

Summary Report

Rapid Assessment of the Proposed Biodiversity Heritage Site in Nawada Forest Division, Bihar

Submitted by

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Front Cover: One of the waterfalls and pools in Kakolat, Nawada, Bihar. Photograph: Vijayan Jithin

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EXECUTIVE SUMMARY

To assess the feasibility and scope of declaring a preliminarily identified area - Kakolat, in the Nawada division in the Bihar state as a potential 'Biodiversity Heritage Site', rapid assessments were undertaken. This preliminary report summarises the microhabitats, and biodiversity recorded from the area mainly composed of forested area and perennial streams, situated near the village of Ektara, south-west of Gobindpur, Nawada. We record a number of diverse microhabitats that are typical to forested and stream areas, and also unique rock formations along the stream. A variety of fauna and flora were recorded during our rapid survey, highlighting the important habitat, home to many aquatic organisms, amphibians and reptiles, mammals, leaf-litter and soil-dwelling invertebrates, butterflies and moths, lianas, aquatic plants, pteridophytes, large trees and diverse herbs and shrubs. The short visit itself revealed a total of 154 species of vascular plants comprising 42 herbs, 20 shrubs, 75 trees and 16 climbers. A total of 96 animal species were recorded, belonging to more than 40 families and 18 orders with 2 reptiles, 4 amphibians, 2 fishes, 2 decapods, 1 millipede, 2 centipedes, 76 insects, 1 mollusc, 1 mammal, and 5 arachnids. Since riparian habitats such as the studied sites are known to function as tropical forest refugia, characterised by high local densities of tropical forest plant species, conservation of such sites are critical in maintaining biodiversity, and thus ensuring the valuable ecosystem services to people. We also present some notes on the importance of these habitats, cultural values of the area, and recommend further actions for the conservation of these important habitats.

1. BACKGROUND

The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) held a meeting during October-November of 1972 in Paris. This meeting recognised that the natural and cultural heritage of our globe is increasingly threatened with destruction and hence also recognised the need for preservation and conservation of this heritage. It was collectively decided in this meeting that the need to identify and protect global heritage should be made the subject of an international convention, which is now embodied in an international treaty called the Convention concerning the Protection of the World Cultural and Natural Heritage or also known as the UNESCO World Heritage Convention. This convention recognised two kinds of heritage: “Cultural heritage” which are monuments, buildings or sites of outstanding universal value from the historical, scientific, aesthetic, and anthropological point of view; and “Natural heritage” which are natural, geological and physiographical formations or features of outstanding universal value from the scientific, conservation and natural beauty point of view. All the countries party to this convention are to identify and delineate different cultural and natural heritage sites on its territory, and as far as possible, ensure that active and effective measures are taken for the protection of these sites. Designation of heritage sites helps in attracting conservation efforts as well as funding to preserve and protect sites from developmental pressures, in addition to boosting local economies and tourism (Ghosh and Mathur 2019).

India has been a party to this convention since 1977 and since then it has inscribed a total of 43 sites on the World Heritage List including 35 cultural sites, seven natural sites and one site of mixed cultural and natural heritage. India has also been taking efforts to identify sites that are of outstanding cultural and natural value at a national level. Biodiversity can be used in a sustainable manner through people's participation, which can generate substantial income. At the state level, under Section 37 of the Biological Diversity Act, 2002 (BDA), the State Government in consultation with local bodies can also notify areas of biodiversity importance as Biodiversity Heritage Sites (BHS). There are several examples of this. On these lines, the Bihar State Biodiversity Board has been actively engaging in identifying ‘Biodiversity Heritage Sites’ across the state. As

part of this effort, a series of biodiversity surveys were conducted in four divisions of Bihar from 1st to 9th December 2024. The objective of this survey was to:

1. Carry out a rapid biodiversity assessment of invertebrates, herpetofauna and flora of Kakolat Waterfalls and surroundings in the Nawada district of the state of Bihar.
2. Identify sites with high biodiversity value as potential Biodiversity Heritage Sites within each of the three districts of Bihar.
3. To suggest future research and management directions for the proposed BHS.

2. METHODOLOGY

Rapid visual encounter surveys were carried out at two streams (Table 1). The rapid survey site details are explained in the Table below:

Table 1. Sites visited during the surveys in Kakolat, Nawada forest division of Bihar.

Site	Date	Sampling hours	Duration	Latitude	Longitude
Stream A	4 December 2024	5	9:00 am - 2:00 pm	24°41'58.03"N	85° 37'41.56"E
Stream B	5 December 2024	4.5	9:30 am - 2:00 pm	24°42'2.34"N	85° 37'27.85"E

Both sites were explored from the lowest to highest elevation, going upstream, covering mainly the streamside portions. Researchers were accompanied by the Forest Department staff during the surveys. During the survey, encountered microhabitats, flora (herbs, shrubs and woody vegetation) and fauna (focusing on stream-dwelling animals, especially herpetofauna and invertebrates) were recorded and photographed. These were later identified at broad taxonomic levels using expert inputs. Unidentified plant individuals were collected for identification while no animal materials were collected as part of the survey.

3. INSIGHTS

Kakolat is an iconic waterfall, and the area is a significant landmark of the district. It is situated near the village of Ektara, south-west of Gobindpur, Nawada, Bihar. It is located on the Kakolat hill, on the border of Bihar and Jharkhand, ~33 km from Nawada. Mahabar hills are also situated in this hill range (O'Malley, 1906). The famous waterfalls are a result of a montane stream cascading from a height of ~160 feet, and flowing to the Lohabar river, through the Hazaribagh mountain range (DFO Nawada, 2025). A large-gathering of people is held here annually during Makar Sankranti (passage of the Sun from Sagittarius to Capricorn). This is also called the 'Vishu Mela', and this fair is also considered the formal beginning of visits to Kakolat, at the onset of summer. In and around the area, there are archaeologically important areas (Grierson, 1893). It is a popular tourist destination in Bihar and has connections to Hindu mythology and folklore. It is also known as the 'Kashmir of Bihar' (Khan, 2018). There is a Shiv temple near the fall.

