

Summary Report (First Draft)

# **Rapid Assessment of the Proposed Biodiversity Heritage Site in Hiranya Parvat of Nalanda Forest Division, Bihar**

Submitted by

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*Front Cover:* View from the Hiranya Parvat showing the rocky cliff side, temple, adjacent agricultural fields, road and urban area, Bihar Sharif, Bihar. Photograph: Vijayan Jithin

*Summary Page:* View from the Hiranya Parvat top showing the archeological remains, loose rocks, and sparse vegetation with the urban area in the background, Bihar Sharif, 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 the Hiranya Parvat inselberg in Bihar Sharif, Nalanda, 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 Hiranya Parvat rock outcrop is an granitic inselberg, falling into the category of castellated Kopje, with a sloppy side, and a vertical (cliff) side. It is surrounded by human habitations, agricultural fields, religious worship places, roads; and a temple and archaeological remains of the mausoleum is situated on top of it. The inselberge is also home to the Hiranya Parvat Nagar Nigam Park managed by the Department of Forest, and thus acts as a centre for religious, aesthetic or nature tourism. The rapid visual encounter survey revealed several microhabitats typically found on rock outcrops including loose rocks, cryptogamic crusts, soil-filled depressions, rock crevices and fissures, monocotyledonous mats, and was home to a wide variety of organisms. The rapid, non-exhaustive survey itself revealed at least 10 families of flowering plants, presence of the desiccation tolerant vascular plant

*Selaginella* cf. *indica*, and animals spanning 14 families across 10 orders. This rock outcrop is home to multiple flowering plants, mosses, pteridophytes, lichens, geckos, lizards, ants, spiders, termites, butterflies, grasshoppers, beetles, wasps, and snails. Wet-season survey will improve this documentation by adding more taxa that may be only detectable during that time. Many organisms along the cliff side and park area remained unexplored during the rapid survey, while almost 20% of loose rocks turned had some animal presence even during the dry season. The relatively less number of invertebrates (e.g. spiders, grasshoppers) might be an indication of the high disturbance in the area. 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 other 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.”*

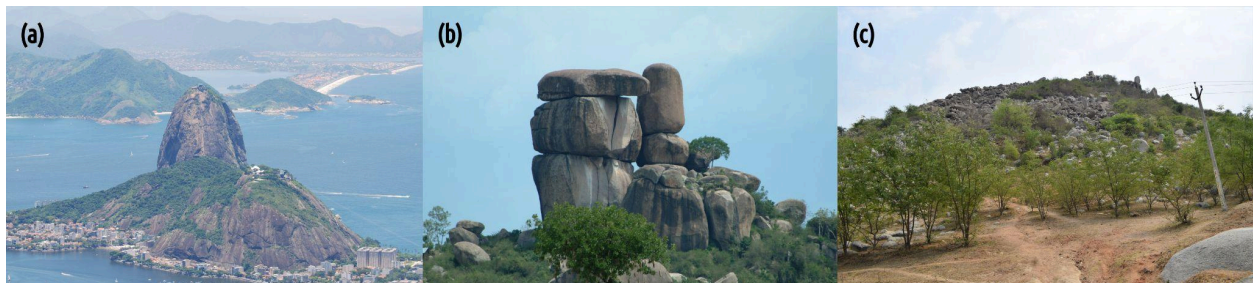
But unfortunately, these reports were not implemented officially, and thus currently these rock outcrops are not under conservation focus.

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.

