Thorny Scrub Patch	633	44

Annexure 10.2: Camera trap effort table:

Habitat Type/ LULC	Along MPC				Control Site	
	Number of cameras	Effort (12 hours)	Numberof cameras	Effort (20 hours)	Number of Cameras	Effort
Thorn Scrub Forest	14	438	8	152	16	360
Open Scrub land	7	236	6	114	6	101
Agricultural Land	6	164	3	38	0	0
Built-up	2	51	2	57	0	0
Total	**29**	**889**	**19**	**361**	**22**	**461**

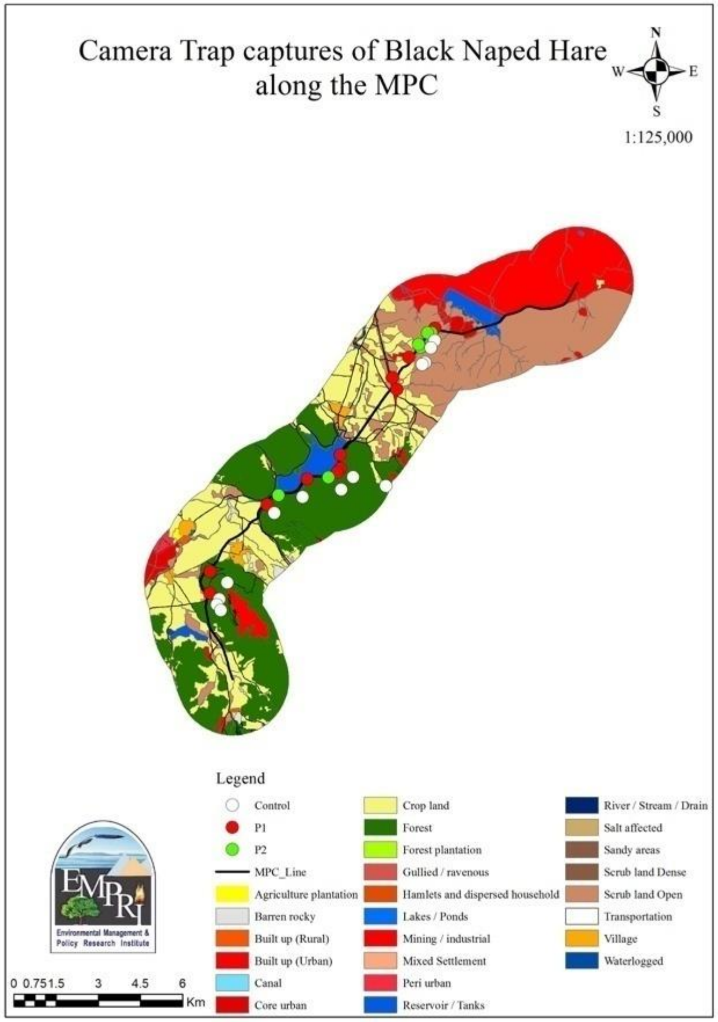
Annexure 10.3. Number of call recordings of all species recorded in the present study including passive recorders and active recorders

Sl. No	Species	Habitat			
		Built - up	Agriculture	Scrub	Forest
1	*Chaerephon plicatus*	47	56	553	67
2	*Hipposideros galeritus*	0	2	2	2
3	*Hipposideros lankadiva*	0	11	0	3
4	*Hipposideros speoris*	0	0	0	17
5	*Miniopterus fuliginosus*	0	0	0	148
6	*Pipistrellus ceylonicus*	211	446	620	1208
7	*Pipistrellus coromandra*	135	352	212	397
8	*Pipistrellus tenuis*	0	13	25	27
9	*Rhinolophus lepidus*	0	159	1	272
10	*Scotophilus heathii*	463	1531	662	626
11	*Scotophilus kuhlii*	0	0	0	13
12	*Tadarida aegyptiaca*	746	824	1091	1253

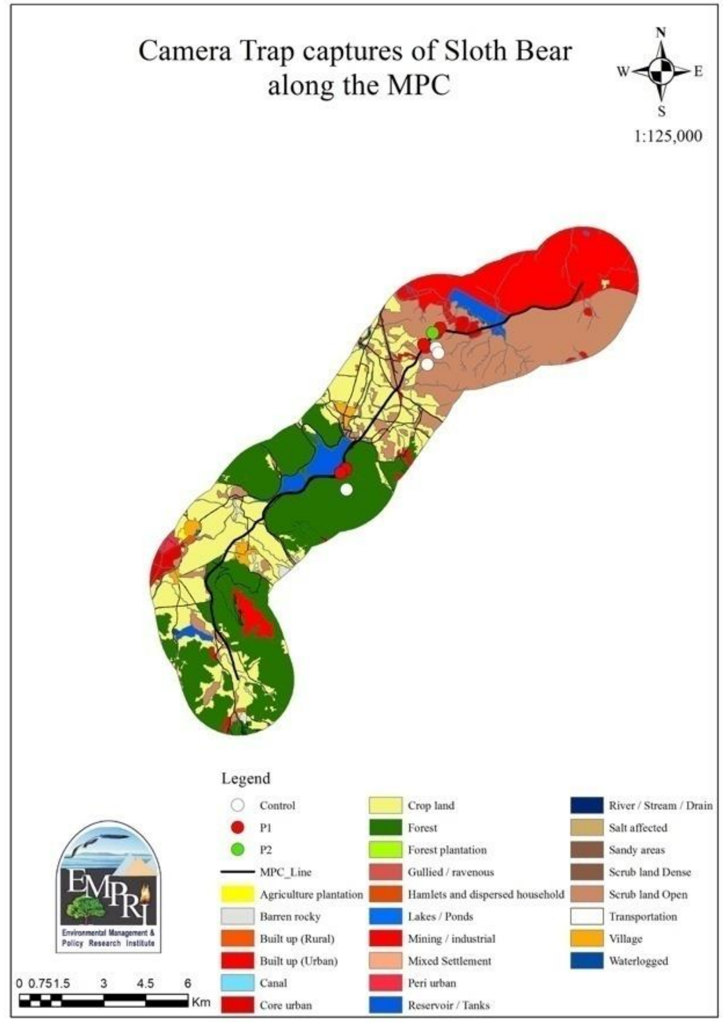
Annexure 10.4. Number of individual bats identified based on call recordings across the transect.

SL	Bat Species	No of batsrecorded in Transect
1	*Chaerephon plicatus*	38
2	*Hipposideros galeritus*	6
3	*Hipposideros lankadiva*	7
4	*Hipposideros speoris*	4
5	*Miniopterus fuliginosus*	61
6	*Pipistrellus ceylonicus*	74
7	*Pipistrellus coromandra*	45
8	*Pipistrellus tenuis*	8
9	*Rhinolophus lepidus*	60
10	*Scotophilus heathii*	30
11	*Scotophilus kuhlii*	10
12	*Tadarida aegyptiaca*	43
	Grand Total	**386**

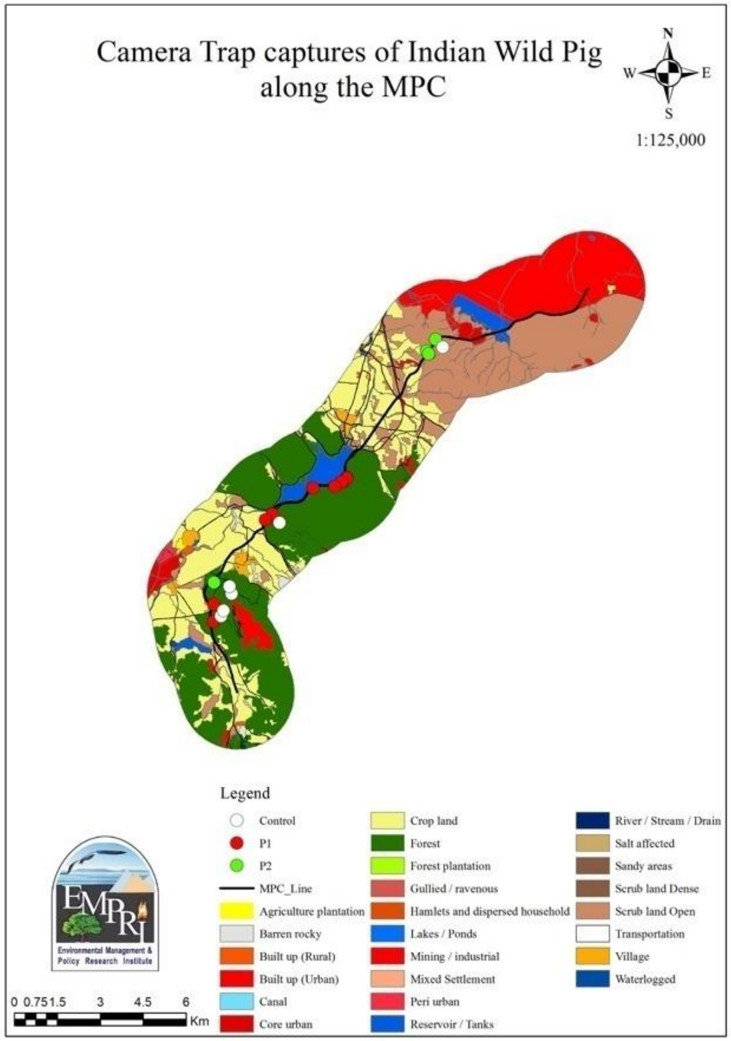
Annexure 10.5: Camera Trap captures of Black-Naped Hare (1), Sloth Bear (2), Indian Wild Pig (3), Indian Crested Porcupine (4) and Leopard (5) along the MPC



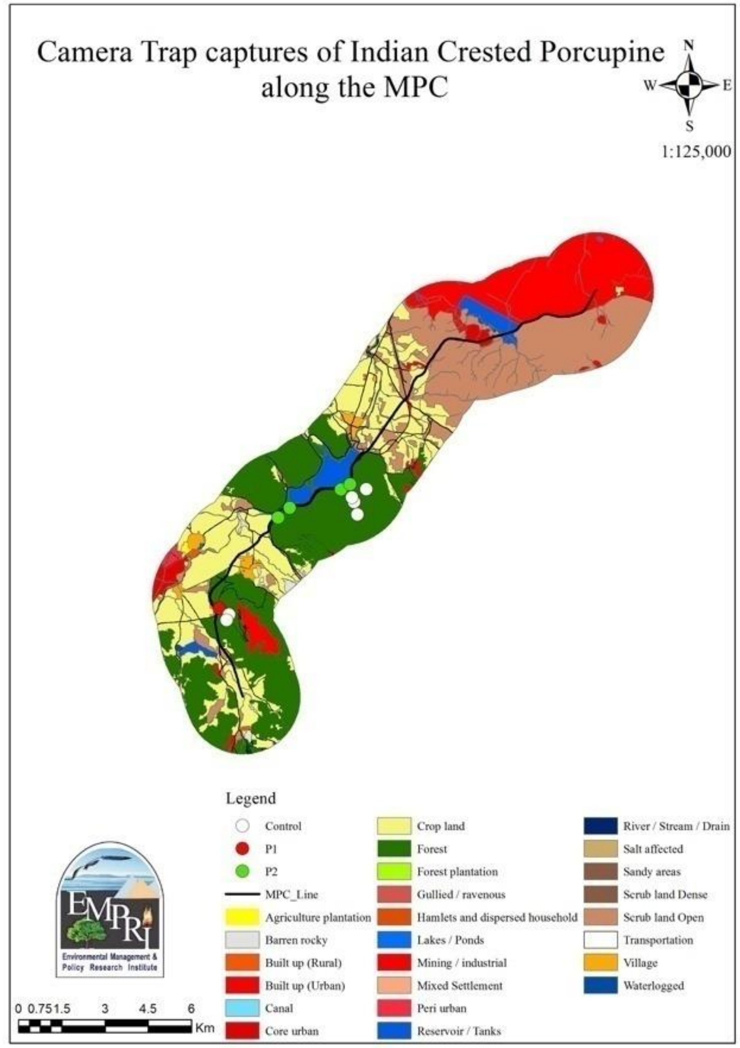
(1)



