

Summary Report

Rapid Assessment of the Proposed Biodiversity Heritage Sites in Banka Forest Division, Bihar

Submitted by

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Submitted to,
The Secretary,
Bihar State Biodiversity Board,

and

The Divisional Forest Officer,
Banka Forest Division.

Note: *This is the draft version of the report, and a full report with more species identifications will be submitted later.*

Photograph Credits:

Front Cover: View of the Mandar hills from the Mandar Biodiversity Park in Banka, Bihar. Photograph: Vijayan Jithin

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EXECUTIVE SUMMARY

Formed millions of years ago, rock outcrops are unique habitats in terms of their geomorphology, and biodiversity, but have received poor research and conservation attention compared to forested ecosystems globally. They have been identified as small natural features that have ecological roles extending beyond their area, a concept similar to 'keystone species', at an ecosystem scale. Rock outcrops of India remain largely understudied, especially the inselbergs of Bihar. Recent research from the southern Indian rock outcrops shows that rock outcrops are cradles of biodiversity with multiple endemic and threatened species, but are facing multiple anthropogenic threats. The Bihar rock outcrops, especially the inselbergs are noteworthy geological structures, that received poor attention compared to other rock outcrops in India, especially in terms of its biodiversity and ecological value. Previous rapid assessments of rock outcrops in Nalanda, Aurangabad, Gaya, and Jamui Divisions of Bihar has shown a range of diverse microhabitats and the biodiversity wealth of these habitats. To assess the feasibility and scope of declaring some of the preliminarily identified rocky outcrops of Bihar as potential 'Biodiversity Heritage Sites' (BHS), a rapid assessment was undertaken in the Tola Abrakha (Katoria), Mandar and Kakwara areas of the Banka Division. Among the examined sites, Kakwara and Mandar hills show great potential as BHSs, considering their biological, geological, and heritage values. This preliminary report summarises the microhabitats, and biodiversity recorded from the inselbergs, along with notes on their cultural values, and recommends further actions for the conservation of these important habitats.

1. BACKGROUND

1.1. Rock Outcrops: Overview

Rock outcrops are unique habitats in terms of their geomorphology, biodiversity, and were formed millions of years ago. They are found on all continents, in most climate zones and vegetation types, but have received poor research and conservation attention compared to forested ecosystems (Inselberg Research Initiative, 2024). Rock outcrops can be a wide variety of physical environments, such as escarpments, overhangs, cliffs, boulder heaps and inselbergs (Fitzsimons & Michael, 2017). They can be broadly classified into three types; (i) inselbergs, which are large dome shaped outcrops, of granite or gneiss, (ii) rocky plateaus, which are naturally formed flat expanses of any rock type, and (iii) cliffs, which are steep and almost vertical exposed rock faces (Fig. 1). Rock outcrops can be technically distinguished from neighbouring areas by having an average of 55% area as exposed rock (Wiser & White, 1999). Rocky outcrops provide critical breeding sites for multiple organisms ranging from top order mammalian and avian predators to smaller invertebrates. They have been identified as examples of small natural features (SNF) that have ecological roles extending beyond their area, a concept similar to 'keystone species', but at an ecosystem scale (Hunter, 2017). They are also old climatically buffered infertile landscapes (OCBILs), that have contributed to high biodiversity (Hopper, 2023)



Figure 1. Type of rock outcrops. (a) an inselberg in Dhanhara, Bihar, (b) rocky plateau in Ratnagiri, Maharashtra, and (c) a cliff in Bihar Sharif, Bihar.

Geologically, they form due to erosion and weathering of softer parts of the landscape over millions of years, leaving behind the hard core of parent rock (Twidale, 2012). Outcrops of West Africa, Madagascar, Australia, Brazil, and USA have received much

research attention, while rock outcrop ecology of other regions such as India has largely remained understudied (Kulkarni et al., 2022). Rock outcrops are non-forested open natural ecosystems (ONEs) which support high biodiversity as well as livelihoods of millions of people, but are highly threatened due to land conversion (Madhusudan & Vanak, 2022). Rock outcrops provide a wide range of ecosystem services to humans, and they have played an important role in shaping human civilizations in the past (Rock Outcrop India Network, 2018). Though rock outcrops are known to harbour a broad range of endemic and highly specialised taxa globally (Porembski & Barthlott 2012), there is a knowledge gap in the literature addressing the conservation value of small, rocky outcrops (Michael et al., 2010). This hampers the scientific management of these fragile habitats which is necessary to reverse habitat degradation happening at many of these unique habitats.

1.2. Rock Outcrops in India

India is home to all the three types of rock outcrops across its breadth, which mostly look dry as arid deserts for almost eight months, but transform to green islands from the onset of monsoon rains. They are home to a large number of unique, endemic organisms. For example, the northern Western Ghats rock outcrops, (the most studied rock outcrop system in the country) holds a significant proportion of its flora as endemic (Watve, 2013). The flora and fauna in these landscapes are adapted to the harsh conditions of rock outcrops and many of plant species have evolved unique features such as desiccation tolerance and carnivory (Smrithy et al., 2023). Most of the Indian rocky outcrops are outside of the protected area network, and are used by people for traditional utilities such as grazing, but are also officially classified as 'wastelands' by the Government of India due to their 'barren' appearance (scarcity of woody species or forest cover) (National Remote Sensing Centre and Ministry of Rural Development, 2019). Recent studies on the rock outcrops of the northern Western Ghats has shown that land-use change associated disturbances are impacting a wide-range of fauna including endemic and threatened animals (Jithin et al., 2023a; Jithin et al., 2024). Despite the huge number of rock outcrops across the country, and their cultural, aesthetic and religious importance, not much is known about its biodiversity and

ecology in India (Inselberg Research Initiative, 2024). This makes these habitats prone to developmental, mining, and industrial activities. These important non-forest habitats thus are vulnerable to anthropogenic threats, despite their ecological, geological, recreational and cultural importance.

1.3. Rock Outcrops in Bihar - Background of Rapid Survey

The Ground Water Information Booklet for the Nalanda district recognizes that the inselberg series of Nalanda surrounded by the Indo-Gangetic alluvium of the Pleistocene age is a notable geological feature, and they mark the northernmost boundary of the Precambrian peninsular shield (Central Ground Water Board, 2013a). Similarly, the booklet for the Aurangabad features the granitic gneiss exposures in the region, and states that they occur at places as inlier at the transition parts from hard rock to alluvial plain (Central Ground Water Board, 2013a). It also notes the crystalline rocks exposed in Rajgir Hills and bedrock that sloping towards the northern side consist of phyllites and quartzites alongwith pegmatitic intrusions. These Precambrian crystallines have undergone intense structural disturbance in the form of multiple foldings (Central Ground Water Board, 2013a). The technical report of the National Biodiversity Strategy and Action Plan (Technical and Policy Core Group & Kalpavriksh, 2005) submitted to the then MoEF (presently The Ministry of Environment, Forest and Climate Change) recognizes the importance of rock outcrops of India, especially the inselbergs found in south India and Bihar (see section 4.1 in Chapter 4). It says:

“The most prominent rock outcrops in India are as follows: Lateritic plateaus, common in western India in high-rainfall areas. Cliffs form a distinct feature in all the hilly areas, e.g. in the Western Ghats. Inselbergs are isolated rock outcrops rising abruptly above their surroundings and are seen throughout south India and Bihar.”

The draft report of the Biodiversity Strategy and Action Plan for Bihar (Mishra, 2004) also identifies inselbergs in the state’s geographic features, though not exactly using the term:

“The alluvial filling south of the Ganga is shallow, a mere veneer and the Peninsular edge is very rugged. Many groups of small craggy hills rise up to 488 metres from islands of bare rock or scrub.”

But unfortunately, these reports were not implemented officially, and thus currently these rock outcrops are not under conservation focus.

From 2002 onwards, there have been efforts in different states to declare Biodiversity Heritage Sites (BHS) under section-37 of the Biological Diversity Act-2002. This includes some rocky hillocks in Karnataka (Karnataka Biodiversity Board, 2023), Kerala (Kuttoo, 2020), and Odisha (Odisha Biodiversity Board, 2019). In some areas, such as Ratnagiri in the state of Maharashtra, efforts are ongoing to propose rock outcrops as BHSs and also to conceptualise frameworks for Local Biodiversity Heritage Sites (Watve & Chavan, 2020; Jithin et al., 2023a). At present, there are no BHS in the state of Bihar, and the Biodiversity Board has interest in proposing some of the rock outcrops as BHS in the future. Previous rapid assessments of rock outcrops in the Nalanda and Aurangabad Divisions have shown they are home to diverse microhabitats and biodiversity focusing on saxicolous (living on or among rocks) organisms (Jithin, 2024). This report summarises the findings from the short-term assessment and literature review to suggest future prospects. Since the rock outcrop sites explored as part of this study are inselbergs, a section on inselberg ecology and research is given, before examining the site-specific insights.

2. INSELBERGS: ECOLOGY AND RESEARCH

2.1. Inselbergs: An Introduction

As mentioned before, Inselbergs are isolated rock outcrops that rise abruptly, above the surrounding plains. These granitic and gneissic inselbergs occur throughout different climatic zones across the world, and are geologically and geomorphologically old. The term 'inselberg' has been proposed by Bornhardt in 1900 to describe hills or groups of hills rising abruptly from a peneplain as an island rises from the sea (Willis, 1934). Geologically, granitic inselbergs can be classified into three basic types; i.e. (i) Bornhardts, which are steep-sided, bald and domical hills, (ii) castle koppies (tors or kopjes) which are steep-sided but angular and blocky with ordered arrangement, and (iii) nubbins, which are conical hills with chaotic mass of blocks and boulders (Twidale, 1981). But these classifications are not rigid, and intermediate forms are many (Fig. 2).

