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MULTIVARIATE ANALYSIS OF ELEMENTS FROM THE MICROHABITATS OF SELECTED PLATEAUS IN THE WESTERN GHATS, MAHARASHTRA, INDIA

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Abstract: The Western Ghats represents a small part of the Deccan Traps continental flood basalt province that erupted about 65 million years ago. It is an area of outstanding scenic beauty and has attracted the attention of geologists, naturalists and geomorphologists for over a century. One of the unique habitats in the Western Ghats are the rocky plateaus. Previous studies have covered plant species composition, geological and geomorphological status of the rocky plateaus. An analytical study of microhabitats and associated therophytes of four rocky plateau sites was conducted. The study sites were Durgawadi Plateau, Naneghat Plateau which are basalt outcrops and Zenda plateau and Amba Plateau, which are laterite outcrops on the escarpment of the northern Western Ghats. The results revealed a correlation between basalt and lateritic rock outcrops as well as ephemeral plant elements. All four outcrops are similar in their nutrient status but the microhabitats of these plateaus are extremely different from each other.

Keywords: Basalt, ephemeral, geology, laterite, Rock outcrop, therophytes.

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Author contribution: PVA—contributed in research idea development and experiment design as well as implementation on field, sample collection and analysis; DCM—suggested and contributed in geochemical and geomorphological characterization of plateaus and interpretation of the data; DMM—contributed in identification of species and microhabitats from the plateau ecosystem; PAK—supported in plateau Ecosystem monitoring, field data collection and technical aspects; SPK—supported in statistical analysis for various tests applied to the data and result interpretation.

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INTRODUCTION

The Sahyadri Range is one of the spectacular geographic features of the Indian subcontinent. Documenting the plant species was necessary to understand the nature of vegetation (Sambhaaji 2015). A compilation with commentary of landmark papers by the Geological Society of India’s (Gunnell & Radhakrishna 2001) findings till date gives us an idea about its uniqueness. One of the distinctive aspects of the geomorphology of the Sahyadri Range is the presence and preservation of two “paleosurfaces” indicated by laterite (Fox 1923; Widdowson & Cox 1996; Widdowson 1997). Cliffs, isolated hills, and platforms of rocks formed due to landscape level activities of weathering are the types of outcrops seen commonly in India, whereas “rock outcrops” is the term recognized by IUCN as a category of habitats wherein some portions of freely exposed bedrock project above the soil level due to natural reasons (Porembski & Watve 2005). According to Porembski (2007) well-known rocky outcrops in the world are inselbergs, barrens, cedar glades, cliffs, serpentine, ultramafic, limestone, and gypsum outcrops. He also suggested that each of these are known to harbor highly specialized vegetation rich in microhabitat-specific and endemic plants. Rock outcrop habitats are generally of small extent within a region and present particular habitat limitations, e.g., greater exposure to sun and scarcity of soil. The microenvironment at the rock surface ranges from very hot and arid in dry season to water logged in the wet season. Hence edaphically controlled herbaceous plant communities are characteristic of rock outcrops. Rock outcrops are very well known throughout the world for their uniqueness, but are less studied habitats. Most studies are from African, American and Australian outcrops (Porembski et al. 1994, 2000; Burke 2005a,b; Jacobi et al. 2007) describing the habitat types and associated vegetation composition. In India, relatively very few reports exist about vegetation on these special habitats (Porembski & Watve 2005; Watve 2008, 2013; Lekhak & Yadav 2012; Bhattarai et al. 2012).