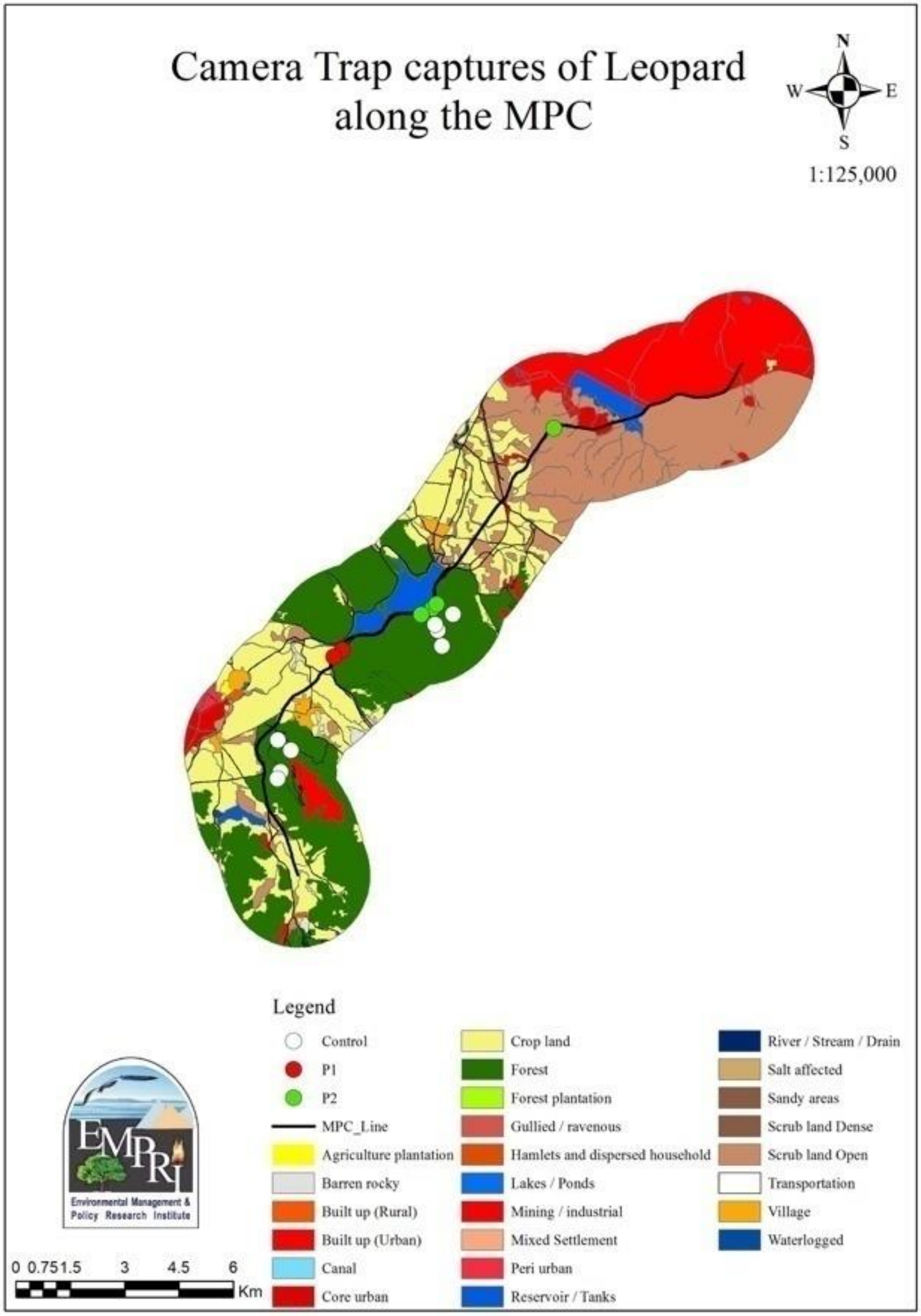
(2)


Camera Trap captures of Indian Wild Pig along the MPC
N
W
E
S
1:125,000
Legend
Control
P1
P2
MPC_Line
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
0 0.751.5 3 4.5 6
Km

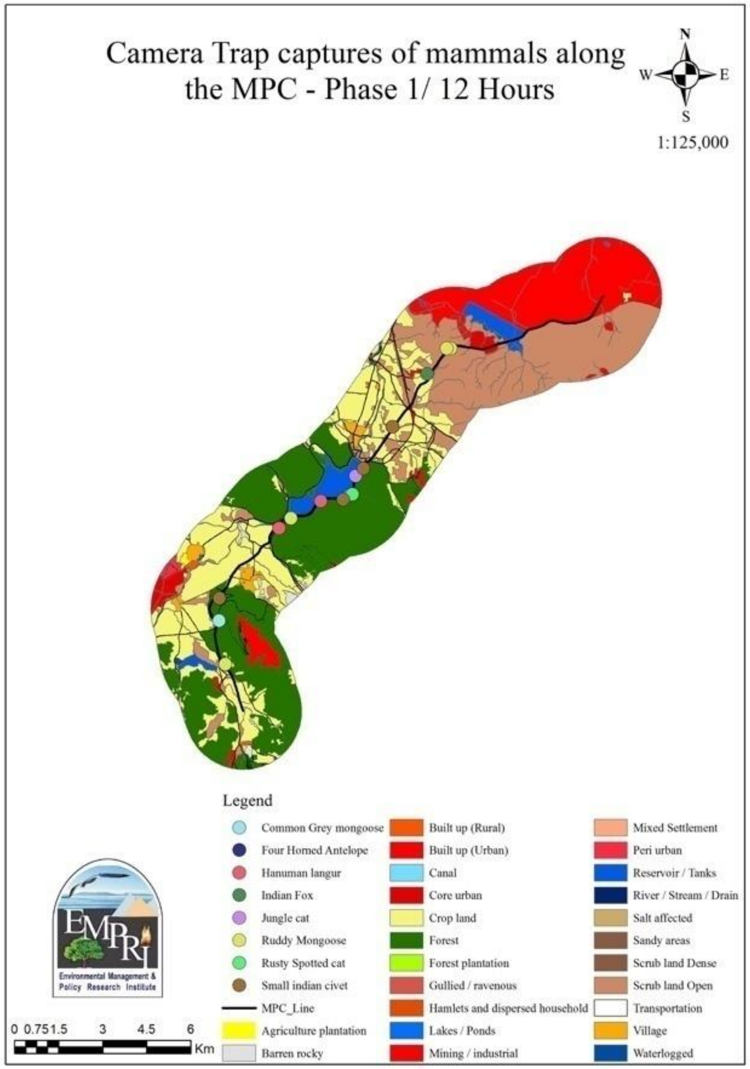
(3)

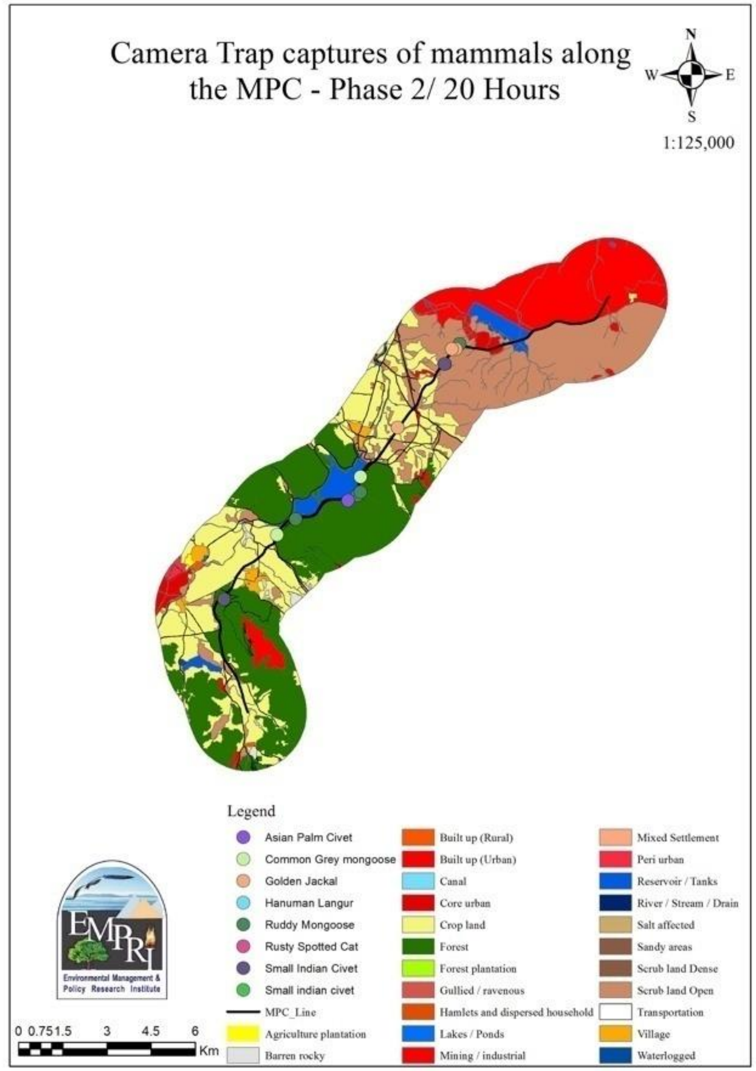

Camera Trap captures of Indian Crested Porcupine along the MPC
N
W
E
S
1:125,000
Legend
Control
P1
P2
MPC_Line
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
0 0.751.5 3 4.5 6
Km

(4)

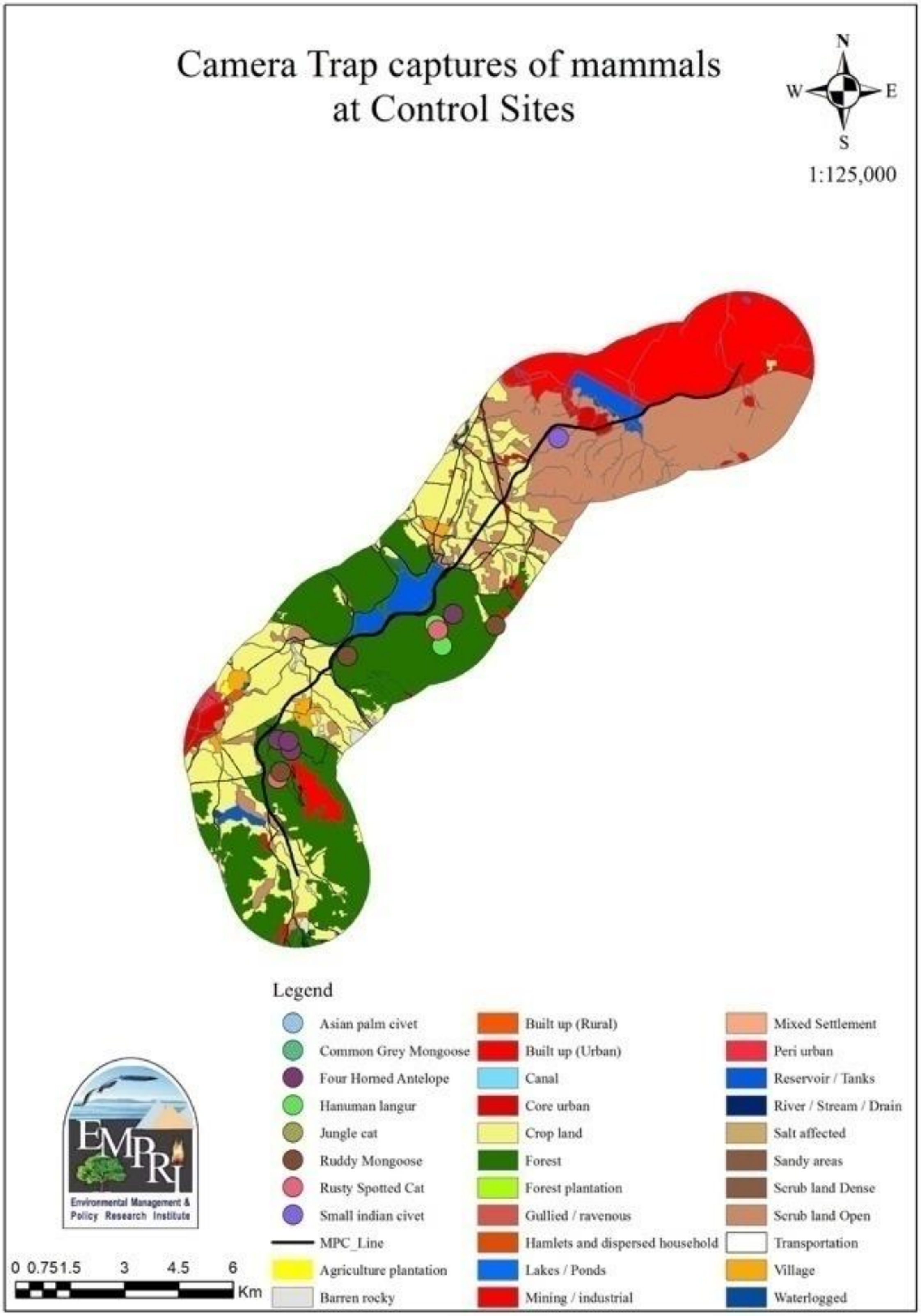

Camera Trap captures of Leopard along the MPC
N
W
E
S
1:125,000
Legend
Control
P1
P2
MPC_Line
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
Environmental Management & Policy Research Institute
0 0.751.5 3 4.5 6
Km

(5)



