Biodiversity and Environmental assessment of proposed doubling of railway track between Kulem and Castlerock in Goa-Karnataka

Final report submitted to Rail Vikas Nigam Limited,

Ministry of Railways, Government of India

Prof. R. Sukumar and Prof. T.G. Sitharam

Center for Ecological Sciences

Department of Civil Engineering and CISTUP

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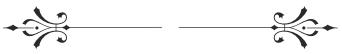

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EXECUTIVE SUMMARY:

Background:

Railway Vikas Nigam Limited (RVNL) has proposed a doubling of the existing rail line from Hospet - Tinaighat - Vasco Port (345km) sanctioned by the Ministry of Railways. There are two phases for this project. Phase 1 - Doubling of line between Hospet and Tinaighat and Phase 2 - Doubling of line between Tinaighat and Vasco, Castlerock - Kulem doubling is part of the Phase-2 Project. RVNL considered several possible alignments for the second line in the Castlerock - Kulem Section, but finally settled on an alignment parallel to the existing railway track.

The second phase of the line passes through forest areas in the states of Karnataka and Goa, including two protected areas, Anshi-Dandeli Tiger Reserve (ADTR, Karnataka) and Bhagwan Mahavir Wildlife Sanctuary (BMWLS, Goa). RVNL thus decided to commission a biodiversity assessment report from the Indian Institute of Science. This report comprises of two major parts, namely, environmental aspects including geo-technical considerations and a detailed assessment of plant and animal diversity. A public consultation was also carried out.

Environmental and geo-technical aspects:

Environmental parameters relating to air, noise, and water were monitored, and geo-technical issues relating to the excavation and tunneling were considered through primary survey and study.

Noise pollution in the vicinity of the railway stations as well as the locations where trains pass by is considered to be unhealthy. Electrification of railway tracks and planning native tree species to absorb noise are recommended to reduce noise pollution. Air quality is expected to worsen by 2-fold from the existing condition by increased use of diesel locomotives. However, this can be reduced with the use of electric locomotives or state-of-the-art energy efficient hybrid locomotives.

As the Railways are planning to electrify the Castlerock-Kulem stretch of railway track, the quality of air is not likely to be directly affected due to exhaust from locomotives or running of the trains. Hence, air quality measurements were not taken in this relatively pristine area. However, air quality monitoring has to be carried out during the construction phase that would generate dust.

Streams and rivers in the Ghat sections are devoid of any industry or industrial affluent in the catchment area of the Castlerock-Kulem section. Water quality analysis carried out during monsoon as well as lean period shows that the streams along the existing railway track are largely pristine in nature. However, *Escherichia coli* bacterial contamination was found in all sampled streams, indicative of faecal contamination.

The present alignment that is parallel to the existing line has several tunnels as a measure to reduce the loss of tree cover. The total muck generated during cutting in formation and tunnels is 10,83527 m^3. About 568373 m^3 can be used in filling, ballast, coarse aggregate and fine aggregate, blending material for blanketing and it could also be used for Gabion.

Biodiversity assessment:

A broad landscape scale mapping of vegetation and land use was carried out before sampling the diversity of plants, and selected animal taxa, namely, butterflies, odonates, fishes, amphibians, reptiles, birds and mammals.

Classification of the landscape elements: A detailed classification of landscape was done into different land use categories based on extensive ground truth points. Landsat imagery from April 2013 was used

for classifying different landscape elements including veget on types. According to our classific on, tropical moist deciduous forests occupied a large area (40.6%), followed by tropical semi-evergreen (23.8%) and tropical evergreen (18.4%) forests. About 83% of the total area is forest followed by 5.8% of agriculture lands and 11.2% of land belonging to other categories such as rocky outcrops, water bodies and open lands.

Diversity of natural vegetation was characterized by laying 0.1 ha sample transects in different vegetation types classified by us. Thirty eight 0.1 sample transects were laid and all woody individuals over 1.0 cm dbh (diameter at breast height) were enumerated. A total of 8593 individuals belonging to 255 different species of flowering plants were enumerated. Among the canopy trees, *Hopea wigh*, *Diospyros candolleana*, *Xylia xylocarpa* and *Terminalia paniculata* were dominant.

In moist deciduous forest type, a total of fourteen transects were laid and 2284 individuals >1 cm dbh belonging to 119 species in 42 families of flowering plants were enumerated. Dominant trees were *Xylia xylocarpa* and *Terminalia paniculata*. Top ten species accounts for 61.3% of total abundance. There were 32 species with one species. The most speciose family was Fabaceae followed by Rubiaceae. There were 16 families with one species. Family Combretaceae had the maximum basal area (42.2%) followed by Fabaceae (22%). Mean species richness was 28 ± 11.4 species/plot and Shannon-Weiner's heterogenity index was 2.50 ± 0.62. Mean density per plot was 163.07 ± 65.94 individuals >1 cm dbh. Basal area of the plot was 4.05 ± 1.87 m2/0.1 ha. Mean height of the canopy was 25 meters.

Seven 0.1 ha sample plots were laid in semi-evergreen forests resulting in 1508 individuals >1 cm dbh belonging to 111 species and 42 families of flowering plants. *Memecylon umbellatum* and *Psychotria dalzellii* were the most abundant species. Among the canopy trees *Hopea wigh*, *Aporusa lindleyeana* and *Diospyros candolleana* dominated the floristics. *Terminalia paniculata* had the highest IVI value and 23 species had just one individual. Most speciose family was Myrtaceae. Family Combretaceae had the maximum basal area. Other families that significantly contributed to the basal area are Lythraceae, Myrtaceae and Clusiaceae. Mean number of species 37.4 ± 5.09 was and Shannon-Weiner's diversity index was 2.85 ± 0.23. Mean density of stems >1 cm dbh was 215 ± 42 with mean basal area of 3.44 ± 1.76 m^2 per plot. Mean height of the canopy was 27 metres.

In evergreen forest type 17 sample plots were laid. A total of 4801 individuals >1 cm dbh belonging to 207 species spread across 61 families of flowering plants. There were 42 species with one individual. Family Lauraceae and Myrtaceae were most speciose followed by Rubiaceae. There were 28 families with one species. Family Oleaceae accounted for most basal area followed by Combretaceae. Mean species richness was 42.8±10.2 per lt and Shannon-Weiner's index was 2.92 ± 0.48. Mean density of stems >1 cm dbh was 282.4 ± 94.1 with a basal area of 4.32 ± 1.82 m^2. Mean height of the canopy 30.5 meters.

About 50% of the total species recorded in the study had distribution confined to India which includes 11.6% of endemics. 16.01% species had Indo-Lankan affinities and 23.37% species showed Indo-Malayan affinities. Diversity recorded in these forests is comparable to several tropical forests in Southeast Asia.

Size class distribution of individuals showed an inverted “J” shape, while basal area is concentrated in the higher size classes. Biomass of forests also showed considerable variation with evergreen plots having high biomass (364.4 ± 97.53 tons/ha) followed by semi-evergreen forests (290.7 ± 86.62 tons/ha) and moist deciduous forests (272.1 ± 54.77 tons/ha). Hard wood species such as *Terminalia paniculata* and *Xylia xylocarpa* contributed significantly to the biomass in moist deciduous forests. In semi-evergreen

forests *Terminalia paniculata* along with *Hopea wigh*and *Aporusa lindleyeana* contribute the maximum to biomass. *Olea dioica, Hopea wigh*and *Memecylon umbellatum* contribute significantly to the biomass in evergreen forests.

If 53255 woody stems >1 cm dbh under Scenario 1 (parallel track) and 175896 stems>1 cm dbh under Scenario 2 (non-parallel track)are to be cut for doubling of the railway line parallel to the existing track, this would result in the loss of 7878.0 tons of standing biomass under Scenario 1 and 20753 tons of standing biomass under Scenario 2 or 3939.0 tons of carbon under Scenario 1 and 10376.8 tons of carbon under Scenario 2.

Order Lepidotera (that includes the butterflies) constitutes the second most diverse group of insects. Four transects of 7 kms were laid along the proposed railway line to enumerate butterflies. Surveys were carried out in the morning along with opportunistic surveys at other times. A total of 2420 individuals belonging to 133 species of butterflies were recorded with family Nymphalidae being the most dominant family. Chocolate Pansy, Common Indian Crow and Grass yellow were the most abundant butterflies.

Tamil Yeoman and Malabar tree nymph were the abundant endemic butterflies. There was considerable variation in both number of species and density of individuals across transects. There were three species - Crimson rose, Malabar banded swallow tail and Danaid egg fly, which are listed in Schedule 1 of Wildlife Protection Act 1972 and several others are listed Schedule 2 of the Wildlife Protection Act 1972. BMWLS harbors much higher diversity of butterflies when compared with other local fles of the Western Ghats.

Odonata are the most popular “flagship” group of insects for their role in aquatic environments. They are also considered as among the best indicators of health of the water bodies and wetlands as they respond rapidly to changes in land use and anthropogenic disturbances. Odonates in BMWLS were sampled extensively in forests and streams by laying belt transects. A total of 57 species of odonates, which constitute about 33% of species reported from the Western Ghats, were recorded during the survey. Nine species are endemic to the Western Ghats. Three species of odonates were “nearly critical” according to IUCN Red List status.

The present study focused on the fish richness of Dudhsagar stream a tributary of Mhadei River in Goa state. Dudhsagar stream originates in the hilly regions of Karnataka state. The stream enters BMWLS in the North Goa district. This stream has the famous Dudhsagar waterfall in the park which attracts thousands of tourists. Four locations were sampled using castnet along the river Dudhsagar while basic water quality measurements were also taken. Twenty three species of fishes were recorded with family Cyprinidae, the most abundant. Sites such as Dudhsagar 1 and Dudhsagar 2 had most number of species and high Shannon's Diversity Index. Disturbed site at Kulem had 10 species. Dudhsagar falls had higher density of individuals. *Salmophasia boopis* was the most abundant fish. According to the guild composition, fish community was mainly composed of surface dwellers followed by mid-column dwellers and bottom dwellers. According to feeding habits, insectivorous feeding guild was dominant followed by algae feeding guild. Of the total fish species recorded, about half of the species are endemic to the Western Ghats.

Fish abundance decreased with increase in electrical conductance and total dissolved solids, but there was no relationship with water temperature. There was a positive relationship between canopy cover and fish abundance.

A mammal survey was undertaken with two basic objectives: 1. To record the mammalian diversity of the proposed project area and 2. Possible direct impacts of proposed project on mammals through train

collisions. Indirect methods included literature survey, faecal Identification and camera traps. Literature survey yielded 42 species of mammals in the region. Among the indirect signs, sambar deer pellets were the most common. Apart from this, two wild dog scats and one leopard scat was also found. Five camera traps were placed for 6 days. Five species were recorded with Indian porcupine recorded most commonly. There were 37 direct sightings of various animals; bonnet macaque and Malabar giant squirrel dominated the list, while leopard and sloth bear were sighted once. Potential crossing points of the larger mammals along the existing railway track were also determined with the aid of a Global Positioning System (GPS) and walking along the entire stretch of the track between Castlerock and Kulem.

Public consultation

A Public consultation was held in May 2016 at Kulem, Goa. Members of the Gram Sabha and others actively participated in the meet. After introduction of the project and its importance given by railway staff, member of the Gram Sabha asked several questions. In the meeting the Gram Sabha members were overall satisfied with the need for doubling the railway track, while also submitting a memorandum to the Railways requesting them to involve them in mitigation measures when the project actually gets commissioned.

Mitigation Measures

Mitigation measures to lessen the impact while executing the project has been suggested. These measures could be broadly environmental and biological. Environmental issues concerns water, air, land and soil while biological measures mainly deal with reducing the pressure on the forests, conserving forests as much as possible and facilitating easy and free movement of wildlife.

CHAPTER 1

BACKGROUND TO THE PROJECT:

M/s Rail Vikas Nigam Limited (RVNL), Bangalore, Ministry of Railways, has undertaken the execution of the proposed doubling of the existing rail line Hospet-Tinaighat-Vasco port (345km) sanctioned by the Ministry of Railways. There are two phases of the current project. Phase-I, involving doubling of the existing line between Hospet and Tinaighat (245 km), is parallel to existing line and within the railway land. Phase-II between Tinaighat and Vasco is also parallel to the existing track, Castlerock - Kulem Doubling is part of the Phase-2 work. The proposed line passes through natural forests of the Western Ghats between Kulem (Sangem Taluk, South Goa District, and Goa State) and Castlerock (Joida Taluk, Karwar District, and Karnataka State). An Environmental Impact Study and mitigation plan is generally necessary for obtaining clearance from both central and state governments as well as the Supreme Court's Centrally-Empowered Committee and the National Board for Wildlife for diversion of forest land from Protected Areas for non-forestry purposes. The proposed railway project will have impact on the local ecology and environment of the area that includes a wildlife sanctuary. The main objective of the biodiversity and environmental impact assessment is to study the potential impacts of the doubling of the railway track, as part of the planning and design process, and to formulate necessary measures to reduce the impacts to acceptable levels. Though the development of railways is for the betterment of economic and social condition of people, it is not ruled out that there would be negative impacts on environment and people living in the immediate vicinity. However, in the present context, the proposed railway line does not pass through any human habitation.

This study has two main components:

1. Development of baseline environmental profile that includes physical factors, biological components and cultural components based on primary and secondary data.

2. Impact prediction and mitigation with appropriate methods including simulation methods, empirical methods and reference to previous studies.

RVNL approached the Center for Ecological Sciences (CES) for a comprehensive and consolidated report on the physical and biological aspects of the proposed railway line. CES agreed to carry out a study on the biodiversity of the area, and Civil Engineering Department (CE) of IISc agreed to undertake an assessment on the environmental aspects including noise pollution, water quality and geo-technical aspects of excavation for the railway line.

M/s Rail Vikas Nigam Ltd wide its letter LOA No. RVNL/SBC/HPT-TGT/Q.01/2013 dt. 01.02.2013 proposed the following terms of reference.

(a) EIA Study

The main objective of the environmental impact assessment is to study, identify and assess environmental impacts of the proposed railway line project as part of the planning and design process, and formulate necessary measures to reduce those impacts to acceptable levels. It may be noted that although the project does not attract EIA Notification 2006, this EIA study in general shall be conducted in compliance with this Notification:

The scope of work includes, but not limited to:

• Review the proposed project activities and delineate the project impact area; this would extend to a minimum of 10 km either side of the proposed railway line;

• Develop baseline environmental and socio-economic profile of the study area based on the both secondary sources of information and necessary field surveys;

• Identify the project activities likely to cause potential significant impacts to the natural

environment, and assess the significance of those impacts (such as permanent or temporary, cumulative, and/or irreversible);

• Conduct alternate analysis for the proposed alignment ("with" and "without" project scenario) and among the existing railway line and proposed parallel alignment

• Develop appropriate mitigation measures and actions to avoid, mitigate, or reduce the identified impacts;

• Formulate Environmental Management Plan including an Environmental Monitoring Plan, effectiveness of mitigation measures during construction and operation; EMP should also include implementation schedule and associated costs for execution of mitigation and enhancement works; and detailing of the requirements for institutional strengthening and training.

• Conduct Public Consultation with project affected persons and stakeholders to incorporate their views. RNL will organize a public consultation as necessary with the help of a Sociologist or institution specializing in Social Sciences at their own cost. The IISc investigators will participate in the consultation and provide inputs.

(b) Baseline Environmental Profile of the Study Area

In order to identify any potential impact on and potential change to the natural and socioeconomic environments, the baseline environmental profile will be developed based on both available secondary sources of information and primary surveys. This baseline will include but not limited to following: Physical Resources (location, topography, soil, geology, seismicity, water, air, land, etc), Ecological Resources (Flora, fauna, forests, protected areas, etc), and Socio-economic profile (demography, economic and social stratification, occupational pattern, land holding, cultural aspects).

Primary data/monitoring to define characteristics of the existing natural environment including soil, water, air, noise, land use, cultural properties and flora & fauna.

• Monitoring to be carried out at critical locations;

• Ambient air and noise monitoring at selected junctions, major settlements, school and hospitals, etc., along the proposed alignment;

• Railway noise at selected points along the existing railway line;

• Water quality monitoring at selected river/streams/ponds and ground water sources near major settlements;

• Soil monitoring at major selected settlements, near surface water bodies.

• Ecological resources surveys (flora & fauna) in consultation with Forest/Wildlife Department to substantiate the secondary data available with the department;

• Inventory of cultural property resources along the alignment.

Secondary Data to define meteorological, geology, seismicity, quarries, borrow areas, and disposal sites.

• Details of quarry and borrow areas to be used will be collected.

• Meteorological data from India Meteorological Department, topo sheets and maps

from Survey of India, geological and soil data from GoI, seismic data from Earth Sciences Department.

• Social data including ownership pattern, identification of tribes, vulnerable social groups, land estimates etc.

Appropriate maps and graphical methods should be used to present the baseline profile. A base map of the study area indicating administrative boundaries, topographical features, forests, wildlife sanctuaries, water bodies, etc. would be prepared.

(c) Impact Prediction & Mitigation

Railway projects may have negative impacts on physical environmental resources (topography, drainage, land, water, air etc), ecological resources (flora and fauna) and socioeconomic (displacement, loss of livelihood etc) and cultural resources (damage to historical /archaeological and cultural sites) depending on the proposed alignment.

Potential impacts of the proposed project would be predicted and assessed with appropriate methods such as model studies, empirical methods, reference to existing similar situations, reference to previous studies, details of mitigation, methods proposed to reduce adverse effects of the project and reference to the models along with the inputs used should be mentioned.

The proposed alignment passes through forest areas and/or protected areas. The project is distinctive to the extent that there are 15 tunnels proposed (covering a length of 3.407 kms) in a total project alignment of 27.75 kms.

The EIA would focus inter-alia on aspects such as:

• Potential impacts on the forests/protected areas;

• Potential impacts due to generation and disposal of large quantities of muck/debris from tunneling;

• Tunnel safety (inter alia should fire safety, lightning, power supply, natural risks, traffic management, ground support, natural risks, ground water and runoff water)

Mitigation measures should be proposed as required during the construction stage as well as the operation stage of the project for all the identified impacts. Measures shall be suitable, effective, feasible and least cost and should focus on mitigation of negative impacts and enhancement of positive benefits of the proposed project. The order of priority in identifying mitigation measures shall be to (i) avoid, (ii) mitigate, (iii) reduce to acceptable levels and/or, (iv) compensate the adverse impacts caused by the project to the extent possible.

AECOM report suggests that muck generated in cutting in formation is 8,51,399 cubic meters and in tunnels is 232128 cubic meters. Of which, 5,68,373 cubic meters will be used for embankment and other purposes. The unused quantity of 5,15,154 cum muck will be disposed in dump yards.

(d) Environmental Management Plan

Environmental Management Plan (EMP) would be developed describing the environmental management measures that will be carried out to mitigate negative impacts during implementation of a project, plus the environmental monitoring to be conducted to ensure

that mitigation is provided and is effective in reducing impacts, or to determine the long-term impacts of a project. The EMP would also include good environmental construction guidelines to be incorporated in the Bid document's work requirements.

EMP would include a review of institutional arrangement for implementation of EMP, required capacity building and training,

Environmental Monitoring Plan shall be elaborated for construction period and operation period covering locations sensitive to pollution aspects as well as areas covering protected areas, wildlife sanctuary, and other eco-sensitive areas along the project alignment. This would include:

- Technical aspects of monitoring for achieving effectiveness in mitigation measures;
- Requirement of monitoring facilities and methods adopted;
- Frequency, location, parameters of monitoring;
- Compilation and analysis of data and reporting system;
- Procurement schedules and budgets in detail;
- Training requirements.

(e) Public Consultation

Public consultation is the process of exchanging information with those persons and organizations with a legitimate interest in a project and/or who are likely to be affected by the project (stakeholders). It is a two-way process that informs and involves the community in developing a project, and informs the proponent about issues and concerns, which can then be addressed in project design. Information disclosure involves stakeholders in monitoring the development and implementation of a project and fosters openness in decision-making by presenting documents and other project materials for public scrutiny.

The present report incorporates the observation of our study team on physical and biological attributes of the area in Goa and Karnataka parts of the proposed line towards building baseline information of the area. This report has several sections including physical/environmental aspects (geotechnical aspects, air, water and noise pollution), as well as biodiversity (floral diversity and faunal diversity of selected groups including mammals, birds, frogs, reptiles, fishes, dragonflies, odonates and butterflies).

This report has three major components: 1. Environmental and Geo-technical section that deals with environmental issues including air, water and noise pollution, and geo-technical aspects relating to excavation of soil/rock and their removal or storage. 2. Biodiversity issues - This section has detailed description of biodiversity components from the proposed area that includes vegetation (forests), insects (butterflies and dragonflies), fishes (fresh water), amphibians (only frogs), reptiles, birds and mammals. This section also has a chapter on economic and ecosystem services of the forests of the region. Each chapter in this section has a detailed account on the methods used in the survey, as well as a quantitative description of the taxa under consideration. 3. The Socio-economic survey in the proposed project site and public consultation is dealt in this component. Finally, the report ends with recommendations to the project proponents on mitigation measures for possible impacts of the doubling of the railway line.

CHAPTER 2

THE PROJECT AREA

The RVNL (Rail Vikas Nigam limited) under the Ministry of Railways, Government of India proposed doubling of existing railway track from Hospet to Vasco-da Gama through Tianighat (407 km). Present investigation between Castlerock and Kulem forms part of this line. As this section of the line passes through two protected areas in an ecologically sensitive area of the Western Ghats, a detailed ecological investigation is mandated. Doubling of the existing track is necessary to have smooth and rapid flow of traffic between two important points, Hospet (mining and industrial belt) and Vasco-da-Gama (port). Also, this proposed line has strategic importance for rapid mobility and transportation between ports and naval bases along the west coast and the interior.

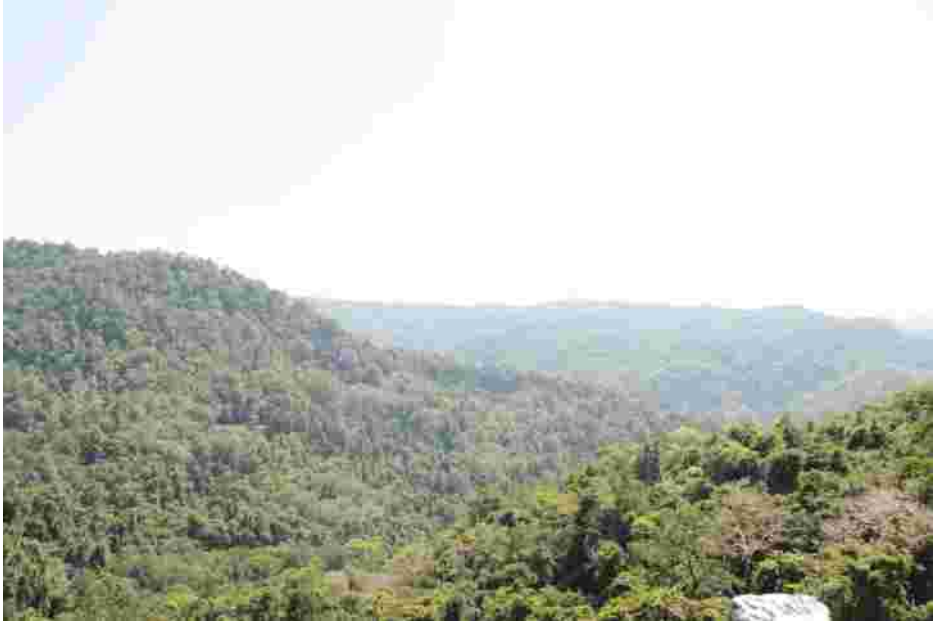
Physical setting:

Present study was conducted in hilly region of southern Goa and adjoining regions of Joida taluk of Uttara Kannada district (Karnataka state). Proposed railway line passes through forested tracts of Anshi-Dandeli Tiger reserve (Joida Taluk, Karnataka state), Bhagawan Mahavir Wildlife Sanctuary (Mollem, Goa), and some private lands of Karanzole settlement.

The hilly region of Goa and Karnataka forms the part of the Western Ghats (8˚20' - 20˚ 40' N Latitude and 73˚- 77˚ E Longitude), a continuous mountain chain that runs parallel to west coast of peninsular India and is approximately 1600 km long.

The Western Ghats extend from Gujarat in the north to Kerala in the south, spreading across five different states in peninsular India. The Western Ghats are a continuous chain of mountains with a major gap near Palghat (Kerala). Mean elevation of the ghats is 900 meters ASL with the highest peak Anaimudi (2695 meters) in the Anamalai range in the south. The Western Ghats along with Sri Lanka are considered to be one of the “hot spots” of biological diversity (Conservation International, www.conservationinternational.org, Botanical Survey of India www.bsienvis.nic.in and Myers, 2000). Goa is located in the central Western Ghats and bio-geographically an important area (Karanth 2003). The Western Ghats accounts for about 4000 species of flowering plants (27% of India's flowering plant species) and large number of them are endemic. The high biological diversity can be attributed to topographical diversity which includes valleys and steep hills and orographic effect. Rainfall is mainly from southwest or summer monsoon which brings high rainfall on the windward slopes of the Ghats. As the monsoon progresses towards east to the Deccan plateau it gets weakened resulting in semi-arid climate. The eastern slopes of the southern region of the Ghats receive some rainfall from the northeast or winter monsoon. The Western Ghats is home to many rivers that flow both in east and west directions. Three large rivers of peninsular India, namely, the Cauvery, the Krishna and the Godavari originate in the Ghats and flows into the Bay of Bengal. There are innumerable small rivers and rivulets that flow westwards to the Arabian Sea. Major rivers that flow west include the Narmada, the Sharavathi, the Aghanashini, the Kali, the Periyar, the Bharatapuzha, the Pamba, the Chaliyar and the Chalakudy.

Vegetation of the Western Ghats is mainly of two types 1. Tropical moist forests including tropical rain forests, semi-evergreen forests and tropical montane forests that are confined to folds of mountains at higher altitudes. 2. Tropical seasonally dry forests including moist deciduous, dry deciduous and dry thorn type. Apart from these two major types there are montane grasslands, mid-elevation swamy grasslands, Myristica swamps and peat bogs usually juxtaposed or associated with one of the major vegetation types.



Closed canopy rainforests in the study area. This kind of closed canopy forest is characteristic of the Wesern Ghats.

Geology:

Goa is situated on the rock system called "Western Dharwar Craton" (Ramakrishnan and Vaidyanadhan, 2008, A,G. Desai, 2011). It is a northwesterly extension of the granitoid-greenstone terrain of Karnataka made up of Precambrian rocks such as gneisses and schists, Deccan traps of Cretaceous – lower Eocene age are also reported from north-eastern corner. Oldest known rock found in Goa is the Anmod Ghat Trondhjemitic Gneiss. The Peninsular gneiss are grey, medium to coarse grained banded rocks forms the basement for the Goa group of rocks. NBSS and LUP have identified 25 different soil series in the state (Soils of Goa, 1999). Most soils are well drained.

Land use and land cover:

Goa state covers an area of 3702km² and has a coastline of 105 kms. topographically three distinct zones may be identified; they are the coastal plain, the mid-upland region and the Western Ghats. Forests cover an area of 1224 km² accounting for 34% of the geographical area. FSI report (2015) reports that there is an increase of 5% in the total forest area due to increase in Mangrove forests. Agriculture including orchards, paddy cultivation and cultivable lands accounts for 37% of the land use. Rice, pulses, and finger millet (ragi), are the main food crops cultivated in the State. Rice cultivation covers about 47,237 ha. Other main cash crops include coconut, cashew nut, areca nut, and sugarcane. Other land use types include salt pans, water bodies, industrial areas and fish farms.

Climate:

Rainfall in the study area is mainly from southwest monsoon which is active during the months of June to September. Mean annual rainfall at Castlerock (crest of the ghats) is 6678 ± 1348 mm (range = 4918 - 9874 mm, N= 33 years). Rainfall is concentrated in three months (June, July and August) and July is the wettest month (Figure 1 a). Monsoon months (June, July, August and September) account for 95% of the total rainfall during a calendar year. We have also presented long term rainfall pattern over western India that broadly captures rainfall over Goa and Konkan parts. Though this is not the actual rainfall received at the proposed project site, it still represents the quantity and spread of the rainfall (Figure 1 b).

Dudhsagar waterfalls with rocks exposed

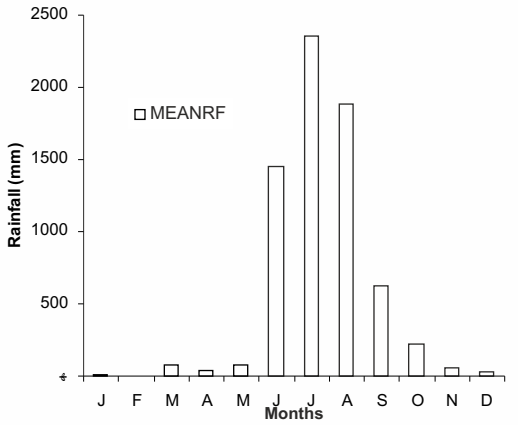


Figure (1 a) Mean monthly rainfall patern at Castle Rock (1980 -2012).

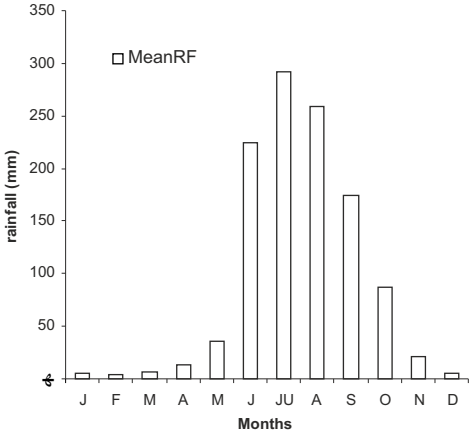


Figure (1 b): Rainfall patern over western peninsular India (1970-2006). Data from IITM, Pune.

Vegetation of the Study Area:

The proposed railway line passes through prime forested tracks between Castle rock and Kulem. Castlerock forests are part of Dandeli-Anshi Tiger Reserve (DATR), in Karnataka, while forests between the Goa-Karnataka border and Kulem fall within the Bhagawan Mahaveer Wildlife Sanctuary (BMWLS) in Goa. Three distinct forest types are found here namely: 1. Southern Tropical evergreen forests, 2. Southern Tropical semi-evergreen forests confined to the hills and 3. Moist deciduous forest found in the coastal plains. BMWLS which accounts for large proportion of proposed project area has about 721 species of wild plants belonging to 490 genera and 119 families (Datar and Lakshminarasimhan, 2013). The family Leguminosae (63 species) is represented by the highest number of species, followed by Poaceae (grasses) (40 species), Rubiaceae (38 species) and Euphorbiaceae, Orchidaceae and Acanthaceae (34 species). Largest genus was Ficus (figs) with 12 species followed by Diospyros (8 species) and Syzygium (6 species). There are about 126 species reported to be endemic with a large number of them confined to the Western Ghats. Though BMWLS account for 0.05% of the area of the Western Ghats, it harbours 8.4% of endemic species that are endemic to the Western Ghats (Datar and Lakshminarasimhan, 2013). BMWLS also accounts for 50% of species that are described from the state of Goa.

- Southern tropical evergreen forests: This forest type is also referred to as West coast Tropical Evergreen forests (Champion and Seth, 1968). It has tall trees with clear stratification. The species association is defined as "*Persea macrantha- Diospyros spp. – Holigarna spp*." by Pascal, 1988. This forest is characterized by abundance of light demanding species in correspondence with lengthing of dry seson (Pascal, 1988). Important canopy trees are *Holigarna grahamii, Canarium strictum, Garcinia spp. Diospyros spp. Syzygium spp*. The middle story includes *Polyalthia fragrans, Syzygium laetum, Memecylon spp. Psychotria dalzelii, Ixora nigricans* etc. Along the stream species such as *Calophyllum spp. Lophopetalum wigh*and *Hydnocarpus pentandrus* are found. Important lianas of this forest type include *Entada rheedi, Ancistrocladus heyneanus, Paramignya monophylla* and *Toddalia asia*. Ground flora is rich in plants belonging to Asteraceae, Cyperaceae, Poaceae and Zingiberaceae.

  • West Coast semi-evergreen forest: These forests are transitions between evergreen forests and moist deciduous forests. Two distinct edaphic formations are recognized in this type (Datar and Lakshminarasimhan, 2013). 1. Cane breaks: These occur on the slopes of the Ghats with *Calamus thwaitesii* and also in lower elevation. 2. Lateristic semi-evergreen forest: They are found at an elevation of 200 metres and above. Important species are *Actnodaphne angussfolia, Lagerstroemia microcarpa, Macaranga peltata, Pterospermm diversifolium* etc*.* Shrub layer in this forest has species such as *Glycomis pentaphylla, Maesa inica, Leea indica, Gnidia glauca*. Some of the common herbs are Asystacia sp., Impatiens sp., and several grasses.

  • Moist deciduous forests: These forests are found in the lower elevation. Important species of this forest include *Xylia xylocarpa, Lagerstroemia microcarpa, Dillenia pentagyna, Terminalia crenulata, Grewia* etc. in the second story are found species such as Randia *dumetorum, Xantolis tomentosa, Strychnos nux-vomica, Canthium spp.* etc. Ground flora is rich in species belonging to families such as Leguminosae, Rubiaceae, Euphorbiaceae and Asteraceae.

Faunal diversity:

Despite it small size, Goa is endowed with a rich faunal diversity. The mammals include several species listed in Schedule I of the Wildlife Protection Act (1972) such as the larger mammals (Indian gaur, tiger,

Inside a tropical evergreen forest in the proposed project area (BMWLS)

leopard). Elephants are rare seasonal visitors from nearby Karnataka. Striped hyena, jackals and dhole are seen. Other mammals include sloth bear, otters, pangolin, and giant squirrel. Over 450 species of birds both resident and migratory have been recorded in the state (Mahabal, A and Patil, S.R. 2008, Birds of Goa www.goaenvis.nc.in/birds.htm). The state bird is Ruby throated yellow bulbul (*Pycnonotus dispar*). According to IUCN rankings White backed vulture and Long-billed vulture are critically endangered, while Malabar pied hornbill and Great pied hornbill are nearly threatened. There is a good reptilian diversity including the poisonous snake King cobra (*Naja hannah*). The Western Ghats harbour notably high diversity of amphibians with several of them being endemic (Daniels, RJR 1997, Aravind NA and Gururaj KV. 2011, Dinesh, KP et al 2015). Thirty two species of amphibians have been added from Goa alone to the taxon list. 205 species of fishes have been described from the state of Goa.

Environmental Issues:

Goa is one of the large exporters of iron ore in the country (www.goaenvis.nic.in, Mallya. K. and Stalin D. 2010). Nearly half of the ore exported from the country is from Goa. Other important ores mined in Goa are Manganese and Bauxite that are economically important. Besides this other minor minerals such as basalt, laterite stones, river sand, rubble and murram, which are used as construction material, are also mined. Mineral rich belt of Goa lies mainly in Bicholim, Sattari, Sanguem, Dharbandora, and Quepem taluks covering an area of 700 sq. km. The largest mining belt is in Sanguem taluk. There are about 105 mines in operation in Goa. Mining in Goa is mainly open-cast type. This type involves cutting in regular depths and important feature of this mining is the high overburden to ore ratio, which requires handling large amount of ore and extensive dumping sites for the reject.

There are several environmental concerns relating to mining (www.downtoearth.org, Ashwin A. 2011 Down to Earth, 2011; Ramesh Guans, 2011. www.indiawaterportal.org, www.cseindia.org 2007). There is large scale encroachment and illegal mining that cause serious environmental problems. There are also socio-economic concerns relating to mines. However, detailed discussion on these issues is available elsewhere and is out of the scope of this report.

Root system in a teopical semi-evergreen forest. In the proposed project area (BMWLS)

Government of India appointed a High Level Working Group (HLWG) headed by Dr. K. Kasturirangan with the mandate "to examine the Western Ghats Ecology Expert Panel report in a holistic and multidisciplinary fashion". After feedbacks from various states on the report of the HLWG, the Ministry of Environment, Forest and Climate Change issued a draft notification on 28th February 2017, in The Gazette of India: Extraordinary (Part 2, Section 3, sub-section ii)) declaring 56,825 sq. km across six states in the Western Ghats as "Western Ghats Ecologically Sensitive Area". The proposed railway line will pass through the Ecologically Sensitive Area.

Although the gazette notification of the Western Ghats ESA does not explicitly mention railway projects, the HLWG mentions that although railway projects do not require environmental clearance, keeping in view the increasing accidents there is a need for more vigilant environmental safeguards. HLWG has also recommended policies to incentivize environmentally sound growth across both natural and cultural landscapes of the Western Ghats. Hence, it is recommended that strict regulation is followed in implementation of EMP while executing the railway project.

Moist deciduous forest in the proposed project area. BMWLS.

SECTION - I

GEO-TECHNICAL PROFILE

CHAPTER 3

GEO-TECHNICAL STUDIES

Introduction

The continuous chain of hills in the western part of peninsular India is known as Western Ghats. This hill range is about 1600 long from Kms Kanyakumari in south (8˚N) to River Tapti (21˚N) in the north and about 100 Kms wide, spread across Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu and parts of Gujarat. For convenience, the entire region is divided into Southern (between 8˚- 12˚ N), Central (12˚ - 16˚N) and Northern (16˚- 21˚ N) Western Ghats. The average elevation in this mountain chain is about 1200 mtrs above mean sea level, with hill ranges in the southern parts have high elevation peaks, Anamudi peak being the highest with 2695 mtrs amsl (https://en.wikipedia.org/wiki/Western_Ghats).

Geology: Faulted and eroded edges of the Deccan Plateau are formed as Western Ghats formed about 150 million years ago, during the break-up of the supercontinent of Gondwana. Basalt rocks are the predominant rock formation of the Western Ghats. Charnockites, granite gneiss, khondalites, leptynites, metamorphic gneisses with detached occurrences of crystalline limestone, iron ore, dolerites and anorthosites are the other rock formations found in the Ghats. Laterite and bauxite ores are found in the southern parts of the Western Ghats.

Climate: The Monsoon, especially the southwest monsoon brings heavy rains to the Western Ghats. The rainfall distribution shows two distinctive peaks -one around June and the other around October. The maximum rainfall is in the month of July, sometimes in August. Rainfall in this region averages 3000-4000 mm with localised extremes touching 9000 mm. Rainfall higher than 5000 mm occurs in north of 11° - 15°N. The eastern region of the Western Ghats which lie in the rain shadow, receive far less rainfall of about 1000 mm. The months April and May are hot, very dry and generally uncomfortable. Weather tends to be oppressive during June due to high humidity and temperature. The highest recorded temperature was 45.6 °C and lowest was 2.8 °C. The winds that blow from the Arabian Sea to the Western Ghats plays a major role in maintaining the climate of the region. In dry summer the winds which blow from Arabian Sea to land mass will bring Monsoon rainfall. They are responsible for drying and cooling in part of the hills. During summer season (December to March) winds blow from Northeast related to dry trade winds which blow over India. In winter/ autumn the direction of winds is reversed.

Biodiversity: The Western Ghats is one of the global biodiversity hotspots. Nearly 4000 species of flowering plants or about 27% of the country's total species are known from the Ghats. Of 645 species of evergreen trees, about 56% is endemic to the Ghats. Among the invertebrate groups, about 350 (20% endemic) species of ants, 330 (11% endemic) species of butterflies, 174 (40% endemic) species of odonates (dragonflies and damselflies), and 269 (76% endemic) species of molluscs (land snails) have been described from this region. The known fish fauna of the Ghats is 288 species with 41% of these being endemic to the region. The amphibian fauna has about 220 species of which 78% are endemic. Of the 225 described species of reptiles, 62% are endemic. Over 500 species of birds and 120 species of mammals are also known from this region. The Western Ghats region harbours the largest known populations of Asian elephant, tiger, dhole, and gaur. The Western Ghats also harbour a number of wild relatives of cultivated plants, including pepper, cardamom, mango, jackfruit and plantain (Report of WGEEP, 2011). A list of 39 serial sites in the Western Ghats are now considered as a World Heritage, based on criteria 9 and 10 of Operational Guidelines of the World Heritage Convention.

In this setting of the Western Ghats, Ministry of Railways has sanctioned railway line doubling in 2010 between Hospet-Tinaighat-Vasco in the states of Karnataka and Goa with a total length of 345 km in two phases. Phase-1 has a stretch of 245 km between Hospet and Tinaighat and is executed in the state of Karnataka, while Phase -2 is about 100 km from Tinaighat to Vasco is executed by the Ministry of Railways

itself. Due to steep gradient of 1 in 37 in the section between Castlerock and Kulem and the proposed alignment passes through wildlife sanctuary and national park, Railway Vikas Nigam Limited (RVNL) has sought suggestions from Center for Ecological Sciences and Department of Civil Engineering, Indian Institute of Science to carry out environmental impact assessment studies in the section between Castlerock and Kulem in 2013.

Water quality, noise level and solid waste management studies were carried out along with geo-technical study in the region. Each of these studies are dealt separately in the document below.

Study area: Castlerock is located within the Duski River catchment, while remaining part of the existing railway line is in Karanzol River and Dudhsagar River catchment. Karanzol River and Dudhsagar River together form tributary of Mhadei River. Dudhsagar falls is about 14 Kms from Castlerock railway station. The landuse pattern of the study area is predominantly forest, interspersed with agriculture. Paddy as a cereal crop; Coconut, Arecanut and Cashew nut as a commercial crop are grown in this region. Apart from this we find forest and vines, but excluding land under trees grown for wood or timber; any other land not arable or under permanent crops, includes permanent meadows and pastures, forests and woodlands, built-on areas, roads, barren land, etc.

Water quality analysis

The water quality analysis was carried out to understand the present water quality in the region and also to understand the impact on the water quality due to implementation of the project. Water is one of the most important compounds of the ecosystem.

Sample collection and Preservation

A water sample was collected in the month of April 2013 (dry season) and in July 2014 (peak monsoon) from Castlerock-Kulem region. Glass bottles were used to collect water samples for chemical analysis, whereas, samples preserved for BOD and COD tests were collected in polyethylene bottles covered with aluminium foils. A few drops of concentrated nitric acid were added to the water sample collected for heavy metals analysis to preserve the samples. The samples were then transported in cooler boxes at temperature below 5°C, and transported immediately to the laboratory. Samples of water were stored in refrigerator at 4°C before proceeding for the analysis. The analysis is carried out following standard methods for examination of water and waste water (APHA, 1998).

Water samples were collected from 2 to 4 order streams at 10 sites along the existing railway line (Figure 1) between Castlerock-Kulem in April 2013 (dry season) and in July 2014 (peak monsoon). Stream network in Castlerock-Kulem region is part of Dudhsagar river that flows into Mandovi river. 42 parameters (listed in Table 1) were tested at M/s Essen and Co. Laboratory in Bengaluru.

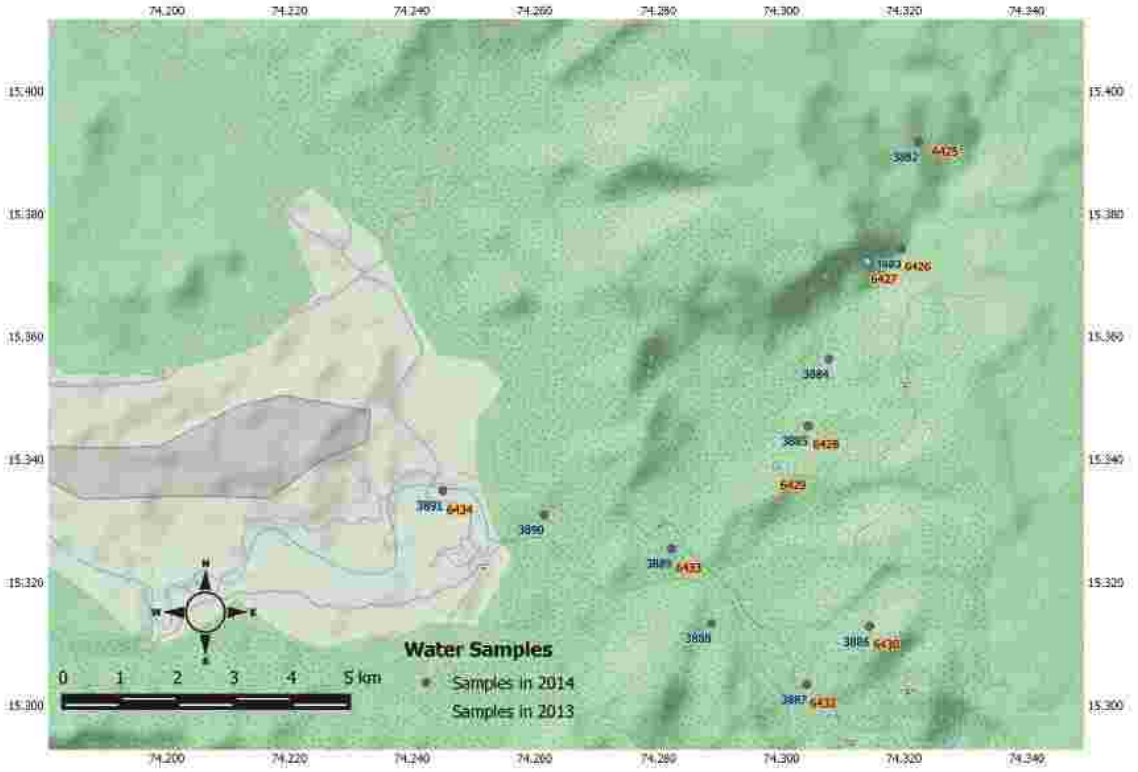


Figure 1. Water quality sample collection points along the existing railway tracks

Results

Water quality analysis shows that the streams along the existing railway track are pristine in nature without any polluting industry in the upper reaches of the streams. Dissolved oxygen (DO) was very low (2.3 mgL-1) at sampling station 6426 in the dry month of 2013. Chemical Oxygen (COD) and Biological Oxygen Demand (BOD) were high in this locality (13 and 40 mgL-1 respectively). Higher COD and BOD were observed at stations close to Dudhsagar falls (3886 and 6428). Escherichia coli bacterial contamination was found to be in all sampled streams, indicative of faecal contamination from trains. The total coliform count was between 221/100mL to 542/100mL, the threshold value limit is 100 count/100mL. None of the sites were below the threshold level. However, railway coaches are being provided with bio-toilets, hence this may not be cause of concern with doubling of railway track.

Table 1. Water quality in 2013 and 2014 across 10 streams between Castlerock and Kulem Stations.

2013	Longtitude	Latitude	Amsl	pH	Turb	Cond	TDS	TSS	DO	BOD	COD	Cl	Fl	Ca	CaCO3	Alk	Mg	NO_3	Na	K
6425	74.32395	15.39338	552	6.99	<1	47.60	31.75	31.00	6.60	0.00	0.00	11.40	0.26	3.53	11.60	6.40	0.68	<0.1	2.40	0.15
6426	74.3195	15.37456	492	7.7	<1	63.70	42.49	29.00	2.30	13.00	40.00	10.60	0.12	6.09	18.80	15.20	0.87	<0.1	0.15	0.00
6427	74.31398	15.37245	479	8.14	<1	71.60	47.76	<5	7.10	0.00	0.00	8.60	0.11	8.82	26.80	22.80	1.17	<0.1	1.40	0.00
6428	74.30454	15.34558	390	8.25	<1	79.20	52.83	<5	7.00	7.00	20.00	10.40	0.21	8.34	25.20	20.40	1.07	<0.1	1.80	0.00
6429	74.29918	15.33899	355	8.04	<1	83.30	55.56	27.00	6.90	0.00	0.00	11.20	0.31	7.70	26.40	22.80	1.75	<0.1	2.30	0.15
6430	74.31436	15.31305	269	8.2	<1	52.90	35.28	<5	7.30	0.00	0.00	8.80	0.33	5.61	16.80	12.80	0.68	<0.1	3.30	0.45
6431	74.31435	15.31283	233	8.14	<1	73.30	48.89	<5	7.20	0.00	10.00	9.20	0.35	7.05	22.00	0.35	1.07	<0.1	2.40	0.60
6432	74.30404	15.30353	174	7.91	<1	75.40	50.29	<5	7.10	14.00	50.00	8.40	0.13	5.61	24.40	24.40	1.36	<0.1	2.30	0.15
6433	74.28214	15.32554	116	7.54	<1	82.60	55.09	<5	7.00	0.00	0.00	8.80	0.26	5.45	30.00	28.80	1.75	<0.1	2.40	0.15
6434	74.24502	15.33496	67	7.5	<1	83.10	55.43	<5	7.20	0.00	0.00	8.60	0.48	3.85	29.60	24.80	1.85	<0.1	2.30	0.15
2014																				
3882	74.32233	15.39185	552	7.6	15.9	47.60	34.27	6.00	6.70	0.00	0.00	11.40	0.18	3.69	13.60	10.80	1.07	10.49	5.91	0.24
3883	74.31957	15.37435	492	7.5	21.3	47.70	31.95	4.00	6.80	0.00	0.00	14.20	0.33	4.97	22.00	14.80	20.33	<0.1	6.59	0.23
3884	74.30776	15.35633	406	8.2	12.1	54.90	36.70	7.00	7.20	0.00	0.00	12.80	0.12	6.90	22.40	14.80	1.75	<0.1	6.53	0.38
3885	74.30433	15.34546	366	8.27	21.3	42.00	28.14	11.00	6.70	0.00	0.00	14.20	0.09	3.85	14.20	11.60	1.17	<0.1	6.58	0.36
3886	74.31435	15.31283	233	8.31	132	50.00	33.56	88.00	6.20	12.00	40.00	12.60	0.07	6.09	20.00	15.20	1.17	0.84	6.70	0.92
3887	74.30418	15.30342	186	8.46	9.7	62.50	34.90	22.00	6.90	0.00	0.00	13.00	0.11	6.57	25.60	14.80	2.24	<0.1	8.89	0.82
3888	74.28856	15.31342	136	7.98	71	55.40	37.11	52.00	7.00	0.00	0.00	18.88	0.07	5.77	30.40	22.80	3.89	<0.1	6.73	0.50
3889	74.28214	15.32554	116	7.47	21.6	58.10	38.27	21.60	7.00	0.00	0.00	14.20	0.41	5.61	30.40	18.00	2.92	<0.1	6.20	0.58
3890	74.26153	15.33103	85	7.32	92	46.60	31.22	10.80	6.80	6.00	20.00	16.79	0.21	5.45	23.60	16.40	2.43	<0.1	5.34	0.30
3891	74.24502	15.33496	67	6.58	23.6	46.50	31.15	10.00	7.20	0.00	0.00	25.19	0.18	3.85	19.20	10.00	2.33	<0.1	5.34	0.30

Table 1. Water quality in 2013 and 2014 across 10 streams between Castlerock and Kulem Stations. Contd…

2013	Temp	Color	SO_4	Fe	Cu	Ag	Cr	Cd	Al	Pb	B	As	Zn	Ni	Mn	OG	Acid	N_2	NH_3	PO_4	Hg
6425	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	0.13	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6426	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	0.06	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6427	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6428	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6429	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6430	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6431	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6432	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6433	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
6434	26.60	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
2014																					
3882	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3883	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3884	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3885	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3886	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3887	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3888	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3889	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3890	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001
3891	26.00	<5	<0.5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.2	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	0.00	nil	<2.00	<0.5	<0.1	<0.001

Noise levels

Noise is defined as unwanted sound, that which causes pain and annoyance. Noise prevention and control is important as noise affects us in hearing, ability to communicate and behaviour. Undoubtedly, lesser noise can make the environment more friendly and life becomes pleasant.

