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Study visit for biodiversity conservation and ecological restoration in forests and adjoining tracts in Bihar

Final Report, submitted to Bihar State
Biodiversity Board, May 2025

T. R. Shankar Raman



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Cover images:

Front cover: Rocky outcrops (top) are an important and unique habitat in Bihar deserving of conservation attention

Back cover: View of cliffs and forests of Kaimur Wildlife Sanctuary as seen from near Kashis waterfall, looking towards Son River in the distance (top); *Butea monosperma* savanna in the Chakrabandha complex (bottom).

Availability of materials:

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Bird checklists and observations: All bird observations are available on the [eBird India portal here](#).

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Executive Summary

Objective of study visit: A week-long rapid study visit was carried out at the invitation of the Bihar State Biodiversity Board in selected forest landscapes of southern Bihar. The purpose of the study visit was to assess opportunities for biodiversity conservation and aspects related to ecological restoration in specific forest areas and adjoining tracts.

Areas visited: Areas visited or seen briefly included Chakrabandha PF, Majhari PF, Sahiyari PF, Umga Pahad, Dulare PF, Karamdih PF, Kaimur Wildlife Sanctuary, Rajgir Wildlife Sanctuary, Ghora Kathora, Kakolat Waterfalls, Ratanpur RF, Dibor PF, Kumbhiyatari PF, Hi-Tech Nursery (near Sirdalla), and the Gautam Buddha Wildlife Sanctuary (Barachatti Range).

Observations: General observations were made on habitat condition, common native plant species, possible signs of degradation, invasive alien plant species occurrence, and record of animals or animal signs observed. Around 80 species of plants were photo-documented on the citizen science platforms iNaturalist, and 73 species of birds were recorded incidentally on eBird during the field visits. Tree planting along roads and plantations (of trees such as *Senna siamea*, *Acacia auriculiformis*, *Peltophorum ferrugineum*, *Eucalyptus* sp.) created in protected areas and adjoining landscapes were also observed, the latter sometimes established in what is likely to have earlier been dry thorn or wooded savanna and open natural ecosystems. The nursery visited near Sirdalla had a substantial fraction of non-native plants besides the native plants being raised. Significant invasive alien species noted in the visited areas included *Lantana camara*, *Mesosphaerum suaveolens* (*vilayati tulsii* or *van tulsii*), *Neltuma* (= *Prosopis*) *juliflora*, *Chromolaena odorata*, *Parthenium hysterophorus*, and *Acacia auriculiformis*. Degraded areas with potential for ecological restoration for biodiversity conservation were noted and discussed with field officers and staff.

Key suggestions for policy and management:

1) Policy on Invasive Alien Species and Ecological Restoration: Bihar state currently lacks a policy framework on invasive alien plant species and ecological restoration. Such a policy is required to properly guide the control and management of invasive alien plant species and to reorient tree planting and greening efforts and government schemes towards ecological restoration, with a focus on original natural ecosystems, native plant species, and with due attention to conservation of open natural ecosystems. A policy is therefore recommended for formulation and adoption at the earliest.

2) Ecological Restoration of Degraded Areas: Current conservation efforts in protected areas seem mainly geared toward protection efforts. Habitat quality can be improved for biodiversity in many areas through careful ecological restoration, that involves steps including:

- a) Identification and documentation of **permanent benchmark ecosystem sites** that are relatively undisturbed in each area or ecoregion to use as reference sites to guide habitat restoration
- b) Establishment of a state-wide network of **native plant nurseries** and strengthening existing nurseries to raise native plants, including shrubs and grasses, to support ecological restoration efforts
- c) Careful, **phase-wise ecological restoration** with removal of invasive alien species such as *Lantana camara*, taking care to retain native plants and regeneration (in contradistinction to generic site clearance operations), and planting of appropriate native species in selected sites

3) Conserving forests and Open Natural Ecosystems (ONEs): Bihar's conservation efforts have emphasised forest conservation and tree planting programmes besides wetlands. More attention is now needed to **identify, map, and conserve Open Natural Ecosystems (ONEs)** such as grasslands and savannas. Long-term Ecosystem Monitoring (LTEM) sites should ideally be established in both forests and ONEs.

4) Additional research and surveys: While considerable general information exists on Bihar's wildlife, additional research and systematic surveys can help enhance biodiversity conservation efforts, including through:

- a) Encouragement of **wildlife research in protected areas (PAs)** of Bihar
- b) Comprehensive **bird and herpetofaunal surveys** in PAs and surrounding areas
- c) **Surveys of little-known taxa** such as small mammals, smaller carnivores, and bats
- d) **Surveys of unique habitats** such as rock-outcrop inselbergs, cliff-faces, *Butea monosperma* (*Palash*) and *Hardwickia binata* (*Anjan*) savannas, and open natural ecosystems.

5) Training needs: There is a need for training field staff to support biodiversity conservation and ecological restoration efforts, especially on the following topics:

- a) **Natural history training** to learn to identify and document native plants and animals, using field guides and citizen science applications such as iNaturalist and Merlin;
- b) **Wildlife monitoring training** to monitor populations of focal taxa, including through use of technology such as camera traps and monitoring apps such as eBird;
- c) **Habitat monitoring training** such as **creation and monitoring of permanent benchmark ecosystem plots**, use of GPS and mapping tools, and recording invasive alien species;
- d) **Training in native plant nursery** development and management, including on germination and raising of native grasses, shrubs, climbers, and trees for ecological restoration.

Introduction

Despite having only 8% of the 94,163 km² geographical area under forest and a very high average population density of 1,106 people per km² (2011 census; currently this would be around 1400 people per km²), the state of Bihar in northern India is significant for biodiversity conservation. Bihar contains a variety of natural and anthropogenic ecosystems falling with two broad terrestrial ecoregions: the Lower Gangetic Plains Moist Deciduous Forests, and the Chhota-Nagpur Dry Deciduous Forests. The state includes a range of forest types from dry thorn forests to dry and moist deciduous and sal forests, as well as open natural ecosystems, wetlands and marshes, rivers and streams. Over half the area of the state is under cultivation and together with agro-forestry, fallows, pasture lands, and other land uses, these comprise the anthropogenic habitats. These natural and human-modified ecosystems support populations of a rich animal life, including over [420 bird species](#) and over 50 species of mammals, including species such as the Gangetic dolphin and tiger.

Bihar state has made significant strides towards conservation, including through the creation of a protected area network consisting of 1 National Park, 12 Wildlife Sanctuaries including a Gangetic Dolphin sanctuary, 2 Conservation Reserves, and 1 Community Reserve. However, it is now widely recognised that biodiversity conservation efforts should take a whole landscape perspective that considers protected reserves as well as surrounding human land uses. The nature of the surrounding landscape matrix and the intensity and kind of land use in human use areas can influence biodiversity at the landscape scale and the viability of populations both within and outside protected areas. The Bihar government has instituted a number of schemes to involve people in greening and tree planting initiatives across the state such as through the Jal Jeevan Hariyali Abhiyan, Hariyali Mission, the Jeevika Didis program, and through incentives for nurseries and agroforestry to increase the tree cover outside forest areas. With suitable modifications, such as through a renewed focus on native plant species and ecological restoration, these schemes can significantly enhance biodiversity conservation efforts in the wider landscape.

The present short study visit was undertaken at the invitation of the Bihar State Biodiversity Board to visit areas in southern Bihar, including protected areas and adjoining landscapes, with a view to identifying potential aspects and initiatives that could be focused on from a biodiversity conservation and ecological restoration point of view.

Itinerary and areas visited

The study visit was undertaken from 31 August 2024 (arrival in Gaya) to 6 September 2024 (departure from Gaya on 7 September). The main protected areas visited were the Chakrabandha forest and adjoining hillocks, Kaimur Wildlife Sanctuary, Rajgir WLS, Kakolat and Rajauli forests and WLS, and Gautam Buddha WLS. The following Table summarises the initially planned itinerary and what areas were ultimately visited during the trip. Areas visited across Bihar are indicated in Map 1.

Date	Time	Field visit as originally planned	Visits as achieved and remarks
31-08-24	Afternoon	Arrival at Bodh Gaya airport	Arrived and held meeting at SFTI, Gaya, with Mr S. Sudhakar IFS, CF, Gaya, Mr Shashikant Kumar IFS, DFO, Gaya, and Ms J. Subh Laxmi, ACF. The overall plan of field visits and objectives were discussed. Night stay at Paharpur FRH.
	Evening	Discussion with CF and DFO Gaya regarding study visit plan at Brahm van	
01-09-24	Morning	Travel to Imamganj range, Gaya forest division.	Travel to Imamganj, Forest Range Office. Met FRO Mr Kuldip Chauhan.
	Forenoon	Visit to Northern dry mixed deciduous forests of Chakrabanda for field observation/evaluation of various flora and fauna in the hilly tracts and in the agricultural field and forest transition zones	Visited and passed through Chakrabandha area via Kokana, Baraha, Panchrrukhiya, Anarban Salaiya, and CRPF camp. Areas included Chakrabandha PF, Majhari PF, and Sahiyari PF (Aurangabad Division) with Shri S. Sudhakar and Smt Ruchi Singh, DFO, Aurangabad.
	Afternoon	Visit to Northern dry mixed deciduous and dry deciduous scrub jungles of Panchrukhiya, Aurangabad Forest division.	Field observations were made along the forest road passing through the area and the Chakrabanda CRPF camp and via Panchrukhiya. Brief interaction with officers at the CRPF camp (Shri Upendra Singh).
	Overnight	Discussion on various observations made in the field.	Night stay at Circuit House, Aurangabad
02-09-24	Forenoon	Visit to dry deciduous and Butea forests of Karamdih and Dulare PFs	Visited Umga Pahad, Dulare PF, and Karamdih PF to observe vegetation in the isolated hillocks and dry thorn forest vegetation.
	Afternoon	Visit to the Indrapuri wetland; Travel to Rohtas Forest Division. Field visits and Field observation in the forest areas of Tilouthu range	Visit to Aurangabad Biodiversity Park, Indrapuri Barrage, and evening visit to Tutla Bhawani Waterfalls and cliffs
	Overnight		Night stay at Sasaram
03-09-24	Forenoon	Visit to Kaimur WLS of Rohtas/ Kaimur Divisions; Gorla PF and adjoining Mixed dry deciduous and Sal jungles of the PA.	Entered Kaimur WLS at 0535 h at Tarachandi gate with ACF Rajeev Kumar, Amit Kumar (Forester), Dhananjay Kumar (driver), and Nathuni Jadav (local guide) and explored forests along road and short distances on foot in Mahua Dihira PF, Gorla PF, and Kachhuar PF