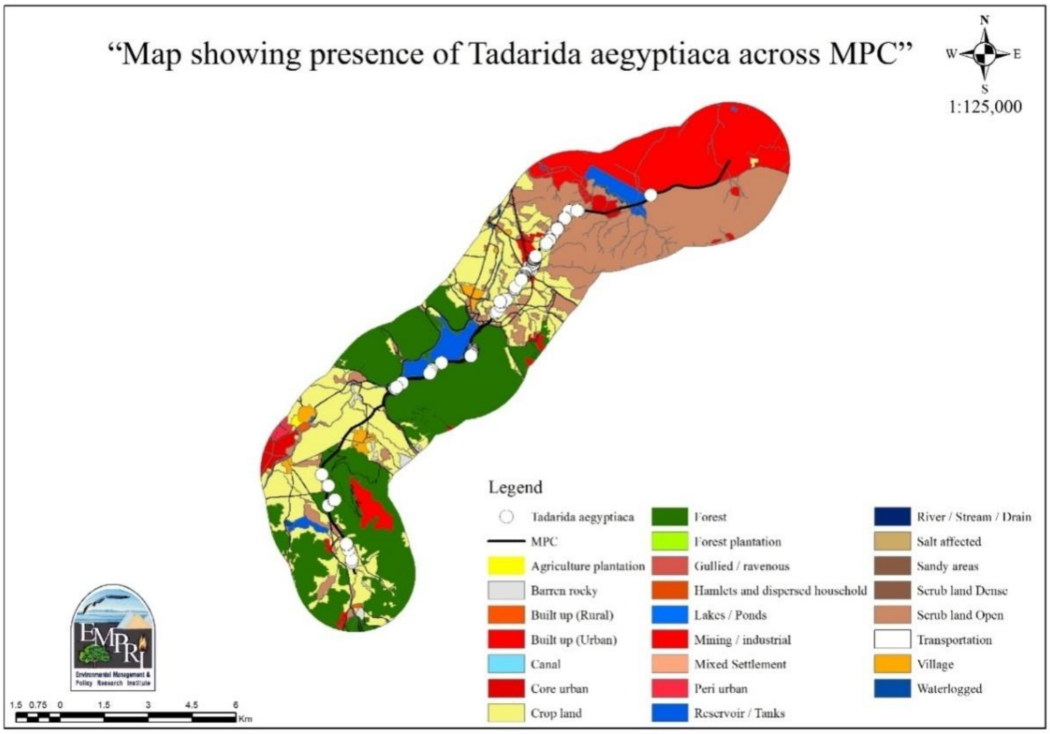


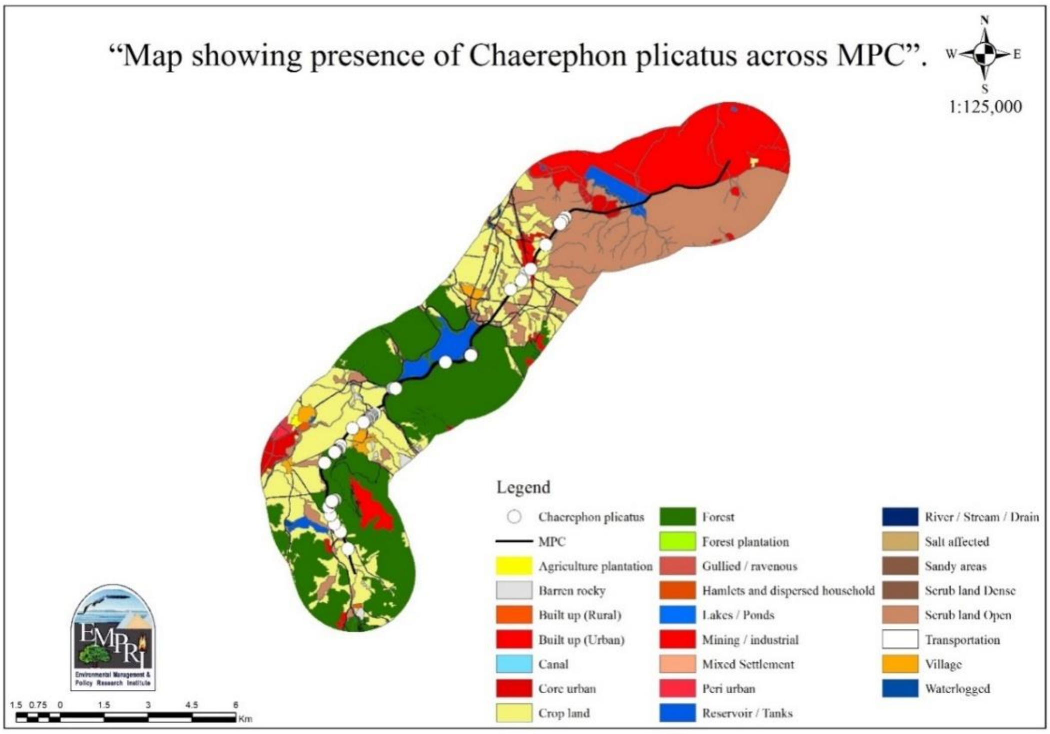
Camera Trap captures of mammals during 12 hours of belt run	Camera Trap captures of mammals during 20 hours of belt run

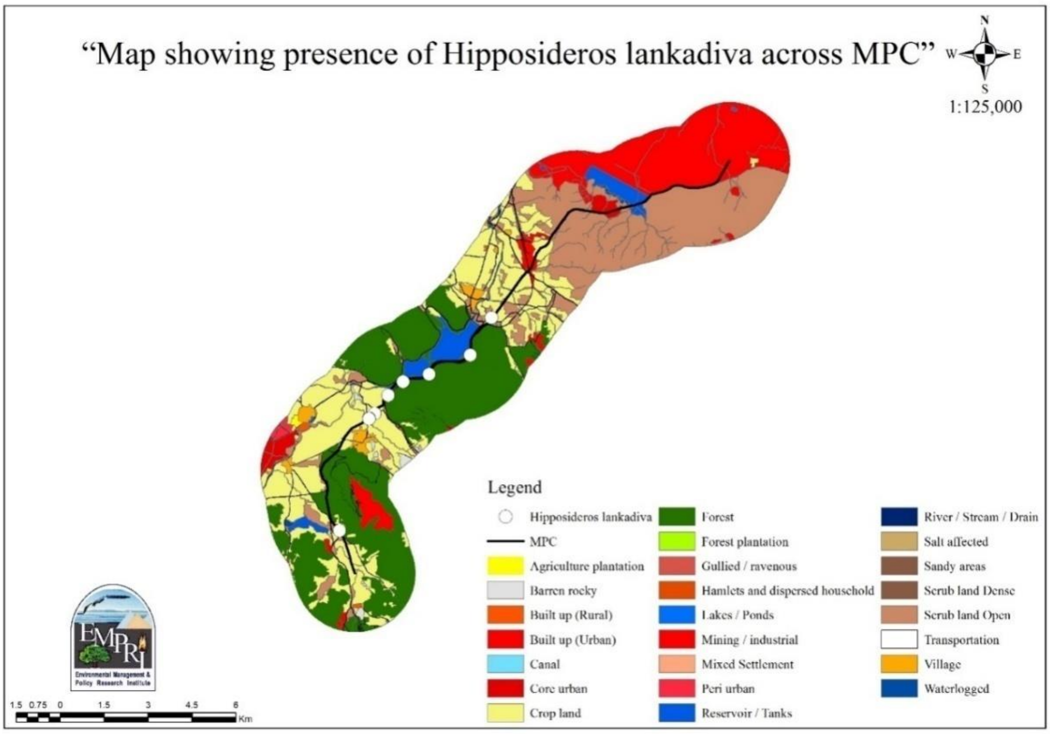


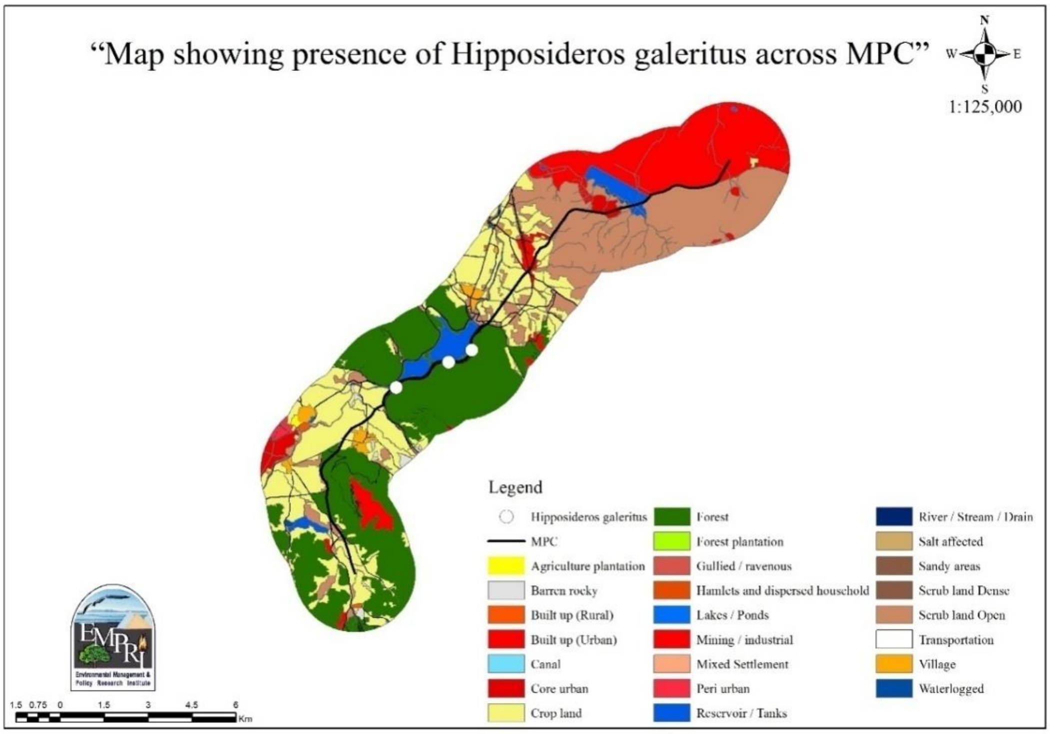
Camera Trap captures of mammals in control sites

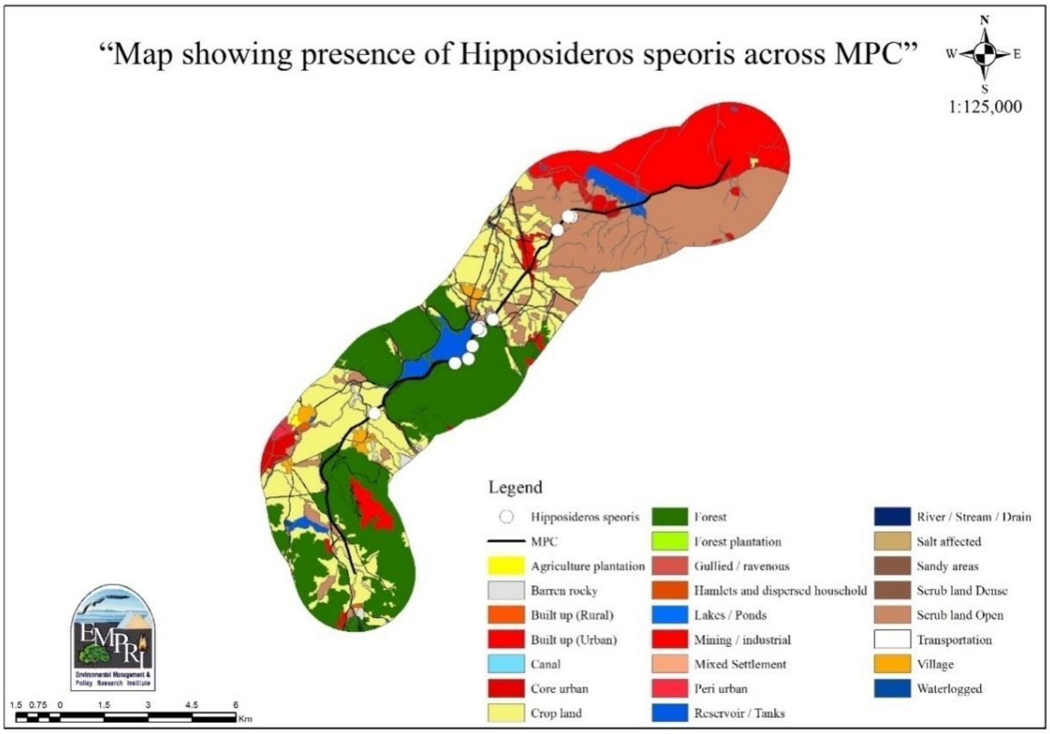
Annexure 10.6. Maps showing the presence of each species of bat across the MPC.