The Central Pollution Control Board recommended noise standards for ambient air and for automobiles, domestic appliances and construction equipment, which were later notified in Environment (Protection) Rules,1986. In an industrial area the permissible sound level during day is 75 dB(A) and during night is 70 dB(A). In a residential area it is 55 dB(A) and 45 dB(A) respectively. For passenger or commercial vehicles exceeding 12 metric tonnes, the permissible level of noise is 91 dB(A).

Noise pollution in the vicinity of the railway stations as well as the locations where trains pass is considered to be unhealthy, regarded as a "quality of life" issue. Rail noise sources include arrival and departure of trains at a station, shunting of engines, engine noise, engine horns, trolley movements, passenger announcements, speakers, anthropogenic pollution, etc. Rail noise studies especially in A forest region are important as there are other associated parameters that need consideration such as the influence of this factor on ecology and environment. Noise measurements were performed at various locations along the rail route and recorded using a hand-held noise meter interfaced with a computer that was capable of recording noise in-situ. Noise readings were taken in the following regions:

• Railway stations along the route

• Tunnel entrances and exits

• Tunnel interiors

• Dense forest areas

All the noise measurements outside of the railway stations were performed when trains moved at 30km/h. Noise levels of 50-60 dB at railways stations (train speed: 5-10 km/h), 85-115 dB at entrance and exit of the tunnels, and 119-121 dB levels inside the tunnels were recorded (Table 2).

Station	Min_dB	Max_dB
Castlerock	71.1	95.1
Tunnel 1	91	104
Tunnel 2	91	103
Tunnel 3	92	108
Tunnel 4	96	105
Tunnel 5	106	111
Bridge DSWF	85.1	96.5
Dudhsagar WF		90.7
Kulem	91	119

Table 2. Noise (dB) from various localities along the existing train track.

At many places, the noise levels from the train were beyond permissible level of 91 dB(A), requiring stringent mitigation measures.

We understand that railways is planning to do electrification along with doubling of railway line. Electrification definitely brings down the noise level along the railway line.

In sensitive zones such as Anshi Tiger Reserve (from Castlerock station – Goa border) and Bhagwan Mahaveer Wildlife Sanctuary, it is suggested to put sound barrier on both sides of the track. The length of the barrier can be decided in consultation with the forest considering the sensitivity of the area as per field conditions.

Waste generation and management

Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials. Strategies for waste disposal should focus on waste prevention and minimization through the '3Rs strategy'- Reduce Reuse and Recycle. Indian Railway generates vast quantities of different types of wastes. The waste is mainly solid waste generated by train passengers, vendors, hawkers, etc. during the journey and also at stations. The garbage accumulated in the trains and station premises are collected by departmentally. The garbage collected from station is to be stored in initially at a dumping yard. At present, waste management and cleaning is being dealt by Medical Department. The waste generated is about 25 kg per day. Per capita waste generation between Kulem and Castlerock station is estimated at about 0.3 to 0.8 kg per day. This needs to be properly quantified. While collecting the debris itself, the biodegradable and non-biodegradable waste are segregated and collected separately and dumped at the end of the platforms. Some part of non-biodegradable wastes (polythenepaper, plastic cups and covers) were burnt and while other non-biodegradable wastes (includes water bottles, cool drink bottles, etc.) were kept separately. The schedule for segregation and cleaning is three times a day (6.00 AM, 9.00 AM & 6.00 PM) at railway platform premises only. In remaining places, one can find lots of plastic wastes that the department has not cleaned. A total of 15 employees (9 men and 6 women) are appointed for cleaning the railway platform premises. We also observed heavy solid waste dumping at Dudhsagar falls during rainy months; this is attributed to the visitors to the Dudhsagar falls and not connected with railways. However, this can be controlled with public campaigns and awareness.

I. Impact and Remedial measures specific to this project :

Rail Vikas Nigam Limited (RVNL) is a Government of India Enterprise under the Ministry of Railways. It has been entrusted with the task of executing Hospet - Hubli - Londa - Castlerock - Kulem - Vasco Railway doubling project (352 kms). This project was sanctioned during the year 2010-11 by the Ministry of Railways.

The project was necessiated because :

•The existing single line capacity is fully saturated. Goa and Hospet in Karnataka being important tourist destinations, there is a huge demand for introduction of new trains. Also Goa being a tourist destination, there is a demand for introducing more and more passenger trains from various parts of the country. Due to the existing single line capacity constraints, it had not been possible to introduce new trains.

•Track doubling would enhance the line capacity and Indian Railways will thus be able to introduce more passenger trains in this section. With the introduction of more trains, it will bring in more and more tourists and thus helps in increasing the employment, business potential and socio-economic development of Goa. Railway doubling, apart from tourism also helps in movement of bulk commodities by rail which is the most energy efficient mode of transport, thereby saving precious foreign exchange due to reduced fuel consumption.

The existing Castlerock - Caranzole - Dudhagar - Sonalium -Kulem railway line (single track) passes through South Goa District, Dharbandra Taluk, which is a hilly terrain. This alignment has a steep gradient of 1 in 37 with sharp curves and poses a lot of operational constraints.

With various alternative alignment routes available for doubling, a study of the project site was undertaken. One of them was '7C', a detour alignment that involved the opening of a new corridor in the forest (natural park). To address the gradient issue, a new parallel alignment with 1 in 60 gradient was found to be the best option. Hence, after careful consideration, Railway Board revised track doubling with parallel alignment instead of detour alignment, thereby avoiding the opening up of new corridor in the forest.

The parallel doubling has the following advantages:

Item	**Track on new detour alignment as originally proposed**	**Parallel alignment to existing tack (Now revised)**	**Remarks**
Length of alignment	35.7 km	27.75 km	
Total volume of cutting	25,38,000 cum	5,66,732 cum	
Total volume of filling	22,00,000 cum	1,36,245 cum	
Total tunneling length	6.2 km	3.40 km	
Total bridging length	2.69 km	0.4 km	
Land area required	97 hectares	21.304 hectares	Drastically Reduced

The above tabulation shows the parallel alignment to existing track will cause least disturbance to the environment.

It is also certified that no work has physically started as on date.

Alignment 7C, runs parallel and on upper reaches from existing railway line is about 35.3 kms. Considering entire length as a single stretch, mean elevation difference from existing line at every 500 mts. chainage is 110.9±72.4 m (Range: 0 – 260m; Median = 90m, Mode = 80m). The arial distance from existing line to proposed line is 2253±2243.7 (Range: 0- 8750m, Median= 1500m, Mode = 600m).

However, if we split the alignment from Castlerock to Dudhsagar (623m – 236m) and from Dudhsagar to Kulem (236m – 73m), the proposed alignment from Castlerock-Dudhsagar has less than 100 mts. elevation on difference (Mean ± SD: 98.85±68.6, Range: 0 – 260m, Median = 90m, Mode = 80m). Similarly, the arial distance from existing line is within 700 mts. (Mean±SD: 685.6 ± 553.36m, Range: 0-2100m, Median = 500m, Mode = 500m), while for Dudhsagar-Kulem, elevation difference is 117.7± 74.3m (Range: 0-260m, Median = 95m, Mode =80m) and arial difference is 3139.13±2356m (Range: 0-8750m, Median = 2750m, Mode =2125m). As the new alignment falls within 100 mts. elevation difference and 700 mts. arial distance from the existing line in the Ghat section, the impact is limited due to proximity.

2. Alignment 7C will have about 9.2 kms of tunnels and 6.4 kms of bridges and requires about 40ha of land. Compared to other proposed alignment, 7C is advantageous in having higher total tunnel length and total bridge length. Despite increase in cost per km, 7C is likely to reduce impacts on existing geomorphology of the terrain and forest cover. This new alignment was on detour alignment and results in opening up of a new corridor.

To avoid the same, Railways have suggested exactly parallel alignment within the available land (in most sectors). As this is a parallel line for the existing track alignment the damage is much less than alignment 7C.

3. Air and noise pollution – With the existing diesel engines, railway line doubling would increase the amount of pollutants. Water pollution is a major concern during the construction as well as during operation phase. Faecal matter and associated bacteria (E. coli) from the trains are going to contaminate water bodies, which has serious health impacts in the downstream. But now coaches are being provided with bio-toilets, therefore contamination would be less. Solid waste generation and management – Unless strict and stringent measures to curb solid waste dumping, railway line doubling adds more trouble to existing management issues with solid waste. Electrification of the double line can completely reduce the air and noise pollution. However solid waste will be a problem which can be mitigated with proper collection, segregation and treatment.

4. Additional land has been acquired for new alignment. This would bring down cutting of many trees as the alignment is exactly parallel to the present alignment (please refer to section on impacts on natural landscapes).

5. Animal corridors – Near / closer to Mahaveer Jain National Park and Anshi-Dandeli Tiger Reserve Park have been suggested.

II. Environmental Impacts and remedial measures

a. Impacts due to Project Location:

1. Loss of Trees/ Forest. – YES

2. Change of Land use - more than 28 ha additional land and trees will go

3. Displacement of people - NIL

b. Impacts due to Project Construction

1. Soil Erosion & Pollution at Construction Sites. – can be managed

2. Soil Disposal Problem – as tunneling / embankment construction are present in this site which will reduce the waste soil.

3. Problems Due to Geological Faults – NO

c. Impacts due to Project Operation:

1. Oil Pollution. – can be reduced by electrification of the lines

2. Accidental Hazards – can be reduced with better maintenance

3. Noise. – can be reduced by electrification

III. General Positive Impacts

i. Employment Opportunities.

ii. Benefits to Economy.

iii. Less Fuel Consumption.

iv. Less Air Pollution.

v. Quick Service & Safety.

vi. On the positive side, the construction of railway line will provide much needed connectivity to coastal region with the interior regions of Karnataka which will offer cheap mode of transportation, bring economic development & new employment opportunities to the whole of Uttar Kannada, Belagavi, Bagalkote, Hubli-Dharwad,Bellary and other northern districts of Goa and Karnataka

vii. The railway line passes into the boundary of the Mahaveer Jain National Park –proper animal corridors needs to be developed.

viii. It was observed that majority of the people are in the favour of construction of doubling of the railway line including villagers/tribales and they are aware of this project.

ix. Movement of mining ores from Bellary area towards the ports (which has caused transport problems such as increase in road traffic, increase in road accidents, increased fuel consumption & more air pollution) will become smoother and lesser after doubling the railway line.

IV. Additional Mitigation Measures for Impact on Environment

i. Proposed to reforestation should be double the amount of Forest Area Lost.

ii. To minimize noise pollution, trees along the tracks must be planted so as to act as sound barriers.

iii. Excavated materials can be used for embarkment, ballast and in making gabian structures.

iv. Trench or dykes can be made on slopes to reduce muck getting into streams and valleys.

v. Filling old manganese mines in down ghats can be an o on to use muck generated during the construction phase.

vi. Recommended to monitor the Water Quality, Public Health, Soil Conservation & Reforestation during Construction & Operational Phases.

vii. Project construction period should be reduced so that impact is reduced

CHAPTER 4

RECONNAISSANCE SURVEY

- Prepared by M/s Sarathy Geotech & Engg. Services Pvt. Ltd. for CiSTUP (IISc)

1.0 Introduction

M/s. CiSTUP (IISc) has approached M/s. Sarathy Geotech & Engineering Services Pvt. Ltd. (SGES) to accompany the team of IISc. scientists involved in the Environmental Impact Assesment project for doubling of Castlerock-Kulem Railway line. The purpose of the site visit was to carry out reconnaissance survey (Geological and Geo-technical aspects) along the proposed double line of Castlerock - Kulem railway line.

2.0 Scope Of Work

• Collecting disturbed soil samples wherever possible along the proposed double line.

• Conducting laboratory tests on collected soil and rock samples.

• Preparation and submission of technical report.

3.0 Field Investigation and Laboratory Testing Programme

SGES sent a team of engineers and a geologist along with IISc scientists to carry out the reconnaissance survey along the Castlerock-Kulem railway line.

From the first station i.e. Castlerock to approximately 1.5km, the type ground is formed by laterite formations with iron and alumina content and changes to white SILT for some distance and is again followed by laterite soil till the tunnel 1. In front of the tunnel 1 there is an existence of short girder bridge. After tunnel 1, a rip rap valley is observed.

Banded Heamordite Quartz (BHQ) formation is observed from just before the tunnel No 2 and granite formation just before the tunnel 3 followed by BHQ thereafter. At the chainage of 29/300m the Rock formation changes from BHQ to Grawec and Metagrawec with Phylites with the moorum and a Quartzite formation just 300m before the second station Caranzol.

At the chainage of 33/500m Diorite sample on both the sides of the existing railway line change to moderately weathered Diorite formation till the end of tunnel 5.

Entrance of tunnel 6 is Diorite with Quartzite band and Granite inside. Towards the exit, there exists a scalpment viaduct and before the tunnel 7 is granite formation.

Tunnel 8 is partly lined because of granite. After the tunnel 8 (ie., at chainage of 35/900m) the soil is Silty SAND and the line exists on both cutting and embankment.

At the chainage of 36/600m the formation is metamorphic Diorite/Gabbro till the tunnel 10 which is formed in Granite formation.

The third station Dudhsagar is on the granite formation with a Silty SAND till the chainage 38/520m i.e. is tunnel 11. At chainage of 39/200m (tunnel 12), the formation of rock is diorite/granite dyke. At the chainage of 39/900m, a retaining wall is constructed because of a loose moorum.

In the tunnel 14 it is observed that a seepage occurring in the Grawec formation and at a chainage of 41/100m a deep valley exists. Tunnel 15 is made in the Grawec formation and changes to Grawec with Phylites till the chainage 43/500m (i.e. tunnel 16). After the chainage 43/500m easy terrain can be seen for the existing railway line.

At the chainage of 46/500m a small length of Quartzite band and a thick forest is observed and again at a chainage of 48/100m laterite formation & at 48/800m weathered Quartzite with schist band is formed.

Chainage 49/500m to fifth station i.e. Kulem, a top 0.5m Silty SAND followed with laterite formations can be seen. The whole stretch of existing railway line is covered with a thick forest area.

The details of the existing 16 tunnels are shown in the Table 1.

Tunnel No	Length (m)	Lining of tunnel	Sample type
1	93.26	Fully	-
2	409.95	fully	BHQ
3	174.95	fully	-
4	131.67	fully	Metagrawec Phylites
5	160.02	partially	Weathered Diorite
6	211.95	unlined	Granite
7	52.0	unlined	Granite
8	289.56	partially	Grawec
9	85.34	partially	Grawec/Gabbro
10	108.50	unlined	Granite
11	204.22	partially	Granite
12	95.09	partially	Granite/diorite dyke
13	141.0	unlined	Granite
14	126.49	partially	Grawec
15	49.98	fully	Grawec
16	142.64	partially	Grawec/Phylites

Table 1: Summary of existing tunnels

The locations of sample collection are shown in appendix. The laboratory test procedures as outlined in relevant Bureau of Indian Standard (BIS) Codes were followed for this investigation campaign.

1.1 Laboratory Testing

After completion of field work, samples were transported to SGES Laboratory. Table 2 & Table 3 (next page) shows the list of laboratory tests performed on Soil and Rock samples.

Table 2: Laboratory Tests on SoilSamples

Laboratory Tests	Codes
Specific Gravity	IS 2720 Part 3
Grain Size Distribution	IS 2720 Part 4
Atterberg Limit	IS 2720 Part 5
Modified Compaction	IS 2720 Part 8

Table 3: Laboratory Tests on Rock Samples

Laboratory Tests	Codes
Physical properties of Rock	IS 13030
Point Load strength Index	IS 8764
Unconfined Compression Test	IS 9143
Slake Durability Index	IS 10050

1.1 Laboratory Tessting Procedures on Soil

1.1.1 Specific Gravity Tests (IS 2720_3)

This test is performed by placing slurry of soil in suspension in distilled water, removing the entrapped air and measuring the volume of water displaced by the soil. Specific gravity is then determined as the ratio of the weight per unit volume of soil solids to the equivalent volume of water.

1.1.2 Grain Size Analysis (IS 2720_4)

Sieve analysis was performed to determine the particle size distribution. The percent of particles passing the 75 µ IS sieve for all particle size distribution tests is tabulated on the summary of test results and boring log.

1.1.3 Atterberg Limits (IS 2720_ 5)

Determininaton of Atterberg limits were performed on selected samples. Liquid limit consisted of determining the water content at which the groove cut in a pat of soil by a grooving tool of standard dimensions will flow together for a distance of 13mm under the impact of 25 blows in a standard liquidlimit device.

Plastic limit is the determination of water content at which a soil will just begin to crumble when rolled into a thread of approximately 3mm in diameter.

1.1.4 Modified Compaction (IS 2720_8)

The equipment used in this test consist of (a) Cylindrical metal mould with detachable base plate having internal volume of 1000cc (b) collar of 50mm effective height and (c) rammer of mass 4.9kg with a height of fall of 450mm. The procedure essentially consists of compacting the soil at different water contents and finding the corresponding dry densities. At each water content the mould with base plate is filled in five layers, each layer being given 25 blows from the standard rammer. Dry density is plotted against water content to obtain the compaction curve. The values of maximum dry density and optimum water content are obtained corresponding to the peak of the compaction curve.

1.2 Laboratory Testing Procedures on Rock

1.2.1 Physical Properties of Rock (IS 13030)

Rock unit weights are routinely determined from direct measurement of sample weight and volume. To determine water absorption, rock samples are dried for at least 24 hours at a temperature of 110±5C and the loss in weight represents the weight of water absorbed. The specific gravity (grain mass) of the rock sample is equilibrium mass of the sample after oven drying at a temperature of110±5C. And Porosity is measured by pore volume to the total volume of specimen.

1.2.2 Point Load Index (IS 8764)

This test is performed as diametric test and axial test (for cylindrical specimens) and point load tests on cut blocks/irregular lumps. Diametrical test is performed on specimens with Length to diameter (L/D) ratio of 1.5 whereas the axial test is performed on samples with length to diameter (L/D) and 0.3 to 1.0 for axial test. Irrespective of the test methods, the rock specimens is placed between two pointed cones and the force applied through a calibrated jack. The force at failure is measured and point load index (Is) is calculated.

1.2.3 Slake durability Index (IS 10050)

This test is conducted on rock samples to ascertain their resistance to disintegration when subjected to two specified cycles of drying and wetting. The test is conducted as per the specification in a standard apparatus. Ten oven dried representative rock lumps, each of 40-60g, i.e. 0.4 to 0.6 N mass with a total mass of 450-500g, i.e. 4.5 to 5.0 N is placed in the 140mm diameter cylindrical drum having 2.0mm mesh. The drum is supported on a trough containing tap water at 200C, such that the water level is 20mm below the supporting axis of the drum. The drum is rotated by a motor at a speed of 20rpm for 10min. After 200 revolutions the lumps are dried in oven at 1050C and weighed. These oven dried lumps are again subjected to second cycle of revolutions, oven dried and weighed. The slake durability index (second cycle) is calculated as the percentage of final to the initial dry mass of rock lumps.

I_{d2} (%)	Classification
0-30	Very low
30-60	Low
60-85	Medium
85-95	Medium high
95-98	High
98-100	Very high

The results of these tests are summarized in the following page

1.0 Test Results

The tests results of samples collected are tabulated in below tables

Sample No.	Specific Gravity	Water Absorption	Porosity	Dry Density	Point Land Index	Uniaxial Compressive Strength Derived From Point Load Index
		%	%	kN/m³	Mpa	Mpa
A1	2.91	0.31	0.9	28.5	16.33	359.16
	2.86	0.58	1.66	28.08		
B1	2.7	0.78	2.12	26.47	17.76	390.84
	2.71	0.71	1.94	26.6		
	2.89	0.63	1.82	28.36		
C1	2.94	0.2	0.58	28.84	7.47	164.44
	2.89	0.16	0.47	28.35		
D1	2.66	2.64	7.03	26.14	9.55	210.14
E1	2.59	4.96	12.86	25.42	3.04	66.91
	2.59	3.32	8.59	25.43		
F1	2.69	3.3	8.87	26.34	1.26	27.66
	2.62	4.29	11.21	25.67		
	2.65	2.82	7.48	26.04		
G1	2.41	3.35	8.08	23.68	0.06	1.47
	2.45	3.78	9.26	24.04		

Table 5 Test values of different rock samples collected in the Castlerock – Kulem region

Sample No.	Specific Gravity	Particle Sie Analysis, %						Group Symbol
		Gravel	Sand			Fines		
			Coarse	Med	Fine	Silt	Clay	
A2	2.74	33	7	13	19	36		
B2	2.76	14	7	6	3	70		MH
C2	2.56	64	8	10	3	15		
D2	2.54	20	7	10	17	45		
E2	2.81	25	5	9	13	48		

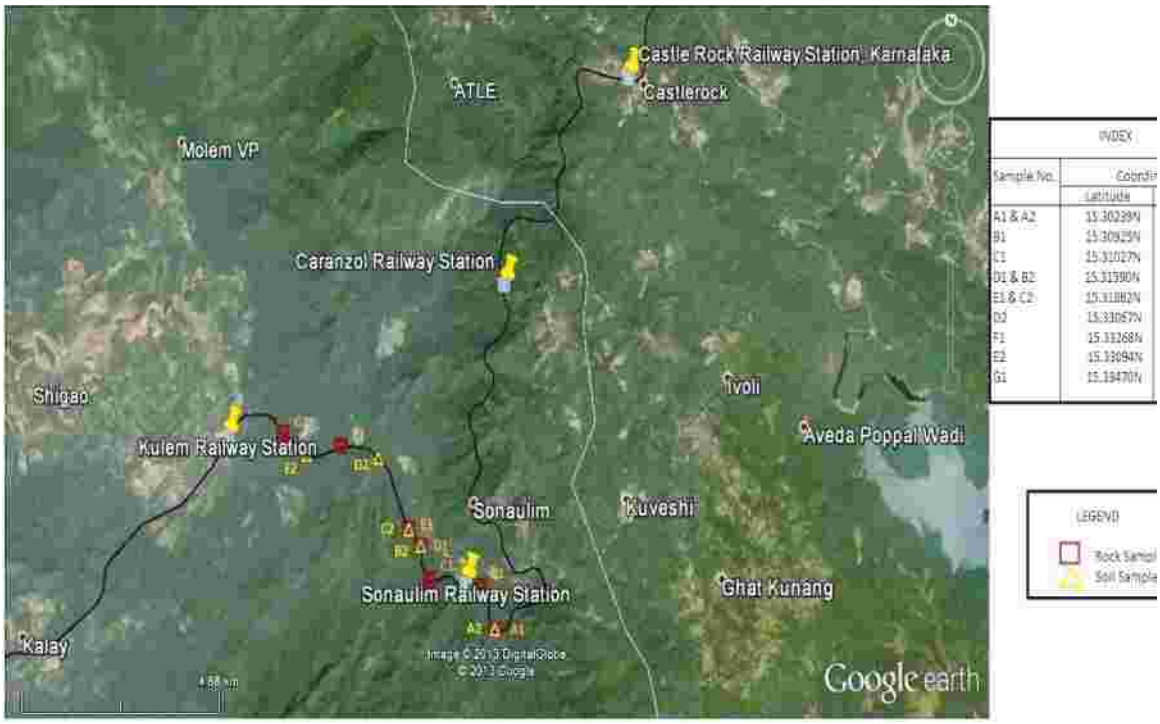
Table 6. Test values of different Soil samples collected in the Castlerock – Kulem region

Modified Compaction was performed on two samples collected near Kulem region which have their optimum dry unit weight in the range of 16.4 to 17.4 kN/m3 and optimum moisture content of in the range of 13-19%.

1.0 Conclusions

The proposed double line from Castlerock to Kulem needs cutting and embankments in many places and there is difficulty in the existing tunnels to align another line since the tunnels are of short widths.

APPENDIX



Location of samples collected along the Castlerock Kulem region

Laterite formation at the Catle rock sttation

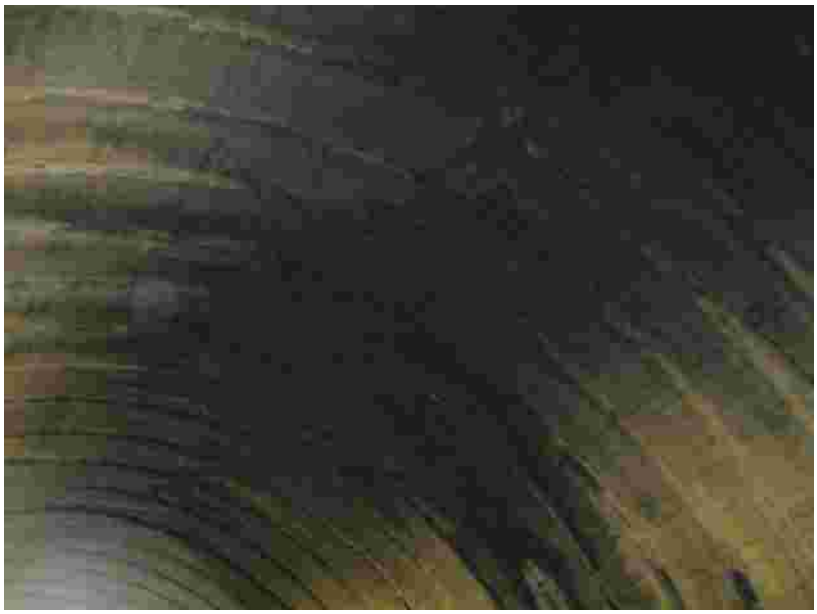
Laterite capping with Alumina and Iron

View near the Tunnel No. 1

Short Span Girder Bridge in front of Tunnel No 1

View near Tunnel No. 2

Banded Heamordite Quartzite formation at just before tunnel No. 2



View of the Tunnel lining

A view of tunnel No. 3

A view of Tunnel No. 4 (Karnataka - Goa Border)

A View of the cutting in Grawec and Metagrawec with chlorite schist's formation after the Tunnel

A View of the Gabion structure after station 2 for a stability of weak formation

View of cutting in Diorite formation on both sides after Tunnel No. 4

Tunnel no. 5 in weathered Diorite formation

View of Tunnel No.6 in Granite formation

Scalpment Viaduct in between Tunnel No 6 and 7

View of Tunnel No.7 in Granite formation

View of Tunnel No. 8 in weathered Grawec formation

Cutting in Diorite/Gabbro formation

View of Tunnel No. 9 in Grawec/Gabbro formation

View of Tunnel No. 10 in Granite formation

View both cutting and Tunnel No. 10 in Granite formation

View after Tunnel No. 10

View of existing Arch bridge at the Dudhsagar falls

View of Tunnel No. 12 in weathered Granite formation

View of Tunnel No. 14 in Grawec formation

View of seepage in Tunnel No. 14

View of stability in red clayey SAND (stepped type)

View of Tunnel No. 16 in Grawec formation

View of Tunnel No. 16 in Grawec and Phylites formation

SECTION - II

BIO-DIVERSITY PROFILE

CHAPTER 5

CLASSIFICATION OF LANDSCAPE BASED ON SATELLITE DATA

- Inputs from: H. S. Suresh, K.G. Avinash and Beependra Singh

Introduction:

Forests not only contribute to the productivity of a system but also provide invaluable ecological services. The primary step towards ecological monitoring of an ecosystem involves characterizing a forested ecosystem in terms of species diversity, heterogeneity, carbon stocks and ecological services (Sukumar et al 1992, Ayyappan and Parthasarathy, 2001, Pellisier and Pasca, 1996, Leigh and Losos 2004). This study focused on a detailed inventory of woody plants found in various forest types in the proposed project area. Along with woody plants, several animal groups were also studied. Animal groups include insects (butterflies and odonates), fresh water fishes, amphibians, reptiles, birds and mammals.

The Western Ghats or "Sahyadri" is a mountain range that runs parallel along the western coast of India and has been identified as a global "biodiversity hotspot". Goa is the mid region of the Western Ghats that run from Gujarat in the north to Tamil Nadu in the south. The proposed project area has two important vegetation types, primarily as a result of local geology, soils and climate that determine the "climax vegetation type" modified by past human activities, namely, 1. Tropical lowland evergreen forests, and 2. the coastal moist deciduous forests. Wet evergreen forests are classified as "Southern tropical wet evergreen forests" 1 C4 type by Champion and Seth (1962). These forest patches are characterized by association of "*Persea macrantha – Diospyros spp. – Holigarna spp*." (Pascal, 1988). These forest patches form the northern limit of lowland evergreen forest found in plains and low elevations of south India. The transition form of the evergreen forest as a result of human disturbance is tropical semi-evergreen forests. They are difficult to distinguish but are characterized by presence of deciduous species and localized openings have resulted in enrichment of heliophilic species. Tropical moist deciduous forest of this region is classified as the sub-type "south Indian moist deciduous forest" (Champion and Seth, 1962). Canopy is dominated mostly by pure stands of one or two species either of *Xylia xylocarpa* or *Terminalia paniculata*. This forest type is not climax moist deciduous forest type seen in eastern part of plateau but a secondary formations due to some disturbance in the past (Pascal, 1988). Domination of *Xylia xylocarpa* is seen on impoverished soils.

Classification of landscape based on satellite data:

Remotely sensed data is often used to classify the landscape into different vegetation categories and decide about the sampling strategy. We have also followed same strategy of classifying the landscape into discernable units. Further, we have used ground truth points to calibrate the classification of the landscape into distinct units.

Resourcesat -AWiFS data of 56m spatial resolution, acquired on 05-feb-2010, was used for unsupervised classification. Classification was then binned to 15 classes/categories. Survey points were selected within 2 km vicinity of the railway track proposed (alignment 1) using the classified image. Further sampling points were selected based on the elevation gradient.

Information on the land use of the landscape was obtained from forty two ground truth points (GTPs) during the first phase of the vegetation survey, including 12 points in evergreen forest, 13 points in semi-evergreen forest, 16 points in moist deciduous forest and one point in dry deciduous forest. For the analysis, dry deciduous forest was merged with moist deciduous forest category.

Finer classification of the landscape was done based on latest Landsat-8 image with spatial resolution of 30 m, acquired 09-April-2013 (which coincided with the starting of survey). Landsat-8 has 8 bands of which four bands represented by Band 2 – Blue (λ: 0.450 - 0.515 µm), Band 3 – Green (λ: 0.525 - 0.600 µm), Band 4 – Red (λ: 0.630 - 0.680 µm) and Band 5 - Near Infrared (λ: 0.845 - 0.885 µm) was used for

μm), Band 4 – Red (λ: 0.630 - 0.680 μm) and Band 5 - Near Infrared (λ: 0.845 - 0.885 μm) was used for classification. The signature files were created using GTPs and were used to classify the image. Other categories such as grassland, open land, agriculture land and water body were identified based on GCPs derived from Google Earth latest update (24-December-2012)

Type land cover	Area (sq kms.)
Evergreen	47.02
Semi-evergreen	60.83
Moist deciduous forest	103.62
Grass land	1.78
Open/rocky outcrop	26.16
Agriculture	14.88
Water bodies	0.44
Overall accuracy (%)	88.14
Kappa statistic	0.86

Table 2a: Area under different land use elements based on satellite data.

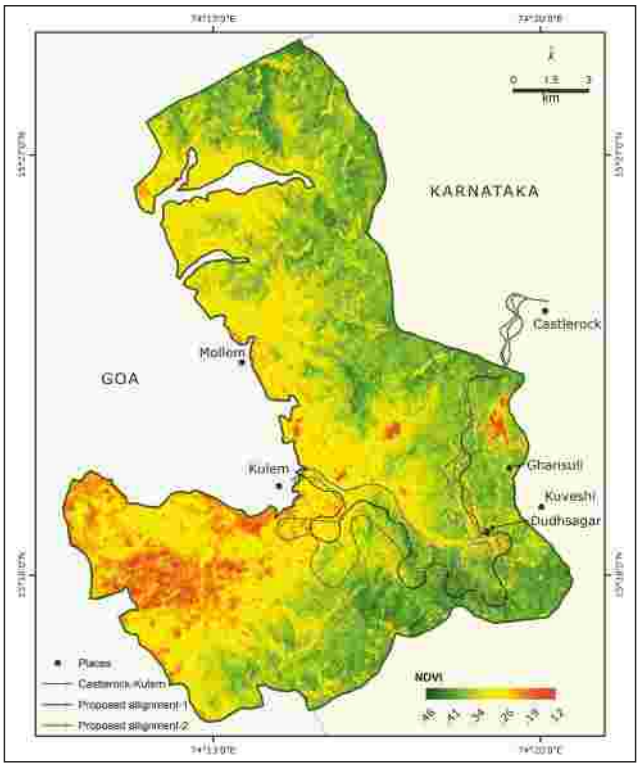


Figure : NDVI of the landscape (Bhagwan Mahavir Sanctuary)

Figure : Vegetation categories of the landscape (Bhagwan Mahavir Sanctuary)

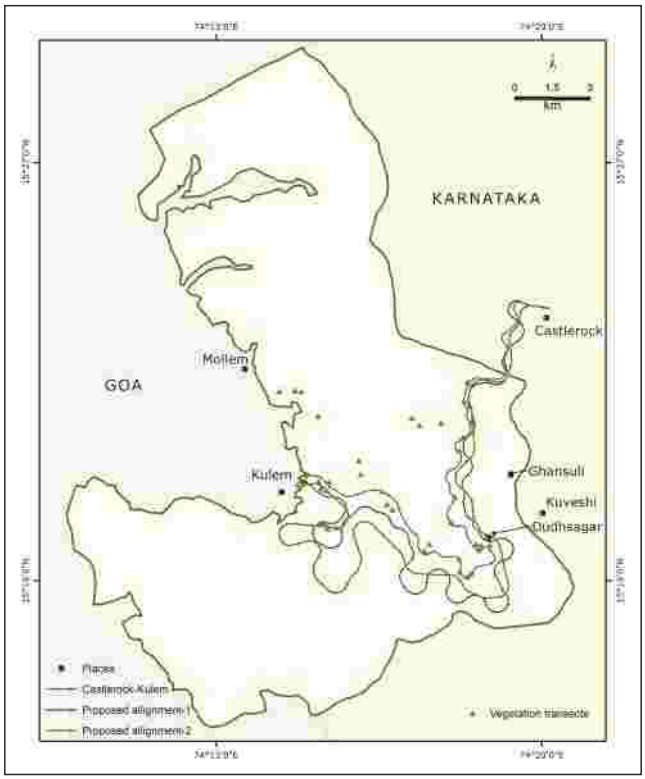


Figure : Sampling points across an elevation gradient in the Bhagwan Mahavir Sanctuary

Landscape near Caranzole railway station

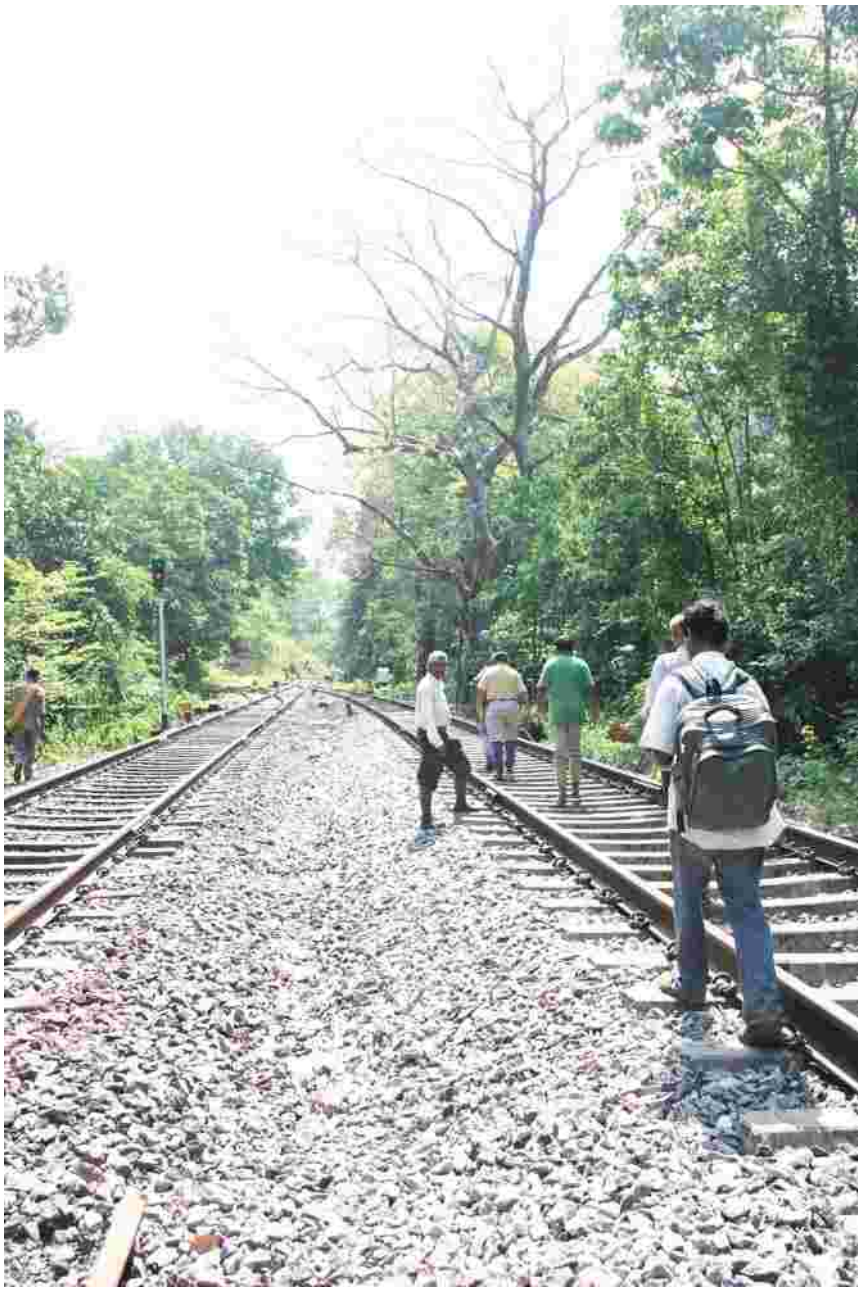
CHAPTER 6

VEGETATION CHARACTERISTICS OF THE PROPOSED PROJECT AREA:

- Inputs from: H. S. Suresh, H. S. Dataraja, D. M. Bhat

Methods:

Forest woody vegetation (>1 cm dbh) and herbaceous (ground) vegetation was enumerated by following standard protocols. Standard belt transect method was followed to estimate the diversity of woody flora (Gentry, 1988). A transect of 0.1 ha (250 meters x 4 meters) dimension was laid as close as possible to the proposed alignment in strips of 50 meters. Geo-coordinates were obtained for each transect. All woody individuals >1.0 cm dbh (diameter at breast height) including woody climbers were identified and measured for size. An ocular estimate of the height was done for all measured individuals. An occular estimate of the canopy was done along the transect line at every 10 metres. Most species were identified at the field site. Voucher specimens were collected for identification in Herbarium JCB.



IISc research team trekking along the rail line to reach the sampling point

Herbaceous vegetation was enumerated by laying $1M^2$ quadrat in different vegetation types. A quadrat of $1M^2$ (1 meter X 1 meter) was laid at regular interval of 10 meters along a strip of 100 meters in each vegetation type. Several such strips were laid in each vegetation type to quantify the abundance and diversity found on the forest floor. Geo-coordinates were obtained for each transect. In each quadrat different species of herbs were identified and counted. In case of grasses the percent occupancy was qualitatively assessed.

IISc team enumerating forests

Results:

A total of thirty eight (38) 0.1 ha transects were laid in three major forest types that are found in the proposed project area to enumerate forest vegetation. A total of 8593 individuals >1.0 cm dbh belonging to 255 different species of flowering plants was recorded. The floristics of the region is dominated by an understory species such as *Memecylon umbellatum* (Melastomaceae) (576 individuals, 6.7% of total abundance) and *Glycosmis pentaphylla* (Rutaceae) (436 individuals, 5.07% of total abundance). Among canopy species dominant species were *Hopea wightiana* (Dipterocarpaceae) (398 individuals, 4.63% of total abundance), *Diospyros candolleana* (Ebenaceae) (366 individuals, 4.25% of total abundance), *Xylia xylocarpa* (Fabaceae)(338 individuals, 3.93% of total abundance) and *Terminalia paniculata* (Combretaceae)(304 individuals, 3.53% of total abundance). There were 150 species with less than 10 individuals and 51 species were one individual. Some of the important species with one individual are *Palaquium ellipticum* (Sapotaceae), species of figs (Moraceae) such as *Ficus callosa* and *Ficus virens*. A comprehensive list of species recorded during the enumeration is provided in the appendix 2.1a.

Forest vegetation:

Moist deciduous forests:

Fourteen 0.1 ha sample points were laid in the moist deciduous forest type. A total of 2284 individuals >1 cm dbh were enumerated belonging to 119 different species of flowering plants spread over 42 different families of angiosperms. Floristics of moist deciduous forest is dominated by canopy species such as Xylia xylocarpa (Fabaceae)(338 individuals, 14.79% of abundance) and Terminalia paniculata (Combretaceae))(229 individuals, 10.02% of abundance). Top ten ranking species account for 61.3% of the total abundance. There were 81 species with less than 10 individuals which includes 32 species with one individual. Some of the species with one individual include Dalbergia latifolia, Pterocarpus marsupium and Albizzia lebbeck. In terms of Importance Value Index (IVI), Terminalia paniculata had the highest value of 142 followed by Xylia xylocarpa (107). Among understory species Calicopteris floribunda had the highest value (105) followed by Ervtamia heyneana (102). IVI values of top ten species is given in the table 2.1.1. Most speciose family was Fabaceae with 11 species followed by Rubiaceae 8 species. There were 16 families of flowering plants represented by one species. They include families such as Dipterocarpaceae, Lythraceae and Symplocaceae. Family Combretaeae had the maximum basal area (42.2%) followed by Fabaceae (22.0%) they together account for 64.2% of the total basal area of the vegetation.

Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance Value Index (IVI)
Terminalia paniculata	10.02	100	32.02	142.05
Xylia xylocarpa	14.79	71.42	21.20	107.43
Calicopteris floribunda	4.64	100	0.85	105.49
Ervatamia heyneana	7.00	92.85	1.70	101.56
Aporusa lindleyeana	2.84	71.42	1.01	75.28
Macaranga peltata	1.75	71.42	0.51	73.69
Scleichera oleosa	0.83	64.28	1.87	66.99
Careya arborea	0.91	64.28	1.37	66.57
Glycosmis pentaphylla	8.27	57.14	0.25	65.67
Diospyros candolleana	2.67	57.14	0.93	60.24

Table 2.1.1: Importance value index of species in moist deciduous forest samples from Goa

Diversity parameters:

Mean species richness recorded in 0.1 ha sample point was 28±11.4 species (range = 11 – 49 species, N=14). Mean Simpson's index (probability of picking individuals belonging to two different species) was 0.83±0.13 (range = 0.52 – 0.93, N= 14). Simpson's index suggests that the diversity among the moist deciduous forest plot is high but with wide range of variability. Shannon-Weiner's index (a measure of heterogeneity) varies from as low as 1.22 to as high as 3.23 with mean 2.50±0.62. Fisher's alpha, plot less measurement of diversity was 10.43±5.07 (range = 3.245 – 20.9, N= 14). Diversity parameters of each plot are listed in the table (2.1.2). Whittaker's measure of Beta diversity (a measure of species turnover between samples) is 3.24.

Sl. No	Number of species	Shannon's index	Simpson's index	Dominance	Fisher's Alpha	Evenness index
Plot1	15	1.319	0.58	0.471	3.40	0.249
Plot2	24	2.73	0.912	0.087	11.42	0.640
Plot3	24	2.76	0.918	0.081	9.18	0.664
Plot4	49	3.23	0.933	0.066	20.9	0.520
Plot5	23	2.28	0.843	0.154	6.90	0.427
Plot6	15	1.90	0.769	0.23	5.63	0.45
Plot7	21	2.28	0.838	0.161	7.09	0.468
Plot8	11	1.22	0.528	0.471	3.24	0.308
Plot9	36	2.83	0.893	0.106	13.49	0.472
Plot10	44	3.07	0.925	0.074	15.36	0.494
Plot11	26	2.73	0.903	0.096	8.72	0.594
Plot12	31	2.97	0.930	0.069	11.5	0.629
Plot13	41	2.89	0.909	0.091	13.79	0.438
Plot14	33	2.82	0.890	0.109	15.48	0.510

Table 2.1.2: Diversity parameters of moist deciduous forest type

Moist deciduous forest landscape in the study area

Semi-evergreen forest vegetation:

Seven 0.1 ha sample transects were laid in the semi-evergreen forest vegetation. A total of 1508 individuals >1 cm dbh belonging to 111 species of flowering plants spread over 42 families of angiosperms were enumerated. Floristics is dominated by two understory species such as *Memecylon umbellatum* (138 individuals and 8.62% of abundance) and *Psychotria dalzellii* (138 individuals and 8.62% of abundance). Among the canopy species *Hopea wightiana* (76 individuals, 5.03% of abundance), *Aporusa lindleyeana* (62 individuals, 4.11% of abundance) and *Diospyros candolleana* (45 individuals, 2.98% of abundance) dominated the floristics. There were 79 species with less than ten individuals and out of that 23 species had only one individual. Some of the species with one individual include *Toona ciliata*, *Celtis cinnamonea*, *Ficus hispida* and *Terminalia crenulata*. In terms of IVI values, the canopy tree *Terminalia paniculata* dominated the floristics (122) followed by an understory species *Ixora nigricans* (109) and a canopy species *Aporusa lindleyeana* (109). Top ten ranking species with their IVI values are listed in the table (2.1.3). Most speciose family was Myrtaceae with 8 species followed by families such as Ebenaceae, Lauraceae, Euphorbiaceae and Rubiaceae with 6 species each. There were seventeen families represented by one species. Family Combretaceae had the maximum basal area (23%) and along with families such as Lythraceae, Myrtaceae and Clusiaceae accounts for 45.6% of the total basal area.

Species	Relative abundance (%)	Relative frequency (%)	Relative dominance (%)	Importance Value Index (IVI)
Terminalia paniculata	10.02	100	32.02	142.05
Ixora nigricans	14.79	71.42	21.20	107.43
Aporusa lindleyeana	4.64	100	0.85	105.49
Olea dioica	7.00	92.85	1.70	101.56
Leea inidca	2.84	71.42	1.01	75.28
Diospyros candolleana	1.75	71.42	0.51	73.69
Paramygna monophyla	0.83	64.28	1.87	66.99
Ervatamia heyneana	0.91	64.28	1.37	66.57
Psychotria dalzelli	8.27	57.14	0.25	65.67
Actinodaphne hookeri	2.67	57.14	0.93	60.24

Table 2.1.3: Importance value index of species in semi-evergreen forest samples from proposed project area.

Diversity parameters:

There were on an average 37.4±5.09 (range = 31-47 species, N=7) species in each transects in semi-evergreen forest vegetation. Mean Simpson's index was 0.89±0.03 (range = 0.83 -0.93, N=7) suggesting that diversity in these patches is high; however, the range is low. Mean value of heterogeinity (Shannon-Weiner's index) was 2.85±0.23 (range= 2.51-3.16, N= 7). Fisher's alpha another unit of measurement of diversity varied from as low as 11.48 to as high as 17.24 with a mean value of 13.20±2.08. The diversity parameters of individual sampling points are listed in the table (2.1.4). The Whittaker's index of beta diversity i.e. the turnover of species between various sampling plots was 1.97 which is lower than the moist deciduous forest type suggesting the relatively high uniformity in species composition among different sampling point in the semi-evergreen forest type.