The rock outcrops in the Western Ghats of Maharashtra are of two types based on the rock formation and soil type developed from it: (i) Lateritic—lateritic rock cover is well preserved over the parent basalt rock and soil rich in iron, and (ii) Basaltic—having black hard rock and soil. Durgawadi and Naneghat plateaus from the northern corner of Pune District are entirely basaltic but have some lateritic soil due to weathering. They have a diversity of micro-habitats and are rich in flora and fauna. Trees or shrubs are less in number, but herbaceous angiosperms, algae, mosses, ferns and lichens are generally abundant in these habitats. Many of the endemic ephemerals, herbaceous angiosperms, pteridophytes and lichens, however, are restricted to these special habitats (Watve 2008). Species composition patterns and outcrop communities are influenced by multiple environmental factors like soil type, elevation, aspect of that rock outcrop and micro-environments (Watve 2013). Moreover, transect studies of plateaus in northern Western Ghats region conducted by Watve (2008 & 2013) discuss the vegetation composition and pattern of some microhabitats on the plateaus. A comprehensive botanical study of two rock outcrops, Durgawadi Plateau (DP) and Naneghat Plateau (NP), on the escarpment of northern Western Ghats revealed a very high plant diversity within the sites and between the sites (Rahangdale & Rahangdale 2014). Herbaceous vegetation of high-level lateritic plateaus of southwestern Maharashtra have been studied by Lekhak & Yadav (2012). These studies have revealed the importance of microhabitats as this plateau vegetation has unique microhabitats that support distinct plant communities depending primarily on soil, depth of the soil and moisture availability. None of these studies describe the interrelationship between nutrient status and plant communities. Hence, the present study was carried out to find out the correlation between nutrient status of selected microhabitats and associated plant communities with the following objectives.

1. Identification and RS & GIS based mapping of microhabitats at plateau ecosystem
2. Sampling and analysis of trace and major elements of rock as well as soil from microhabitats
3. Identification and selection of ephemerals in plateau ecosystem
4. Sampling and analysis of trace and major elements of selected plant communities
5. Understanding correlation among elements, microhabitats and plant communities as well as plateaus using statistical methods

STUDY AREA

Durgawadi Plateau (Image 1): It is located 60km from Junnar Town at 1,200m altitude. The plateau top can be reached after a steep climb from Inglun Village at 19.193°N, 73.695°E & 19.217°N, 73.642°E. The road passes through the villages of Ambe, Hatwij, and Kathewadi and ends at the sacred grove of Durgawadi, which overlooks the Konkan area. Adjacent to it is the
plateau of Warsubai Temple. The Durgawadi Plateau is floristically very important because a number of new taxa are described from this region or adjacent region. According to Rahangdale (2009), Yadav (2010), Aitawade & Yadav (2012), and Rahangdale & Rahangdale (2012) all new taxa described from the location are endemic to Durgawadi.

Naneghat Plateau (Image 2): It is located 26km away from Junnar Town at 19.271°N, 73.720°E & 19.298°N, 73.672°E, 700m. The rocky hills of this region are well known forts. There is a tar road from Junnar to Naneghat (Ghatghar Village). The basalt is exposed as a broad expanse at a low altitude and bounded by sacred groves, reserve forest patches, rice fields and vertical slopes. The outcrop and its surroundings are affected by biotic pressures. Hemadri (1980) and Rahangdale (2009) denoted that Naneghat Plateau area is rich in plant diversity.

Amba Plateau (Image 3): Amba plateau is located at 16.985°N, 73.784°E & 16.987°N, 73.797°E, 740m, and overlooks the Amba Ghat which is a famous monsoon tourist destination. The plateau top can be reached from a forested path through Amba village.

Zenda plateau (Image 4): Zenda-Dhangarwada Plateau is a least disturbed outcrop located at 16°55'5.50"N, 73.918°E & 16.904°N, 73.849°E, 1025m. The plateau is known as Zenda Hill and is located between Manoli-Gajapur-Dhangarwada villages near Amba Ghat. The plateau top on Manoli side can be approached from a forested footpath branching from Amba to Vishalgad road (Images 5 & 6).
Image 3. Amba Plateau.

Image 4. Zenda Plateau.

Image 5. Zenda Plateau during the monsoon season.

Image 6. During the eight months plateaus are dry, but possess therophytic communities of endemic plants which are less studied. (Zenda Plateau, Kolhapur) during dry conditions.
METHODS

Maharashtra possesses characteristic habitats called high level plateaus (Watve 2007). Many of them represent lateritic, basaltic as well as sandy characteristics. Of the four plateaus which were found least disturbed, the ones representing basalt and laterite were selected for the said research. All of these are located in the Western Ghats at Pune and Kolhapur regions. These were specifically selected after referencing existing literature and after conducting several field surveys.