Date	Time	Field visit as originally planned	Visits as achieved and remarks
	Afternoon	Continuation of visit; Kachhuar PF of Kaimur WLS, Kashis Waterfall and cliffs	Explored forests passing Gorla, Bhokarwa, and Chakdi; met Rohtas RFO Hemchand Mishra at Rohtas Range Office; travel to Rajgir WLS
	Overnight		Overnight stay at Rajgir FRH
04-09-24	Forenoon	Visit to Rajgir WLS and other forest areas of Nalanda Division including Nature safari/ Zoo safari and adjoining Sal forests and scrub jungle/ bamboo in the hills upto Jethian and Athri range (Gaya division) that are constantly affected by fire.	Visit to Ghora Kathora and forests of Rajgir (Pant) WLS, explored the forests on foot and along the main access road with ACF Sathyam, Forest Guard Akhilesh Kumar, and Guard Rajni Kant Kumar; Area between Uday Giri and Ratnagiri
	Afternoon	Rajgir WLS visit continues as above	Visited forest areas in valley between Son Giri and Vyavhar Giri and streamside vegetation
	Overnight	Travel to Kakolat, Nawada Forest Division	Night stay at Aranya Dhara, Kakolat; explored area on night walk with Shri Bharat Jyoti Chairperson, BSBB, S. Sudhakar, IFS, CF, Gaya Shresth Kumar Krishna, IFS, ACF, Nawada.
05-09-24	Forenoon	Visit to the Dry Peninsular Sal and forests of Nawada and Kauakol ranges; observations in PFs of Ranigadar, Mahuliatarn etc., and in Nawada WLS.	Visit to Ratanpur RF, mining and stone quarry area; Dibor PF near Hardiya Dam; and other areas
	Afternoon	Travel to Gaya	Visit to Kumbhiyatari PF along the Dhanarjay River near Jorasimar close to Jharkhand border; evening visit to Hi-Tech nursery near Sirdalla.
	Overnight		Travel to Gaya and night stay at Paharpur FRH.
06-09-24	Forenoon	Visit to Gurpa and Baracha ranges, Field observations at GBWLS protected area; river and mountain landscape of Badki Chappi, Balua area including wetlands in the ESZ of the sanctuary.	Visit to Gautam Buddha WLS, Barachatti Range; open thorn forest and savanna vegetation; cheetal path road to Barandih through Barandih PF; Barwadiah checkdam and lake and bear rescue centre with Shri S. Sudhakar IFS, and forest staff Abhimanyu, Rohit Kumar Chauhan Shashi Bhushan and Kumar Sinha, ACF.
	Afternoon		Walk through forests along Harkatty Nala to reach Mohane River near Chhutki Champi area with Mukesh Kumar, Nitish Kumar, Akhilesh Kumar, Vikash Kumar, Sanjay Yadav (tracker guard), Hriday Kumar, and Vijay Yadav, along with RFO and CF Gaya
	Overnight	Return to FRH and discussion with CF and DFO Gaya	Discussions with CF and DFO Gaya and Night stay at Paharpur FRH.
07-09-24	12:10 PM	Departure from Bodhgaya airport	Visit to Butterfly Park, Mahabodhi Temple and departure from Bodhgaya airport

Map 1: Bihar state map showing location of the forests and protected areas in the southern part of the state that were visited on this study visit.



Field Observations

At the outset, it is to be noted that these observations made on the study visit are of a very general nature due to the very short duration of the visit and the fact that they were made while almost constantly on the move. However, it is hoped that the biodiversity and ecological restoration lens through which these observations are made will aid in providing a different perspective and some guidance for conservation and management. Around 80 species of plants were photo-documented on the citizen science platforms iNaturalist, and 73 species of birds were recorded incidentally on eBird during the field visits (see: **Appendix 1 and 2**).

Chakrabandha Complex

The Chakrabandha area, referred to here as the Chakrabandha Complex, forms a large tract comprised of numerous protected forests (PFs) of which Chhakrabandha PF (in Gaya Division), and Sahiyari PF and Umga PF (in Aurangabad Division) are the largest. The overall area of this tract is over 400 km² (see Map 2) and the hill tracts and forests extend into neighbouring Jharkhand state.

A range of forest types and various stages of degradation were noted including:

(a) Dry thorn (scrub) forest and open and wooded savannas, characterised by more open vegetation with scattered trees, thorny shrubs in the understorey, and grass cover at the ground layer. Tree species noted here include *Butea monosperma*, *Cassia fistula*, *Senegalia catechu*, *Diospyros melanoxylon*, *Zizyphus sp.*, *Aegle marmelos*, *Lagerstroemia parviflora*, *Terminalia arjuna* and *Wrightia/Holarrhena sp.*

(b) *Butea monosperma* savanna such as near Baraha, which is a unique habitat and potential Long-term Ecosystem Monitoring (LTEM) site

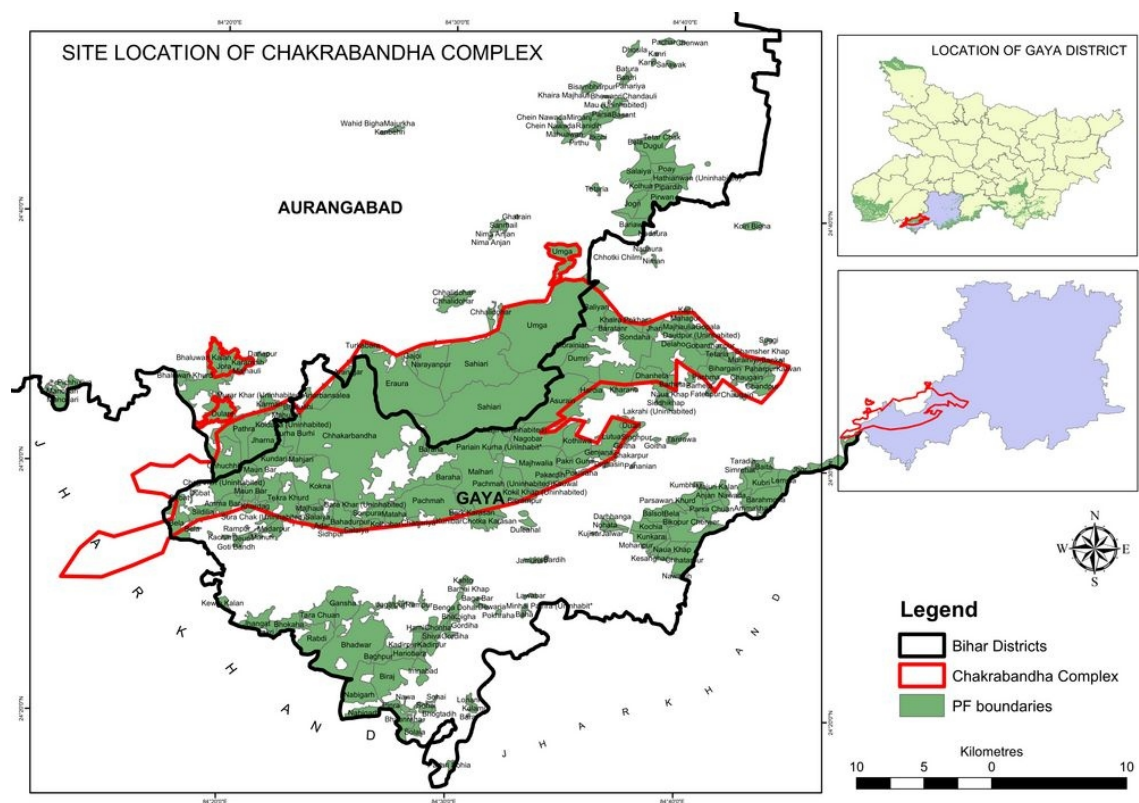
(c) Mixed deciduous sal forest, such as at Majhari PF, with *Shorea robusta*, *Madhuca longifolia* (Mahua), *Lagerstroemia parviflora*, *Buchanania lanzan*, etc.

Degraded areas were noticed close to the road with that were invaded by *Lantana camara*, possibly due to earlier land uses or disturbance caused by the road itself. Villages such as Kokana, Baraha, Panchrukhiya, and Anarban Salaiya are present in the area with agriculture and livestock. The effects of these on the vegetation could not be assessed; it is possible that limited livestock grazing may be helping to sustain the savanna-like vegetation in some areas.

The CRPF camp occupies a large area and, although presence of insurgents appears to be at an end, they are continuing combing operations to find and defuse land mines (of which many are still present in the area and pose a risk to humans, livestock, and wildlife).



Dense invasion of *Lantana camara* and *Chromolaena odorata* in Chakrabandha Complex



Map 2. Map of Chakrabandha Complex and associated protected forests and villages

Hillocks: Umga Pahad, Dulare, and Karamdih

A number of hillocks occur in the Chakrabandha Complex as inselbergs/rock outcrops or connected to east-west chain of hills. Dulare, Karamdih and Umga Pahad along the northern boundary of the Complex should be included with the Forest Complex in planning conservation measures.

Umga Pahad (with the Sun Temple located in the NW corner) is a rocky area with dry thorn and low deciduous forest vegetation including species such as *Boswellia serrata*, *Sterculia urens*. Animal signs in the area include Indian hare (*Lepus nigricollis*), Nilgai (*Boselaphus tragocamelus*), Northern plains langur (*Semnopithecus entellus*) and wild pig (*Sus scrofa*) are found.