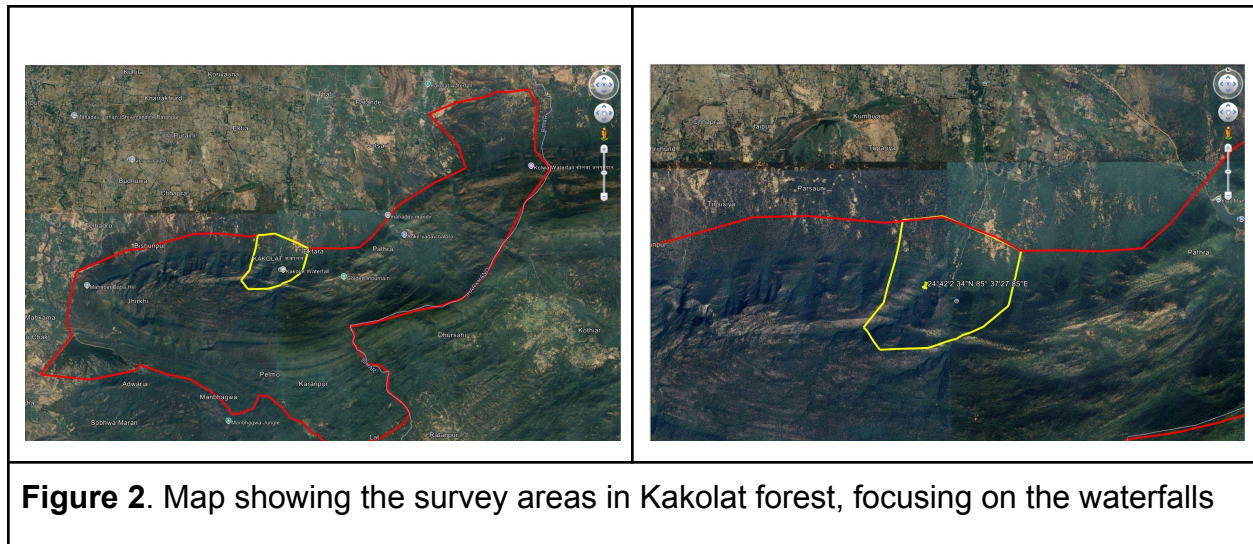
Interestingly, there are rock-art sites reported from sites near the Kakolat Falls (Tiwarly et al., 2018). This waterfall is believed to have served as a playground for Lav and Kush (sons of Sita and Rama in the Hindu epic, the Ramayana). Another popular story says, a king (Nahus?) in the Treta Yuga was cursed by a sage (Augustaya?) to become a snake (Python?) and stay here, and after the sight of the Pandavas (five legendary brothers in the Hindu epic Mahabharata) during their exile, the king got rid of this curse. There are other versions of this story, for example saying the King was a dragon, and the waterfall was his abode. Local folklore says Lord Krishna used to bathe in these waterfalls, with the queens. It is believed that whoever bathes in the waterfall will never be reborn as a snake.

Recent developments in the waterfalls area have built tourist facilities including a bathing pool, rock stabilization, changing rooms, toilets, gazebos, viewpoints, a water treatment plant, parking facilities, a cloakroom, electrification, dormitories, and a rest house. According to the comparative stratigraphy from Bihar, as given in the geological map of GSI, it falls in the Kodarma group with massive quartzite, with quartz-schist and

quartz mica schist, in the metamorphics of Chotanagpur Mica belt (Mohammad et al., 2022). It is listed as an Intangible Cultural Heritage (IHC) of the Bihar state, having great historical and mythological importance, in the Central zone of India for its geo education, geotourism and geoconservation potentials in connection with the snake charmers community (Halder & Sarda, 2021). From biodiversity point of view, the site has contributed to the report of a new sedge (*Kyllinga bulbosa*) to the flora of Bihar (Kumar et al., 2017). This sub-tropical and sub-humid climate area is also home to wild animals such as sloth bear, sambar deer, and wild boars (Kumar & Paul, 2021).



Figure 1. An aerial view of the Kakolat waterfalls, showing the renovated pathway for accessing the waterfalls, Nawada, Bihar. Credits: Nawada Forest Division



3.1. Noteworthy habitats recorded in Kakolat

Forest Habitat

The vegetation of the two perennial streams at Kakolat and its surroundings can be described as tropical closed canopy forest which varies from being dominated by evergreen species growing mostly along perennial streams to being dominated by deciduous species away from the streams and towards the steeper and higher reaches of the hill slopes. Structurally the forest is a closed canopy, however, the canopy was observed to open up on really steep and rocky terrain. Vertically, the forest exhibits just one or two strata - canopy and understorey, depending on the location. Canopy height was found to vary between 10 - 20 m, but can reach up to 25 meters at the mouth of the two valleys where the terrain is mostly flat and gentle.



Figure 3. Forest habitats of Kakolat waterfall, Nawada, Bihar

Trees are the most dominant life forms of this forest, but lianas (woody climbers) were found to be quite abundant as well. Shrubs were few w.r.t. abundance and species richness while epiphytes were almost entirely missing from the area. Grass cover and herb cover vary depending on the canopy cover and soil moisture respectively. The riverine habitat was represented by a number of unique and surprising species, from the phytogeographic point of view, and those not otherwise found in the surrounding landscape of Bihar and Chota Nagpur plateau. Apart from the typical species that are generally found along riverine forests, such as *Syzygium cumini*, *Terminalia arjuna*, *Ficus racemosa* and *Ficus microcarpa*, the unusual species recorded during the survey were *Walsura trifoliolata*, *Syzygium nervosum*, *Syzygium salicifolium*, *Glochidion ellipticum* and *Neolamarkia cadamba*. Similarly, *Ardisia solanacea*, *Ixora undulata* were the two other rare, understorey species that were recorded exclusively along the riverine habitat. Lianas were particularly abundant in the valleys and along the stream habitats growing over and hanging down from the canopy of trees. The most commonly observed species of Liana were *Combretum roburghii*, *Spatholobus parviflorus*, *Poranopsis paniculata*, *Smilax* sp., *Ventilago denticulata*, *Ziziphus oenopolia*, *Phanera vahlii* and *Senegalia* sp. The forests away from the influence of streams consisted of tree species typically of moist deciduous forests of central India and Himalayan foothills. These include *Adina cordifolia*, *Mallotus philippensis*, *Garuga pinnata*, *Albizia*

odoratissima, *Cassia fistula*, *Terminalia anogeissiana*, *Dillenia pentagyna*. *Sterculia urens*, *Sterculia villosa*, *Diospyros melanoxylon* and *Hymenodictyon orixense* were observed growing on steep and rocky slopes of Kakolat. Species that were of relatively rare occurrence or those that were encountered only once were *Cordia* sp., *Schrebera swietenoides*, *Stereospermum suaveolens* and *Miliusa tomentosa*. We also observed a small population of *Combretum nanum* - a rare geoxyle (plants with below-ground woody structures), growing in the understorey of open canopy Sal forest and associated with *Casearia graveolens*, *Woodfordia fruticosa*, and *Antidesma ghaesembilla*.