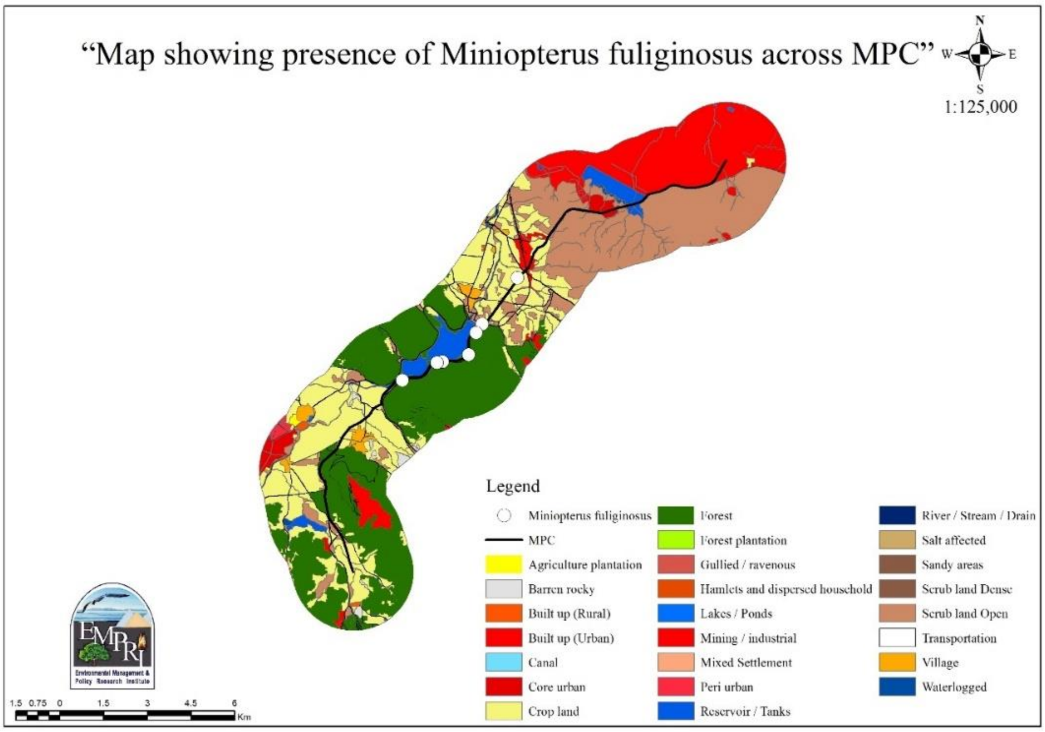



"Map showing presence of Hipposideros lankadiva across MPC"
N
W
E
S
1:125,000
Legend
Hipposideros lankadiva
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
1.5 0.75 0 1.5 3 4.5 6
Km

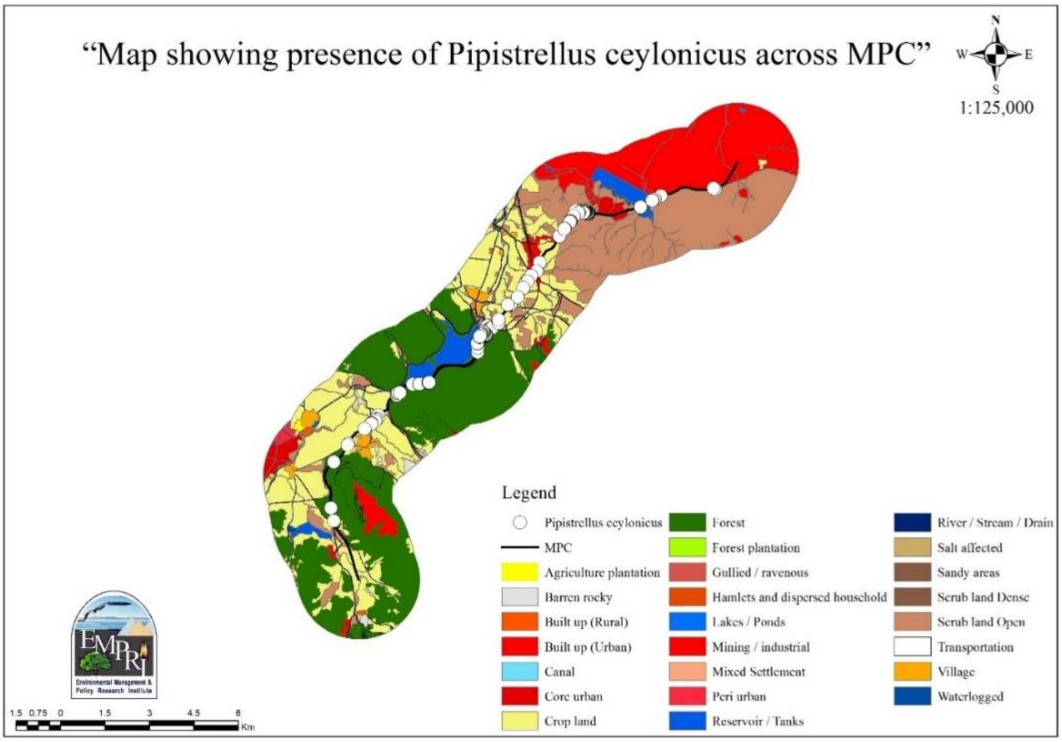

"Map showing presence of Hipposideros galeritus across MPC"
N
W
E
S
1:125,000
Legend
Hipposideros galeritus
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
1.5 0.75 0 1.5 3 4.5 6
Km

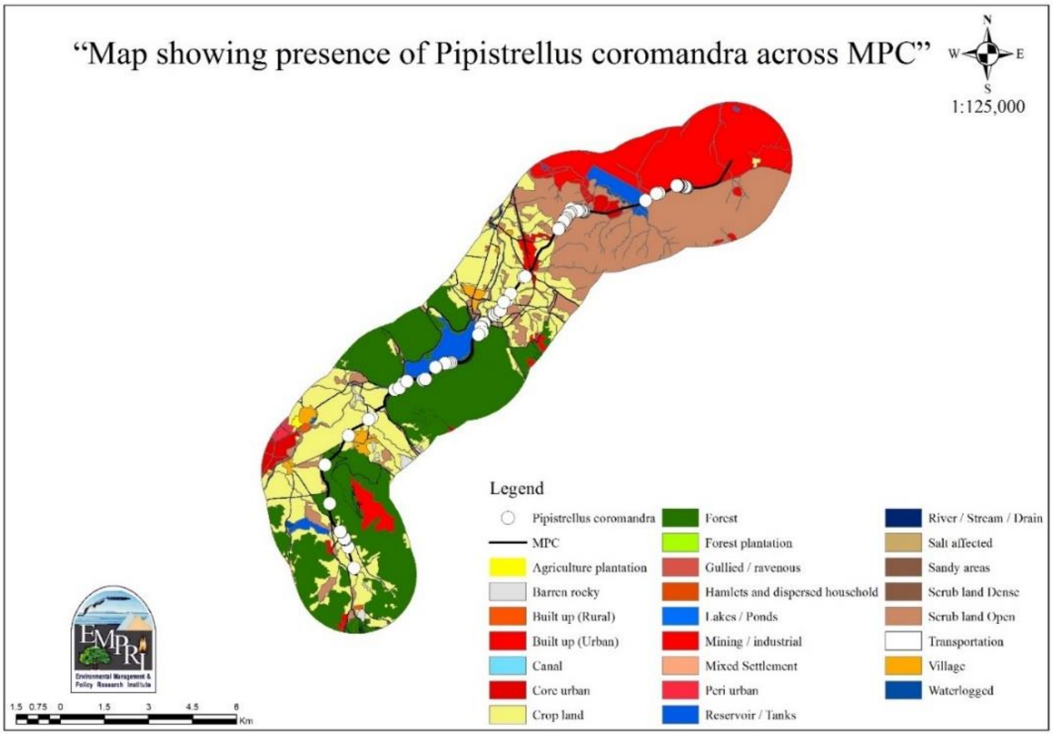


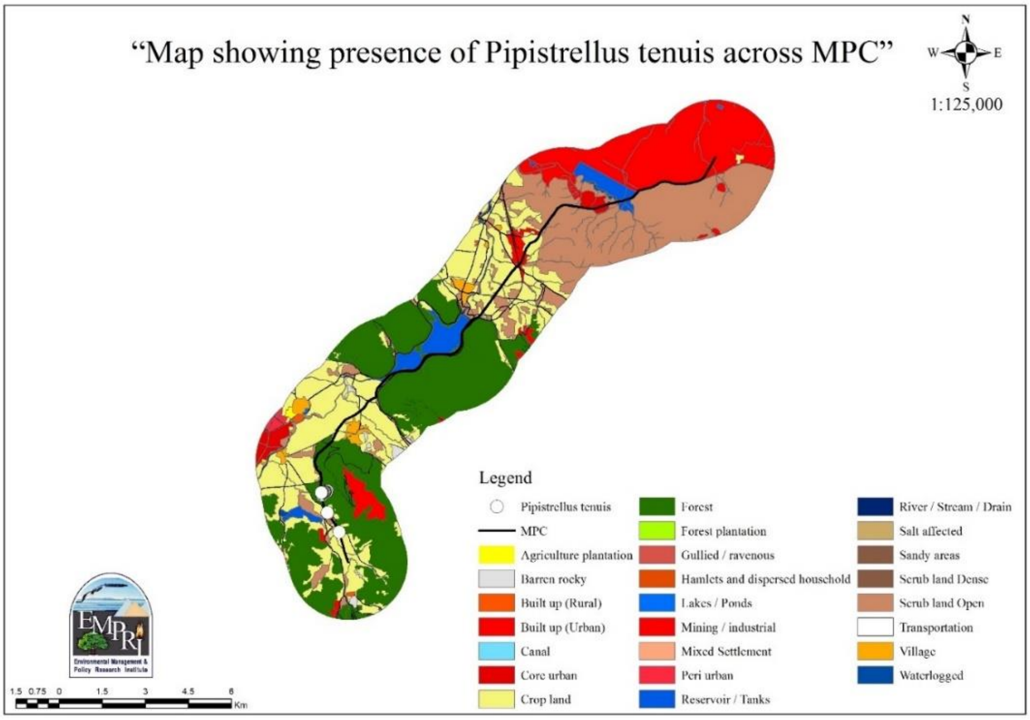
"Map showing presence of Hipposideros speoris across MPC"
N
W
E
S
1:125,000
Legend
Hipposideros speoris
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
1.5 0.75 0 1.5 3 4.5 6
Km