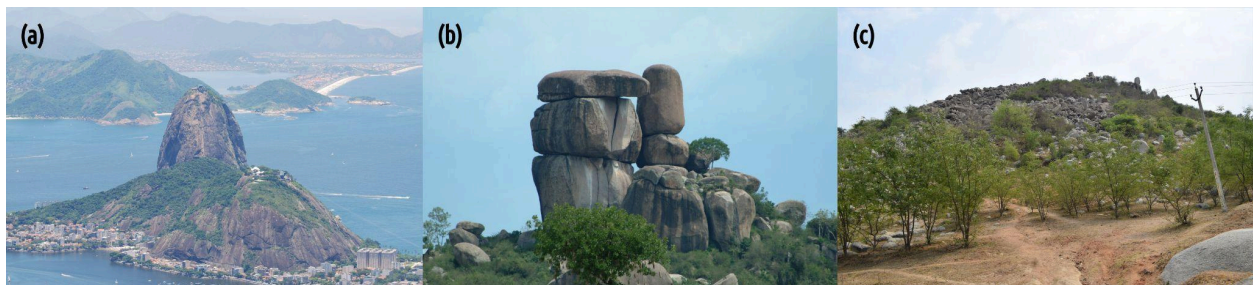


Figure 2. Examples for types of inselbergs; (a) Sugarloaf Mountain, a bornhardt, Rio de Janeiro, Brazil; (b) Kit-Mikayi, a castle kopje near Kisumu, Kenya; and (c) Jhunjhunwa Pahar, a bouldery nubbin in Bihar, India. Photograph (a) by Paul Mannix, CC BY-SA 2.0, and (b) by Valerius Tygart CC BY-SA 3.0 via Wikimedia Commons.

Inselbergs form micro climatically and edaphically dry growth sites, which are home to highly specialised vegetation. Inselbergs are known as 'microclimatic deserts' as the air temperature on its slopes and insolation are considerably high, and low relative air humidity compared to the surrounding region (Porembski, 2007). In addition to this, comparatively very less amount of soil is present on these habitats with severe limitation of nitrogen and phosphorus, and high surface water run-off during rains which makes the habitat a harsh environment.

Despite these stressful conditions, inselbergs mainly contain advanced flowering plants, but are also home to ferns, gymnosperms and basal flowering plants. Within the flowering plants group, most species are from the families Poaceae, Cyperaceae (grasses) and Fabaceae (peas). *Vellozia*, *Rhynchospora*, *Cyperus* (sedges), and *Utricularia* (bladderworts) are among the most species rich genera (Porembski & Barthlott, 2012), as reported from African studies and include biologically interesting groups exhibiting desiccation tolerance, carnivory and succulence. Southeastern Brazil, Madagascar and southwestern Australia are currently known as 'hot spots of inselberg plant diversity' (Porembski, 2007). But our knowledge of vegetation on inselbergs of several tropical regions such as India and Angola is still sparse, and this requires research attention.

Inselbergs are known to contribute to the local and regional plant species richness (Burke et al. 2003b). Rocky outcrops such as inselbergs support unique biological communities, with high levels of species endemism, and are considered important in the conservation of biodiversity worldwide (Fig. 3). For example, they occur in fragmented landscapes and play a key role in conserving reptile biodiversity in the modified environments (Michael et al., 2008). Rock outcrops are important to reptiles as they can provide resources such as basking and retreat sites, and micro-gradients in climatic conditions which are often limited in the surrounding landscape (Michael et al., 2010). It is also known that though inselbergs cover a small portion of area, they can provide resources that are uncommon in the landscape, which makes them local hotspots of avian diversity (Trager & Mistry, 2003). Apart from the microscopic organisms that grow on the rocks (Büdel et al., 2000), the rocks also provide spaces suitable for colonisation by macroscopic organisms including cliff flora and carnivorous plants (Larson et al., 2000; Seine et al., 1996). One of the main threats to the inselberg vegetation include invasion of exotic weeds due to high climatic disturbances and human impacts such as intentional burning, grazing, quarrying, construction of buildings such as temples in India, leisure (rock climbing) and touristic activities (construction of buildings, cable cars) (Porembski, 2007; Burke, 2003; Porembski, 2000). Large scale quarrying for granite and gneiss extraction is one of the leading causes of inselberg destruction (e.g., Bangalore, Karnataka).

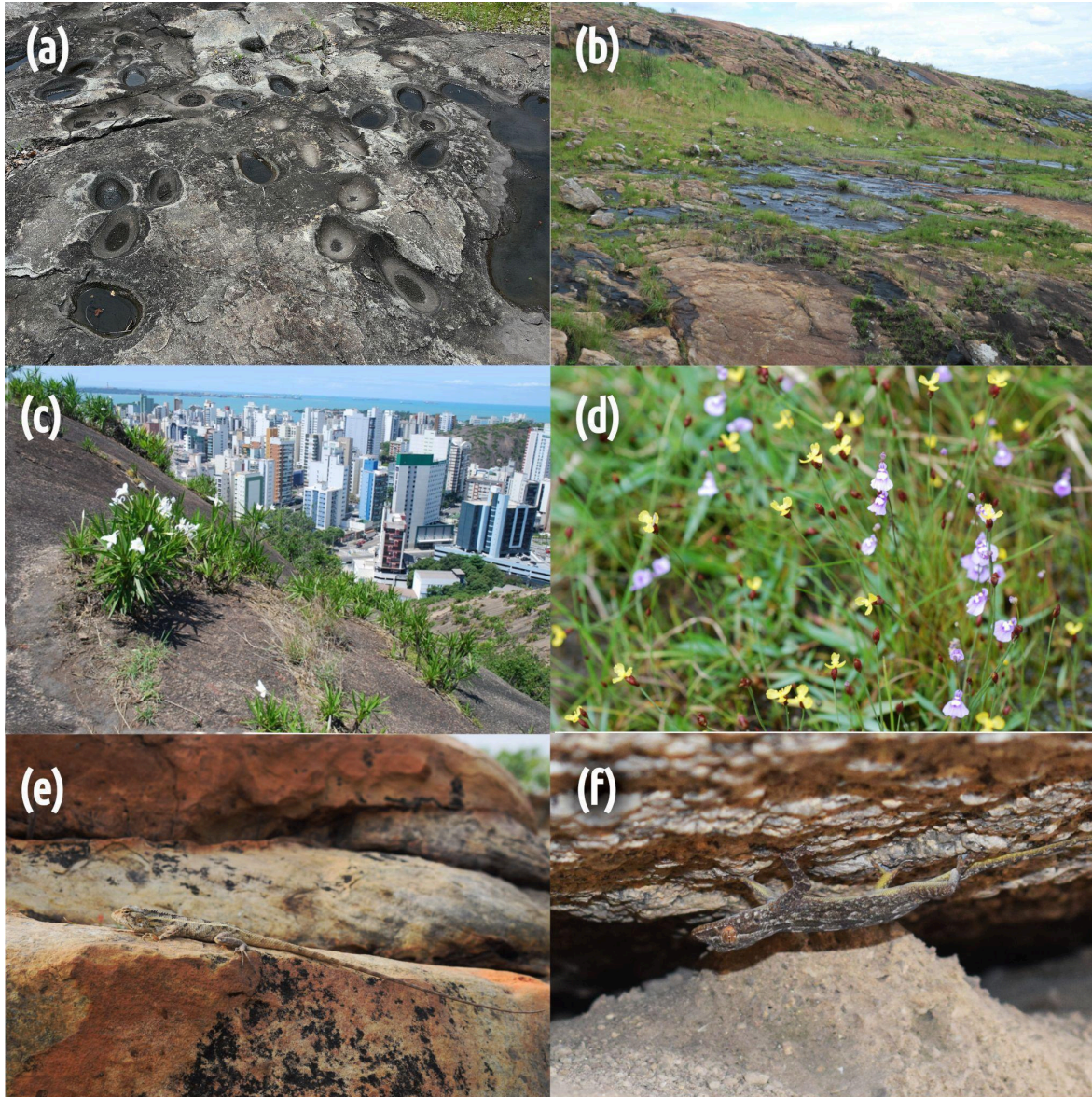


Figure 3. Microhabitats and biodiversity on inselbergs; (a) rockpools on an inselberg in Côte d'Ivoire, Africa; (b) ephemeral flush vegetation on an inselberg in Madagascar; (c) *Vellozia plicata* mats formed in Espirito Santo, Brazil; (d) *Utricularia* sp. and *Xyris* sp. as ephemeral flush vegetation in Madagascar; (e) Common garden lizard and; (f) a Yellow-belly gecko on inselbergs of Bihar, India. Photographs (a-d) courtesy: Inselberg Research Initiative. © 2024 Universität Rostock, Germany.

2.2. Inselbergs of India

The Indian peninsular landscape, shaped by the divergent weathering and differential erosion after Gondwanaland breakup, are characterised by the granite-gneissic landscape with undulating plains and boulder inselbergs and Deccan Trappean landscape with flat-topped, stepped hills separated by valleys (Kale & Vaidyanadhan, 2014). In peninsular India, especially in the semi-arid continental interior, granite landforms can be seen as rugged clusters of oddly shaped bedrock monoliths and boulders (Gunnell, 2014). Granitic outcrops and boulder-strewn hills (nubbins) create a dramatic landscape in the cratonic parts of the Indian Peninsula. Shravanabelagola, Savandurga, Nandi, and Ramanagara hills near (Bengaluru), Moula Ali and Bhongir Hills (Hyderabad), and Narlai (Aravalli Hills) are examples of domed inselbergs or bornhardts (Fig. 4). Boulder-strewn hills and castle koppies are common such as the one near Hampi, Barabar and Nagarjuni Hills in Bihar. Jalore and Siwana inselbergs in Rajasthan are also well-known (Kale & Vaidyanadhan, 2014).



Figure 4. Monolithic Savandurga Hill near Bengaluru in India viewed from the southern side. Photograph by Pravega, CC BY-SA 4.0, via Wikimedia Commons.

Despite the rock outcrop occurrence in huge numbers across the country and their immense multi-dimensional importance, not much is known about their biodiversity and ecology in contrast to the highly studied geomorphology and geology aspects (Inselberg Research Initiative, 2024). Monolithic outcrops are typically found in humid regions such as Kerala, while kopjes dominate the drier parts of India (e.g. Andhra Pradesh, Bihar). It is interesting to note that some of the famous monolithic inselbergs in India are Savandurga near Bengaluru and Mandar hills in Bihar (Rock Outcrop India Network, 2018) (Fig. 5). Indian inselbergs' vegetation appearance closely resembles that of other tropical regions with lesser roles of desiccation-tolerant mat forming monocotyledonous (DTMFM) vascular plants (Porembski et al. 2021). More information needs to confirm this, in relation to the recent observations of *Tripogon* mats on inselbergs near Bengaluru (Inselberg Research Initiative, 2024).



Figure 5. Mandar hills in the Banka division of Bihar. Photograph by Devesh Bhatta, CC BY-SA 4.0, via Wikimedia Commons.

