

Summary Report (First Draft)

Rapid Assessment of a Proposed Biodiversity Heritage Site in Aurangabad Forest Division, Bihar

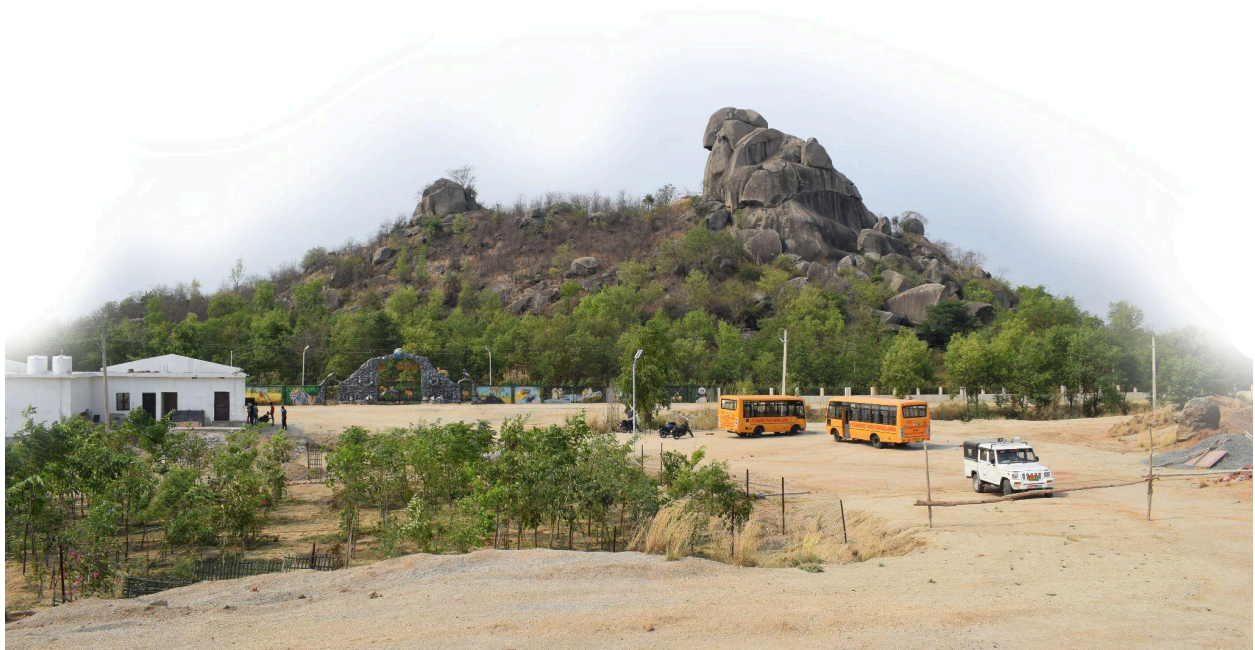
Submitted by

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A preliminary report submitted to the Aurangabad Forest Division,
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Front Cover: Inselberg inside the Aurangabad Biodiversity Park showing the rocky bouldery (nubbin) nature of the site, adjacent buildings, and Miyawaki forest, Aurangabad, Bihar. Photograph: Vijayan Jithin

Summary Page: A view from the inselberg outside the Aurangabad Biodiversity Park towards the road side, showing the depression in the landscape, and another inselberg in the background on the other side of the road, Aurangabad, 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. To assess the feasibility and scope of declaring some of the preliminarily identified inselbergs of Bihar as potential 'Biodiversity Heritage Sites' (BHS), a rapid assessment was undertaken in the Nalanda and Aurangabad Forest Divisions of Bihar. The examined inselbergs show great potential as BHS, considering their biological, geological, and heritage values. This preliminary report summarises the microhabitats, and biodiversity recorded from some of the inselbergs in Aurangabad, along with notes on its cultural values, and recommends further actions for the conservation of this important habitat.

In the rapid assessment, it was found that the rock outcrops inside and outside of the Aurangabad Biodiversity Park are granitic inselbergs, falling into the category of bouldery nubbins. They are surrounded by agricultural fields, and human habitations, situated near to the Batane river. One of the inselberg is well protected as the Aurangabad Forest Division has developed a biodiversity park around it, while the other is outside of it, allowing free access. The area is well connected with the road, and nearby to a village, home to other inselbergs such as the famous Pawai Jhunjhunawa Pahad. The rapid visual encounter survey revealed several microhabitats typically found on rock outcrops including loose rocks, rock pools, rock crevices and fissures, monocotyledonous mats, and was home to a wide variety of organisms. The rapid, non-exhaustive survey itself revealed at least 13 families of flowering plants, presence

of the desiccation tolerant vascular plant *Selaginella* cf. *indica*, and animals spanning 22 families across 11 orders. This relatively undisturbed rock outcrop is home to multiple flowering plants, pteridophytes, geckos, lizards, ants, spiders, butterflies, grasshoppers, wasps, and snails. Diversity of grasshoppers in the habitat is noteworthy with 9 genera from 2 families. Wet-season survey will improve this documentation by adding more taxa that may be only detectable during that time. Further detailed field studies during the monsoon are essential to confirm some of these observations. It is possible that there are more interesting animals and plants, especially geckos, and ephemeral plants, which needs further exploration using night time surveys for herpetofaunal species and wet-season surveys for ephemeral vegetation respectively. Preliminary suggestions for the conservation and further research in this rock outcrop are detailed at the end of this report.