Riparian Habitat

Riparian habitats are known to function as tropical forest refugia (Meave et al., 1991). It is characterised by high local densities of tropical forest plant species. In these habitats, moisture supply is temporally continuous, fire frequencies are lower, and they have high soil fertility compared to the larger landscape (Meave et al., 1991). It is important to note that while this moisture influence is stronger at the stream banks and thus creates an edge effect, a similar edge effect associated with canopy opening could be negligible at stream banks since canopies above small headwater streams are mostly closed (Biswas et al., 2019). Globally, riparian forests are also important corridors for animal dispersion, allowing gene flow and preventing local extinctions (Corrêa et al., 2018). Microhabitats here can act as important refugia for multiple animals and plants across taxa. For example, in the case of forest litter, its characteristics such as depth, humidity and food availability there can influence various organisms occurring there.



Figure 4. Riparian habitat in Kakolat waterfalls, Nawada, Bihar

The riparian zone is also very dynamic spatially and temporally, due to the bioclimatic, geo-morphological and land-use condition changes over time under natural and human interactions (Riis et al., 2020). It offers a variety of ecosystem services, the contributions that ecosystems make to human well-being including provisioning services, regulation and maintenance services, and direct or indirect cultural services. This includes biomass, genetic resources, filtration of pollutants and chemical conditions of freshwaters, carbon sequestration, erosion control, flow regulation, pollination and seed dispersal, maintenance of nursery populations and habitats, pest control, and regulation of microclimate (Riis et al., 2020). Riparian systems have the capacity to deliver a disproportionately high amount of such services relative to their extent in the landscape, but they are under significant threats from alteration of disturbance regime, stream-flow

regulation by dams, pollution, land-use change, timber harvesting, water diversion, mining, deforestation, and from invasive species (Riis et al., 2020).

Streams are home to a multitude of animals spanning from aquatic invertebrates to mammals, which are aquatic, terrestrial or amphibious species (Robinson et al., 2002). Animals such as fishes, crustaceans, frogs, and insects can utilize the diverse microhabitats within the aquatic ecosystem. Streams are complex habitats with meso habitats such as run, riffles, cascades and pools, and microhabitats including but not limited to pebbles, aquatic vegetation, leaf litter, algal growth, and humus. This complex structure provides a diversity of habitats for various life stages of animals. For example, tadpoles (Anuran larvae) can be entirely dependent on certain microhabitats in the stream system, whereas the adult frog can also utilize the terrestrial habitats.

3.2. Microhabitat Survey

The details of microhabitats recorded during the rapid survey at the Kakolat sites are given below.



Run portion of the stream



Rock crevice



Moist crevices on waterfalls



Cliff edge



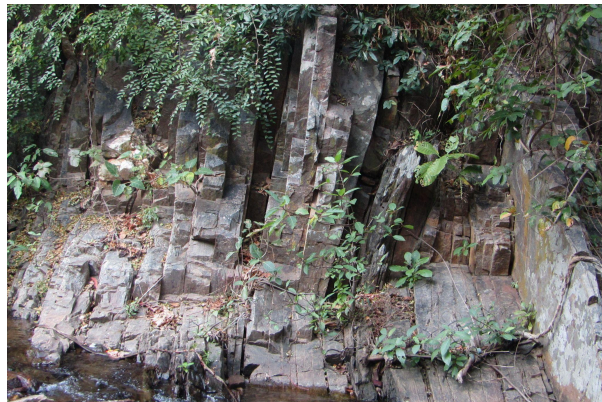
Rocky areas along stream with lithophytic trees showing riffles and pool



Salt lick (?) formed along the stream



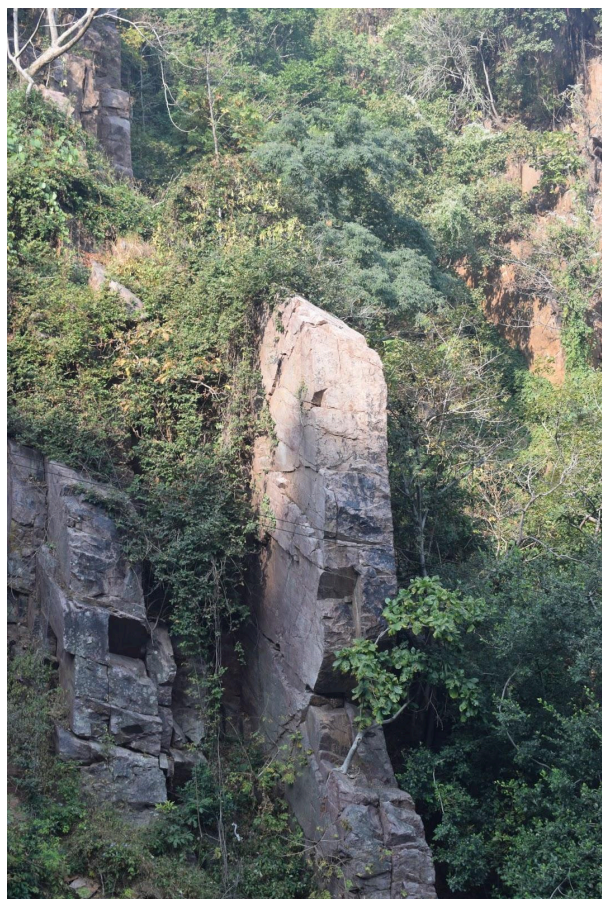
Rocks with sheet-like structuring



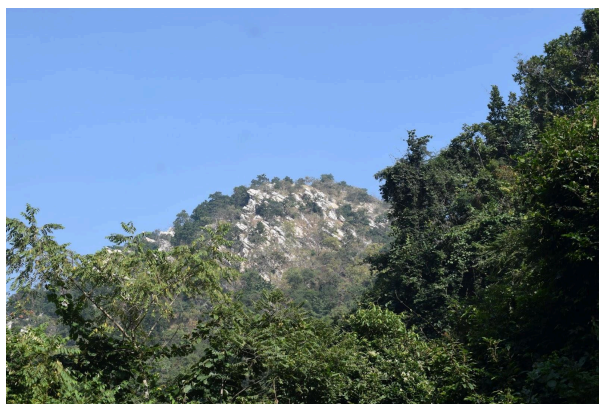
Columnar rocks with fissures, ledges and large crevices