Many of these tall inselbergs are of potassium-rich late Archean or younger granitic rocks. Compared to other cultures, Indian granitic landscapes have been harnessed in large scale by humans for worship, warfare, runoff agriculture, and stone quarrying. It is also important to note that India has one of the world's largest quarrying industries associated with the rock outcrops (Inselberg Research Initiative, 2024). Many Indian outcrops have small or large shrines and places of worship, and some of the strange rock shapes are explained by myths, anecdotes and stories through traditional knowledge (Rock Outcrop India Network, 2018). Many inselbergs have a pond, or a large pool near to the base, or agricultural fields, which utilise the rain water runoff from the inselbergs. They are also places of landscape tourism, wildflower tourism, recreational or adventure activities. Mass blooming in some of these habitats help pollination of nearby crops (Rock Outcrop India Network, 2018). Though groundwater potentiality is generally poor in inselbergs (Sivakumar et al., 2013), the run-off from these geological formations are critical for adjacent agricultural fields. Studies have shown typical geomorphic attributes such as inselbergs can control the productivity of the land and also the socioeconomic conditions of the local people (Mahato & Jana, 2019).

2.3. Status of Research on Inselbergs

Though the oceanic islands attracted much scientific attention in the past to develop some of the important ecological theories (eg. Charles Darwin - evolutionary processes; Robert H. MacArthur - island biogeography theory), terrestrial habitat-islands such as inselbergs were often neglected (Porembski, 2007). There is a large knowledge gap on inselbergs of many regions particularly in India. Discoveries of new rock-dwelling animals and plants continues from rock outcrops in southern India due to the relatively recent research attention it has received (Grandison & Soman, 1963; Biju et al., 2009; Agarwal et al., 2020; Prasanth & Sardesai 2022). There needs to be more research and conservation focus on rock outcrops in other regions of India as well, for example, Bihar.

2.4. Microhabitats on Inselbergs

Recognizing that inselbergs are composed of varying microhabitats relative to their surroundings are important, as they are hypothesised to be bioclimatic 'islands' of xeric conditions in a humid matrix in tropical and temperate regions, and 'islands' of mesic conditions in arid regions (Burke, 2003). Microhabitats differ mainly with respect to soil type, depth and moisture and each has its specific vegetation (Rock Outcrop India Network, 2018). A few microhabitats that are found on inselbergs are briefly described below:

2.4.1. Loose Rocks

Loose rocks on the surface of inselbergs are important microhabitats for a broad range of animals and plants (Watve, 2013; Jithin et al., 2023a). They are subject to high levels of anthropogenic disturbance, and it is known that land-use change on rock outcrops impacts the animal community living under the loose rocks (Jithin et al., 2023a; Goldsbrough et al., 2003). The percentage of animal occupancy varies across study regions. For example, while fauna were present under almost 90% of surveyed rocks in Sydney, ~45% of rocks harboured fauna in the northern Western Ghats (Jithin et al., 2023a; Goldsbrough et al., 2003). The animal community assemblage is mostly dominated by predators and opportunistic scavengers, indicating the low productivity in the habitat. These loose rocks are also home to cyanobacteria, lichens, moss cushions, ferns, and liverworts while supporting lithophytes (plants that grow on bare rock) such as orchids, bladderworts, and grasses (Watve, 2013).

2.4.2. Rock Pools

Rock pools are seasonally water-filled depressions on the rocks with a thin layer of soil. They are mainly inhabited by short-lived plants (ephemerals), which grow only during favourable moist conditions and passing the unfavourable periods as seeds. They are also home to aquatic plants, cryptogams, and a wide range of aquatic invertebrates (Krieger et al., 2003; Jocque et al., 2010). In the otherwise dry environment (soil and microclimate) of rock outcrops, rock pools provide

locally wet conditions. They can act as critical breeding habitats for animals like amphibians (Jocque et al., 2010; Jithin & Naniwadekar, 2024; Jithin et al., 2024).

2.4.3. Shallow Depressions

Shallow depressions are widespread on inselbergs which are small depressions filled with shallow substrate. They are only briefly inundated compared to the rock pools following heavy rains. Though vegetation cover is sparse, plants from the families Poaceae, Asteraceae, Balsaminaceae, Commelinaceae are common in these habitats. They are also habitats for cyanobacteria, liverworts, mosses, annuals, geophytes, and rarely for trees and shrubs (Porembski, 2007).

2.4.4. Cryptogamic Crust

A continuous layer of cryptogamic vegetation (cyanobacteria, lichens, mosses etc.) which supports other vegetation seen on rocky surfaces is known as cryptogamic crust. The greyish or brownish colours at inselbergs rocks are mostly due to cryptogams, which forms almost continuous biofilm on the exposed rocks. They are extremely tolerant to heat, high rates of solar irradiation and survive complete desiccation (Porembski, 2007). Their composition can vary across the surface on which they are growing; eg. exposed rocky slopes, boulders and drainage channels.

2.4.5. Rock Crevices and Clefts

Rock crevices on the inselbergs can be very deep and are rich in humus and soil. They are favourable microhabitats for plants that develop underground storage organs containing a perennating bud (geophytes) and perennial herbs (Porembski, 2007). Under shade conditions, ferns and mosses also occur in the crevices and clefts. Perennial species can be found in clefts, which are broader and deeper.

2.4.6. Monocotyledonous mats

Monocot plants in large clumps and their network of roots forms a mat-like appearance on flat and inclined open rocky slopes. They are attached to the

rocks by dense wiry roots. This characteristic feature has been recorded in plants from the families Bromeliaceae, Poaceae, Cyperaceae and Velloziaceae. They can be xerophytic (plant adapted to survive with little water availability), and desiccation-tolerant. *Tripogons* (Poaceae) can be seen on inselbergs and cliffs, which can be easily lifted up (Porembski, 2007; Smrithy et al. 2023).

2.4.7. Caves

Caves are naturally formed cavities associated with rock outcrops, shelter fauna such as bats, spiders, lizards, geckos and vultures, and are suitable microhabitats for shade-loving rock-dwelling plants. In general, caves are undisturbed due to inaccessibility and thus, the species occupying the caves is undisturbed (Smrithy & Datar, 2023).

2.4.8. Ephemeral Flush Vegetation

Short-lived vegetation that can be seen on the rock surfaces mainly during the rainy period are known as ephemeral vegetation. Typical plants are bladderworts (*Utricularia*) and pipeworts (*Eriocaulons*). They are dependent on the water seepage, and grow in the matrix formed by Poaceae and Cyperaceae (Porembski, 2007; Rock Outcrop India Network, 2018).

2.5. Adaptations on Inselbergs

High diversity of plants, invertebrates, amphibians and reptiles are common on outcrops, especially during the monsoon. Some of these organisms adapt to these extreme habitats to avoid desiccation in dry periods. Both plants and animals show unique adaptive strategies to survive on outcrops. Much is known about the adaptations of plants compared to animals. Inselbergs are known as 'centres of diversity' for plants that are particularly adapted for survival under its extreme environmental conditions (Porembski, 2007). Water scarcity and low nutrient availability in these habitats are leading causes, among many others such as microclimatic and edaphic dryness. This impacts the floristic composition of inselbergs, resulting in a different plant community on inselbergs compared to its surroundings. Some plant adaptations are briefly described below:

2.5.1. Desiccation tolerance

Some plants in the rock outcrop habitats have the unique ability to recover from almost complete loss of water, and thus they can survive periods of drought and recover when water is available (Tuba et al., 1998). They are called desiccation-tolerant (DT) plants or resurrection plants. Ferns such as *Selaginella*, some grasses (Cyperaceae, Poaceae etc.), Figworts, and Velloziaceae plants are known to have this unique adaptation in extreme habitats such as rock outcrops and deserts (Kulkarni et al., 2023). Rock outcrops (such as cliffs, plateaus, and inselbergs) are found to be the most important sites for Indian DT plants, and 90% of the global DT plants are known to grow on inselbergs (Smrithy et al., 2023; Porembski and Barthlott, 2000). DTs can be found as mat-formers, or in shallow depressions and seasonal rock pools (Porembski, 2007). Some of the DT *Selaginella* species are used in Indian traditional medicine, and considered a magical resurrection herb called 'Sanjeevani' (Sah et al., 2005).

2.5.2. Succulent Plants

Some plants on inselbergs have thick and fleshy parts which can retain water in plant tissues of leaves, stems, and roots, and they are known as succulent plants (Biedinger et al. 2000). *Cactus*, *Opuntia* are some examples.

2.5.3. Carnivory

Inselbergs are nutrient-poor habitats. In such conditions, certain plants are evolved to obtain nutrients like nitrogen and phosphorus through phyto- and zoo-planktons, small insects, and nematodes. They attract, ingest, and digest the prey (Givnish 1989). Plant species of Lentibulariaceae and Droseraceae are known for this adaptation.

2.5.4. Dwarfism

On inselbergs, some plants tend to be extremely short, and are termed 'dwarfism'. Globally, species of Eriocaulaceae, Scrophulariaceae, Juncaceae, and Cyperaceae are known to show dwarfism (Kulkarni et al., 2022).

2.5.5. Other Adaptations

Presence of dual photosynthetic pathways to deal with the scarcity of water, dominance of pollination using wind (anemophily), mass flowering to simultaneously attract a large number of pollinators are some of the other adaptations plants show in these habitats (Kulkarni et al., 2022).

3. APPROACH

3.1. Scope & Objectives

Rapid visual encounter surveys were carried out at three sites in Banka (Table 1):

- a. To rapidly assess the ecological value of some of the proposed rocky outcrops BHS in terms of rock-dwelling flora and fauna.
- b. To suggest future research and management directions for some of the proposed rocky outcrops BHSs.

3.2. Methodology

The rapid survey site details are explained in the table below:

Site	Date	Sampling Hours	Duration	Latitude	Longitude
Tola Abrakha (Katoria)	7 December 2024	1.5	3:30 pm - 5:00 pm	24°47'36.6"N	86°41'41.0"E
Mandar hills	8 December 2024	4	10:00 am - 2:00 pm	24°50'14.68"N	87° 2'5.90"E
Kakwara hills	8 December 2024	1	3:45 pm - 4:45 pm	24°49'56.80"N	86°52'21.71"E

Table 1. Rock outcrops visited during the surveys in the Banka forest division of Bihar.