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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. 1.1). 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 1.1. 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 2000), 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 them 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., 2023b). 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, 2013). 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, 2013). 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, 2013). 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 Box. 4.1 in its 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. Preliminarily identified potential areas include the Hiranya Parvat in the Bihar Sharif (Nalanda Division) and other inselbergs in the Aurangabad Division. To assess the feasibility and scope of these areas as BHS, a rapid biodiversity assessment focusing on saxicolous (living on or among rocks) organisms was conducted during May 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. 2.1).

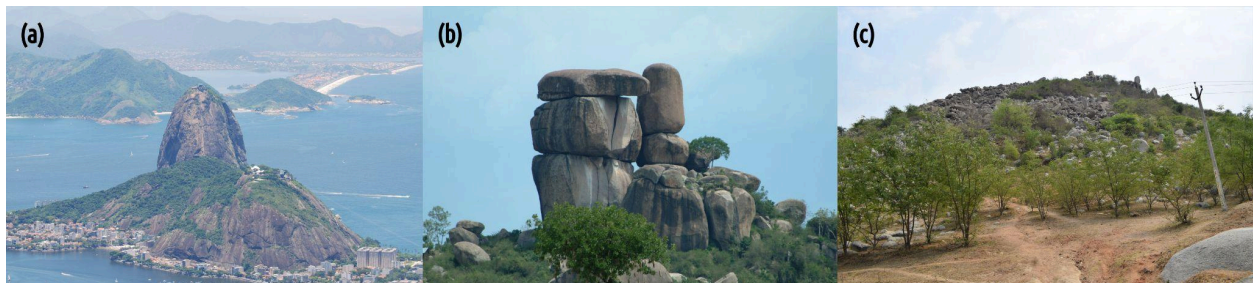


Figure 2.1. Examples for types of inselbergs; (a) Sugarloaf Mountain, a bornhardt, Rio de Janeiro, Brazil; (b) Kit-Mikayi, a castle kopje near Kisumu, Kenya; and (c) Jhunjhunwa Pahar, a bouldery nubbin in Bihar, India. Photograph (a) by Paul Mannix, CC BY-SA 2.0, and (b) by Valerius Tygart CC BY-SA 3.0 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). Most species are from the genera *Vellozia*, *Rhynchospora* and *Cyperus* (sedges), and *Utricularia* (bladderworts) (Barthlott & Porembski 2000) as reported from African studies and include biologically interesting groups exhibiting desiccation tolerance, carnivory and succulence as reported from African studies and include biologically interesting groups exhibiting desiccation tolerance, carnivory, and succulence as reported from African studies and include biologically interesting groups exhibiting desiccation tolerance, carnivory and succulence. Though southeastern Brazil, Madagascar and southwestern Australia are known as 'hot spots of inselberg plant diversity' (Barthlott & Porembski 2000), our knowledge of vegetation on inselbergs of several tropical regions such as India and Angola is still sparse.

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. 2.2). 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 inselberg vegetation facing is 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).