Dulare PF in Aurangabad Range is an isolated hillock with trees such as *Phoenix* and *Borassus flabellifer* palms, *Wrightia/Holarrhena*, *Lagerstroemia parviflora*, *Ficus mollis*, and *Butea monosperma*. The foothills area is covered with an extensive carpet of the invasive alien herb *Mesosphaerum suaveolens* (*vilayati tulsi* or *van tulsi*). This invasive herb appears to have overrun the open grassland area and may have reduced the forage available for livestock and wild herbivores. Furthermore, the natural vegetation in this area has been completely altered in some locations through plantations of *Senna siamea*, a non-native tree to this area that also showed signs of profuse regeneration and spreading widely. The combination of invasive tree and herb may pose a big challenge for ecological restoration of the original grassland or savanna habitats.



Senna siamea (an alien species in the area) plantation showing signs of *Senna* regeneration as well as dense invasion of *vilayati tulsi* or *van tulsi* (*Mesosphaerum suaveolens*)

Karamdih PF in Maharajganj Range is a very interesting hillock dominated by low scrubby vegetation covered extensively with lianas (*Combretum* sp.?), besides scattered trees such as neem (likely planted), and an unidentified Rutaceae tree.

Suggestions for management

- 1) The Chakrabandha Forest Complex could be considered for further biodiversity conservation measures through dialogue with the local communities resident in the areas. Possible options could be the establishment of Community or Conservation Reserves in the PFs surrounding villages in the Chakrabandha Complex. The remaining PFs, including the larger Chhakarbandha PF and Sahiyari and Umga PFs could be consolidated into a protected area such as a wildlife sanctuary after due process and recognition of rights of local people in the area. The Community and/or Conservation Reserves can act as a natural buffer zone for the protected area, if established.
- 2) Areas along the road in Chakrabandha PF and those invaded by *Lantana camara* can be taken up for **phase-wise ecological restoration** with careful removal of the *Lantana* taking care to retain all native vegetation and naturally regenerating saplings. This can be carried out in a phasewise manner targeting some 10-20 hectares per year. The local people and (Bhoktha) tribals in the area can be prioritised for employment in this task as they would have an intimate understanding of the local native plants and also derive employment and livelihood.
- 3) To assist in setting appropriate restoration targets, **benchmark ecosystem sites** that are minimally disturbed can be identified and documented in detail in the following areas: Majhari PF, Sahiyari PF, and *Butea* savanna near Baraha. By referring to the native plant species community found in these benchmark sites, appropriate species can be chosen both for forest restoration as well as savanna/grassland restoration in the area, which can significantly boost biodiversity conservation and wildlife populations in the area.
- 4) Local people in the villages may be involved in the creation of **native plant nurseries** and growing and planting trees, shrubs, and grasses for use in the restoration efforts where required—this may signify a livelihood opportunity as well as a way to involve local people in conservation efforts.

Kaimur Wildlife Sanctuary

On the evening of 2 September 2024, a brief visit was made to the Tutla Bhawani waterfalls and cliffs at the eastern edge of Kaimur WLS. The next day, the sanctuary was explored mainly along the road from Tarachandi Gate through Mahua Dihira PF and past the Jawarh watchtower area, passing Gorla, Bhokarwa, Chhabri, and Chakdi villages, onward to Rohtas. The road descending to Rohtas was being widened and there was massive disturbance and destruction of hillside vegetation evident. The following observations are notable.

Bat Exodus in Tutla Bhawani

Although only a very brief late evening visit was made to the Tutla Bhawani waterfalls and cliffs area, the following observations are significant. At around 18:15 hours there was a massive emergence of bats from the caves high up in the adjoining cliffs. The term 'bat exodus' refers to the nightly movement of bats as they exit their roosting sites to feed in the wider landscape. At Tutla Bhawani, thousands of bats streamed out in the bat exodus that lasted for about ten minutes since it was first noticed. One exodus was over a kilometre long, while another from nearby was a shorter exodus. The species of bat could not be identified due to poor light and the distance, but this could be a Wrinkle-lipped Free-tailed Bat (*Chaerephon plicatus*) exodus according to bat expert Dr Rohit Chakravathy. Other possible species that cannot be ruled out include tomb bats



Massive exodus of insectivorous bats from the Tutla Bhawani cliffs, Kaimur

(*Taphozous* sp.) and mouse-tailed bats (*Rhinopoma* sp.). Such a large bat exodus, especially of cliff/cave-dwelling insectivorous bats is rare and has possibly not been reported earlier in Bihar or other parts of India (regular exodus of the large Indian flying fox *Pteropus giganteus* from roosting trees is commonly known). The observation is therefore notable and a proper study of bat populations in Bihar, especially along the cliffs such as at Kaimur WLS, will be very worthwhile.

Cliff Biodiversity

Cliffs and nearly-vertical rock-faces such as those in the Kaimur area (and also seen in Rajgir WLS, see later) are important habitats for many uniquely adapted plants, cliff-dwelling animals (including primates that use them as roosting sites), and cave-dwellers. It would be worthwhile to map the cliffs of Bihar, estimate the vertical face area, presence and extent of caves, and survey the cliffs for plants and other wildlife. A detailed survey may require vertical mapping, drones for viewing difficult/impossible to access areas, and other tools.

Forests and tree species of Kaimur

Kaimur WLS occupies a large tract of 1676.93 km² comprising highlands with forests and open natural ecosystems. The forests include dry and mixed deciduous forests, sal forests, and *Boswellia serrata* forests, with the following tree species noted during the study visit: *Boswellia serrata*,



View of cliffs and forests from near Kashis waterfall in Kaimur Wildlife Sanctuary, Bihar

Shorea robusta, *Buchanania lanzan*, *Zizyphus mauritiana*, *Terminalia anogeissana*, *Diospyros melanoxylon*, *Erythrina* sp., *Bauhinia* sp., *Albizia odoratissima*, *Shorea robusta*, *Terminalia elliptica*, *T. belerica*, *Cassia fistula*, *Garuga pinnata*, *Phyllanthus emblica*, *Lannea coromandelica*, *Nyctanthes arbor-trists*, *Bombax ceiba* and *Lagerstroemia parviflora*.

Open Natural Ecosystems (ONEs) of Kaimur

Besides the forest tracts, there are Open Natural Ecosystems (ONEs) in Kaimur WLS. This includes open grassland (such as on the Mahua Dihira plateau, open, shrub, and wooded savannas with significant grass cover at the ground layer. **These areas should be recognised as ONEs and the savanna and grassy habitats should be conserved.** It was noticed that at least in one location, a dense tree plantation was established in an ONE on the plateau, which can be construed as a form of habitat disturbance or destruction and should be avoided in the future.



Tree planting in Open Natural Ecosystem of Kaimur WLS: such tree planting should be discouraged as it signifies loss of an important habitat

Long-term Ecosystem Monitoring Sites in Kaimur

The unique landscape and natural ecosystems of Kaimur WLS suggest that areas here could be considered for establishment of Long-term ecosystem monitoring (LTEM) sites. The study visit was too brief and covered only a small part of this vast protected area to arrive at any specific locations. However, the establishment of at least two LTEM sites (one in a forest and one in an Open Natural Ecosystem) could be considered. Among the sites visited, potential areas could be on the Mahua Dihira plateau (ONE) and in the deciduous forests in Kachuar PF within the Kaimur WLS area.

Rajgir Wildlife Sanctuary

Vegetation and Potential Long-term Ecosystem Monitoring (LTEM) site

The forest was explored along the road towards Ghora Kathora in the forenoon. This area appeared as a low forest dominated by *Aegle marmelos* and bamboo thickets with other trees such as *Diospyros sp.*, *Zizyphus sp.*, *Cassia fistula*, *Senegalia catechu*, *Butea monosperma*, *Bauhinia spp.*, *Fernandoa adenophylla*, *Gardenia resinifera*, *Diospyros melanoxylon*, *Bridelia retusa*, *Bombax ceiba*, *Shorea robusta*, *Milletia pinnata*, *Madhuca longifolia*, *Albizia procera*, *Mallotus philippensis*, *Lannea coromandelica*, and *Terminalia anogeissana*. There are also areas of dry thorn vegetation (scrub savanna) with low shrubs (*Carissa sp.*, *Helicteres isora*). The climber *Butea superba* was also noticed. The bel-dominated forest could be considered for establishing a long-term ecosystem monitoring (LTEM) site that is unique, with great value for research and training being in Rajgir.

Tree plantations

Many tree plantations have been established in the area, including of species not-native to the area (neem *Azadirachta indica*, *Melia azederach*), alien and known invasive species (*Acacia auriculiformis* and *Eucalyptus*). Other trees such as *Alstonia scholaris*, *Neolamarckia cadamba*, *Pterospermum acerifolium* (*kanak champa*) also had been planted in different places.

Invasive alien species and ecological restoration

The *Acacia auriculiformis* plantation (near the Watchtower in Ghora Kathora PF just outside Rajgir WLS boundary) is a matter of concern as the species is known to be invasive in many areas. Efforts should be made to carefully remove this species and restore the native vegetation. Other invasives noted here include dense growth of *Lantana camara*, *Chromolaena (Eupatorium) odorata*, and *Mesosphaerum suaveolens*, especially along the road and in the scrub forest/shrub savanna area.