Researchers were accompanied by the Forest Department staff during the surveys. Throughout the survey, microhabitats, flora (herbs, shrubs and woody vegetation) and fauna (focusing on rock-dwelling animals, especially herpetofauna and invertebrates) encountered in the sites were recorded and photographed. These were later identified at broad taxonomic levels using expert inputs. Unidentified plant individuals were collected for identification while no animal materials were collected as part of the survey.

4. INSIGHTS

4.1. Tola Abrakha

Situated in the Bhairoganj beat of Katoria range in the Banka division, a small stream in the village Tola Abrakha flows near the *Acacia* plantation. The area is approximately 700 m away from the Sultanganj-Deoghar road, near to the Kanwariya route, and the Anand Talab. It is connected to the Odhni Reservoir, and flows through many agricultural fields and rocky areas. The area is also modified with water conservation structures, for watershed management practices (Kushwah et al., 2016).

Many rocks are exposed here, and small rocks are embedded in the soil. The soil appeared to be fine loamy to coarse sandy loamy, especially near to the water. The rocks in this area are of precambrian origin, with fissured formations of Granite-Gneiss, Biotite-Gneiss, Hornblende-Gneiss Amphibolite Quartzite, and Mica-Schist, which are the Chotanagpur Granite Gneissic Complex and meta sedimentaries (Central Ground Water Board, 2013b). Wetland associated flora thrives here, with amphibians, odonates, butterflies, and other insects. The area forms a moderately modified wetland habitat.

Similar wetlands hold a crucial role in offering a wide range of ecological services including recharging and discharging groundwater, controlling floods, and regulating water flow; and thus needs special attention. It is also important to note that the social and environmental benefits they provide needs to be taken into account, and the consequences of wetland degradation need to be studied in the future (Pandey & Bharti, 2024).

Figure 6. <Map need to be added>



Figure 7. Map showing the Tola Abrakha wetland area. Credits: Google Maps



The hilly terrain along the stream



One of the large pools of the stream

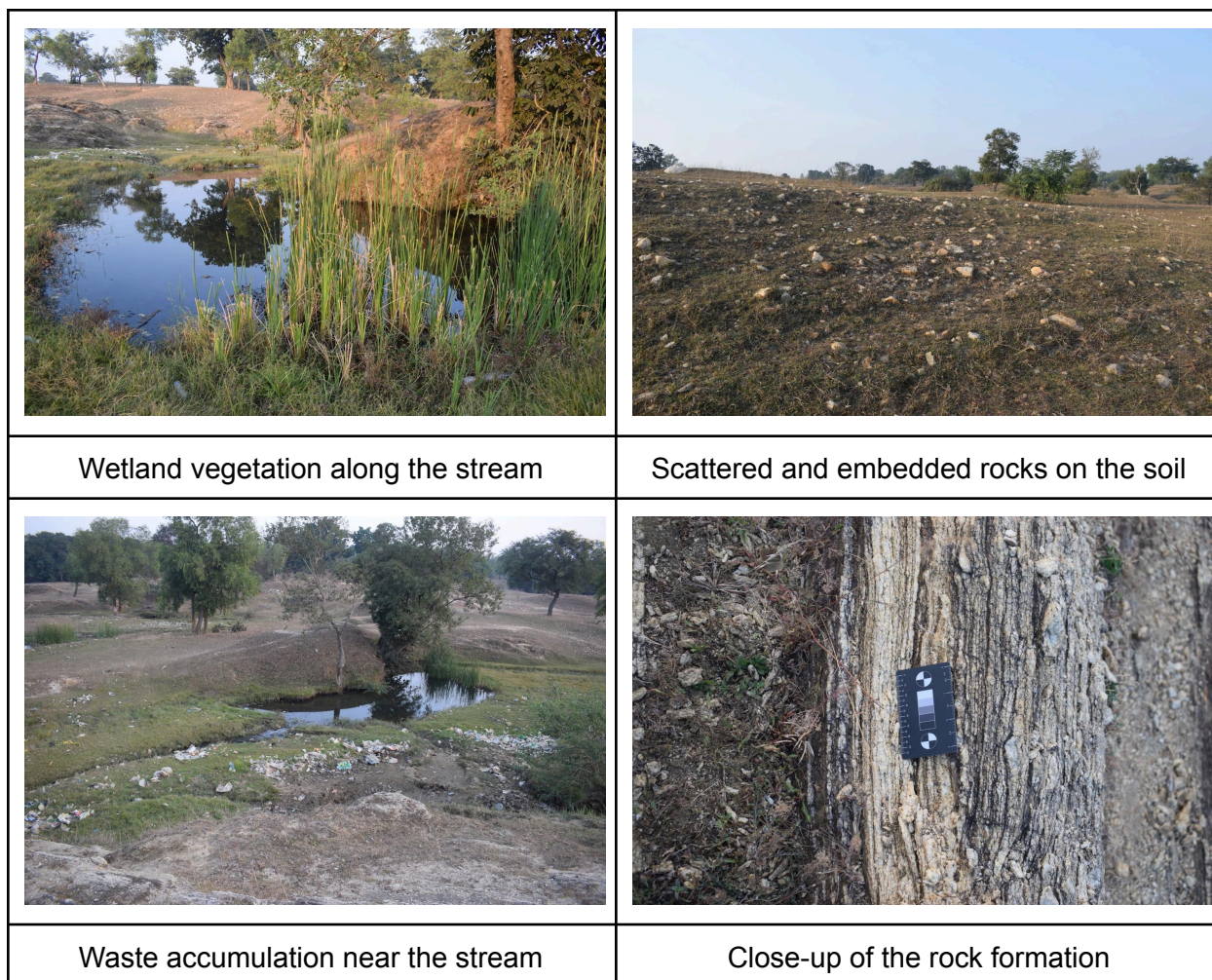


Figure 8: Photographs of the landscape features of Tola Abrakha.

Microhabitat Survey

The details of microhabitats recorded during the rapid survey are given below. Please refer to section 2.4 on microhabitats for detailed descriptions.

	
Grassy patches along the stream	Rock cuttings and crevices
	
Burrows on vertical surface	Plants growing in the rock fissures

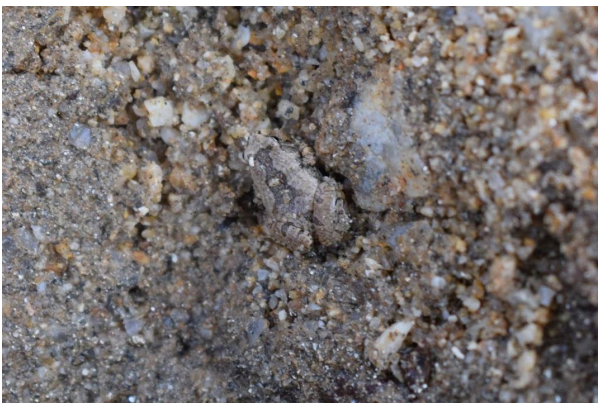
Figure 9: Photographs of observed microhabitats from Tola Abrakha.

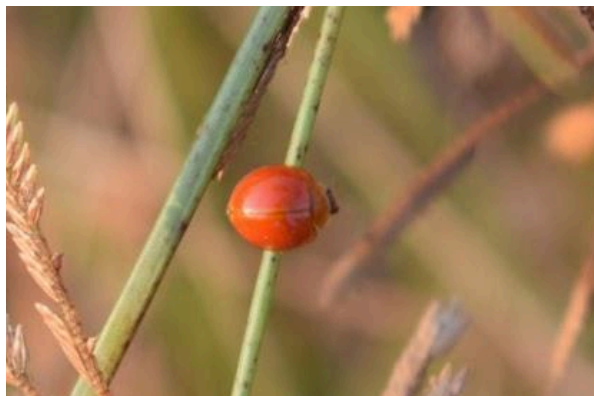
4.1.1. Biodiversity Survey

The details of biodiversity elements recorded during the rapid survey are given below. Please refer to section 2.5 for additional details. Please note that the '[?]' mark indicates the identification needs further verification, and the list is not exhaustive.

4.1.1.1. Fauna

From the Tola Abrakha stream area, we recorded a total of 25 animal species belonging to 19 families with 3 amphibians, 1 fish, 18 insects, 1 gastropod, and 2 arachnids, across 10 orders. Further exploration in more vegetated areas might improve this documentation. Details are given below:

	
<i>Euphlyctis cyanophlyctis</i>	<i>Microhyla nilphamariensis</i>
	
<i>Minervarya</i> sp.	Viviparidae



Cycloneda (?)



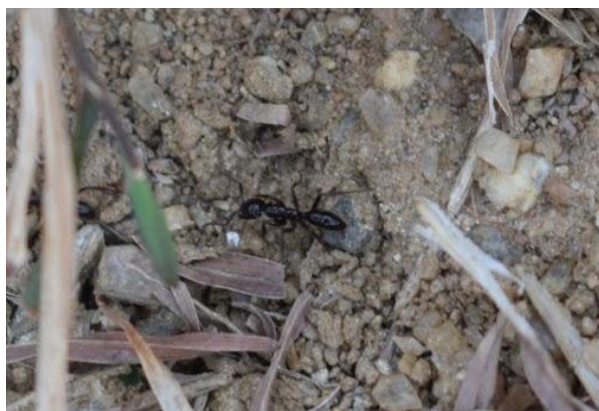
Cicadellidae (?)



Gerridae (Hemiptera)



Aplocheilus sp. (?)



Leptogenys cf. *chinensis*



Trichomyrmex sp.



Acrida sp. (?)



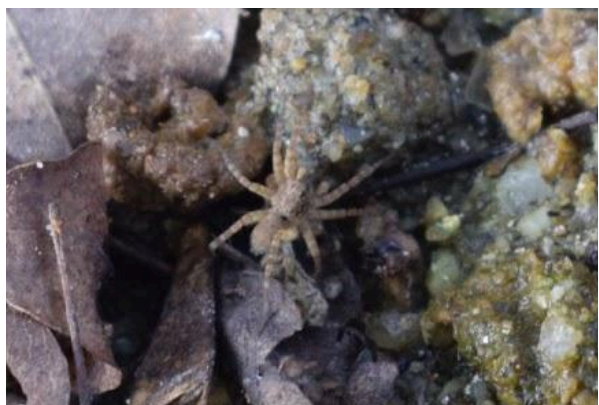
Orthoptera



Trigonidium sp.