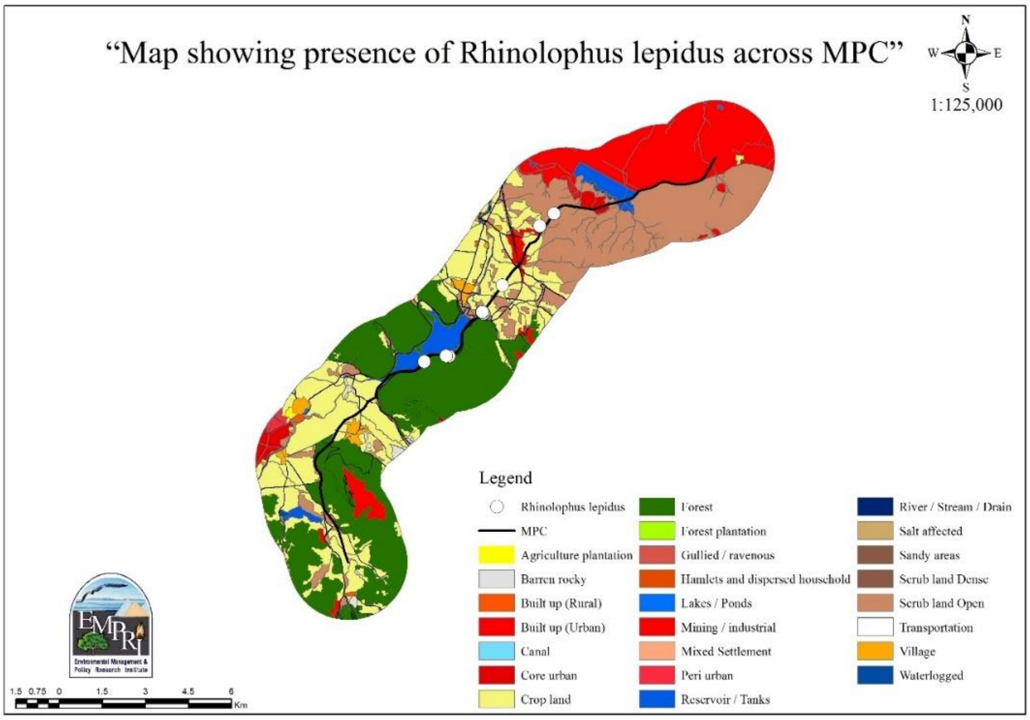


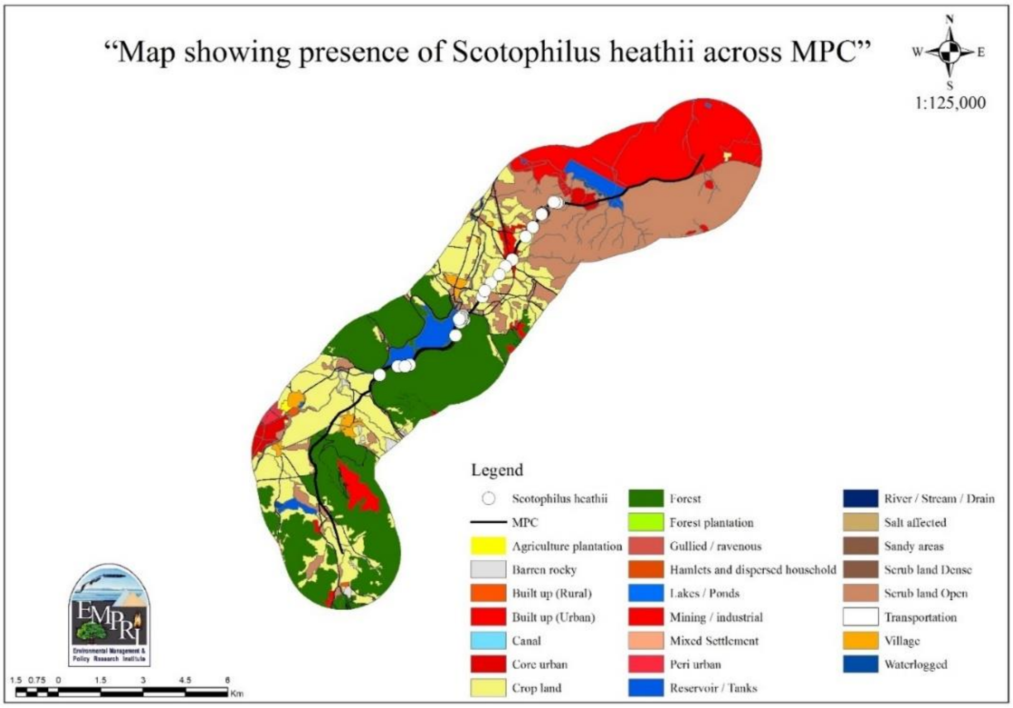
"Map showing presence of Miniopterus fuliginosus across MPC"
N
W
E
S
1:125,000
Legend
Miniopterus fuliginosus
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
1.5 0.75 0 1.5 3 4.5 6
Km

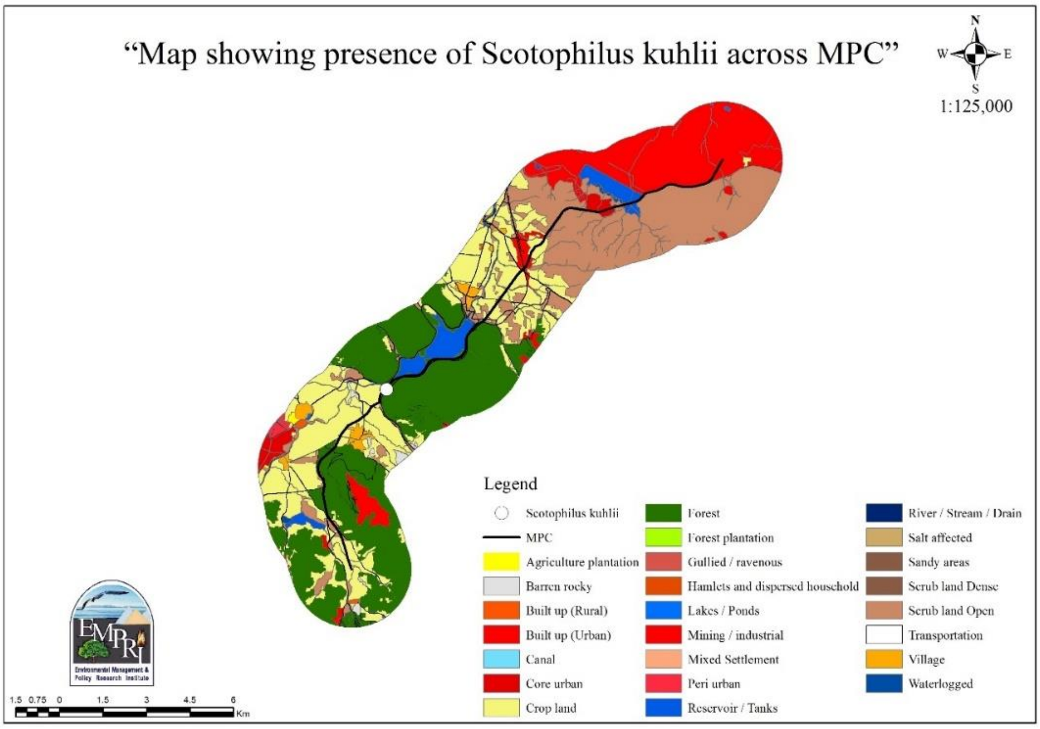

"Map showing presence of Pipistrellus ceylonicus across MPC"
N
W
E
S
1:125,000
Legend
Pipistrellus ceylonicus
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
EMPRI
Environmental Management & Policy Research Institute
1.5 0.75 0 1.5 3 4.5 6
Km


"Map showing presence of Pipistrellus coromandra across MPC"
N
W
E
S
1:125,000
Legend
Pipistrellus coromandra
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
EMPRI
Environmental Management & Policy Research Institute
1.5 0.75 0 1.5 3 4.5 6
Km


"Map showing presence of Pipistrellus tenuis across MPC"
N
W
E
S
1:125,000
Legend
Pipistrellus tenuis
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
EMPRI
Environmental Management & Policy Research Institute
1.5 0.75 0 1.5 3 4.5 6
Km


"Map showing presence of Rhinolophus lepidus across MPC"
N
W
E
S
1:125,000
Legend
Rhinolophus lepidus
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
EMPRI
Environmental Management & Policy Research Institute
1.5 0.75 0 1.5 3 4.5 6
Km


"Map showing presence of Scotophilus heathii across MPC"
N
W
E
S
1:125,000
Legend
Scotophilus heathii
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
EMPRI
Environmental Management & Policy Research Institute
1.5 0.75 0 1.5 3 4.5 6
Km


"Map showing presence of Scotophilus kuhlii across MPC"
N
W
E
S
1:125,000
Legend
Scotophilus kuhlii
MPC
Agriculture plantation
Barren rocky
Built up (Rural)
Built up (Urban)
Canal
Core urban
Crop land
Forest
Forest plantation
Gullied / ravenous
Hamlets and dispersed household
Lakes / Ponds
Mining / industrial
Mixed Settlement
Peri urban
Reservoir / Tanks
River / Stream / Drain
Salt affected
Sandy areas
Scrub land Dense
Scrub land Open
Transportation
Village
Waterlogged
EMPRI
Environmental Management & Policy Research Institute
1.5 0.75 0 1.5 3 4.5 6
Km

Annexure 11.1: Measurement of sound frequency at different stations in Naarihalla dam

Station No.	Latitude	Longitude	Sound frequency (DB)
1	15.124255 N	76.605298 E	50.20
2	15.122699 N	76.607368 E	60.10
3	15.120366 N	76.606717 E	64.90
4	15.113542 N	76.603787 E	66.70
5	15.103292 N	76.680581 E	66.20
6	15.113864 N	76.590433 E	46.60

Annexure 11.2: Water quality parameters

Sl. No	Parameters	Stations					
		1	2	3	4	5	6
1	Air temperature (˚C)	30	30	30.9	33.5	34.6	32.1
2	Temperature (˚C)	28.9	28.8	29.9	30.7	33	30.9
3	pH	7.56	7.64	7.74	7.98	7.89	7.78
4	DO (mg/l)	8.03	6.93	8.15	9.06	7.42	7.89
5	BOD (mg/l)	1.22	1.24	2.32	2.48	2.78	1.86
6	Ammonia (µg-at/l)	3.24	3.12	3.57	3.94	3.8	3.02
7	Nitrite (µg-at/l)	2.37	2.39	2.23	2.92	1.99	2.01
8	Nitrate (µg-at/l)	4.58	5.24	5.58	6.21	6.46	5.84
9	Phosphorous (µg-at/l)	1.01	1.42	1.98	2.01	2.64	1.98
10	TSS (mg/l)	24	52	32	40	60	38
11	TDS (mg/l)	80	82	85	89	88	87
12	Alkalinity (mg/l)	78	79	81	87	86	82
13	Turbidity (NTU)	6.36	6.09	6.14	10.76	10.02	10.96

Annexure 11.3 Qualitative and quantitative analysis of phytoplankton at different Stations in Naarihalla dam

SL. No.	Species(no/l)	Stations					
		1	2	3	4	5	6
1	*Chlorella spp*	12	10	20	15	12	16
2	*Cyanobacteria spp*	13	20	19	18	17	20
3	*Flagellaria spp*	18	22	10	21	18	19
4	*Oscillatoria spp*	11	15	14	26	22	17
5	*Pediastrum spp*	8	9	7	9	10	11
6	*Anabaena spp*	4	6	7	9	8	4
7	*Ulothrix spp*	5	3	6	7	8	3
8	*Microspora spp*	12	15	16	18	18	19
9	*Pandorina spp*	9	8	6	8	5	9
10	*Planktonella spp*	12	14	16	15	9	8
11	*TaBallaria spp*	11	19	19	10	9	8
12	*Synedra spp*	4	9	7	8	11	9
13	*Blue green algae*	25	30	32	29	28	34

Annexure 11.4 Qualitative and quantitative analysis of Zooplankton at different Stations in Naarihalla dam

SL. No.	Species (no/l)	Stations					
		1	2	3	4	5	6
1	Copepod spp	9	8	6	7	5	8
2	Daphnia spp	4	6	7	10	11	9
3	Brachionus spp	2	6	8	11	8	7
4	Filina spp	4	6	5	7	8	10
5	Cyclops spp	7	8	7	9	4	5
6	Volvax spp	5	4	8	9	8	5
7	Bosmina spp	3	2	1	2	3	4
8	Rotaria spp	15	16	14	12	14	11
9	Plurotella spp	10	5	8	7	6	4
10	Tricocera spp	9	8	9	7	5	6

Annexure 11.5 Fish diversity recorded at different stations in Naarihalla dam

Sl no	**Common Name**	**Scientific name**
1	Catla	*Catla Catla*
2	Rohu	*Labeo rohita*
3	Mrigal	*Cirrhinus mrigala*
4	Common carp	*Cyprinous cario*
5	Nile tilapia	*Oreochromis niloticus*
6	Mozambique tilapia	*Oriochromis mossambicus*
7	Notopterus	*Notopterus chitala*
8	Fresh water eel	*Anguilla bengalensis*
9	Murrels	*Channa striata*
10	Catfish	*Heteropneustes fossillis*
11	Fresh water prawn	*Macrobrachium rosenbergii*
12	Minor carp	*Labeo gonius*

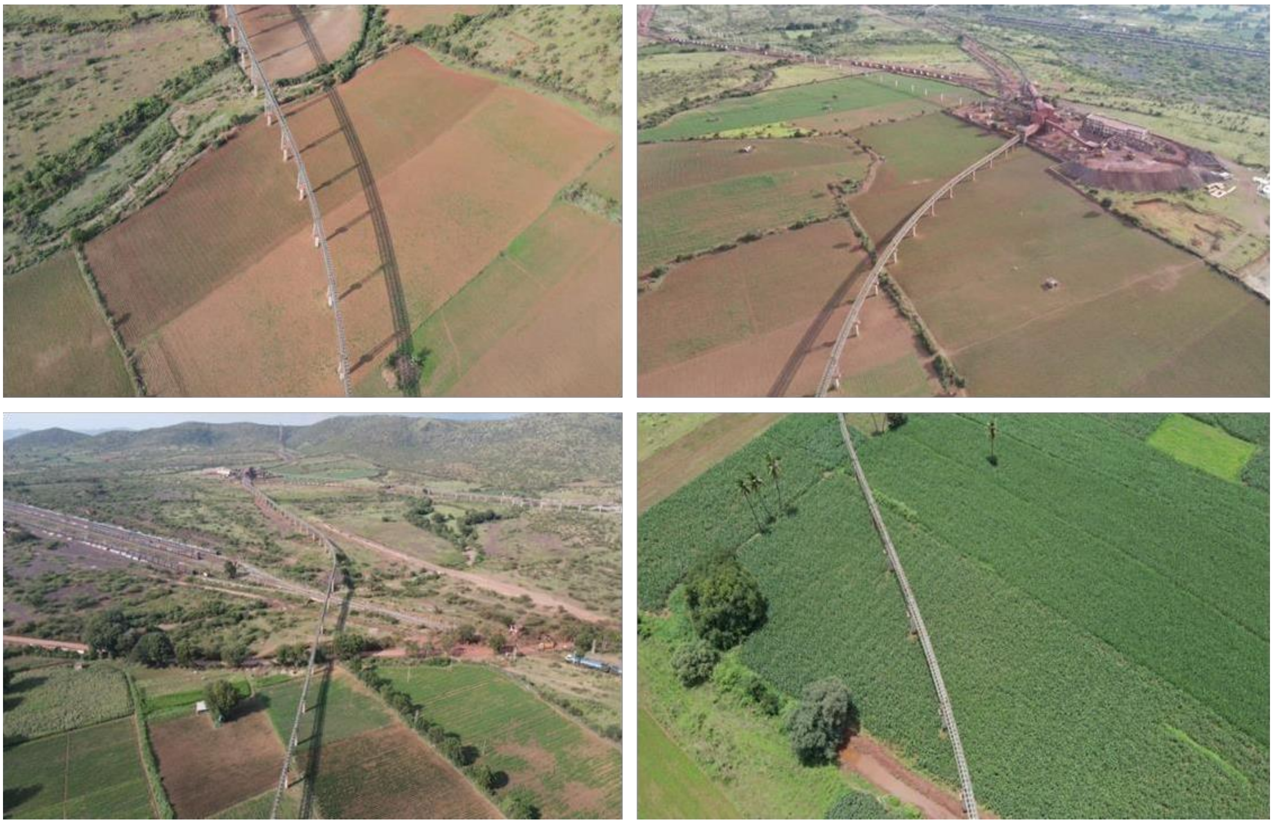


Plate 1.1: MPC along Agricultural land use

Plate 1.2: MPC along Built-up land use.