GIS mapping – tools and techniques

The research area was surveyed extensively to mark the boundaries of the plateaus. Exact latitudes and longitudes were recorded and marked by using Garmin 5 handheld GPS. These lat-long values were then calibrated with Google Earth version 6.2 (http://www.Google.com/earth/index.html) to get .kmz images as a reference database. For freshly captured images, satellite data was procured from NRSC, Hyderabad. The data was further used to mark each microhabitat at each plateau (Table 1) on ArcGIS and ERDAS 9.1 platform. Each plateau as well as each microhabitat was GIS marked.

In all, three field study visits were carried out during different seasons: pre-monsoon (March–May), monsoon (June–October), and winter (November–February) to understand the seasonal variations from 2013 to 2017.

Sampling and analysis of soil and rock

Rock and soil sampling was done from the microhabitats marked using GIS; wherever soil was accumulated in microhabitats soil samples were collected from 100cm depth. For habitats like boulders and exposed rock surfaces, the intact rocks were broken and samples were collected. These samples were analyzed using x-ray fluorescence spectrophotometry (XRF). It is a non-destructive analytical technique used to determine the elemental composition of materials. XRF analyzers determine the chemistry of a sample by measuring the fluorescent (or secondary) x-ray emitted from a sample when it is excited by a primary x-ray source. The method is used extensively to analyze trace and major elements of rock as well as soil in a powdered form. Nutrients, Nitrogen by Kjeldahl's method and organic Carbon by Walkley & Black method. The data of XRF analysis is heterogeneously distributed over 50 elements around two rock types from four locations distributed over 10–11 microhabitats. Dimensions of which are $2^*4^*11^*50$ and types of measurements are percentage and part-per-million.

The statistical analysis was carried out using R v.3.3.3 and ggplot2 v.2.2.0 package.

| Microhabitat                  | Durgawadi | Naneghat | Amba | Zenda |
|------------------------------|-----------|-----------|------|-------|
| Cliffs                       | Rock      | Rock      | Rock | Rock  |
| Exposed rock surfaces        | Rock      | Rock      | Rock | Rock  |
| Ephemeral pools              | Soil      | Soil      | Soil | Soil  |
| Sacred groves               | Soil      | Soil      | NA   | NA    |
| Soil covered areas          | Soil      | Soil      | Soil | Soil  |
| Seasonal ponds              | Soil      | Soil      | Soil | Soil  |
| Rock crevices               | Rock      | Rock      | Rock | Rock  |
| Boulders                   | Rock      | NA        | Rock | Rock  |
| Soil richareas              | Soil      | Soil      | Soil | Soil  |
| Soil filled depressions     | Soil      | Soil      | Soil | Soil  |
| Plateau tree cover          | Soil      | Soil      | Soil | Soil  |
and major elements (Table 2). Kjeldahl’s and Walkley & Black methods were used for nutrients like Nitrogen and organic Carbon, respectively. Multivariate statistical analysis was done using software like PAST and R. This was done to understand correlation among elements, microhabitats and plant communities as well as plateaus (Shtangieva & Alber 2009). Interrelationship among elements was also identified. Table 1 shows the details of the samples collected and processed.

RESULTS AND DISCUSSION

The multivariate analysis of variance (MANOVA) was carried out between the selected elements of plants and rocks across four regions (Durgawadi, Naneghat, Amba, and Zenda) for 10 nutrient elements. The p-values were estimated using multivariate Pillai–Bartlett test statistic.

The overall MANOVA, carried out across all the regions, indicated a significant difference in the content of all the nutrient elements between rocks and plants (p-value = 2.2e-16; <0.001) (Fig. 1).

In the case of Durgawadi region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.795e-12; <0.001). Further investigations revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Durgawadi (Fig. 2) plateau.