Orthoptera



Lycosidae



Lycosidae



Gryllidae



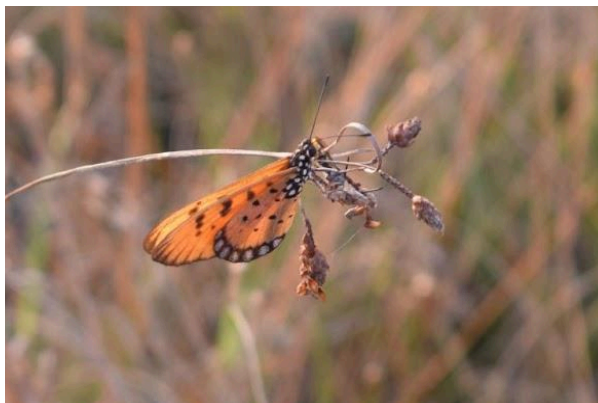
Reduviidae



Lycaenidae (*Zizeeria* sp.?)



Zizina sp.



Acraea terpsicore



Agriocnemis pygmaea

	
<i>Copera marginipes</i>	<i>Pseudagrion</i> sp.
	
<i>Diplacodes trivialis</i>	

Figure 10. Documentation of fauna from the Tola Abrakha area.

4.1.1.2 Flora

The surveyed habitat in Tola Abrakha area is an open exposed rock outcrop comprising shallow and deep soil-filled areas. It is predominantly covered by herbaceous vegetation, resembling a grassland, with scattered trees interspersed throughout. The wetland in this region adds to the habitat's plant diversity. Most dominant vegetation is of herbaceous species, scattered tree species. From the rapid assessment, we recorded 30 species belonging to 14 families comprising 2 trees, 1 shrub, 1 climber and 27 herbaceous species (Table 2). Out of the total, four species belong to pteridophytes.

Table 2. List of recorded plants from the Tola Abrakha area.

Family	Species	Habit
Acanthaceae	<i>Andrographis longipedunculata</i> (Sreem.) L.H.Cramer ex Karthik. & Moorthy	Herb
Acanthaceae	<i>Andrographis paniculata</i> (Burm.f.) Wall. ex Nees	Herb
Acanthaceae	<i>Barleria cristata</i> L.	Herb
Acanthaceae	<i>Lepidagathis hamiltoniana</i> Wall.	Herb
Acanthaceae	<i>Rostellularia procumbens</i> (L.) Nees	Herb
Amaranthaceae	<i>Celosia argentea</i> L.	Herb
Apocynaceae	<i>Hemidesmus indicus</i> (L.) R.Br.	Climber
Arecaceae	<i>Phoenix loureiroi</i> var. <i>pedunculata</i> (Griff.) Govaerts	Tree
Asteraceae	<i>Tridax procumbens</i> L.	Herb
Asteraceae	<i>Vicoa indica</i> (L.) DC.	Herb
Caryophyllaceae	<i>Polycarpaea corymbosa</i> (L.) Lam.	Herb
Cyperaceae	<i>Bulbostylis barbata</i> (Rottb.) C.B.Clarke	Herb
Cyperaceae	<i>Cyperus</i> sp.	Herb
Cyperaceae	<i>Cyperus amabilis</i> Vahl	Herb
Cyperaceae	<i>Cyperus difformis</i> L.	Herb
Cyperaceae	<i>Fuirena ciliaris</i> (L.) Roxb.	Herb
Cyperaceae	<i>Schoenoplectiella praelongata</i>	Herb
Fabaceae	<i>Butea monosperma</i> (Lam.) Kuntze	Tree
Fabaceae	<i>Indigofera linifolia</i> (L.f.) Retz.	Herb
Lamiaceae	<i>Leucas aspera</i> (Willd.) Link	Herb
Lamiaceae	<i>Leucas cephalotes</i> (Roth) Spreng.	Herb

Onagraceae	<i>Ludwigia perennis</i> L.	Herb
Poaceae	<i>Cenchrus pedicellatus</i> (Trin.) Morrone	Herb
Poaceae	<i>Dactyloctenium aegyptium</i> (L.) Willd.	Herb
Poaceae	<i>Oplismenus burmanni</i> (Retz.) P.Beauv.	Herb
Polygonaceae	<i>Persicaria</i> sp.	Aquatic herb
Pteridaceae	<i>Adiantum philippense</i> L.	Herb
Pteridaceae	<i>Hemionitis tenuifolia</i> (Burm.f.) Christenh.	Herb
Pteridaceae	<i>Pteris vittata</i> L.	Herb
Selaginellaceae	<i>Selaginella bryopteris</i> (L.) Baker	Herb
Verbenaceae	<i>Lantana camara</i> L.	Shrub

Note: A diverse array of natural and modified microhabitats of cracks and holes are present here. The relatively less number of invertebrates (spiders, grasshoppers etc.) might be an indication of the high disturbance in the area.

It is important to note that species identification from photographs are preliminary in nature. Further detailed field studies during monsoon are essential to confirm some of these observations, and it is possible that there are more interesting animals and plants, especially geckos, butterflies, and other plants, which needs further exploration across seasons and time (eg. Night time surveys are required for more detection of herpetofaunal species including amphibians, agamids and skinks; wet-season surveys are required for ephemeral vegetation).

4.2. Site : Mandar hills

Mandar hills are iconic granitic inselberg of the country, which have been mentioned across literature. The Banka district itself is recognized with the presence of it, situated in Bounsi Block about 18 Kms away from the district headquarters. The Mandar Hill is connected with the mythological story of the Skanda Purana (Samudramanthan event), in which the hill is used as a churner for the ocean. In it, gods (Devas) and demons (Asuras) churned the ocean of milk (Kshira Sagara) to obtain the nectar of immortality, 'Amrita', with the help of Vishnu. A sculpture depicting this story can be seen near the temple, where the *Papaharini* pond (meaning 'purifies from sin') is situated. There are Hindu and Jain temples on this site. Huge fairs are annually held at this site, including the Banka festival (Kumar & Das, 2023). On the top of the inselberg, there is a Digambara Jain temple of Lord *Vasupujya Swami*. There are rope-ways, stairs and railings installed for devotees and tourists to reach to the top of the inselberg.

The inselberg's distinct shape is interesting, shaped by natural processes over time, adding to its geological and cultural significance. Beglar in his 1878 report, describe this in both words and illustration as:

"The eastern face of the hill is peculiarly impressive in appearance; it rises sheer up, a mass of smooth stone without a single blade of grass all the way up in the central portion; the form in outline is a graceful curve somewhat resembling a parabola with its vertex upwards. When within about 30 feet of the ground, vegetation begins to shew itself, and thence the slope is a gentle one in the reverse direction till it meets the plain; the outline, therefore, of the entire hill here is a curve of a double flexure, and is singularly beautiful" - Beglar (1878). P. 132.

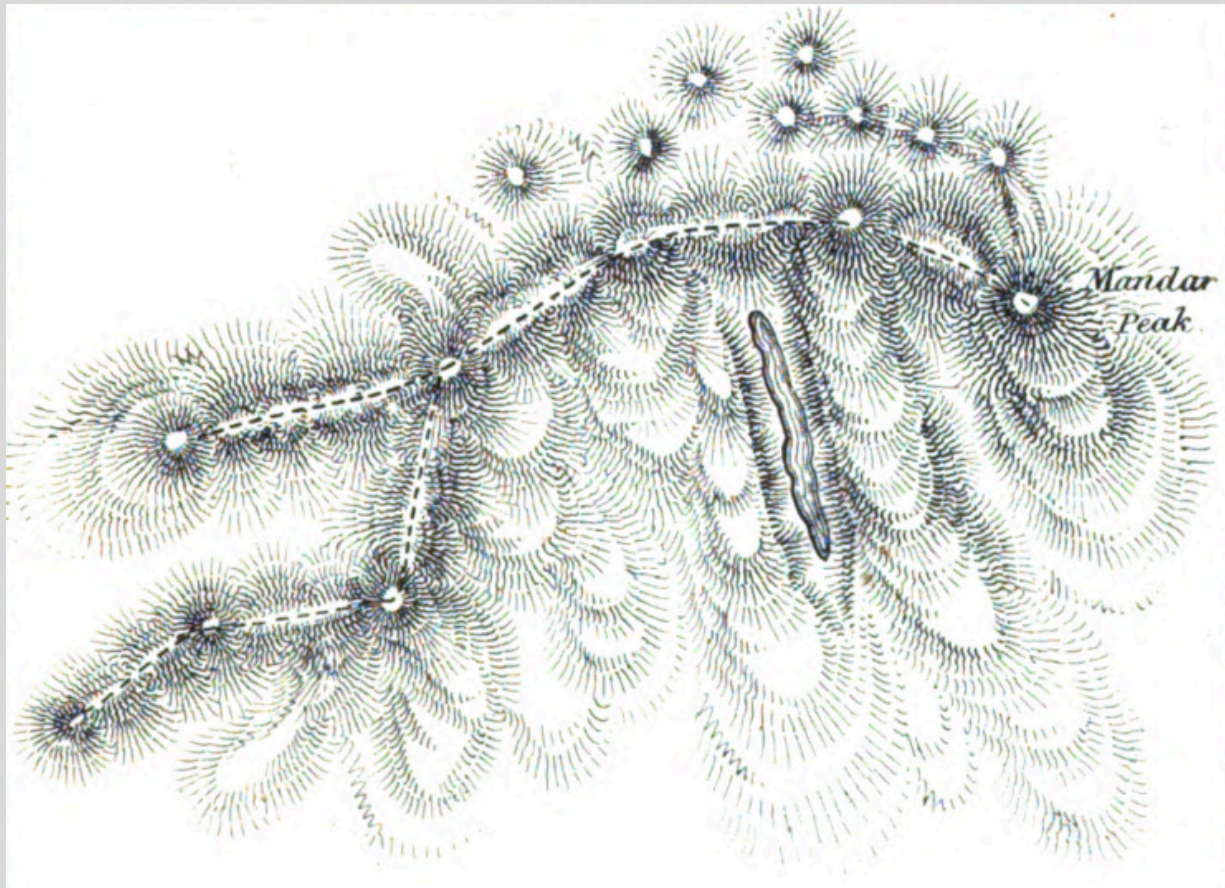


Figure extracted from “*Report of a tour through the Bengal Provinces of Patna, Gaya, Mongir, and Bhagalpur, the Santal Parganas, Manbhum, Singhbhum, & Birbhum, Bankura, Raniganj, Bardwan and Hughli in 1872-73 (Vol. 8)*” - Digitized by Google; No Scale; Original Illustration by J.D. Beglar. del.; Lithographed at the Surveyor General Office, Calcutta, February 1878.