Sl. No	Number of species	Shannon's index	Simpson's index	Dominance	Fisher's Alpha	Evenness index
Plot 1	37	2.62	0.836	0.163	13.39	0.371
Plot 2	37	2.78	0.877	0.122	12.37	0.438
Plot 3	39	3.07	0.931	0.068	14.5	0.556
Plot 4	47	3.16	0.928	0.071	17.24	0.505
Plot 5	31	2.94	0.918	0.081	11.65	0.615
Plot 6	38	2.51	0.850	0.149	11.81	0.325
Plot 7	33	2.86	0.905	0.094	11.48	0.325

Table 2.1.4: Diversity parameters of semi-evergreen forest type from the proposed project area

Evergreen forest vegetation:

We laid a total of seventeen 0.1 ha sampling points in the evergreen vegetation type in the proposed project area. A total of 4801 individuals belonging to 207 species and 61 families of the flowering plants were enumerated. Most abundant species was *Memecylon umbellatum* (417 individuals and 8.68% of total abundance) an understory tree followed by canopy species such as *Hopea wightiana* (320 individuals and 6.66% of total abundance), *Diospyros candolleana* (260 individuals and 5.41% of total abundance) and *Olea dioica* (256 individuals and 5.33% of total abundance). There were 42 species with one individual in the study and they include species such as *Ficus callosa, Mammea suriga* and *Stereospermum personatum*. Among all the species, canopy trees such as *Diospyros candolleana* (108) and *Olea dioica* (97) had high IVI values followed by understory shrub species such as *Ervatamia heyneana* (96) and *Leea indica* (92). IVI values of top ten species is listed in the below table (2.1.5). Family Lauraceae and Myrtaceae were the speciose families having 15 species each followed by Rubiaceae 12 species. There were 28 families with one species. Family Oleaceae accounted for large basal area (9.79%) followed by Combretaceae (8.93%). Though families Lauraceae amd Myrtaceae were the most speciose they accounted for 4.31% and 4.91% of total basal area respectively.

Species	**Relative abundance (%)**	**Relative frequency (%)**	**Relative dominance (%)**	**Importance Value Index (IVI)**
Diospyros candolleana	10.02	100	32.02	142.05
Olea dioica	14.79	71.42	21.20	107.43
Ervatamia heyneana	4.64	100	0.85	105.49
Leea indica	7.00	92.85	1.70	101.56
Glycosmis pentaphylla	2.84	71.42	1.01	75.28
Mallotus philippenensis	1.75	71.42	0.51	73.69
Aporusa lindleyeana	0.83	64.28	1.87	66.99
Calamus sp.	0.91	64.28	1.37	66.57
Hydnocarpus wighitianum	8.27	57.14	0.25	65.67
Psychotria dalzelli	2.67	57.14	0.93	60.24

Table 2.1.5: Importance Value Index of species in evergreen forest samples from the proposed project area.

Sl. No	Number of species	Shannon's index	Simpson's index	Dominance	Fisher's Alpha	Evenness index
Plot1	27	2.34	0.823	0.176	9.33	0.386
Plot2	43	2.08	0.768	0.231	11.55	0.187
Plot3	54	3.44	0.944	0.055	26.05	0.581
Plot4	44	3.15	0.932	0.067	18.26	0.530
Plot5	34	2.47	0.869	0.130	9.09	0.349
Plot6	28	2.28	0.806	0.193	8.27	0.350
Plot7	39	2.49	0.796	0.203	10.96	0.310
Plot8	39	3.11	0.938	0.061	14.35	0.576
Plot9	46	3.39	0.952	0.047	22.53	0.644
Plot10	27	2.24	0.808	0.191	8.13	0.349
Plot11	60	3.55	0.955	0.044	25.16	0.580
Plot12	46	3.03	0.921	0.078	13.79	0.451
Plot13	38	2.97	0.925	0.074	11.96	0.513
Plot14	54	3.32	0.942	0.057	18.85	0.513
Plot15	46	3.33	0.953	0.046	14.91	0.609
Plot16	58	3.29	0.943	0.057	18.6	0.465
Plot17	47	3.23	0.942	0.057	14.15	0.550

Table 2.1.6: Diversity parameters of evergreen forests from the proposed project area.

Diversity parameters:

Mean species richness of the evergreen forest plots was 42.88±10.20 species (range = 27 – 60, N = 17). There is a wide range in species richness as observed in moist deciduous vegetation of the project area. Simpsons' index varied from 0.76 to 0.95 with mean value of 0.89±0.06 (range = 0.76 – 095, N = 17). The value of heterogeneity (Shannon's index) had mean value of 2.92±0.48 (range = 2.08 – 3.55, N = 17) and Fisher's alpha varied from 8.13 to 26.05 with a mean value of 15.07±5.71. The diversity parameters of each plot are listed in the table above (2.1.6). Whittaker's Beta Diversity index was 6.02 suggesting high species turnover rate between sampling units among different vegetation types.

Parameters	**Moist deciduous forest (N = 14)**	**Semi-evergreen forest (N = 7)**	**Evergreen forest (N = 17)**
Number of species	28.0 ± 11.4	37.4 ± 5.09	42.88 ± 10.20
Shannon-Weiner's index (H')	2.50 ± 0.62	2.85 ± 0.23	2.92 ± 0.48
Simpson's index (D)	0.83 ± 0.13	0.89 ± 0.03	0.89 ± 0.06
Fisher's alpha	10.43 ± 5.7	13.20 ± 2.08	15.07 ± 5.71
Evenness index	0.49 ± 0.11	0.47 ± 0.10	0.46 ± 0.12

Table 2.1.7: Community wide diversity parameters of each forest type of the proposed project area

Canopy of a rainforest in the study area

Structural characteristics:

Mean density of individuals >1 cm dbh in moist deciduous forest patch was 163.07±65.94 (range = 75-276, N= 14). Basal area in moist deciduous forest patches was found to be 4.05±1.87 M2/0.1 ha. Mean height of the canopy was 25.2 meters and largest tree was Xylia xylocarpa (Fabaceae) with 265.47 cm dbh.

Density of individuals in semi-evergreen forest patch was found to be 215.42±42.0 stems >1 cm dbh. Basal area was 3.44±1.76 M2/0.1 ha. Mean height of the canopy was 27.06 meters and tree with largest diameter was Mangifera indica (Anacardiaceae) with 103.19 cm dbh.

Evergreen forest patches had 282.41±94.16 stems >1 cm dbh in 0.1 ha sampling units. Basal area was 4.32±1.82 M2/0.1 ha. Mean height of the canopy was 30.64 meters and large sized tree was Tetrameles nudiflora (Datiscaceae) with 191.94 cm dbh. Structural parameters of different forest types is presented in the next page table (2.1.8).

Forest type	Density	Basal area (M^2/0.1 ha)	Mean Canopy Height (meters)	Tree with largest diameter (cm)
Moist deciduous	163.07±65.94	4.05±1.87	26.4	265.4
Semi-evergreen	215.42±342.0	3.44±1.76	30.8	103.1
Evergreen	282.41±94.16	4.32±1.82	30.64	191.94

Table 2.1.8: Structural parameters of forest samples from the proposed project area

There was a pronounced difference in mean density of stems between moist deciduous and evergreen forest patches (t= 3.99, df= 29, p<0.0001) though the density of stems between moist deciduous vs semi-evergreen (t = -1.90, df=19, p<0.03) and semi-evergreen vs evergreen (t = -1.79, df= 22, p<0.04) forest patches was significant, the p value was low. Basal area did not show significant difference between forest patches (T test NS in all cases).

There was a remarkable similarity in size class distribution of individuals in different forest types of the proposed project area (Figure 2.1.1a,b,c). The size class distribution of individuals is typically inverted "J" shaped curve suggesting lot of stems in the lower size class. More than 50% of the total stem in all forest type were in less than 5 cm dbh class. Less than 10% of stems were over 30 cm dbh class. In fact moist deciduous forest type had 6.88% stems over 30 cm dbh class while semi-evergreen (4.38%) and evergreen (4.54%) forests had less than 5% of the stems larger than 30 cm dbh. Though more than 50% of the stand is individuals less than 5 cm dbh, they account for 1.63% of total basal area in moist deciduous forest, 3.09% in semi-evergreen forest and 2.93% in evergreen forest patches. Trees above 30 cm dbh account for more than 60% of total basal area in different forest types. In moist deciduous forest trees above 30 dbh account for 67.21% of the basal area, in semi-evergreen forest 62.95% and in evergreen forests 63.81% of the basal area is accumulated in trees above 30 cm dbh class (Figure 2.1.1 a,b,c).

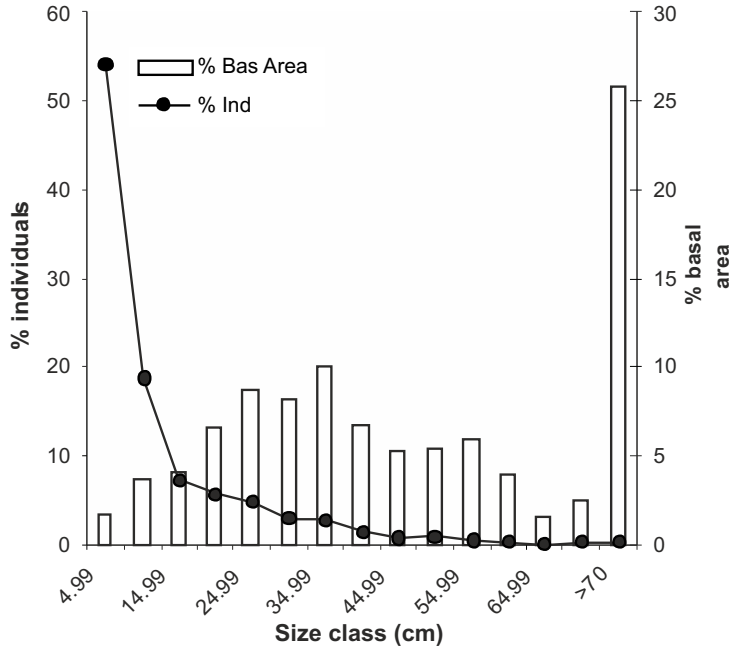


Fig. 2.1.1a. Size class & basal area distribution among different size classes in moist deciduous forest of the project area.

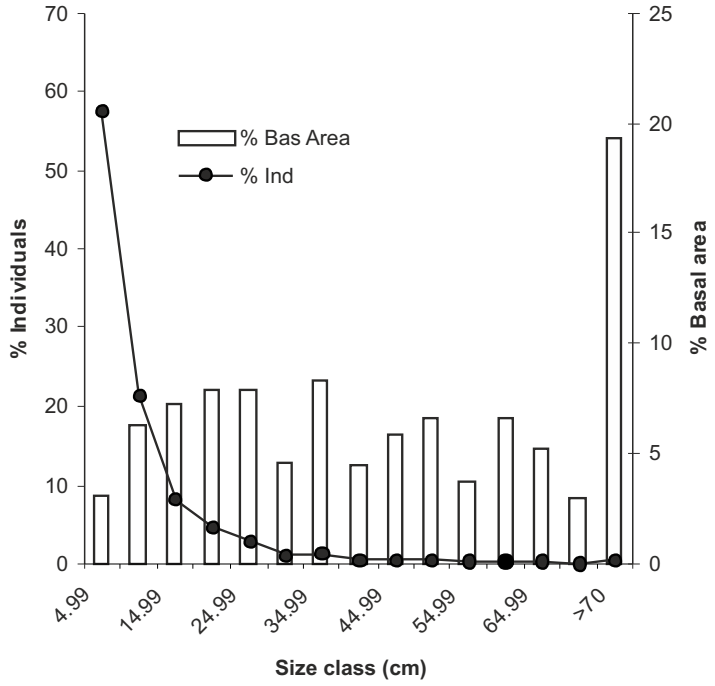


Fig. 2.1.1b. Size class & basal area distribution among different size classes in semi-evergreen forest of the project area.

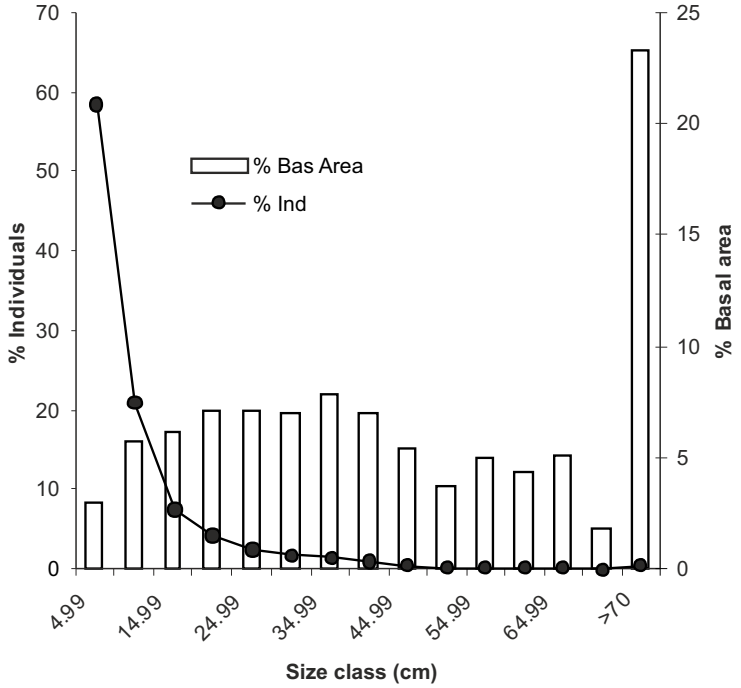


Fig. 2.1.1c. Size class & basal area distribution among different size classes in evergreen forest of the project area.

Biomass and C-stocks:

Biomass of each sample point was estimated by allometric method using diameter of each tree. Universal mean value of 0.6 (IPCC standards) was assumed as wood density for each species. Half the biomass was assumed to be carbon stocks.

In moist deciduous forest patches *Terminalia paniculata* (24.08%), *Xylia xylocarpa* (17.69%) and *Terminalia crenulata* (5.75%) contributes to over 47% of the total biomass. Another important canopy species *Lagerstroemia microcarpa* contributes 3.49% to the total biomass. All the above mentioned species are canopy species, hardwood species and are important timber yielding species. An understory species that has significant contribution to biomass is *Ervatamia heyneana* that contributes 4.35% to the total AGB.

Sl. No.	Moist deciduous forest Type		Semi Evergreen forest Type		Evergreen forest Type	
	Biomass (Tons/ha)	C-stocks (Tons/ha)	Biomass (Tons/ha)	C-stocks (Tons/ha)	Biomass (Tons/ha)	C-stocks (Tons/ha)
1.	333.82	166.91	476.67	238.33	315.78	157.89
2.	223.19	111.59	316.32	158.16	466.59	233.29
3.	204.62	102.31	223.54	111.77	367.40	183.70
4.	338.50	169.25	250.30	125.15	304.67	152.33
5.	269.77	134.88	252.88	126.44	414.99	207.49
6.	192.46	96.23	261.19	130.59	356.62	178.31
7.	265.04	132.52	254.15	127.07	343.50	171.75
8.	322.05	161.02			221.37	110.68
9.	255.14	127.57			223.82	111.91
10.	287.02	143.51			273.96	136.98
11.	351.67	175.83			298.94	149.47
12.	249.46	124.73			433.81	216.90
13.	318.48	159.24			354.45	177.22
14.	198.31	99.51			419.75	209.89
15.					341.31	170.65
16.					622.06	311.03
17.					436.31	218.15
Mean	272.11	136.05	290.72	145.36	364.43	182.21
SD	54.77	27.38	86.62	43.31	97.53	48.76

Table 2.1.9: Biomass and Carbon stock values for different forest types in the proposed project area

On an average *Terminalia paniculata* contributes 65.5 tons to the biomass in a hectare of forest in moist deciduous type followed by *Xylia xylocarpa* (48.1 tons/ha), *Terminlia crenulata* (15.6 tons/ha) and other canopy species *Lagerstroemia microcarpa* 9.5 tons/ha. Contribution of top ten species to the biomass storage and C-stocks in a moist deciduous forest is given in the table below (2.1.10).

Species	Biomass (tons/hectare)	C-stocks (tons/hectare)
Terminalia paniculata (Combretaceae, Canopy)	65.5	32.76
Xylia xylocarpa (Fabceae, Canopy)	48.1	24.07
Terminalia crenulata (Combretaceae, Canopy)	15.6	7.83
Ervatamia heyneana (Apocyanceae, Understory)	11.8	5.92
Lagerstroemia microcarpa (Lythraceae, Canopy)	9.51	4.75
Calicopteris floribunda (Combretaceae, Understory)	8.07	4.03
Dillinia pentagyna (Dilliniaceae, Canopy)	5.98	2.99
Aporusa lindleyeana (Euphorbiaceae, Canopy)	5.46	2.92
Scheichera oleasa (Sapindaceae, Canopy)	5.24	2.73
Glycosmis pentaphylla (Rutaceae, understory)	4.99	2.49

Table 2.1.10.Contribution of top 10 species to the biomass & C-stocks in moist deciduous forests in the proposed project area.

In Moist deciduous forest had 272.11±54.77 tons (range = 192.46 – 351.67 tons, N= 14) of above ground biomass per hectare while semi-evergreen forest patches had 290.72±86.62 tons (range = 223.5 – 476.67 tons, N= 7) of biomass a hectare and evergreen forest patches had 364.4±97.53 tons (range = 221.37 – 622.06 tons, N= 17) of above ground biomass a hectare in the proposed project area. Mean biomass of the evergreen forest and moist deciduous forest is significantly different ($t = 3.15$, $df=29$, $p<0.001$) with evergreen forest patch significantly storing higher biomass than the moist deciduous patch. Biomass storage in evergreen forest and semi-evergreen forest was also significantly different ($t= 1.73$,$df = 22$, $p<0.04$) but standing biomass between moist deciduous and semi-evergreen forest patches did not differ significantly ($t = -0.60$, $df = 19$, $p>0.05$, NS), Biomass of each sample point in different forest types is listed in the table (2.1.9).

Unlike in moist deciduous forests, in semi-evergreen forests there is accumulation of biomass in some species. *Terminalia paniculata* contributes largely to the biomass (10.7%) followed by *Hopea wightiana* (7.48%) and *Aporusa lindleyeana* (5.41%). Top ten species contributes to 47.1% of the total biomass. On an average, *Terminalia paniculata* contributes 31.15 tons/ha of AGB followed by *Hopea wightiana* 21.75 tons/ha and *Aporusa lindleyeana* (15.74 tons/ha). Among the top ten species that contribute significantly to the biomass, eight species are canopy and two are understory species that include *Ixora nigricans* (13.05 tons/ha) and *Memecylon umbellatum* (9.69 tons/ha). Contribution of top ten species to the biomass storage and C-stocks in a semi-evergreen forest is given in the next page table (2.1.11).

Species	Biomass (tons/hectare)	C-stocks (tons/hectare)
Terminalia paniculata (Combretaceae, Canopy)	31.15	15.57
Hopea wightiana (Dipterocarpaceae, canopy)	21.75	10.87
Aporusa lindleyeana (Euphorbiaceae, canopy)	15.74	7.87
Ixora nigricans (Rubiaceae, understory)	13.05	6.52
Callophyllum apetalum Clusiaceae, canopy)	10.81	5.40
Lagerstroemia microcarpa (Lythraceae, canopy)	10.01	5.00
Memecylon umbellatum (Melastomaceae, understory)	9.69	4.84
Diospyros candolleana (Ebenaceae, canopy)	8.65	4.32
Syzygium cumini (Myrtaceae, canopy)	8.28	4.14
Lophopetalum wightianum (Celastraceae, canopy)	7.99	3.99

Table 2.1.11. Contribution of top ten species to the biomass and C-stocks in a semi-evergreen forest in the proposed project area.

A secondary species in evergreen forest, *Olea dioica* (9.84%) had the highest contribution to the biomass of the evergreen forest, followed by *Hopea wightiana* (5.94%) and an understory species *Memecylon umbellatum* (5.00%), an associate species of the formation of this forest type (Pascal, 1988). *Terminalia paniculata* the dominant species in both moist deciduous and semi-evergreen forest had 3.53% of contribution to the total biomass. Top ten species accounted for 42.6% of the total biomass in evergreen forest type. *Olea dioica* contributed 35.8 tons/ha of biomass followed by *Hopea wightiana* 21.64 tons/ha and *Memecylon umbellatum* 18.23 tons/ha of biomass. Contribution of top ten species to the biomass storage and C-stocks in evergreen forest is given in the next page table (2.1.12).

Carbon stock is assumed to be 50% of the biomass. Moist deciduous forest had 136.05±27.38 tons of carbon locked up in the standing vegetation per hectare. Semi-evergreen forests had 145.36±43.31 tons of Carbon while evergreen forests had 182.21±48.76 tons of Carbon stored in the standing vegetation. In all these forest types canopy species had maximum storage of carbon in them. Canopy species in moist deciduous forest contributed 80.9% to the total carbon pool while in semi-evergreen forest the contribution of canopy species to the carbon pool was 67.7% and in evergreen forest it was 71.7%.

Species	Biomass (tons/hectare)	C-stocks (tons/hectare)
Olea dioica (Oleaceae, canopy)	35.88	17.94
Hopea wightiana (Dipterocarpaceae, canopy)	21.64	10.82
Memecylon umbellatum (Melastomaceae, understory)	18.23	9.11
Diospyros candolleana (Ebenaceae, canopy)	14.90	7.45
Lophopetalum wightianum (Celastraceae, canopy)	12.98	6.49
Terminalia paniculata (Combretaceae, canopy)	12.88	6.44
Hopea ponga (Dipteroarpaceae, canopy)	11.51	5.75
Holigarna arnottiana (Ancardiaceae, canopy)	9.90	4.95
Ixora nigricans (Rubiaceae, understory)	9.61	4.80
Lagerstroemia microcarpa (Lythraceae, canopy)	7.70	3.85

Table 2.1.12. Contribution of top ten species to the biomass and C-stocks in evergreen forest in the proposed project area.

Carbon stock is assumed to be 50% of the biomass. Moist deciduous forest had 136.05±27.38 tons of carbon locked up in the standing vegetation per hectare. Semi-evergreen forests had 145.36±43.31 tons of Carbon while evergreen forests had 182.21±48.76 tons of Carbon stored in the standing vegetation. In all these forest types canopy species had maximum storage of carbon in them. Canopy species in moist deciduous forest contributed 80.9% to the total carbon pool while in semi-evergreen forest the contribution of canopy species to the carbon pool was 67.7% and in evergreen forest it was 71.7%.

Largest carbon holding in the proposed project area is in the canopy tree *Terminalia paniculata* (677.31 tons) which accounts for 11.25% followed by species such as *Xylia xylocarpa* (337.08 tons, 5.59% of the total) and *Olea dioica* (336.44 tons, 5.58%). Both *Terminlia paniculata* and *Xylia xylocarpa* are principally moist deciduous forest trees while *Olea dioica* is semi-evergreen associate. All three species are hardwood trees. Top ten species in the project area contributes to 43.1% of the total carbon pool. Among the understory species that contributes significantly to the carbon pool are *Memecylon umbellatum* (196.76 tons and 3.26%) and *Ixora nigricans* (142.76 tons and 2.37%).

Similarity analysis

We developed the similarity matrix for each forest type by their species and its abundance. The similarity diagram was drawn using the correlation values between each sample plots. Based on correlation values we could identify four distinct clusters of sample points (Figure 2.1.2).

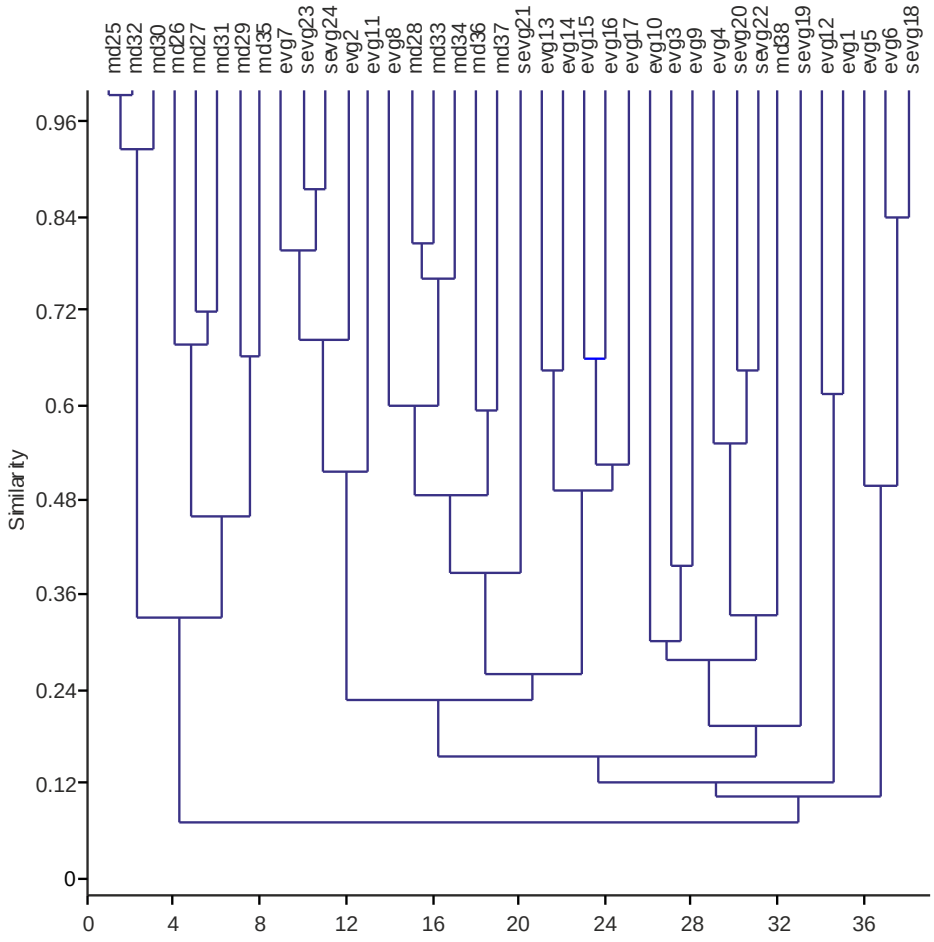


Figure (2.1.2). Similarity diagram of all sample plots

First major cluster that segregates with less than 10% similarity has sample plots from moist deciduous forest type. Second major cluster has three plots from evergreen and semi-evergreen forest types. Third and fourth cluster that segregates with less than 24% similarity has mainly evergreen and semi-evergreen sample plots with an exception of the third cluster that has several moist deciduous forest plots. The third cluster consists of low-land forest plots which share several species and hence a transition zone.

Among the evergreen forest plots there are two distinct clusters which are segregated and their segregation could be attributed to altitude. Plots from Caranzole to Castlerock (plot 9 to plot17) forms one cluster while from Caranzole to Kulem (plot 1 to plot 6) forms another cluster with two plots having similar attributes (Figure 2.1.3).

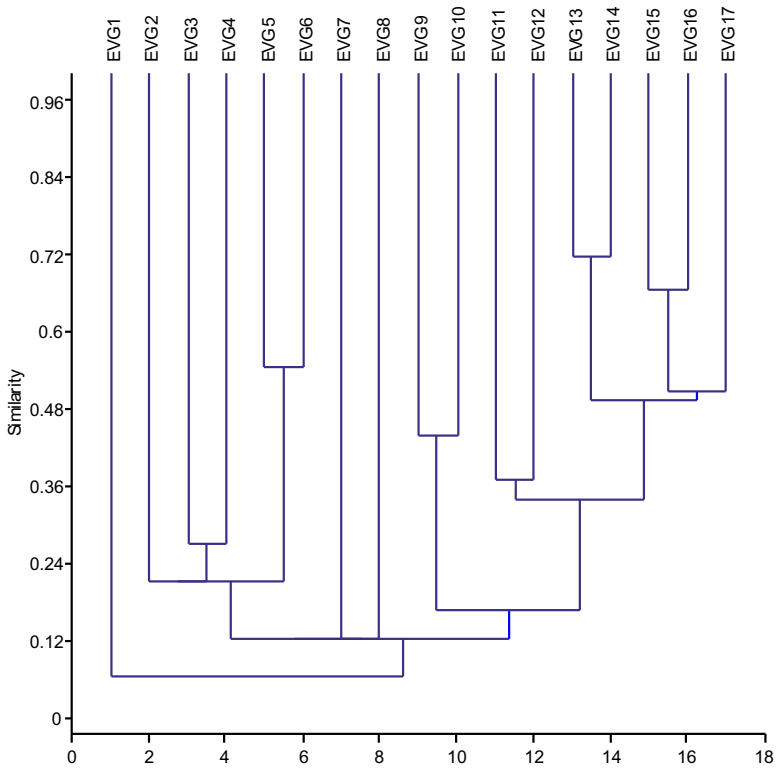


Figure (2.1.3) Cluster diagram of similarity among evergreen forest plots in the proposed project area.

Three broad clusters based on species correlations could be segregated among the semi-evergreen forest plots (Figure 2.1.4). First cluster is having one plot (plot 18) and the second also has one plot (plot 19) within the large cluster. Plots 20 to plot 24 forms the third cluster and within the third cluster there is a distinct association of plots - plot20 to plot22 form one unit and plot 23 & plot 24 form the other. Among the semi-evergreen plots, plot no. 18 stands as a distinct unit.

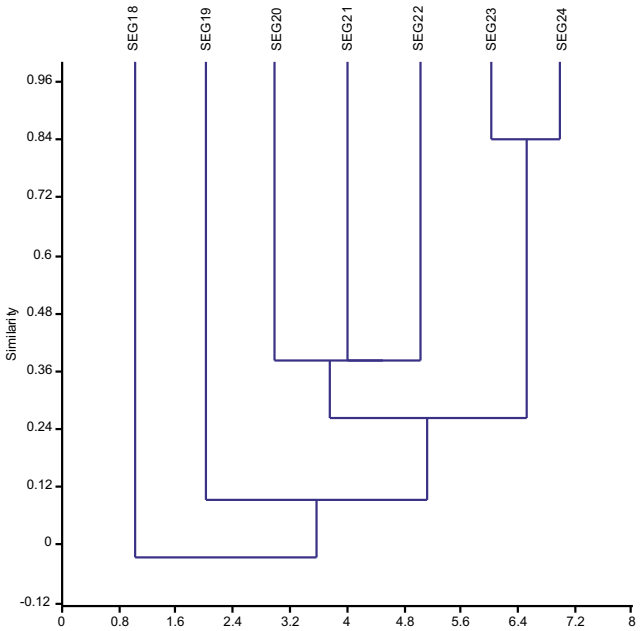


Figure (2.1.4) Cluster diagram of similarity among semi-evergreen forest plots in the proposed project area.

There are three broad clusters within the moist deciduous plots. Cluster 1 has one plot (plot 38) and it is distinct from others. Second cluster is formed by plots which are slightly away from the main forest block around the Bhagwan Mahaveer Wildlife Sanctuary office at Mollem. In this cluster Plots 33 and plot 34 form one unit and plots 36 and 37 form the other while 35 is a distinct unit (figure 2.1.5). Third cluster is constituted by forest plots around Mollem to Dudhsagar falls. This is a large tract of moist deciduous forest. Within this cluster there are distinct sub-units. Plot 25 forms a distinct unit, while plots 26 to plot 28 form another unit with plot 28 a distinct unit. Plot29 forms a distinct unit and plots 30-32 are one unit with high similarity (Figure 2.1.5). These three plots have similar species composition with *Xylia xylocarpa* being the dominant species.

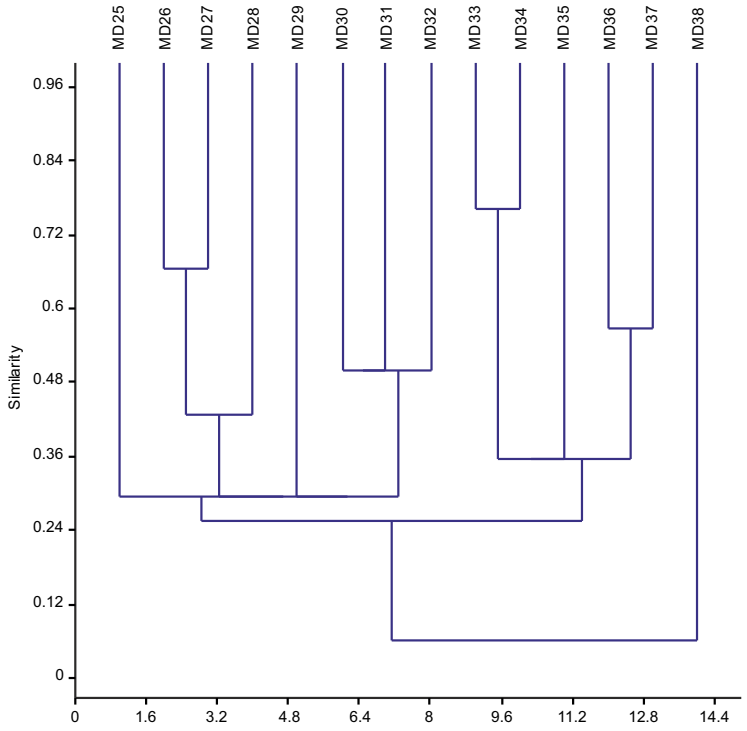


Figure (2.1.5) Cluster diagram of similarity among moist deciduous forest plots in the proposed project area

Phytogeographical affinities:

We analyzed the distribution of the species recorded in the project area with respect to their global phytogeographical distribution. Of the total tree species recorded, about 50% showed narrow distribution in the Indian sub-continent. This includes the 11.6% of endemic species largely confined to the Western Ghats. 16.01% species had Indo-Lankan (distribution spanning India and extending to Sri Lanka) affinities and 23.37% of species showed Indo-Malayan (distribution spanning India and Southeast Asian region) affinities. Nineteen species (8.22%) had distribution throughout old tropical areas while 4 species showed affinities with dry areas of African tropics, they are primarily found in the deciduous forest of the project area. There was only one introduced species *(Acacia auriculiformis)* in the lowlands (deciduous belt) of the project area. This species primarily from the dry regions of Australia raised as plantation crop to meet the fuel wood demand of the local population. Among the endemic species there were four species such as *Diospyros paniculata*, *Polyalthia fragrans* and *Holigarna arnottiana* seen commonly. There were five species which occurred rarely; they are *Palaquium ellipticum*, *Cryptocarya bourdillonii*, *Litsea sp.* the palm species *Arenga wightii* and unidentified species belonging to the family

Lauraceae. Family Lauraceae and Clusiaceae had large proportion of endemic species. Lauraceae is a large pantropical family while Clusiaceae is restricted to India and Southeast Asia. Many species in the rain forests have shown their conservative affinities to a narrow phytogeographical area.

Species	Family
Actinodaphne angustifolia	Lauraceae
Actinodaphne hookeri	Lauraceae
Arenga wightii	Palmae
Beilschmedia wightii	Lauraceae
Calophyllum apetalum	Clusiaceae
Cinnamomum sulphuratum	Lauraceae
Cryptocarya bourdilloni	Lauraceae
Diospyros paniculate	Ebenaceae
Diospyros pruriens	Ebenaceae
Diospyros saldanhe	Ebenaceae
Euonymus anugulatus	Celastraceae
Goniathalamus cadiopetalus	Annonaceae
Heterophragma quadricularae	Bignoniaceae
Holigarna arnottiana	Anacardiaceae
Knema attenuate	Myristicaceae
Litsea floribunda	Lauraceae
Litsea mysorensis	Lauraceae
Litsea sp.	Lauraceae
Mangifera indica	Anacardiaceae
Myristica malabarica	Myristicaceae
Palaquim ellipticum	Sapotaceae
Polyalthia fragrans	Annonaceae
Scolopia crenata	Flacourtiaceae

Table 2.1.13 List of Endemics in the propose project area (Endemism is with respect to Western Ghats)

Comparative analysis:

We also compared the diversity pattern observed in proposed project region with published data from various studies across the Western Ghats (Ganesh et al., 1996, Pascal , 1988, Bhat et al., 2000, and Parthasarathy et al., 2001.). It was not easy to find other studies that had adopted similar sampling design, especially the area sampled (1000 m2) adopted in our study and, therefore, the number of such comparisons is limited. We report the comparison for two size classes: all stems >3 cm dbh and all stems >10 cm dbh.

We present community-wide results for three different forest types where all the samples are pooled. Evergreen forest type was the richest community in the proposed project area in all respects followed by semi-evergreen and moist deciduous forest type (Table 2.1.14). The diversity estimates at >3 cm dbh level differed significantly among the forest types (diversity t test, p>0.0001, all cases,).

The diversity estimates at 10 cm dbh were also significantly different (diversity t test, p>0.0001, all cases,). The species richness (number of species per unit area) and the diversity (Shannon's diversity) of the proposed project area is comparable to that of other wet evergreen forests such as Gundia (Sakaleshpur), Kudremukh, Silent Valley, and Attapadi in the Western Ghats, but lower than the forests of Utara Kannada at >3 cm dbh level and at >10 cm dbh level forests in Sengeltheri, Kalakad-Mundanthorai had the highest number of species (Table 2.1.15). Fisher's alpha in the proposed project area is higher than evergreen forests elsewhere in India (Table 2.1.16) and comparable to rain forests of Palanan (Phillipines).

Parameters	Evergreen forest type	Semi-evergreen forest type	Moist deciduous forest type
	All individuals >3 cm dbh		
Number of Species	191	103	102
Dominance	0.027	0.031	0.068
Shannon's Index	4.19	3.86	3.40
Simpson's Index	0.97	0.96	0.93
Fisher's Alpha	42.7	26.8	23.3
Evenness	0.34	0.46	0.29
	All individuals >10 cm dbh		
Number of Species	127	74	67
Dominance	0.036	0.044	0.12
Shannon's Index	3.99	3.63	2.86
Simpson's Index	0.96	0.95	0.87
Fisher's Alpha	38.53	29.7	18.56
Evenness	0.42	0.50	0.26

Table 2.1.14: Comparison of diversity estimates (per ha) of different forest types within the project area

The proposed project area has higher density of stems compared to other sites in the Western Ghats but the number of stems are in the range that evergreen forests along the ghats supporting both with >3 cm dbh and >10 cm dbh cut offs (Table 2.1.15). However, forests have number of species in the range found in other sites in the Western Ghats. Basal area and presumably biomass are also in the range of values reported for other sites in the Western Ghats (Table 2.1.15).

The values of Fisher's alpha, one of most robust diversity estimate is higher than reported values for several Indian forests and also for Thailand. But the value for Thailand is from a dry forest.

Sources of data are as follows: Gundia, Kudremukh and Silent Valley based on our studies including unpublished data; Bhagavathi from Pascal 1988; Attapadi from Singh et al. 1986; Uttara Kannada from Bhat et al. 2000; Sengaltheri from Parthasarathy et al. 2001. In some cases the number of species in 1000 m^2 has been inferred from data on species-area relationship for plots of larger sizes.

Locality Stems >3 cm dbh	**Altitude** (m asl)	**Plot size** m^2	**No of trees**	**Average No. of species**	**Shannon's Diversity** (H')	**Basal area** m^2/ha
Castlerock, Goa, Present study, Only ever green plots are used	100-500	1000	217.9	37.4	2.86	45.1
Gundia, Karnataka	160-950	1000	108.6	35.9	2.90	38.0
Kudremukh, Karnataka	1000	1000	170.5	36.3	2.68	78.8
Silent Valley, Kerala	1050	1000	185.5	35.8	2.83	41.3
Bhagavathi, Kerala	900	1000	222	12.0	2.1	64.0
Attapadi, Kerala	1100	1000	-	37.0	3.5	31.5
Uttara Kannada, Karnataka	500-1000	1000	77.9	46.8	-	22.9
Stems >10 cm dbh						
Castlerock, Goa, Present study, Only ever green plots are used	100-500	1000	59.0	20.0	2.41	39.8
Gundia, Karnataka	160-950	1000	46.0	21.1	2.41	36.3
Kudremukh, Karnataka	1000	1000	84.35	24.3	2.4	75.6
Silent Valley, Kerala	1050	1000	65.16	20.0	2.28	38.0
Sengaltheri, Kalakad Tamilnadu	900-1170	1000	85.2	39.0	3.5	59.7

Table 2.1.15: Comparison of vegetation studies in evergreen forests of the Western Ghats.

Sl No.	Place	Country	Fisher's alpha diversity
1.	Castle Rock, Bhagwan-Mahavir WLS, present study	India	42.04
2.	Gundia (Central Western Ghats)	India	20.3
3.	Mudumalai (Dry forest, Nilgiris)	India	8.9
4.	Huai Kha Khaeng	Thailand	31.7
5.	Lambir	Sarawak (Malaysia)	152.6
6.	Pasoh	Peninsular Malaysia	100.3
7.	Sinharaja	Sri Lanka	23.2
8.	Palanan	Phillippines	43.4

Table 2.1.16 : Fisher's alpha diversity (stems above 3cm dbh) of some moist Asian tropical forests, with the exception of Mudumalai and Huai Kha Khaeng that represent tropical dry forests.

Diversity in the herbaceous community (understory) in the proposed project area:

We laid several 1m2 quadrat in the proposed project area covering different forest types. We laid seventeen 100 meter long transect line along the proposed alignment. At every 10 meter along the line we laid 1 meter X 1meter quadrat to estimate the herbaceous (understory) diversity. We counted all individuals below 1 meter in height. For grasses all stems arising out of same root stock was considered as one individual. Each root stock was counted for grasses. Transect lines were laid randomly and geo-coordinates of each line was taken. These lines were classified as evergreen lines (in evergreen forests) and deciduous lines (in deciduous forests). Several herbaceous species could not be identified as many species were not seen with reproductive stages. We have tried our best give accurate scientific name for many species as far as possible. We could identify the tree seedlings perfectly. We have used our field expertise, different floras and herbarium to identify many herbs and tree seedlings.

A total of one hundred and sixty quadrats were laid both in evergreen and deciduous habitats. A total of 8872 individuals belonging to 191 species of herbs and tree seedlings were enumerated. There were 69 families of the flowering plants. Poaceae with 15 species was the most dominant family followed by Rubiaceae (14 species), Acanthaceae (11 species) and Euphorbiaceae (11 species). There were 25 families with one species.

We enumerated 957 individuals belonging to 80 different species of herbs and tree seedlings in evergreen forest area. Piper sp. with 110 individuals accounting for 11.5% of the total abundance was the dominant herbaceous species recorded followed by an unidentified grass (GRSSP1)(102 individuals, 10.65% of abundance). Seedlings of canopy tree species such as Hopea wightiana (27 individuals, 2.82% of abundance) and understory species Ixora brachiata (69 individuals, 7.21% of abundance) was among the dominant species recorded in the plot.

In the deciduous region of the proposed project area, we enumerated 7915 individuals belonging to 140 species. Species belonging to genus Indigofera dominated the floristics with 1475 individuals and accounting for 18.63% of abundance. Other species that dominated the floristics are Impatiens sp. (616 individuals, 7.78% of abundance), Phyllanthus niruri (Euphorbiaceae) (477 individuals, 6.02% of abundance) and Curculigo orchioides (Liliaceae) (431 individuals, 5.44% of abundance). Among the canopy species Xylia xylocarpa had good representation in the understory layer apart from Polyalthia fragrans. Other important canopy species Terminalia paniculata had 17 individuals and other understory species that had representation were Psychotria flavida and Ervtamia heyneana.

Mean number of species in deciduous belt is more than the number of species recorded from evergreen belt (Table 2.1.17). The diversity parameters are listed in the table (2.1.17). The density of understory species is much more in deciduous belt (879.4±822.3) than the evergreen belt (136.7±21.4). However, the deciduous belt had wide variability in the density.

Number of species	33.06±7.05	23.14±3.13
Dominance	0.16±0.08	0.17±0.11
Shannon-Weiner's index (H')	2.42±0.30	2.39±0.40
Simpson's index (D)	0.83±0.08	0.82±0.11
Fisher's alpha	8.09±1.95	8.13±1.68
Evenness index	0.34±0.08	0.49±0.12

Table 2.1.17. Diversity parameters of understory layer in each forest type

There was a distinct cluster of plots from the evergreen and deciduous patches based on the correlation of species and their abundances (Figure 2.1.6). The clusters are also function of altitude. All the moist deciduous patches are in low elevation while the evergreen patches are at the higher elevation. Within the two broad clusters there are three distinct clusters (Figure 2.1.6).

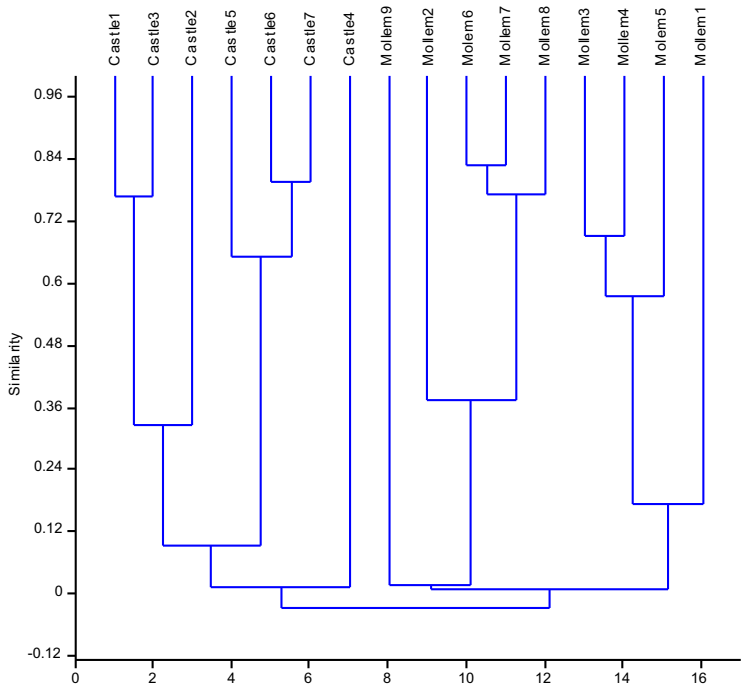


Figure 2.1.6: Similarity among different herbaceous transects in the proposed project area

CHAPTER 7

DIVERSITY AND ABUNDANCE OF BUTTERFLIES (Lepidoptera: Insecta)

- Inputs from: Sridhar S Halali

Introduction:

Butterflies belonging to the order Lepidoptera, which means scaly wings (*lepis*- scale, *pteron*- wings), are one of the most colorful insects. Lepidoptera, which comprises of both butterflies and moths, form the second most species diverse groups of Insecta with over 140,000 species. In India, the order Lepidoptera is divided into five families (Table 2.2.1).

Family	Common Name	Diversity
Papilionidae	Swallowtails	13 genera, 107 species
Pieridae	Whites and yellows	20 genera, 109 species
Nymphalidae	Brush-footed butterflies	98 genera, 521 species
Lycaenidae	Blues	90 genera, 443 species
Hesperiidae	Skippers	99 genera, 321 species

Table 2.2.1: Table shows families of Order Lepidoptera and their diversity in India (obtained from Kunte 2000).

In India approximately 1,800 species and subspecies of butterflies are known to occur. Out of this about 15-20% are endemic to the Indian region which makes this an especially important region for butterfly diversity and conservation (Kunte *et al.* 2015). In the Western Ghats, 333 species of butterflies have been recorded out of which 33 species are endemic to this region and an additional eight species are shared between Western Ghats and Sri Lanka biodiversity hotspots, making a total number of endemic and narrowly endemic species as 41 or 12.3% of Western Ghats butterfly fauna (Kunte 2008).

In Goa 254 species of butterflies have been recorded till date; this constitutes 76.3% diversity of Western Ghats. Compared to several other faunal taxa, butterflies of the state are very well documented. The most dependable study on the butterflies of Western Ghats has been by Gaonkar (1996) which documents 330 species in Western Ghats of which 251 species are reported from Goa. Rangnekar & Dharwadkar (2009) added three more new records *viz.* Black-vein Sergeant *(Athymaranga),* White-banded Awl *(Hasoriataminatus)* and Coon *(Psolosfuligo)* to the state fauna making total count of 254. Borkar and Komarpant (2004) documented 97 species of butterflies in Bondla Wildlife Sanctuary and 90 common and few rare species have been documented by Rangnekar (2007). Apart from these work not much of studies are being carried out on butterflies in Goa.

Present study was carried out to study butterfly diversity and abundance in Bhagwan Mahaveer Wildlife Sanctuary and adjacent places. This is first of study in Goa which aims in collecting quantitative data on butterfly species abundance.

Methodology:

Study Area:

The study was conducted in Bhagwan Mahaveer Wildlife Sanctuary and adjoining areas from April (2013) to May (2014). The surveys were restricted close to the present railway track (that is proposed to be doubled) and the species occurring and their abundance were recorded. Surveys were conducted from Kulem to Castlerock during the study period. Since the area was large, it was divided in-to four transects

of approximately seven kilometers each in length. Hence from each transect three kilometers transect was selected and was surveyed for estimating species richness and abundance. Transects surveyed are given Table 2.2.2.

Name of transect	Total Length (km)	Surveyed Length (km)
Collem– Sonalium (Transect I)	7	3
Sonalium-Dudhsagar (Transect II)	5	3
Dudhsagar-Caranzol (Transect III)	7	3
Caranzol-Castlerock (Transect IV)	7	3

Table 2.2.2: Transects surveyed for estimating diversity and abundance of butterflies in Western Ghats

Study Methods:

Belt transect method with dimensions of 2km × 10m was used to estimate species abundance. Species which were encountered within this strip was recorded along with their number of individuals. Species were identified visually in the field; for species difficult to identify photographs were taken in the field and later identified using field guide (Kunte 2000; Rangnekar 2007). Sampling was carried out from 8.30am to 11.0 am during which they show maximum activity. Also some opportunistic were surveys were carried out in order to record species that would have been missed in the sample survey. However, such species are only included in checklist and are not used in the quantitative analysis.