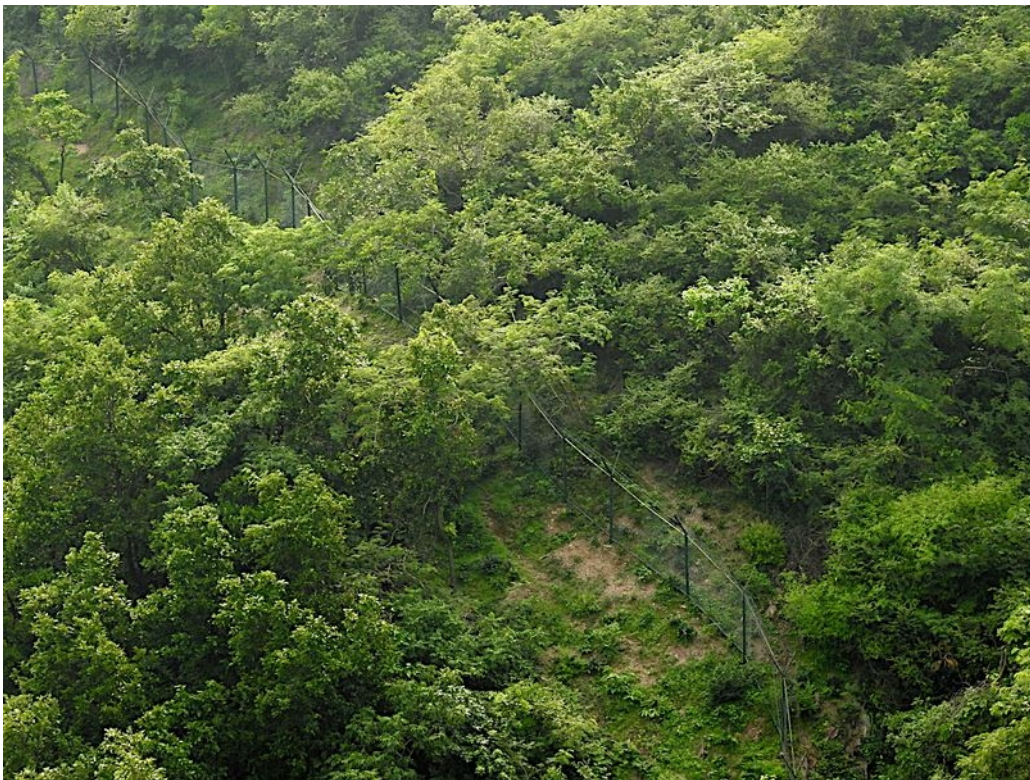
The Rajgir safari park area could be used to develop a native plants nursery and plants grown here can be used to support ecological restoration efforts in the **shrub savanna landscape**. The approach road to Ghora Kathora and resting sites en route could be used to **display informative boards and material about the unique bel forests and shrub savanna habitats** and also to inform and educate visitors about ecological restoration.



Dense invasion of *Lantana camara*, *Chromolaena odorata*, and *Mesosphaerum suaveolens* in Rajgir WLS

Removal of boundary fences

The long boundary fence and the fences around plantations act as barriers to animal movement, besides presenting an unnatural sight. Also, the envisaged purpose of this fencing seems no longer relevant. Biodiversity would benefit from removal of these fences.



Long boundary fences such as this in Rajgir WLS are linear intrusions that act like an animal barrier as well as conduit for the spread of invasive alien species.

Kakolat and Rajauli (Nawada) Forests and Wildlife Sanctuary

Kakolat Waterfalls

During the night walk at Kakolat, 1 adult female sambar in the forest and a common palm civet on fruiting *Ficus racemosa* tree were observed. The forests included tree species such as *Sterculia urens*, *Grewia tiliifolia*, *Lannea coromandelica*, *Ziziphus sp*, *Ficus microcarpa*, *Garuga pinnata*, and *Croton persimilis*. *Phanera vahlii* liana was also noted.



Forests of Kakolat area, Nawada WLS

Degraded areas for potential restoration

Two areas visited showed significant degradation and could be targeted for ecological restoration. The first was the mining quarry in Ratanpur RF. This stone quarry was operational till 2018-19 and was subsequently protected in the Rajauli WLS but illegal mining was reported to continue till 2022 when it was stopped. The area around shows significant signs of degradation with invasives such as *Lantana camara* and *Chromolaena odorata*. The second area visited was in Dibor PF (ESZ zone) near Hardiya Dam. Here the vegetation was highly degraded and heavily invaded by species such as *Lantana camara*, *Chromolaena odorata*, and *Mesosphaerum suaveolens*, besides *Parthenium hysterophorus* along roads.

There are significant opportunities for ecological restoration in the area around the old quarry as well as in Dibor. As remnant natural vegetation and natural regeneration is evident in the midst of the invaded vegetation and these degraded sites are close to forests and seed sources, it is possible that the vegetation will recover with just **assisted natural regeneration** (ANR) involving invasives removal taking particular care to retain native plants and regeneration during the process.

Establishment of Benchmark Ecosystem Site

One area with a good potential to establish a benchmark ecosystem site is the relatively less disturbed sal forest in the Kumbhiyatari PF along the Dhanarjay River (24.52745° N, 85.51927° E, 205 m elevation). This forest can serve as a reference site to identify the appropriate native species for restoration of degraded forests in Nawada WLS. Tree species noted in this area included:

Bombax ceiba, *Madhuca longifolia*, *Butea monosperma*, *Shorea robusta*, *Diospyros melanoxylon*, *Semecarpus anacardium*, *Terminalia belerica*, *T. Anogeissana*, *Mitragyna parviflora*, *Ficus benghalensis*, *Buchanania lanzan*, *Aegle marmelos*, *Lannea coromandelica*, *Cleistanthus collinus*, *Mallotus philippensis*, *Cassine glauca*, *Holarrhena antidystenterica*, *Gmelina arborea*, *Holoptelea integrifolia*, and *Ziziphus oenoplia*.



Relatively undisturbed forest tracts such as this in Nawada WLS can be identified for establishment of benchmark ecosystem sites and plots that can serve as reference sites to guide restoration

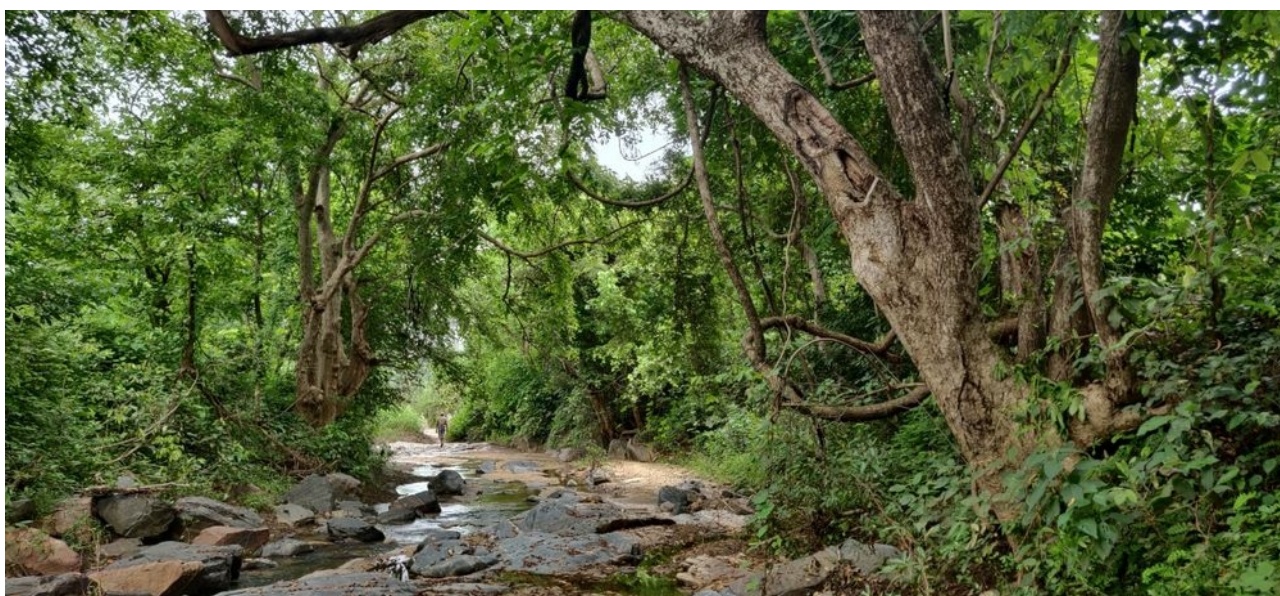
Gautam Buddha Wildlife Sanctuary

The short visit to Gautam Buddha WLS mainly covered areas in Barachatti Range, extending to the Mohane River (tributary of Phalgu River) adjoining Jharkhand.

Vegetation

A range of vegetation types was evident, from open savanna and shrub savanna to forests. The open and shrub savanna habitats on flat lands appear to be good examples of Open Natural Ecosystems (ONEs). While only chital (*Axis axis*) were seen during the short visit, this may be an important habitat for ungulates, Indian hare, Indian fox (*Vulpes bengalensis*), and jackal (*Canis aureus*), among other species. This habitat had extensive grass cover at the ground layer along with sparse to moderate tree cover with species like *Butea monosperma*, *Boswellia serrata*, *Ziziphus maritima*, *Lagerstroemia parviflora*, *Senegalia catechu*, *Mitragyna parviflora*, *Diospyros melanoxylon*, *Wrightia tinctoria*, *Croton persimilis*, and *Lannea coromandelica*. Palms included *Borassus flabellifer* and *Phoenix sp.*. The main invasive species here appears to be *Lantana camara*; although very dense and continuous thickets were not seen, the species is prevalent. Other invasive alien species included *Chromolaena odorata* and *Parthenium hysterophorus*, the latter particular near villages and cattle-grazed areas.

The forests near the Mohane River include both mixed deciduous forests with *sal* (*Shorea robusta*) as well as riverine gallery forests with *kahua* (*Terminalia arjuna*), *Bombax ceiba*, *Ailanthus*



Riverine forests along the Harkatty Nala flowing towards the Mohane River

sp., and other trees. Trees noticed in this forest area include *Madhuca longifolia*, *Holarrhena antidysenterica*, *Ziziphus sp.*, *Aegle marmelos*, *Croton persimilis* (*masondha*, very common here—a village nearby is also called Masondha), *Lagerstroemia parviflora*, *Terminalia anogeissana*, *Buchanania lanzan* and *Wrightia tinctoria*. Areas with *Lantana camara* and *Chromolaena odorata* invasion were also noticed.

Potential Long-term Ecosystem Monitoring (LTEM) site and Research Station

As there has been little attention to conservation and monitoring of Open Natural Ecosystems (ONEs) in Bihar (in contrast to the focus on forests and tree planting), it would be useful to establish Long-term Ecosystem Monitoring (LTEM) sites in such ONEs to develop a better documentation and understanding of these ecosystems. One potential Long-term Ecosystem Monitoring (LTEM) site in Gautam Buddha WLS could be in the Barachatti Range at about 24.46974° N, 85.12057° E (elevation 203 m).