The site is archaeologically important as many rare artefacts, inscriptions, and ruins have been recorded from this site (Beglar, 1878), as well as ethno-archaeologically, considering the Sauriya and Mai Pahariya tribes (Tyagi & Sinha, 2004). The inselberg is also important in terms of the run-off water. Since it is located in an agricultural landscape which is principally dependent on rain fed irrigation, run-off from these geological formations are critical for adjacent agricultural fields as they can control the productivity of the land and also the socioeconomic conditions of the local people (Mahato & Jana, 2019).

There have been studies on the limnology of the *Papaharini* pond, of which the details are unavailable to the authors at the moment (Sinha et al., 1992). In a 2019 study, 15 species of moths have been recorded from Mandar hills (Singh, 2019). Another study indirectly shows that it is home to ~10 species of aquatic beetles (Vazirani, 1967). In a previous study of flora, it has been shown that, comparatively, Mandar was the most diverse site in the Banka district followed by Inarabaran, Chandan Dam, Maholia Jungle, Biharu Pahar and Chaubatia Village (Chandra et al., 2022). The most dominant species found here were *Streblus asper*, *Phoenix sylvestris*, *Diospyros cordifolia*, *Flacourtia indica*, *Ziziphus xylopyrus*, *Cassia fistula*, *Ficus mollis*, *Holarrhena pubescens*, *Bridelia retusa*, and *Ehretia laevis* (Chandra et al., 2022).

The soil here is Micaceous, containing particles of mica (Arisdason et al., 2018), and the granite is considered included in the Dumka Granite Suite, which is medium to coarse-grained with grey or pink colours, and Proterozoic (Mohanty, 2000). The lithological type is identified as Porphyritic gneiss of Precambrian stratigraphic horizon, and a geological cross-section along its W-E direction shows both white sand and clay stones (Singh et al., 1987). The inselberg can be seen home to scattered boulders, rock pools, shrub patches and other various microhabitats.

<Map need to be added>

Figure 11. Map showing the Mandar inselberg, demarcating the temple and the biodiversity park.



View of the Mandar hills from the biodiversity park.



View of the temple below the Mandar hills



View of the hilltop from the steps on the rocks



Rope-way to the hill-top



View of the inselberge portions inside the Biodiversity park from the Mandar hills



Engravings on the rocks on the inselberg.

	
View of the surrounding landscape from the inselberg	View of Mandar hills from the park bridge
	
Balancing rocks on the inselberg	Type of rock pattern from the inselberg, near the peak
	
Type of rock pattern from the inselberg portion inside the park	Type of rock pattern from the inselberg inside the park

Figure 12. Photographs of landscape features of Mandar inselberg and its surroundings.

Microhabitat Survey

The details of microhabitats recorded during the rapid survey are given below. Please refer to section 2.4 on microhabitats for detailed descriptions.

	
<i>Selaginella bryopteris</i> mats growing on the rock	Loose, large flat rocks amidst the <i>Mesosphaerum suaveolens</i> growth
	
Shade-loving ferns under the rock	Weathered rocks and gravelly soil patch



Grass growing inside the fissures on the rock



Disintegrating rocks from the inselberg creating multiple microhabitats, including loose rocks, fissures, caves, and gaps.



A shallow rock pool



Small stream originating from the inselberg.

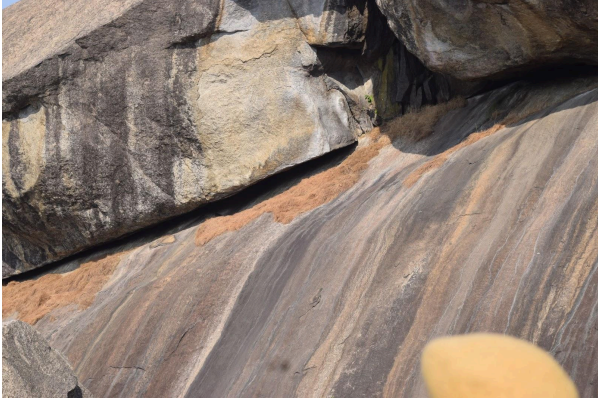
	
Ephemeral vegetation along the stream, on the rock	A large rock pool with ephemeral vegetation
	
Cryptogamic crusts and monocotyledonous mats	Loose rocks and vegetation growth on the inselberg top
	
Soil-filled large depressions supporting shrubs, small trees and climbers	<i>Oropetium thomaeum</i> growing on the cryptogamic crusts of moss and algae

Figure 13. Documentation of microhabitats observed at Mandar inselberg

4.1.2. Biodiversity Survey

The details of biodiversity elements recorded during the rapid survey are given below. Please refer to section 2.5 for additional details. Please note that the '(?)' mark indicates the identification needs further verification, and the list is not exhaustive.

4.2.1.1. Fauna

From the Mandar inselbergs, we recorded a total of 32 animal species belonging to 23 families with 1 mammal, 1 amphibian, 3 reptiles, 8 arachnids, and 19 insects only. A total of 12 orders are documented during the short visit. Details are given below:

	
<i>Euphlyctis cyanophlyctis</i>	<i>Calotes versicolor</i>
	
<i>Naja naja</i> (?)	<i>Hemidactylus flaviviridis</i>



Semnopithecus entellus



Orthoptera



Orthoptera



Orthoptera



Eurema sp.



Neptis sp.



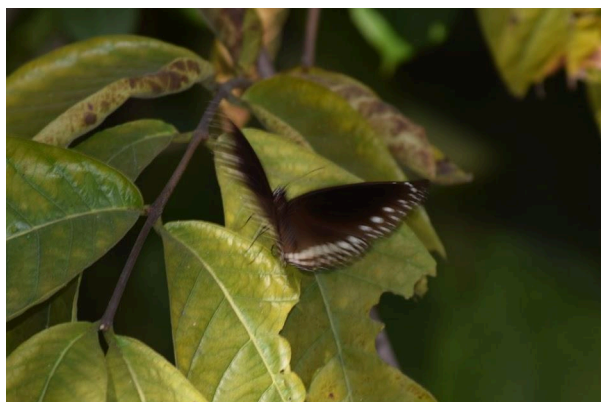
Tarucus sp.



Junonia hierta



Junonia almana



Euploea core



Zizina sp.



Junonia lemonias



Myrmeleontidae



Poeantius festus



Wadicosa sp.



Nephila pilipes



Wadicosa sp.



Wadicosa sp.



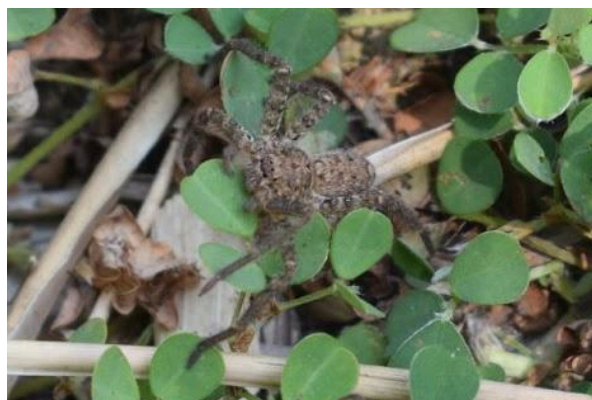
Salticidae



Unidentified Arachnid



Oxyopus sp.



Sparassidae



Eristalinus megacephalus



Apis florea

	
<i>Dactylopius</i> sp.	Myrmicinae (sub-family)
	
Phasmatodea	<i>Schizocephala bicornis</i>

Figure 14. Documentation of fauna from Mandar Inselberg

4.2.1.2. Flora

From the surveyed site of Mandar Inselberg, a total of 41 plant species from 22 families were recorded, including 4 trees, 6 shrubs, 3 climbers, and 29 herbaceous species (Table 3). Greater plant diversity was observed on the protected sides of Mandar Hills, where human activity was minimal. In contrast, areas with higher human presence, particularly along the path leading to the temple and its adjacent regions, exhibited lower diversity in terms of species richness. Desiccation-Tolerant Mat-Forming Monocotyledons (DTMFM) from the family Poaceae, such as *Oropetium thomaeum*, *Eragrostiella* spp., *Eragrostis multiflora* and *Microchloa indica*, were commonly found on

slopes and in shallow depressions, often with the fern *Selaginella bryopteris* (commonly known as Sanjeevani). The semi-succulent *Coleus strobilifer* was also observed growing in rock crevices and among these DTMFM species.

Seepage areas on the protected side of Mandar Hills supported a high abundance of ephemeral vegetation, including *Eriocaulon* sp., *Murdannia* sp., *Commelina* sp., and *Rotala indica*. However, the spread of invasive species such as *Mikania micrantha*, *Chromolaena odorata*, *Lantana camara*, and *Mesosphaerum suaveolens* was negatively impacting native flora in surrounding deep soil-filled areas.