Alpha Diversity:

Alpha diversity is a measure of species diversity in a given location or habitat measured using indices such as Shannon's and Simpson's index. Evenness was calculated to know how the species are locally distributed. All the indices were computed using program PAST (Hammer et al. 2001).

Results:

Species richness and abundance:

Surveys in Bhagwan Mahaveer Wildlife Sanctuary recorded 133 species of butterflies belonging to five families. Family Nymphalidae dominated with 50 (37.5%) species from 36 genera followed by Lycaenidae 33 (24.8 %) species from 29 genus, Hesperiidae with 18 species (13.5 %) represented by 16 genus, Papilionidae with 17 (12.78%) species represented by six genus and Pieridae with 15 (11.2%) species represented by 10 genus. Species like Papilio buddha, Hebomoea glaucippe, Spindasis lohita were recorded during opportunistic surveys. Out of 133, 12 species were endemic to Western Ghats. Checklist of all species recorded in given in Table 2.2.3.

Total of 2420 individuals were recorded from 133 species. Some of the common species such as Junonia iphita, Cirrochroa thais, Euploea core, Idea malabarica, Catopsilapomona, Papilio polymnestor, Eurema sps. were recorded in high numbers. Two of the endemic species Cirrochroa thais and Idea malabarica were recorded abundantly. The plot of abundance of 20 common species and endemic species is given in Figure 3 and 4.

Table 2.2.3: Matrix showing checklist of species recorded in BMWS

1	Blue Mormon	*Papilio polymnestor*
2	Common Bluebottle	*Grahium sarpedon*
3	Common Jay	*Grahium doson*
4	Common Mime	*Papilio clytia*
5	Common Mormon	*Papilio polytes*
6	Common Rose	*Pachliopta aristolochiae*
7	Crimson Rose	*Pachliopta hector*
8	Lime Butterfly	*Papilio demoleus*
9	Malabar Banded Swallowtail*	*Papilio liomedon**
10	Malabar Banded Peacock*	*Papilio buddha**
11	Malabar Raven*	*Papilio dravidarum**
12	Malabar Rose*	*Arophaneura pandiyana**
13	Paris Peacock	*Papilio paris*
14	Red Helen	*Papilio helenus*
15	Southern Birdwing*	*Troides minos**
16	Spot Swordtail	*Graphium nomius*
17	Tailed Jay	*Graphim agamemnon*
Family: Pieridae		
18	Common Albatross	*Appias albina*
19	Common Emigrant	*Catopsila pomona*
20	Common Grass Yellow	*Eurema hecabe*
21	Common Gull	*Cepora nerissa*
22	Common Jezebel	*Delias eucharis*
23	Common Wanderer	*Pareronia valeria*
24	Dark Wanderer	*Pareronia ceylanica*
25	Great Orange Tip	*Hebomoia glaucippe*
26	Lesser Gull	*Cepora nadina*
27	Mottled Emigrant	*Catopsilia pyranthe*
28	Pioneer	*Anaphaeis aurota*
29	Psyche	*Leptosia nina*
30	Small Grass Yellow	*Eurema brigitta*
31	Spotless Grass Yellow	*Eurema laeta*
32	Three Spot Grass Yellow	*Eurema blanda*
Family: Nymphalidae		
33	Angled Castor	*Ariadne ariadne*
34	Atumn leaf	*Doleschallia bisaltide*
35	Black Rajah	*Charaxes solon*
36	Blue Oakleaf	*Kallima horsfieldi*
37	Blue Pansy	*Junonia orithya*
38	Blue Tiger	*Tirumala limniace*
39	Chestnut Streaked Sailer	*Neptis jumbah*
40	Chocolate Pansy	*Junonia iphita*
41	Clipper	*Parthenos sylvia*

42	Colour Sergeant	*Athyma nefte*
43	Commander	*Moduza procris*
44	Common Baron	*Euthalia aconthea*
45	Common Bushbrown	*Mycalesis perseus*
46	Common Castor	*Ariadne marione*
47	Common Crow	*Euploea core*
48	Common Evening Brown	*Melanitis leda*
49	Common Five Ring	*Ypthima baldus*
50	Common Four Ring	*Ypthima huebneri*
51	Common Lascar	*Pntoporia hordonia*
52	Common Leopard	*Phalanta phalanta*
53	Common Map	*Cyrestis thyodamas*
54	Common Nawab	*Polyura athemas*
55	Common Palmfly	*Elymnias hypermnestra*
56	Common Sailer	*Neptis hylas*
57	Common treebrown	*Lethe rohita*
58	Cruiser	*Vindu laerota*
59	DanaidEggfly	*Hypolimnas misippus*
60	Gaudy Baron	*Euthalia lebentina*
61	Glad eye Bushbrown*	*Mycalesis patina**
62	Glassy Tiger	*Parantica aglea*
63	Great egg Fly	*Hypolimnas bolina*
64	Grey Count	*Tanaecia lepidea*
65	Grey Pansy	*Juonia atlites*
66	Lemon Pansy	*Junonia lemonias*
67	Malabar tree Nymph*	*Idea malabarica*
68	Nigger	*Orsotrioena medus*
69	Painted Courtesan	*Euripus consimilus*
70	Painted Lady	*Vanessa cardui*
71	Peacock Pansy	*Junonia almanac*
72	Plain Tiger	*Danaus chrysippus*
73	Red Spot Duke*	*Dophla evelina**
74	Rustic	*Cupha erumanthis*
75	Short Banded Sailer	*Phaedyma columella*
76	Small Leopard	*Phalanta alcippe*
77	Striped Tiger	*Danaus genutia*
78	Tamil Lacewing*	*Cethosia nietneri**
79	Tamil Yoeman*	*Cirrichroa thais**
80	Tawny Coster	Acraea violae
81	Tawny Rajah	*Charaxes berbardus*
82	Yellow Pansy	*Junonia hierta*
Family: Lycaenidae		
83	Angled Pierrot	*Caletaca leta*
84	Common Cerulean	*Jamides celeno*
85	Common Hedge	*BlueAcytolepis puspa*

86	Common Imperial	*Cheritrafreja*
87	Common Lineblue	*Prosotas nora*
88	Common Pierrot	*Castalius rosimon*
89	Common Tinsel	*Catapaecilma elegans*
90	Dark Cerulean	*Jamides bochus*
91	Dark Pierrot	*Tarucus ananda*
92	Fluffy Tit	*Zeltu samasa*
93	Forget-me-not	*Catochrysops strabo*
94	Gram Blue	*Euchrys opscneju*
95	Grass jewel	*Freyeria trochylus*
96	Indian Red Flash	*Rapala airbus*
97	Indian Sunbeam	*Curetis thetis*
98	Large Oakblue	*Arhopala amantes*
99	Leaf Blue	*Amblypodia anita*
100	Longbanded Silverline	*Spindasis lohita*
101	Malayan	*Megisba malaya*
102	Monkey Puzzle	*Rathinda amor*
103	Pea Blue	*Lampides boeticus*
104	Peacock Royal	*Tajuria cippus*
105	Plains Cupid	*Chilades pandava*
106	Plane	*Bindaha raphocides*
107	Plum Judy	*Abisara echerius*
108	Pointed Ciliate Blue	*Anthene lycaenina*
109	Quaker	*Neopithecops zalmora*
110	Red Spot	*Zesius chrysomallus*
111	Slate Flash	*Rapala manea*
112	Tailless Line Blue	*Prosotas dubiosaindica*
113	Tiny grass Blue	*Zizula hylax*
114	Yamfly	*Loxura atymnus*
115	Zebra Blue	*Leptoptes plinius*
Family: Hesperiidae		
116	Brown Awl	*Badamia exclamationis*
117	Bush Hopper	*Ampittia dioscorides*
118	Chestnut Bob	*Lambrix salsala*
119	Common Dartlet	*Oriens goloides*
120	Common Spotted Flat	*Celaenorrhinus leucocera*
121	Coon	*Sancus fuligo*
122	Grass Demon	*Udaspes folus*
123	Indian Palm Bob	
124	Pigmy Scrub Hopper	*Aeroma chusjhora*
125	Restricted Demon	*Notocrypta curvifascia*
126	Rice Swift	*Borbo cinnara*
127	Spotted Small Flat	*Sarangesa purendra*
128	Suffused Snow Flat	*Tagiades gana*
129	Tamil grass Dart*	*Taractrocera ceramas**
130	Tamil Spotted Flat*	*Celaenorrhinus ruficornis**
131	Tricolored Pied Flat	*Coladenia indrani*
132	Water Snow Flat	*Tagiades littigosa*
133	White Banded Awl	*Hasora taminatus*

*Note: Species marked in * are endemic to Western Ghats*

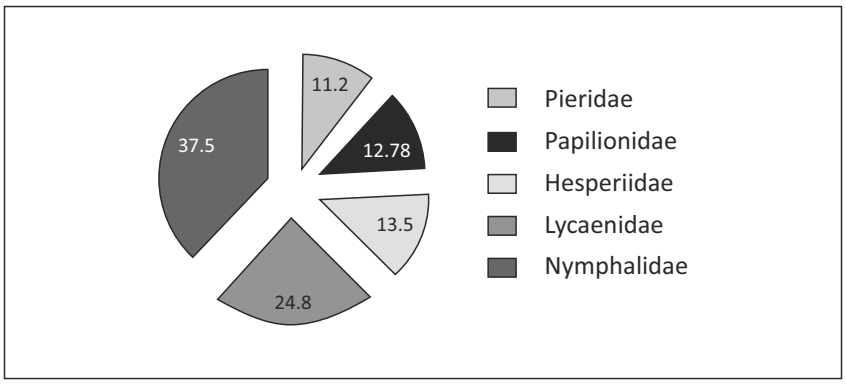


Figure 2.2.1: Pie chart showing family contribution under Order - Lepidoptera:

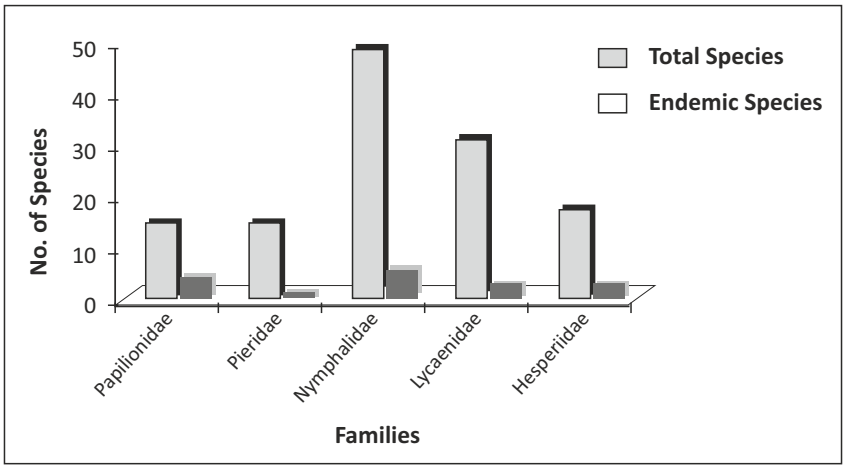


Figure 2.2.2: Graph showing total number of species and endemic species with respect to families of Order- Lepidoptera:

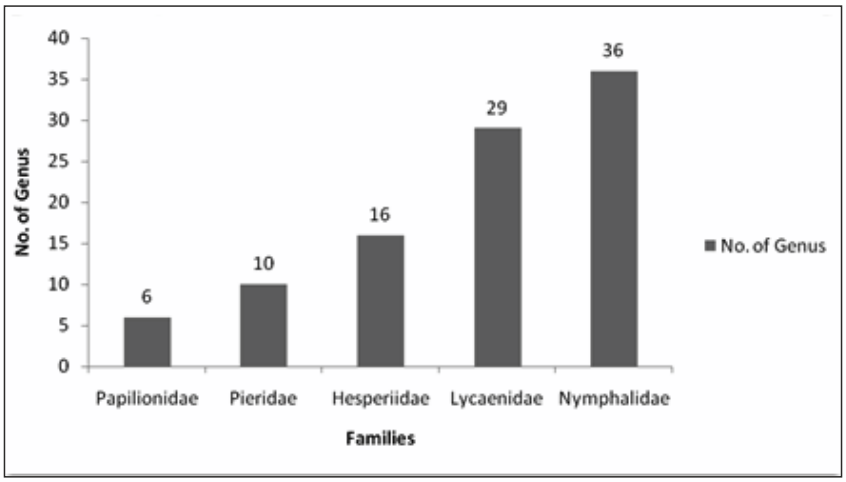


Figure 2.2.3: Graph showing number of genera represented in families of Order- Lepidoptera:

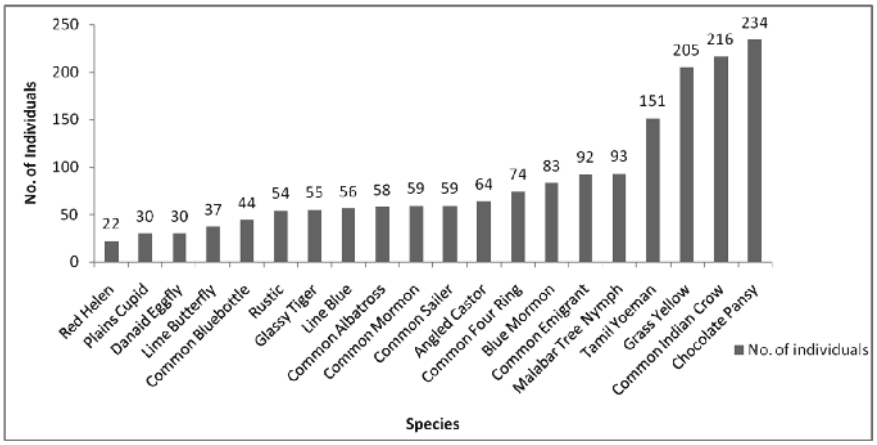


Figure 2.2.4: Graph showing abundance of 20 common species of Order-Lepidoptera

Richness and abundance of endemic species:

Out of 133 species recorded, 12 species were endemic to the Western Ghats. Five species were represented by family Papilionidae and Nymphalidae while two species by family Hesperiidae. None of the endemic species were recorded in family Lycaenidae. Two endemic species *Cirrochroathais* and *Idea malabarica* were commonly observed and were most abundant in the study area while other species like *Papilio limeodon*, *Atrophaneurapandiyana* and other Hesperiids were observed only one or two times during the entire field study. Endemic species in respective families is given in Table 2.2.4 and abundance of endemic species in given in Figure 2.2.5.

Family	Endemic Species
Papilionidae	*Southern Birdwing, Malabar Banded Swallowtail, Malabar Banded Peacock, Malabar Raven, Malabar Rose*
Pieridae	*None*
Nymphalidae	*GladeyeBushbrown, Tamil Yoeman, Malabar Tree Nymph, Red Spot Duke, Tamil Lacewing*
Lycaenidae	*None*
Hesperiidae	*Tamil Spotted Flat, Tamil Grass Dart*

Table 2.2.4: Table showing the list of endemic species represented in different families of Order: Lepidoptera

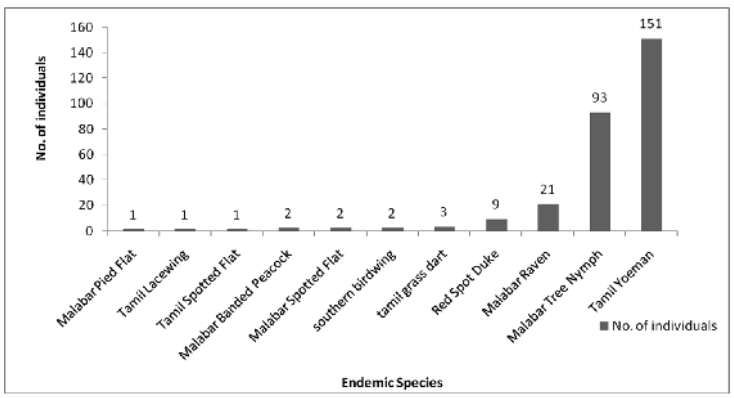


Figure 2.2.5: Graph showing abundance of endemic species

Species diversity and abundance across transects:

Along the transects, Transect 1 showed maximum richness with 114 species from 1332 individuals followed by Transect 2 with 80 species and 573 individuals, Transect 3 with 34 species from 103 individuals and Transect 4 with 53 species from 322 individuals. Shannon (H) and Simpson's indices which are used to measure alpha diversity also show similar trend. Transect 1 showed higher Shannon's index followed by Transect 2, 3 and 4. In spite of having lower species richness, Transect 4 and 3 show evenly distributed abundance as compared to Transect 1 and 2. Dominance was maximum Transect 2 and Transect 4 followed by Transect 1 and 2. Measures of alpha diversity indices are given in Table 2.2.5.

Indices	Transect 1	Transect 2	Transect 3	Transect 4
Species richness	114	80	34	53
No. of Individuals	1132	573	193	322
Dominance	0.040	0.051	0.12	0.049
Shannon's	3.81	3.49	2.64	3.38
Simpson's	0.96	0.94	0.87	0.95
Evenness	0.39	0.40	0.41	0.55

Table 2.2.5: Table showing alpha diversity indices for transects.

Species richness and abundance of schedule species (Wildlife Protection Act 1972):

Under the Wildlife Protection Act 1972 many of the Indian Lepidopterans are given conservation importance by placing them into schedules. In current study, out of 133 species recorded 18 species were represented in schedules. Three species are in Schedule I, 14 species in Schedule II and two species in Schedule IV. Three species belonged to family Papilionidae, three to family Pieridae, eight in family Nymphalidae and four in family Lycaenidae.

Species like *Hypolymnasmissipus*, *Appias albino*, *Pachliopta hector*, *Pareronia valeria*, *Lampides boeticus*, *Tarucus ananda* were seen in large numbers. While some species like *Spindasis lohita*, *Euthalialebentina*, *Papilio buddha* were recorded only one or two times during the study period.

Butterfly species and their schedule category according to Wildlife Protection Act 1972) is provided in the Table 2.2.6. next page.

Comparing butterfly diversity of Bhagwan Mahaveer Wildlife Sanctuary with other areas of Western Ghats.

In current study 133 species of butterflies were recorded in Bhagwan Mahaveer Wildlife Sanctuary which is comparable to other areas of Western Ghats. Several workers documented butterfly diversity in different parts of Western Ghats. Patwardhan (2014) recorded 142 species of butterflies in Sanjay Gandhi National Park. Arun (2002) recorded 75 species of butterflies were recorded in Siruvani forests, 32 species in Puyankutty forests (Arun & Azeez 2003), 153 species in Phansad Wildlife Sanctuary (Patwardhan 2014), 139 species in Thrissur (Aneesh et al. 2013), 73 species in Kozhikode (Nair 2002), 100 species in Silent Valley National Park (Mathew & Rahamathulla 1992) and Borkar et al. (2004) recorded 91 species of butterflies in Bondla Wildlife Sactuary.

Comparing species diversity of Bhagwan Mahaveer Wildlife Sanctuary with these areas certainly shows that it harbors rich diversity of butterflies.

Common Name	Scientific Name	Schedule
Family: Papilionidae		
Crimson Rose	*Pachliopta hector*	*Schedule I* *
Malabar Banded Swallowtail	*Papilio buddha*	*Schedule I*
Malabar Banded Peacock	*Papiplio buddha*	*Schedule* II
Family: Pieridae		
Common Albatross	*Appias albina*	*Schedule II**
Lesser Gull	*Cepora nadina*	*Schedule* II
Common Wanderer	*Pareronia valeria*	*Schedule* II
Family : Nymphalidae		
Danaid Eggfly	*Hypolimnas missipus*	*Schedule I, II*
Small Leopard	*Phalanta alcippe*	*Schedule II*
Redspot Duke	*Dophla evelina*	*Schedule II*
Common Baron	*Euthalia aconthea*	*Schedule* II
Grey Count	*Tanaecia lepidea*	*Schedule* II
Common Albatross	*Appias albina*	*Schedule* II
Blue Oakleaf	*Kallima horsfieldi*	*Schedule II*
Gaudy Baron	*Euthalia lebentina*	*Schedule IV*
Family : Lycaenidae		
Pea Blue	*Lampides boeticus*	*Schedule II**
Long banded Silverline	*Spindasis lohita*	*Schedule II*
Dark Pierrot	*Tarucus ananda*	*Scheule IV*

Note: Species marked in * were recorded in opportunistic surveys

Table 2.2.6: Table showing species represented under schedule according to Wildlife Protection Act, 1972:

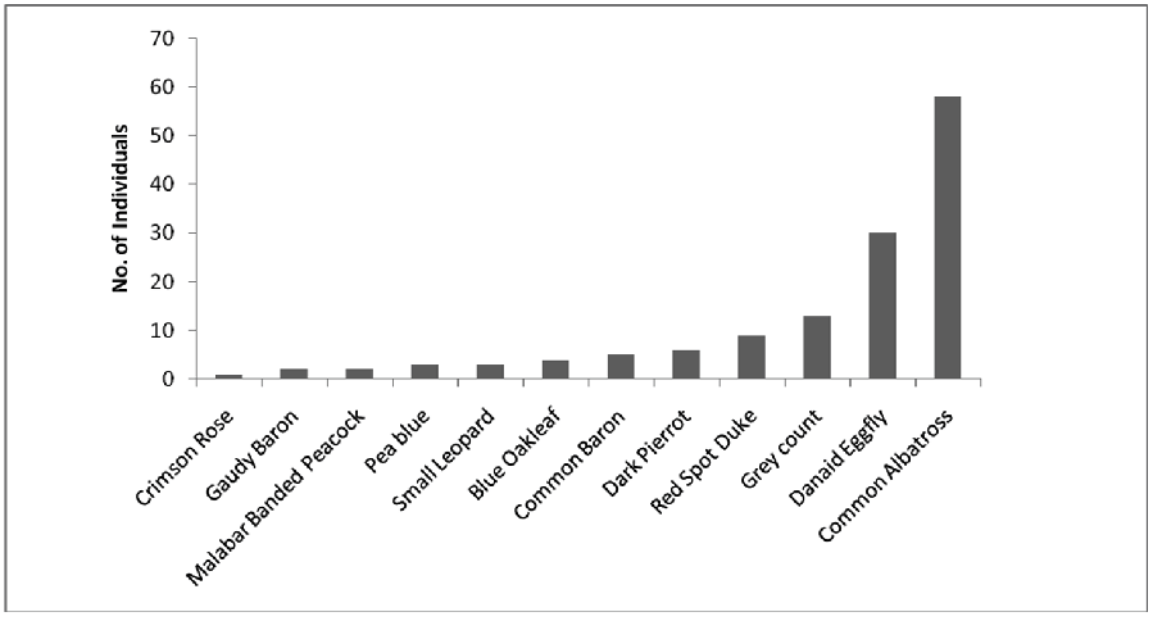


Fig. 2.2.6: Graph showing abundance of species which are represented schedule according to Wildlife Protection Act, 1972:

Comparing butterfly diversity of BhagwanMahaveer Wildlife Sanctuary with other areas of Western Ghats.

In current study 133 species of butterflies were recorded in Bhagwan Mahaveer Wildlife Sanctuary which is comparable to other areas of Western Ghats. Several workers documented butterfly diversity in different parts of Western Ghats. Patwardhan (2014) recorded 142 species of butterflies in Sanjay Gandhi National Park. Arun (2002) recorded 75 species of butterflies were recorded in Siruvani forests, 32 species in Puyankutty forests (Arun & Azeez 2003), 153 species in Phansad Wildlife Sanctuary (Patwardhan 2014), 139 species in Thrissur (Aneesh *et al.* 2013), 73 species in Kozhikode (Nair 2002), 100 species in Silent Valley National Park (Mathew & Rahamathulla 1992) and Borkar *et al.* (2004) recorded 91 species of butterflies in Bondla Wildlife Sactuary.

Comparing species diversity of Bhagwan Mahaveer Wildlife Sanctuary with these areas certainly shows that it harbors rich diversity of butterflies.

Discussion and Conclusions:

This is the very first study in Goa emphasizing on largely on quantitative data on butterfly diversity and abundance which will act as benchmark to carry out further research in different parts of Goa and also highlighting on immense diversity of butterflies. Current study records 133 species of Lepidoptera which is comparable to other regions of Western Ghats. Out of these 12 species were endemic to Western Ghats which forms 36.36% of total endemic species of Western Ghats.

Butterfly fauna of Western Ghats which is one of the global biodiversity hotspots and an important conservation area. (Kunte 2008). Out of 12, three endemic species *Cirrochroathais*, *Idea malabarica* and *Papiliodravidarum* were observed abundantly in this area. This species prefer riparian vegetation which is provided by river and forest streams flowing through this forests. Also many species were recorded only once or twice during entire field survey which can be concluded as rare species. Some sparsely distributed non endemics also have high conservation values (Kunte 2008).

In current study, out of 133 species recorded 18 species were represented in schedule according to Wildlife Protection Act 1972 which are given legal protection. Three species were in Schedule I, 14 species in Schedule II and two species in Schedule IV. Three species *Pachliopta hector, Papilio buddha and Hypolimnas missippus* are given protection under Schedule I. All these species were commonly recorded in Bhagwan Mahaveer Wildlife Sanctuary which gives this area a prime conservation importance.

The current study area experiences high level of disturbance due to continuous movement of railways and other private vehicles. Some areas in Bhagwan Mahaveer Wildlife Sanctuary, like Dudhsagar Waterfall, which is a frequently visited tourist spot, are creating pressures on the habitat.

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CHAPTER 8

Sub-order: Anisoptera	Sub-order: Zygoptera
Gomphidae	Coenagrionidae
Aeshnidae	Platystictidae
Chlorogomphidae	Platycnemididae
Cordulagasteridae	Chlorocyphidae
Macromiidae	Calopterygidae
Corduliidae	Euphaeidae
Libellulidae	*Megapodagrioniidae
	*Philogangidae
	Lestidae*
	Synlestidae

*Species marked * are not represented from the Western Ghats*

Table 2.3.1: Families represented under sub-order Anisoptera and Zygoptera.

DIVERSITY AND ABUNDANCE OF DRAGONFLIES & DAMSELFLIES (Odonata : Insecta)

- Inputs by Sridhar Halali

Introduction:

The Odonata (commonly called as Dragonflies and Damselflies) are common insects seen hovering above lakes, ponds, rivers and other water bodies. Based on morphology the order Odonata is being divided into three main groups' *viz.* Anisoptera (dragonflies), Anisozygoptera and Zygoptera (Damselfies). Anisozygopetra is considered as "living fossils" consisting of only two species worldwide of which *Epiohlebia laidlawi* is found in India. Order Anisoptera is divided further into seven families while Zygoptera is divided into ten families. All the families represented by both orders are given in *Table 2.3.1.*

The life history of odonates is closely linked with water bodies using a wide range of flowing and stagnant water bodies. Habitat specificity has an important bearing on the distribution and ecology of odonates. Odonates lay eggs their eggs in a wide range of aquatic lentic and lotic habitats. Most of the endemic species of Western Ghats prefer hill streams and rivers. Species of hill streams are more narrowly distributed than species which breed in pools or other stagnant water bodies. They are highly specific for certain types of wetlands (Subramanian et al. 2008).

In India 474 species and 50 sub-species of Odonata are recorded belonging to 142 genera and 18 families out of which 174 species are recorded in Western Ghats with 69 endemics (Subramanian et al.2011, Subramanian, 2014). In recent years increasing studies are documenting Odonata diversity in different parts of the Western Ghats, for example, in Kerala (Emiliyamma & Radhakrishnan 2002; Emiliyamma 2005; Emiliyamma et al. 2007; Adarsh et al. 2014; Varghese et al. 2014; Adarsh et al. 2015), Goa (Rangnekar et al. 2010; Rangnekar & Naik 2014), and Maharashtra (Koparde et al. 2014; Tiple et al. 2012, Tiple & Koparde 2015).

The Odonata of Goa is well explored and comprises of 87 species (Rangnekar et al. 2010, Rangnekar and Naik 2013). Recently, a new species Idionyx gomantakensis Subramanian, Rangnekar and Naik, 2013 (Subramanian et al. 2013) was described from Goa. However, most of these studies are restricted only to checklists and none are available on ecological aspects.

Odonata are among the most popular "flagship" group of insects for their role they play in aquatic environments (Hawking & New 2002). Odonates are also used as potential environmental indicators and that their conspicuousness renders them valuable for rapid assessment of water quality, so that "a count of dragonflies would provide a quick and therefore low cost identification of the health or richness of the wetland" (Moore 1997 obtained from Hawking & New 2002). Information on diversity and distribution of various taxa at habitat and regional scale is the key to biodiversity conservation, especially of little known taxa such as Odonata (Subramanian 2008). Also the recognition of endemic species areas is also important in conservation and management of biodiversity. Most of the endemic species are more susceptible to extinction due to natural and anthropogenic changes in environment (Babu et al. 2013).

Several studies have shown that Odonata species diversity and composition can be used in determining health of water body. Hawking and New (2002) used Odonata diversity as aid in conservation assessment in Australia. Subramanian et al. (2008) used Odonata diversity and abundance as indicators of riparian ecosystem health in south western Karnataka, India. Several species or families are sensitive to change in water chemistry and landuse patterns of the wetlands. Families such as Platystictidae are very sensitive to habitat modifications and disappear completely when riparian forests are removed from evergreen and semi-evergreen forests (Subramanian et al. 2008). Also other anthropogenic factors like agricultural expansion, industrialization, deforestation of riparian cover, water flow modification are some of the major threats to odonates.

The present study was carried out in Bhagwan Mahaveer Wildlife Sanctuary, Goa, to study Odonata

diversity and abundance which will provide baseline data on species diversity and their conservation. As the proposed doubling of the railway track is expected to result in transfer of a certain amount of soil and rock debris into the streams and rivers, thus potentially changing water quality, we chose to carry out this study of odonates that are sensitive biological indicators of water quality.

Methodology:

Study Area:

Bhagwan Mahaveer Wildlife Sanctuary has wetlands mainly in the form of rivers and forest streams. Extensive surveys were conducted from April (2013) to March (2014) to estimate diversity and abundance of Odonates.

Adult odonates were sampled between 10.00 and 13.00 hours. For surveying, a belt transect of 200m was used and all species within strip of 5m were counted. Most of the species were identified visually; for difficult species photographs were taken and later identified by using field guides (Subramanian 2008, Nair 2011). Classification follows Subramanian (2014).

Diversity Measures:

Alpha diversity is a measure of species diversity in a given habitat. It was measured using indices such as Shannon's and Simpson's index. Evenness was calculated to know how evenly the species were distributed in a locality. Beta (â) diversity is the measure of degree of variation in diversity between two habitats, patches or communities. Bray-Curtis similarity measure was used to calculate beta diversity. All the indices were measured using program PAST (Hammer et al.2001).

Results and Discussion:

Odonate diversity and abundance:

Surveys conducted from April (2013) to May (2014), 57 species of Odonata were recorded belonging to 11 families and 51 genera. This forms nearly 32.8 % of diversity of Western Ghats. Sub-order Anisoptera dominated with 33 species represented by four families. Family Libellulidae dominated with 23 species followed by Gomphidae (6 species), Aeshnidae (3 species) and Macromiidae (1 species). In sub-order Zygoptera, 24 species belonging to seven families were recorded. Family Coenagrionidae dominated with nine species followed by Platycnemididae (4 species), Calopterygidae (3 species), Euphaeidae, Chlorocyphidae (2 species each) and Platystictidae (1 species).

Out of 57 species, nine species belonging to five families are endemic to the Western Ghats; These include Family Gomphidae represented by three endemic species, Libellulidae by three, Platystictidae and Euphaeidae by two species each, and Coenagrionidae with one endemic species.

Species richness was dominated by Libellulidae is because of high dispersal capacity and adaptability while Zygopterans are less abundant is because of less adaptability and less dispersal capability (Kadoya et al. 2004). Also Libellulids prefer lentic habitats for breeding which are widely available; this may also be the reason for high species richness of Libellulids (Subramanian et al. 2008).

All the recorded species with their common name and threat status according IUCN Red List criteria is given in *Table 2.3.1. below.*

Locality	Abbrevations	Habitat	Water Persistence
Collem River	Col_Rvr	River	Perennial
Dudhsagar River	Dudh_Rvr	River	Perennial
Dudhsagar Waterfall	Dudh_Wat	Forest Stream	Perennial
Tunnel Stream	Tun_Strm	Forest Stream	PerenniaL
Temporary Stream	Temp_Strm 1	Forest Stream	Seasonal

Table 2.3.1: Showing locations surveyed and their type of habitat.

Figure 2.3.1: Map showing localities surveyed in Bhagwan Mahaveer Wildlife Sanctuary and adjacent areas.

Table 2.3.2. *Matrix showing species recorded with their IUCN status.*

Sr. No	Scientific Name	Common Name	IUCN Status
	Sub-order: Anisoptera		
	Family: Papilionidae		
1.	Heliogomphus promelas (Selys, 1873)	Indian Lyretail	NT
2.	Ictinogomphus rapax (Rambur, 1842)	Common Clubtail	LC
3.	Paragomphus lineatus (Selys, 1850)	Common Hooktail	LC
4.	Gomphidia kodaguensis Fraser, 1923*	-	DD
5.	Megalogomphus hannyngtoni (Fraser,1923)*	-	NT
6.	Merogomphus longistigma (Fraser,1922)*	-	DD
	Family: Aeshnidae		
7.	Anax guttatus (Burmeister, 1839)	Blue tailed green darner	LC
8.	Gynacantha bayadera Selys, 1891	Parakeet Darner	LC
9.	Gynacantha dravida Leiftinck, 1960	Brown Darner	LC
	Family: Macromiidae		
10.	Epophthalmia vittata Burmeister,1839	Common Torrent Hawk	LC
	Family: Libellulidae		
11.	Brachythemis contaminata (Fabricius,1793)	Ditch Jewel	LC
12.	Cratilla lineata (Foerster, 1903)	Emerald Banded Skimmer	LC
13.	Crocothemis servilia (Drury, 1770)	Brown backed red marsh skimmer	LC
14.	Diplacodes trivialis (Rambur,1842)	Ground skimmer	LC
15.	Lathrecista asiatica (Fabricius, 1798)	Asiatic bloodtail	LC

Continued ....

Table 2.3.2. *(Continued)*

16.	Neurothemis fulvia (Drury, 1773)	Fulvous forest skimmer	LC
17	Neurothemis tullia (Drury, 1773)	Paddy pied skimmer	LC
18	Onychothemis testacea (Laidlaw, 1902)	Stellate river hawk	LC
19	Orthetrum chrysis (Selys, 1891)	Crimson tailed skimmer	LC
20	Orthetrum glaucum (Brauer, 1865)	Little blue skimmer	LC
21	Orthetrum luzonicum (Brauer, 1868)	Tricolored skimmer	LC
22	Orthetrum pruinosum (Burmeister,1839)	Crimson tailed marsh hawk	LC
23	Orthetrum Sabina (Drury, 1770)	Green marsh hawk	LC
24	Pantala flavescens (Fabricius, 1798)	Wandering glider	LC
25	Potamarcha congener (Rambur, 1842)	Yellow tailed ashy skimmer	LC
26	Rhodothemis rufa (Rambur,1842)	Rufous marsh glider	LC
27	Rhyothemis variegata (Linnaeus, 1763)	Common picture wing	LC
28	Trithemis aurora (Burmeister, 1839)	Crimson marsh hawk	LC
29	Trithemis festiva (Rambur, 1842)	Black stream glider	LC
30	Trithemis pallidinervis (Kirby, 1889)	Long legged marsh glider	LC
31	Hylaeothemis indica Fraser, 1946*	Blue hawklet	DD
32	Idionyx saffronata Fraser,1924*	-	DD
33	Zygonyx iris malabarica Selys, 1869*	Irridiscent stream glider	LC
Sub-order: Zygoptera			
Family: Lestidae			
34	Lestes elatus (Hagen in Selys, 1862)	Emerald spreadwing	LC
Family: Platistictidae			
35	Protosticta sanguinostigma (Fraser, 1992)*	Redspot reedtail	VU
Family: Calopterygidae			
36	Neurobasis chinensis (Linnaeus, 1758)	Stream glory	LC
37	Vestalis apicalis Selys,1873	Black tipped forest glory	LC
38	Vestalis gracilis (Rambur,1842)	Clear winged glory	LC
Family: Chlorocyphidae			
39	Libellago lineata (Burmeister, 1839)	River heliodor	LC
40	Heliocypha bisignata Rambur, 1842	Stream Jewel	LC
Family: Euphaeidae			
41	Euphaea fraseri (Laidlaw,1920)*	Malabar torrent dart	LC
42	Dysphaea ethela Fraser, 1924	Black torrent dart	DD
Family: Platycnemididae			
43	Copera vittata Selys, 1863	Blue bush dart	LC
44	Copera marginipes (Rambur, 1842)	Yellow bush dart	LC

Continued ....

Table 2.3.2. *(Continued)*

45	Caconeura ramburi (Fraser,1922)	Coorg bambootail	DD
46	Prodasineura verticalis (Selys,1860)	Black bambootail	LC
Family: Coenagrionidae			
47	Agriocnemis pieris Laidlaw,1919	White dartlet	LC
48	Agriocnemis pygmaea (Rambur, 1842)	Pigmy dartlet	LC
49	Agriocnemis splendidissima Laidlaw,1919	Splendid dartlet	NA
50	Ceriagrion cerinorubellum (Brauer, 1865)	Orange tailed marsh dart	LC
51	Mortonagrion varralli Fraser,1920	Brown dartlet	DD
52	Pseudagrion indicum Fraser, 1924*	Yellow striped blue dart	DD
53	Pseudagrion microcephalum (Rambur, 1842)	Blue dart	LC
54	Pseudagrion rubriceps Selys, 1876	Saffron faced blue dart	LC
55	Ischnura senegalensis (Rambur,1842)	Senegal golden dartlet	LC

*Note: Species marked in * are endemic to Western Ghats*

Table 2.3.2. Matrix showing species recorded with their IUCN status.

Families	Genera	Species	Endemics
Sub-Order: Anisoptera			
Gomphidae	6	6	3
Aeshnidae	2	3	0
Macromiidae	1	1	0
Libellulidae	16	23	3
Sub-Order: Zygoptera			
Lestidae	1	1	0
Platystictidae	1	1	1
Calopterygidae	2	3	0
Chlorocyphidae	2	2	0
Euphaeidae	2	2	1
Platycnemididae	3	4	0
Coenagrionidae	5	9	1

Table 2.2.3: Species, genera and endemics represented in each family recorded from Bhagwan Mahaveer Sactuary

Odonata Abundance:

Table 3 provides sampling localities and species abundance recorded in the present study from BMWS.Of 56 species, total of 940 individuals were recorded belonging to 11 families. Species like *Orthetrum Sabina, Diplacodes trivialis, Neurothemis tullia, Trithemis aurora*, *Copera vittata, Copera marginipes* are abundant andwere recorded from all localities.While endemic species like *Idionyx saffronata*, *Hylaeothemis indica, Protosticta sanguinostigma*were mostly found confined to rivers and streams with high shade cover. Abundance of most common species are shown in *fig 2.3.2 & 2.2.3.*

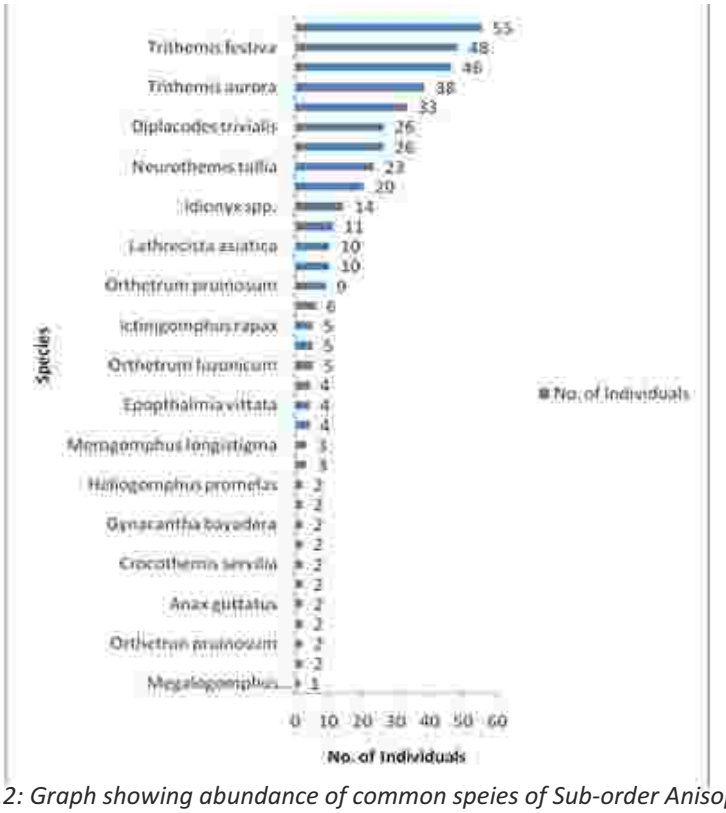

Figure 2.3.2: Graph showing abundance of common speies of Sub-order Anisoptera:

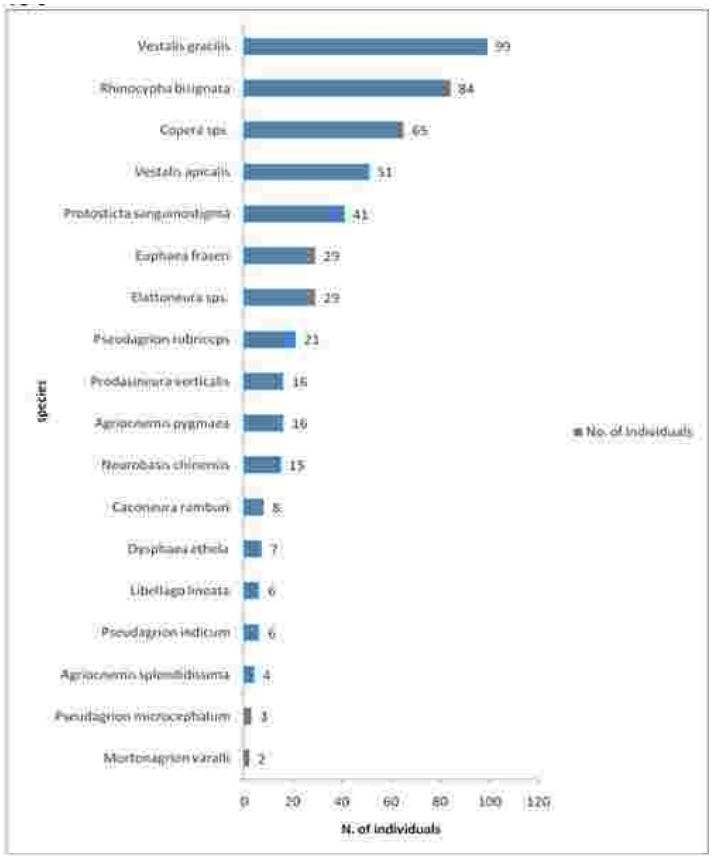

Figure 2.3.3: Graph showing abundance of common species belonging to Sub-Order: Zygoptera

Species	Col_Str	Dudh_wat	Dudh_Rvr	Temp_Str 1	Tun_Str
Agriocnemis pygmaea	13	0	3	0	0
Agriocnemis splendidissima	4	0	0	0	0
Anax guttatus	2	0	0	0	0
Brachythemis contaminate	7	0	3	0	1
Bradinopyga geminate	0	1	0	0	1
Caconeura ramburi	0	2	0	2	4
Copera sps.	8	0	0	22	34
Cratilla lineata	5	0	0	0	5
Crocothemis servilia	1	0	0	0	1
Diplacodes trivialis	7	0	7	5	7
Dysphaea ethela	3	0	4	0	0
Elattoneura sps.	0	0	29	0	0
Epopthalmia vittata	2	0	2	0	0
Euphaea fraseri	2	3	3	7	11
Gomphidia koduguensis	0	0	0	2	0
Gynacantha bayadera	0	0	0	2	0
Gynacantha dravida	0	0	0	2	0
Heliogomphus promelas	0	0	0	1	1
Hylaeothemis indica	0	0	0	1	3
Ictinigomphus rapax	3	0	1	1	0
Idionyx saffronata	0	10	0	1	3
Lathrecista asiatica	0	0	3	1	6
Libellago lineata	6	0	0	0	0
Megalogomphus hannygtoni	0	0	0	1	0
Merogomphus longistigma	0	0	0	2	1
Mortonagrion varalli	0	0	0	0	1
Neurobasis chinensis	7	1	2	0	5
Neurothemis fulvia	1	1	2	0	11
Neurothemis tullia	3	1	0	0	15
Onychothemis testacea	0	0	1	0	0
Orthetrum chrysis	7	9	0	6	18
Orthetrum glauccum	0	0	0	1	0
Orthetrum luzonicum	3	0	0	1	1
Orthetrum pruinosum	7	0	0	2	0
Orthetrum Sabina	25	2	13	6	7
Orthetrun pruinosum	0	0	0	0	2
Pantala flavescens	21	11	0	0	1
Paragomphus lineatus	4	0	0	0	0
Prodasineura verticalis	6	0	9	0	1
Protosticta sanguinostigma	0	3	35	1	1
Pseudagrion indicum	6	0	0	0	0
Pseudagrion microcephalum	3	0	0	0	0
Pseudagrion rubriceps	18	0	0	0	3
Rhinocypha bisignata	6	7	7	16	27
Rhodothemis rufa	2	0	0	0	0
Rhyothemis variegate	0	0	0	0	5
Trithemis aurora	32	0	0	0	6
Trithemis festiva	31	6	0	4	4
Vestalis apicalis	11	0	12	17	9
Vestalis gracilis	4	6	0	32	49
Zygonyx iris malabarica	0	17	1	0	8

Table 2.3.3: Matrix showing abundance of Odonates across different localities:

Alpha and Beta Diversity:

Table 2.3.4 (below) shows different measures of alpha diversity of all localities sampled during the study period. Shannon's index was maximum in Collem River (3.09), followed by tunnel Stream (2.86), temporary stream (2.54), Dudhasagar Waterfall (2.45) and Dudhsagar River (2.29). It is interesting to note that temporary streams also show high species richness despite retaining water only seasonally.

Indices	Col_Rvr	Dud_Wat	Dudh_Rvr	Temp_Strm	Tun_Strm
Dominance	0.06	0.10	0.14	0.12	0.085
Simpson's	0.93	0.89	0.86	0.88	0.91
Shannon's	3.09	2.45	2.28	2.53	2.86
Evenness	0.69	0.68	0.58	0.50	0.53

Table 2.3.4: Alpha diversity measures of Odonate abundance

For measuring beta diversity, dendrogram of Bray-Curtis Similarity was plotted (Figure 2.3.4). All the five sites clustered into two groups. Temporary stream and tunnel stream formed one cluster due to their similar species composition, while Dudhsagar River and Collem River formed a second cluster.

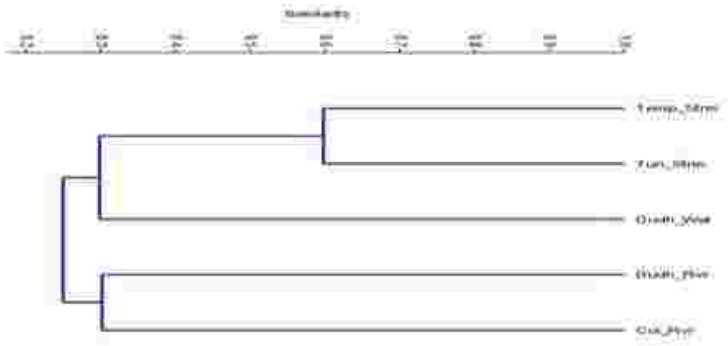

Figure 2.3.4: Dendrogram using Bray Curtis similarity for locations sampled.

Species richness and endemicity across different habitats:

Bhagwan Mahaveer Wildlife Sanctuary has wetlands in the form of forest streams and rivers. Collem River showed maximum number with 49 species followed by tunnel stream with 32 species, while Dudhsagar Waterfall and Dudhsagar River showed 15 and 18 species, respectively 25 species were recorded in the temporary stream. Species richness across different habitats is shown in fig 2.3.5.

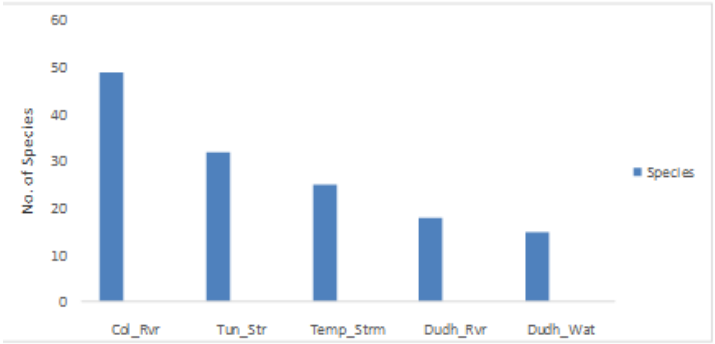

Figure 2.3.5: Graph showing species richness across different habitats

All the five localities can be broadly classified as perennial forest streams (tunnel stream, Dudhsagar Waterfall stream), seasonal forest stream (temporary stream) and rivers (Collem and Dudhsagar River). Both perennial and temporary streams are grouped under "Streams".

In current study nine endemic species (in W. Ghats) of Odonates were recorded of which *Gomphidia koduguensis, Megalogomphus hannygtoni, Idionyx saffronata, Zygonyx iris malabarica, Hylaeothemis indica, Euphaea fraseri and Protosticta sanguinostigma, Merogomphus longistigma* were recorded in streams. On the rivers, three endemic species, *Protosicta sanguinostigma, Euphaea fraseri and Pseudagrion indicum* were recorded.