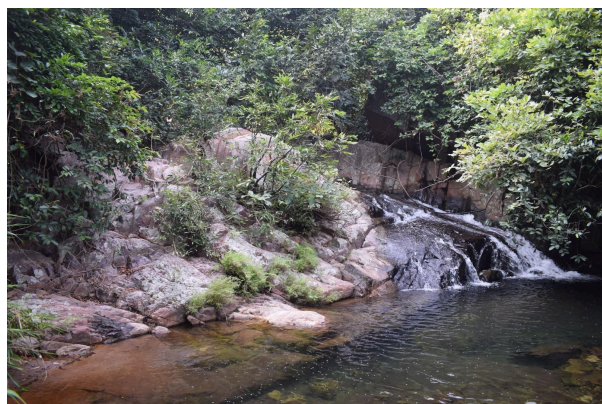
Modified microhabitats along the main waterfalls



Rock fissures



Exposed rocks



Cascade and pool



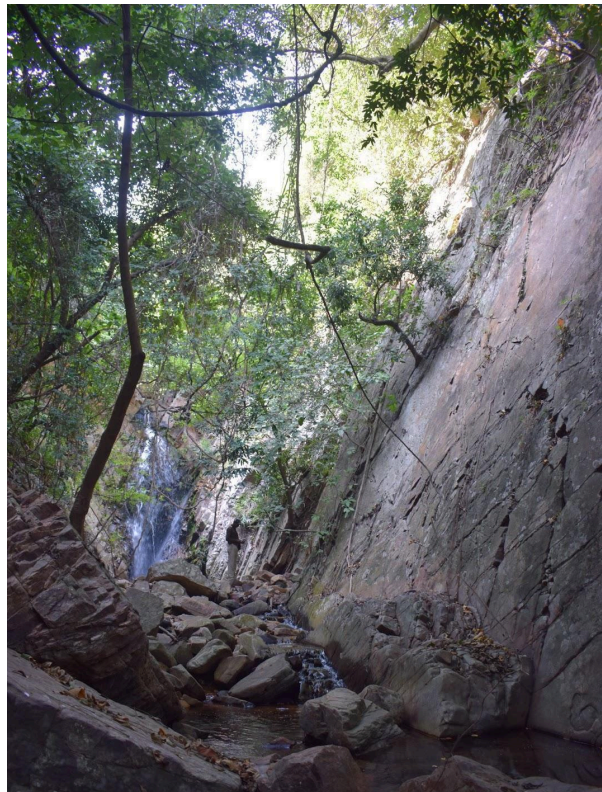
Scattered rocks and pebbles along the run portion of the stream



Disturbed microhabitats due to human use



Large pool with cascade



Slanted rocks and waterfalls

Figure 5. Photographs of observed microhabitats from Kakolat streams.

3.3. Biodiversity Survey

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

3.3.1. Fauna

During our visit at the Kakolat streams and associated forest, we recorded a total of 96 animal species belonging to more than 40 families with 2 reptiles, 4 amphibians, 2 fishes, 2 decapods, 1 millipede, 2 centipedes, 76 insects, 1 mollusc, 1 mammal, and 5 arachnids. A total of 18 orders were identified. Details are given below:

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



Polypedates maculatus



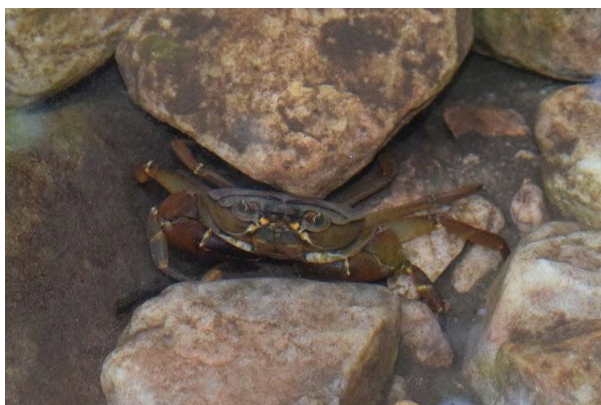
Python molurus



Ptyas mucosa (?)



Gastropoda



Decapoda



Dytiscidae, Coleoptera



Paracanthocobitis moorei



Thermonectus sp. (Dytiscidae, Coleoptera)



Macrobrachium sp. (?)



Garra mullia



Gerridae (Hemiptera)



Hydrometridae (Hemiptera)



Diplopoda



Family Limoniidae; Subfamily Chioneinae
[*Styringomyia* sp. (?)]



Rusa unicolor



Mecopoda elongata (?)



Mantis nymph (Mantodea)



Orthoptera



Orthoptera (Tettigoniidae ?)



Orthoptera



Chrotogonus sp. (?)



Diabolocatantops sp. (?)



Gryllodes sigillatus (?)



Ophionea indica



Ischnojoppa luteator



Leptocorisa acuta



Wadicosa sp.



Argiope sp.



Lycosidae



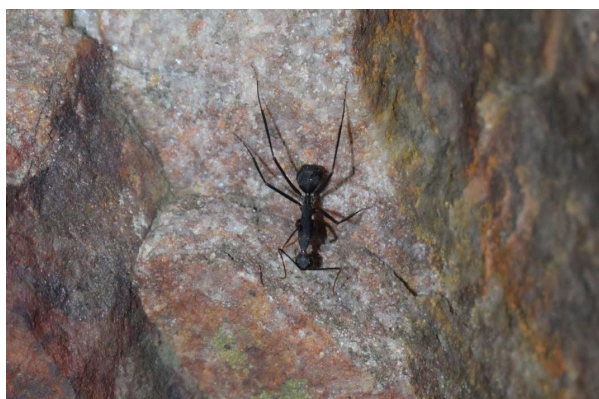
Lycosidae



Hippasa sp.



Camponotus compressus and *Oecophylla smaragdina*



Camponotus angusticollis



Oecophylla smaragdina



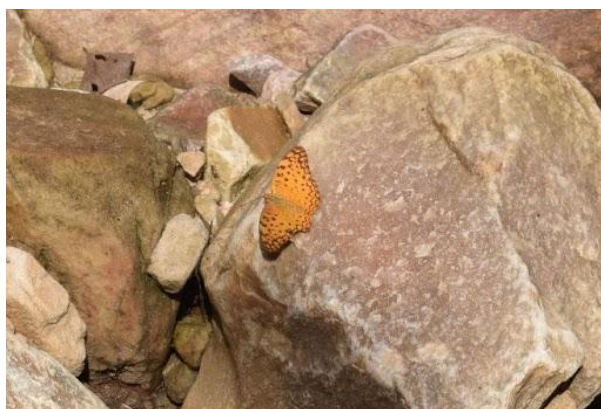
Erebidae (caterpillar)



Empty pupal cocoon of a *Limacodidae* sp.