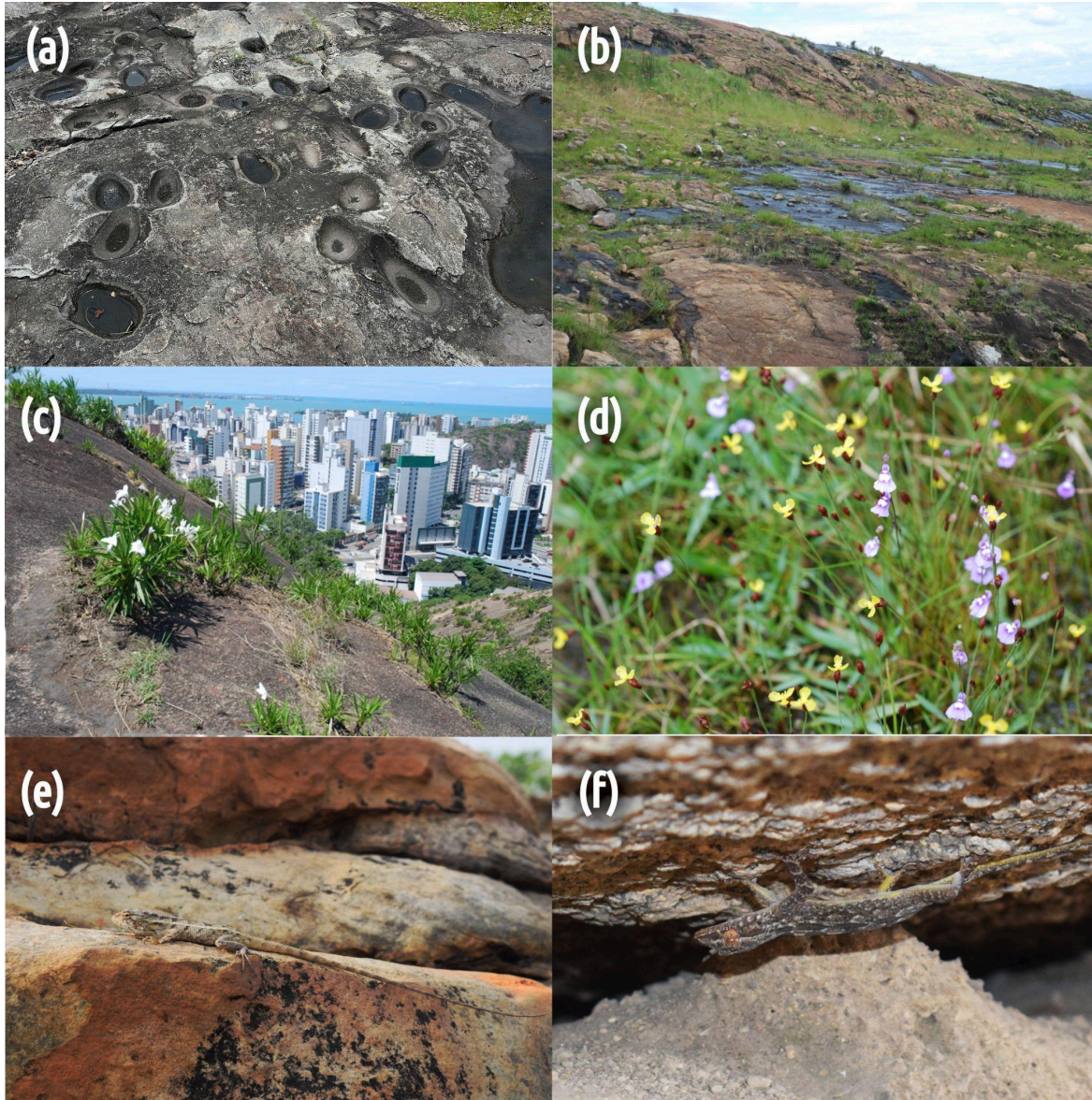
Inselbergs form micro climatically and edaphically dry growth sites, which are home to highly specialised vegetation. Inselbergs are known as 'microclimatic deserts' as the air temperature on its slopes and insolation are considerably high, and low relative air humidity compared to the surrounding region (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 outcrop BHS.

#### 3.2. Methodology

Rapid visual encounter surveys were carried out at the inselberg following literature review. The rapid surveys were carried out on 6th May, 2024 during afternoon (15:00-16:00), and 7th morning (07:00-10:00) at Hiranya Parvat, Bihar Sharif (25°12'19.26"N; 85°30'26.52"E). A total of 4 hrs was spent at the site, exploring from its lowest to highest elevation. Cliff side was mostly uncovered due to inaccessibility, and was only assessed from the road side. VJ was accompanied by the Forest Department staff during the surveys (Fig. 3.1).