Species such as *Protosticta sanguinostigma* were recorded in all three habitats having high shade cover. Large numbers of juveniles and adults of this species were seen during the onset of monsoons. Also another endemic species *Euphaea fraseri* was recorded in both stream and rivers. *Pseudagion indicum* was found restricted to rivers. It was seen that even temporary streams support many endemic species. Two species *Gomphidia koduguensis* and *Megalogomphus hannygtoni* were recorded only in temporary stream.

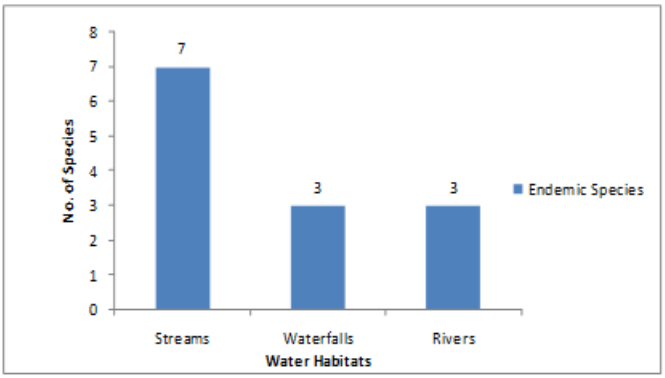

Figure 2.3.6: Graph showing number of endemic species (in Western Ghats) in different water bodies

Record of IUCN Red List species:

In the current study, three species *Heliogomphus promelas, Megalogomphus hannygtoni* and *Protosticta sanguinostigma* are represented in IUCN Red List were recorded. *Heliogomphus promelas* and *Megalogomphus hannygtoni* both belong to family Gomphidae and are in near threatened category while *Protosticta sanguinostigma* is a vulnerable species.

	Species	IUCN Status
Family: Gomphidae		
	Heliogomphus promelas	Near threatened
	Megalogomphus hannygtoni	Near threatened
Family: Platystictidae		
	Protosticta sanguinostigma	Vulnerable

IUCN Red List species

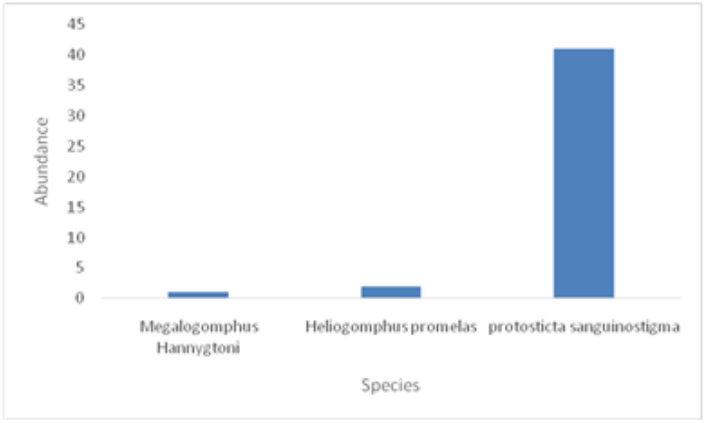

Figure 2.3.7: Graph showing abundance of IUCN Red List species in Bhagwan Mahaveer Widlife Sanctuary.

Megalogomphus hannygtoni and *Protosticta sanguinostigma* are endemic species of Western Ghats. *Protosticta sanguinostigma* was abundantly recorded during pre-monsoon period on streams and rivers and was found in areas with high canopy over. Large numbers of juveniles were recorded during months of May and June. *Heliogomphus promelas* and *Megalogomphus hannygtoni* was recorded only in streams.

Discussion:

56 species of Odonates were recorded in Bhagwan Mahaveer Wildlife Sanctuary which form 66.6 % of total Odonate fauna of Goa; of these 9 species are endemic to Western Ghats.

Rivers show the maximum diversity followed by perennial streams while seasonal stream show comparatively lower levels of diversity. Streams however support more endemic species than do the rivers. Species such as *Protosticta sanguinostigma, Protosticta gravelyi, Megalogomphus hannygtoni, Euphaea fraseri, Dysphaea ethela, Hylaeothemis indica, Idionyx saffronata* have very narrow distribution range and are found confined only to forest streams with high canopy cover. Recently, a new species *Idionyx gomantakensis* Subramanian, Rangnekar and Nayak, 2014 was discovered in tunnel stream; however this species was not recorded during our study period. This is the only type locality known of this species.

Species like *Euphaea fraseri* is found in areas having torrential water flow. *Dysphaea ethela,* recorded in the present study, is considered to be characteristic of unpolluted water bodies. Also species belonging to family Platystictidae such as *Protosticta saguinostigma* is found in forest streams with high shade cover. Families such as Platystictidae are very sensitive to habitat modifications and disappear completely when riparian forests are removed from evergreen and semi-evergreen forests (Subramanian *et al.* 2008).

Odonate diversity is directly linked to the water body as their larvae's lay eggs and development takes into the water. Hence change in water chemistry will affect will affect these species. Also it is seen that even temporary streams show high species richness and endemicity. Riparian deforestation, agricultural expansion and organic pollution are major threats to odonata diversity. Conservation of odonata is directly linked with the conservation of the riverine ecosystem of the region (Subramanian *et al.* 2008). This baseline study of odonate diversity can be used to monitor the health of rivers and streams in this region in the event of projects such as the doubling of the railway track being undertaken.

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CHAPTER 9

DIVERSITY OF FRESH WATER FISHES

- Inputs from Vidyadhar Atkore

INTRODUCTION

Tropical freshwater systems, especially tropical Asian rivers and associated habitats, harbour among the richest aquatic life globally (Dudgeon 2000). Freshwater systems, which provide numerous ecosystem services, are under acute anthropogenic pressure such as impropriation of water usage, construction of large hydro-electric power plants, pollution, deforestation, and invasive species (Revanga, *et al, 2005)*. There have been numerous taxonomic surveys on freshwater fishes in the Western Ghats region (Bhat, 2002). There are more than 320 species of freshwater fishes known from the Western Ghats ; of these more than forty percent of the species described are endemic to the Ghats. This study was conducted in order to understand the baseline diversity pattern of freshwater fishes of the Mhadei river and factors that governing their abundance and distribution.

The river Mhadei forms a lifeline in Goa state, providing basic livelihood options to farmers and fishing communities. The river originates near Degaon village at an elevation of 760 m in the Bhimgad Wildlife Sanctuary situated in the Karnataka state. From there river flows westward directions and meet the Arabian Sea near Panjim. The total length of Mhadei is 77 km, of which 29 km falls within the states of Karnataka and 52 km in Goa. The river has a 2032 sq.km catchment area in Karnataka state while 1580 sq.km catchment area lies in Goa. River Mhadei enters north Sattari taluk and flows through Cumbarjua, Divadi and Chodne villages, before entering the Arabian Sea near Panaji. On its way, various small to medium size streams join the main river. Some of the main tributaries are Dudhsagar, Ragada, Khandepar, Karanjhol, Panas, Patwal, and Cumtol. River Mhadei run through several protected areas, namely, Mhadei Tiger Reserve, Bhimgad Wildlife Sanctuary and Bhagvan Mahaveer Wildlife Sanctuary and National Park.

The present study focuses on the fish richness of Dudhsagar stream, a tributary of Mhadei River in Goa. Dudhsagar stream originates in the hilly regions of Karnataka state. The stream enters into the Bhagvan Mahaveer Wildlife Sanctuary & National Park in the North Goa district. This stream has a famous Dudhsagar waterfall in the park which attracts thousands of tourists.

Aims and Objectives

1. To study the patterns of fish diversity in the Dudhsagar stream
2. To document functional guild composition
3. To study the factors that influence the fish species richness and abundance

METHODS

During a pilot survey key habitats were identified in the stream. A stream reach or a segment of 100-150 m was identified as an unit for sampling stream fishes. The sites for sampling identified in the Dudhsagar stream were: Cullem (N 15.33876 E74.24847, Elevation 94 m), Dudhsagar 1 (N 14.3415E 74.26423, Elevation 85 m), Devachikon (N 15.3332 E74.2769, Elevation 97 m) and Dudhsagar water fall (N 15.30894 E74.31214, Elevation 146 m).

A systematic sampling of fishes was conducted by using castnet – a traditional fishing gear used by fisher folks. There were four such segments identified and sampled both in dry and wet season during 2013-2014. Approximately, each habitat was sampled for 120 minutes. Besides, fish sampling, basic water quality parameters such as water temperature, pH, Electrical conductivity, total dissolved solids and presence of canopy cover (%) were measured.

The functional guild was categorized in two ways - habitat guild and feeding guild. Fishes were classified according to their trophic position as surface dwellers, mid column dwellers, and bottom dwellers. For feeding guilds, fishes were categorized into broad feeding habits as insectivore, carnivore, detritivore, algivore, herbivore and omnivore.

Based on the field observations, fishes were also assessed according to their abundance to disturbance levels.

Analytical methods

All the analysis including the calculation of species diversity indices was done in R statistical software (R2013).

RESULTS

Pattern of species richness

Twenty three species of fish were recorded at four sampling sites in two seasons. The family Cyprinidae was the most dominant with 18 species followed by families such as Belonidae, Bagridae, Mastacembelidae Cichlidae and Gobidae with one species each. Two sites were equal in species richness, namely, 'Dudhsagar 1' and 'Dudhsagar fall' (Fig 2.4.1). Another site 'Devachikon' had the least number of species, whereas 'Cullem'- a site which is just outside the park and exposed to disturbance had ten species. The Shannon entropy was higher in two sites, namely, 'Dudhsagar fall' and 'Dudhsagar1' as compared to the other two sites. The Simpson diversity index was highest in 'Dudhsagar fall'. The Pielou evenness was maximum at 'Devachikon' whereas it was almost similar at other sites.

Among the four sites, 'Dudhsagar fall' was the most abundant in terms of number of individuals of fish caught followed by Cullem. 'Devachikon' had the least number of individuals. Of all the species, proportionately, *Salmophasia boopis* was the most dominant (40%) followed by *Devario malabaricus* (14%) and *Garra mullya* (10%).

Sr. No.	Site	N0	H	N2	E1	E2	J
1.	Cullem	10	1.670	3.765	0.531	0.376	0.725
2.	Devachikon	07	1.480	3.272	0.628	0.467	0.761
3.	Dudhsagar Falls	15	1.981	5.282	0.483	0.352	0.731
4.	Dudhsagar 1	15	1.956	4.429	0.471	0.295	0.722

Note: N0= species richness, H = Shannon entropy, N2 = Simpson diversity number, E1 & E2= Hill's ratio, J = Pieloue evenness

Table 2.4.1: Fish species diversity at four sampling segments in Mhadei river system

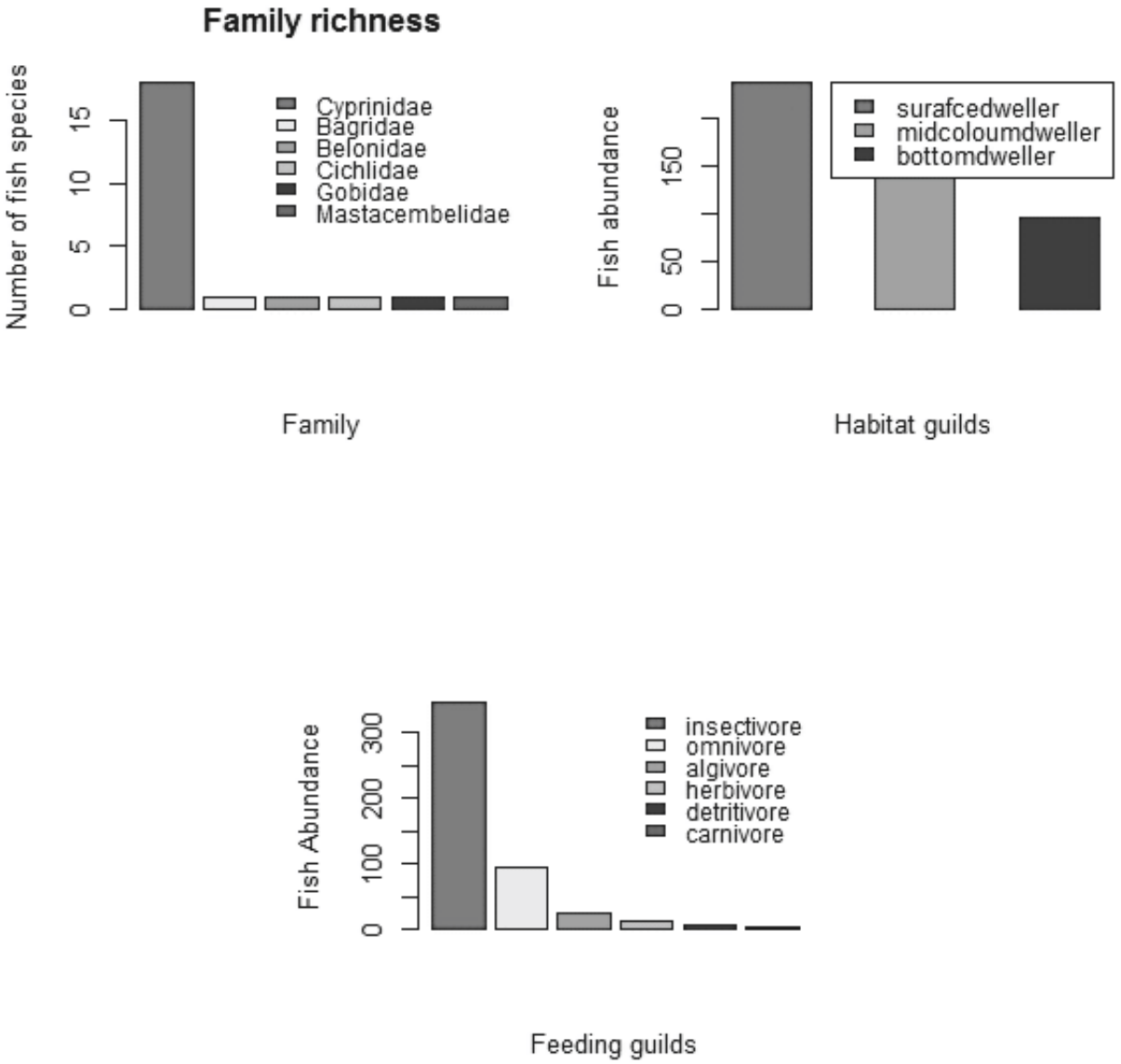

Figure 2.4.1 showing the family richness, habitat guilds and feeding guilds

Role of habitat covariates on the fish abundance

Among the measured water quality parameters, the values of electrical conductivity ranged from 0.03 to 0.015 µS/cm, and total dissolved solids were 0.01 to 0.03. The water temperature ranged from 22 to 25 ^{0}C and canopy cover varied from 45 % to 90 %. Interestingly, fish abundance decreased with increase in the electrical conductivity at the four sites (R^2 = 0.79, p <0.01). Similar is the trend with total dissolved solids (R^2 =0.62, p <0.21). But the fish abundance did not show any relationship with the water temperature (R^2= 0.00, p <-0.90). Fish abundance showed a strong positive relationship with canopy cover (R^2=0.73, p <0.14), see Fig 2.

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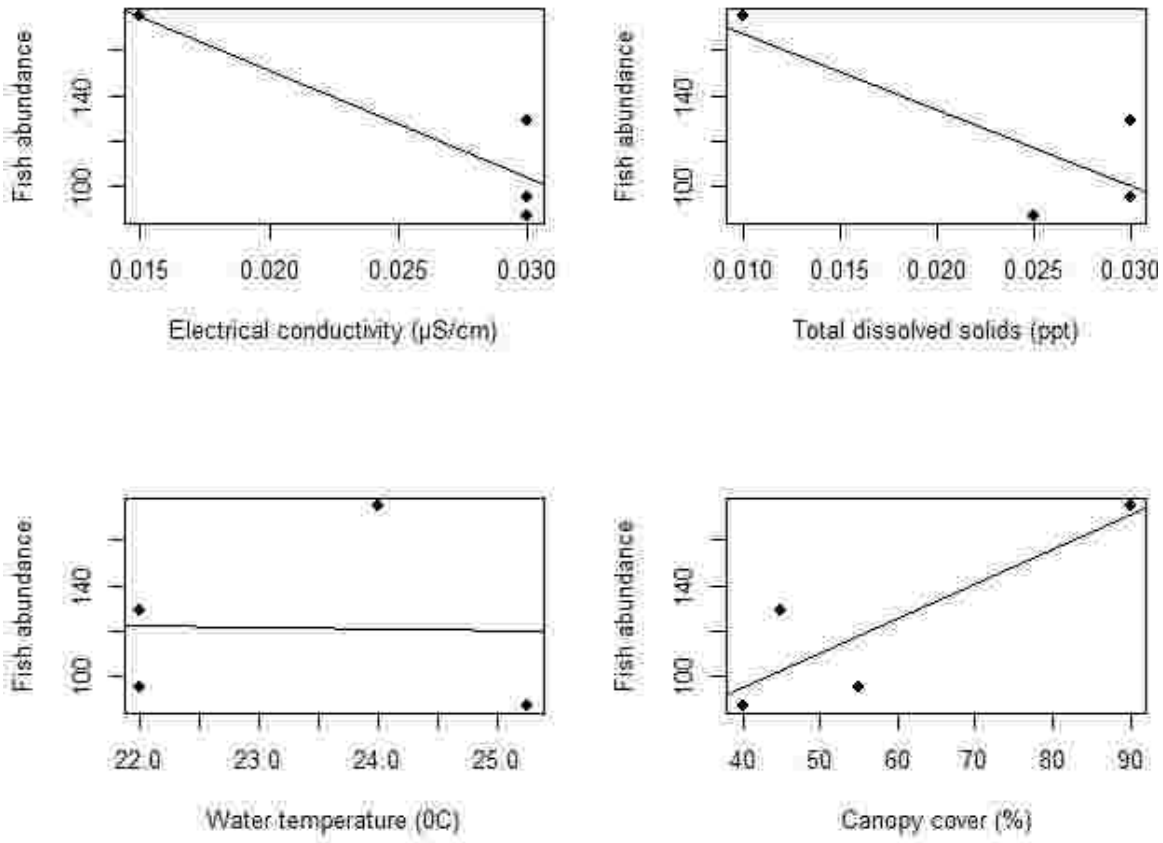


Figure 2.4.2. Showing the relationship between the fish abundance and other habitat covariates

Functional guild composition

Assessing a functional guild composition is an important community characteristic. The results from this study suggest that the fish community was mainly composed of surface dwellers guild which contributed more than 49 %, followed by mid-coloum dweller guild with 30 % and a bottom-dweller guild contributing up to 19% in all four study sites. According to feeding habits of fishes, an insectivore feeding guild was the most dominant with more than 70 % followed by algivore feeding guild with 19%. There are thirteen species tolerant to various disturbances and about ten species were intolerant (See Fig 2.4.1 &Table 2.4.2). Fish species composition is shown by NMDS plot in figure 3. Species which were intolerant to disturbances (are also endemic to the WG region) includes Tor khudree, Hypselobarbus dobsoni are aligned on right hand side of the axes. Similarly, more generalist species such as Salmophsia boopis, Rasbora daniconius are close to each other thus forming a separate cluster.

Fish species	%	IUCN Status	Endemic to WGs	T/IT	Habitat Preference	HG	FG
Dawkinsia filamentosa	2.47	LC		T	pl	sd	i
Devario malabaricus	14.82	LC		T	pl, rn, rfl	mcd	i
Etroplus suratensis	3.08	LC		T	pl	bd	o
Garra biconuta	0.20	NT	Endemic	IT	pl	bd	a
Garra mullya	10.90	LC	Endemic	T	pl	bd	a
Garra stenorhynchus	0.20	LC	Endemic	IT	pl	bd	a
Glossogobius guirius	1.45	LC		IT	pl	bd	d
Hypselobarbus curmuca	0.20	LC	Endemic	IT	pl, rn	bd	c
Hypseobabus dobsonii	0.42	DD	Endemic	IT	pl, rn	bd	h
Hypselobarbus jerdonii	0.62	LC	Endemic	T	pl, rn	bd	o
Mastacembelus armatus	0.82	LC		T	pl	bd	c
Mystus bleekeri	0.20	NA		T	pl	bd	c
Osteochilicthys nashi	5.35	LC	Endemic	IT	pl, rn	mcd	a
Osteochilicthys thomassi	2.68	LC	Endemic	IT	pl, rn	mcd	a
Pethia narayani	6.99	LC	Endemic	IT	pl, rn	mcd	i
Pethia setnai	0.41	VU	Endemic	IT	pl	mcd	i
Pethia ticto	0.20	LC		T	pl, rn	bd	o
Puntius amphibious	0.61	DD		T	pl, rn	bd	o
Rasbora daniconius	4.52	LC		T	pl, rn	sd	i
Salmostella boopis	39.50	LC		T	pl, rn	sd	i
Salmostella novacula	2.67	LC		T	pl, rn	sd	i
Tor khudree	0.61	EN	Endemic	IT	pl, rn	mcd	o
Xenentodon cancila	1.02	LC		T	pl	sd	c

LC= Least concern, NT = Near threatened, NA= Not assessed, VU=Vulnerable, DD=Data deficient, EN=Endangered; pl=pool, rn = run, rfl =riffle; I = intolerant, T= Tolerant, HG = Habitat guilds: sd = surface dweller, mcd=mid coloum dweller, bd = bottom dweller; FG = Feeding guilds: a=algivore, c=carnivore, d=detritivore, h =herbivore, i=insectivore, o = omnivore

Table 2.4.2 showing the fish species proportion, endemism, tolerance to disturbance and habitat preference

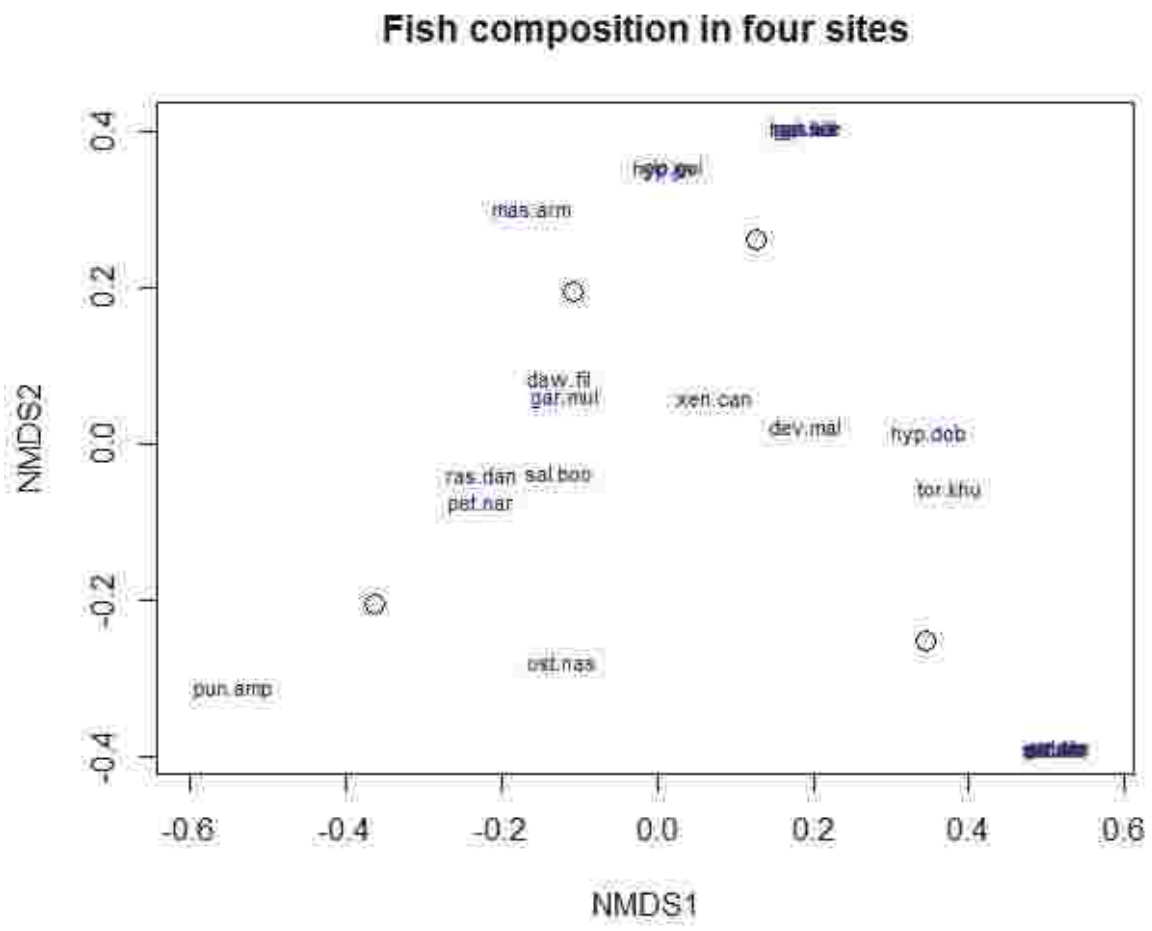


Figure 2.4.3. The fish species composition by NMDS plot.

Conservation status and endemism

Of the total species recorded in this survey, about half of them were endemic to the Western Ghats's region. In total, 16 species were least concerned, one was near threatened, two were data deficient, one was vulnerable and two species were in endangered category according to the IUCN Red List status. We found one species i.e. Mystus bleekeri in our sampling which was not assessed by IUCN (see table 2.4.2).

Probable impacts of disturbances to the fish community structure

The reason why two sites were higher in its species richness could be attributed to the good quality habitat i.e. pool, effect of shade and minimal level of disturbance. The fish abundance was high typically during the dry season around April-May. Only during this time, most fishes tend to breed and migrate upstream for spawning purpose. Therefore, it is quite evident that many fishes would have migrated to the relatively higher elevation zones i.e. Dudhasagar and Dudhsagar fall.

We found a small difference between the measured values of the electrical conductivity as well as total dissolved solids, but even then the fish abundance seems to show a strong positive relationship. This would mean that fish abundances are strongly influenced by conductivity and dissolved solids. A higher level of salinity could occur in the water due to river bank soil erosion or weathering of rocks. Studies from American streams have shown that higher levels of salinity deter the movement pattern and navigation of fish (Work and Gophen 1999,). This will have negative implications to the local migration behavior which in turn affecting the feeding and spawning migration of endangered and endemic species such as Deccan mahseer (Tor khudree). In addition to this, the surface dweller and mid column

dweller fishes will be mainly affected by higher salinity or conductivity level. Since these stream sites are situated in moist and dense evergreen forests, leaf insects that falls on the surface will be preyed upon by surface dwellers guild fishes which are insectivorous in their feeding diet. Disturbance such as turbidity, salinity and conductivity will affect the navigation thereby affecting feeding habit of these fishes.

'Dudhsagar fall' site is situated deep inside the forest but this site is disturbed due to the large numbers of tourists. The regular movement of vehicles also makes the water constantly turbid. During the sampling time, we observed the presence of only a few tolerant fish species at this site but not intolerant species such as *Tor khudree, Dawkinsia filamentosa*, etc which would have either migrated upstream or downstream to find a suitable habitat or would have perished. The tolerance limit of many tropical stream fishes to the water quality parameters is given in the following table.

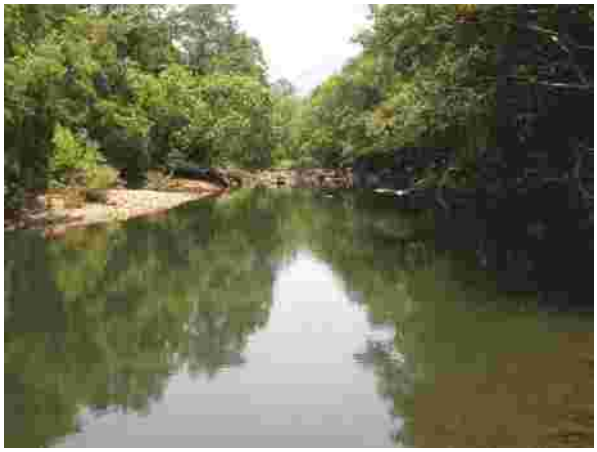
Water quality parameters	**Unit**	**Range**
Water temperature	^{0}C	28 -32
pH		6.5 to 8.5
Turbidity	cm (NTU)	30-80
Electrical conductivity	µS/cm	100-2000
Total dissolved solids	ppt	2
Inorganic nitrates	mg/l	1.2 mg/l or less free ammonia
Total alkalinity	ppm	80-200
Dissolved oxygen survive)	mg/l	> 4mg/l (4 mg/l = catfishes
Hardness	mg/l	75-150
Calcium hardness	mg/l	25-100
Chlorides	mg/l	60
Free CO^2	mg/l	> 100
Biological oxygen demand	ppm	3-6

Table 2.4.3. Tolerance level for tropical freshwater fishes

Dudhsagar Falls site was also had higher levels of fish abundance. Of this, typically two species dominate this abundance level. They are *Salmophasia boopis* and *Rasbora daniconius* which are generalists and have widespread distribution. They are surface dweller fishes, occur in small to bigger schools with other species in pools and in habitats with flowing water.

A fish community is considered “ideal” when the functional guild composition is proportionately comprised of more of insectivorous-algivore-herbivore and less of omnivorous guild (Karr 1981). This study is consistent with this expectation. Omnivorous species often tend to occur in mostly perturbed or polluted sites due to their high tolerance level to such conditions; they feed on variety of food resources ranging from fruits, detritus, insects, mollusks to crabs. These fishes are also opportunistic in their feeding diet. On the other hand, insectivorous guilds are specialized and perhaps restricted to the stream reaches that pass through the dense forest canopy where the insects from the canopy fall on the surface water.

Cullem



Devachikon

Dudhasagar 1

Dudhsagar waterfall

Intolerant fish species: Osteochilicthys nashi, Tor khudree


Tolerant fish species: Salmophasia boopis and Rasbora daniconius

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CHAPTER 10

ANURAN DIVERSITY

- Inputs from Gururaja K V

Introduction

Amphibians include frogs and toads (order: Anura), salamander and newts (order: Caudata), and caecilians and ichthyophis (order: Gymnophiona). Anurans are found in many habitats and microhabitats ranging from human habitations to desert regions, and from high tree canopy to below ground. There are about 7400 amphibian species world over, of which India has recorded 385 species belonging to all three extant orders. Western Ghats has 218 described species of amphibians, of which 193 are anurans.

In the past decade and a half, 112 new species of amphibians have been discovered from the Western Ghats, indicating the high levels of species richness as well as the need for systematic studies in the region. Among the 218 described species from the Western Ghats, 87.8% (158 species) are endemic to the region. Amphibians inhabit two different habitats (water and land) during their life cycle. Amphibians are highly sensitive and susceptible to external changes and regarded as "Canaries of a coal mine". In the ecosystem, amphibians function both as prey and predator, and they constitute a vital component of the ecosystem. In ecosystem management, they are biological pest controllers. Monitoring anuran diversity and their distribution would provide an insight into the prevailing environmental conditions of an ecosystem. Such monitoring and documentation are important towards assessment and conservation of bio-diversity of a region. The present study of anuran diversity and distribution was carried out along the Castlerock-Kulem railway line and catchment area of the railway line to record diversity, relative abundance and ecological status of anurans in the region.

Materials and Methods

Study area

Anuran survey was carried out mainly in the catchment area of the existing railway line between Castlerock and Kulem (15.323654-15.440458˚N and 74.230929-74.376374˚E) in varied elevation and

Localities	Longitude (°E)	Latitude (°N)	Elevation (m amsl)	Predominant Land-use
Systematic survey				
Caranzole	74.274546	15.362433	150	Deciduous Forest
Dudhsagar Falls	74.315219	15.313057	313	Deciduous Forest with Stream
Castlerock	74.321281	15.402246	545	Semi-evergreen Forest
Kulem	74.249606	15.320439	106	Deciduous Forest with Stream and Laterite Plateau
Opportunistic survey				
Kalamboli	74.325706	15.424585	591	Semi-evergreen Forest with Stream
Kungini	74.357004	15.391268	622	Grassland
Ghotga	74.349846	15.363055	585	Deciduous Forest
Caranzole (stream)	74.320603	15.374776	545	Deciduous Forest with Stream
Sonalium	74.287919	15.320052	130	Deciduous Forest
Tamdi Surla	74.200130	15.41122	058	Agricultural land with Stream
BMWLS	74.246429	15.400320	101	Deciduous Forest with stream

Table 2.5.1: Sampling plots for amphibian survey

land-use categories. Figure 1 and 2 depicts survey area, detailed sampling localities and elevation profile.

Methods

To record overall anuran diversity, opportunistic surveys were carried out in various localities (Figure 2.5.1, Table 2.5.1). Four sampling localities within catchment area of Castlerock-Kulem railway line with systematic stratified sampling method. Stratification is based on the altitude and land-use categories. For estimating relative abundance of anurans, in four sites, anurans were systematically sampled between 18:30-20:30hr in May, July and October of 2013 and 2014. Visual encounters, calls, tadpoles, foam nests, spawn were used to record the anurans in the field. One man hour of searching is made using torch lights by walking across the streams, forest floors, gleaning leaf litters, prodding bushes, wood logs, rock crevices etc. Species were identified at the site using Frog Find (Android App) and Pictorial Guide to Frogs and Toads of the Western Ghats (Gururaja, 2012), IUCN Red List status, Endemism, Abundance, general habitat and breeding habitat recorded.

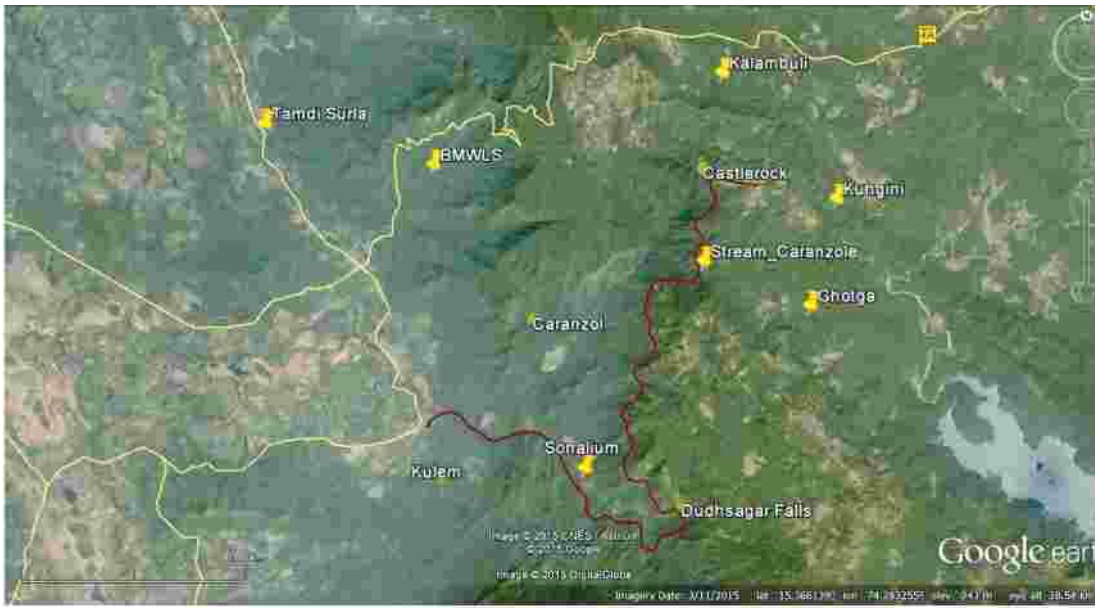

Figure 2.5.1. Anuran sampling points in Castlerock-Kulem railway line catchment area. Darkbrown line is the existing railway line. Green dots indicate systematic anuran sample points and yellow pins indicate opportunistic observation points. Image source: Google Earth, 2015.

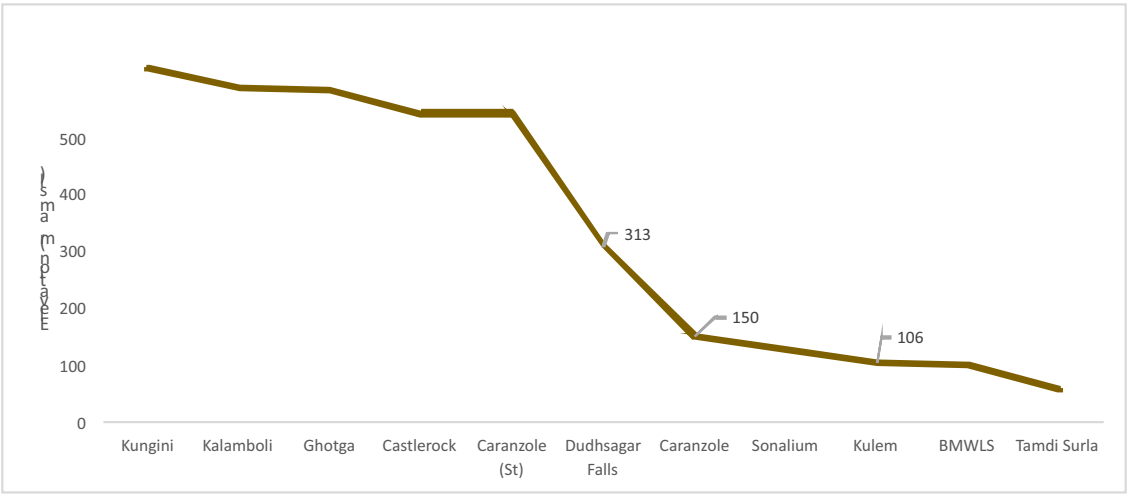

Figure 2.5.2. Elevation profile of sampling localities in this study.
Elevation of systematic sampled localities are given as labels on the graph.

Results

Anuran Diversity

During this study, 24 species of anurans belonging to 19 genera and 8 families were observed. Details of their habitat, breeding habitat, IUCN status and endemism are provided in Table 2. This is about 13% of overall anuran diversity in the Western Ghats (192 species). Family Dicroglossidae represents highest number of species (7), while Nyctibatrachidae and Micrixalidae are represented by one species each.

Species	Habitat	Breeding	IUCN RedList	WG Endemic
Bufonidae				
Duttaphrynus melanostictus	Terrestrial	Aquatic-Lentic	Least concern	-
Pedostibes tuberculosus	Arboreal	Aquatic-Lotic	Endangered	Endemic
Dicroglossidae				
Euphlyctis aloysii	Semi-Aquatic	Aquatic-Lentic	Not evaluated	Endemic
Endemic*Euphlyctis cyanophlyctis*	Aquatic	Aquatic-Lentic	Least concern	-
Hoplobatrachus tigerinus	Semi-Aquatic	Aquatic-Lentic	Least concern	-
Minervarya sahyadrensis	Semi-Aquatic	Aquatic-Lentic	Endangered	Endemic
Sphaerotheca breviceps	Terrestrial	Aquatic-Lentic	Least concern	-
Zakerana caperata	Semi-Aquatic	Aquatic-Lentic	Not evaluated	Endemic
Zakerana rufescens	Semi-Aquatic	Aquatic-Lentic	Least concern	Endemic
Micrixalidae				
Micrixalus uttaraghati	Terrestrial	Aquatic-Lotic	Not evaluated	Endemic
Microhylidae				
Microhyla ornata	Semi-Aquatic	Aquatic-Lentic	Least concern	-
Microhyla rubra	Semi-Aquatic	Aquatic-Lentic	Least concern	-
Uperodon mormorata	Semi-Aquatic	Aquatic-Lentic	Endangered	Endemic
Uperodontaprobanicus	Semi-Aquatic	Aquatic-Lentic	Least concern	-
Nyctibatrachidae				
Nyctibatrachus petraeus	Aquatic	Aquatic-Lotic	Least concern	Endemic
Ranidae				
Clinotarsus curtipes	Semi-Aquatic	Aquatic-Lentic	Near threatened	-
Hydrophylax malabarica	Semi-Aquatic	Aquatic-Lentic	Least concern	-
Indosylvirana caeseri	Semi-Aquatic	Aquatic-Lentic	Not evaluated	Endemic
Ranixalidae				
Indirana chiravasi	Terrestrial	Semi-terrestrial	Not evaluated	Endemic
Indirana semipalmata	Terrestrial	Semi-terrestrial	Least concern	Endemic
Rhacophoridae				
Polypedates maculatus	Arboreal	Aquatic-Lentic	Least concern	-
Pseudophilautus amboli	Arboreal	Direct	Critically Endangered	Endemic
Raorchestes bombayensis	Arboreal	Direct	Vulnerable	Endemic
Rhacophorus malabaricus	Arboreal	Aquatic-Lentic	Least concern	Endemic

Table 2.5.2. List of anurans observed in this study.

Castlerock is the type locality (from where the original specimen was described) of Nyctibatrachus petraeus Kunte and Das, 2005 and Raorchestes bombayensis (Annandale, 1919). Recently, Biju et al (2014) described 14 new dancing frogs. One of them is Micrixalus uttaraghati and it is found in the streams that cut across the existing Castlerock-Kulem railway line. Similarly, these streams are home to Indosylvirana caesari and Indirana chiravasi, the frog species that were described recently (Biju et al 2015; Padhey et al, 2014). Plates 1 and 2 illustrate some anuran species from the study area.

Plate 1. a. Nyctibatrachus petraeus(Caslterock Night Frog); b. Indosylvirana caesari (Maharashtra Golden-backed Frog); c. Micrixalus uttaraghati (Northern Dancing Frog) and d. Raorchestes bombayensis(Bombay Bush Frog).

Plate 2. **a.** *Zakerana caperata*(Common Cricket Frog); **b.** *Pseudophilautus amboli* (Amboli Bush Frog) – a critically endangered & endemic species; **c.** *Pedostibes tuberculosus* (Malabar Tree Toad) – an endangered species and d. *Indirana chiravasi* (Amboli Leaping Frog).

Ecological status and endemism

Of the 24 species observed in the study, 14 species are endemic to the Western Ghats. Of these *Nyctibatrachus petraeus, Indirana chiravasi* and *Micrixalus uttaraghati* are known to exhibit point endemism (known only from very few localities within Western Ghats). Figure 2.5.3 shows the percentage endemic species among the total observed species during the study.

According to IUCN Red List Assessment (2015), *Pseudophilautus amboli* is a critically endangered species recorded from the study area. There are three endangered species, namely, *Pedostibes tuberculosus*, *Uperodon mormoratus* and *Minervarya sahyadrensis*. Figure 4 illustrates the ecological status of 24 species recorded. Ecological status of five anuran species that are recently discovered are not evaluated still. Taking a very conservative approach, all these five species could end up among threatened status of IUCN Red List considering their habitat and population structure.

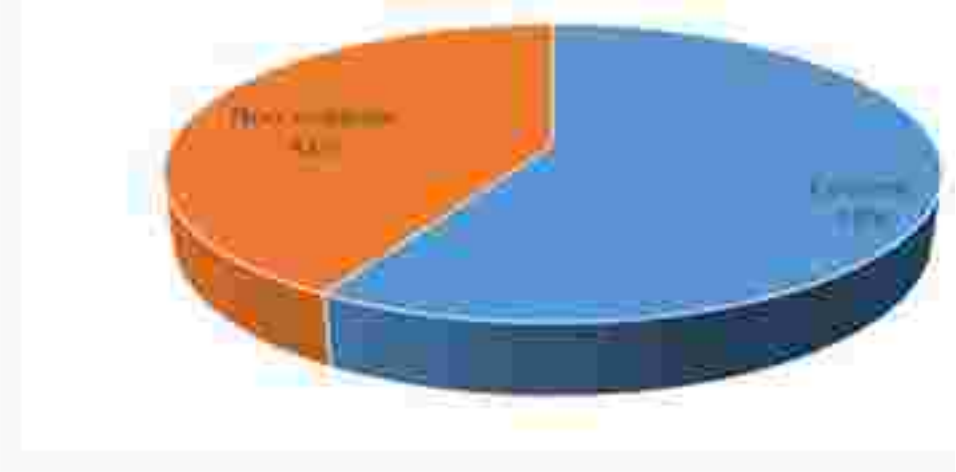

Figure 2.5.3. Percentage endemic and non-endemic anuran species reported in the present study.

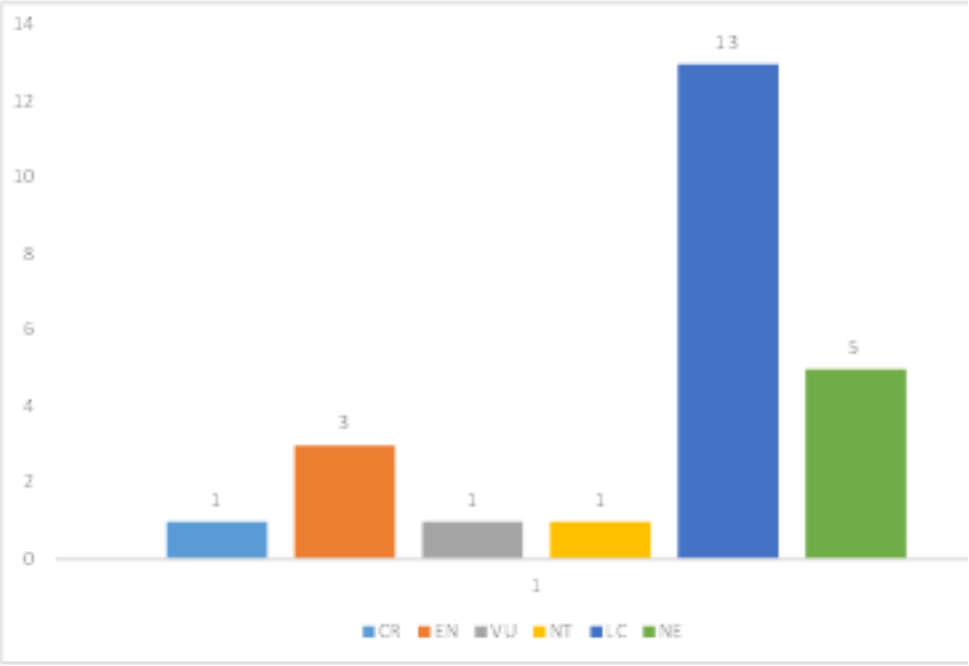

Figure 2.5.4. Ecological status of 24 species of anurans observed in the study.

Habitat dependency

Based on their occupancy in the life span, anurans in this study are categorized into 4 habitat specific groups, namely, aquatic, semi-aquatic, terrestrial and arboreal. Twelve species are semi-aquatic habitat dwellers, while 2 are aquatic and 5 each are arboreal and terrestrial dwellers.

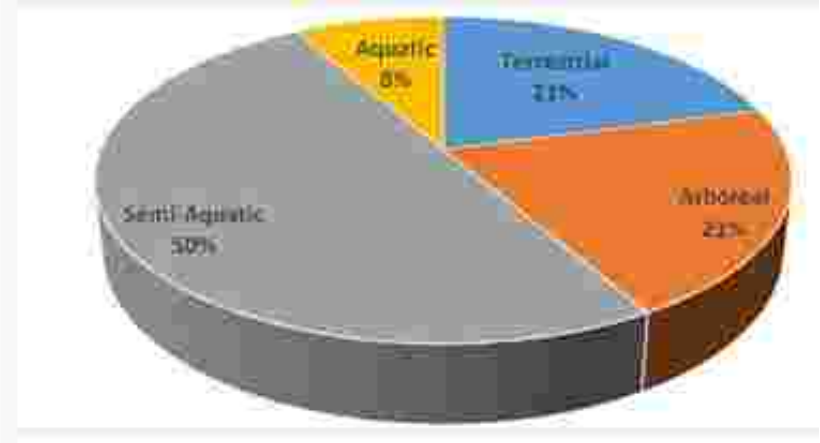

Figure 2.5.5. General habitat dwellers of anurans in the study area

Considering habitat specificity in their breeding period, anurans are grouped into aquatic-lentic, aquatic-lotic, semi-terrestrial and direct developing categories. Seventeen of them breed in stagnant waterbodies, while 3 species are stream breeders. Two are direct developing species without tadpole stage that require water for development. Figure 6 illustrates the percentage breakup of breeding habitat dwellers.

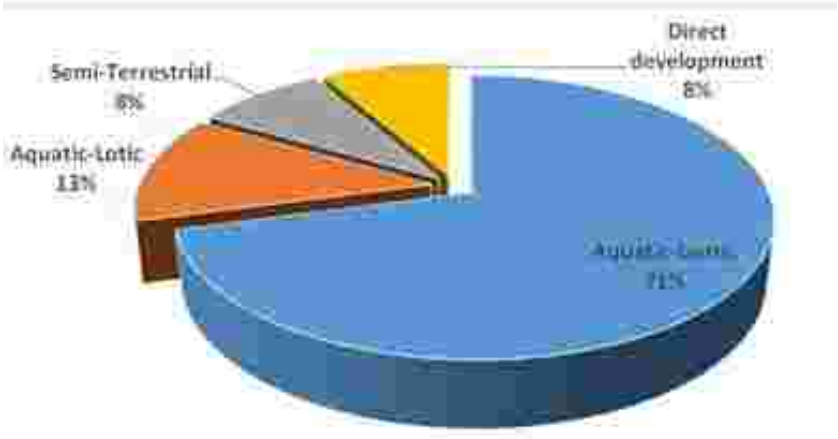

Figure 2.5.6. Breeding-habitat specific anurans in the present study.