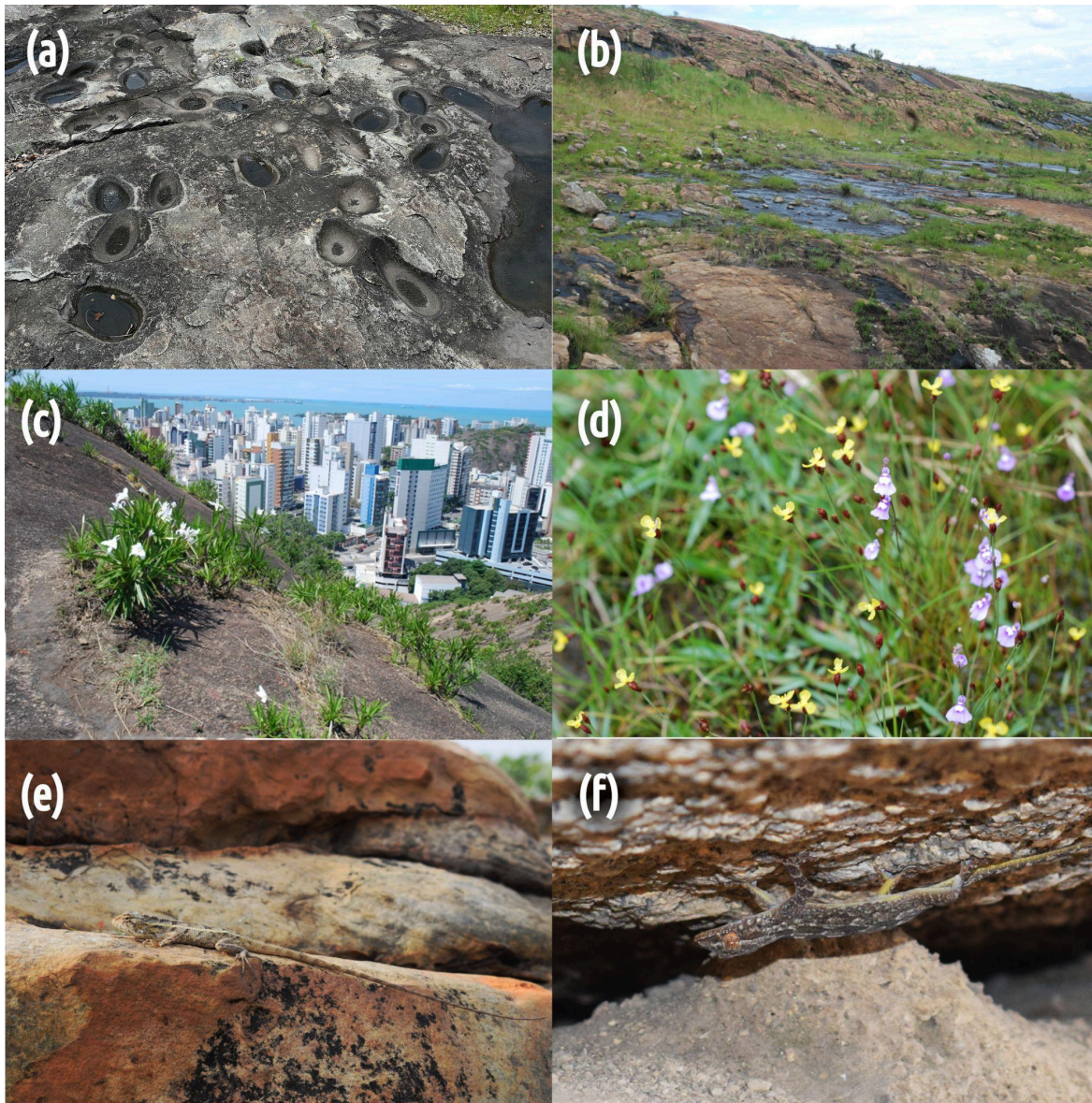


Figure 2.2. Microhabitats and biodiversity on inselbergs; (a) rockpools on an inselberg in Côte d'Ivoire, Africa; (b) ephemeral flush vegetation on an inselberg in Madagascar; (c) *Vellozia plicata* mats formed in Espirito Santo, Brazil; (d) *Utricularia* sp. and *Xyris* sp. as ephemeral flush vegetation 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 peninsula 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. 2.3). 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 2.3. 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. 2.4). Indian inselbergs vegetation appearance closely resembles that of other tropical regions with lesser roles of monocotyledonous mats of desiccation-tolerant vascular plants. More information needs to confirm this, in relation to the recent observations of *Tripogon* mats on inselbergs near Bengaluru (Inselberg Research Initiative, 2024).



Figure 2.4. Mandar hills in 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, and 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 large pool near its base, or agricultural fields, which are using rain water runoff from the inselbergs. They are also places of landscape tourism, wildflower tourism, recreational or adventure tourism. Mass blooming in some of these habitats help pollination of crops nearby (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 have been somewhat neglected (Porembski, 2007). There is a large knowledge gap on inselbergs of many regions such as 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, such as 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, *Hoya* sp., *Neanotis* sp., 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).

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 form dense stands in mat-like appearance on flat and inclined open rocky slopes. They are attached to the rocks by dense wiry roots, and may

contain plants of Bromeliaceae, Cyperaceae and Velloziaceae. They can be xerophytic (plant with adaptations to survive with little liquid water), and desiccation-tolerant. *Tripogon* (Poaceae) can be seen on inselbergs and cliffs, which can be easily lifted up (Porembski, 2007).

2.4.7. Caves

Some outcrops may have deep caves that are home to special flora and fauna. They are formed due to weathering.

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. Typically this include bladderworts and Eriocaulons. They depend on the seepage water, 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 in monsoon period. 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 of 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). Examples can be *Cactus* plants.

2.5.3. Carnivory

In the nutrient-poor substrates of inselbergs, some plants have evolved an adaptation to obtain nutrients such as nitrogen and phosphorus through phyto- and zoo-planktons, small insects, and nematodes. They can attract, ingest, and digest the prey (Givnish 1989).

2.5.4. Dwarfism

On inselbergs, some plants tend to be small, an adaptive strategy called '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

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

3.2. Methodology

Rapid visual encounter surveys were carried out at two inselbergs (Table 3.1) following literature review. Two additional sites were visited to assess the scope for future studies. The rapid surveys were carried out on 8th May, 2024 during morning (06:00-09:00) at site A, and during afternoon (14:30-18:00) at Site B. A total of 3 hrs was spent at Site A, and 3.5 hrs at Site B. Only the lower half portion of these inselbergs were covered. VJ was accompanied by the Forest Department staff during the surveys. During the survey, microhabitats encountered on the inselbergs were recorded and flora and fauna were photographed using a NIKON D5300 DSLR camera. These were later identified at broad taxonomic levels using expert inputs. No animals/ plant materials were collected as part of the survey.