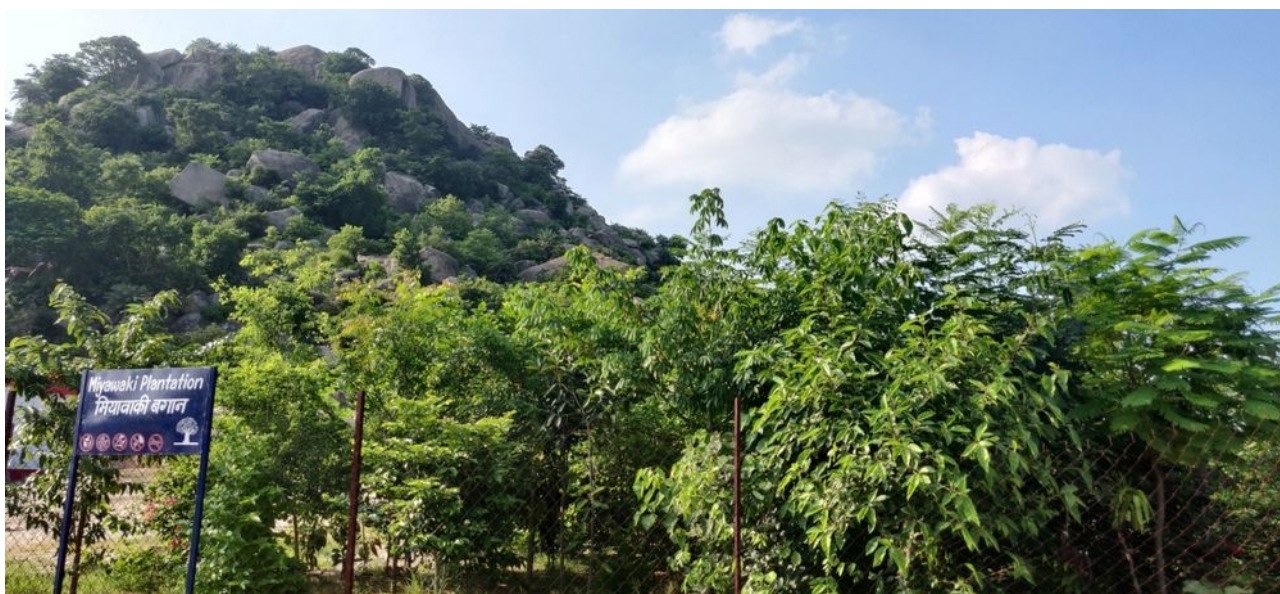
The LTEM site can be supported by the establishment of a Wildlife and Ecosystem Research Station under the aegis of the Bihar Forest Department. A potential site for this is the Barwadih bear rescue centre near Barwadih lake, where space and minimal facilities is available at present along with road access, water, electricity, and telecommunications.



Bear rescue centre at Barwadih in Gautam Buddha WLS

Biodiversity Parks, Safari Parks, and Butterfly Parks

Although these were not the main focus of the study visit, a few observations are made on the Aurangabad Biodiversity Park and Rajgir Safari Park area. The **Aurangabad Biodiversity Park** is an attractive park near the main highway and is geared to provide visitors with a recreational space. However, the potential to transform this into a more informative or educational space about biodiversity remains untapped. The park is planted almost entirely with ornamental and non-native plant species and *Senna siamea* trees and is in that sense indistinguishable from any number of municipal parks. The park abuts remarkable inselberg rock outcrops with unique assemblages of plants and animals, but there is nothing about the local geology, biodiversity, or their conservation significance evident in any display, section, or signage in the park. Outside the park gates, there is a fenced-in Miyawaki plantation, appearing like a thicket packed at an unnaturally high density with many non-native or unsuitable plant species. Such **Miyawaki plantations should be strongly discouraged at sites like this that retain their own ecological uniqueness** and instead efforts made to foster native vegetation with a high diversity of locally native plant species at natural and appropriate densities. This could be accompanied with informative and attractive signages that provide a rich learning experience along with the recreational and entertainment use of the Park – as a form of infotainment or edutainment – rather than the purely recreational experience which is currently offered that signifies a lost opportunity.



Miyawaki thickets are neither forests nor true plantations and should be discouraged from an ecological restoration and biodiversity conservation point of view

The **Rajgir Zoo and Safari Park** area could not be fully visited except for the glass-bridge area that provides visitors a unique experience and view of the forests. However, the Park and the road to Ghora Kathora used by visitors could be used to develop informative and well-designed signages on Bihar's biodiversity, ecosystems, geology and cliffs, and ecological restoration. Along the road, a series of 10 stops with self-discovery signage boards with QR codes can be placed that will link to website where specific aspects viewed at that location can be further explained or learned about.

The **Butterfly Park and Rearing Centre** in Bodh Gaya was visited and the technical staff there (Ms Preeti Ram and Mr Ashok Kumar) gave an excellent account of butterfly species in the park, besides rearing and release methods. Forest Staff Mr Anjay Kumar guided the walk through the park. This park, too, is pleasing and attractively laid out and numerous butterflies were active during the visit. However, even in this park, there can be a greater emphasis on use of native plants as host plants of butterflies. There is currently a reliance of many non-native plants and one of the host plants kept is the invasive alien species *Lantana camara*. A native plants garden and nursery supporting the butterfly park could also increase the interest of local citizens in growing native plants and diversifying their garden to support urban biodiversity.



Example of interpretive signage on a pollinator meadow with native plants
(Photo credit: IndyTaylor, CC-BY-SA 4.0, via Wikimedia Commons).

Examples of good biodiversity-related signages for biodiversity parks showing trail map and things to look out for (top), birds of the area (middle), and rocks and geology (bottom).
(Photos from Kishanbagh, a desert and dune ecosystem-themed biodiversity park in Jaipur)

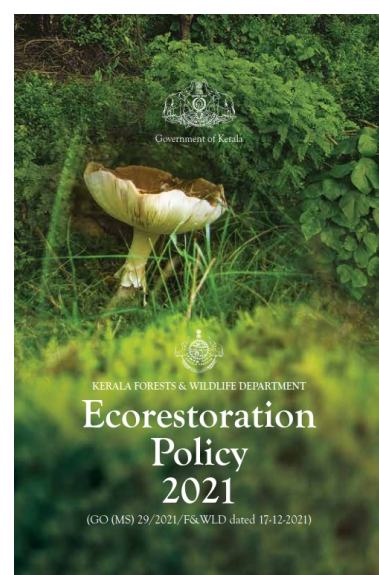
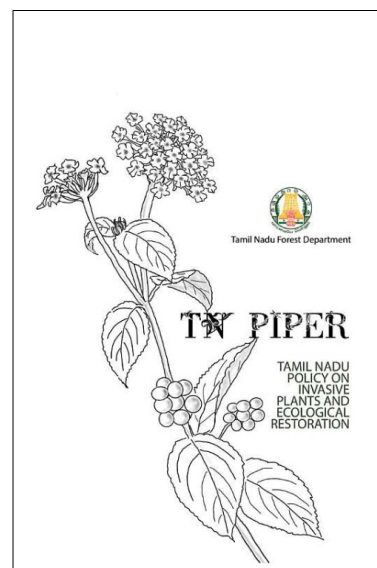


Suggestions and recommendations for policy and management

Policy on Invasive Alien Species and Ecological Restoration

Almost all areas visited had areas with significant presence of invasive alien plant species, which pose a conservation threat (Raj et al. 2023). There presently appears to be no concerted effort to tackle this issue at the state level, although weed removal may be carried out in the context of habitat management in PAs. Bihar state currently lacks a **policy framework on invasive alien plant species and ecological restoration**. Such a policy is urgently required to properly guide the control and management of invasive alien plant species state-wide and enhance the biodiversity conservation potential. Further, there is a need to reorient existing tree planting and greening efforts and schemes towards ecological restoration. These schemes could be given a focus on original natural ecosystems as they exist in different regions of Bihar, primarily target the ***growing and planting of native plant species***, and pay due attention to conservation of ***open natural ecosystems***. Specific proscribed (prohibited) list of species should be developed for the state and species such as *Acacia auriculiformis*, *Senna siamea*, *Eucalyptus*, and other alien species should be strictly avoided. At the same time, suitable lists of native species for different regions of Bihar should be developed consulting botanists and restoration ecologists so that nurseries in each region of Bihar can focus on growing the appropriate native species to support tree planting and restoration programs.

A comprehensive policy that addresses invasive alien species along with guidelines for ecological restoration and tree planting schemes is therefore recommended for formulation and adoption at the earliest. The Bihar Policy can be modelled on similar policies developed in states such as Tamil Nadu and Kerala. The Kerala state [Ecorestoration Policy 2021](#) (Kerala Forest Department GO (MS) 29/2021/F&WLD dated 17-12-2021) and the [Tamil Nadu Policy on Invasive Plants and Ecological Restoration \(TN-PIPER\)](#) adopted by the state government may be consulted for reference.





Large-scale invasion by *vilayati tulsi* or *van tulsi* (*Mesosphaerum suaveolens*) may signify loss of significant open natural ecosystems and grasslands



Dense *Lantana camara* and *Chromolaena odorata* invasion in Dibor PF

Ecological Restoration of Degraded Areas

Current conservation efforts in protected areas seem mainly geared toward protection efforts.

Habitat quality can be improved for biodiversity in many areas through *careful ecological restoration*. This can also offer livelihood opportunities for local people in nursery work, weed removal, and restoration planting and site maintenance activities. Such ecological restoration efforts may involve many steps including:

- a) Identification and documentation of **permanent benchmark ecosystem sites** that are relatively undisturbed in each area to use as reference sites to guide habitat restoration
- b) Establishment of a state-wide network of **native plant nurseries** and strengthening existing nurseries to raise native plants, shrubs and grasses, to support ecological restoration efforts
- c) Careful, phase-wise **application of ecological restoration** with removal of invasive alien species such as *Lantana camara*, taking care to retain native plants and regeneration, and planting of appropriate native species in selected sites

Identifying and setting-up benchmark ecosystem sites

Identification of benchmark ecosystem sites or reference sites is a crucial part of ecological restoration. It is important to note that unlike generic tree planting, ecological restoration is always oriented towards a specific goal of recovering original or pre-disturbance ecosystems. Benchmark ecosystem sites or reference sites help determine that goal. For example, corresponding to different ecoregions, a benchmark ecosystem site might be a relatively intact grassland, savanna, or forest type. The right benchmark can be identified in different ways:

- **Based on pre-disturbance information:** A benchmark site can be based on information available from a particular location or site itself as it was prior to being degraded or destroyed. For instance, if sites were thoroughly surveyed for their plants and animal communities before destruction due to logging or mining, then one can use that information as a reference for restoration. However, this is rarely the case and information on sites as they were prior to disturbance is usually lacking and we may need other approaches to identify benchmark sites (Mudappa and Raman 2010).
- **Based on historical sources:** Benchmark sites may also be determined based on historical sources such as old floras, working plans, maps, and other publications including

travelogues, which describe the vegetation, landscape, and land uses prior to the onset of major disturbances.