Similar to Durgawadi, the Naneghat region also showed a significant difference in the content of nutrient elements between rocks and plants (p-value = 4.761e-09; < 0.001). However, Copper did not contribute significantly towards the differences between rocks and plants in the Naneghat (Fig. 3) region.

When Amba region was analysed using MANOVA it revealed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 5.667e-10; <0.001). Further investigation revealed that except Zinc, all other elements significantly contributed towards the differences in nutrients of rocks and plants in the Amba region, which is similar to Durgawadi (Fig. 4).

In case of Zenda region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.31e-06; <0.001). Closer inspection showed that the elements Calcium, Manganese, Zinc and Copper did not contribute towards the significant differences in plants and rocks of Zenda region (Fig. 5). It shows that the nutrient profiles of plant and rocks in Zenda region is characteristically different from other regions.

MANOVA between Plants and Rocks

The Multivariate Analysis of Variance (MANOVA) was carried out between plants and rocks across four regions (Durgawadi, Naneghat, Amba and Zenda) for ten nutrient elements. The p-values were estimated using multivariate Pillai–Bartlett test statistic.

In case of the Durgawadi region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.795e-12; <0.001). Further investigation revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Durgawadi (Fig. 1: Durgwadi_manova_boxplot.png) region.

Similar to Durgawadi, the Naneghat region also showed significant difference in the content of nutrient elements between rocks and plants (p-value = 4.761e-09; < 0.001). However, Copper did not contribute significantly towards the differences between rocks and plants in the Naneghat (Fig. 2: Naneghat_manova_boxplot.png) region.

When Amba region was analyzed using MANOVA it revealed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 5.667e-10; <0.001). Further investigation revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Amba region, which

Table 2. Selection of elements for XRF and nutrient analysis of ephemeral plants.

| Type of element | Name of the element | Reason for selection | Method of estimation |
|-----------------|---------------------|----------------------|---------------------|
| Nutrients       | Organic Carbon, Nitrogen, Phosphorous, Potassium | Essential nutrients | OC (Walkley & Black), Nitrogen (Kjeldahl’s), Phosphorous & Potassium (XRF) |
| Major elements  | Calcium, Magnesium, Iron, Manganese | Selected as per t-test results across the regions | XRF method |
| Trace elements  | Zinc, Copper        | Selected as per t-test results across the regions | XRF method |
Figure 1. The variation of nutrient elements between rocks and plants in the Durgawadi region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).
Figure 2. The variation of nutrient elements between rocks and plants in the Naneghat region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).
Figure 3. The variation of nutrient elements between rocks and plants in Amba region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).
Figure 4. The variation of nutrient elements between rocks and plants in Zenda region. The p-values were estimated using multivariate Pillai–Bartlett test statistic (MANOVA).
Figure 5. The overall variation of nutrient elements between rocks and plants in all the regions (Durgawadi, Naneghat, Amba Zenda). The p-values were estimated using multivariate Pillai–Bartlett test statistic (MANOVA).
is similar to Durgawadi (Fig. 3: Amba_manova_boxplot.png).

In case of Zenda region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.31e-06; <0.001). Closer inspection shows that the elements Calcium, Manganese, Zinc and Copper do not contribute towards the significant differences in plants and rocks of Zenda region (Fig. 4: Zenda_manova_boxplot.png). It shows that the nutrient profiles of plant and rocks in Zenda region is characteristically different from the other regions.

The overall MANOVA, carried out across all the regions, also indicated the significant difference in the content of all the nutrient elements between rocks and plants (p-value = 2.2e-16; < 0.001) (Fig. 5: Combined_manova_boxplot.png).