Relative abundance and diversity indices

A total of 137 individuals representing all 24 species were recorded from four systematically studied localities. Among the four sites, Castlerock recorded all species and had four species unique to Castlerock. No other site had any unique species. Four species, namely, *Zakerana caperata*, *Euphlyctis cyanophlyctis, Duttaphrynus melanostictus* and *Pseudophilautus amboli* are recorded in all sites. Figure 7 depicts species abundance recorded from all sites.

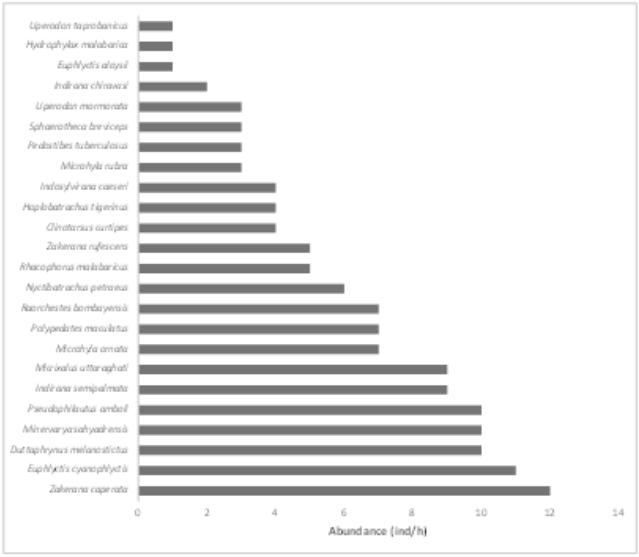

Figure 2.5.7. Species abundance for each species.

Species abundance of anurans is listed in Table 2.5.3. *Zakerana caperata* is the most abundant species with 12 individuals recorded from all sites. It is followed by *Euphlyctis cyanophlyctis* with 11 individuals and *Duttaphrynus melanostictus*, *Minervarya sahyadrensis* and *Pseudophilautus amboli* with 10 individuals each. *Hydrophylax malabaricus*, *Uperodon taprobanicus* and *Euphlyctis aloysii* are recorded only once each. Diversity index calculated on the relative abundance data from the four localities are given in Table 2.5.4.

Species	Castlerock	Caranzole	Dudhsagar	Kulem
Clinotarsus curtipes	1		1	2
Duttaphrynus melanostictus	3	2	1	4
Euphlyctis aloysii	1			
Euphlyctis cyanophlyctis	4	2	3	2
Hoplobatrachus tigerinus	1	1		2
Hydrophylax malabarica	1			
Indirana chiravasi	2			
Indirana semipalmata	6	1	2	
Indosylvirana caeseri	1		2	1
Micrixalus uttaraghati	6		3	
Microhyla ornata	2		2	3
Microhyla rubra	1			2
Minervarya sahyadrensis	4	2		4
Nyctibatrachus petraeus	3	1	2	
Pedostibes tuberculosus	21			
Polypedates maculatus	2		2	3
Pseudophilautus amboli	5	2	1	2
Raorchestes bombayensis	4	1	2	
Rhacophorus malabaricus	3	2		
Sphaerotheca breviceps	1		1	1
Uperodon mormorata	1	1	1	
Uperodon taprobanicus	1			
Zakerana caperata	1	4	2	5
Zakerana rufescens	2			3

Table 2.5.3. Anuran abundance (ind/hr) from four study localities

Castlerock had highest diversity (24 species) of anurans and relative abundance (58 ind/hr). Caranzol had least diversity (12) and abundance (20 ind/hr). Similar trend is observed in Shanon-Weiner (H') and Simpson's (D) index (Table 4). Interestingly, species evenness is highest in Dudhsagar falls (0.93) and it was least in Castlerock (0.82).

	Castlerock	Caranzol	Dudhsagar	Kulem
Species richness	24.00	12.00	14.00	13.00
Abundance (ind/hr)	58.00	20.00	25.00	34.00
Simpson's (D)	0.94	0.90	0.92	0.91
Shannon's (H)	2.97	2.37	2.57	2.47
Evenness	0.82	0.89	0.93	0.91

Table2.5.4. Species richness and diversity index.

Conclusion

Castlerock-Kulem catchment area has 24 species of anurans, of which 14 are endemic to the Western Ghats. Such diversity is comparable to other tropical moist forest sites across the Western Ghats. Castlerock is the type locality for two species of anurans, *Nyctibatrachus petraeus* and *Raorchestes bombayensis*. Many of the streams that cut across the existing railway line and vegetation on either side of the track are inhabited by various habitat specialist and endemic anurans. It is emphasized that presence of one critically endangered species - *Pseudophilautus amboli* and three endangered species *Pedostibes tuberculosus, Uperodon mormorata* and *Minervarya sahyadrensis* clearly indicates that the catchment area still has microhabitats required for these species to thrive. The proposed railway alignment could potentially affect habitat and breeding sites of many of the anurans listed in the report both in the short-term (construction phase) as well as the long-term (operative phase). It can also be argued that the presence of anurans closer to existing railway line and movement of locomotives may indicate the adaptive nature of anurans to human-modified environment. However, such arguments call for scientific studies and evaluation of impact of railway line on anuran behavioural and breeding biology as there is neither any baseline information on anurans that existed prior to the existing railway line nor any study on the impacts of existing railway line (short term or long term) on the species recorded.

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2. **Biju, S. D., S. Garg, K. V. Gururaja, Y. S. Shouche**, and **S. A. Walujkar. 2014**. DNA barcoding reveals unprecedented diversity in Dancing Frogs of India (Micrixalidae, Micrixalus): a taxonomic revision with description of 14 new species. Ceylon Journal of Science, Biological Sciences 43: 1- 87.
3. **Biju, S. D., S. Garg, S. Mahony, N. Wijayathilaka, G. Senevirathne,** and **M. Meegaskumbura. 2014.** DNA barcoding, phylogeny and systematics of Golden-backed frogs (Hylarana, Ranidae) of the Western Ghats-Sri Lanka biodiversity hotspot, with the description of seven new species. Conributions to Zoology. Amsterdam 83: 269–335.
4. **Gururaja, K.V. 2012.** A pictorial guide to frogs and toads of the Western Ghats. Gubbi Labs LLP.
5. **Padhye, A. D., N. Modak,** and **N. Dahanukar. 2014.** *Indirana chiravasi,* a new species of Leaping Frog *(Anura: Ranixalidae)* from Western Ghats of India. Journal of Threatened Taxa 6: 6293–6312.
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CHAPTER 11

SURVEY OF REPTILES

- Inputs from Jagadish Chittaragi

Introduction

Reptiles play a significant role in the ecosystem sustenance as links in food chains, bio-monitors in controlling insect pests and also as excellent ecological indicators owing to their high degree of sensitivity to even a minor change in the environment (Lips 1998; Roy 2002; Daniels, 2003). India harbors 518 species of reptiles which include 3 species of crocodiles, 34 species of turtles and tortoises, 202 species of lizards and 279 species of snakes belonging to 28 families recorded till to this date from India (Aegnals et al., 2012), among which Western Ghats comprise 203 species with 61% (124 spp.) endemism (Radhakrishnan & Rajmohana, 2012).

No comprehensive studies are conducted on snake diversity of the hitherto study area. Therefore, an attempt was made to fill this lacuna through the investigation to document the diversity of Reptilian fauna.

Methods:

Study area:

The study area was Castlerock (Joida Taluk, Karwar District, and Karnataka State) and Kulem (Sangem Taluk, South Goa District, and Goa State)

Survey:

A checklist of reptiles enumerated by actual sighting during the visual encounter survey (VES) method of Heyer *et al*. (1994); Crump and Scott, (1994); Doan, (2003); Rodda *et al*. (2007) coupled with *ad_ hoc* randomized walk was carried out along with active searches (Ganesh *et al*., 2012) by inspecting probable micro-habitats (*viz*., under fallen logs, rocks, leaf litter, tree holes, buttress inter-spaces and rock crevices). The sampling was done at different sites of the study area to record the reptile species during day and evening hours along the existing Castlerock- Kulem railway line. Specimens were, photographed and identified *in-situ*. During survey no specimen (dead individuals or materials) was collected or preserved, although the dead specimens were removed out of the line to avoid multiple counts of the same kill on the next survey.

Indirect Records

The study also included a few species of reptiles which were encountered opportunistically within the study area apart from selected survey sites are also presented in the checklist. Moreover, good photographs by local inhabitants and/or railway department staff as well as news reports (after confirmation) were also included in the checklist to record the maximum reptilian diversity of the study area (Ganesh *et al*., 2012).

Identification of Reptile Species

The species were identified on site or through photographs using available literature and field guides (Boulenger, 1890; Smith, 1943; Daniels, 2002; Whitaker and Captain, 2004, 2008).

Results and Discussion

The study recorded a total of 81 individuals of 27 species of reptiles belonging to 10 families, distributed over 20 genera (Table 2.6.1). The maximum number of species were observed from family Colubridae (n=10, 12.34%) followed by Viperidae with four species (n=04, 4.93%), Natricidae with three species (n=03, 3.7%), Gekkonidae, Agamidae, Elapidae with two species (2.4%) each, and Scincidae,

Uropeltidae, Varanidae and Pythonidae family with one species (1.2%) each. Among all species of reptiles recorded, a major share (16 species, 6 families) was contibuted by snakes. Out of these, *Naja naja, Bangarus caerulus, Daboia russulli, Timeresurus graminus*, *Timeresurus malabaricus* and *Hypnale hypnale* are venomous species.

Out of 27 species of reptiles, Lower Risk near threatened (LR-nt) were 59.25% (16 species), Lower Risk least concern (LR-lc) were 33.33% (09 species) Vulnerable (VU) was 3.7% (1 species) and Data deficient (DD) was 3.7% (1 species) under IUCN status of reptiles was recorded (Fig. 3). Common Garden Lizard *Calotes versicolor,* Roux's Forest Calotes *Calotes rouxii,* Bronze Grass Skink *Eutrophis macularia* Green Vine snake *Ahaetulla nasuta* and Indian Rat snake *Ptyas mucosus* were quite common in the study area. This report indicates that the area has rich reptile diversity.

This diversity is supported by the composition of uniquely diverse habitats of the study area from Dry-deciduous to Evergreen jungle as one move down from Castlerock to Kolem of Goa. The hitherto study on reptilian fauna also evidenced the presence of juveniles of various reptiles like Bronzeback tree snakes, Forest Calotes, Skinks and Oriental garden lizard *etc.* revealing their breading activities. Many of these reptiles (Table 2.6.1) were commonly observed near the vicinity of the railway line either for basking or for hiding and/or moving across fragmented habitats to meet their resources. Some of them were recorded killed by railway while crossing the line especially the snakes. During study **three snakes** (each of Checkered Keelback, Bonzeback Tree Snake and an Unidentified) and **one unidentified Lizard** as well as other fauna (Frogs, Rats and Birds) were found killed on railway line. Cutting and clearing vegetation altered the natural habitat of these secretive reptiles as well as other herpetofauna. Further, these individuals may happen to be prone for predation by their natural enemies and disturbed by anthropogenic activities (Onkar *et al*., 2014).

The study was carried out during the inactive period of reptiles (winter) where the intensity of the impact could not be assessed properly due to their high seasonal activity, secretiveness and less conspicuousness. The problem arises when the active period coincides with the railway traffic and other activities. Hence, we emphasize to study the impact of railway transport and related factors during the active period (Monsoon, June-August) which may help to arrive at precise inferences and recommendations.

No.	Scientific name	Common name	No. of Individuals	Conservation Status
I Family: Gekkonidae				
1	*Hemidactylus cf. brookii*	Brook's House Gecko	1	LR-lc
2	*Hemidactylus cf. frenatus*	Common House Gecko	3	LR-lc
II Family: Agamidae				
3	*Calotes versicolar*	Oriental Garden Lizard	9	LR-nt
4	*Calotes rouxii*	Roux's Forest Calotes	13	LR-nt
III Family: Scincidae				
5	*Eutrophis macularia*	Bronze Grass Skink	8	LR-lc
IV Family: Varanidae				
6	*Veranus bengalensis*	Bengal Monitor Lizard	4	Vu
V Elapidae				
7	*Bangarus caerulus*	Common Krait	5	LR-nt
8	*Naja naja*	Common Cobra	2	LR-nt
VI Viperidae				
9	*Vipera russelli*	Russell's Viper	1	LR-nt
10	*Hypnale hypnale*	Hump Nosed Pit Viper	3	LR-nt
11	*Timeresurus.malabaricus*	Malabar Pit Viper	2	LR-nt
12	*Timeresurus.graminus*	Bamboo Pit Viper	2	LR-nt
VII Colubridae				
13	*Ptyas mucosus*	Rat Snake	4	LR-nt
14	*Lycodon aulicus*	Common Wolf Snake	3	LR-lc
15	*Lycodon cf.travencoricus*	Travencore Wolf Snake	2	LR-nt
16	*Ahaetulla nasuta*	Green Vine Snake	3	LR-n
17	*Ahaetulla pulverulenta*	Brown Vine Snake	1	LR-nt
18	*Boiga beddomei*	Beddome's Cat Snake	1	DD
19	*Dendrelaphis tristis*	Common Bronzeback Tree Snake	1	LR-lc
20	*Dendrelaphis sp.*	Giri's Bronzeback Tree Snake	1	LR-nt
21	*Oligodon arnesis*	Common Kukri Snake	1	LR-lc
22	*Oligodon taeniolatus*	Russel's Kukri Snake	2	LR-lc
VIII Natricidae				
23	*Xenochrophis piscator*	Checkered Keelback	2	LR-lc
24	*Macropisthodon plumbicolor*	Green Keelback	3	LR-nt
25	*Amphisema stolatum*	Buff Striped Keelback	1	LR-nt
IX Uropeltidae				
26	*Uropeltis ellioti*	Elliot's Shield Tail	2	LR-lc
X Pythonidae				
27	*Python molurus*	Indian Rock Python	1	LR-nt
		Total	**81**	

Table 2.6.1. Checklist of Reptile species recorded in Castlerock-Kulem area

CHAPTER 12

Images of a few birds seen during the survey. ***A.*** *Chestnut Headed Bee Eater.*
B. *Legge's Hawk Eagle.* ***C.*** *Mountain Imperial Pigeon.* ***D.*** *Great Pied Hornbill.*
E. *Asian Fairy Blue Bird.* ***F.*** *Small Green Barbet.*
(All images except ***A*** *&* ***B*** *are from elsewhere & used for representational purposes only).*

IMPACT ON CAVITY NESTING BIRDS

Inputs from: Poornima Badrinath; Ramya Badrinath; Seshadri K S and Vidisha M. K

Background

While much of the land required to lay the new track is already owned by the South Western Railways, there are places in which the new alignment will deviate from existing line and here, several trees will be cut. A possible impact would be on tree-cavity nesting animals, especially birds.

There are estimates of tree loss done with data from vegetation sampling (interim report, 2013 and current report). The loss of tree specially >10and >60cm dbh would impact on the nesting of birds in the proposed project area.

It is here that the impact on avifauna becomes tangible. Many bird species, including several endemic to the Western Ghats, are found in that region and the impact of doubling the railway line could be through reduction of keystone food resources like *Ficus* spp. and nesting cavities on existing trees along the track that will be cut.

The Site Visit

A first visit to the site was made during September 2014. However, the time of the year being prone to onset of monsoon, heavy rainfall prevented our team from carrying out any field studies. Hence another visit was made during the non-monsoon period in May 2015. The team traversed the length of the existing track from Castlerock to Kulem and made a checklist of all birds observed. In order to quantify the impact of track doubling, the study team looked for nest cavities in trees and nests on trees on either side of the track and noted their presence. Each observation accompanied the geographic coordinates to aid in spatial analysis. Four observers were involved in this rapid assessment. For logistics, the surveys were a combination of walking on the track and on slow moving goods trains. In the goods train, the open brake van was used for full visibility and nests were located. The primary objective of this survey was to identify the number of nest cavities that would be affected to the proposed track doubling process.

Key findings:

- A total of 35 species of birds, belonging to 21 families were observed. 9 of them were endemic to the Western Ghats (Appendix 1).
- A total of 54 bird nest cavities in trees were observed along the 26 km long track. The occurrence of bird nest cavities varied with the habitat along the tracks. The nearest nest was about 1 m and the farthest being about 10 m away from the center of the track. Several trees had multiple nest cavities and were invariably large trees with wide girth.
- The nest cavity abundance was mapped on the existing railway track and a “heatmap” of their

abundance were computed. This showed us the potential areas where the likelihood of nesting cavities is high (Figure 2.7.2).

Fig. 2.7.1: Nest cavities observed. A: Nest of Chestnut Headed Bee Eater and B. Tree cavity nest of unknown species

- Endemic species like the Chestnut headed Bee Eater (*Merops leschenaulti*) were observed to be nesting along mud embankments in Castlerock station yard. Several tree hole cavities were possibly of the endemic Hornbills, of which three species were sighted

Challenges

The proposed doubling of the railway line can potentially cause damage to the protected forests on either side of the track, even if it is aligned in parallel. Some of these effects may spread beyond the railway track itself and lead to degradation of the habitat. Some of the potential challenges area also discussed:

1. Habitat loss, fragmentation and degradation: The expansion of the railway line will lead to destruction of 1.17 Ha of forests. This however, is the area lost to the railway line itself. Accounting for the damage caused from movement of construction material; dumping of construction waste and movement of construction personnel will lead to further loss of habitat. With trees being felled for track laying, the resources available for wildlife in terms of fruiting trees will be fragmented. The general quality of the habitat itself will deteriorate further with increased human movement.
2. Destruction of habitat for Schedule 1 species. The Great Indian Hornbill, listed in the Wildlife Protection Act of 1972. The loss of the forest for track doubling may affect the nesting of this species

Conclusions

The doubling of railway line between Castlerock and Kulem even though parallel to the existing track will affect nesting birds. This is because several trees along the track exist where bird nests were seen and these trees have potential nesting habitats. Apart from direct impact from loss of nesting cavities, secondary impacts can be caused by loss of fruiting trees like *Ficus sp.* and increased noise and traffic.

Recommendations

- Care should be taken to keep the number of trees to be cut to the bare minimum; if possible, the felling of the tree should be avoided at all costs.
- The immediate solution to mitigate the impact of track doubling on nesting birds and mammals would be to undertake habitat enrichment activities.
- Efforts need to be undertaken to contain the noise and smoke from the locomotives and this could be done by using electric locomotives or by planting trees of native species along the railway line so that they attenuate noise. Barricade for sound proofing may be erected n consultation with forest department.

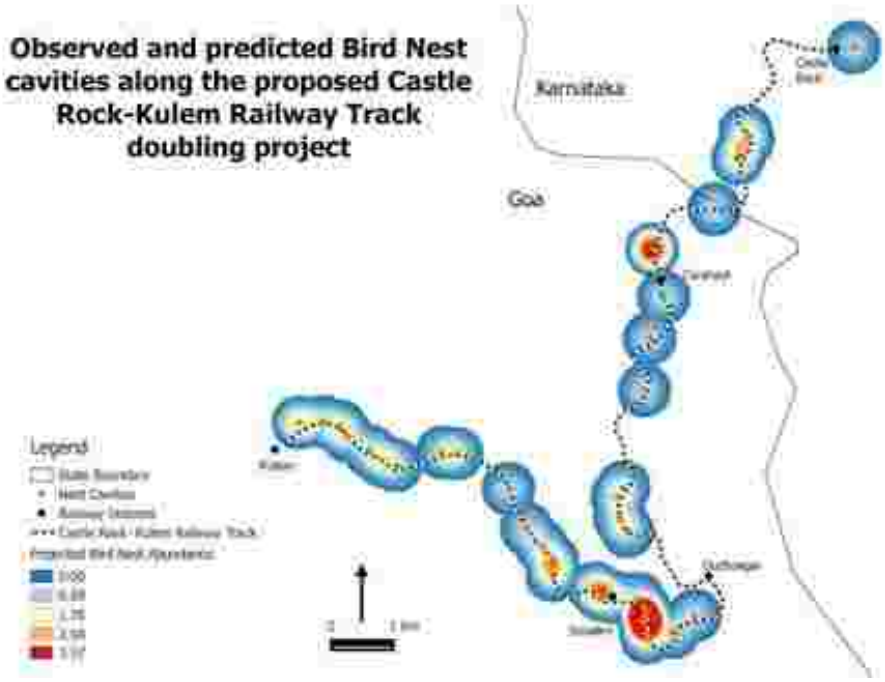

Figure 2.7.2: Map showing the study visit area. Heat Map generated based on the presence of Nest Cavities along the track to a buffer of 500 m. Parts of railway track passing through tunnels do not show any nests.

No.	Scientific name	Common name	No. of Individuals sighted	IUCN Status
	Accipitridae			
1.	*Ictinaetus malai ensis*	Black Eagle	3	LC
2.	*Spilornis coronatus*	Creasted Serpent Eagle	2	LC
3.	*Circaetus gallicus*	Short-toed Snake	1	LC
4.	*Nsaetus kelaarti*	Legge's Hawk Eagle	1	LC
	Bucerotidae			
5.	*Ocyceros griseus*	Malabar Grey Hornbill	2	LC
6.	*Anthracoceros coronatus*	Malabar Pied Hornbill	2	NT
7.	*Buceros* bicornis	Great Pied Hornbill	2	NT
	Columbidae			
8.	*Ducula bada*	Mountain Imperial Pigeon	10	LC
9.	*Tereron affinis*	Grey fronted green Pigeon	5	LC
	Corvidae			
10.	*Carvus macrorhynchos*	Large billed Crow	2	LC
	Cuculidae			
11.	*Herococcyx varius*	Common Hawk Cuckoo	1	LC
12.	*Centropus sinensis*	Greater Coucal	3	LC
	Dicaedae			
13.	*Dicaeum erythrohynchos*	Pale billed Flower Pecker	5	LC
	Halcyonidae			
14.	*Halcyon smyrnensis*	White throated Kingfisher	1	LC
	Irenidae			
15.	*Irena puella*	Fairy Blue Bird	3	LC
	Leiothrichedae			
16.	*Turdoides subrufa*	Rufous Babbler	2	LC
	Megalaimidae			
17.	*Megalaima viridis*	White-Cheeked Barbet	4	LC
18.	*Megalaima* malabarica	Malabar Barbet	1	LC
	Meropidae			
19.	*Merops Leschenaulti*	Chestnut headed Bee-eater	10	LC
20.	*Merops orientalis*	Small Green Bee-eater	2	LC
	Muscicapidae			
21.	*Myophonus horsfieldii*	Malabar Whistling Thrust	4	LC
22.	*Copsychus saularis*	Magpie Robin	2	LC
	Pellorneidae			
23.	*Alcippe poioicephala*	Brown-cheeked Fulvetta	1	LC
	Phasinidae			
24.	*Gallus sonnerattii*	Grey Jungle Fowl	1	LC
	Picidae			
25.	*Dinipium benghalense*	Lesser Flameback	3	LC
	Psittaculidae			
26.	*Psittacula columboides*	Malabar Parakeet	2	LC
27.	*Loriculus vernalis*	Hanging Parrot	10	LC
	Pycnonotidae			
28.	*Acritillas indica*	Yellow Browed Bulbul	11	LC
29.	*Hypsipetes ganees*a	Black Bulbul	4	Not recognised
30.	*Pycnonotus jocosus*	Red-Whiskered Bulbul	2	LC
	Stumidae			
31.	*Acridotheres fuscus*	Jungle Myna	1	LC
	Timaliidae			
32.	*Pomatorhinus horsfieldii*	Scimitar Babbler	2	LC
33.	*Rhopocichla atriceps*	Dark Fronted Babbler	1	LC
	Trogonidae			
34.	*Harpectes fasciatus*	Malabar Trogon	2	LC
	Zesteropidae			
35.	*Zosterops palpebrosus*	Oriental White-eye	2	LC
	Total		**120**	

Table 2.7.1: List of Birds sig sighted during the two day survey from Castle Rock to Kulem.

No.	Scientific name	Common name	No. of Individuals sighted	IUCN Status
	Bucerotidae			
1.	*Ocyceros griseus*	Malabar Grey Hornbill	2	LC
2.	*Anthracoceros coronatus*	Malabar Pied Hornbill	2	NT
	Leiothrichdae			
3.	*Turdoides subrufa*	Rufous Babbler	2	LC
	Megalaimidae			
4.	*Megalaima viridis*	White-Cheeked Barbet	4	LC
5.	*Megalaima* malabarica	Malabar Barbet	1	LC
	Muscicapidae			
6.	*Myophonus horsfieldii*	Malabar Whistling Thrust	4	LC
	Psittaculidae			
7.	*Psittacula columboides*	Malabar Parakeet	2	LC
	Trogonidae			
8.	*Harpactes fasciatus*	Malabar Trogan	2	LC
	Columbidae			
9.	*Tereron affinis*	Grey fronted green Pigeon	5	LC
	Total		**34**	

Table 2.7.2: *Birds endemic to the Western Ghats that were seen along the railway line during the two day survey.*

References:

1 **Raman T. S. 2011.** Framing ecologically sound policy on linear intrusions affecting wildlife habitats *Background paper for the National Board for Wildlife, Ministry of Environment and Forests, New Delhi.*

2 **Gururaja et al. 2014.** Environmental Impact Assessment of Castlerock-Kulem railway line doubling Poster based on EIA work, CISTUP, Bangalore, India.

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4 **Dorsey et al. 2015.** Ecological effects of railways on wildlife. Handbook of Road Ecology. van der Ree, R., Smith, D.J. & Grilo, C (eds.). John Wiley & Sons, Oxford. 552 pp. ISBN: 978-1-118-56818-7

CHAPTER 13

MAMMALIAN DIVERSITY

- Inputs from Mukti Roy

Introduction:

The Western Ghats harbor a fairly intact mammalian fauna typical of peninsular India. Of the 137 species of mammals described from the region, 16 species are endemic to the Ghats with 13 of them categorized as Threatened in the IUCN Red List (Nameer et al. 2001). The distribution of mammalian fauna in the Ghats is of course determined by a number of factors such as topography, temperature, rainfall, vegetation and the history of habitat disturbance, transformation and fragmentation. Mammals are usually among the taxa that are directly impacted by linear intrusions into their habitat; this is especially true of the larger mammals that are prone to collisions with vehicles on roads (Forman et al. 2003) or with trains along railway tracks (Gunderson & Andreasson 1998, Roy et al. 2009). With increased traffic with the doubling of the Castlerock-Kulem railway line, the risks of collisions of mammals with trains would automatically increase and, thus, mitigation measures will have to be built in at the time of design and construction of the second line.

Objectives:

i) Prepare a list of the larger mammal species in this area

ii) Map the major locations of crossing points for the larger mammals along the existing track that is proposed to be doubled.

Methods:

Study area:

The study area was Castlerock (Joida Taluk, Karwar District, and Karnataka State) and Kulem (Sangem Taluk, South Goa District, and Goa State)

Methods

Indirect methods:

I) Belt transects: Belt transect (100m*10m) was laid and walked for recording animal signs (foot print, track sign, feeding sign, scat/pellets/faeces, and scrapes/stretches) (Vinod and Sathya 1998, Shershta and Basnet 2005, Archana *et al.*2007, Sathyakumar *et al.* 2011). Also direct sightings were recorded of all mammal encounters during the survey period.

ii) Camera traps: Camera traps were deployed on potential paths of animals (as determined from their signs) in order to get photograph evidence of mammal species present (Karanth and Nichols 1998, Karanth et al. 2000, Varma et al 2006, Marc et al. 2012).. Five camera trap were used for this rapid survey.

Results:

Indirect signs: A total of 25 transects, each measuring (100m*10m) were laid randomly across different vegetation types. In these transects forty nine (100) animal signs (Dung/pellet, scat, den, digging, scratch mark) were found. Sambar deer pellets constituted 24%, langur scat (9%), porcupine den (8%), porcupine digging signs (8%) and civet cat (scats) 7% among the more commonly encountered signs (Table 2.8.1).

Besides this, outside the transects scats of dhole (Wild dogs) were encountered at two locations (close to Caranzool village near the forest) and leopard scat (near Soneleum Railways Station). In agricultural

fields of Caranzool village sambar deer pellets, black-naped hare, gaur hoof mark and dung, porcupine pellet, and civet cat pellets were commonly found. In this sanctuary Bhoma and Moida areas were also trekked and various animal signs (pellet, scat, and foot print) found. Interestingly, one tiger scat was also found in this place. The area north of the highway was also visited once (Tramisula Road). The staff here reported dhole feeding on sambar kill. We also found sambar remnants in this place. The Railway staff of Sonaleum also reported that they have seen tiger/leopard crossing the Railway track. The Range Officer Mollem also informed that a four-horned antelope was rescued from a village area near Colem. The staff of Aranayak Forest Complex (Mollem Range) also informed that last year one sambar was killed in a railway accident and there were three Gaur killed at Caranzol village due to illegal electrocution. Details of indirect signs survey are given in *Fig. 2.8.1, Fig. 2.8.2, Fig. 2.8.3* and *Fig.2.8. 4.*

Common Name	Scientific Name	Sign	No	%
Sambar	*Rusa unicolor*	Pellet	24	24.00
Langur	*Semnopithecus entellus*	Scat	9	9.00
Porcupine	*Hystrix indica*	Digging	8	8.00
Civet cat	*Viverra zibetha*	Scat	7	7.00
Bison	*Bos gaurus*	Dung	6	6.00
Porcupine	*Hystrix indica*	Pellet	5	5.00
Sloth bear	*Melursus ursinus*	Digging	5	5.00
Sloth bear	*Melursus ursinus*	Scat	5	5.00
Gaur	*Bos gaurus*	Hoof mark	4	4.00
Otter	*Lutra lutra*	Scat	4	4.00
Sloth bear	*Melursus ursinus*	Digging	2	2.00
Pangolin	*Manis crassicaudata*	Scat	2	2.00
Bonnet macaque	*Macaca radiata*	Scat	1	1.00
Malabar giant squirrel	*Ratufa indica*	Nest	1	1.00
Malabar giant squirrel	*Ratufa indica*	Scat	1	1.00
Palm civet	*Paradoxurus hermaphroditus*	Scat	1	1.00
Porcupine	*Hystrix indica*	Thorn	1	1.00
Rodent borrow		Borrow	1	1.00
Leopard	*Panthera pardus*	Scratch	1	1.00
Unknown pellet_1		Pellet	1	1.00
Unknown scat_2		Scat	1	1.00
Unknown scat_3		Scat	1	1.00
Unknown scat-4		Scat	1	1.00

Table 2.8.1. Animal signs recored along the transects in the proposed project site.

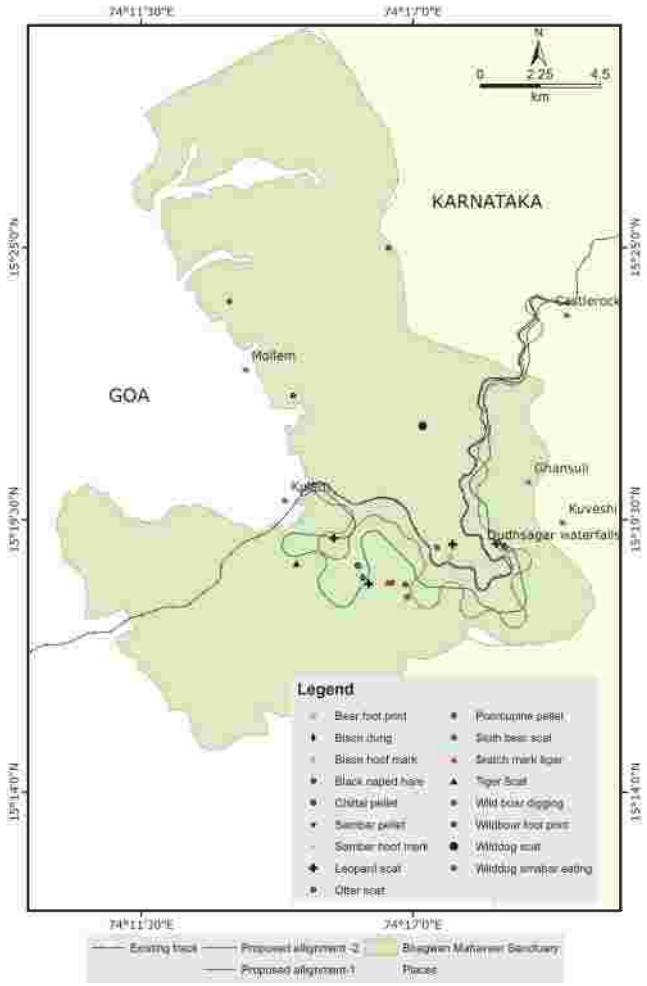

Fig 2.8.1. Indirect signs of mammals outside the transects in Bhagwan Mahavir Wildlife Sanctuary, Goa

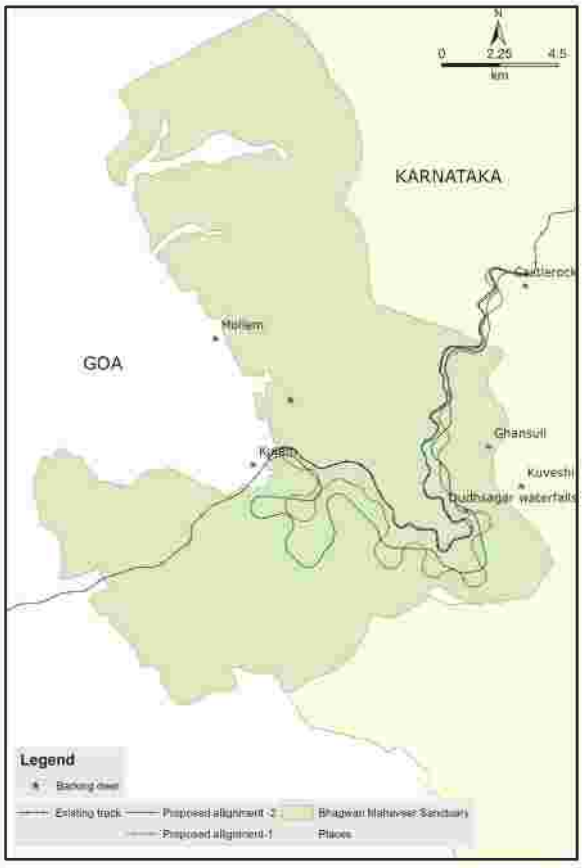

Fig 2.8.2. Evidence of barking deer at proposed project site during the field survey

Fig 2.8.3. Evidence of civet cat at Bhagwan Mahavir Wildlife Sanctuary, Goa during field survey

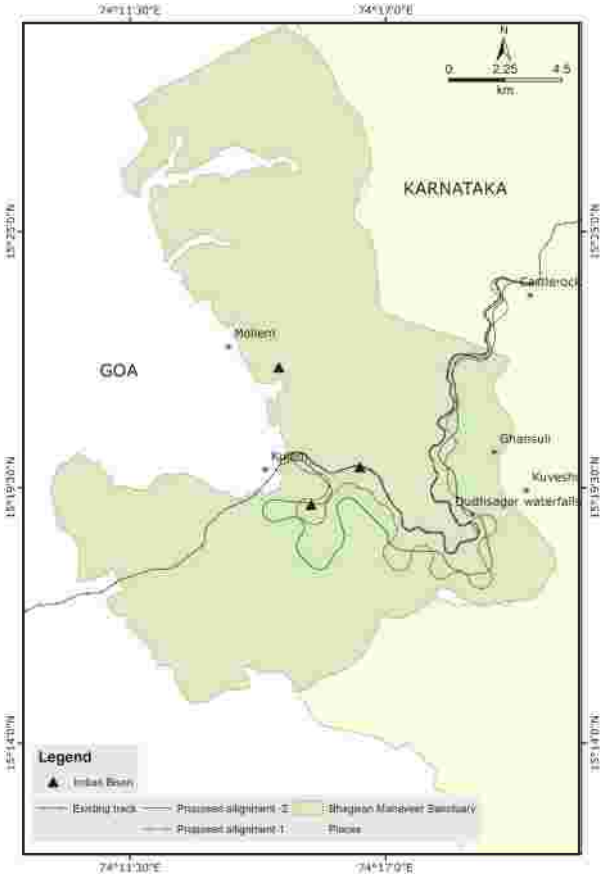

Fig 2.8.4. Evidence of Indian gaur at Bhagwan Mahavir Wildlife Sanctuary, Goa.

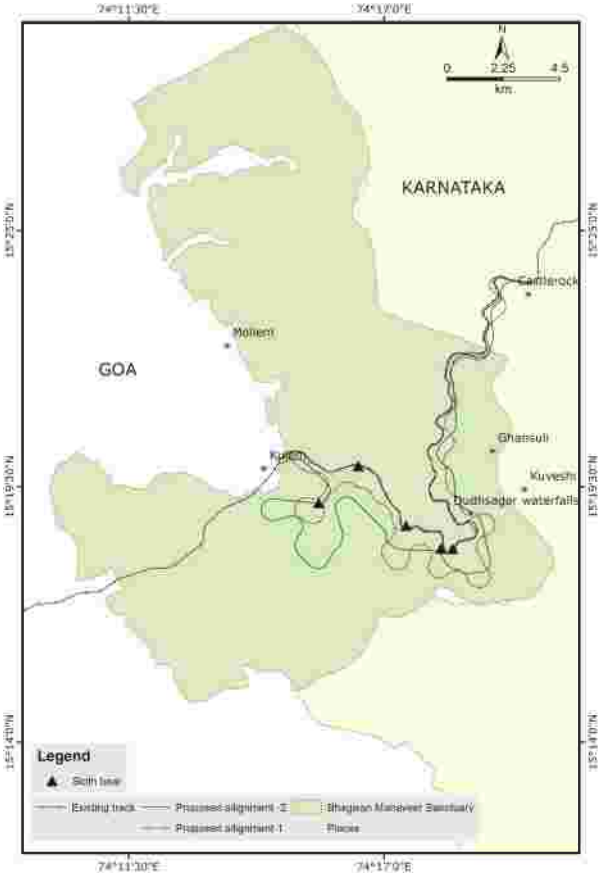

Fig 2.8.5. Evidence of Sloth Bear at Bhagwan Mahavir Wildlife Sanctuary, Goa.

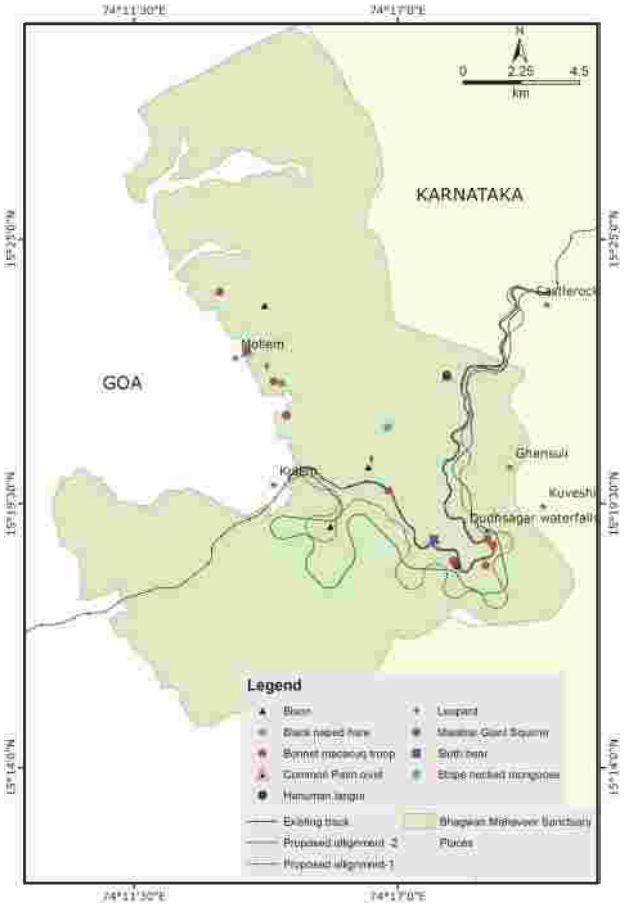

Fig 2.8.6. Locations of direct sighting of mammals at Bhagwan Mahavir Wildlife Sanctuary, Goa during the field survey

Direct Sightings:

There were a total of 37 animal sightings done during (31.03.2013 - 10.04.2013; 23.04.2013 - 28.04.13 and 09.05.20113 - 13.05.2013) out of which Bonnet macaque (8 times), Malabar giant squirrel (8), Hanuman langur troop (7) were recorded most frequently (*Table 2.8.2* and *Fig 2.8.6*).

Animal sighted	Scientific name	No	%
Bonnet macaque	*Macaca radiata*	8	21.6
Malabar Giant Squirrel	*Ratufa indica*	8	21.6
Hanuman langur	*Semnopitheaus entellus*	7	18.9
Gaur	*Bos gaurus*	6	16.2
Black naped hare	*Lepus nigricollis*	2	5.4
Common palm civet	*Paradoxurus hermaphroditus*	2	5.4
Leopard	*Panthera pardus*	2	5.4
Sloth bear	*Melursus ursinus*	1	2.7
Stripe necked mongoose	*Herpestes vitticollis*	1	2.7
		37 nos.	

Table 2.8.2: Direct sighting of mammals in the study area

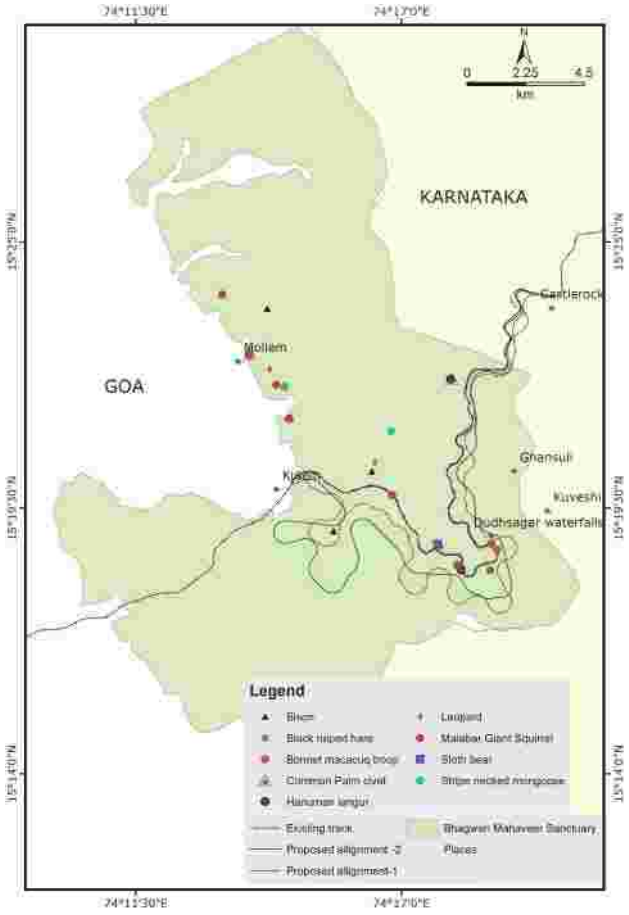

Fig 2.8.6. Locations of direct sighting of mammals at Bhagwan Mahavir Wildlife Sanctuary, Goa during the field survey

Camera trapping:

Five camera traps were placed in the Dudhsagar area (03.04.2013 - 05.04.2013) and Caranzool area (06.04.2013 - 08.04.2013) for a total of 6 days. Five mammal species were recorded in the camera traps (Table 2.8.3). Indian porcupine was by far the most commonly recorded animal (46 times), followed by wild boar (5 times), small Indian civet (once), mouse deer (2 times), and brown palm civet (once). Five camera traps were placed in the Arnnyak and Moida and Sonealuem areas (24.04.2013 - 25.04.2013) and Caranzoll area (27.04.2013 - 28.04.2013); in these gaur herd (1), wild boar (3), and sloth bear (2) were recorded. Four camera traps were kept in Aranyak and Sonaleun areas (10.05.2013 - 11.05.2013), and five cameras kept in the Arnayak and Caranzool areas (12.05.13 - 13.05.13); no photographs were obtained here, possibly because of camera malfunction. The details of camera trapping are given in Table 2.8.3 and Fig 2.8.7.

We also walked along the track to get an idea of animal crossing points so that they can be included in the management plan to mitigate the death of animals due to accidents. The points (GPS locations) are given in the table 2.8.4.

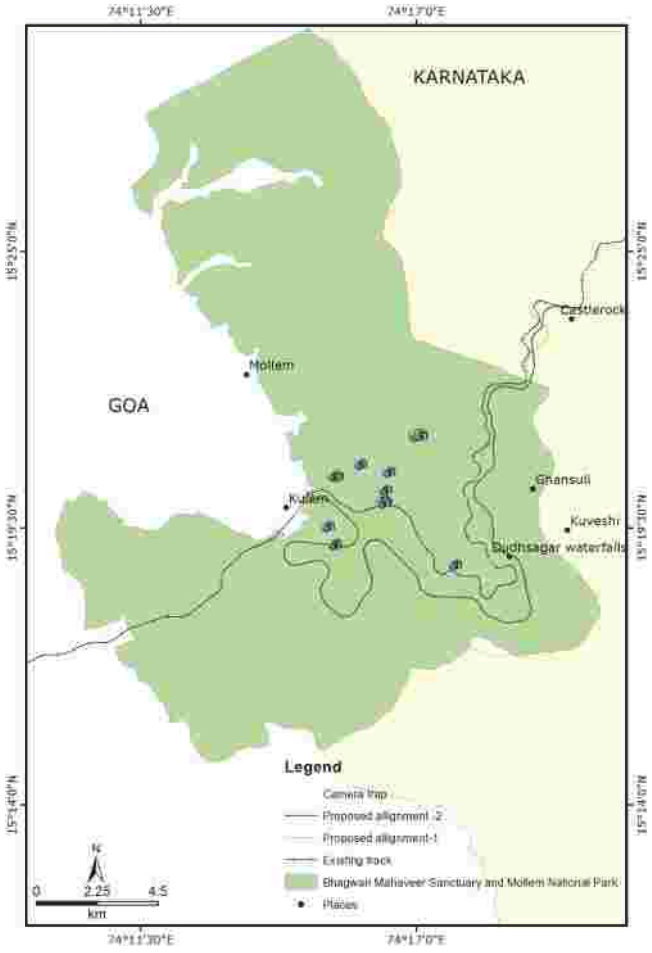

Fig 2.8.7. Camera trap locations at Bhagwan Mahavir WLS

Camera trap pictures recorded at Bhagwan Mahavir WLS, Goa

Brown Palm civet (Paradoxurus jerdoni)

Mouse deer (Moschiola indica)

Camera trap pictures recorded at Bhagwan Mahavir WLS, Goa

Indian Porcupine (Hystrix indica)

Indian Porcupine (Hystrix indica)

Animal Movement Paths or Crossing Points:

We walked along the track from Castlerock to Kulem and recorded visible crossing points based on animal signs and paths. Forty-one Animal Crossing Points were recorded. Castlerock – Caranzool: 3 places; Caranzool—Dushsagar: 2 places, Dudhsagar-—Sonaleum 6 places, Sonaleum—Kulem: 29 places; beyond Kulem 1 animal crossing /movement path was found. The details are given below in Fig 2.8.8.