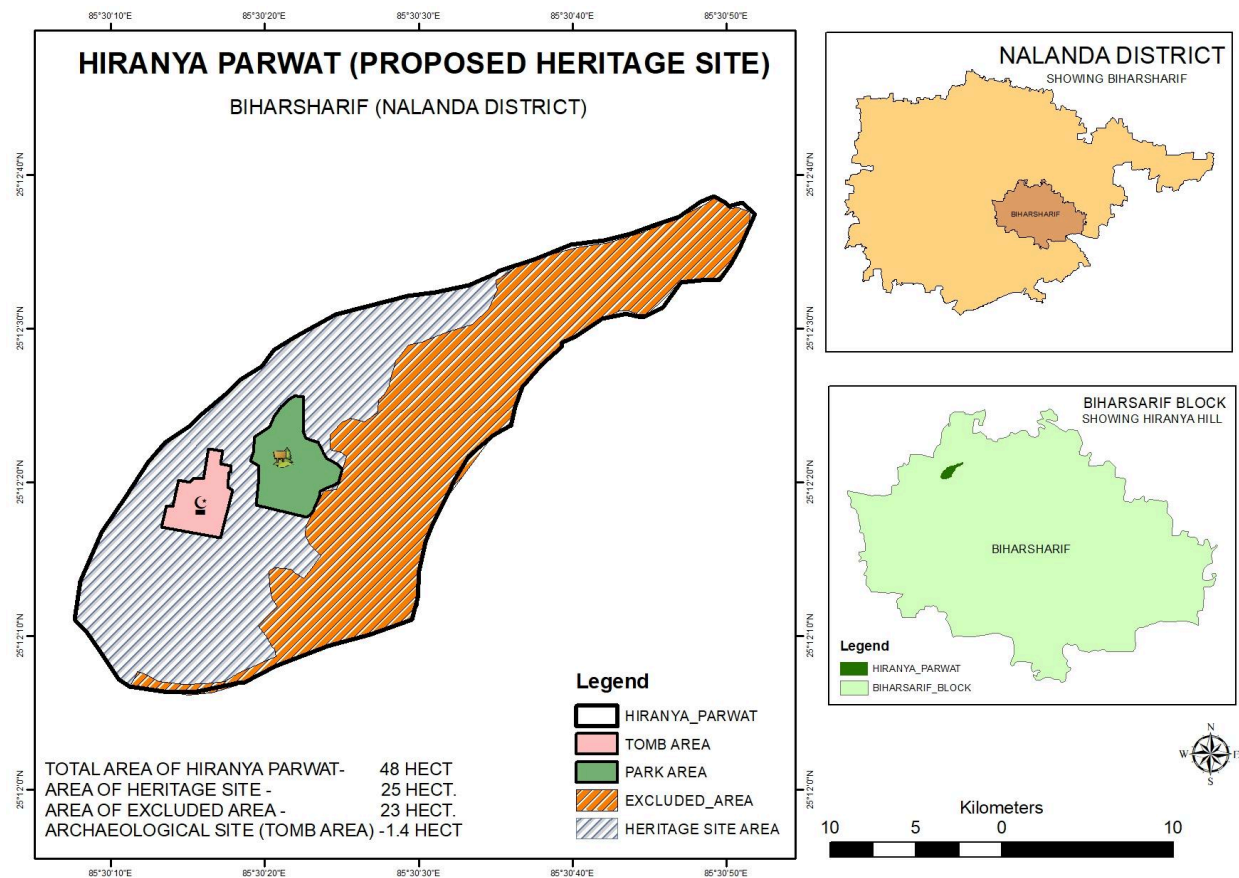


**Figure 3.1.** Photograph of the rapid assessment team at the Hiranya Parvat, Nalanda Division.

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.

#### 4. INSIGHTS

Hiranya Parvat is a granite inselberg that rises abruptly above the surrounding plains. Locally known as 'Bari Pahari', it is surrounded by human habitation on one side which is a slope, and agricultural fields and a road on the other side which is a cliff (Fig. 4.1). On top of the inselberg, a Hanuman and Shiv temple is situated which attracts devotees, and the archaeological remains of the mausoleum of 14th-century Sufi warrior Syed Ibrahim Malik Bayu (Britannica, 2016) under the Archeological Survey of India. In addition to this, Hiranya Parvat Nagar Nigam Park is situated on the inselberg, which is managed by the Department of Forest (Fig. 4.2).



**Figure 4.1.** Map showing the proposed BHS area at the Hiranya Parvat, demarcating the park area, archaeological mausoleum, and excluded areas where the human settlements and temple are located.