Site Details	Latitude	Longitude
Site A* - Inselberg inside the Aurangabad Biodiversity Park	24°42'47.41"N	84°19'5.00"E
Site B* - Inselberg opposite to the Aurangabad Biodiversity Park	24°42'57.65"N	84°19'4.87"E
Site C - Pawai Jhunjhunawa Pahad	24°43'28.49"N	84°18'44.35"E
Site D - Lal Pahad	24°43'18.89"N	84°26'49.98"E

Table 3.1. Rock outcrop sites visited during the surveys in Aurangabad forest division of Bihar. *Rapid-surveys were done at these sites.

4. INSIGHTS

4.1. Site A and B: Inselbergs Inside and Near the Aurangabad Biodiversity Park

The inselberg inside the Aurangabad Biodiversity park (A) is a bouldery nubbin which is very close to Site B, another similar inselberg (Fig. 4.1).

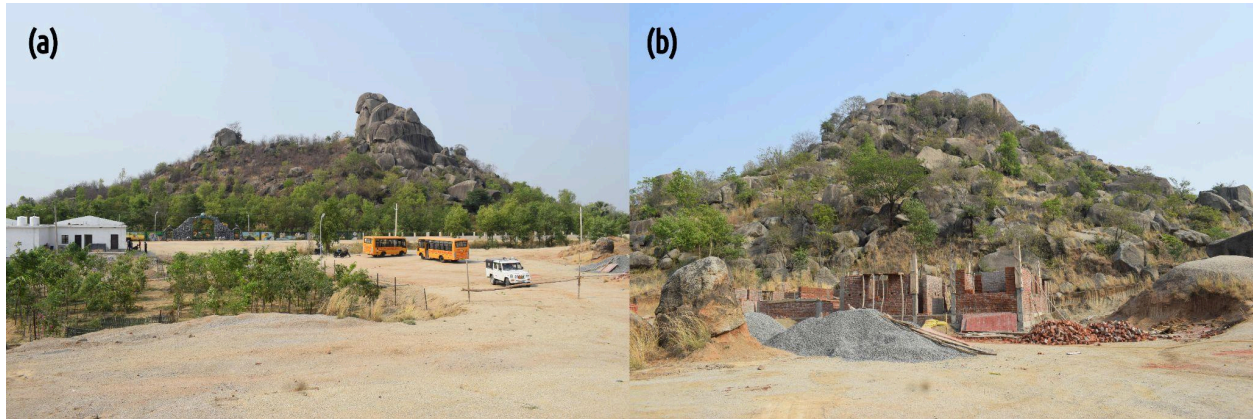


Figure 4.1. Inselbergs in and around the Aurangabad Biodiversity Park; (a) Site A showing the park, related building, and the Miyawaki plantation, as seen from the Forest Guest House; (b) Site B, under which construction works are in progress.

Inselberg A is currently protected as the Aurangabad Forest Division has developed a biodiversity park around it, and admission to the area is currently restricted. Forest Department Guest House and related buildings are situated nearby, with a recently developed Miyawaki plantation. The area is well connected with the road, and nearby to a village, home to other inselbergs such as the famous Pawai Jhunjhunawa Pahad. It is mostly an agricultural area, with depression towards the midpoint between the two inselbergs, an area that might be flooded during the rains (Fig. 4.2). In the map, three distinct inselbergs can be seen. The northern inselberg in the cluster was not sampled due to time constraints.

LOCATION MAP OF PROPOSED HERITAGE SITE IN DEO BLOCK (AURANGABAD DISTRICT)