CONCLUSION

The overall results show that nutrients, trace and major elements under study in all four selected plateaus are significantly different. The Zenda Plateau, the least disturbed plateau in all four plateaus, shows characteristically different nutrient and element content. As Calcium, Manganese, Zinc, and Copper do not contribute towards significant differences in plants and rocks of Zenda region. Each of these areas is different and needs to be studied in detail to understand the dynamics of the ecosystem. Except Zinc, similarity was observed in all elements when samples were analyzed from rocks as well as plants at Durgawadi– Basalt and Amba-Lateritic plateaus. For understanding the causes of such similarities more such studies are needed. The environmental exceptionality, high diversity, lack of studies and speedy destruction of these ecosystems pose an abrupt challenge for their conservation. These should not be considered as wastelands as they are ecologically significant and a hold scientifically unknown facts.

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Appendix 1. Species recorded from four plateaus.

| Species | Family | Durgawadi microhabitat | Naneghat microhabitat | Amba microhabitat | Zenda microhabitat |
|---------|--------|------------------------|-----------------------|-------------------|-------------------|
| Acanthospermum hispidum DC. | Asteraceae | - | CE | - | - |
| Acmella paniculata (Wall. ex DC.) R.K. Jansen | Asteraceae | - | SC | - | - |
| Adenocoryza coestrum (Lindl.) Brand | Commelinaceae | + | SC | - | SC |
| Adenoom indicum Dalzell | Araceae | - | - | - | SFD |
| Adiantum sp. | Adiantaceae | - | - | - | B |
| Alysicarpus belgaumensis Wight | Fabaceae | - | - | - | SFD |
| Antracon jubata Hack | Poaceae | CE, SC, PTC | CE, SC, PTC | - | CE, SC, PTC |
| Antracon lanceolatus var. meeboldi (stapf) welzen | Poaceae | - | - | - | SFD |
| Argemone mexicana L. | Papaveraceae | - | - | - | - |
| Argyrea cuneata Ker Gawl. | Convolvulaceae | SG | - | PTC | - |
| Argyrea sericea Dalzell | Convolvulaceae | SG | SG | - | PTC |
| Arisaeana murrayi (Graham) Hook. | Araceae | SRA,B | SRA,B | SRA,B | SRA,B |
| Arundinella ciliata | Poaceae | - | SFD | - | - |
| Arundinella pumila (Hochst. ex A. Rich.) Steud | Poaceae | - | - | SRA | - |
| Asystasia dalzelliana Sant. | Acanthaceae | CE, RC, SG | CE, RC, SG | CE, RC | CE, RC |
| Begonia crenata Dryand. | Begoniaceae | CE, B | CE, B | CE, B | CE, B |
| Bidens bennetata (Lour.) Merr. & Sherff. | Asteraceae | - | ERS | - | - |
| Biophytum sensitivum | Oxalidaceae | SRA | - | - | - |
| Biophytum sensivum (L.) DC. | Oxalidaceae | SRA | - | - | - |
| Bilephasis maderaspatsensis B. Heyne ex Roth | Acanthaceae | - | ERS, RC | - | - |
| Blumea malcolmii Hook.f. | Asteraceae | CE, RC | CE, RC | CE, RC | CE, RC |
| Buchnera hispida Buch.-Ham. | Scrophulariaceae | SCA | - | - | - |
| Burmannia coelestis | Burmanniaceae | - | - | SRA | - |
| Canscora diffusa (Vahl.) R. Br. ex Roem. & Schult. | Gentianaceae | CE, RC | CE, RC | CE, RC | CE, RC |
| Carvia callosa (Nees) Bremerk. | Acanthaceae | - | B, SG, SCA | - | - |
| Catharanthus pusillus (Murr.) G.Don | Apocynaceae | - | ERS,SRA | - | - |
| Celosia argentea L | Amaranthaceae | B, CE | CE | B, CE | - |
| Ceropogia roilae Hemadri | Asclepiadaceae | RC, SFD | - | - | RC, SFD |
| Chlorophytm glaucoidez Blatt. | Anthericaceae | SRA | - | - | SRA |
| Chlorophytm laxum R.Br. | Anthericaceae | - | SCA | - | - |
| Chrysopogon polyphyllus Blatt. & Mc.C. | poaceae | SCA | SCA | - | - |
| Commelina benghalensis L. | Commelinaceae | SCA, RC, SFD | SCA, RC, SFD | - | SC, RC, SFD |
| Commelina maculata Edgew. | Commelinaceae | - | - | SCA | - |