Table 3: List of Flora (Pteridophytes and Angiosperms) from Mandar hills

Family	Species	Habit
Acanthaceae	<i>Andrographis longipedunculata</i> (Sreem.) L.H.Cramer ex Karthik. & Moorthy	Herb
Amaranthaceae	<i>Achyranthes aspera</i> L.	Herb
Amaranthaceae	<i>Celosia argentea</i> L.	Herb
Amaranthaceae	<i>Pupalia lappacea</i> (L.) Juss.	Herb
Amaranthaceae	<i>Trichuriella monsoniae</i> (L.f.) Bennet	Herb
Apocynaceae	<i>Alstonia scholaris</i> (L.) R.Br.	Tree
Apocynaceae	<i>Hemidesmus indicus</i> (L.) R.Br.	Climber
Arecaceae	<i>Phoenix loureiroi</i> var. <i>pedunculata</i> (Griff.) Govaerts	Tree
Asteraceae	<i>Acmella uliginosa</i> (Sw.) Cass.	Herb
Asteraceae	<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Subshrub
Asteraceae	<i>Mikania micrantha</i> Kunth	Climbing shrub
Asteraceae	<i>Tridax procumbens</i> L.	Herb
Asteraceae	<i>Vicoa indica</i> (L.) DC.	Herb
Cactaceae	<i>Opuntia elatior</i> Mill.	Succulent shrub

Caryophyllaceae	<i>Polycarpaea corymbosa</i> (L.) Lam.	Herb
Commelinaceae	<i>Cyanotis axillaris</i> (L.) D.Don ex Sweet	Herb
Cyperaceae	<i>Bulbostylis barbata</i> (Rottb.) C.B.Clarke	Herb
Cyperaceae	<i>Cyperus amabilis</i> Vahl	Herb
Cyperaceae	<i>Cyperus niveus</i> Retz.	Herb
Eriocaulaceae	<i>Eriocaulon</i> sp.	Herb
Euphorbiaceae	<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	Tree
Fabaceae	<i>Indigofera linifolia</i> (L.f.) Retz.	Herb
Lamiaceae	<i>Coleus strobilifer</i> (Roxb.) A.J.Paton	Herb
Lamiaceae	<i>Mesosphaerum suaveolens</i> (L.) Kuntze	Subshrub
Lythraceae	<i>Rotala indica</i> (Willd.) Koehne	Herb
Malvaceae	<i>Helicteres isora</i> L.	Shrub
Molluginaceae	<i>Paramollugo nudicaulis</i> (Lam.) Thulin	Herb
Moraceae	<i>Ficus mollis</i> Vahl	Tree
Olaceae	<i>Olax scandens</i> Roxb.	Liana
Poaceae	<i>Bambusa</i> sp.	-
Poaceae	<i>Cenchrus pedicellatus</i> (Trin.) Morrone	Herb
Poaceae	<i>Chrysopogon fulvus</i> (Spreng.) Chiov.	Herb
Poaceae	<i>Eragrostis coarctata</i> Stapf	Herb
Poaceae	<i>Eragrostis multiflora</i> Trin.	Herb
Poaceae	<i>Eragrostiella</i> sp.	Herb
Poaceae	<i>Heteropogon contortus</i> (L.) P.Beauv. ex Roem. & Schult.	Herb
Poaceae	<i>Oplismenus burmanni</i> (Retz.) P.Beauv.	Herb
Poaceae	<i>Oropetium thomaeum</i> (L.f.) Trin.	Herb

Polygonaceae	<i>Persicaria</i> sp.	Aquatic herb
Pteridaceae	<i>Hemionitis</i> sp.	Herb
Pteridaceae	<i>Hemionitis tenuifolia</i> (Burm.f.) Christenh.	Herb
Selaginellaceae	<i>Selaginella bryopteris</i> (L.) Baker	Herb
Verbenaceae	<i>Lantana camara</i> L.	Shrub

Notes: There is a need to document species in the wet season.

4.3. Site : Kakwara hills

Kakwara hills is situated east to the Odhni reservoir in Banka, close to the Banka-Deoghar road on its eastern side, Kakwara-Katoria road on its north, and Rampur Kali temple road on its southern side. It is situated in a landscape matrix of agricultural land, and towns and villages including the Kakwara Tola. It is a local tourist attraction, and a religious worship place with temples including a Shiva Temple. From the top of the hill, Mandar hills can be seen, to its eastern side. The area is also home to some bouldery nubbins (24°49'33.63"N; 86°52'38.23"E).

The lithological types are identified as Amphibolite and Quartzite of Precambrian stratigraphic horizon, and a geological cross-section along its NW-SE direction shows both Hornblende Gneiss and Amphibolite stones (Singh et al., 1987). The rocks in this area are of precambrian origin, with fissured formations of Granite-Gneiss, Biotite-Gneiss, Hornblende-Gneiss Amphibolite Quartzite, and Mica-Schist, which are the Chotanagpur Granite Gneissic Complex and meta sedimentaries (Central Ground Water Board, 2013b). Many rocks are exposed here, and small rocks are embedded in the soil. It is a hilly area with scattered boulders, loose rocks, rock pools, shrub patches and other various microhabitats. Grazing of goats, and leisure visits by people were noted. There is a temple situated on the way to the top of the hill.

In a previous study conducted in the nearby area, the most dominant species found were *Shorea robusta*, *Butea monosperma*, *Phoenix sylvestris*, *Madhuca longifolia* var. *latifolia*, *Borassus flabellifer*, *Syzygium cumini*, *Holarhena pubescens*, *Alangium salviifolium*, and *Sterculia villosa* (Chandra et al., 2022). A very short exploration itself showed that the area is home to many interesting animals including a variety of spiders, insects, and geckos.

<Map need to be added>

Figure 15. Map showing the Kakwara hills site.



Hill-top with scattered rocks and sparse vegetation



Temple on the way to the hill-top



The habitation and agricultural land adjacent to the hill



Rocks are used for drying cow dung cakes



View of the agricultural land from the hill-top



Cattles grazing in the hill-top

	
Scattered boulders between the tree vegetation on the way to hill-top	View of livelihood in the transition zone between the edge of hill-forest and rocky hill-top
	
Screengrabs from a YouTube video showing other nearby bouldery nubbins; most probably 24°49'33.63"N; 86°52'38.23"E (https://www.youtube.com/watch?v=Ski7xx7PxRA)	

Figure 16. View of the Kakwara hill landscape and nearby nubbins

4.3.1. Microhabitat Survey

The details of microhabitats recorded during the rapid survey are given below. Please refer to section 2.4 on microhabitats for detailed descriptions.



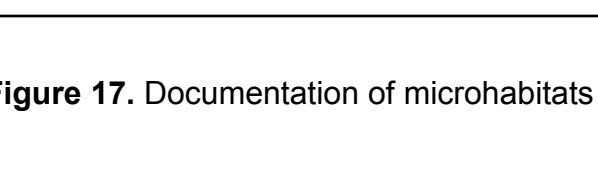
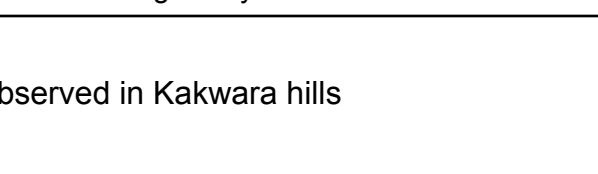
A shallow rock pool with ephemeral vegetation	Cracks and crevices in the rock
	
Cave-like structures	Protruding rocks from the ground
	
Vegetation growth on the rock crevices	Exposed bare rock
	
Scattered loose, and soil-embedded rocks	Pit-fall traps of Myrmeleontidae larvae in gravelly soil with sand
	

Figure 17. Documentation of microhabitats observed in Kakwara hills

4.1.3. Biodiversity Survey

The details of biodiversity elements recorded during the rapid survey are given below. Please refer to section 2.5 for additional details. Please note that the '(?)' mark indicates the identification needs further verification, and the list is not exhaustive.

4.3.1.1. Fauna

From the Kakwara hill, we recorded a total of 21 animal species belonging to 18 families with 1 reptile, 3 arachnids, 2 centipedes, and 15 insects. A total of 12 orders were documented during the short visit. Details are given below:

	
<i>Hemidactylus cf. kushmorensis</i>	Orthoptera
	
Orthoptera	<i>Diplacodes trivialis</i>



Gryllidae



Buthidae



Cormocephalus sp.



Geophilomorpha



Isoptera



Blattodea



Erthesina acuminata



Coleoptera



Noctuidae (?)



Oncocera sp. (?)



A moth cocoon



Reduvius sp.

	
Lycosidae	Sparassidae
	
<i>Camponotus compressus</i> tending coccids (Coccidae)	<i>Camponotus compressus</i>
	
<i>Paratrechina longicornis</i>	

Figure 18. Documentation of fauna from Kakwara hills.

4.3.1.2 Flora

From the surveyed rock outcrop on the Kakwara hills, a total of 15 plant species belonging to 9 families comprising 1 tree, 1 shrub, 1 climber and 12 herbaceous species were recorded (Table 4). Typical inselberg species such as *Oropetium thomaeum* and *Cyperus amabilis* were occupying the shallow depressions and dried rock pools, while *Hemionitis* spp. growing on the shaded shelters beneath scattered loose rocks. Other species are mostly opportunistic lithophytes seen common in semi-dried or xeric habitats. Surrounding the rock outcrops are dominated by tree vegetation. The flora is highly disturbed due to anthropogenic and grazing pressure and also due to the invaded species *Mesosphaerum suaveolens* which dominates in the post-monsoon

Table 4. List of Flora (Pteridophytes and Angiosperms) from Kakwara hills

Family	Species	Habit
Acanthaceae	<i>Andrographis longipedunculata</i> (Sreem.) L.H.Cramer ex Karthik. & Moorthy	Herb
Acanthaceae	<i>Rostellularia procumbens</i> (L.) Nees	Herb
Apocynaceae	<i>Hemidesmus indicus</i> (L.) R.Br.	Climber
Arecaceae	<i>Phoenix loureiroi</i> var. <i>pedunculata</i> (Griff.) Govaerts	Tree
Asteraceae	<i>Tridax procumbens</i> L.	Herb
Cyperaceae	<i>Bulbostylis barbata</i> (Rottb.) C.B.Clarke	Herb
Cyperaceae	<i>Cyperus amabilis</i> Vahl	Herb
Lamiaceae	<i>Mesosphaerum suaveolens</i> (L.) Kuntze	Subshrub
Poaceae	<i>Cenchrus pedicellatus</i> (Trin.) Morrone	Herb
Poaceae	<i>Eragrostis coarctata</i> Stapf	herb
Poaceae	<i>Oplismenus burmanni</i> (Retz.) P.Beauv.	Herb
Poaceae	<i>Oropetium thomaeum</i> (L.f.) Trin.	Herb

Poaceae	Unidentified grass	Herb
Pteridaceae	<i>Hemionitis</i> sp.	Herb
Pteridaceae	<i>Hemionitis tenuifolia</i> (Burm.f.) Christenh.	Herb

Note: The rapid assessment of the rock outcrop in Kakwara Hills was conducted during winter, when most plants were dried, and in the late evening, which likely resulted in a lower species count. However, the site is expected to support a high diversity of typical outcrop elements and xerophytic specialists. Further documentation during the monsoon season is essential, as it would reveal the occurrence of ephemeral plants and the formation of rock pools.

Figure 19. Photographs representing the flora across the surveyed sites

	
<i>Barleria cristata</i>	<i>Polycarpaea corymbosa</i>
	
<i>Vicoa indica</i>	<i>Pteris vittata</i>
	
<i>Ludwigia perennis</i>	<i>Lepidagathis hamiltoniana</i>



Fuirena ciliaris



Cyperus amabilis



Andrographis paniculata



Unidentified species



Opuntia elatior



Dicliptera sp.