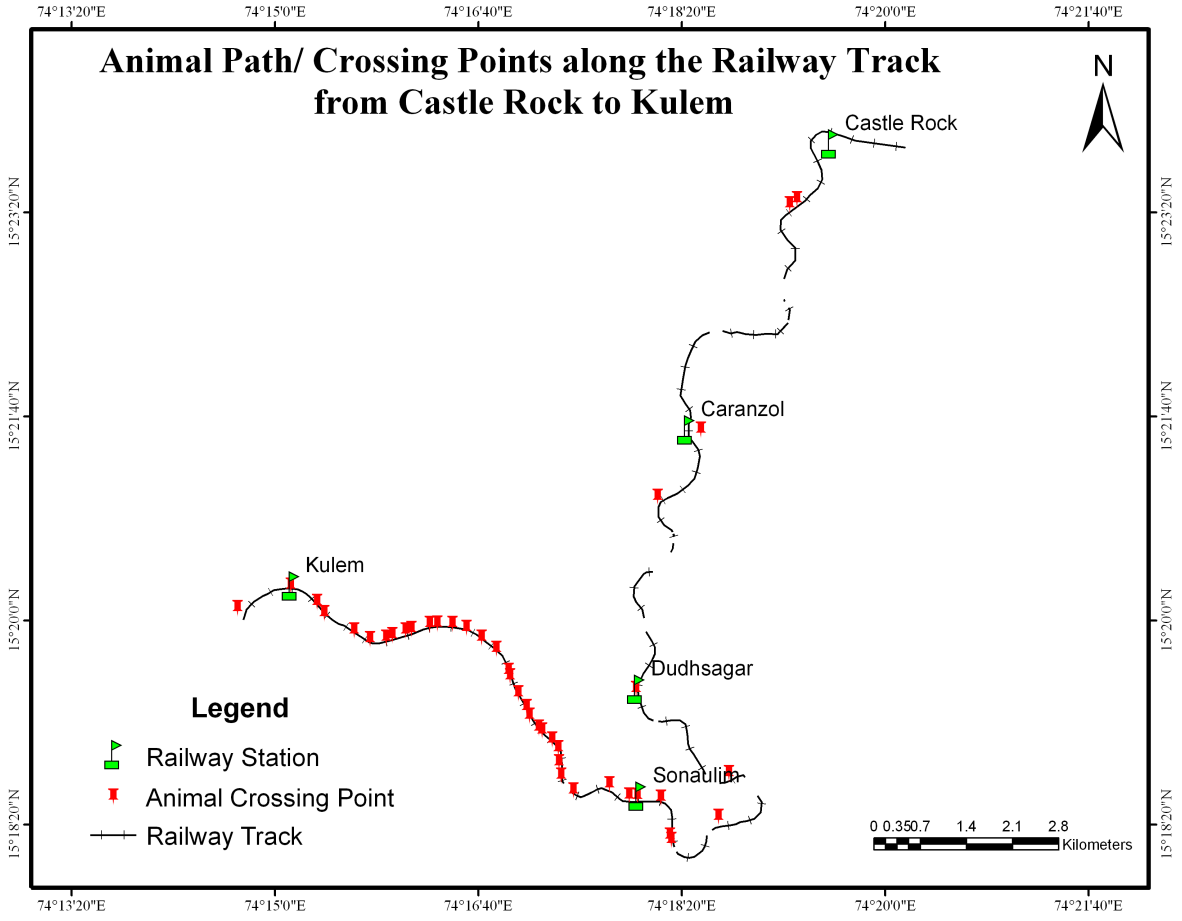

Fig 2.8.8. Animal paths/ crossing points / along the railway track between Castlerock and Kulem

Sl No.	From To	No of nights	Area of camera trap location	Camera No.	GPS	GPS	Remarks
1	3-Apr-13 5-Apr-13	3	Dudhsagar area	D_39	15.35560	74.28303	1st trip
2	3-Apr-13 5-Apr-13	3	Dudhsagar area	D_165	15.35585	74.28490	1st trip
3	3-Apr-13 5-Apr-13	3	Dudhsagar area	D_181	15.35548	74.28322	1st trip
4	3-Apr-13 5-Apr-13	3	Dudhsagar area	D_192	15.35587	74.28453	1st trip
5	3-Apr-13 5-Apr-13	3	Dudhsagar area	D_UK	15.33376	74.27315	1st trip
6	6-Apr-13 8-Apr-13	3	Caranzool area	D_39	15.35604	74.28304	1st trip
7	6-Apr-13 8-Apr-13	3	Caranzool area	D_165	15.35547	74.28321	1st trip
8	6-Apr-13 8-Apr-13	3	Caranzool area	D_181	15.35577	74.28453	1st trip
9	6-Apr-13 8-Apr-13	3	Caranzool area	D_192	15.35577	74.28490	1st trip
10	6-Apr-13 8-Apr-13	3	Caranzool area	D_UK	15.31300	74.29635	1st trip
11	24-Apr-13 26-Apr-13	3	Moida & Arnayak	D_39	15.31948	74.25632	2nd trip
12	24-Apr-13 26-Apr-13	3	Moida & Arnayak	D_165	15.34217	74.25697	2nd trip
13	24-Apr-1326-Apr-13	3	Moida & Arnayak	D_181	15.32556	74.25392	2nd trip
14	24-Apr-1326-Apr-13	3	Moida & Arnayak	D_192	15.34234	74.25607	2nd trip
15	24-Apr-1326-Apr-13	3	Moida & Arnayak	D_UK	15.31981	74.25629	2nd trip
16	27-Apr-1328-Apr-13	2	Caranzool & Sonaleum	D_39	15.33767	74.27316	2nd trip
17	27-Apr-1328-Apr-13	2	Caranzool & Sonaleum	D_165	15.34363	74.27421	2nd trip
17	27-Apr-1328-Apr-13	2	Caranzool & Sonaleum	D_181	15.33441	74.27216	2nd trip
17	27-Apr-1328-Apr-13	2	Caranzool & Sonaleum	D_192	15.33332	74.27248	2nd trip
17	27-Apr-1328-Apr-13	2	Caranzool & Sonaleum	D_UK	15.34613	74.26478	2nd trip
18	10-May-1312-May-13	2	Aranayak & Caranzoll	D_39	15.33767	74.27316	3rd trip
19	10-May-1312-May-13	2	Aranayak & Caranzoll	D_165	15.34363	74.27421	3rd trip
20	10-May-1312-May-13	2	Aranayak & Caranzoll	D_181	15.33441	74.27216	3rd trip
21	10-May-1312-May-13	2	Aranayak & Caranzoll	D_192	15.33332	74.27248	3rd trip
22	12-May-1313-May-13	1	Aranayak & Caranzoll	D_39	15.33767	74.27316	3rd trip
23	12-May-1313-May-13	1	Aranayak & Caranzoll	D_165	15.34363	74.27421	3rd trip
24	12-May-1313-May-13	1	Aranayak & Caranzoll	D_181	15.33441	74.27216	3rd trip
25	12-May-1313-May-13	1	Aranayak & Caranzoll	D_192	15.33332	74.27248	3rd trip
25	12-May-1313-May-13	1	Aranayak & Caranzoll	D_Uk	15.34613	74.26478	3rd trip

Table 2.8.3. Details of camera trap placed at nights at the Bhagwan Mahavir WLS

S_No	Date_	From_	To	Latitude	Longitude
1	26-Nov-14	Castle Rock Stn	Tunnel No1	15.39064	74.32130
2	26-Nov-14	Castle Rock Stn	Tunnel No2	15.38996	74.32032
3	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30944	74.29955
4	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30918	74.30274
5	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30918	74.30274
6	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30400	74.30397
7	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30341	74.30414
8	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30657	74.31058
9	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.31250	74.31203
10	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.32400	74.29932
11	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.35013	74.30230
12	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.35927	74.30818
13	27-Nov-14	Sonaleum Rly Stn	Karanzool Rly Stn	15.30947	74.29842
14	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31100	74.29571
15	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31018	74.29079
16	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31218	74.28909
17	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31401	74.28880
18	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31590	74.28873
19	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31711	74.28789
20	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31833	74.28650
21	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.31870	74.28605
22	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.32034	74.28479
23	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.32154	74.28438
24	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.32337	74.28325
25	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.32570	74.28215
26	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.32642	74.28193
27	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.32942	74.28026
28	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33095	74.27823
29	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33231	74.27618
30	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33281	74.27425
31	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33289	74.27222
32	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33285	74.27115
33	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33216	74.26865
34	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33195	74.26789
35	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33128	74.26606
36	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33098	74.26521
37	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33076	74.26300
38	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33192	74.26083
39	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33431	74.25676
40	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33584	74.25576
41	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33805	74.25217
42	28-Nov-14	Sonaleum Rly Stn	Kulem Rly Stn	15.33498	74.24493

Table 2.8.4: Geo-cordinates of animal crossing location along the existing railway track in the proposed project area

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APPENDIX-2:

List of mammals recorded at Bhagwan Mahavir WLS, Goa, by direct indirect & camera trap methods:

Sl. No.	Name of the Animal	Scientific Name	Code	Code-1	Remarks
1	Tiger	*Panthera tigris*	Carnivore	Large mammal	Indirect
2	Leopard	*Panthera pardus*	Carnivore	Large mammal	Indirect & Direct
3	Gaur	*Bos gaurus*	Herbivore	Large mammal	Indirect, Direct and Camera trap
4	Sambar deer	*Rusa unicolor*	Herbivore	Large mammal	Indirect
5	Chital deer	*Axis axis*	Herbivore	Large mammal	Indirect
6	Barking deer	*Muntiacus muntjak*	Herbivore	Large mammal	Indirect
7	Wild boar	*Sus scrofa*	Herbivore	Large mammal	Indirect, Direct and Camera trap
8	Langur	*Semnopithecus entellus*	Herbivore	Large mammal	Indirect & Direct
9	Bonnet macaque	*Macaca radiata*	Herbivore	Small mammal	Indirect & Direct
10	Sloth bear	*Melursus ursinus*	Omnivore	Large mammal	Indirect, Direct and Camera trap
11	Otter	*Lutra lutra*	Carnivore	Large mammal	Indirect
12	Indian Pangolin	*Manis crassicaudata*	Carnivore	Large mammal	Indirect
13	Asiatic Wild dog	*Cuon alpinus*	Carnivore	Small mammal	Indirect
14	Asian palm civet	*Paradoxurus hermaphroditus*	Carnivore	Small mammal	Indirect
15	Indian Porcupine	*Hystrix indica*	Carnivore	Small mammal	Indirect , Camera trap
16	Black naped hare	*Lepus nigricollis*	Herbivore	Small mammal	Direct
17	Small Indian Civet	*Viverra zibetha*	Herbivore	Small mammal	Indirect & Direct
18	Malabar giant squirrel	*Ratufa indica*	Herbivore	Small mammal	Indirect & Direct
19	Stripe necked mongoose	*Herpestes vitticollis*	Herbivore	Small mammal	Direct
20	Brown Palm civet	*Paradoxurus jerdoni*	Herbivore	Small mammal	Camera trap
21	Mouse deer	*Moschiola indica*	Herbivore	Small mammal	Camera trap
22	Fourhorned antelope	*Tetracerus quadricornis*	Herbivore	Small mammal	Indirect (Mollem Range officer)
23	Flying squirrel	*Petaurista philippensis*	Herbivore	Small mammal	Indirect (forest Staff rescued animal)

SECTION - III

SOCIO-ECONOMIC PROFILE

CHAPTER 14

ECOSYSTEM SERVICES & ECONOMIC VALUATION OF THE FORESTS

- Inputs from: H. S. Suresh

There is growing interest in economic valuation and analysis of the goods and services provided by natural ecosystems (Costanza, 2000, Farber et al 2002, Chee, 2004). Such goods and services are often underestimated during the process of decision making in developmental projects. Ecosystem goods and services include water, forage, timber, biomass, fiber, pharmaceuticals and industrial products. The services can be organized into different sectors such as production of goods, regeneration services, stabilizing services, life-fulfilling services, preservation of ecological and other components of natural ecosystems.

Ecosystem services could be organized into three broad sectors such as production services, regulation services and cultural services. The following table summarizes (following Hein et al. 2006) examples of ecosystem services provided by an ecosystem under each category.

Category	Definition	Examples of the services
Production services	Includes goods and services produced in the ecosystem	Food Fodder Fuel (including wood and dung) Timber, fiber and other raw material Biochemical and pharmaceutical resources Genetic material
Regulation services	Capacity of the ecosystem to regulate climate, hydrological, biochemical cycles, and a variety of biological process	Carbon sequestration Biological nitrogen fixation Regulation of stream and river flows Regulation of species reproduction Regulation of pests and pathogens Pollination Protection against noise and dust Regulation of erosion and sedimentation
Cultural services	Relate to the benefits that people obtain from ecosystem such as recreation, relaxation and spiritual reflection	Cultural, historical and religious heritage sites Provision of educational and scientific information Provision for opportunities for recreation and tourism

We attempt to list some of the services provided by this forest in the proposed project area under various categories. All plant species provides common services such as replenishing oxygen, sequestering carbon and bio-diversity value which we could not quantify. There are several species with multi uses to people while several species have no known direct value.

There several species that provides timber for both domestic and commercial purposes. Some of the species exploited largely for timber in earlier times include *Calophyllum sp., Xylia xylocarpa, Terminalia paniculata, Hopea ponga, Terminalia crenulata* and *Palaquium ellipticum.*

The timber volume of several species estimated in this region are: *Acacia auriculiformis* (63.6 m^3/ha), *Agalaia sp.* (32.7 m^3/ha), *Albizia lebbeck* (4.17 m3/ha), *Aphanamixis polystachya* (2.44 m^3/ha), *Alstonia scholaris* (72.1 m3/ha), *Calophyllum sp.* (332.1 m^3/ha), *Artocarpus integrifolia* (11.2 m^3/ha), *Dalbergia latifolia* (19.94 m^3/ha), *Diospyros sp.* (49.3 m^3/ha), *Hopea ponga* (269.9 m^3/ha), *Lagerstroemia microcarpa* (164.7 m^3/ha), *Lophopetalum wightianum* (308.2 m^3/ha), *Memecylon sp.* (19.9 m^3/ha), *Palaquium ellipticum* (2.80 m^3/ha), *Pterocarpus marsupium* (7.04 m^3/ha), *Syzygium sp.* (182.8 m^3/ha), *Terminalia paniculata* (201.0 m^3/ha), *Terminalia crenulata* (94.8 m^3/ha), *Toona ciliate* (62.2 m^3/ha), *Xylia xylocarpa* (157.9 m^3/ha) and *Xantolis tomentosa* (8.4 m^3/ha).

Species that are of medicinal value (Indian Materia Medica, Nadkarni, 1985) include (the relative abundance of a given species in the project area is given in parathensis): *Alangium lamarkii* (frequent), *Alstonia scholaris* (frequent), *Arenga wightii* (rare), *Callicarpa tomentosa* (frequent), *Casearia esculenta* (frequent), *Cassia fistula* (frequent), *Diospyros embrypteris* (frequent), *Embelia ribes* (frequent), *Ficus benghalensis* (ocassional), *Ficus glomerata* (frequent), *Garcinia indica* (frequent), *Holarrenha antidysentreica* (frequent), *Helicteres isora* (frequent), *Lasiosiphon eriocephalus* (rare), *Mallotus philippenensis* (common), *Nothopodytes foetida* (common), *Pterocarpus marsupium* (rare), *Phyllanthus emblica* (frequent), *Syzygium cumini* (common), *Strychnos nux-vomica* (frequent), *Terminalia bellerica* (frequent), *Toddalia asiatica* (rare), *Xantolis tomentosa* (common). Description of the medicinal use, parts used in preparation of medicine and methods of preparation are beyond the scope of this report.

There are several species that yield non-timber forest produce (minor forest produce). Collection within the protected area is however banned. People may collect some of these products for their domestic consumption. They include species such as *Acacia concinna* (common), *Alangium lamarkii* (frequent), *Antiaris toxicaria* (rare), *Aporusa lindleyeana* (common), *Artocarpus integrifolia* (common), *Bridelia retusa* (frequent), *Buchanania lanzan* (rare), *Calicarpa tomentosa* (frequent), *Calophyllum inophyllum* (frequent), *Canarium strictum* (rare), *Carissa carandas* (frequent), *Caryota urens* (frequent), *Cinnamomum malabathrum* (frequent), *Cinnamomum verum* (frequent), *Dichapetalum gelanoides* (ocassional), *Garcinia indica* (frequent), *Holarrenha antidysenterica* (frequent), *Mallotus philippenensis* (common), *Mammea suriga* (ocassional), *Myristica malabarica* (frequent), *Pandanus odaratissma* (ocassional), *Pongamia glabra* (frequent), *Pterocrapus marsupium* (rare), *Scheichera oleosa* (common), *Sterculia foetida* (frequent), *Strychnos nux-vomica* (frequent), *Xantolis tomentosa* (common). This is however not an exhaustive list of species which yield non-timber forest produce from the project area.

Some of the endemic species that are commonly seen include *Diospyros paniculata*, *Holigarna arnottiana, Polyalthia fragrans* and *Mangifera indica*. *Actinodaphne angustifolia, Ancistrocladus heyneanus, Calophylum apetalum, Diospyros pruriens, Garcinia gummi-gutta* and *Myristica malabarica*. Rare endemics are *Arenga wighti* (palm), *Cryptoarya boudillnii, Litsea stocksii* and *Palaquium ellipticum*. Large proportion of species that are rare have distribution restricted in the Indian mainland.

Another important ecosystem service provided by several species is carbon storage. Species such as *Xylia xylocarpa, Lagerstroemia microcarpa, Terminalia paniculata, Terminalia crenulata, Lophopetalum wightianum, Dalbergia latifolia, Hopea ponga* which are hardwoods and store considerable amount of carbon. We lack data on growth rate for many species hence we cannot estimate the carbon sequestration rates for many species. However, we have estimated the total carbon stocks of these forests as half of the above ground biomass

Other species that add to ecosystem services other than the anthropogenic value are *Ficus sps.* that provide resources (fruits) to avifauna and mammals during lean season. Several species that bear fleshy fruits which are palatable to mammals such as *Mangifera indica, Syzygium cumini, Garcinia sp., Scolopia crenata, Grewia tiliifolia, Myristica sp.* (arils), *Schleichera oleosa, Phylanthis emblica, Artocarpus integrifolia, Terminalia bellerica, Careya arborea, Artocarpus lakoocha, Aporusa lindleyeana*, *Nothopegia clobrookeana*. *Ziziphus sp.* Species that produce profuse pollen for bees include *Memecylon umbellatum, Pongamia piñata, Symplocos sp*., *Tetrameles nudiflora*, and *Terminalia bellerica*. Several species provide nesting sites for birds, bats and other small mammals.

The proposed project area has considerable potential for tourism. Important recreation points are Devil's canyon view point and Dudhsagar waterfalls. Devil's canyon view point is a large rock formation with puddles of the river Mandovi that is supposed to be a good spot for watching wildlife. Dudhsagar waterfall on the river Mandovi is one of the tallest falls in India (310 meters). There are hundreds of vehicles that ply between Kulem and Dudhsagar during the summer months. It is one of the major sources of revenue for the people of Kulem.

Mahadev temple at Tambdi Surla is another place of cultural significance. This temple is a little interior and attracts several pilgrims across the state. This temple was built by Hemadri, Minister of the Yadava King Ramachandra in the Hemadpanthi (Jain) style. It is situated on the banks of the river Surla. It is considered as the only specimen of Kadamba-Yadav in basalt stone architecture in Goa. This temple is dedicated to Lord Mahadev and bears resemblance with temples in Aihole (Karnataka). There are no other places or artifacts that have cultural, historical or religious significance in the project area. Despite the invasion of Goa, this temple has survived because of its location deep inside the forest. Tourism has to be regulated in order to minimize disturbance to wildlife and direct negative impacts on the environment.

CHAPTER 15

SOCIO-ECONOMIC SURVEY

Prepared for the Indian Institute of Science, Bengaluru
By:

Gubbi Labs LLP

BANGALORE

SOCIO-ECONOMIC SURVEY

The Issue

In 2010, the Ministry of Railways approved the doubling of railway line measuring about 352.28 km, between Hospet-Hubli-Londa-Vasco. The proposed doubling will be carried out in two phases. While the first phase is already underway, the second phase, measuring 108 km between Tinaighat-Vasco is being planned. A part of this route falls between Castlerock in Karnataka to Kulem in Goa. This track is about 26 km long and passes through Anshi Dandeli Tiger Reserve, Sri Bhagwan Mahaveer Jain Wildlife Sanctuary and Mollem National Park in Karnataka and Goa respectively is being planned. The railway line between Castlerock-Kulem has a ruling gradient of 1 in 37 and the proposed line is to attain a gradient of 1 in 60. In order to achieve this reduced gradient, the new line will have to be realigned and will increase the length from ca. 26 km to ca. 39 km. This proposed doubling work s aimed to assuage the traffic on the existing route and increase number of passenger and freight trains to facilitate efficient transport of coal and iron Ore.

This proposed development work being in the Bio-diversity Hotspot of the Western Ghats, naturally causes concern among ecologists and conservation practitioners. Vast expanses of the Western Ghats have already been converted to non-forestry purposes, in particular to mines, dams, roads and railway lines. Any further expansion of such human modified landscapes will have profound effects on the ecosystems. To mitigate the impact on bio-diversity, the proposed line is aligned to pass parallel to the existing track to a large extent. However, in spite of this, there is an estimated 1.17 ha of forest loss. Though the forest loss appears benign, it is significant as the destruction will occur within three protected areas.

The Context

The following is extracted from letter No. RVNL/SBC/HPT-TGT/Environment dated 02-07-2013 sent by Mr. Alok Tiwari, Chief Project Manager, Rail Vikas Nigam Limited, Bangalore to the Additional Principal Chief Conservator of Forests/Wildlife, Bangalore.

"*The alignment of proposed Railway line form Tinaighat-Castle Rock is parallel to existing alignment with centre to centre distance of 5.3 m. The alignment beyond Castlerock up to Kulem is far away from the existing alignment to ease out the grade from existing 1 in 37 to 1 in 60.....*

... In order to execute the doubling parallel to existing alignment, there is absolute minimum requirement of 1.17 Ha of land between chainage km 21/200 to 22/900 km in Castle Rock Wildlife range which is under jurisdiction of Dandeli-Anshi Tiger Reserve."

In order to quantify the impact of this project and determine its feasibility, the Indian Institute of Science carried out a socio-economic impact assessment in the affected settlements through a questionnaire. The questionnaire was designed to capture the responses from the residents/citizens of the four key settlements: Castlerock, Caranzol, Sonalim and Kulem. The same is enclosed in Annexure A. A total of 60 responses were gathered by enumerators in these settlements that was carried out during 15th – 18th May 2015.

Earlier, the Centre for Infrastructure Sustainable Transport and Urban Planning along with the Civil Engineering Department conducted an impact assessment focusing on the Geo-technical and Geological aspects of the doubling. A bird survey and other ecological investigations are also carried out in parallel led by the Centre for Ecological Sciences, Indian Institute of Science and other researchers.

The Assessment

Demography

Of this, about 88% of the respondents were males, while the remaining were females (Figure 3.2.1). Of the respondents, 75% were married (Figure 3.2.2). A majority of the respondents stated that they were able to speak, write and read Marathi and Hindi (>90%), while about 39% of the stated to know of Kannada (Figure 3).

Gender *(69 responses)*

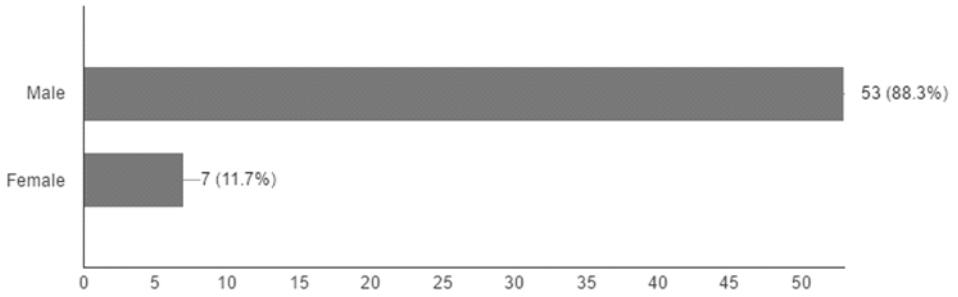


Figure 3.2.1 : Gender profile of the respondents

Marital status *(69 responses)*

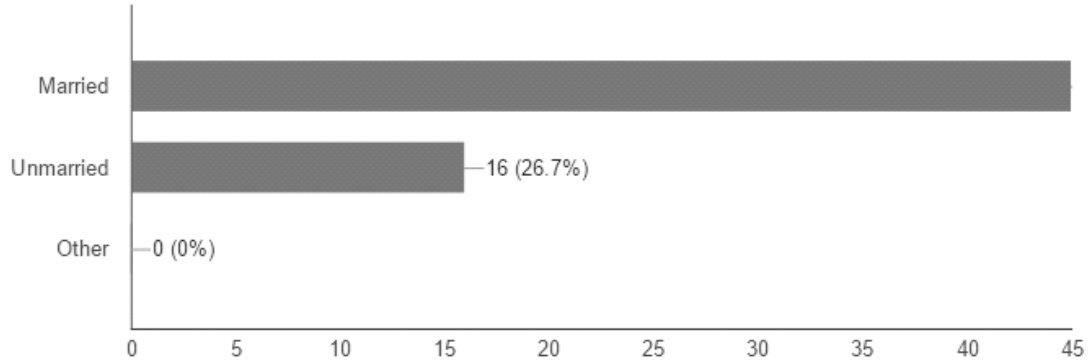


Figure 3.2.2 : Marital status of the respondents

Languages

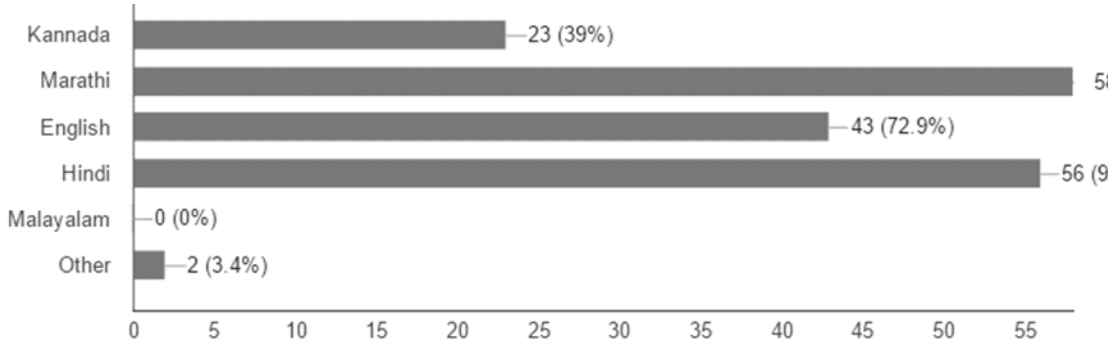


Figure 3.2.3 : Languages spoken/written/read by the respondents

Housing and Income

In terms of housing, a majority of them lived in brick walled and asbestos sheet type of houses followed by brick walled and RCC roof, with about 8% living in hut/mud walled house types (Figure 3.2.4). About 82% of the respondents stated to live in their own houses with only 18% lived in rented houses (Figure 3.2.5).

In terms of income, about 50% of them responded stating their average monthly income was in the range of Rs. 5000 to Rs. 10000, followed by about 30% in the range of Rs. 10000 to Rs. 15000. About 12% of the respondents stated to have an income less than Rs. 5000 per month.

Housing *(69 responses)*

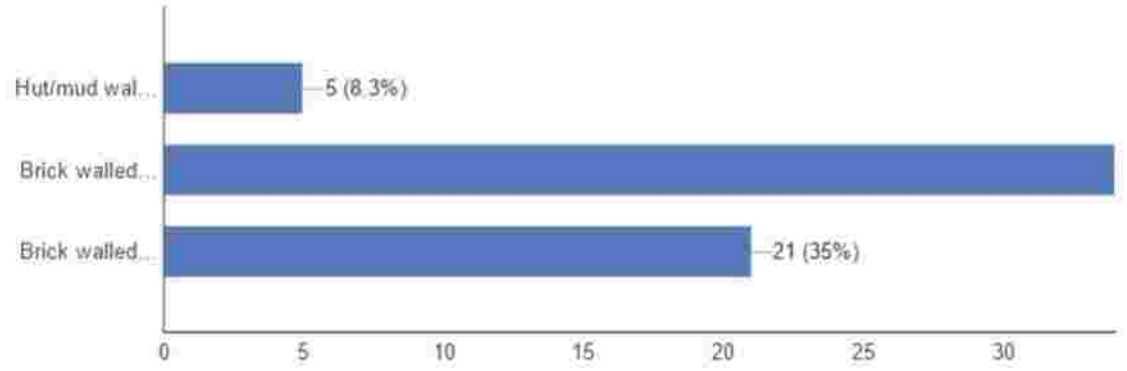


Figure 3.2.4 : Type of Housing

Ownership of House *(69 responses)*

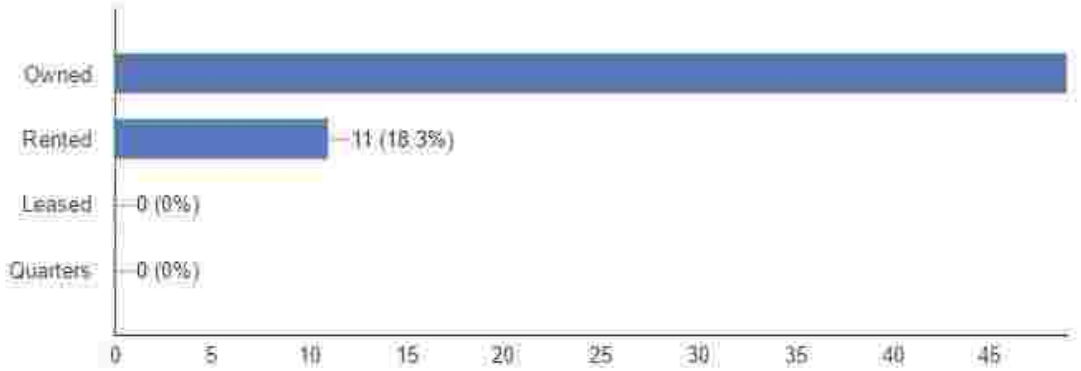


Figure 3.2.5 : Ownership of House

Monthly Income *(69 responses)*

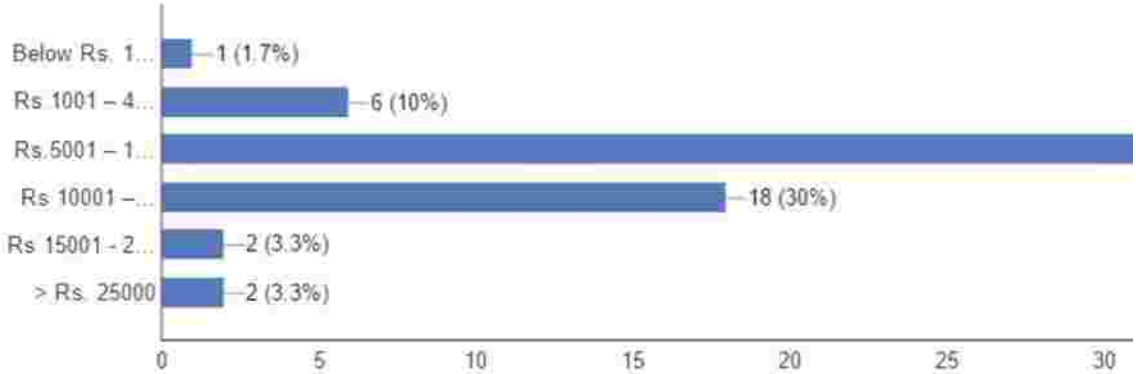


Figure 3.2.6 : Total Monthly Income

Commuting: Access and Mobility

It seemed that of the respondents, about 85% of them commuted (Figure 3.2.7) for work followed by shopping (38%) and education (12%). Of these, almost 90% of them are using train for commuting followed by government bus (55%) and personal modes of two-wheelers (52%) and car (28%) – Figure 3.2.8. Further, it was learnt that on an average they travelled about 37 km daily.

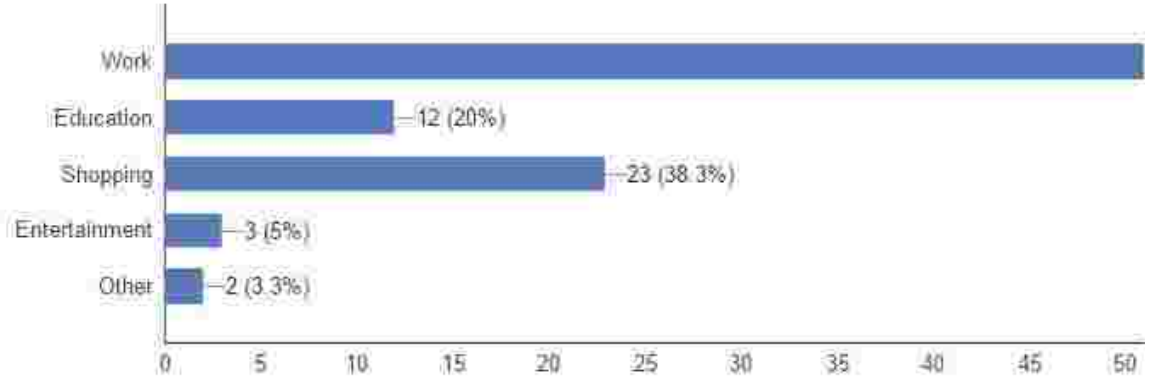


Figure 3.2.7 : Primary reason for commuting

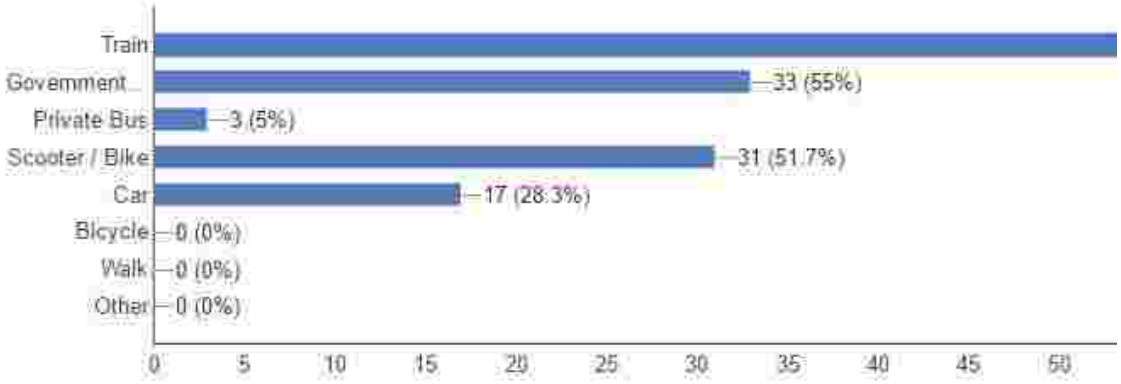
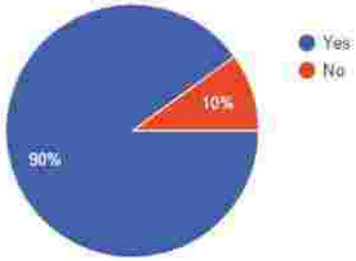


Figure 3.2.8 : Mode of transport used for commuting

Subsequently, on eliciting responses for any member of the household using the train for commuting (Figure 3.2.9), about 90% of them responded positively. Thus, indicating that the mode of commuting by train is a key lifeline for the residents. About 24% of them use the train almost daily, while 39 % use it at least once a week, 13% use it once a month and followed by about 24% using it occasionally (Figure 3.2.9).

Is Train a mode of transport for commuters ? *(60 respondents)*



If 'YES', How Frequently ? *(54 responses)*

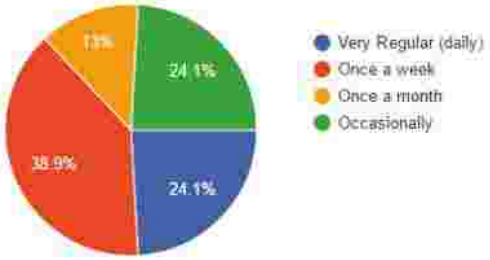


Figure 3.2.9 : Train as a means of commuting by the households and frequency of travel

General awareness about the Railway Doubling Project

The respondents were queried on whether they were aware of the railway doubling project. Interestingly, about 77% of them were already aware of the project while about 23% not aware (Figure 3.2.10). On eliciting a response whether they were in favour of the railway doubling project, about 77% did respond positively while the latter were not in favour.

A further query on how they perceived the impact of the project on their life and livelihood, a majority of them responded that it would impact them very positively for a) Access to Services and Amenities, b) For Work and Employment and c) For Regular Commuting. Overall, this was followed by positive response to all of the above. A key aspect was there were no responses that perceived any negative impact or even were they neutral about this (Figure 3.2.12).

Further, on the impact during and post construction of the project, almost all of them perceived this to impact them only post construction in terms of their daily trips and access to amenities, without any responses to the nature of impact during its construction (Figure 3.2.13).

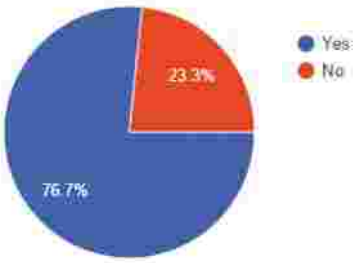


Figure 3.2.10 : Awareness of the railway doubling project

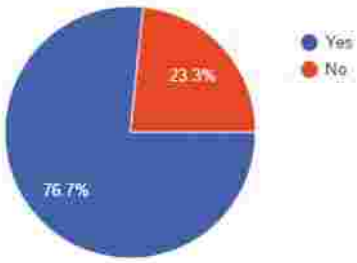


Figure 3.2.11 : Preferences in favour of the railway doubling project

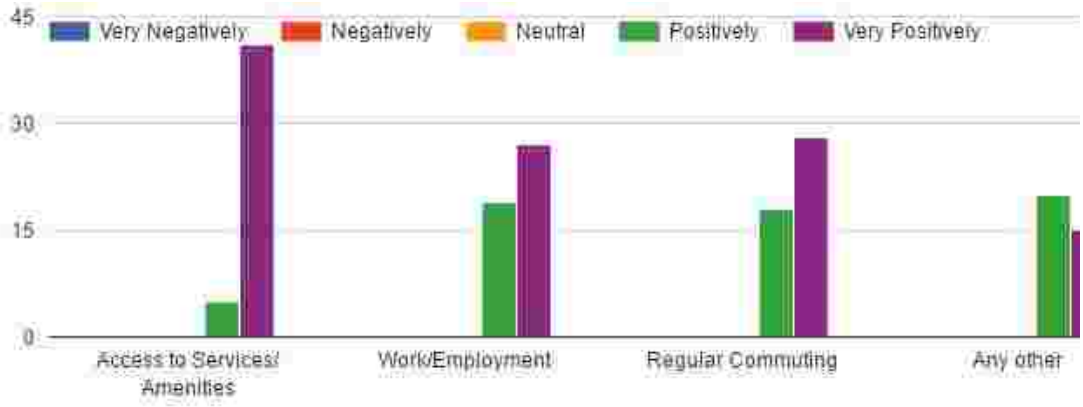


Figure 3.2.11 : Preferences in favour of the railway doubling project

Figure 3.2.12 : Impact due to the Project during and post construction as perceived by the respondents

Summary

Based on the above responses, it is apparent that the residents/citizens in these settlements are largely in favour of the railway doubling project and perceive a sense of positive impact on their lives and livelihood. In particular, they perceive the project would enhance their opportunities for commuting and, hence, to better employment, and access to amenities and services.

Going forward, it would be good to carry out a public consultation explaining the advantages and disadvantages of the project, both during and post construction. The consultation can highlight the implications on them from socio-economic aspects as well as the ecological aspects too.

ANNEXURE A:

Format of Questionnaire for the Socio-economic Assessment Survey done on the proposed doubling of railway track from Castlerock to Kulem

SAMPLE No:		
Name of respondent:		
Address:		
Phone Number:	Date of interview:	
Interview start time:	Interview end time:	Interview duration (In minutes):
MALE……....1	FEMALE……2	

VILLAGE NAME	Circle below
Castle Rock	1
Caranzol	2
Sonalim	3
Colem	4
Others	5

SPEAK TO AN ADULT PERSON IN THE HOUSEHOLD

Good Day Sir / Madam! I am _____ from Indian Institute of Science, Bangalore. We are currently doing a study on the doubling of railway track from Castle Rock to Colem by the Railways. We are trying to understand the socio-economic implications of this. Hence, we would greatly appreciate it if you could spare a few minutes to answer a few questions. Thank you!

SECTION A - SCREENING

A1. Have you or anybody in your household been interviewed for a survey like this in the last 6 months?

YES…….....1	**TERMINATE**	**NO**…….....1	**CONTINUE**

A2. Can you tell me how many members are there in the household, in the age group of 18-55 years? Please include all men and women in the age group **18-55** years who currently reside in this household?

A3. Could you please tell me the names of members of your family who are aged between **18 to 55 years**? I would like to know their ages and gender also. **(INV: WRITE DOWN ALL THE NAMES, AGE IN THE GRID BELOW CODE THE GENDER)**
Let us start from the youngest person who is above **18** years. **RECORD IN ASCENDING ORDER**

GRID FOR RECORDING THE RESPONDENT SELECTED FOR THE INTERVIEW				
Number	Name of HH member (18 to 55 years) Record from youngest to oldest always	Age	Gender	SELECTED RESPONDENT
1			M F	**1**

SECTION B - HOUSEHOLD INFORMATION

B1. Can you please look at this card (SHOW TABLE B1) tell me your marital status? (ONLY SINGLE CODE POSSIBLE)

B1
Married 1
Unmarried 2
Others (widowed / divorced) 3

B2. What is your mother tongue? _____ (RECORD VERBATIM)

B3. Can you please look at this card (SHOW TABLE B4) and tell me the languages you can speak / write / read fluently?

B3	Language	Speak	Read	Write
A	Kannada	1	2	3
B	Marathi	1	2	3
C	Hindi	1	2	3
D	English	1	2	3
E	Malayalam	1	2	3
F	Others	1	2	3

If others: _____ (RECORD VERBATIM)

B4. Select the type of house? (ONLY SINGLE CODE POSSIBLE)

B4
Hut/mud walled..... 1
Brick walled & asbestos sheet..... 2
Brick walled & RCC roof 3

B5. Can you please look at this card (SHOW TABLE B6) tell me on ownership of house? (ONLY SINGLE CODE POSSIBLE)

B5
Owned..... 1
Rented..... 2
Leased..... 3
Quarters..... 4

B6-A. [In order to classify various people according to their income groups, we need to know their income.] Could you please look at this card (SHOW CARD F1) and tell me in which of these income groups does your TOTAL MONTHLY INCOME fall? Please include salaries of all the earning members including pensions, rent from rented out premises, dividends, interest, business income, agricultural income, etc. (ONLY SINGLE CODE POSSIBLE)

B6-B. Now, Could you please tell me, by looking at this card (SHOW CARD F1), what your PERSONAL MONTHLY INCOME is, i.e. your earnings excluding earnings from other family members? (ONLY SINGLE CODE POSSIBLE)

B6	**B6-A** (Total Monthly Income)	**B6-B** (Total Personal Monthly Income)
Below Rs.1000/-		1
Rs.1001/- to Rs.4000/-		
Rs.4001/- to Rs.10000/-		
Rs.10001/- to Rs.15000/-		
Rs.15001/- to Rs.25000/-		
Above Rs.25001/-		

SECTION C – ACCESS and MOBILITY

C1. Can you please tell me (SHOW TABLE C 1), what is the primary reason for you to commute daily?(MULTIPLE CODING POSSIBLE)

C1	Reason for Commuting	
A	Work	1
B	Education	2
C	Entertainment	3
D	Shopping	4
E	Others	5

C2. Can you please tell me (SHOW TABLE C 2), which mode of transport do you use to commute on a daily basis?(MULTIPLE CODING POSSIBLE)

C1	Reason for Commuting	
A	Train	1
B	Government Bus	2
C	Private Bus	3
D	Scooter / Mobike	4
E	Car	5
F	Bicycle	6
G	Walk	7
H	Others	8

C2a. Could you please tell me, on an average, how many kilometers do you travel in a day?

_____km (RECORD VERBATIM)

C2b. Could you please tell me, on an average, how much time do you travel in a day?

_____Hours (RECORD VERBATIM)

SECTION D – RAILWAY DOUBLING PROJECT

D1. Does anybody in the household travel using the train? YES / NO

D2. Are you aware of the proposed Railway Doubling project by the railways? YES / NO

D3. If Yes, are you in favour this project? YES / NO

D4. If 'YES', how do you think it is going impact your life and livelihood? Please rate:

B3	PARAMETERS	Very Negatively	Negatively	Neutral	Positively	Very Positively
A	**Access to Services/Amenities**	1	2	3	3	5
B	**Work/ Employment**	1	2	3	3	5
C	**Regular Commuting**	1	2	3	3	5
D	**Any Other :**	1	2	3	3	5
E	**Overall**	1	2	3	3	5

D5. Do you foresee any impact of the doubling project on:

Activity	During Construction	Post Construction
a) On your daily work trip		
b) On other trips		
c) Availability of amenities like shop		
d) Other activity: Please specify		

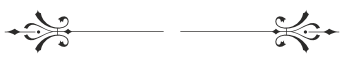
Miscellaneous Notes / Observations:

_____

_____

_____

THANK AND CLOSE THE INTERVIEW



CHAPTER 16

Mr. Sahu, AGM, Railways, explaining the project

Mr. Raju answering a query from one of the members.

View of the assembly

PUBLIC CONSULTATION

Public consultation regarding the doubling of railway line between Kulem and Castle Rock of the Vasco-Hospet line in southwestern Railway zone was held on 12th June 2016 at Village Panchayat office in Kulem.

Gram panchayat members including the sarpanch, Mrs. Kiran K. Mamlekar, were present. Members present were: Shri Nilesh Satpalkar, Shri Naresh Shigoakar, Smt. Savita P. Desai (Chairperson, Biodiversity Committee), Shri Ramesh Khandeparkar, Smt. Jyotiba S. Ghevde (Member, Biodiversity

Location of Village Panchayat Office in Kulem

Dr. Suresh, CES, IISc, introducing the topic

Committee), Shri Dinesh Desai (Member, Biodiversity Committee), Smt. Manisha U. Gawas, Smt. Savitri S. Gawas, Smt. Roopa Vir, Shri Sadanand Desai, Shri Khushali D. Mamlekar (Member, Biodiversity Committee) and Shri Nilesh H. Velip.

Other members present were: Mr. Sahu Assistant General Manager, RVNL, Mudgoan, Mr. Raju, Site engineer, RVNL, Hubli and Dr. H. S. Suresh, Research Botanist, Center for Ecological Sciences, Indian Institute of Science, Bangalore.

Sarpanch of the village, Kulem, Mrs. Kiran Mamlekar welcomed guests and other members of the panchayat. Dr. Suresh introduced the subject and explained the reasons for the meeting. Dr. Suresh also explained the ecological work done by various scientists of Indian Institute of Science at the site. Dr. Sahu, AGM, explained the project details and the relevance and need to double the existing railway line.

After the introduction and detailing of project, the floor was open for discussion. One of the members of the public, Mr. Tushani Mamblekar (wildlife enthusiast) raised the concern about the number of gaur (Bos gaurus) killed by railway traffic especially between Karanzole and Kulem. Mr. Raju, Site Engineer, answered his concern and explained the measures such as providing underpass, erecting barricades and providing sign boards for loco-pilots taken by the Railways as per the suggestions given by the Range Forest Officer, Conservator of Forests and Chief Conservator of Forests of Belgaum Circle.

Dr. Suresh explained the efforts to mark the animal crossing points along the existing railway tract and also animal accident locations as gathered by railway staff in different stations between Castle Rock and Kulem with the help of a GPS. This would be a part of the advisory to the Railways who would take precautions for smoother passage for animals crossing the track.

Members of Kulem Gram Panchayat wanted a meeting with all stakeholders at least 3 months before the commencement of the project. They wanted a committee to set up with Chairman and members of the biodiversity committee of the Kulem gram sabha.

One of the member wanted an over bridge near level crossing (LC) at the Kulem station for people to cross over. Mr. Raju addressed his request and said that if there is doubling of the railway line, trains will not stay for long time at railway station and public waiting time at the LC will be actually reduced. They may not be a need for an over bridge or under bridge at Maida (Kulem).

The panchayat members also stressed that the beauty of Dudhsagar waterfalls should be maintained, as Kulem is known for Dudhsagar waterfalls and a large part of the economy of Kulem is dependent on tourists visiting waterfalls.

Other general suggestions from public and biodiversity members are:

1. Scenic beauty of Dhudhsagar waterfalls should not be affected by doubling of the railway line.

2. Railways should make sure that vibrations at Sonalium station should not affect the temple close to Sonalium station.

Medicinal plants such as “Ansuti” (Most probably Woodfordia fruticosa) should be protected. Flowers of Ansuti are believed to be of value in the cure of cancer

CHAPTER 17

LIKELY IMPACT ON PHYSICAL AND BIOLOGICAL ENVIRONMENT

The impact of the proposed railway line on the ecology of the region can be discussed under two different heads. 1. Impact on the physical environment and 2. Impact on the bio-diversity of the proposed area.

1. Impact on the physical environment:

- Air

- The main constituents of present diesel engine exhaust are carbon (soot), CO, CO_2, Nitrogen (N), Oxides of nitrogen (NOx), Oxides of sulphur, Hydrocarbons (HC) and Polycyclic aromatic hydrocarbons (PAH) and particulate matter (PM). The size and chemical composition of PM is responsible for health and environmental impacts. Many of diesel exhaust gases are carcinogenic.
- Phasing out of diesel engines and converting them to electro-motive engines could drastically reduce air pollution due to absence of diesel exhaust.
- Planting trees along the sides of the railway line helps in containing the exhaust locally.

- Noise

- In the present study, noise levels (dB(A)) were higher than the standard level of 90 dB(A). Points where the engines were in idling position, crossing over, in tunnels and on bridges had high noise levels.
- Noise has potential impact on wildlife that are dependent on sound for communication (viz., insects, amphibians, birds and mammals). Frequent exposure to noise can impart deafness in humans.
- Sound barriers constructed along the railway line can restrict sound to local area.
- Planting trees along the railway line can cushion and reduce sound to certain extent.

- Water

- There is no dearth of water for use in the region to competing users.
- Water quality analysis shows that the streams along the existing railway track are pristine in nature without any polluting industry in the upper reaches of the streams. Dissolved oxygen (DO) was very low (2.3 mgL^{-1}) at sampling station 6426 in the dry month of 2013. Chemical Oxygen (COD) and Biological Oxygen Demand (BOD) were high in this locality (13 and 40 mgL^{-1} respectively). Higher COD and BOD were observed at stations close to Dudhsagar falls (3886 and 6428). *Escherichia coli* bacterial contamination was found to be in all sampled streams, indicative of fecal contamination from trains. The total coliform count was between 221/100mL to 542/100mL, the threshold value limit is 100 count/100 mL. None of the sites were below the threshold level.
- During the construction phase, there will be sedimentation in streams that are closer to railway lines.
- It is advised to restrict the movement of sediments by construction of dikes and retaining walls along the railway line where construction happens.

2. Impact of the project on biodiversity:

This assessment is for two proposed alignments. Scenario-1, running parallel to the existing tract and Scenario-2, close to the existing tract but not parallel. The alignment that runs parallel requires 15 meters of land and the other one requires 30 meters of clearance. Assumption here is that the proposed railway line runs above the surface, and tunnels or any other structures are not taken into account. Estimated area that undergoes change in the land-use under both alignments is as follows:

Natural landscape	**SCENARIO-1 (15 mtrs. of land for parallel alignment)** *[Area in ha]*	**SCENARIO-2 (30 mtrs. of land for a non parallel alignment)** *[Area in ha]*
Evergreen Forest	3.69	26.73
Semi-Evergreen Forest	8.91	23.17
Moist Deciduous Forest	14.49	30.95
Grassland	0.047	1.01
Open / Rocks	2.54	6.04
Agriculture	1.43	1.68
Water	NA	0.07

Table 6.1. Area required by railways under two different possible alignments

A total of 27.1 hectares would be undergoing land use change with alignment that runs parallel to the existing line. Moist deciduous forest accounts for more than 50% of the area required followed by semi-evergreen forests (32.8%) and evergreen forests (13.6%). But with the second scenario (30 meter clearance) the area required would be 80.8 hectares. Among the natural landscapes that undergo maximum change in land use would be moist deciduous forests which account for 38.2% of the total land followed by evergreen forest (33.0%) and semi-evergreen forests (28.6%).