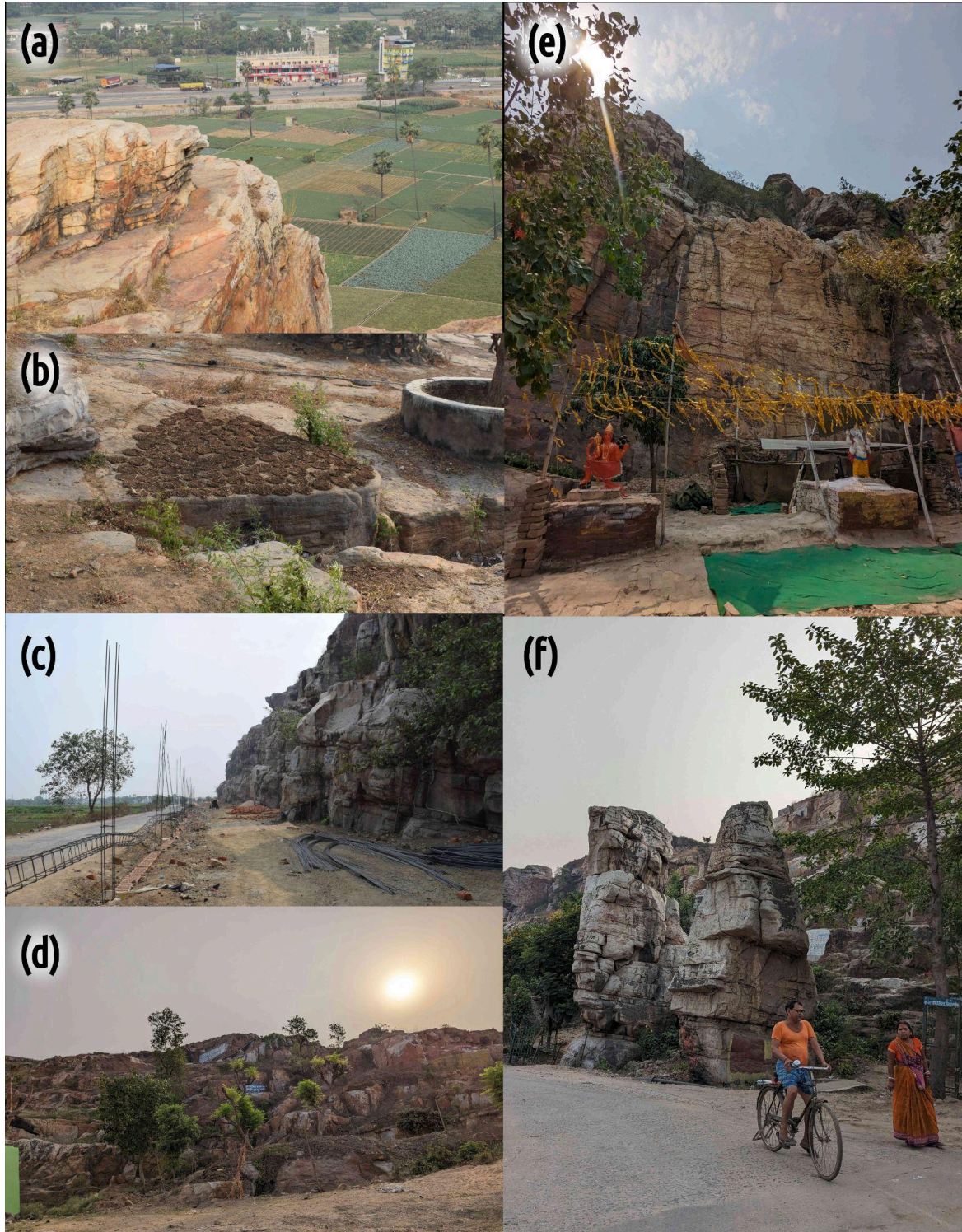


The park is well utilised by the common people for leisure activities and it is moderately developed with artificial fountains, water channels, tree rings, games and open gym etc. The temple attracts a large number of devotees, especially during festival times, and the archaeological site is an important tourist area visited by the general public. In addition to this, on the cliff side, along the road, there are religious worship places with idols and recent construction work for a cliff-side park (Fig. 4.3). Two pillar rocks near the road that leads to the entrance of the park are remarkable (Fig. 4.3-f).



**Figure 4.2.** Photographs showing the (a) park area, (b) cliff-side view of the inselberg, (c) temple on the hill top, (d) archaeological site, and (e) human settlements. Photograph (a) by Rohit Kumar; (b) and (c) are by Odantapuribs, CC BY-SA 4.0 via Wikimedia Commons.