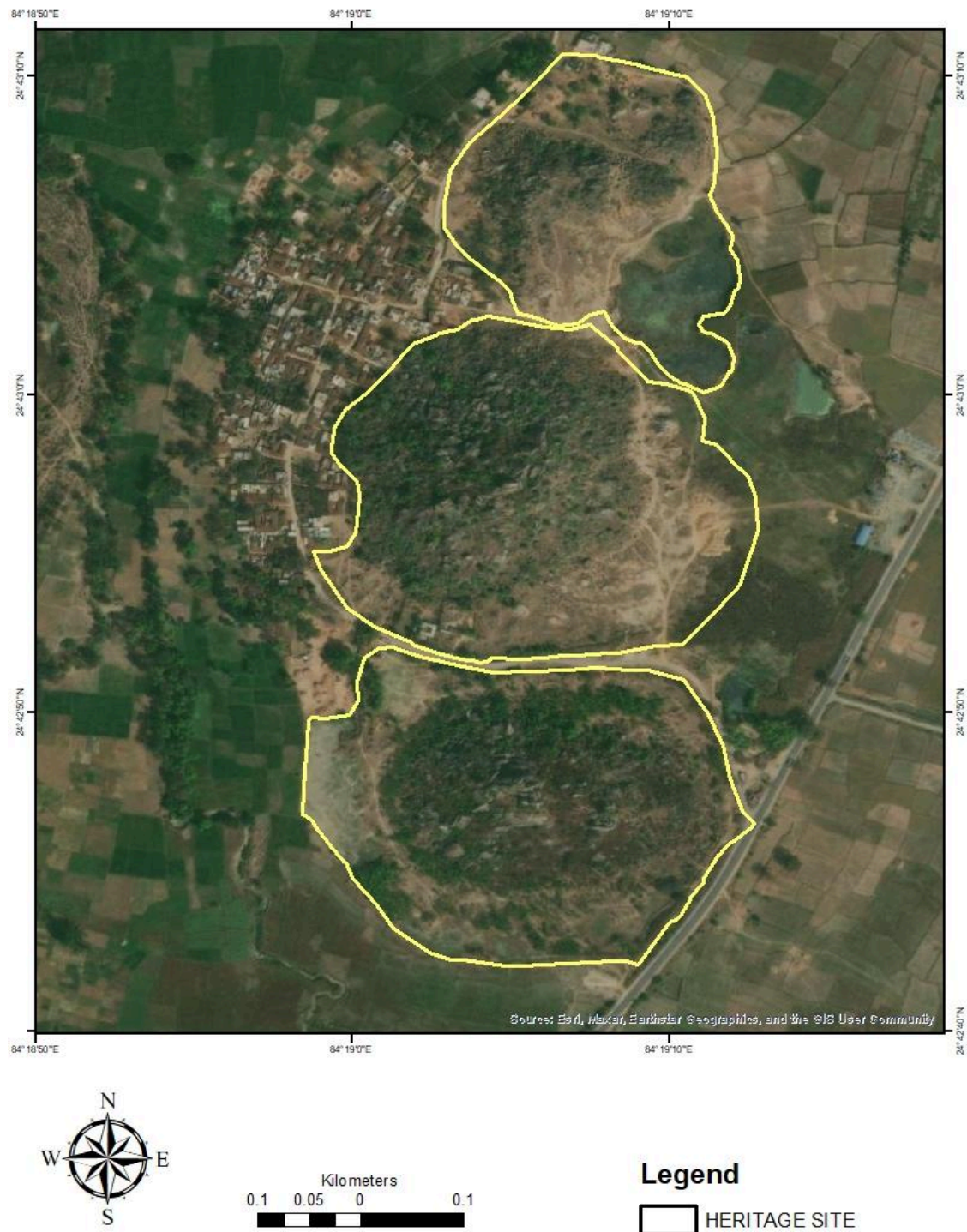


Figure 4.2. Map showing the proposed BHS area at the Deo Block, Aurangabad, Bihar.

The first inselberg has an elevation of approx. 145 masl. (Site A), and the second (Site B) is approx. 165 masl (Fig. 4.3).