Plate 1.3: MPC along Forest habitat.

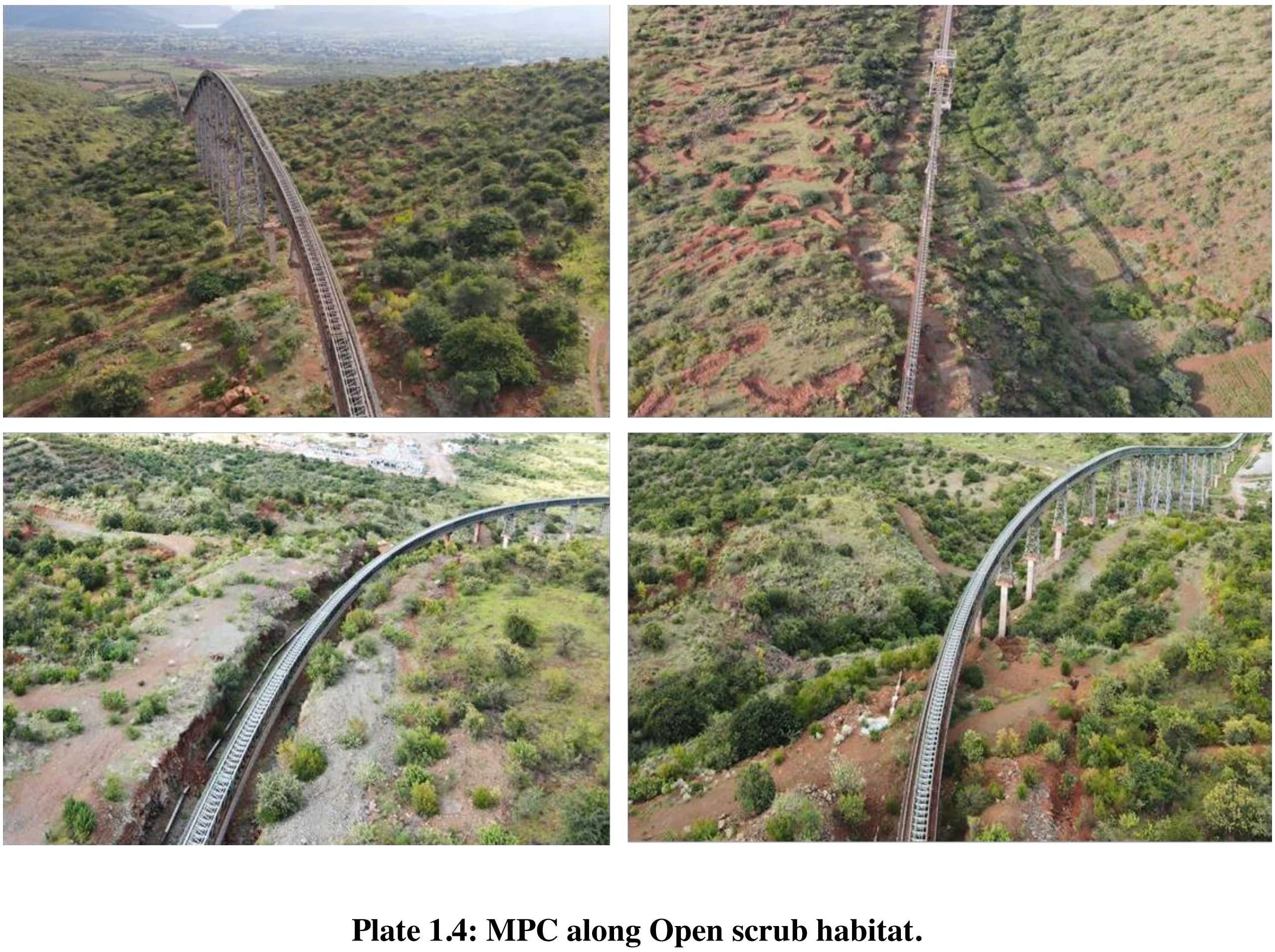


Plate 1.4: MPC along Open scrub habitat.

Plate 1.5: MPC along water bodies at Narihalla reservoir.

Plate 2.1: Wildlife team with Director general, EMPRI and Chief advisor during field visit.








Plate 2.2: Meeting sessions with External experts and Project coordinator.

Plate 2.3: Field photographs during the time of external experts visit.

Plate 2.4: Field photographs of data enumeration by wildlife team, EMPRI.

Plate 2.5: Field photographs of vegetation study.

Plate 2.6: Field photographs of mammals study.

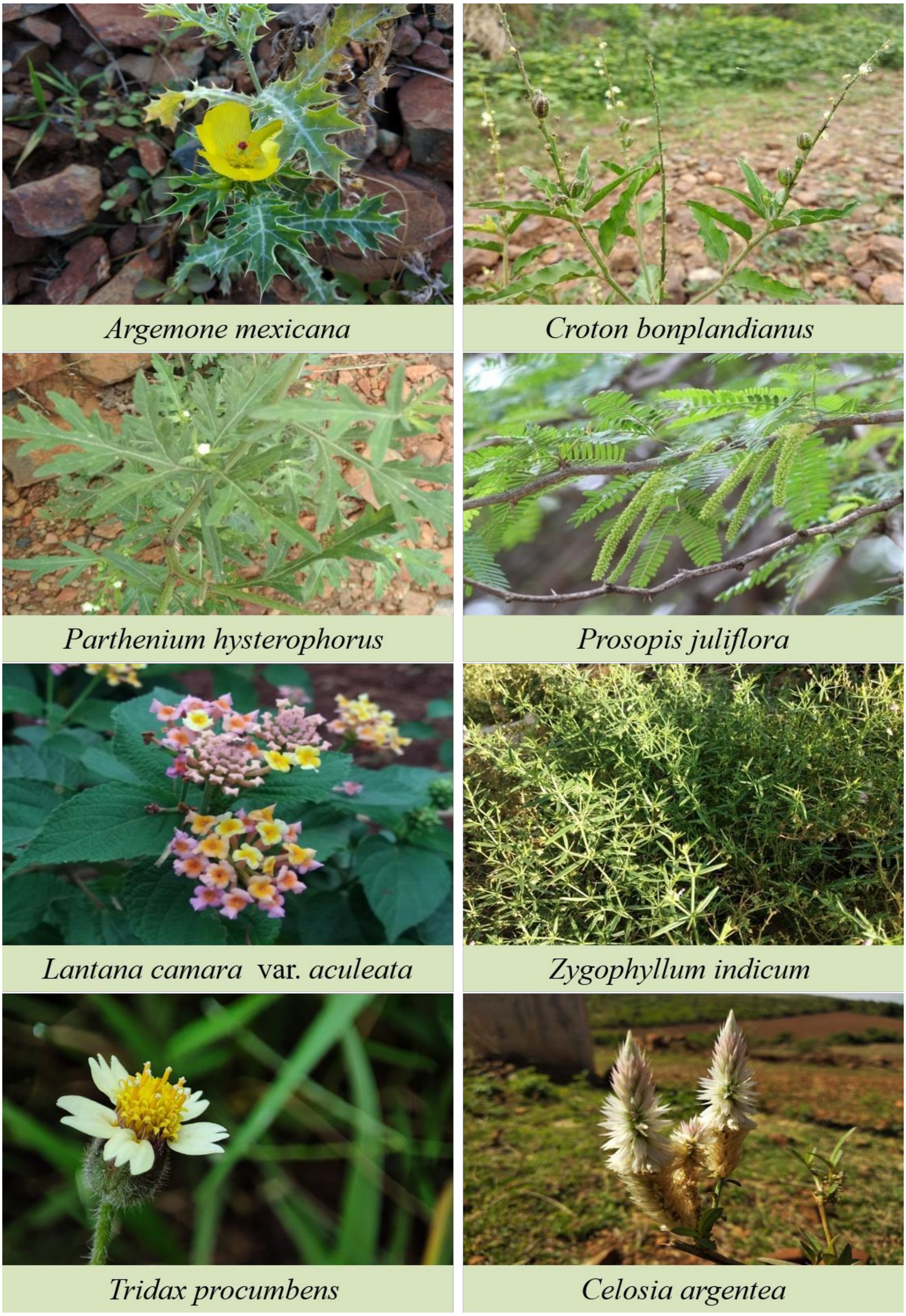


Plate 5.1: Invasive species recorded in the study area.

Cleome felina

Cymbopogon martini

Dolichandrone atrovirens

Gardenia gummifera

Grewia orbiculata

Hardwickia binata

Justicia glauca

Striga densiflora

Plate 5.2: Endemic species recorded in the study area.

Senegalia chundra

Morinda coreia

Albizia amara

Dalbergia paniculata

Vachellia nilotica

Vachellia horrida

Balanites roxburghii

Cassia fistula

Plate 5.3: Forest native tree species recorded in the study area.

Gymnosporia montana | *Dodonaea viscosa*

Cadaba fruticosa | *Mimosa hamata*

Senna auriculata | *Flueggea leucopyrus*

Phyllanthus reticulatus | *Canthium coromandelicum*

Plate 5.4: Shrub species recorded in the study area.

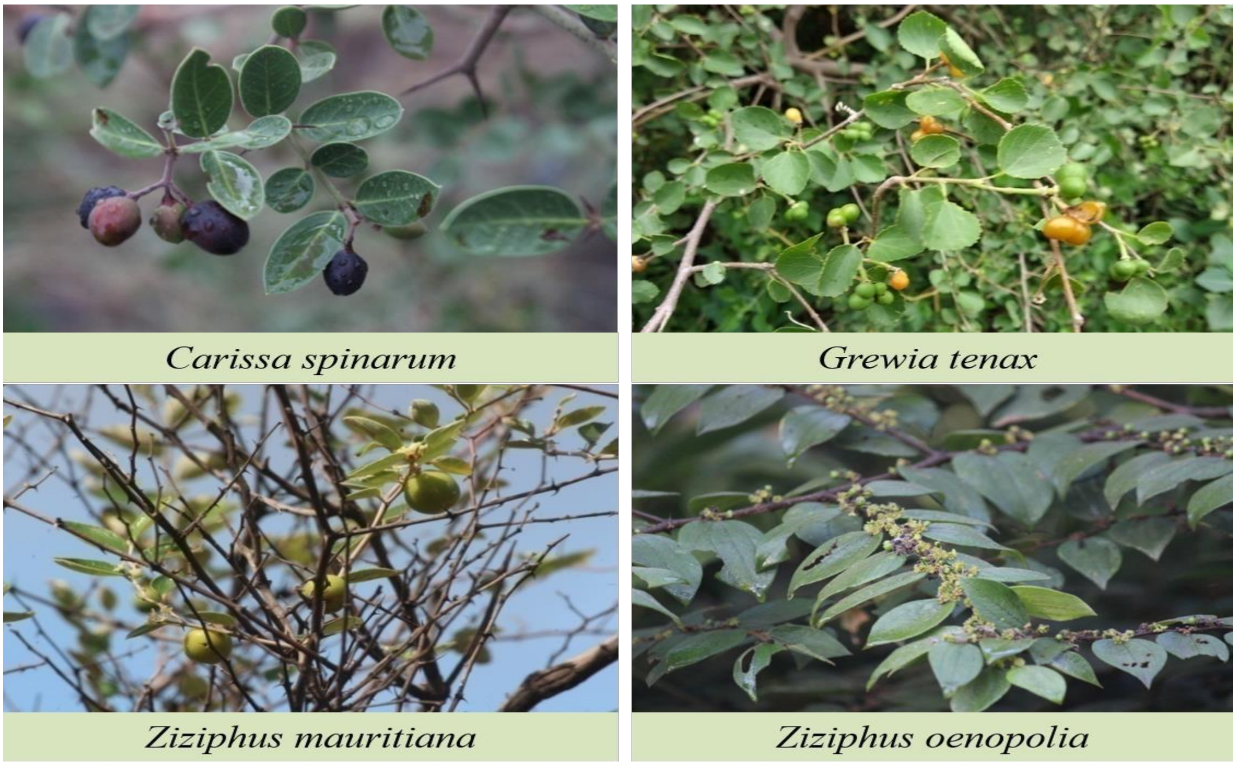


Plate 5.5: Wild edible fruit bearing flowering plants.