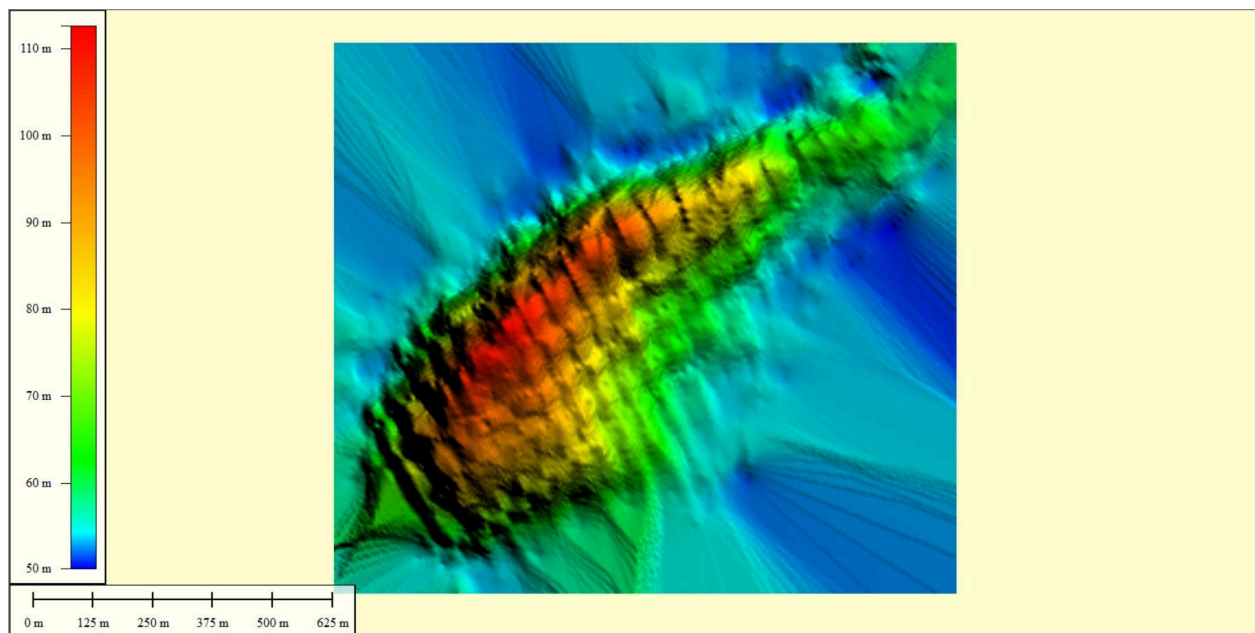
**Figure 4.3.** Photographs showing (a) agricultural fields and constructions near the cliff side, (b) cow dung cakes on the rocks of inselberg inside the park, (c) cliff-side road and park construction, (d) human modified portion of the inselberg, (e) religious places near the cliff, and (f) two pillar rocks near the inselberg.



The inselberg is also featured in some internet websites and books like ‘The Splendid Archaeological Heritage of Buddhism in Bangladesh & South Asia’ (Barua, 2018). The book says:

*“According to the Tibetan records there were about 12000 students at Odantapuri which was situated at a mountain called Hiranya Prabhat Parvat & by the bank of the river Panchanan. In the modern era, it is situated in Bihar Sharif headquarters of Nalanda district.”*

Though there is no conclusive scientific evidence to back these claims (Rajani & Kumar, 2021), many tourists/ devotees from Tibet visit this area during October-January and carry out devotional practices in the area, as informed by the park managers (*needs further verification*). It is also noted that people have been observed to collect specific herbs from the inselberg during this time (*needs verification*).



**Figure 4.4.** Digital elevation modelling showing the vertical structure of Hiranya Parvat inselberg.

The human settlements towards the eastern side of the inselberg are interesting, as they have been built on the inselberg slope, merging with the rock structures. People use the embedded rocks for cow dung cake drying (Fig. 4.3-b). The south-eastern side is moderately human modified with water pipes, and advertisements that have defaced some of the rocks (Fig. 4.3-d).