Castalius rosimon



Phalanta phalantha



Junonia atlites



Melanitis sp.



Suastus sp.



Symphaedra nais



Blattodea



Robber fly (Asilidae)



Orthoptera



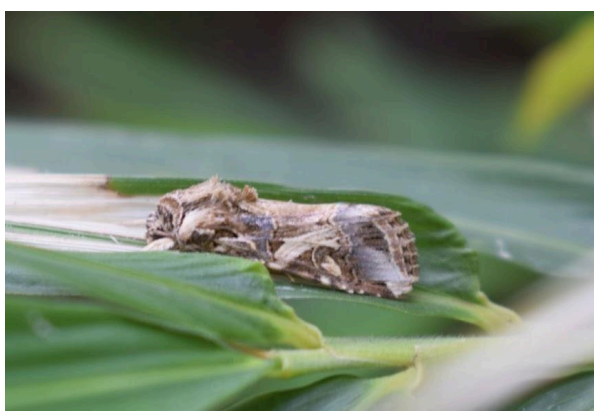
Carabidae



Cormocephalus sp. (?) [Scolopendridae]



Geophilomorpha



Spodoptera litura



Erebidae



Olene mendosa (?)



Cheromettia sp.

	
<i>Eysarcoris ventralis</i>	<i>Apis dorsata</i>
	
Coccoidea (?)	Isoptera

Figure 6. Documentation of fauna from Kakolat waterfalls

Table 2: List of butterflies (Insecta: Lepidoptera) from Kakolat

Common Name	Scientific Name	Family
Rice swift	<i>Borbo cinnara</i>	Hesperiidae
Dark Palm Dart	<i>Telicota bambusae</i>	Hesperiidae
Palm bobs	<i>Suastus</i> sp.	Hesperiidae
Common pierrot	<i>Castalius rosimon</i>	Lycaenidae
Plains cupid	<i>Luthrodes pandava</i>	Lycaenidae
Zebra blue	<i>Leptotes plinius</i>	Lycaenidae
Slate Flash	<i>Rapala manea</i>	Lycaenidae
Common Flash	<i>Rapala nissa</i>	Lycaenidae

Common Name	Scientific Name	Family
Indigo flash	<i>Rapala varuna</i>	Lycaenidae
Apefly	<i>Spalgis epius</i>	Lycaenidae
Common Silverline	<i>Cigaritis vulcanus</i>	Lycaenidae
Tawny coster	<i>Acraea terpsicore</i>	Nymphalidae
Common castor	<i>Ariadne merione</i>	Nymphalidae
Plain tiger	<i>Danaus chrysippus</i>	Nymphalidae
Striped tiger	<i>Danaus genutia</i>	Nymphalidae
Common crow	<i>Euploea core</i>	Nymphalidae
Great eggfly	<i>Hypolimnias bolina</i>	Nymphalidae
Peacock pansy	<i>Junonia almana</i>	Nymphalidae
Grey pansy	<i>Junonia atlites</i>	Nymphalidae
Yellow pansy	<i>Junonia hierta</i>	Nymphalidae
Lemon pansy	<i>Junonia lemonias</i>	Nymphalidae
Blue pansy	<i>Junonia orithya</i>	Nymphalidae
Common evening brown	<i>Melanitis leda</i>	Nymphalidae
Dark Evening Brown	<i>Melanitis phedima</i>	Nymphalidae
Common sailer	<i>Neptis hylas</i>	Nymphalidae
Sullied sailer	<i>Neptis soma</i>	Nymphalidae
Spotted rustic	<i>Phalanta phalantha</i>	Nymphalidae
Baronet	<i>Symphaedra nais</i>	Nymphalidae
Blue tiger	<i>Tirumala limniace</i>	Nymphalidae
Common jay	<i>Graphium doson</i>	Papilionidae
Common rose	<i>Pachliopta aristolochiae</i>	Papilionidae
Lime Swallowtail	<i>Papilio demoleus</i>	Papilionidae
Common Mormon	<i>Papilio polytes</i>	Papilionidae
Common Albatross	<i>Appias albina</i>	Pieridae
Lemon Emigrant	<i>Catopsilia pomona</i>	Pieridae
Mottled Emigrant	<i>Catopsilia pyranthe</i>	Pieridae
Lesser gull	<i>Cepora nadina</i>	Pieridae
The common gull	<i>Cepora nerissa</i>	Pieridae
Common Jezebel	<i>Delias eucharis</i>	Pieridae

Common Name	Scientific Name	Family
Small grass yellow	<i>Eurema brigitta</i>	Pieridae
Common Grass Yellow	<i>Eurema hecabe</i>	Pieridae
Indian Wanderer	<i>Pareronia hippia</i>	Pieridae
Indian cabbage white	<i>Pieris canidia</i>	Pieridae

Note:

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, especially amphibians, and snakes 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).

3.3.2. Flora

A total of 154 species of vascular plants were recorded comprising 42 herbs, 20 shrubs, 75 trees and 16 climbers. The climbers include 5 lianas and 1 twiner. Detailed list (Table 3) and photographs (Figure 7) are given below

Table 3: List of recorded plants from the Kakolat falls and associated forest

Family	Species	Habit
Acanthaceae	<i>Andrographis longipedunculata</i> (Sreem.) L.H.Cramer ex Karthik. & Moorthy	Herb
Acanthaceae	<i>Barleria cristata</i> L.	Herb
Acanthaceae	<i>Eranthemum pulchellum</i> Andrews	Herb
Acanthaceae	<i>Rostellularia procumbens</i> (L.) Nees	Herb
Acanthaceae	<i>Rungia</i> sp.	Herb
Amaranthaceae	<i>Achyranthes aspera</i> L.	Herb
Amaranthaceae	<i>Allmania nodiflora</i> (L.) R.Br. ex Wight	Herb
Amaranthaceae	<i>Celosia argentea</i> L.	Herb
Anacardiaceae	<i>Buchanania cochinchinensis</i> (Lour.) M.R.Almeida	Tree
Anacardiaceae	<i>Lannea coromandelica</i> (Houtt.) Merr.	Tree