- ***Based on nearby intact ecosystems:*** Most frequently, benchmark ecosystems sites are selected as relatively undisturbed sites located in the same ecoregion and geography, sharing a similar environment. These may be ecosystem remnants at nearby locations that have a similar elevation, climate, and soil type, containing a relatively complete or near-intact communities of native plants and animals. For instance, relatively undisturbed sites within nearby protected areas such as National Parks and Wildlife Sanctuaries can be identified as benchmark ecosystem sites or reference sites to guide ecological restoration in nearby degraded areas.
- ***Based on indigenous knowledge:*** Finally, traditional knowledge of indigenous people and local communities can be a rich source of information on the kinds of natural ecosystems and native species in an area. As these communities live close to nature, they often have a deeper understanding of local landscapes and how they have changed over time, including in their oral histories, traditions, myths, and songs.

Establishing native plant nurseries

A native plant nursery to raise a diversity of native species appropriate for each location is a critical need in for any ecological restoration programme. Native plant species that are found in the ecosystem benchmark sites can be targeted for raising in the nurseries. It is important to collect seeds and maintain the nursery year-round as seeds of different species will be produced and available at different times of the year and the seedlings require continuous nurture. It is best if trails and roads through forests and other ecosystems are regularly monitored (at least weekly) for seed collection. Mature seeds fallen on the ground may be collected from forest/ecosystem edges, or along the trails or roads. Seedlings ('wildlings') can also be collected occasionally. Most of the seeds and seedlings along trails or roads are likely to get run over or cleared during maintenance, and so can be 'rescued' for nurture in the nursery. It is **important to avoid collecting seeds or seedlings from within forest or ecosystem interiors as it may negatively affect natural regeneration**. Try to collect seeds from multiple mother plants to ensure better genetic diversity and vitality and apply appropriate germination and nursery care techniques. Ethical practices must be followed to avoid over-harvest of seeds or seedlings, especially of rare and threatened species.



Hi-Tech nursery at Sirdalla visited during the study. The nursery maintains a large collection of saplings, but only of a limited set of plant species, including many non-native species such as *Senna siamea* and ornamental trees. Such nurseries offer an excellent opportunity to increase the native species diversity and stock and also develop as grassland nurseries to support restoration in open natural ecosystems.

Other suggestions for management:

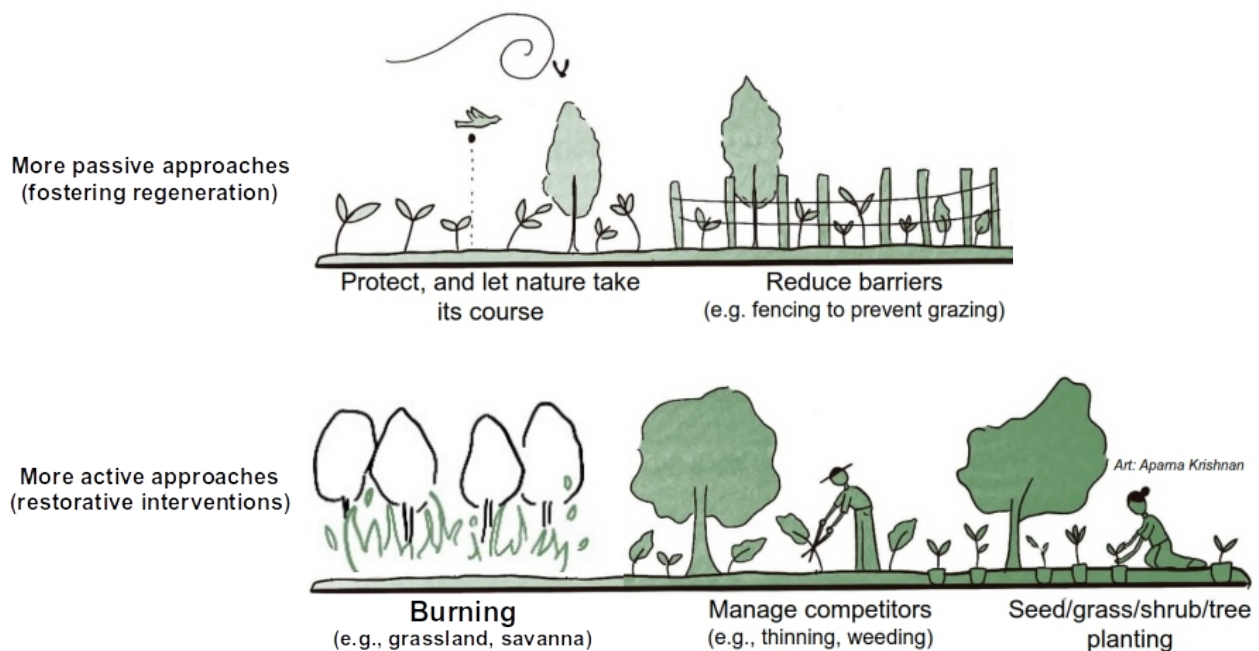
1. The Bihar state government and Forest Department can reorient the existing missions and schemes that support nurseries across the state to **increase the diversity of native plant species**, including trees, climbers, herbs, and grasses.
2. Nurseries in different parts of Bihar can be **ecoregion-specific native plant nurseries**, matched to the corresponding ecoregion or natural ecosystem type and their constituent native species. For instance, grassland nurseries in the terai region and for other open natural ecosystems, forest nurseries with species specific to mixed sal forests, and dry deciduous forests, or wooded savanna.
3. The Bihar State Biodiversity Board can maintain up-to-date **Checklists of prohibited and permitted plant species for state nurseries**. Prohibited species can include unsuitable and invasive alien species and such as *Senna siamea*, *Lantana camara*, etc., which should be strictly avoided in any planting programmes or distribution for ornamental purposes. The permitted list can include a higher diversity of species including mainly native and some naturalised (non-invasive) species.

Approaches to Ecological Restoration

Ecological restoration may include a spectrum of activities, each of which may be suitable in different landscape and site contexts. The Table below gives a broad overview.

Type of ecological restoration	Method	Landscape/site context
Passive Restoration	Identify and stop factors causing degradation, in order to allow sites to recover on their own	Areas with adequate natural regeneration potential and adjoining seed sources / native habitats
Assisted natural regeneration	Carefully remove invasive plants while retaining native plants in order to foster better regeneration	Areas adjoining natural ecosystems (forests/grasslands) and seed sources with potential for natural recovery
Active restoration with diverse native species	Carefully remove invasive plants, retaining native plants, and increase diversity through planting a diversity of appropriate native species with reference to benchmark sites	Highly degraded areas away from seed sources, which are otherwise of high conservation value, such as corridors, riparian tracts, protected area buffers

Approaches to Ecological Restoration (the passive – active continuum)



After Krishnan and Osuri (2023). Art by Aparna Krishnan, modified for illustrative purposes.

Conserving Forests and Open Natural Ecosystems (ONEs)

According to the Forest Survey of India (2024), forest types that occupy over 100 km² area within the state of Bihar are:

3C/C2b(i)	Bhabar-dun sal (268.68 km ²)
43C/C3a	West Gangetic moist mixed deciduous forest (179.14 km ²)
65B/C1a	Dry Siwalik sal forest (384.43 km ²)
75B/C1c	Dry peninsular sal forest (1,571.67 km ²)
85B/C2	Northern dry mixed deciduous forest (2,335.80 km ²)
95/DS1	Dry deciduous scrub (291.49 km ²)
105/E2	<i>Boswellia</i> forest (317.79 km ²)

Among these, the latter four forest types appeared to be the main forest types in the areas visited in southern Bihar.

However, the above categorisation focused on forest types overlooks the equally valuable Open Natural Ecosystems (ONEs) that are also characterised by their own unique plant and animal diversity. Open Natural Ecosystems (ONEs) are non-forest ecosystems that constitute over a third of the Earth's terrestrial habitats and around 10% of India's land area (Madhusudan and Vanak 2023, Vanak *et al.* 2024). These open ecosystems range from hot and cold deserts, rock outcrops and bouldery areas to biologically rich and diverse grasslands and savanna ecosystems with high rates of endemism in flora and numerous specialised faunal species, including high densities of wild mammalian herbivores and carnivores. At present, land use and land cover classifications and forest cover maps of Bihar fail to give due attention to these ONEs.

All areas visited during this study visit also had ONEs that deserve recognition and conservation. The following main types of ONEs that occur in the surveyed areas need to be recognised and given due attention in Bihar (Madhusudan and Vanak 2023, Koulgi and Madhusudan 2024). Data and digital layers made available by Koulgi and Madhusudan (2024) may be incorporated into Bihar State Forest Department maps and land use, land cover classifications. This will enable better monitoring and conservation of ONEs in the state. The ONE maps developed by Koulgi and Madhusudan (2024) can be adopted by Bihar state and both forests and other natural ecosystems including the delineated ONEs can together guide biodiversity conservation and ecological restoration efforts in the future.

Broad categories of Open Natural Ecosystems (ONEs) with examples from Bihar

Open Savanna: Areas with grasses and shrubs in the understorey and trees above. Tree cover is very sparse.



Open savanna in Kaimur WLS

Shrub Savanna: Areas with grasses and shrubs in the understorey and trees above. Tree cover is sparse. Understorey can include short-statured woody vegetation.