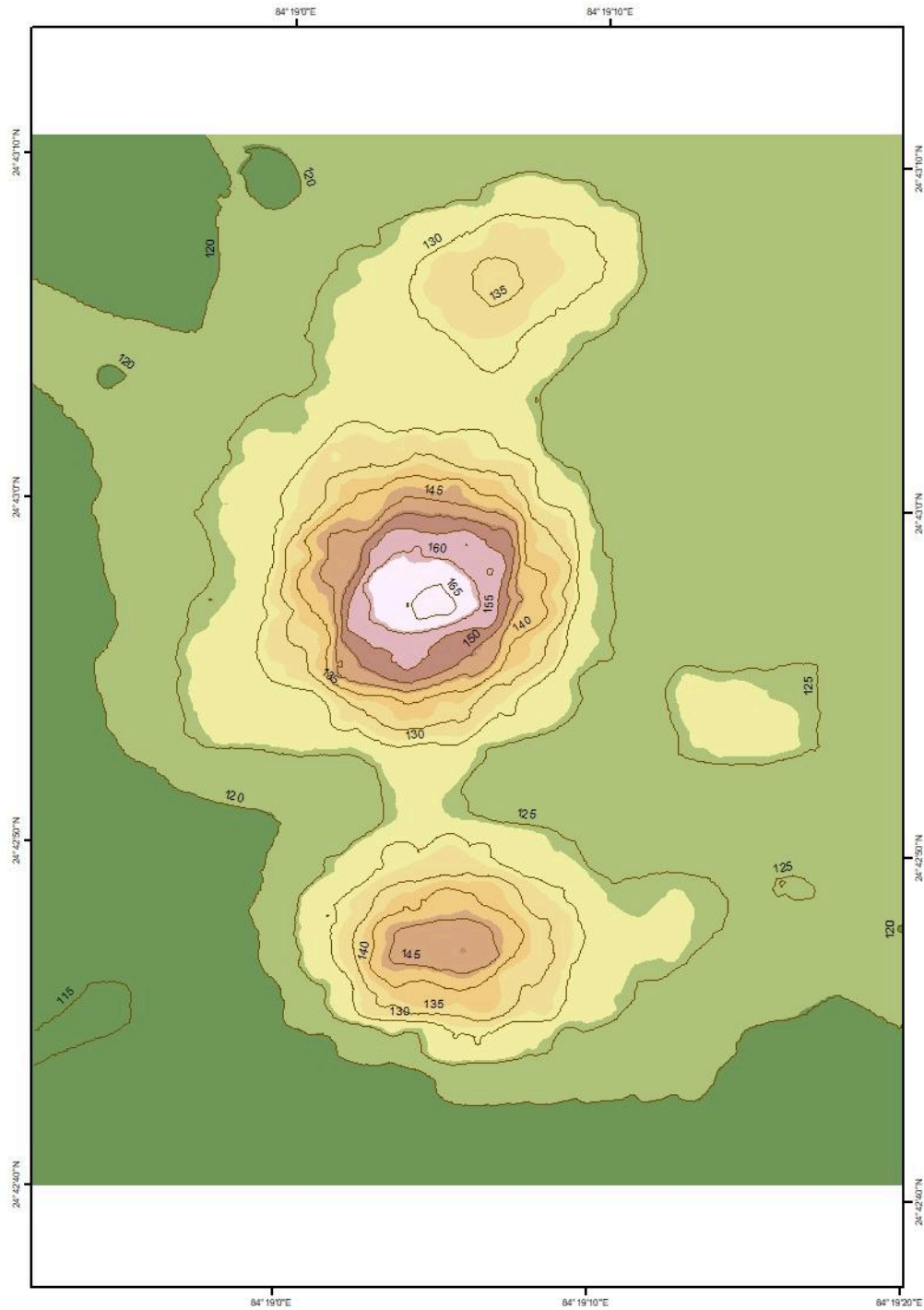


Figure 4.3. Contour map of the proposed BHS area at the Deo Block, Aurangabad, Bihar.

Some rocks of Site A are defaced with old advertisements, and Site B is prone to fires (Fig. 4.4). The park which is encircling inselberg A, is well-maintained with landscape elements integrated to the gardenscape (Fig. 4.5). It is home to a lily pond, floral garden, children's park, open gym, a large water reservoir with boating facility, basic amenities, and gazebos. Rock climbing and plastic usage are forbidden in the park. The lily pond is said to be constructed on an existing water body, which might be a natural depression that collects run-off water from the inselberg. The park is quite famous locally, and in social media, attracting a good number of visitors.



Figure 4.4. Photographs showing (a) the top rock of Inselberg A defaced by advertisement in the past, (b) A view from the Site B towards the road side, showing the depression, and another inselberg in the background on the other side of the road, (c) A view of Site A from Site B, showing the park entrance, buildings and road, and (d) areas that are caught fire on inselberg B.

A conversation with the local people revealed that jackals, crabs, snails, cockroaches, earthworms, centipedes, millipedes, mongoose, snakes, and porcupines are common in the area. This needs further examination during the monsoon season.



Figure 4.5. Photographs showing the integration of rock outcrop features in Biodiversity Park

4.1.1. Microhabitat Survey

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

	
Grass growing vertically in a rock fissure	Scattered boulders
	
Garden lizard using the space between boulders	Grasses on rock outcrop remains



Ficus sp. growing attached to a large boulder



Opuntia sp. growing near a large boulder



A rock pool on inselberg boulder



Garden lizard using a burrow under the rock



A large dislodged rock forming cave-like structure, extensively used by garden lizards



Monocotyledonous clumps on the rock



A loose boulder near the inselberg



Ferns and *Ficus* sp. Using rock fissures



A yellow-belly gecko using a rock fissure



A garden lizard burrow (?) under the rock

4.1.2. Biodiversity Survey

The details of biodiversity elements recorded at site A & B during the rapid survey are given below. Please note that the '(?)' mark indicates the identification needs further verification, and the list is not exhaustive. Opportunistic observations of a few species during the night is also added in this list.

	
<i>Tripogon</i> sp. (?)	Poaceae (grass)
	
<i>Launaea</i> sp. (?)	<i>Selaginella</i> cf. <i>indica</i>



Opuntia sp.



Evolvulus alsinoides



Mollugo sp.



Solanum virginianum



Unidentified grass



Unidentified grass



Euphorbia hirta



Polygonum sp. (?)



Medicago sp. (?)



Cyperaceae (?)



Dried pteridophyte



Unidentified grass

	
Unidentified	Unidentified
	
Unidentified	Unidentified
	
<i>Allotropa</i> sp. (?)	<i>Phoenix</i> sp. and grass (<i>Apluda</i> sp. (??))



Calotes versicolor



Hemidactylus flaviviridis



Fowlea piscator (juvenile)



Polypedates maculatus



Duttaphrynus stomaticus



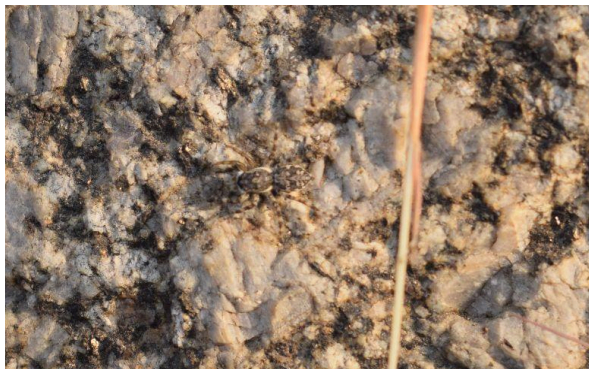
Spariolenus sp. (Found inside the building)



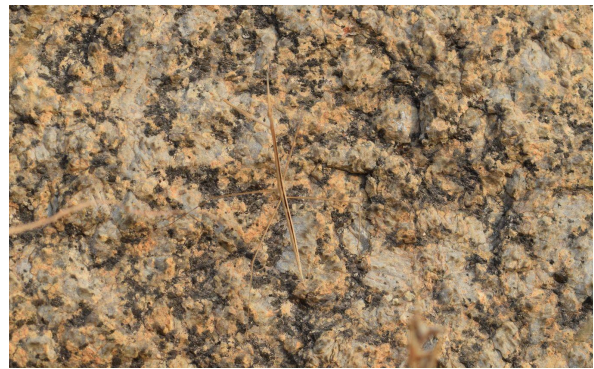
Argiope sp.