Anacardiaceae	<i>Mangifera indica</i> L.	Tree
Anacardiaceae	<i>Semecarpus anacardium</i> Blume	Tree
Annonaceae	<i>Huberantha cerasoides</i> (Roxb.) Chaowasku	Tree
Annonaceae	<i>Milium tomentosa</i> (Roxb.) Finet & Gagnep.	Tree
Apocynaceae	<i>Carissa</i> sp.	Shrub
Apocynaceae	<i>Hemidesmus indicus</i> (L.) R.Br.	Herb
Apocynaceae	<i>Holarrhena pubescens</i> Wall. & G.Don	Tree
Apocynaceae	<i>Ichnocarpus frutescens</i> (L.) W.T.Aiton	Twiner
Apocynaceae	<i>Wattakaka volubilis</i> Stapf	Climber
Apocynaceae	<i>Wrightia arborea</i> (Dennst.) Mabb.	Tree
Apocynaceae	<i>Wrightia tinctoria</i> R.Br.	Tree
Araliaceae	<i>Heptapleurum venulosum</i> (Wight & Arn.) Seem.	Tree
Aristolochiaceae	<i>Aristolochia</i> sp.	Climber
Asparagaceae	<i>Asparagus</i> sp.	Climber
Aspleniaceae	<i>Diplazium</i> sp.	Herb
Asteraceae	<i>Acmella uliginosa</i> (Sw.) Cass.	Herb
Asteraceae	<i>Ageratum conyzoides</i> L.	Herb
Asteraceae	<i>Blumea</i> sp.	Herb
Asteraceae	<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.	Shrub
Asteraceae	<i>Mikania micrantha</i> Kunth	Climber
Asteraceae	<i>Parthenium hysterophorus</i> L.	Herb
Bignoniaceae	<i>Oroxylum indicum</i> (L.) Kurz	Tree
Bignoniaceae	<i>Stereospermum chelonoides</i> (L.f.) DC.	Tree
Boraginaceae	<i>Cordia</i> sp.	Tree
Burseraceae	<i>Boswellia serrata</i> Roxb.	Tree
Burseraceae	<i>Garuga pinnata</i> Roxb.	Tree
Burseraceae	<i>Protium serratum</i> Engl.	Tree
Cannabaceae	<i>Trema orientalis</i> (L.) Blume	Tree
Celastraceae	<i>Celastrus paniculatus</i> Willd.	Liana
Celastraceae	<i>Elaeodendron glaucum</i> (Rottb.) Pers.	Tree
Combretaceae	<i>Combretum albidum</i> G.Don	Climber
Combretaceae	<i>Combretum nanum</i> Buch.-Ham. ex D.Don	Shrub
Combretaceae	<i>Terminalia anogeissiana</i> Gere & Boatwr.	Tree
Combretaceae	<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	Tree
Combretaceae	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Tree
Combretaceae	<i>Terminalia chebula</i> Retz.	Tree
Commelinaceae	<i>Cyanotis</i> sp.	Herb
Convolvulaceae	<i>Erycibe paniculata</i> Roxb.	Liana
Convolvulaceae	<i>Poranopsis paniculata</i> (Roxb.) Roberty	Climber
Cyperaceae	<i>Cyperus amabilis</i> Vahl	Herb
Cyperaceae	<i>Cyperus</i> sp.	Herb

Dilleniaceae	<i>Dillenia pentagyna</i> Roxb.	Tree
Dipterocarpaceae	<i>Shorea robusta</i> C.F.Gaertn.	Tree
Ebenaceae	<i>Diospyros melanoxylon</i> Roxb.	Tree
Eriocaulaceae	<i>Eriocaulon</i> sp.	Herb
Euphorbiaceae	<i>Croton persimilis</i> Müll.Arg.	Tree
Euphorbiaceae	<i>Euphorbia nivulia</i> Buch.-Ham.	Shrub
Euphorbiaceae	<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	Tree
Euphorbiaceae	<i>Trewia nudiflora</i> L.	Tree
Fabaceae	<i>Albizia odoratissima</i> (L.f.) Benth.	Tree
Fabaceae	<i>Butea monosperma</i> (Lam.) Kuntze	Tree
Fabaceae	<i>Cassia fistula</i> L.	Tree
Fabaceae	<i>Dalbergia lanceolaria</i> subsp. <i>paniculata</i> (Roxb.) Thoth.	Tree
Fabaceae	<i>Dalbergia volubilis</i> Roxb.	Tree
Fabaceae	<i>Erythrina stricta</i> Roxb.	Tree
Fabaceae	<i>Millettia extensa</i> (Benth.) Baker	Liana
Fabaceae	<i>Mimosa rubicaulis</i> subsp. <i>himalayana</i> (Gamble) H.Ohashi	Shrub
Fabaceae	<i>Phanera vahlii</i> (Wight & Arn.) Benth.	Liana
Fabaceae	<i>Polhillides velutina</i> (Willd.) H.Ohashi & K.Ohashi	Subshrub
Fabaceae	<i>Senegalia</i> sp.	Tree
Fabaceae	<i>Spatholobus parviflorus</i> (Roxb. ex G.Don) Kuntze	Climber
Gentianaceae	<i>Canscora alata</i> (Roth) Wall.	Herb
Gentianaceae	<i>Canscora diffusa</i> (Vahl) R.Br. ex Roem. & Schult.	Herb
Hypoxidaceae	<i>Curculigo orchioides</i> Gaertn.	Herb
Lamiaceae	<i>Clerodendrum infortunatum</i> L.	Shrub
Lamiaceae	<i>Coleus strobilifer</i> (Roxb.) A.J.Paton	Herb
Lamiaceae	<i>Gmelina arborea</i> Roxb.	Tree
Lamiaceae	<i>Leucas aspera</i> (Willd.) Link	Herb
Lamiaceae	<i>Leucas cephalotes</i> (Roth) Spreng.	Herb
Lamiaceae	<i>Leucas montana</i> (Roth) Spreng.	Herb
Lamiaceae	<i>Mesosphaerum suaveolens</i> (L.) Kuntze	Shrub
Lamiaceae	<i>Vitex altissima</i> L.f.	Tree
Lauraceae	<i>Litsea glutinosa</i> (Lour.) C.B.Rob.	Tree
Lauraceae	<i>Litsea monopetala</i> (Roxb.) Pers.	Tree
Lecythidaceae	<i>Careya arborea</i> Roxb.	Tree
Loranthaceae	<i>Dendrophthoe falcata</i> (L.f.) Ettingsh.	Parasite
Lythraceae	<i>Lagerstroemia parviflora</i> Roxb.	Tree
Lythraceae	<i>Woodfordia fruticosa</i> Kurz	Tree
Malpighiaceae	<i>Hiptage benghalensis</i> (L.) Kurz	Liana
Malvaceae	<i>Bombax ceiba</i> L.	Tree
Malvaceae	<i>Grewia hirsuta</i> Vahl	Tree