Shrub savanna in Rajgir WLS (with *Mesosphaerum suaveolens* invasion)

Woodland Savanna: Areas with grasses and shrubs in the understorey and trees above. Tree cover is moderate. Large openings in the tree canopy cover remain, and the understorey is predominantly grasses.



Woodland Savanna in Kaimur WLS

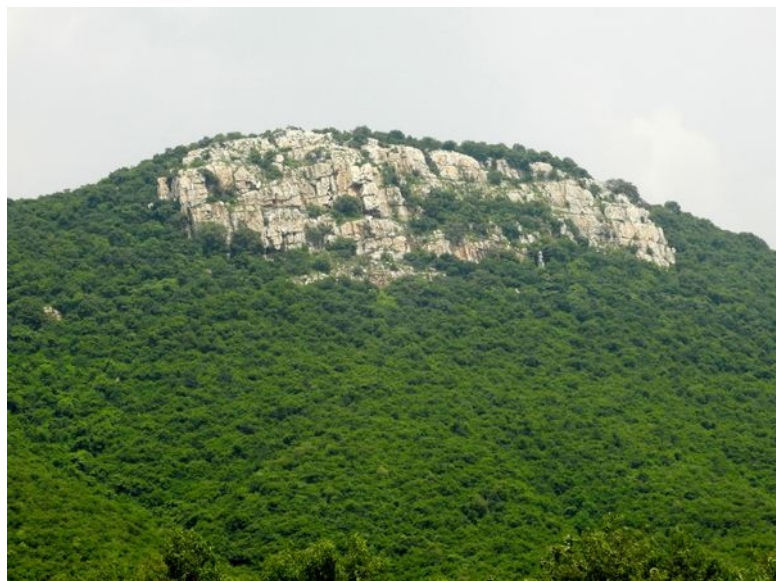
Additional Research and Surveys

Interactions with forest staff and consideration of information available in the management plans of the protected areas indicates that considerable general information exists on the flora and fauna in Bihar. However, knowledge on various aspects continues to be limited, including on little-known species and habitats, population trends, and long-term conservation status. This paucity of information can be addressed by encouraging wildlife research, especially in protected areas, and by systematic surveys to document areas and taxa crucial for enhancing biodiversity documentation and conservation efforts in Bihar. The following steps are suggested:

- a) Encouraging **wildlife research**, especially in Protected Areas (PAs) of Bihar, by creation of supporting infrastructure (such as field stations and camps in PAs which can serve as a base for researchers), providing research permits and logistical support, and creation of research and publications database
- b) Comprehensive **bird and herpetofaunal surveys** in the protected areas, open natural ecosystems, and wetlands of Bihar can be carried out. Bihar has a history of such monitoring efforts in the annual Asian Waterfowl Census that is carried out in winter. **However, surveys for terrestrial birds have not been carried out and this could be supported, following models such as the Kanha Bird Survey and Periyar Bird Survey.**
- c) **Surveys of little-known taxa** such as small mammals, smaller carnivores, and bats. Bihar is likely to have a rich array of wildlife species including many little-known species and taxonomic groups. Small mammals (shrews, rodents, flying squirrels), smaller carnivores (e.g., ratels, civets etc), and bats are worth surveying through targeted efforts. The bat exodus at Tutla Bhawani suggests that surveys of cliffs and caves may also yield many surprises and valuable records.
- d) **Floristic surveys of unique habitats** such as rock-outcrop inselbergs, cliff-faces, *Butea monosperma* and *Hardwickia binata* (Anjan) savannas, and open natural ecosystems. The rock outcrops of Bihar are unique in northern India and deserve greater attention as indicated by earlier rapid surveys (Vijayan 2024a,b). **Among the savanna habitats, the *Butea monosperma* savannas and *Hardwickia binata* savannas (latter could not be visited due to time constraints on this visit) may have rich repository of grasses, sedges, and herbaceous flora that is worth documenting.**
- e) **The exceptional cliffs of Bihar also deserve close documentation: their distribution, length and area, presence of caves, and other aspects including biodiversity may be considered.**



Cliffs such as the ones at Tutla Bhawani (above) and in Rajgir WLS (right) are an important and unique habitat in their own right that deserve better exploration and documentation from a biodiversity perspective.



Training Needs

Finally, interactions with field-level forest staff suggested a strong need for more and better training on aspects related to ***biodiversity, natural history, and ecological restoration***. While many of the forest staff are familiar with their local areas and species (mainly through their names in local languages), they did not seem more broadly aware in biodiversity and natural history of Bihar. In areas such as Chakrabandha Complex and Gautam Buddha Wildlife Sanctuary, staff had so far not participated or gained experience in wildlife surveys or monitoring, such as through censuses, walking transects, or deploying and monitoring camera traps. There is also a lack of field guides and resource material in local languages that can support such training efforts. There is a clear need for training field staff to support biodiversity conservation and ecological restoration efforts.

Such training for field staff, which may be carried out in the respective sites or in forest training institutes by resource persons, can be particularly focused on the following topics:

- a) **Natural history training** to learn to identify and document native plants and animals, using field guides and citizen science applications such as iNaturalist and Merlin;
- b) **Wildlife monitoring training** to monitor populations of focal taxa, including through use of technology such as camera traps and monitoring apps such as eBird;
- c) **Habitat monitoring training** such as creation and monitoring of permanent benchmark ecosystem plots, use of GPS and mapping tools, and recording invasive alien species;
- d) **Training in native plant nursery** development and management, including on germination and raising of native grasses, shrubs, climbers, and trees for ecological restoration.



Training of field staff, including in advanced methods of habitat restoration and wildlife monitoring, is a crucial need.

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Digital Resources

- Ebird India portal: <https://ebird.org/india/>
- ERA-India: Ecological Restoration Alliance – India. <https://era-india.org>
- Global Invasive Species Database. Invasive Species Specialist Group, IUCN. <http://www.iucngisd.org/gisd/>
- Global Register of Introduced and Invasive Species. <https://griis.org>
- Indian Alien Flora Info https://images.assettype.com/ncfindia/import/publications/000/000/114/original/Rainforest_Restoration_20Booklet_NCF_India_web.pdf Information Database (ILORA). <https://ilora2020.wixsite.com/ilora2020>
- iNaturalist. <https://www.inaturalist.org/>
- Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. <http://www.plantsoftheworldonline.org/>

Appendix 1. List of plant species recorded.

Note: A full list of all observations with photographs, including insects and other biodiversity, is available on [iNaturalist here](https://www.inaturalist.org/observations?place_id=6894&user_id=trsrman&verifiable=any).

URL: https://www.inaturalist.org/observations?place_id=6894&user_id=trsrman&verifiable=any

The screenshot shows the iNaturalist interface for the state of Bihar. It lists 182 observations, 93 species, 25 identifiers, and 1 observer. The observations are displayed in a grid format, each with a photo, the species name, a location tag (Lendia), a research grade, and the number of identifications.

Species	Location	Research Grade	Identifications
<i>Fernandoa adenophylla</i>	Lendia	Research Grade	1
<i>Lagerstroemia parviflora</i>	Lendia	Research Grade	2
<i>Ehretia laevis</i>	Lendia	Research Grade	1
<i>Butea monosperma</i>	Lendia	Research Grade	2
<i>Genus Bauhinia</i>	Lendia	Research Grade	1
<i>Bridelia retusa</i>	Lendia	Research Grade	2
<i>Fernandoa adenophylla</i>	Lendia	Research Grade	1
<i>Shorea robusta</i>	Lendia	Research Grade	1

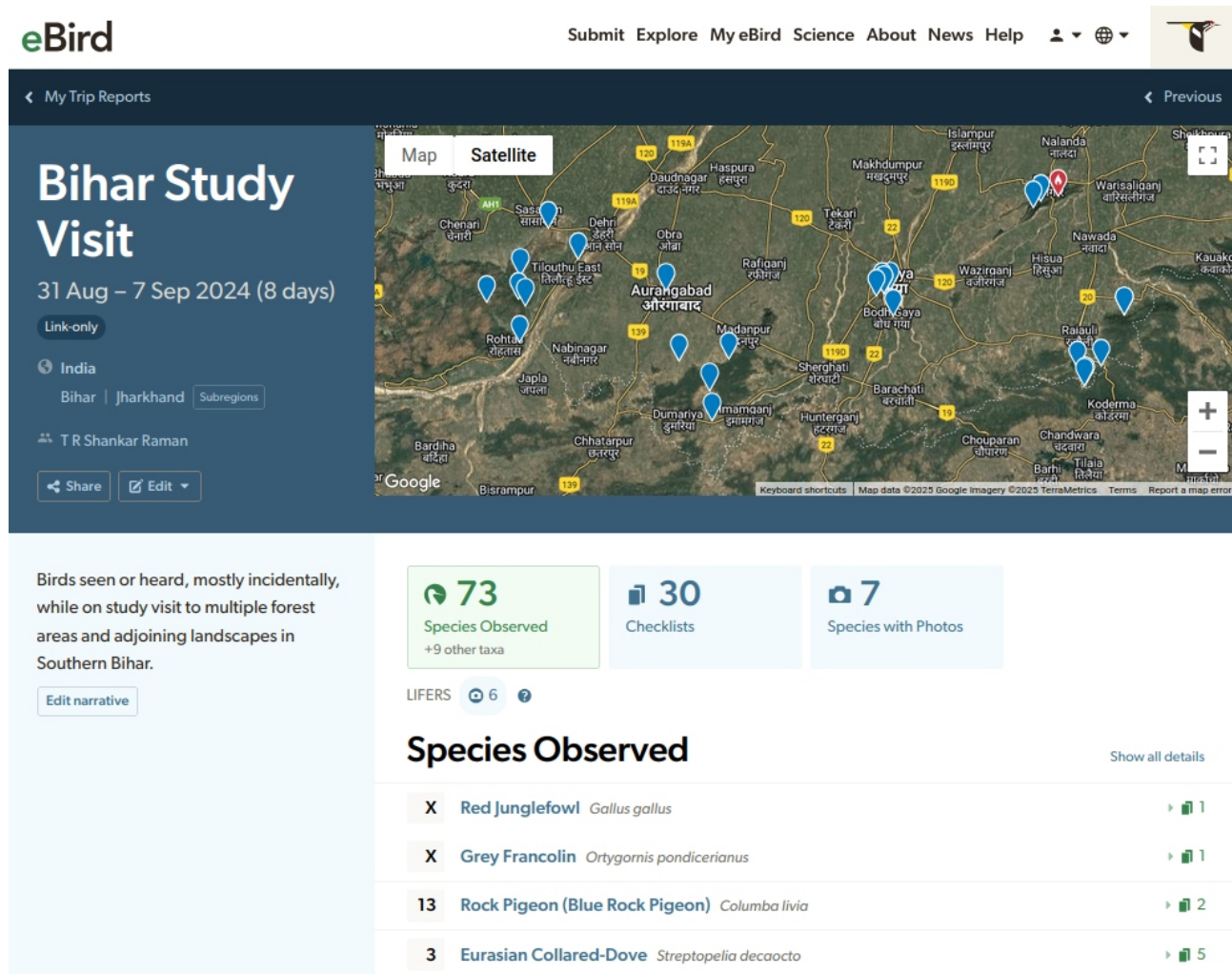
Family	Scientific name	
Arecaceae	<i>Borassus flabellifer</i>	Sapotaceae
	<i>Phoenix sp.</i>	
	<i>Phoenix sylvestris</i>	
Boraginaceae	<i>Cordia myxa</i>	Fabaceae
	<i>Ehretia laevis</i>	
Capparaceae	<i>Capparis sepiaria</i>	
Celastraceae	<i>Cassine glauca</i>	
Ebenaceae	<i>Diospyros cordifolia</i>	
		<i>Diospyros melanoxylon</i>
		<i>Madhuca longifolia</i>
		<i>Manilkara hexandra</i>
		<i>Albizia lebbeck</i>
		<i>Albizia procera</i>
		<i>Bauhinia sp.</i>
		<i>Bauhinia racemosa</i>