A total of 53255 woody plants >1 cm dbh including canes, reeds and palms would be lost under scenario one. Moist deciduous forests accounts for a loss of 23639 (44.3%) woody individuals followed by 19194 (36%) woody stems from semi-evergreen forest and 10421 (19.5%) woody stems from evergreen forest type. A total of 76.3% of stems were <10 cm dbh (diameter at breast height) and 56.3% of stems were >5 cm dbh that contributed for the potential future forest stand. A total of 23.6% stems were above 10 cm dbh that contributed largely to the present forest stand and biomass. Sum of 13711 trees >10 cm dbh (present stand) would be lost including 445 large trees above 60 cm dbh.

Evergreen forest type would lose a total of 75488 stems >1 cm dbh under scenario two. With the conversion of 80 ha of natural landscape, a total of 175896 stems >1 cm dbh would be lost. Though a large area of moist deciduous forest would undergo land use change, it accounts for 28.7% of tree loss (50492 woody stems >1 cm dbh). Semi-evergreen forests lose 49914 woody individuals (28.3% of the total). Sum of 81904 stems <5 cm dbh that includes shrubs and tree saplings (future stand) would be lost. A total of 35877 trees >10 cm dbh would be lost and 1189 large trees (>60 cm dbh) would be lost.

Natural landscape		Scenario 1. (15 meters of land)	Scenario 2 (30 meters of land)
Moist deciduous forest type			
Total Number	>1 cm DBH	23639	50492
	<5 cm DBH	12306	26285
	>10 cm DBH	6903	14745
	>65 cm DBH	165	353
Semi-evergreen forest type			
Total Number	>1 cm DBH	19914	49914
	<5 cm DBH	10870	28267
	>10 cm DBH	4187	10889
	>65 cm DBH	190	496
Evergreen forest type			
Total Number	>1 cm DBH	10420	75488
	<5 cm DBH	6177	44749
	>10 cm DBH	2175	15754
	>65 cm DBH	89	644

Table 6.2. Loss of trees in different sizes under two different scenarios in different forest types

Total biomass lost under scenario 1 is 7878.0 tons that includes 3942.9 tons (50.0% of the total) of moist deciduous forest, 2590.3 tons (32.8%) of semi-evergreen forest and 1344.7 tons and (17.0%) of evergreen forest. Biomass lost under scenario 2 is 20753.7 tons that includes 9741.4 tons (46.%) of evergreen forest followed by semi-evergreen forest 2590.3 tons (12.5%) and moist deciduous forest 8421.9 tons (40.5%). Considering 50% of the standing above ground biomass as carbon, loss of carbon stocks under scenario 1 would be 3939.0 tons while under scenario 2 it would be 10376.8 tons.

There is considerable variation in species specific contribution to abundance and carbon pool. Species that contribute significantly to carbon pool need not be one of the abundant species in a community. Important species that contribute to the carbon pool in moist deciduous forest are *Terminalia paniculata* (24%), *Xylia xylocarpa* (17.6%) and *Terminalia crenulata* (5.7%). These three are important timber species and have been exploited in the past for several purposes. But these three species account for 25% of abundance in moist deciduous forests while they contribute to 47.5% of total carbon pool. In evergreen forest type important species that contribute to the carbon pool are *Hopea wightiana* (10.2%), *Terminalia paniculata* (6.6%) and *Lophopetalum wightianum* (5.29%) except for *Hopea wightiana* that is the most abundant species, *Terminalia paniculata* (1.4%) and *Lophopetalum wightianum* (1.59%) do not contribute significantly to abundance. In semi-evergreen forests species such as *Terminalia paniculata* (10.7%), *Hopea wightiana* (7.4%) and *Aporusa lindleyana* (5.4%)

contribute significantly to carbon pool while their total contribution to stand is 11.2%. The stand is dominated by three understorey species that contributes 8.3% to total carbon pool. Unlike in moist deciduous forest where the abundance and carbon stocks are concentrated in some species in evergreen and semi-evergreen forests abundance and carbon pool is shared with several species.

We could get phytogeographical distribution i.e. availability or extent of species distributed in the world, for 167 species. Over 85% of the species had distribution in tropical countries of southeast Asia. A total of 19 species (11.3%) were endemic to the Western Ghats. Of the 19 endemic species, *Syzygium laetum* and *Polyalthia fragrans* were abundant and rest were frequently seen except for the palm species *Arenga wightii*, which is rare. List of endemic species is given in the following table.

Species	Abundance level	Habitat type
Actinodaphne angustifolia	Frequent	Evergreen
Actinodaphne hookeri	Frequent	Evergreen
Alseodaphne semicarpifolia	Frequent	Evergreen
Ancistrocladus heyneanus	Frequent	Evergreen
Arenga wightii	Rare	Evergreen
Beilschmiedia sp.	Frequent	Evergreen
Callophyllum apetalum	Frequent	Evergreen
Callophyllum inophyllum	Frequent	Evergreen
Calophyllum tomentosum	Frequent	Evergreen
Cinnamomum malabatrum	Frequent	Evergreen
Cinnamomum zeylanicum	Frequent	Evergreen
Diospyros candolleana	Frequent	Evergreen
Diospyros pruriens	Frequent	Evergreen
Diospyros saldanhae	Frequent	Evergreen
Garcinia gummigutta	Frequent	Evergreen
Litsea sp	Frequent	Evergreen
Neolitsea zeylanica	Frequent	Evergreen
Polyalthia fragrens	Common	Evergreen
Syzygium laetum	Common	Evergreen

Table 6.3. List of Endemic species recorded in the study area

Among all the species *Mangifera indica* and *Ziziphus oenoplea* had pantropical distribution. *Acacia auriculiformis* is the only introduced species from Australia recorded during the enumeration at the foot hills and surrounding Cashew nut plantations. There were 27 species recorded as rare in terms of abundance during the enumeration.51 species were found commonly and 72 species were found frequently. There were 16 species occurred occasionally during the enumeration.

Butterflies and Dragonflies:

Bhagwan Mahaveer Wildlife Sanctuary harbours rich diversity of butterflies. A total of 133 species was recorded from this area. Out of 133 species recorded 12 species were endemic and 18 species were in different schedules wildlife protection act. Three species are in schedule 1 which gets highest protection. Several species of butterflies are habitat specific and many are known found along riparian habitats. The proposed project impacts the microhabitats in forests and hence the butterflies.

Aquatic habitat specificity makes Odonates (dragon flies) special group of insects that are sensitive to habitat alteration. They are the health indicators of wetlands. The proposed project area had 57 species of Odonates that accounted for 33% of species in the Western Ghats. There were 9 species endemic to the Western Ghats. Two species are in IUCN near threatened category and one species in vulnerable category. Siltation and changes in water chemistry would impact the diversity of this group of insects.

Fresh water fish diversity:

There are more than 320 species of fresh water fishes described from the Western Ghats and large numbers of these are endemic to the Ghats. This study has brought out relationship between ecological variables and fish diversity in the proposed project area. The changes in turbidity, salinity and conductivity that results from the different activities proposed during the execution of the project would impact the fish diversity. The pollution of water bodies tends to increase the abundance of omnivore fish population resulting in decline of specialist herbivore, insectivore and algivore species of fishes.

Anurans (Amphibians) (Frogs)

Amphibians are extremely sensitive to habitat modification and they indicate the prevailing condition of an ecosystem. Large numbers of species described from the Western Ghats are endemic. They are found in range of habitats and micro-habitats.

There were 24 species of frogs recorded during the study of which 14 species were endemic and 4 species were unique to Castle rock area. One critically endangered and three endangered according to IUCN classification occupies several streams that cut across the existing railway line. Many species apart from the above mentioned also has their home in these streams. Proposed project would definitely impact these species. Though it is argued that the presence of anurans close to the human modified environment, such arguments require careful scrutiny.

Reptiles:

There were 27 species of reptiles recorded during the study. There were 5 species of poisonous snakes recorded during the study. Several species of reptiles were observed on the existing railway line basking, hiding or moving across. Hence the existing railway line provides a good habitat for them. There were 3 snakes and one unidentified lizard which were found killed during the study period. As the study was mainly during the inactive season for reptiles, any major project work during the rainy season (active season) would impact these animals.

Birds:

Major impact on bird species would be the loss of nesting sites, loss of keystone species such as *Ficus sp.* and prey availability for the insectivorous birds. 54 nesting cavities were observed along the track during the study. Habitat enrichment and minimum modification of the habitat are the best solutions.

Mammals

Both direct method and indirect methods were followed to estimate mammalian population. Indirect evidences belong to mammals such as Sambar, Porcupine, Langur and Civet cats were frequently encountered. There were anecdotal evidences that were obtained for mammals such as Dholes, Tiger/Panther, Bison and four-horned antelope.

Major impacts on mammals are accidental killing by trains. Traffic is expected to double with doubling of track and would lead to more such accidents. The habitat modification would impact fruit dependent mammals such as langurs and other smaller mammals.

Mitigation measures are suggested in a different chapter for all the components.

CHAPTER 18

RECOMMENDATIONS AND MITIGATION MEASURES

There are several issues, both environmental and biological, that need attention while executing the project. We highlight the main issues and propose some remedial measures that should be taken up by the Railways in consultation with the state forest departments and local scientific institutions or experts. These recommendations can be incorporated into the Environmental Management Plan.

During construction phase

The length of new railway line is 25 km. which is parallel to the existing railway line. The advantage of parallel railway line is that no new corridor is opened in the forest and habitat is not further bifurcated. Further, total length of tunnel is 3.497 km. For tunneling no trees are to be cut, and the forest cover is maintained intact. This ensures continuity of the forest for wild animals to cross the railway tracks. However, if required in consultation with the forest department, flyovers at animal crossings may be provided. DCF/Goa vide letter No, 1-609/WL&ET (N)/ 18-220 dt. 08.05.2017 has suggested for wild animal crossings at the following locations suitable underpasses/over bridge may be provided:

1. Chainage No. 45/500. GPS. 15º19'30.6" N and 74 º 16'56.3" E

2. Chainage No 49/500 GPS 15 º 20'16.9" N and 74 º 15'07.4" E

The waterway bridges provided can also act as underpasses for animal crossings.

There should not be any labour camps, permanent or temporary, in the sanctuary area during the course of construction of the road. Collection of firewood shall be prohibited.

I. Environmental issues:

1.1 *Air quality:*

There are two important issues regarding air quality – dust generation and vehicular emissions. Dust generation could be through construction activities, transport, storage, blasting and rail bed formations. Dust and other pollutants can settle on the surrounding vegetation and impair photosynthesis, resulting in lower survival of trees and other plants. Precautions to minimize these pollution impacts should include the following measures during construction:

1.1.1 Transport of the materials, especially sand, cement and other materials that can inject particulate matter into the atmosphere, should be done through covered vehicles. Loading and unloading of construction materials should be done preferably in covered areas or in areas where water fogging can be used to arrest dust emission into the atmosphere.

1.1.2 Approach roads at the construction site should be paved. Water should be sprayed on earthworks and related works so that the dust is arrested.

1.1.3 Vehicles and machinery should be regularly maintained to cut down emissions. Diesel generating (DG) sets should be fitted with adequate stack height as per prescribed standards. Low Sulphur diesel should be used in DG sets and machinery. Ambient air quality should be monitored as per EMoP standards.

1.1.4 The use of ultra low Sulphur diesel by locomotives is strongly recommended. At the same time, electrification would be a better option to practically avoid air pollution. Railways already have plans for electrification of the track.

1.1.5 Speed limit with the stretch of road passing through the sanctuary should be restricted to 40km/hr.

1.1.6 All the trees along the road shall be protected by the user agency.

1.2 *Noise levels:*

Excessive noise from the blasting and use of construction machinery would disturb the wildlife, especially some of the larger species such as gaur that are relatively shy and sensitive to disturbance. The Railways should ensure that noise levels are minimized and localized to the extent possible during the construction phase.

1.2.1 The executioners of the project should see that all machinery and vehicles should be serviced in time to minimize the operational noise. All construction equipment and machinery should be fitted with silencers and maintained properly.

1.2.2 Construction timings may be regulated in sensitive areas and the Railways can also think of providing temporary noise barriers in such locations. No construction should be undertaken during night time in order to minimize disturbance to wildlife.

1.2.3 Noise level in the project area should be monitored as per Environmental Management Plan (EMP)

1.3 *Soil and land stability:*

The most serious impacts on the environment would happen during the phase of construction that would involve blasting of rock and excavation of soil, especially along the steep slopes of the Bhagavan Mahavir Wildlife Sanctuary. This has potential for rock and soil debris to be washed down slope thereby impacting the vegetation outside the project area as well as increasing the turbidity of the streams and rivers and impacting aquatic life. Railways should pay attention during the construction stage.

1.3.1 Top soil from the excavations should be preserved and used in plantation activities and embankment of slopes should be stabilized to prevent soil erosion. There should be periodic inspection of the slopes to ensure that landslides and washing of mud down slope do not occur.

1.3.2 Soil obtained from cutting should be used for filling, construction of access roads and embankments. Embankment slopes should be protected by proper pitching, slope protection frames and masonry if required.

1.3.3 The natural drainage pattern of the area should be maintained. There should be side drains to direct water to natural drains.

1.3.4 Earth stockpiles should be provided with gentle slopes to prevent soil erosion. Provision should be made for treatment of hill slope instabilities from cutting hill slopes. The cost of such measures should be included in the overall cost estimate.

1.4 *Water quality:*

As stated earlier, the dangers of water pollution from soil erosion, dumping of debris as well as fecal contamination from the large work force could impacts aquatic life of the streams and rivers.

1.4.1 Railways should ensure that all its contractors use surface water to the maximum extent for construction work without exploiting ground water. They should use water harvesting measures to recharge ground water wherever possible.

1.4.2 Measures should be taken to minimize the deposition of debris and soil in stream and rivers and prevent siltation of water bodies due to construction or storage activity. This is possibly one of the most important environmental safeguards required in this project to ensure the biological health of aquatic systems in the protected areas.

1.4.3 Earthworks or stone works should not impede the flow of natural flow of rivers, streams and any

other water sources. The run off from side drains should be connected with the natural drainage system in the area.

1.4.4 Measures should be taken to prevent any seepage of oil and grease into the soil and into the water bodies. Vehicles and machinery should be refueled and maintained at designated localities some distance from surface water points. These designated localities should have oil and grease traps. Construction camps should be away from the water bodies to prevent direct pollution of water bodies.

1.4.5 Water quality should be monitored periodically in major streams and rivers. The frequency of sampling should be at least fortnightly during the peak monsoon period of June-September and at lower frequency during other months. This task could be entrusted to a local institution or laboratory so that the results are available in the shortest possible time period for mitigation steps to be initiated in case water quality is below the prescribed environmental standards.

1.4.6 To prevent contamination of water from drains railway coaches are to be provided with bio toilets.

1.5 *Railway Operational Protocols:*

1.5.1 **Sensitization of the train drivers -**Workshops should be organized for the train drivers and guards to sensitize them about the importance of protecting wild animals and observing necessary precautions while passing through forests. Feedback can also be taken from them.

1.5.2 **Use of signages** - Signages at both ends of identified stretches of sensitive stretches of railway track to caution train drivers should be erected immediately.

1.5.3 **Using experienced drivers -** In this Ghat section, particularly in the evening and night trains, experienced drivers for train operations should be deployed.

1.5.4 **Regulating garbage disposal -** Food items have been found attracting wild animals onto the track, which is an important cause of accidents. The railway department should warn the caterer to stop waste disposal inside the forest area. For passengers of other trains, the railway department should make arrangements for announcements at the Castlerock and Kulem railway stations before departure of the train, requesting them not to throw any waste or hazardous items within the park area. Posters should be put up to this effect at railway stations. These measures will help in reducing such problems.

1.5.5 **. Putting posters in Running rooms and at Railway stations.**
Posters related to wildlife conservation and wildlife mortality by trains in Castlerock- Kulem area should be placed in running rooms and railway offices at Londa, Castlerock, Kulem and Vasco.
1.5.6 **Announcement at Castlerock and Kulem railway stations -** Before departure of any train from Castlerock to Kulem or Kulem to Castlerock, an announcement should be made for train drivers and guards to travel carefully in the problematic zone of the park area. For train passengers, announcements should be made related to the garbage disposal problem.
1.5.7 **Training and workshops -** There is a need to organize workshops involving all concerned forest officials, the railway authorities. NGOs and conservationists to share their information and other suggestion. Formal training should also be given to the ground level forest staff for tackling accident cases and to local vets for attending such cases.
1.5.8 Suitable vibration control measures to be provided to avoid impact on temple near Sonalium station.
1.5.9 **Joint patrolling** Forest guards of the concerned beat along with railway staff can be entrusted to monitor presence of animals in the critical areas. Joint patrolling by the forest guards of the concerned beat along with railway staff can be an approach. While doing so, they can also regularly seek information from local people about animal movement.

II. Biodiversity Conservation:

The impacts of the construction and operation of a second railway track on biodiversity would include (a) cutting of trees and increasing the gap in the forest with consequences for forest dynamics, (b) the pollution of streams and rivers with impacts on aquatic life, (c) hindrance for wildlife crossing and increased risk of direct collisions of wildlife with trains.

2.1 *Forest conservation*

2.1.1 All efforts should be made to minimize the cutting/removal of trees along the proposed line. Integrity of the forest area should be maintained. While removing trees, care should be taken not create artificial gaps by cutting branches unnecessarily. Care should also be taken while removing endemic, medicinal and utilitarian trees. In the case of restricted endemics or rare species, the Railways should identify pole-size stems that are to be cut with the assistance of local botanists and arrange to uproot them for replanting in the forest nearby.

2.2.2 A compensatory afforestation plan should be in place after the discussions with the forest department. There should be scope for planting in areas such as river banks, stations etc. At the same time, the major aim of compensatory afforestation should be to consolidate the habitat of the two protected areas involved, namely, Bhagawan Mahavir WLS and Anshi-Dandeli Tiger Reserve. Random afforestation efforts would not compensate for the loss of tree cover through doubling of the railway track.

2.3.3 Maximum care should be taken to reduce the pressure on the forests while execution of the project such as providing LPG facility to labour camps to avoid extraction of firewood by the labour force.

2.3.4 For conserving the associated taxa such as butterflies, birds and mammals, railways in consultation with forest department should establish “Biodiversity parks”. Biodiversity parks should have native plant species that act as “gene pools” also serve as host plants for several of these species.

2.2 *Preserving aquatic life*

2.2.1 Railways should adopt best construction procedures to reduce turbidity in the streams and rivers resulting from siltation and water contamination. This would be the best way of preserving native aquatic /amphibian communities including fishes, frogs and dragon flies.

2.2.2 Much of the disturbance to the Dudhsagar stream is mainly due to the daily vehicular traffic and tourism. Necessary steps should be taken to regulate tourism. This is obviously the joint responsibility of the forest and tourism departments of Goa. The use of detergent, soap and other inorganic chemicals should be strictly prohibited as it may affect the natural fish community composition. Stream bed at Kulem is often transformed into a road especially for vehicle movements. This has direct implications to the fish community structure itself. Natural stream bed composition serves as a vital and potential breeding ground for many intolerant (sensitive) fish species such as *Tor khudree*, *Pethia narayani*, *Osteochilicthys nashii*. Due to such activity these fishes would no longer persist in such habitats. Immediate attention needs to be given to stabilise or restore the stream bed to its natural state either by constructing a bridge over two locations: at 'Kulem' and another at 'Dudhsagar 1' site. Any perturbation which increases either salinity or turbidity would harm fish migration both upstream and downstream. Therefore it is important to incorporate information on the tolerance levels of fishes into the management plan.

2.2.3 While executing the operations, they should ensure that noise generated through blasting is within the range to sustain fish life. They should also make sure that such activity is restricted during the breeding season (April-August) of fishes.

2.3 *Proving passages for animals and reducing collision risks*

One of the problems with increased train traffic in a track running through a forested area with wildlife is the increased risk of collisions with animals. There have been instances of a large mammal such as the Indian gaur, being involved in such accidents as well as a host of other animals though there are no systematic records available.

2.3.1 Railways should provide whistle boards in forested areas where animals cross the railway track. The crossing points are provided in the report

2.3.2 Railways should construct under passes for the movement of animals upon the advice of forest department. They should also maintain existing culverts, underpasses and other drainage structures along the railway line or improve upon the existing structures if required. Such culverts and smaller drainage structures can facilitate the movement of a variety of smaller animals including anurans, reptiles, and small mammals.

2.3.3 Upon the advice of the forest department, railways should construct barricades in designated localities to prevent the animals crossing tracks at locations where such crossings are risky for the animals.

2.3.4 Such linear construction over a stretch of 26 km through protected area would invariably disrupt the natural movement of animals, both large and small. Fresh excavation of the hill slope to accommodate the second line would change local topography and make it more difficult to animals to cross over. Construction should therefore be undertaken in segments, with gaps in between to allow animals to find alternative paths to cross the railway track. The length of each segment can be decided in consultation with the local forest officials. There would, of course, be operational constraints in implementing this recommendation, but the Railways should make a sincere attempt to ensure that wildlife movement is not totally disrupted during the period of construction. The recommendations given in the following manuals can be used as guide lines during construction and operational phase of the project.

1. Raman, T.R.S. 2011. Framing ecologically sound policy on linear intrusions affecting wildlife habitats. Nature Conservation Foundation, Mysore.
2. Ujjal Kumar S. P. S. Easa and V. Menon. Deadly tracks-A scientific approach to understanding and mitigating elephant mortality due to to train hits in Assam. Occasional Report. 24. Wildlife Trust of India, Noida.
3. Singh. A. K., A. Mookerjee and V. Menon. 2001. Jumbo Express-A scientific approach to understanding and mitigating elephant mortality due to train accidents in Rajaji National Park. Wildlife Trust of India, Noida.
4. Roy, M. and Sukumar, R. (2017). Railways and wildlife: A case study of train-elephant collisions in northern West Bengal, India. In Railway Ecology, Borda-de-Água, L., Barrientos, R., Beja, P., Pereira, H.M. (Eds.). Springer. ISBN 978-3-319-57496-7.

2.3.5 Railways should de-weed along the tracks to improve the visibility for the loco-pilots so as to reduce the risks of accidents with wildlife.

2.3.6 One of the reasons for animals to linger along railway lines is to feed on garbage thrown by

passengers. Railways should carry out an awareness campaign regarding the cleanliness along the track for the passengers. They can probably utilize “Swachh Bharat Abhiyan” theme for the same.

2.3.7 Water logging along the tracks should be avoided as this could attract animals which could then be at enhanced risk of being run over by trains.

2.3.8 Train speed would be automatically restricted on the ghat section by considerations of the terrain. However, there is potential to increase the speed of trains running through flat terrain such as the foothills of Bhagwan Mahavir Wildlife Sanctuary in Goa as well as a short section of Dandeli-Anshi Tiger Reserve and adjoining reserve forests in Karnataka, thereby increasing the risk of collisions with wildlife. Train speeds should be restricted by the Railways to safe limits in these flat sectors in consultation with the respective forest departments.

III. Public consultation:

Members of Kulem Gram Panchayat have desired a meeting with all stakeholders at least three months before the commencement of the project. They wish to set up a group with Chairman and members of the biodiversity committee of the Kulem *Gram Sabha* to monitor the progress and environmental safeguards during the construction phase.

APPENDIX (2.1.a).

LIST OF PLANT SPECIES

List of woody plant species with their life form recorded during the enumeration of forests in the proposed project area:

Sl. No.	Species (Family)	Life form
1.	*Acacia auriculiformis* (Fabaceae)	Understory
2.	*Acacia concinna* (Fabaceae)	Liana
3.	*Acronychia pedunculata* (Rutaceae)	Canopy
4.	*Acrocarpus fraxinifolius* (Fabaceae)	Canopy
5.	*Actinodaphne angustifolia* (Lauraceae)	Canopy
6.	*Actinodaphne hookeri* (Lauraceae)	Canopy
7.	*Aglaia anamalayana* (Meliaceae)	Canopy
8.	*Aglaia elaeagnoidea* (Meliaceae)	Canopy
9.	*Aglaia lawii* (Meliaceae)	Canopy
10.	*Aglaia roxburghiana* (Meliaceae)	Canopy
11.	*Alangium salvifolium* (Alangiaceae)	Understory
12.	*Albizia lebbeck* (Fabaceae)	Canopy
13.	*Allophyllus cobbe* (Sapindaceae)	Understory
14.	*Alseodaphne semecarpifolia* (Lauraceae)	Canopy
15.	*Alstonia scholaris* (Apocyanaceae)	Canopy
16.	*Annoanacae*	
17.	*Antiaris toxicaria* (Moraceae)	Canopy
18.	*Antidesma menasu* (Euphorbiaceae)	Understory
19.	*Aphanamixis polystachya* (Meliaceae)	Canopy
19.	*Aporusa lindleyana* (Euphorbiaceae)	Canopy
20.	*Ardisia solanacea* (Myrsinaceae)	Understory
21.	*Arenga wightii* (Palmae)	Understory
22.	*Argyreia* (Convolvulaceae)	Understory
23.	*Artocarpus integrifolia* (Moraceae)	Canopy
24.	*Artocarpus lakoocha* (Moraceae)	Canopy
25.	*Bauhinia racemosa* (Fabaceae)	Understory
26.	*Beilscmedia dalzelii* (Lauraceae)	Canopy
27.	*Blachia denudate* (Euphorbiaceae)	Canopy
28.	*Bridelia scandens* (Euphorbiaceae)	Liana
29.	*Bridelia retusa* (Euphorbiaceae)	Understory
30.	*Buchanania lanzan* (Euphorbiaceae)	Canopy
31.	*Calamus* (Aracaceae)	Understory
32.	*Callicarpa tomentosa* (Verbenaceae)	Understory
33.	*Callicarpa wightiana* (Verbenaceae)	Understory

34.	*Calicopteris floribunda* (Combretaceae)	Liana
35.	*Calophyllum apetalum* (Clusiaceae)	Canopy
36.	*Calophyllum inophyllum* (Clusiaceae)	Canopy
37.	*Calophyllum tomentosum* (Clusiaceae)	Canopy
38.	*Calophyllum wightianum* (Clusiaceae)	Canopy
39.	*Canarium strictum* (Burseraceae)	Canopy
40.	*Canthium sp.* (Rubiaceae)	Understory
41.	*Canthium diococcum* (Rubiaceae)	Understory
42.	*Capparis rheedi* (Capparaceae)	Understory
43	*Caralia integrima* (Rhizophoraceae)	Canopy
44	*Careya arborea* (Lecythidaceae)	Understory
45.	*Carissa carandas* (Apocyanaceae)	Understory
46.	*Caryota urens* (Palmae)	Understory
47.	*Casearia esculenta* (Flacourtiaceae)	Understory
48.	*Casearia ovoides* (Flacourtiaceae)	Understory
49.	*Casearia tomentosa* (Flacourtiaceae)	Understory
50.	*Cassia fistula* (Fabaceae)	Understory
51.	*Euonymus* (Celastraceae)	Understory
52.	*Celtis cinnamonea* (Ulmaceae)	Canopy
53.	*Chukrasia tabularis* (Meliaceae)	Canopy
54.	*Cinnamomum malabathrum* (Lauraceae)	Canopy
55.	*Cinnamomum sulphuratum* (Lauraceae)	Canopy
56.	*Cinnamomum verum* (Lauraceae)	Canopy
57.	*Cinnamomum zeylanicum* (Lauraceae)	Canopy
58.	*Cleidion javanicum* (Euphorbiaceae)	Canopy
59.	*Clerodendron viscosum* (Verbenaceae)	Understory
60.	*Colobrookea oppositifolia* (Lamiaceae)	Understory
61.	*Combretum ovalifoilum* (Combretaceae)	Liana
62.	*Connorus wightii* (Connaraceae)	Liana
63.	*Cryptocarya bourdillonii* (Lauraceae)	Canopy
64.	*Dalbergia latifolia* (Fabaceae)	Canopy
65.	*Dalbergia sympathetic* (Fabaceae)	Liana
66.	*Democarpus longan* (Sapindacae)	Canopy
67.	*Derris* (Fabaceae)	Understory
68.	*Desmodium giganticum* (Fabaceae)	Understory
69.	*Dichapetalum gelonoides* (Dichapetalaceae)	Understory
70.	*Dillenia pentagyna* (Dilliniaceae)	Canopy
71.	*Diospyros candolleana* (Ebenaceae)	Canopy

72.	*Diospyros embryopteris* (Ebenaceae)	Canopy
73.	*Diospyros microphylla* (Ebenaceae)	Canopy
74.	*Diospyros montana* (Ebenaceae)	Canopy
75.	*Diospyros oocarpa* (Ebenaceae)	Canopy
76.	*Diospyros paniculata* (Ebenaceae)	Canopy
77.	*Diospyros pruriens* (Ebenaceae)	Canopy
78.	*Diospyros saldanhae* (Ebenaceae)	Canopy
79.	*Dipliclisia glauscens* (Menispermaceae)	Liana
80.	*Dysoxylum binectariferum* (Meliaceae)	Canopy
81.	*Elaeocarpus serratus* (Eleaocarpaceae)	Canopy
82.	*Eleagnus conferta* (Eleagnaceae)	Liana
83.	*Embelia ribes* (Myrsinaceae)	Understory
84.	*Entada pursaetha* (Fabaceae)	Liana
85.	*Ervatamia heyneana* (Apocyancaeae)	Understory
86.	*Eugenia sp.* (Myrtaceae)	Understory
87.	*Eunonyms angulatus* (Celastraceae)	Understory
88.	*Euonymus undulatus* (Celastraceae)	Understory
89.	*Eurya nitida* (Ericaceae)	Understory
90.	*Exococarya agaloocha* (Euphorbiaceae)	Understory
91.	*Ficus asperima* (Moraceae)	Canopy
92.	*Ficus benghalensis* (Moraceae)	Canopy
93.	*Ficus callosa* (Moraceae)	Canopy
94.	*Ficus glomerata* (Moraceae)	Canopy
95.	*Ficus hispida* (Moraceae)	Canopy
96.	*Ficus nervosa* (Moraceae)	Canopy
97.	*Ficus tsjckela* (Moraceae)	Canopy
98.	*Ficus virens* (Moraceae)	Canopy
99.	*Flacourtia montana* (Flacourtiaceae)	Understory
100.	*Garcinia cambogea* (Clusiaceae)	Canopy
101.	*Garcinia gummi-gutta* (Clusiaceae)	Canopy
102.	*Garcinia indica* (Clusiaceae)	Canopy
103.	*Garcinia morella* (Clusiaceae)	Canopy
104.	*Glochidion velutinum* (Euphorbiaceae)	Understory
105.	*Glycosmis pentaphylla* (Rutaceae)	Understory
106.	*Gnetum scandens* (Gnetaceae)	Liana
107.	*Gnetum ulva* (Gnetaceae)	Liana
108.	*Goniothalamus cardiopetalus* (Annonaceae)	Understory
109.	*Grewia tiliifolia* (Tiliaceae)	Canopy

110.	*Grewia sp.* (Tiliaceae)	Understory
111.	*Gymnosporea rothiana* (Celastraceae)	Understory
112.	*Helicteres isora* (Sterculiaceae)	Understory
113.	*Heterophragma* (Bignoniaceae)	Canopy
114.	*Holigarna arnottiana* (Anacardiaceae)	Canopy
115.	*Holigarna grahamii* (Anacardiaceae)	Canopy
116.	*Holarrenha antidysenterica* (Apocyanaceae)	Understory
117.	*Hopea ponga* (Dipterocarpaceae)	Canopy
118.	*Hopea wightiana* (Diptercarpaceae)	Canopy
119.	*Hydnocarpus wightiana* (Flacourtiaceae)	Canopy
120.	*Ipomea* (Convolvulaceae)	Liana
121.	*Ixora brachiata* (Rubiaceae)	Understory
122.	*Ixora nigricans* (Rubiaceae)	Understory
123.	*Knema attenuate* (Myristicaceae)	Canopy
124.	*Kydia calycina* (Malvaceae)	Understory
125.	*Lagerstroemia microcarpa* (Lythraceae)	Canopy
126.	*Lannea coromandelica* (Ancardiaceae)	Canopy
127.	*Lapisanthes microphylla* (Sapindaceae)	Understory
128.	*Lasiosiphon eriocephala* (Thymeliaceae)	Understory
129.	*Leea indica* (Leeaceae)	Understory
130.	*Litsea floribunda* (Lauraceae)	Canopy
131.	*Litsea mysorensis* (Lauraceae)	Canopy
132.	*Litsea stocksii* (Lauraceae)	Understory
133.	*Lophopetalu wightianu* (Celastraceae)	Canopy
134.	*Macaranga peltatum* (Euphorbiaceae)	Understory
135.	*Mallotus philippenensis* (Euphorbiaceae)	Understory
136.	*Mallotus tetracocus* (Euphorbiaceae)	Canopy
137.	*Mama paniculata*	
138.	*Mammea suriga* (Clusiaceae)	Canopy
139.	*Mangifera indica* (Anacardiaceae)	Canopy
140.	*Memecylon edule* (Melastomaceae)	Understory
141.	*Memecylon sp.* (Melastomceae)	Understory
142.	*Memecylon talbotianum* (Melastomaceae)	Understory
143.	*Memecylon umbellatum* (Melastomaceae)	Understory
144.	*Miliusa tomentosa* (Annonaceae)	Understory
145.	*Mimusops elengii* (Sapotaceae)	Canopy
146.	*Murraya exotica* (Rutaceae)	Understory
147.	Murraya paniculata (Rutaceae)	Understory

148.	Myristica beddomei (Myristicaceae)	Canopy
149.	Myristica dactyloides (Myristicaceae)	Canopy
150.	Myristica malabarica (Myristicaceae)	Canopy
151.	Neolitsea zeylanica (Lauraceae)	Canopy
152.	*Neonauclea purpurea* (Rubiaceae)	Canopy
153.	*Nothopegia colobrookiana* (Anacardiaceae)	Understory
154.	*Nothopodytes foetida* (Icacinaceae)	Understory
155.	Unidentified sp.	
156.	*Ochna obtuse* (Ochnaceae)	Understory
157.	*Ochlandra* (Poaceae)	Understory
158.	*Olea dioica* (Oleaceae)	Canopy
159.	*Palaquium ellipticum* (Sapotaceae)	Canopy
160.	*Pandanus odoratissimus* (Pandanaceae)	Understory
161.	*Paramigyna monophylla* (Rutaceae)	Liana
162.	*Persea macrantha* (Lauraceae)	Canopy
163.	*Phyllanthus emblica* (Euphorbiaceae)	Understory
164.	*Pittosporum floribunda* (Pittosporaceae)	Understory
165.	*Plectronia rheedii* (Rubiaceae)	Understory
166.	*Polyalthia fragrans* (Annonaceae)	Canopy
167.	*Pongamia glabra* (Fabaceae)	Understory
168.	*Psychotria dalzelii* (Rubiaceae)	Understory
169.	*Psychotria flavida* (Rubiaceae)	Understory
170.	*Pterigota alata* (Sterculiaceae)	Canopy
171.	*Pterocarpus marsupium* (Fabaceae)	Canopy
172.	*Pterospermum acerifolium* (Sterculiaceae)	Canopy
173.	*Pterospermum sp.* (Sterculiaceae)	Canopy
174.	*Pterospermum broadleaf* (Sterculiaceae)	Canopy
175.	*Randia dumetorum* (Rubiaceae)	Understory
176.	*Randia rugulosa* (Rubiaceae)	Understory
177.	*Randia uliginosa* (Rubiaceae)	Understory
178.	*Sapindus sp*. (Sapindaceae)	Understory
179.	*Schlecheira oleasa* (Sapindaceae)	Canopy
180.	*Scolopia crenata* (Flacourtiaceae)	Understory
181.	*Scutia myrtina* (Rhamnaceae)	Liana
182.	*Smilax zeylanica* (Smilacaceae)	Liana
183.	*Sterculia foetida* (Sterculiaceae)	Canopy
184.	*Sterculia guttata* (Sterculiaceae)	Canopy
185.	*Stereospermum personatum* (Bignoniaceae)	Canopy

186.	*Strobilanthus sp.* (Acanthaceae)	Understory
187.	*Strombosia ceylanica* (Olacaceae)	Canopy
188.	*Strychnos climber* (Loganiaceae)	Liana
189.	*Strychnos nux-vomica* (Loganiaceae)	Canopy
190.	*Symplocos sp.* (Symplocaceae)	Canopy
191.	*Symplocos beddomei* (Symplocaceae)	Canopy
192.	*Symplocos cochinchinensis* (Symplocaceae)	Canopy
193.	*Syzygium microphylla* (Myrtaceae)	Canopy
194.	*Syzygum sp* (Myrtaceae)	Canopy
195.	*Syzygium corymbosa* (Myrtaceae)	Canopy
196.	*Syzygium cumini* (Myrtaceae)	Canopy
197.	*Syzygium densiflorm* (Myrtaceae)	Canopy
198.	*Syzygium gardeneri* (Myrtaceae)	Canopy
199.	*Syzygium hemisphericum* (Myrtaceae)	Canopy
200.	*Syzygium laetum* (Myrtaceae)	Understory
201.	*Syzygium macrophylla* (Myrtaceae)	Canopy
202.	*Syzygium macrosepala* (Myrtaceae)	Canopy
203.	*Syzygium sp.* (Myrtaceae)	Canopy
204.	*Syzygium zeylancum* (Myrtaceae)	Canopy
205.	*Terminalia bellerica* (Combretaceae)	Canopy
206.	*Terminalia crenulata* (Combretaceae)	Canopy
207.	*Terminalia paniculata* (Combretaceae)	Canopy
208.	*Tetrameles nudiflora* (Datiscaceae)	Canopy
209.	*Tilia sp* (Tiliaceae)	Understory
210.	*Toddalia asiatica* (Rutaceae)	Liana
211.	*Toona ciliata* (Meliaceae)	Canopy
212.	*Trema oreientalis* (Ulmaceae)	Understory
213.	*Uvaria* (Annonaceae)	Understory
214.	*Ventilago madrapatana* (Rhamnaceae)	Liana
215.	*Vitex altissima* (Verbenaceae)	Canopy
216.	*Vitis discolor* (Vitaceae)	Liana
217.	*Wagatea spicata* (Fabaceae)	Liana
218.	*Walsura trijuga* (Meliaceae)	Canopy
219.	*Wendlandia thyrsoides* (Rubiaceae)	Understory
220.	*Xantolis tomentosa* (Sapotaceae)	Canopy
221.	*Xylia xylocarpa* (Fabaceae)	Canopy
222.	*Ziziphus oenoplea* (Rhamnaceae)	Liana
223.	*Ziziphus rugosa* (Rhamnaceae)	Liana
224.	*Ziziphus xylopyros* (Rhamnaceae)	Understory

APPENDIX (2.1.b).

LIST OF BIRDS REPORTED FROM THE STUDY AREA

M – MIGRATORY, **R** – RESIDENT, **U** – UNCLEAR

1. Little Cormorant *Phalacrocorax niger* R
2. Little Egret *Egretta garzetta* R
3. Cattle Egret *Bubulcus ibis* R
4. Indian Pond-Heron *Ardeola grayii* R
5. Malayan Night Heron *Gorsachius melanocephalus* M
6. Oriental Honey-buzzard *Pernis ptilorhyncus* R
7. Black Kite *Milvus migrans* R
8. Crested Serpent Eagle *Spilornis cheela* R
9. Crested Goshawk *Accipiter trivirgatus* M/R
10. Shikra *Accipiter badius* R
11. Black Eagle *Ictinaetus malayensis* R
12. Rufous-bellied Eagle *Hieraaetus kienerii* **VG**
13. Changeable Hawk Eagle *Spizaetus cirrhatus* **R**
14. Red Spurfowl *Galloperdix spadicea* **R**
15. Grey Junglefowl *Gallus sonneratii* **R**
16. Indian Peafowl *Pavo cristatus* **R**
17. Nilgiri Wood Pigeon *Columba elphinstonii* **R/V**
18. Spotted Dove *Streptopelia chinensis* **R**
19. Emerald Dove *Chalcophaps indica* **R**
20. Grey-fronted Green-Pigeon *Treron pompadora* **R**
21. Mountain Imperial-Pigeon *Ducula badia* **R**
22. Vernal Hanging-Parrot *Loriculus vernalis* **R**
23. Plum-headed Parakeet *Psittacula cyanocephala* **R**
24. Malabar Parakeet *Psittacula columboides* **R/E**
25. Pied Cuckoo *Clamator jacobinus* **M**
26. Common Hawk Cuckoo *Hierococcyx varius* **R**
27. Indian Cuckoo *Cuculus micropterus* **U**
28. Banded Bay Cuckoo *Cacomantis sonneratii* **R/M**
29. Indian Plaintve Cuckoo *Cacomantis passerinus* **R**
30. Drongo Cuckoo *Surniculus lugubris* **R**
31. Asian Koel *Eudynamys scolopacea* **R**

32. Blue faced Malkoha *Phaenicophaeus viridirostris* R
33. Greater Coucal *Centropus sinensis* R
34. Oriental Scops-Owl *Otus sunia* R
35. Collared Scops-Owl *Otus bakkamoena* R
36. Brown Fish-Owl *Ketupa zeylonensis* R
37. Brown Wood Owl *Strix leptogrammica* R
38. Jungle Owlet *Glaucidium radiatum* R
39. Spotted Owlet *Athene brama* R
40. Brown Hawk-Owl *Ninox scutulata* R
41. Ceylon Frogmouth *Batrachostomus moniliger* R
42. Jerdon's Nightjar *Caprimulgus atripennis* U
43. Little Swift *Apus affinis* R
44. Crested Tree-swift *Hemiprocne coronata* R
45. Malabar Trogon *Harpactes fasciatus* R
46. Common Kingfisher *Alcedo atthis* R
47. Oriental Dwarf Kingfisher *Ceyx erithacus* R
48. Stork-billed Kingfisher *Halcyon capensis* R
49. White-throated Kingfisher *Halcyon smyrnensis* R
50. Blue-eared Kingfisher *Alcedo meningting* R
51. Lesser Pied Kingfisher *Ceryle rudis* R
52. Blue-bearded Bee-eater *Nyctyornis athertoni*R
53. Green Bee-eater *Merops orientalis* R
54. Chestnut-headed Bee-eater *Merops leschenaulti* R
55. Malabar Grey Hornbill *Ocyceros griseus* R
56. Great Hornbill *Buceros bicornis* R/NT
57. Malabar Pied Hornbill *Anthracoceros coronatus* R/NT
58. Brown-headed Barbet *Megalaima zeylanica* R
59. White-cheeked Barbet *Megalaima viridis* R
60. Malabar Barbet *Megalaima rubricapilla* R
61. Coppersmith Barbet *Megalaima haemacephala* R
62. Speckled Piculet *Picumnus innominatus* M/R
63. Brown-capped Pygmy Woodpecker *Dendrocopos n*anus R
64. Rufous Woodpecker *Celeus brachyurus* R

65. Great Black Woodpecker *Dryocopus javensis* R
66. Common Flameback *Dinopium javanense* R
67. Lesser Golden-backed Woodpecker *Dinopium benghalense* R (Black-rumped Flameback)
68. Greater Golden-backed Woodpecker *Chrysocolaptes lucidus* R
69. Heart-spotted Woodpecker *Hemicircus canente*
70. Indian Pitta *Pitta brachyura* R/M
71. Common Swallow *Hirundo rustica* M
72. Wire-tailed Swallow *Hirundo smithii* R
73. Red-rumped Swallow *Hirundo daurica* R
74. Forest Wagtail *Dendronanthus indicus* M
75. White-browed Wagtail *Motacilla maderaspatensis* R
76. Grey Wagtail *Motacilla cinerea* M
77. Paddyfield Pipit *Anthus rufulus* R
78. Large Cuckoo-shrike *Coracina m*acei R
79. Black-headed Cuckoo-shrike *Coracina melanoptera* R/M
80. Small Minivet *Pericrocotus cinnamomeus*
81. Orange Minivet *Pericrocotus flammeus* R
82. Bar-winged Flycatcher-shrike *Hemipus picatus* R
83. Malabar Woodshrike *Tephrodornis gularis* R
84. Common Woodshrike *Tephrodornis pondicerianus* R
85. Grey-headed Bulbul *Pycnonotus priocephalus* R/E
86. Flame Throated Bulbul *Pycnonotus melanicterus gularis* R/E
87. Red-whiskered Bulbul *Pycnonotus jocosus* R
88. Red-vented Bulbul *Pycnonotus cafer* R
89. Yellow-browed Bulbul *Iole indica* R
90. Square-tailed Bulbul *Hypsipetes leucocephalus* M
91. White-browed Bulbul *Pycnonotus luteolus R*
92. Common Iora *Aegithina tiphia* R
93. Asian Fairy-Bluebird *Irena puella* R
94. Jerdon's Leafbird *Chloropsis cochinchinensis* R
95. Golden-fronted Leafbird *Chloropsis aurifrons* R
96. Brown Shrike *Lanius cristatus* M
97. Long-tailed Shrike *Lanius schach* M

98. Blue-capped Rock-Thrush *Monticola cinclorhynchus* M
99. Malabar Whistling Thrush *Myophonus horsfieldii* R
100. Orange-headed Thrush *Zoothera citrine cyanotus* R
101. Indian Blackbird *Turdus merula* U
102. Oriental Magpie-Robin *Copsychus saularis* R
103. White-rumped Shama *Copsychus malabaricus* R
104. Indian Robin *Saxicoloides fulicata* R
105. Puff-throated Babbler *Pellorneum ruficeps* R
106. Indian Scimitar Babbler *Pomatorhinus horsfieldii* R
107. Dark-fronted Babbler *Rhopocichla atriceps* R
108. Rufous Babbler *Turdoides subrufus* R/E
109. Jungle Babbler *Turdoides striatus* R
110. Brown-cheeked Fulvetta *Alcippe poioicephala* R
111. Grey-breasted Prinia *Prinia hodgsonii* R
112. Ashy Prinia *Prinia socialis* R
113. Blyth's Reed-Warbler *Acrocephalus dumetorum* M
114. Greeenish Warbler *Phylloscopus trochiloides M*
115. Green Warbler *Phylloscopus nitidus*
116. Common Tailorbird *Orthotomus sutorius* R
117. Large-billed Leaf-Warbler *Phylloscopus magnirostris* M
118. Western Crowned Leaf Warbler *Phylloscopus occipitalis* M
119. Asian Brown Flycatcher *Muscicapa dauurica* M
120. Brown-breasted Flycatcher *Muscicapa muttui* M
121. Red-thraoted Flycatcher *Ficedula parva* M
122. Verditer Flycatcher *Eumyias thalassina* M
123. White-bellied Blue-Flycatcher *Cyornis pallipes* R/E
124. Tickell's Blue-Flycatcher *Cyornis tickelliae* R
125. Black-naped Monarch *Hypothymis azurea* M
126. Asian Paradise-Flycatcher *Terpsiphone paradisi* R/M
127. White-throated Fantail *Rhipidura albicollis* R
128. Black-lored Tit *Parus xanthogenys* R
129. Velvet-fronted Nuthatch *Sitta frontalis* R
130. Thick-billed Flowerpecker *Dicaeum agile* R

131. Nilgiri Flowerpecker *Dicaeum concolor* R
132. Purple-rumped Sunbird *Nectarinia zeylonica* R
133. Crimson-backed Sunbird *Nectarinia minima* R/E
134. Purple Sunbird *Nectarinia asiatica* R
135. Loten's Sunbird *Nectarinia lotenia* R
136. Little Spiderhunter *Arachnothera longirostra* R
137. Oriental White-eye *Zosterops palpebrosus* U
138. Common Rosefinch *Carpodacus erythrinus* M
139. White-rumped Munia *Lonchura striata* R
140. Black-throated Munia *Lonchura kelaarti* M
141. Scaly-breasted Munia *Lonchura punctulata* U
142. Black-headed Munia *Lonchura malacca* M/R
143. House Sparrow *Passer domesticus* R
144. Chestnut shouldered Petronia *Petronia xanthocollis* R
145. Baya Weaver *Ploceus philippinus* R
146. Blyth's Starling *Sturnus blythii* M
147. Chestnut-tailed Starling *Sturnia malabarica*
148. Jungle Myna *Acridotheres fuscus* R
149. Lesser Hill Myna *Grecula indica(religiosa)*
150. Indian Golden Oriole *Oriolus oriolus* M
151. Black-hooded Oriole *Oriolus xanthornus* R
152. Black Drongo *Dicrurus macrocercus* R
153. Ashy Drongo *Dicrurus leucophaeus* M
154. White-bellied Drongo *Dicrurus caerulescens* R
155. Bronzed Drongo *Dicrurus aeneus* R
156. Spangled Drongo *Dicrurus hottentottus* M
157. Greater Racket-tailed Drongo *Dicrurus paradiseus* R
158. Ashy Woodswallow *Artamus fuscus* R/M
159. Indian Treepie *Dendrocitta vagabunda* R
160. House Crow *Corvus splendens* R
161. Jungle Crow *Corvus macrorhynchos* R