Malvaceae	<i>Grewia tiliifolia</i> Vahl	Tree
Malvaceae	<i>Kydia calycina</i> Roxb.	Tree
Malvaceae	<i>Sida cordata</i> (Burm.f.) Borss.Waalk.	Herb
Malvaceae	<i>Sterculia urens</i> Roxb.	Tree
Malvaceae	<i>Sterculia villosa</i> Roxb.	Tree
Melastomataceae	<i>Melastoma malabathricum</i> L.	Woody Shrub
Meliaceae	<i>Walsura trifoliolata</i> (A.Juss.) Harms	Tree
Molluginaceae	<i>Paramollugo nudicaulis</i> (Lam.) Thulin	Herb
Moraceae	<i>Ficus arnottiana</i> (Miq.) Miq.	Tree
Moraceae	<i>Ficus benghalensis</i> L.	Tree
Moraceae	<i>Ficus microcarpa</i> L.f.	Tree
Moraceae	<i>Ficus racemosa</i> L.	Tree
Moraceae	<i>Ficus semicordata</i> Buch.-Ham. ex Sm.	Tree
Moraceae	<i>Ficus tinctoria</i> subsp. <i>gibbosa</i> (Blume) Corner	Tree
Moraceae	<i>Ficus virens</i> Aiton	Tree
Myrtaceae	<i>Syzygium cumini</i> (L.) Skeels	Tree
Myrtaceae	<i>Syzygium nervosum</i> A.Cunn. ex DC.	Tree
Myrtaceae	<i>Syzygium salicifolium</i> J. Graham	Tree
Olacaceae	<i>Olax scandens</i> Roxb.	Shrub
Oleaceae	<i>Nyctanthes arbor-tristis</i> L.	Tree
Oleaceae	<i>Schrebera swietenoides</i> Roxb.	Tree
Opiliaceae	<i>Cansjera rheedei</i> Blanco	Climber
Oxalidaceae	<i>Biophytum sensitivum</i> (L.) DC.	Herb
Phyllanthaceae	<i>Antidesma acidum</i> Retz.	Shrub
Phyllanthaceae	<i>Antidesma ghaesembilla</i> Gaertn.	Tree
Phyllanthaceae	<i>Bridelia retusa</i> (L.) A.Juss.	Tree
Phyllanthaceae	<i>Flueggea virosa</i> (Roxb. ex Willd.) Royle	Shrub
Phyllanthaceae	<i>Glochidion ellipticum</i> Wight	Tree
Phyllanthaceae	<i>Phyllanthus maderaspatensis</i> L.	Herb
Poaceae	<i>Cenchrus pedicellatus</i> (Trin.) Morrone	Herb
Poaceae	<i>Dactyloctenium aegyptium</i> (L.) Willd.	Herb
Poaceae	<i>Eragrostis</i> sp.	Herb
Poaceae	<i>Eragrostis coarctata</i> Stapf	Herb
Poaceae	<i>Eragrostis multiflora</i> Trin.	Herb
Poaceae	<i>Heteropogon contortus</i> (L.) P.Beauv. ex Roem. & Schult.	Herb
Poaceae	<i>Oplismenus burmanni</i> (Retz.) P.Beauv.	Herb
Poaceae	<i>Pogonatherum</i> sp.	Herb
Poaceae	<i>Thysanolaena latifolia</i> (Roxb. ex Hornem.) Honda	Herb
Primulaceae	<i>Ardisia solanacea</i> Roxb.	Shrub
Pteridaceae	<i>Adiantum philippense</i> L.	Herb

Pteridaceae	<i>Pteris vittata</i> L.	Herb
Rhamnaceae	<i>Ziziphus oenopolia</i> (L.) Mill.	Shrub
Rhamnaceae	<i>Ziziphus xylopyrus</i> (Retz.) Willd.	Shrub
Rubiaceae	<i>Adina cordifolia</i> (Roxb.) Benth. & Hook.f. ex B.D.Jacks.	Tree
Rubiaceae	<i>Canthium kuntzeanum</i> (Burm.f.) Alston	Shrub
Rubiaceae	<i>Ceriscoides turgida</i> (Roxb.) Tirveng.	Tree
Rubiaceae	<i>Deccania pubescens</i> (Roth) Tirveng.	Tree
Rubiaceae	<i>Gardenia latifolia</i> Aiton	Tree
Rubiaceae	<i>Hymenodictyon orixense</i> (Roxb.) Mabb.	Tree
Rubiaceae	<i>Ixora pavetta</i> Andrews	Shrub
Rubiaceae	<i>Ixora undulata</i> Roxb. ex Sm.	Shrub
Rubiaceae	<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Tree
Rubiaceae	<i>Oldenlandia</i> sp.	Herb
Rubiaceae	<i>Pavetta indica</i> L.	Shrub
Rutaceae	<i>Murraya exotica</i> L.	Shrub
Salicaceae	<i>Casearia graveolens</i> Dalzell	Tree
Salicaceae	<i>Casearia tomentosa</i> Roxb.	Tree
Salicaceae	<i>Flacourtia ramontchi</i> L'Hér.	Tree
Sapindaceae	<i>Schleichera oleosa</i> (Lour.) Oken	Tree
Sapotaceae	<i>Madhuca longifolia</i> var. <i>latifolia</i> (Roxb.) A.Chev.	Tree
Schizaeaceae	<i>Lygodium flexuosum</i> (L.) Sw.	Climber
Selaginellaceae	<i>Selaginella bryopteris</i> (L.) Baker	Herb
Smilacaceae	<i>Smilax</i> sp.	Climber



Mallotus philippensis



Croton persimilis



Syzygium nervosum



Bridelia retusa



Deccania pubescens



Combretum nanum



Ardisia solanacea



Ixora undulata



Spatholobus parviflorus



Dendrophthoe falcata



Huberantha cerasoides



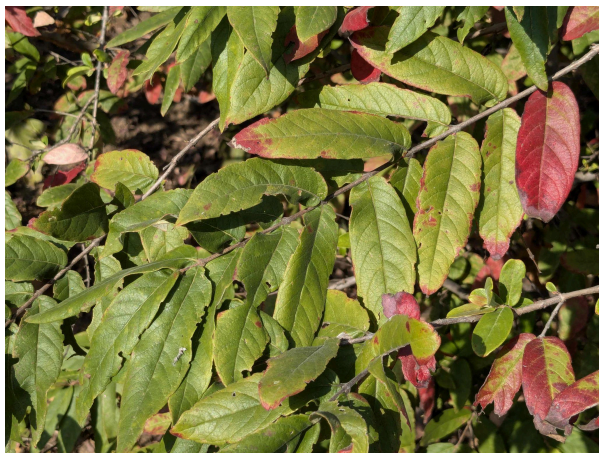
Miliusa tomentosa



Poranopsis paniculata



Combretum roxburghii



Woodfordia fruticosa



Ficus semicordata



Melastoma malabathricum



Eranthemum pulchellum



Ficus microcarpa



Erycibe paniculata



Walsura trifoliolata



Glochidion ellipticum



Allmania nodiflora



Barleria cristata



Ageratum conyzoides



Lygodium flexuosum



Pogonatherum sp.