	<i>Butea monosperma</i>		<i>Grewia tiliifolia</i>
	<i>Butea superba</i>		<i>Helicteres isora</i>
	<i>Dalbergia sissoo</i>		<i>Sterculia urens</i>
	<i>Erythrina stricta</i>	Combretaceae	<i>Combretum sp.</i>
	<i>Neltuma juliflora</i>		<i>Terminalia anogeissiana</i>
	<i>Phanera vahlii</i>		<i>Terminalia arjuna</i>
	<i>Senegalia catechu</i>		<i>Terminalia bellirica</i>
	<i>Tamarindus indica</i>		<i>Terminalia elliptica</i>
	<i>Vachellia nilotica</i>	Lythraceae	<i>Lagerstroemia parviflora</i>
Apocynaceae	<i>Calotropis sp.</i>	Myrtaceae	<i>Syzygium cumini</i>
	<i>Carissa carandas</i>		<i>Syzygium salicifolium</i>
	<i>Holarrhena pubescens</i>	Moraceae	<i>Ficus benghalensis</i>
	<i>Wrightia tinctoria</i>		<i>Ficus hispida</i>
Rubiaceae	<i>Adina cordifolia</i>		<i>Ficus microcarpa</i>
	<i>Gardenia sp.</i>		<i>Ficus mollis</i>
	<i>Gardenia resinifera</i>		<i>Ficus racemosa</i>
	<i>Mitragyna parvifolia</i>		<i>Ficus religiosa</i>
	<i>Spermacoe sp.</i>	Rhamnaceae	<i>Ziziphus</i>
Bignoniaceae	<i>Fernandoa adenophylla</i>		<i>Ziziphus oenopolia</i>
Lamiaceae	<i>Mesosphaerum suaveolens</i>	Ulmaceae	<i>Holoptelea integrifolia</i>
Oleaceae	<i>Nyctanthes arbor-tristis</i>	Anacardiaceae	<i>Buchanania cochinchinensis</i>
Pedaliaceae	<i>Sesamum indicum</i>		<i>Lannea coromandelica</i>
Verbenaceae	<i>Lantana camara</i>		<i>Semecarpus anacardium</i>
Annonaceae	<i>Miliusa velutina</i>	Burseraceae	<i>Boswellia serrata</i>
Euphorbiaceae	<i>Croton persimilis</i>		<i>Garuga pinnata</i>
	<i>Euphorbia sp.</i>	Rutaceae	<i>Aegle marmelos</i>
	<i>Euphorbia neriifolia</i>		
	<i>Jatropha gossypifolia</i>		
	<i>Mallotus philippensis</i>	Solanaceae	<i>Physalis angulata</i>
Phyllanthaceae	<i>Bridelia retusa</i>	Lygodiaceae	<i>Lygodium sp.</i>
	<i>Flueggea sp.</i>		
Putranjivaceae	<i>Putranjiva roxburghii</i>		
Salicaceae	<i>Flacourtia indica</i>		
Dipterocarpaceae	<i>Shorea robusta</i>		
Malvaceae	<i>Bombax ceiba</i>		

Appendix 2. Bird checklists and observations.

Note: All bird observations are available as a trip report on the [eBird India portal here](https://ebird.org/tripreport/318626).

URL: <https://ebird.org/tripreport/318626>



Checklist:

- 1) Red Junglefowl *Gallus gallus*
- 2) Grey Francolin *Ortygornis pondicerianus*
- 3) Rock Pigeon (Blue Rock Pigeon) *Columba livia*
- 4) Eurasian Collared-Dove *Streptopelia decaocto*
- 5) Spotted Dove *Spilopelia chinensis*
- 6) Laughing Dove (Little Brown Dove) *Spilopelia senegalensis*
- 7) Greater Coucal *Centropus sinensis*
- 8) Sirkeer Malkoha *Taccocua leschenaultii*
- 9) Pied Cuckoo (Jacobin Cuckoo) *Clamator jacobinus*
- 10) Asian Koel *Eudynamys scolopaceus*

- 11) Common Hawk-Cuckoo *Hierococcyx varius*
- 12) Asian Palm Swift *Cypsiurus balasiensis*
- 13) White-breasted Waterhen *Amaurornis phoenicurus*
- 14) Yellow-wattled Lapwing *Vanellus malabaricus*
- 15) Red-wattled Lapwing *Vanellus indicus*
- 16) Bronze-winged Jacana *Metopidius indicus*
- 17) Asian Openbill *Anastomus oscitans*
- 18) Little Cormorant *Microcarbo niger*
- 19) Red-naped Ibis (Indian Black Ibis) *Pseudibis papillosa*
- 20) Black-crowned Night Heron *Nycticorax nycticorax*
- 21) Indian Pond-Heron *Ardeola grayii*
- 22) Eastern Cattle-Egret *Ardea coromanda*
- 23) Black-winged Kite (Black-shouldered Kite) *Elanus caeruleus*
- 24) Short-toed Snake-Eagle *Circaetus gallicus*
- 25) Bonelli's Eagle *Aquila fasciata*
- 26) Shikra *Tachyspiza badia*
- 27) Black Kite *Milvus migrans*
- 28) White-eyed Buzzard *Butastur teesa*
- 29) Rock Eagle-Owl (Indian Eagle-Owl) *Bubo bengalensis*
- 30) Jungle Owlet *Glaucidium radiatum*
- 31) Indian Grey Hornbill *Ocyrceros birostris*
- 32) Asian Green Bee-eater *Merops orientalis*
- 33) Blue-tailed Bee-eater *Merops philippinus*
- 34) White-throated Kingfisher *Halcyon smyrnensis*
- 35) Indian Roller *Coracias benghalensis*
- 36) Coppersmith Barbet *Psilopogon haemacephalus*
- 37) Brown-headed Barbet (Large Green Barbet) *Psilopogon zeylanicus*
- 38) White-naped Woodpecker *Chrysocolaptes festivus*
- 39) Black-rumped Flameback (Lesser Goldenbacked Woodpecker) *Dinopium benghalense*
- 40) Peregrine Falcon *Falco peregrinus*
- 41) Rose-ringed Parakeet *Psittacula krameri*
- 42) Plum-headed Parakeet *Psittacula cyanocephala*
- 43) Indian Pitta *Pitta brachyura*
- 44) Indian Cuckooshrike *Coracina macei*
- 45) Indian Golden Oriole *Oriolus kundoo*
- 46) Black Drongo *Dicrurus macrocercus*
- 47) Indian Paradise-Flycatcher *Terpsiphone paradisi*
- 48) Bay-backed Shrike *Lanius vittatus*
- 49) Rufous Treepie *Dendrocitta vagabunda*
- 50) House Crow *Corvus splendens*
- 51) Large-billed Crow *Corvus macrorhynchos*
- 52) Ashy-crowned Sparrow-Lark (Ashy-crowned Finch-Lark) *Eremopterix griseus*

- 53) Common Tailorbird *Orthotomus sutorius*
- 54) Grey-breasted Prinia *Prinia hodgsonii*
- 55) Jungle Prinia *Prinia sylvatica*
- 56) Ashy Prinia *Prinia socialis*
- 57) Plain Prinia *Prinia inornata*
- 58) Zitting Cisticola *Cisticola juncidis*
- 59) Red-vented Bulbul *Pycnonotus cafer*
- 60) Greenish Warbler *Phylloscopus trochiloides*
- 61) Large-billed Leaf Warbler *Phylloscopus magnirostris*
- 62) Indian White-eye (Oriental White-eye) *Zosterops palpebrosus*
- 63) Indian Scimitar-Babbler *Pomatorhinus horsfieldii*
- 64) Jungle Babbler *Argya striata*
- 65) Common Babbler *Argya caudata*
- 66) Indian Pied Starling (Pied Myna) *Gracupica contra*
- 67) Common Myna *Acridotheres tristis*
- 68) Indian Robin *Copsychus fulicatus*
- 69) Oriental Magpie-Robin *Copsychus saularis*
- 70) Tickell's Blue Flycatcher *Cyornis tickelliae*
- 71) Pale-billed Flowerpecker *Dicaeum erythrorhynchos*
- 72) Purple Sunbird *Cinnyris asiaticus*
- 73) Grey Wagtail *Motacilla cinerea*



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