Lycosidae - Wolf spider (?)



Menemerus cf. *bivittatus*



Stick insect



Oxya *hyla*



Diabolocatantops *innotabilis*

	
<i>Oedipodinae</i> (nymph)	Unidentified Orthoptera
	
<i>Acrida exaltata</i> (nymph)	<i>Dittopternis venusta</i>
	
<i>Aiolopus</i> cf. <i>thalassinus</i>	<i>Sphingonotus</i> sp.



Eyprepocnemis sp.



Chrotogonus (chrotogonus) trachypterus



Junonia orithya



Suastus gremius



Autocharis sp.



Myrmeleontidae (Antlions)



Wasp nest



Ootheca of mantis



Wasp nest



Ootheca of mantis



Nylanderia sp. (Formicinae subfamily)?



Snail shell

	
Bark eating caterpillar (?)	Paper wasp nest

Notes: Common garden lizards were plenty in the area. 13 individuals were sighted during the 6.5 hrs survey. Grasshoppers, ants and small spiders were also plenty. Diversity of grasshoppers in the habitat is noteworthy. The ‘Kaadi’ grass which is locally used for broom making, ‘Sirki’ grass for roof thatching, *Casearia tomentosa*, and *Senegalia catechu* was common on the inselbergs. A jackal was encountered during the afternoon survey at Site B, near a cave-like structure. DT *Selaginella* sp. was encountered occasionally. Boulders near the inselbergs, and the ones along the road to the village were quite extensively used by people to dry cow dung cakes (Fig. 4.4b). Scattered inselbergs of varying sizes were found in the village amidst the agricultural fields.

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, and other ephemeral 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 C and D: Pawai Jhunjhunawa Pahad and Lal Pahad

At the famous Jhunjhunwa Pahar - 'tingling hill' (a bouldery nubbin) in the nearby village to Site A&B, sonorous or lithophonic rocks can be found, which attracts people to this area (Fig. 4.6a). These 'ringing rocks' are similar to the ones reported from the USA, South Africa and Southern India (Bolvin, 2004). They resonate with a bell-like sound when struck, and these rocks are of high geological heritage value.

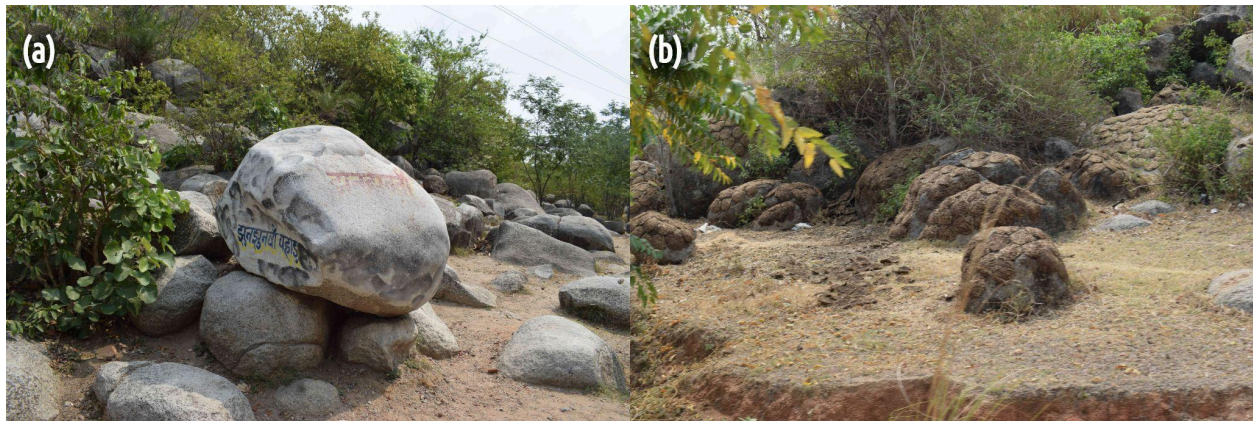


Figure 4.6. (a) Sonorous rock in the Jhunjhunwa Pahar, Bihar; (b) cow dung cakes kept on boulders for drying.

The Lal pahad ('red hill') along the Delhi-Kolkata highway is also interesting due to its unique red rocks and soil (Fig. 4.7). Its appearance is similar to a hill chain surrounded by agricultural fields. The three small hillocks in the chain are of small, medium and large sizes. There were a higher number of loose rocks compared to other inselbergs in the Aurangabad Division. Burning has happened recently in the habitat. This area needs a separate examination in the future. Other interesting inselbergs around Site A&B includes kopjes with relatively intact rock surface exposing sheet structures, flat-topped inselbergs on which trees are grown, and buildings have been constructed (Fig. 4.8).



Figure 4.7. Photographs showing (a) a landscape view of the Lal Pahad, Bihar, and (b) the rock structure on the inselberg.