Eragrostis coarctata



Rostellularia procumbens



Rungia sp.

	
<i>Adiantum philippense</i>	<i>Eragrostis multiflora</i>
	
<i>Canscora diffusa</i>	<i>Canscora alata</i>
	
<i>Eriocaulon</i> sp.	<i>Diplazium</i> sp.

Figure 7. Photographs representing the flora across the surveyed sites

4. DISCUSSION

The rapid surveys show that the explored streams are of great biological, and cultural significance, especially in light of the increasing anthropogenic disturbance and habitat modifications. Though much of the biodiversity has not been documented due to the limited scope of this short-duration assessment, further detailed explorations, covering hydrological and geological aspects, and taxa-specific surveys are highly recommended to reveal the ecological value of these least studied stream habitats. 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 streams and associated forested areas. Bihar is home to some interesting streams and rivers (Fig. 8). They can act as lifelines that support unique biodiversity in the already heavily modified landscape, providing necessary ecosystem services to neighbouring regions, with cultural, touristic and aesthetic values.



Figure 8. Sakri River near Darhi Village, Bihar. Photograph by Hashmiamir, Wikimedia Commons

Keeping in mind the limited information this report has generated, a few conservation recommendations and future research dimensions are suggested below:

4.1. Conservation Recommendations

- 4.1.1. The conceptual framework developed for establishing Local Biodiversity Heritage Sites (LBHS) for rock outcrop conservation in the northern Western Ghats can be used as a model, keeping the socio-ecological landscape in mind (Watve & Chavan, 2020).
- 4.1.2. Possibilities of giving 'Conservation Reserve Status' to the riverine forests of Kakolat and adjacent hills can be explored. It may be important to note that the proposed conservation measures consider the fact that restricting all forms of human land use and herding activities in these areas (Michael et al. 2008), may decrease biodiversity by reducing habitat diversity. Thus, historical relationships between prehistoric human land-use practices and contemporary conditions of biodiversity require continued investigation, species inventories and statistical analyses (Bauer, 2018).
- 4.1.3. Since the area is also listed as an 'Intangible Cultural Heritage', and of importance in terms of geodiversity and geoheritage, which are integral parts of biological diversity and natural heritage, assessments of geoheritage and prospects of geotourism need to be undertaken in these habitats similar to Karnataka and West Bengal (Prabhakar & Radhika, 2022; Ghosh et al., 2021). The scope for this needs to be discussed with the help of Geological Survey of India and other relevant departments in the light of recently announced 'Draft Geoheritage Sites and Geo-relics (Preservation and Maintenance) Bill, 2022'.
- 4.1.4. Identification of stream habitats 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 streams is of importance.

4.1.5. Extensive modifications of the stream habitats need to be avoided.

4.1.6. Preparation of 'ecotourism/ conservation tourism' plans and 'ethical guidelines for tourism' are of importance. Rigorous scientific monitoring of managerial impacts and mid-course corrections as and when required need to be done.

4.1.7. *Specific management recommendations based on the rapid survey are:*

4.1.7.1. Protect streams from human disturbances that cause damage to the microhabitats (trampling of flora, removing plants and animals from microhabitats, removal and displacement of in-stream loose rocks etc.). This could be achieved by restricting the visitors along the designated paths.

4.1.7.2. Regular monitoring of vegetation changes (using repeated photography across seasons, maybe at bi-weekly intervals) would be useful to gauge the degree of human disturbance (such as tree cutting, firewood extraction and human-induced fires) as well as the spread of invasive species.

4.1.7.3. Ensuring the proper identification and removal of emerging invasive species such as *Mesosphaerum suaveolens* and *Parthenium hysterophorus* by uprooting them at the seedling stage is proposed as a long-term management strategy to preserve and naturally restore the floral community.

4.1.7.4. Restoration of disturbed (rock removal, grazing, vandalism, loss of native vegetation, chance of weed invasion and fires etc.) stream habitats needs to be done scientifically since many studies have been conducted across the globe (González et al., 2015).

- 4.1.7.5. The upstream habitat of Kakolat waterfall is one of the best riparian habitats seen in the Nawada division and it is important to maintain the ecological integrity of that valley. Access to the habitat upstream of the waterfall may be provided for research and monitoring purposes only while tourism activities can be regulated only up till the waterfall.
- 4.1.7.6. The adjacent perennial stream (Site B) is also equally important ecologically and in terms of floristic diversity. Access to that stream should not be restricted but should certainly be regulated by providing a well-trained nature guide or a naturalist. This would ensure responsible tourism and would help in curbing littering and degradation of the habitat due to unregulated tourism.
- 4.1.7.7. Protocols should be put in place for long-term monitoring of Flora, Herpetofauna, Birds and Arthropods. Field guides and information brochures should be designed that showcase the biodiversity of Kakolat. Signages providing information on trees, birds, lizards, frogs, mammals and arthropods can be set up enroute to the waterfall from the parking area.
- 4.1.7.8. Local youth can be trained as naturalists and guides who would then accompany the tourists and also serve as a resource person on the local biodiversity.
- 4.1.7.9. It should be ensured that the quality of water and habitat should not be compromised at any cost as a result of the tourism activity.

4.2. Research Directions

- 4.2.1. As the first stage, species inventories 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. The help of experts in stream habitat biodiversity can be availed.

Ecological studies of aquatic vegetation, cliff-dwelling flora, and stream-dwelling animals need to be undertaken to have a clear picture of the biodiversity in these habitats, which will be crucial in determining its ecological value. This can be done with student volunteers and interns who are interested in conservation and ecological research. Appropriate training for these needs to be conducted.

- 4.2.2. Taxonomists and ecologists need to work together on lesser-known taxa such as spiders, orthopterans, aquatic invertebrates, mosses and lichens, and research should be conservation-oriented which gives feedback to area managers.
- 4.2.3. Assessing the impacts of local festivals, tourism, fuelwood collection, and medicinal plant extraction on biodiversity is essential for the sustainable management of the habitat. Therefore, management-level planning should include structured resource-use monitoring and regulated access to balance conservation efforts with community needs while reducing conflicts and promoting long-term sustainability
- 4.2.4. 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.

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