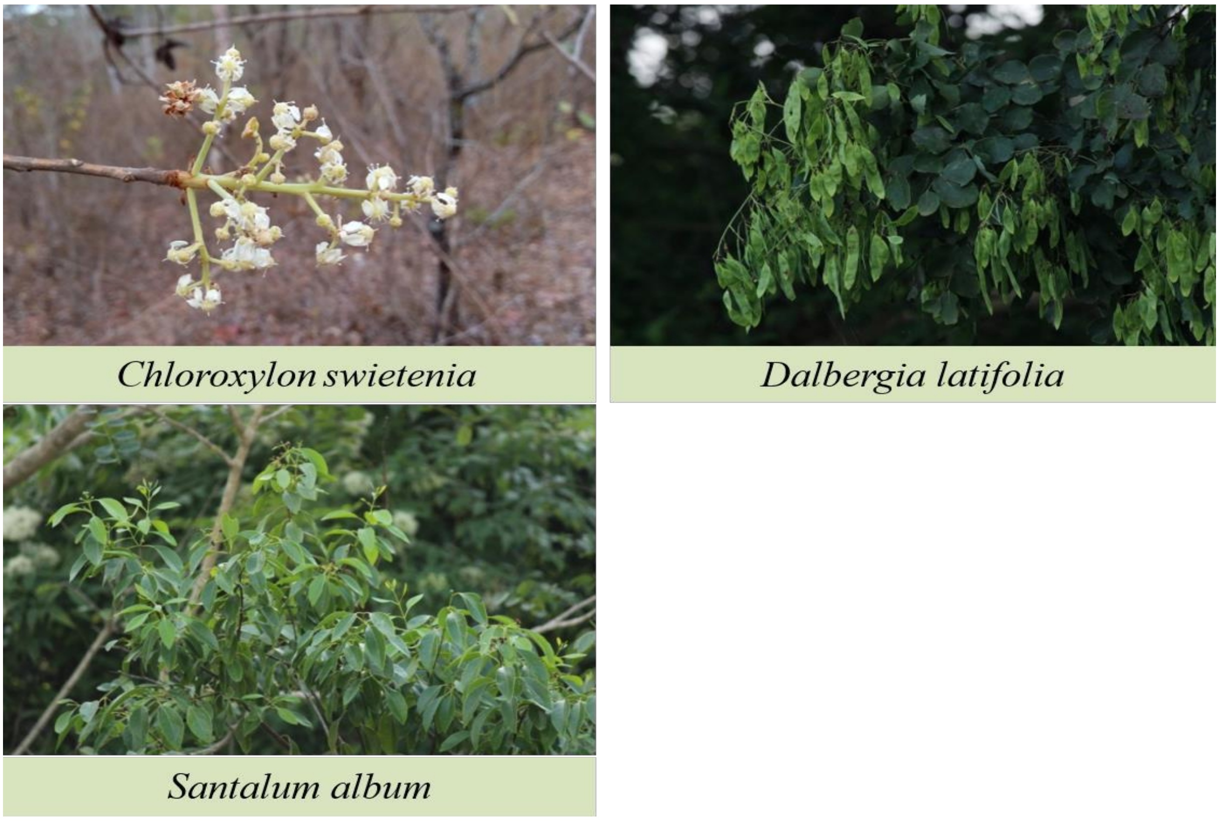


Plate 5.6: Vulnerable species recorded in the study area.

Plate 5.7: Grass species recorded in the study area.

Boerhavia diffusa

Cryptolepis buchananii

Bacopa monnieri

Hemidesmus indicus

Eclipta prostrata

Rotheca serrata

Hybanthus enneaspermus

Wrightia tinctoria

Plate 5.8: Few medicinal plants recorded in the study area.

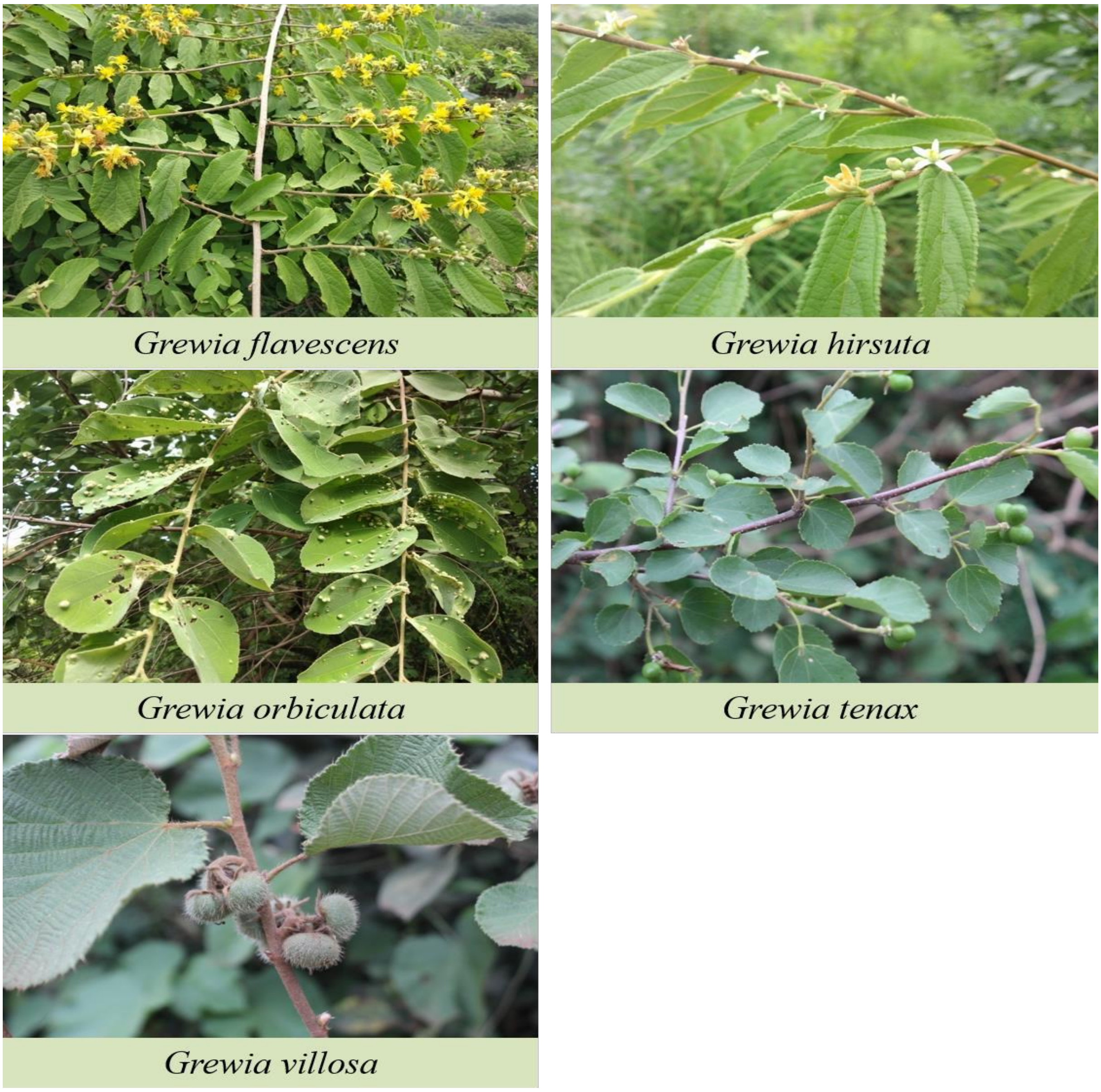


Plate 5.9: *Grewia sp.* recorded in the study area.

Plate 5.10: Rarely found species in the study area.

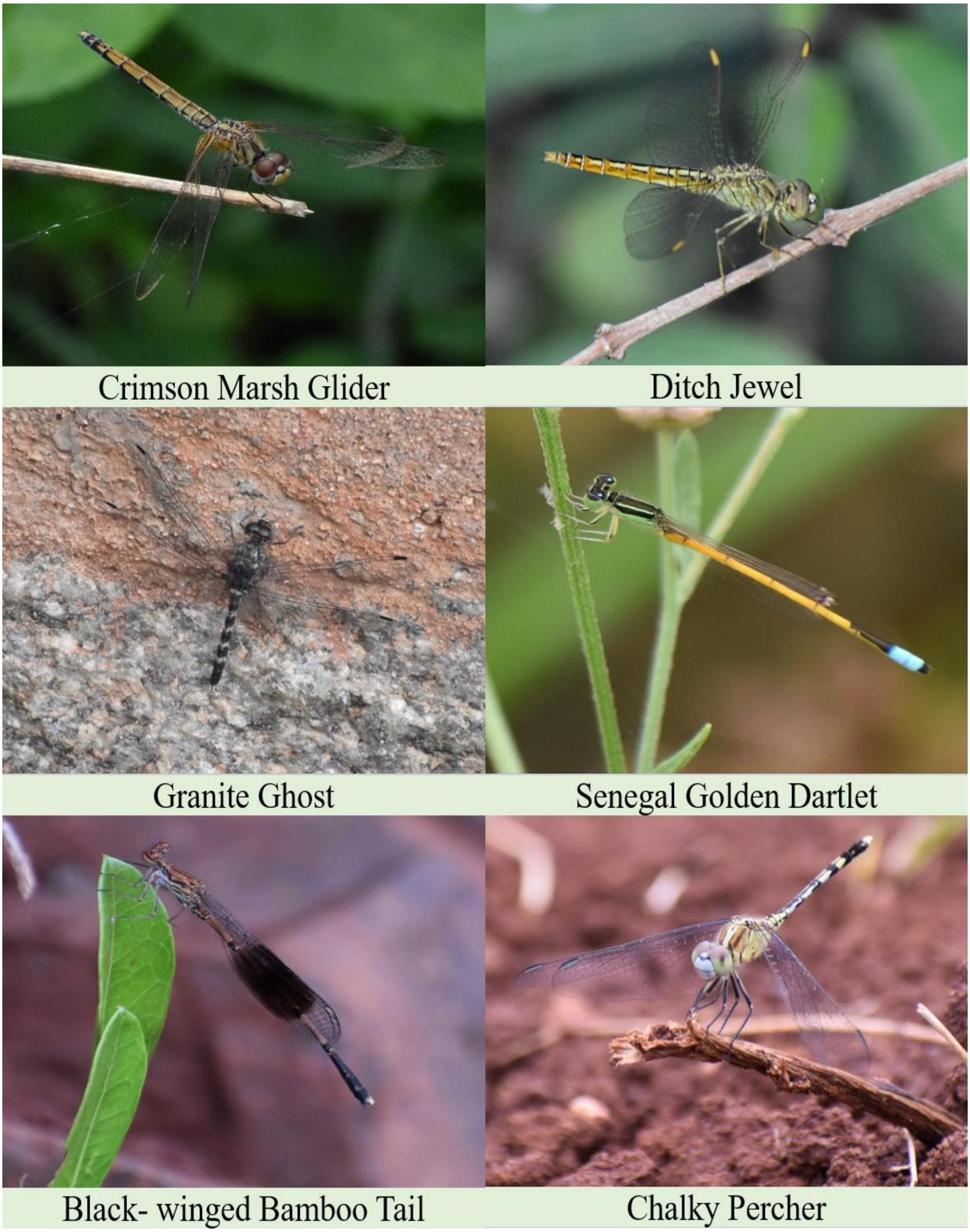


Plate 6.1: Few species of Odonates

Plate 6.2: Few species of Dictyoptera

Brown Grass hopper

Green Grass hopper

Spur Throated Grass hopper

Bush Cricket

Grass hopper (*Acridaexalatata*)

Aulacobrthrus sp.