The inselberg is of approximately 110 m.a.sl. in height, and the site descriptions match with typical rock outcrops that are featured prominently in human landscapes (Technical and Policy Core Group & Kalpavriksh, 2005; Fig. 4.4). Most inselbergs typically have temples on the hill tops (eg. Shravanabelagola shrine in Karnataka) and are centres for religious, aesthetic or nature tourism. Geologically, the inselberg matches with the description of a castellated Kopje, with a sloppy side, and a vertical (cliff) side. This needs further examination and verification.

#### 4.1.1. Microhabitat Survey

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

|                                                                                                              |                                                                                      |
|--------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|                             |    |
| Cliff side of the inselberg with step-like features, soil-filled depressions, and rock crevices and fissures | A large rock with cryptogamic crusts                                                 |
|                           |  |
| A gecko using holes and gaps in the archeological brick structures                                           | Scattered loose flat rocks                                                           |





*Selaginella* cf. *indica* growing in the cracks of bricks



Cryptogamic crust on the modified habitat of archeological remains



Flat-topped rocks embedded, as seen in the park



Monocotyledonous mats, and soil filled depressions on the cliff side



Clump of loose rocks, with one rock removed to examine the substrate



Soil filled depressions on the horizontal rocks of cliff side and *Ficus* sp.





Exposed orthogonal joint sets (?) in the rock



Grasses growing on the vertical rock surface with cryptogamic crusts



Flora on the soil-filled rock crevice



Gaps between rocks used by geckos



Loose rocks on an embedded flat rock



Modified rock microhabitat used by gecko





Gecko using a modified habitat with lichens on the rocks



A hole used by Garden lizard



Hole with rock cover, used by a Garden lizard



Dislodged artificial rock used for pavement



Patterns on the flat rock



*Selaginella* cf. *indica* growing in rock crevice





Lichen growth on the rocks of archeological remains



A large gap formed in the archeological remains, extensively used by geckos, and spiders



Geckos using the microhabitats of archeological remains



Wasp nest among the bricks of archeological remains



A rock crevice, with very little soil



Rock sheet structure (?) exposed in the park area





Cliff microhabitats



Protruding cliff rock with *Ficus* sp.



Bryophyte mat on the cliff-side



Cave-like structure on the cliff-side with  
stray dogs nearby

#### 4.1.2. Biodiversity Survey

The details of biodiversity elements recorded at Hiranya Parvat 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.

|                                                                                     |                                                                                      |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|    |    |
| <i>Lepidagathis</i> sp. (?)                                                         | <i>Blepharis</i> cf. <i>maderaspatensis</i>                                          |
|  |  |
| <i>Tinospora cordifolia</i>                                                         | <i>Selaginella</i> cf. <i>indica</i>                                                 |

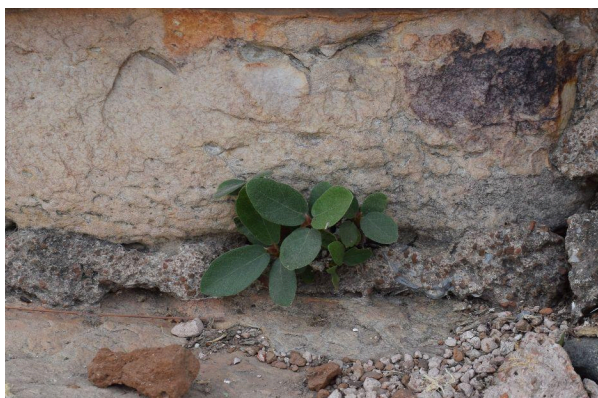




*Calotropis procera* and *Tephrosia* sp.



Cruciferae member (?)



*Ficus* sp.



Unidentified grass



*Ocimum* sp. (?)



*Launaea* sp.





*Brachythemis contaminata* (?)



A Spider under a flat rock



*Calotes versicolor*



*Hemidactylus flaviviridis*



*Diabolocatantops innotabilis*



*Chrotogonus (chrotogonus) trachypterus*





*Catochrysops strabo*



*Danaus chrysippus* (larvae) on *Calotropis procera*



Darkling Beetle (?)



Termites



Snail shells near *Boerhavia* sp. (?)



Wasp nest





Earthworm castings (?)



Unidentified wasp nest



*Camponotus* cf. *compressus*.



Ants (Myrmicinae) carrying a fly.



*Lepisiota* sp. (?) on *Sida* sp. (?) leaves



Wasp nest (?)