Bambusa sp.



Leucas aspera



Persicaria sp.



Dactyloctenium aegyptium



Selaginella bryopteris



Cyanotis axillaris



Lygodium flexuosum



Mikania micrantha



Hemidesmus indicus



Trichuriella monsoniae



Murdannia sp.



Oropetium thomaeum



Microchloa indica



Helicteres isora



Hemionitis tenuifolia



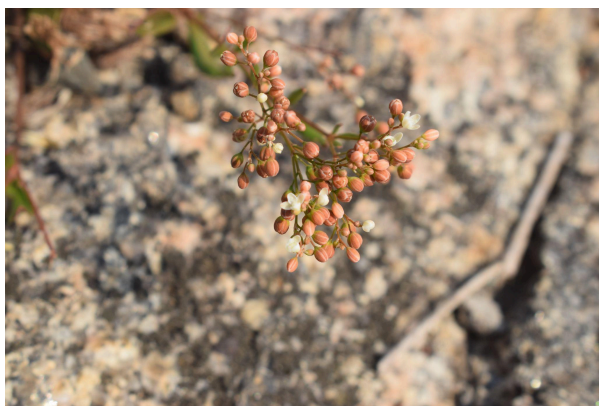
Phoenix loureiroi var. *pedunculata*



Leucas cephalotes



Eriocaulon sp.



Paramollugo nudicaulis



Cyperus amabilis



Cyperus niveus



Ziziphus oenoplia



Acnella uliginosa



Mallotus philippensis



Eragrostiella sp.



Alstonia scholaris

4. DISCUSSION

The rapid surveys show that the explored sites, especially the Mandar and Kakwara hills are of great biological, geological and hydrological significance, in light of the increasing anthropogenic disturbance and habitat modification. Though much of the seasonal biodiversity has not been documented due to the limited scope of this short-duration assessment in the dry season, a further exploration in the wet-season is highly recommended to reveal the ecological value of these least studied rock outcrops. The preliminary observations that are made in this report will be useful for ecologists and conservation practitioners alike, as these record some of the first documented biodiversity observations of Bihar rock outcrops, which were so far neglected. Bihar is home to some of the very interesting rock outcrops that are of conservation values including the Mandar Hills (explored in this report), Inselberg near the Durgavati Reservoir (Fig. 20), and small inselbergs embedded in the agricultural-human settlement matrix (such as the ones explored in Gaya, Aurangabad, and Jamui). They can act as patches that support unique biodiversity in the already heavily modified landscape, providing necessary ecosystem services to neighbouring regions, with cultural, touristic and aesthetic values.



Figure 20. Inselberg near the Durgavati Reservoir (Karamchat Dam), Kaimur, Bihar. Photograph by Binay Babu, CC BY-SA 4.0, via Wikimedia Commons.

Considering the high tourism potential, cultural and archeological values of these poorly known habitats, thorough explorations and ecological studies need to be undertaken in the future, with support from other departments. Keeping in mind the limited information this report has generated, a few conservation recommendations and future research dimensions are suggested below:

4.1. Conservation Recommendations

- 4.1.1. The conceptual framework developed for establishing Local Biodiversity Heritage Sites (LBHS) for rock outcrop conservation in the northern Western Ghats can be used as a model, keeping the socio-ecological landscape in mind (Watve & Chavan, 2020).
- 4.1.2. Possibilities of giving 'Conservation Reserve Status' to the inselbergs can be explored, following similar effort by the joint initiative of the Western Ghats Task Force, Karnataka Biodiversity Board, (Government of Karnataka), and the Ministry of Science and Technology, and Ministry of Environment and Forests (Government of India) (Chandran et al., 2012).
- 4.1.3. Since some of these inselbergs are also acting as grasslands, their management needs to be in accordance with the guidelines developed to provide clear strategies and steps that different government agencies can undertake to secure and conserve grasslands in India (Watve et al., 2019).
- 4.1.4. It may be important to note that the proposed conservation measures consider the fact that restricting all forms of human land use and herding activities in these areas (Michael et al. 2008), may decrease biodiversity by reducing habitat diversity. Thus, historical relationships between prehistoric human land-use practices and contemporary conditions of biodiversity requires continued investigation, species inventories and statistical analyses (Bauer, 2018).

- 4.1.5. How the Biodiversity Act (2000) can be utilised for rock outcrop conservation is a topic that of recent interest, especially with regards to the Konkan lateritic outcrops in Maharashtra. More details on this can be obtained at the Rock outcrop of India Network Website (<https://rockoutcropofindia.in/conservation-action/f/use-of-biodiversity-act-2002-for-conservation-of-sada>). The extensive discussion arising from this project can be considered as a template for inselberg conservation in Bihar.
- 4.1.6. Tree plantation in the inselberg habitat would alter the open habitat structure and negatively impact the biodiversity and microclimatic conditions of the original ecosystems.
- 4.1.7. Since the inselbergs are also of importance in terms of geodiversity and geoheritage, which are integral parts of biological diversity and natural heritage, assessments of geoheritage and prospects of geotourism need to be undertaken in these habitats similar to Karnataka and West Bengal (Prabhakar & Radhika, 2022; Ghosh et al., 2021). The scope for this needs to be discussed with the help of Geological Survey of India and other relevant departments in the light of recently announced 'Draft Geoheritage Sites and Geo-relics (Preservation and Maintenance) Bill, 2022'.
- 4.1.8. Involvement of the Maharashtra Forest Department in rock outcrop conservation and an extensive discussion following that is publicly available. These resources can be utilised (Biome Conservation Foundation, 2013).
- 4.1.9. Since rock outcrops are classified as 'wastelands' in the Govt. of India records, but are important open natural ecosystems (ONEs), examination of identified inselbergs in the background of ONE map need to be done. This can be carried out using the interactive web application (Madhusudan & Vanak, 2022) through which state and district-level- summaries of their area and distribution, and other

overlay statistics can be obtained (Available here: <https://mdm.users.earthengine.app/view/open-natural-ecosystems>).

- 4.1.10. Conservation of rock outcrops, related land-use and their utilisation as touristic centres needs a nuanced, multi-stakeholder approach (eg. determining the carrying capacity of tourist influx). A recent global literature review on these aspects (Fitzsimons & Michael, 2016) can be another starting point. Micro-planning for this purpose needs to be undertaken by the Forest department, Revenue department, scientists, local NGOs, local community and other relevant stakeholders.
- 4.1.11. Identification of rock outcrops within working plans of the Forest departments need attention. Capacity building of Forest department staff to deal with conservation of ecologically sensitive areas and special habitats such as the inselbergs is of importance.
- 4.1.12. Extensive constructions on the rock surface need to be avoided, as this will damage the microhabitats which are critical in sustaining biodiversity.
- 4.1.13. Preparation of 'ecotourism/ conservation tourism' plans and 'ethical guidelines for tourism' are of importance. Since scientific management of rock outcrops in India is at its early stages, rigorous scientific monitoring of managerial impacts and mid-course corrections as and when required need to be done. Panchgani Tableland conservation and related Supreme Court orders can be a background for such activities (The honourable Supreme Court upheld conservation of a small 100 acre rocky plateau, and reducing impacts of tourism infrastructure, using zonation in a revenue land).
- 4.1.14. *Specific management recommendation based on the rapid survey are:***
 - 4.1.14.1. Protect inselbergs from heavy human disturbances that cause damage to the microhabitats on rocks (trampling of

flora, removing plants and animals from microhabitats, removal and displacement of loose rocks etc.). This could be achieved by restricting the visitors along the designated paths leading up the temples and tourist spots.

- 4.1.14.2. Regular monitoring of vegetation changes on the inselberg (using repeated photography across seasons, maybe at bi-weekly intervals) would be useful to gauge the degree of human disturbance (such as tree cutting, firewood extraction and human induced fires) as well as spread of invasive species.
- 4.1.14.3. Among the four sites visited, Mandar hills may be developed as benchmark inselbergs of this division, and Kakwara hills as a biodiversity pocket in the expanding human habitation. Ensuring the proper identification and removal of invasive species such as *Mikania micrantha*, *Chromolaena odorata*, *Mesosphaerum suaveolens* and *Lantana camara* by uprooting them at the seedling stage is proposed as a long-term management strategy to preserve and naturally restore the native species in these habitats.
- 4.1.14.4. Restoration of disturbed (rock removal, vandalism, loss of native vegetation, chance of weed invasion and fires etc.) rocky habitat areas needs a more nuanced approach based on studies from Australia, and requires further field studies at the site itself (O'Sullivan et al., 2023; Jithin et al., 2023a).

4.2. Research Directions

- 4.2.1. As the first stage, species inventories of inselbergs need to be developed, with the help of experts in various taxa to identify unique species occurring here, in terms of endemism and special adaptations. Help of experts in rock habitat biodiversity from India

and abroad can be availed as inselberg ecology is still at a relatively nascent stage in India. Seasonal studies of ephemeral vegetation, cliff-dwelling flora, and rock-dwelling animals need to be undertaken to have a clear picture of the biodiversity in these habitats, which will be crucial in determining its ecological value. This can be done with student volunteers and interns who are interested in conservation and ecological research. Appropriate training for these needs to be conducted.

- 4.2.2. Identification and mapping of all rocky outcrops in the Bihar state, following proper scientific floral and faunal study need to be undertaken. Their cultural value, importance as habitats of endangered, endemic and rare species, species with unique adaptations, species which are not occurring in the surrounding area, and as ecosystem service providers needs to be understood, which can help managers to decide appropriate conservation measures.
- 4.2.3. Taxonomists and ecologists need to work together on lesser known taxa such as spiders, fungi, orthopterans, and lichen on inselbergs, and research should be conservation oriented which give feedback to area managers.
- 4.2.4. Fuel wood collection, medicinal plants extraction (eg. *Selaginella* sp.), and grazing, their sustainability and impacts on biodiversity need to be studied with the involvement of the local community.
- 4.2.5. Research needs to be undertaken on the livelihood impact in terms of water and nutrient incomes, and to know how the importance of these habitats can be communicated to the local people and tourists in this area.
- 4.2.6. Research needs to be undertaken to know how the inselbergs are acting as islands, and thus influencing the evolutionary radiation of rock-dwelling animals such as reptiles in the region, along with threat status assessment of the flora and fauna.

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