Gryllus sp.

Chrotogonus sp.

Plate 6.3: Few species of Orthoptera

Plate 6.4: Phasmida Species

Plate 6.5: Dermoptera Species

Plate 6.6: Isoptera Species

Plate 6.7: Few species of Hemiptera

Plate 6.8: Neuroptera Species

Plate 6.9: Few species of Lepidoptera

Plate 6.10: Few species of Diptera

Plate 6.11: Few species of Hymenoptera

Plate 6.12: Few species of Coleoptera

Plate 6.13: Julida Species

Plate 6.14: Polydesmida Species

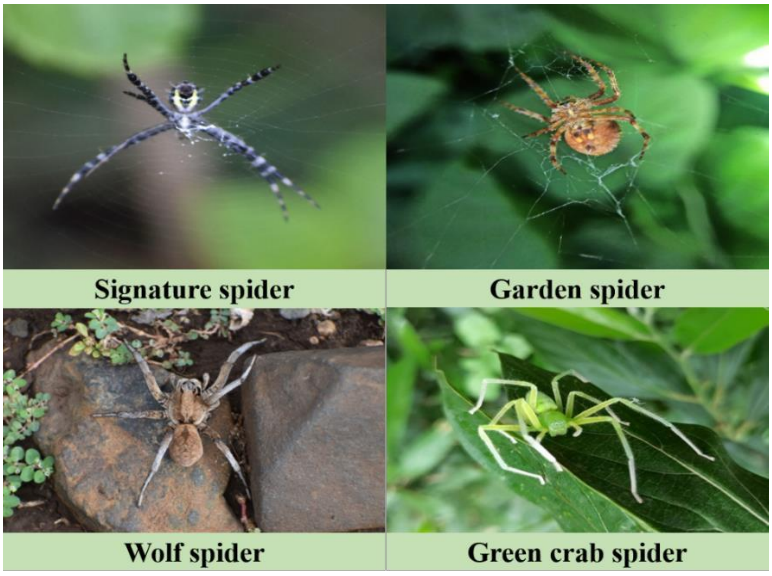


Plate 6.15: Few species of Aranea

Plate 7.1: Amphibians observed during the field survey.

Plate 7.1: Amphibians observed during the field survey.

Plate 8.1: Reptiles observed during the field survey.

Plate 8.1: Reptiles observed during the field survey.

Plate 8.1: Reptiles observed during the field survey.

Plate 9.1: Birds observed during the field survey.

Plate 9.2: Birds observed during the field survey.

Plate 9.3: Birds observed during the field survey.

Black -winged Kite

Shikra

Bonelli's Eagle (Pale Morph)

Rufous-bellied Eagle

Short-toed Snake Eagle

Black Eagle

Indian Spotted Eagle

Brahminy Kite

Plate 9.4: Birds observed during the field survey.

Plate 9.5: Birds observed during the field survey.

Plate 9.6: Birds observed during the field survey.

Plate 9.7: Avi-faunal components perched on MPC structure

Indian Nightjar

Spotted Owlet

Plate 9.8: Nocturnal bird species from the study area

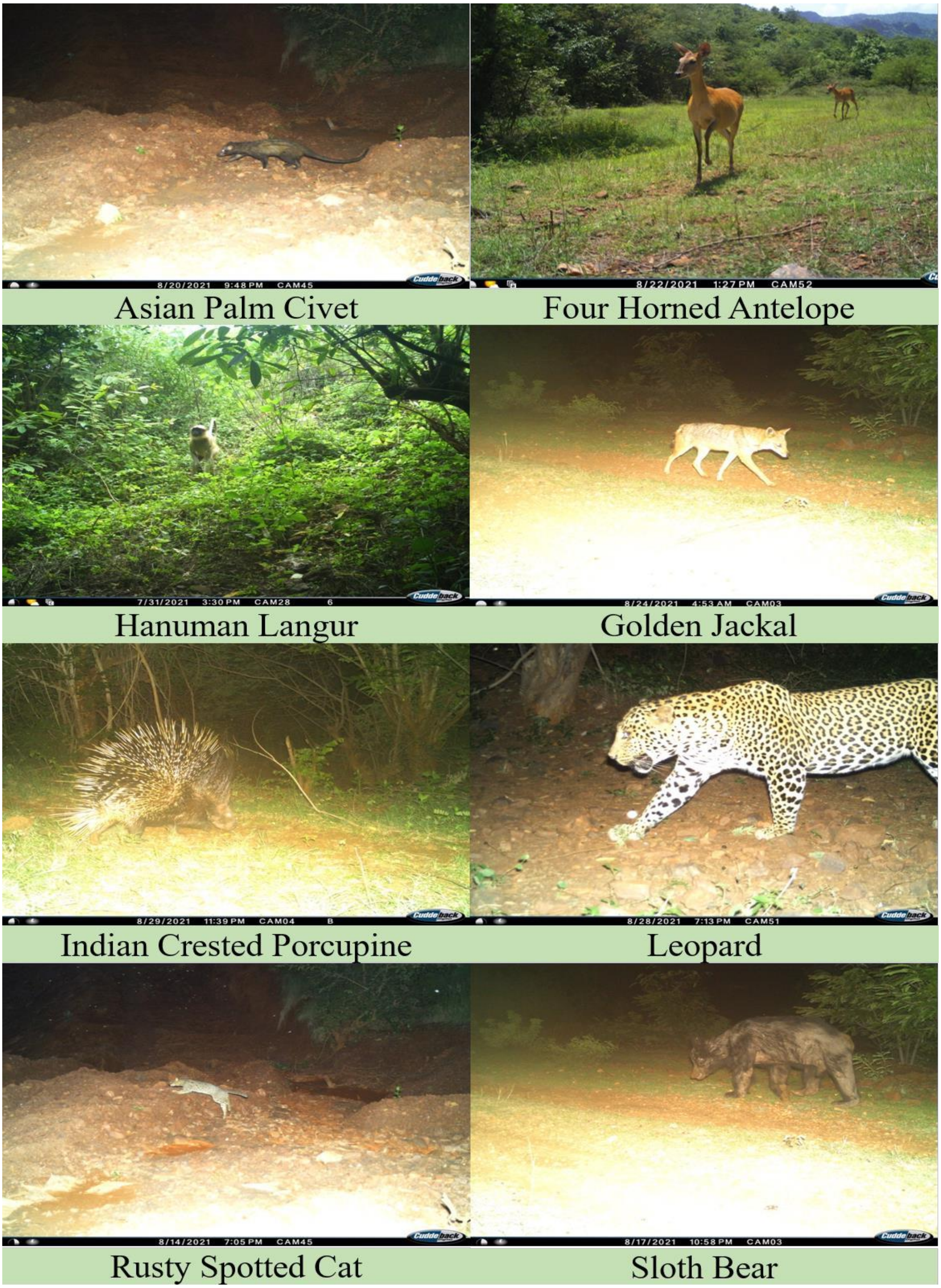


Plate.10.1: Mammal - "Camera trap captures of mammals in study area"

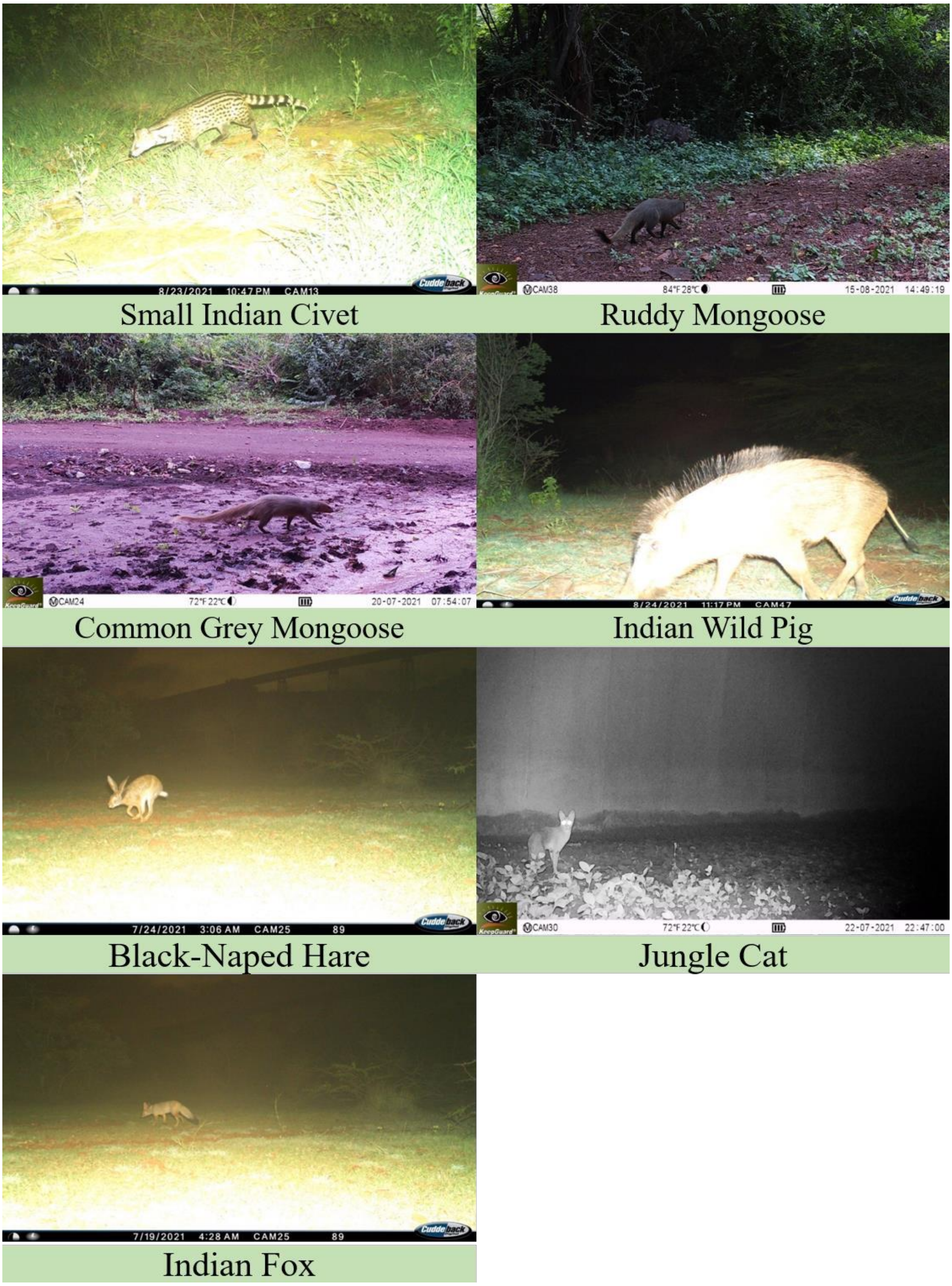
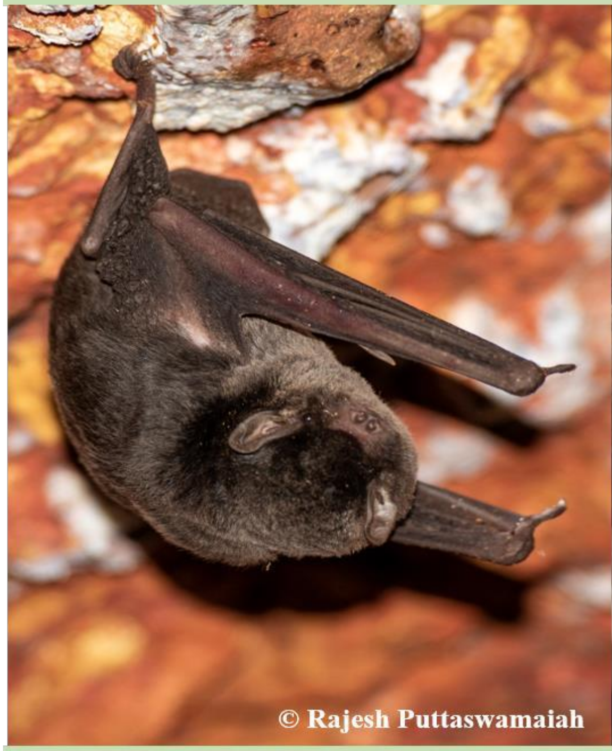


Plate.10.1: **Mammal - "Camera trap captures of mammals in study area"**

Tadarida aegyptiaca

Pipistrellus ceylonicus



Miniopterus fuliginosus

Rhinolophus lepidus

Plate.10.2: Photographs of few bat species found in the study area (These photographs are representative images only except for *Hipposideros lankadiva* which was photographed under the bridge next to MPC.)

Plate.10.3: Photographs of few of the bat species found in the study area (These photographs are representative images only except for *Hipposideros lankadiva* which was photographed under the bridge next to MPC.)

Plate.10.4:"Photographs of a few rodents recorded from the study area"

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