Figure 4.8. Photographs showing inselbergs near to site A&B; (a) a kopje with relatively intact rock surface, (b) close-up view of same inselberg (as depicted in the red square in a) showing the rock sheet structure, (c) A flat-top inselberg with trees on the surface, (d) another flat-top inselberg of lesser height, on which a building has been built.

5. DISCUSSION

The rapid surveys (also see the survey report for the site in Nalanda Division) show the explored inselbergs are of high scope for conservation, especially in light of the high disturbance in the areas, biodiversity wealth, and their eco-hydrological roles as micro-watersheds. 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, Inselberg near the Durgavati Reservoir (Fig. 5.1), and small inselbergs embedded in the agricultural-human settlement matrix. They can act as patches of biodiversity in the already heavily modified landscape, providing necessary ecosystem services to neighbouring regions, with cultural, touristic and aesthetic values.

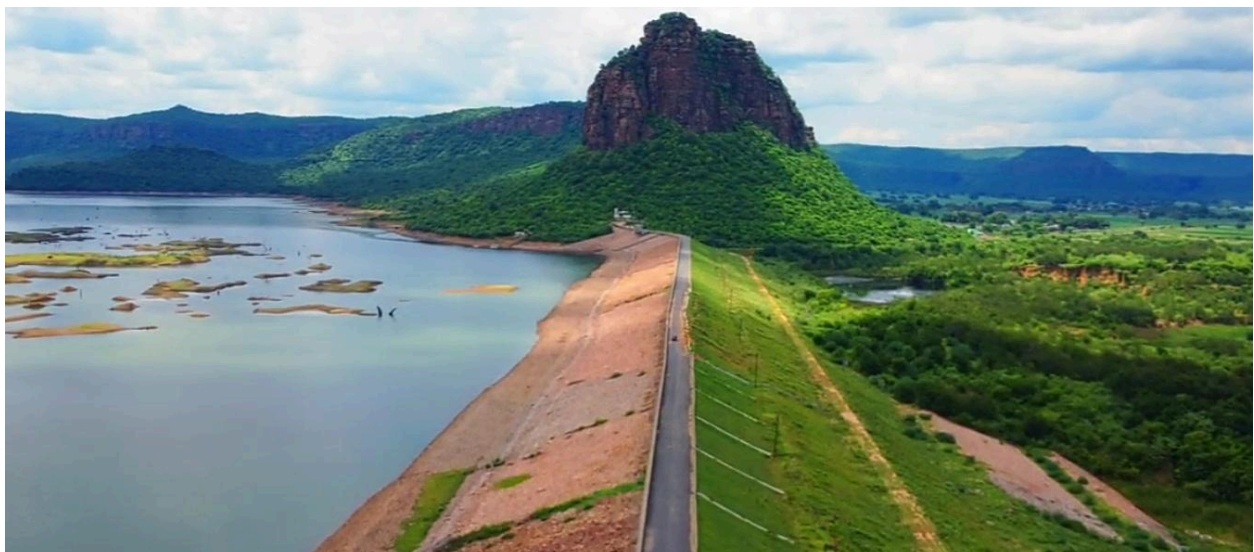


Figure 5.1. Inselberg near the Durgavati Reservoir (Karamchat Dam), Kaimur, Bihar. Photograph by Binay Babu, CC BY-SA 4.0, via Wikimedia Commons.

Considering the high tourism potential (Hindusthan Team, 2019), 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:

5.1. Conservation Recommendations

- 5.1.1. 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).
- 5.1.2. 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).
- 5.1.3. 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).
- 5.1.4. It is of high importance that the conservation measures need to be taken into account the fact that restricting all forms of human land use and herding activities on 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).

- 5.1.5. 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.
- 5.1.6. Tree plantation in the inselberg habitat might alter the open habitat structure and impact microclimatic conditions in the ecosystems. Thus, further modification of these landscapes needs to be done scientifically.
- 5.1.7. 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'.
- 5.1.8. 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).
- 5.1.9. 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>).

- 5.1.10. 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.
- 5.1.11. Identification of plateaus 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.
- 5.1.12. Converting inselbergs to waste dumping sites, constructions on the rock surface etc. need to be avoided.
- 5.1.13. 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).
- 5.1.14. Specific management recommendation based on the rapid survey are:

- 5.1.14.1. Protect inselbergs from human disturbances that cause damage to rock microhabitat (trampling of flora, removing plants and animals from microhabitats, removal and displacement or loose rocks etc.)
- 5.1.14.2. Regular monitoring of vegetation changes on the inselberg (using repeated photography across season, maybe at biweekly intervals)
- 5.1.14.3. At some sites such as the Site in Nalanda Division, heavy human disturbance (rock removal, grazing, vandalism, loss of native vegetation, chance of weed invasion and fires etc.) has caused severe damage to the microhabitats. Restoration of rocky habitat will be necessary in these areas. This 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).

5.2. Research Directions

- 5.2.1. 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.
- 5.2.2. 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.

- 5.2.3. Taxonomists and ecologists need to work together on lesser known taxa such as spiders, fungi, and lichen on inselbergs, and research should be conservation oriented which give feedback to area managers.
- 5.2.4. 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.
- 5.2.5. 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.
- 5.2.6. 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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