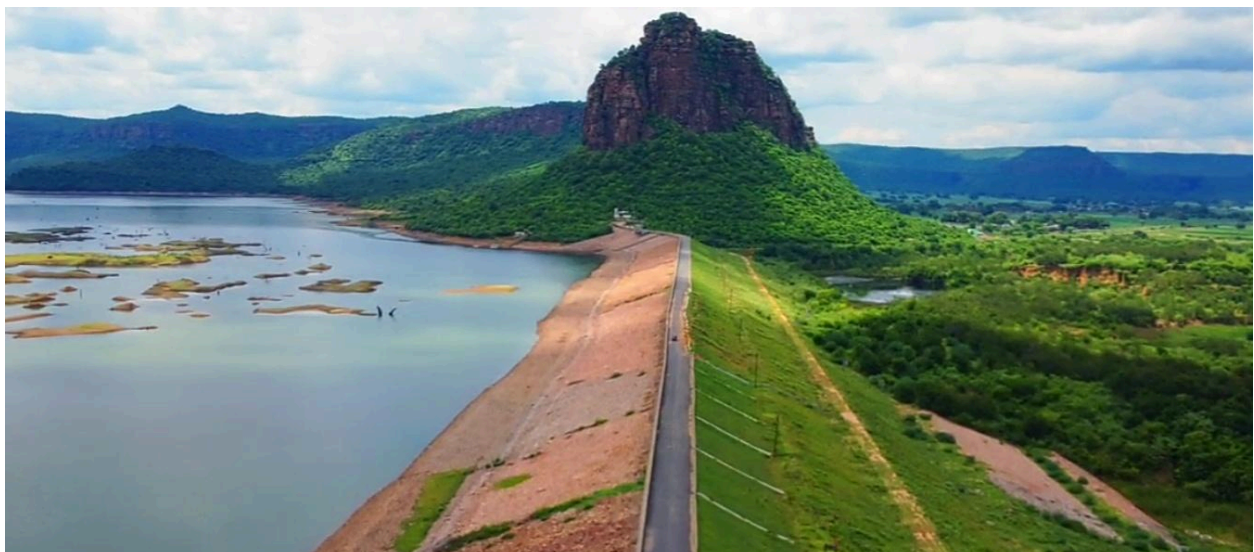
**Notes:** Yellow-belly geckos (*Hemidactylus flaviviridis*), Common garden lizards (*Calotes versicolor*) and DT *Selaginella* sp. were abundant in the area using a diverse array of natural and modified microhabitats of cracks and holes. Occasional presence of Cactus and small spiders were noted. On the cliff side, mainly *Ficus* sp. Were found along with *Tinospora cordifolia*. Isolated grass patches on the vertical habitat and cliff-flora in general need to be explored in detail. Remains of gecko eggs, and excrements were quite abundant near the bricks indicating their extensive use. Almost 20% of loose rocks turned had some animal presence. But a thorough rock-dwelling animal survey needs to be conducted in a time/ area constrained fashion (Jithin et al., 2023a). The relatively reduced number of invertebrates (spiders, grasshoppers etc.) might be an indication of the high disturbance in the area. A conversation with the park managers revealed that during and after the rains, scorpions, centipedes, and mice are common (*needs further verification*). During the survey, parakeets, pigeons, raptors, and mynahs were quite commonly seen. A thorough bird and mammal survey will be useful in the future. A few red-coloured mites were seen on the brick ruins, but photographs could not be taken. This needs further examination after the rains.

*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).*



## 5. DISCUSSION

The rapid surveys (also see the survey report for the sites in Aurangabad 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 (especially in the Hiranya Parvat site) 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. Stray dogs were seen on the cliff side of Hiranya Parvat during the survey, which may be a threat to the local biodiversity. This needs to be addressed.
- 5.1.8. 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'.
- 5.1.9. 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).

- 5.1.10. 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>).
- 5.1.11. 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.
- 5.1.12. 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.
- 5.1.13. Converting inselbergs to waste dumping sites, constructions on the rock surface etc. need to be avoided.
- 5.1.14. 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).

5.1.15. Specific management recommendation based on the rapid survey are:

- 5.1.15.1. 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.)
- 5.1.15.2. Regular monitoring of vegetation changes on the inselberg (using repeated photography across season, maybe at biweekly intervals)
- 5.1.15.3. At some sites such as Hiranya Parvat, 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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