| Commelina paludosa Blume | Commelinaceae | - | - | SCA | - |
| Commelina suffrutcosa Blume | Commelinaceae | - | SCA | - | - |
| Conyza stricta Wild. | Asteraceae | - | - | SRA | - |
| Cosmos bipinnatus Cav. | Asteraceae | ERS | - | - | - |
| Crinum latifolium L. var. latifolium | Amaryllidaceae | SRA | - | SFD | SFD |
| Crinum pratense Herb. | Amaryllidaceae | - | - | SCA, SFD, RC | - |
| Crotolaria filipes Benth. | Fabaceae | - | SFD | - | - |
| Curcuma pseudomontana Grah. | Zingiberaceae | SG,SRA | SG,SRA | SRA | SRA |
| Cyanotis fasciculata (Heyne ex Roth) Schult.f. | Commelinaceae | RC, SCA | RC, SCA | RC, SCA | - |
| Cyanotis tuberosa (Roehb.) Schult.f. var. tuberosa | Commelinaceae | SRA | SRA | - | SRA |
| Cyathocline lutea Law ex Wight | Asteraceae | SEP, SCA | - | - | - |
| Cynodon dactylon (L.) Pers. | poaceae | SRA | - | - | - |
| Cyperus diffomis L. | Cyperaceae | SEP, SP | - | - | - |
| Cyperus rotundus L. | Cyperaceae | SRA | - | SRA | SRA |
| Cyperus tenuisipica Steud. | Cyperaceae | SEP, SP | - | - | SRA, SP |
| Species                    | Family         | Durgawadi microhabitat | Naneghat microhabitat | Amba microhabitat | Zenda microhabitat |
|---------------------------|----------------|------------------------|-----------------------|-------------------|-------------------|
| Delphinium malabaricum    | Ranunculaceae  | CE, SG                 | CE, SG                |                | CE                |
| Desmodium triflorum       | Fabaceae       | -                      | -                     | SCA               | -                 |
| Digitaria stricta         | poaceae        | -                      | -                     | SFD               | -                 |
| Drimia indica             | Hyacinthaceae  | ERS                    | ERS                   | -                 | -                 |
| Drosera indica L.         | Droseraceae    | SCA, SEP               | SCA, SEP              | SCA, SEP          | SCA, SEP          |
| Elephantopus scaber L.    | Asteraceae     | -                      | PTC                   | PTC               | PTC               |
| Emilia sonchufolio        | Asteraceae     | -                      | SFD                   | -                 | -                 |
| Eragrostis unioloides     | Poaceae        | SCA                    | SCA                   | SCA               | SCA               |
| Eriocalon achiiton Korn   | Eriocalaceae   | ERS                    | -                     | -                 | ERS               |
| Eriocalon eurypepalon Korn| Eriocalaceae   | -                      | -                     | -                 | -                 |
| Eriocalon sedgwickii Korn | Eriocalaceae   | SEP, SP                | SEP, SP               | -                 | SEP, SP           |
| Euphorbia thymifolia L.   | Euphorbiaceae  | -                      | ERS                   | -                 | -                 |
| Eulovivulus aslinoides L. | Poaceae        | -                      | ERS, SCA              | SFD               | -                 |
| Exacum lawii C.B. Clarke  | Gentianaceae   | SCA, SFD               | SCA, SFD              | SCA, SFD          | SCA, SFD          |
| Fimbristylus lawiana L.J.Kern | Cyperaceae   | SRA                    | SRA                   | SRA               | SRA               |
| Fimbristylis tenera Schult | Cyperaceae     | -                      | -                     | -                 | CR, SFD           |
| Gloriosa superba L.       | Colchicaceae   | SCA, SG                | -                     | -                 | -                 |
| Glyphaetos perlucilata C.E.C. Fischer | Poaceae | SFD                   | SFD                   | -                 | SFD               |
| Gymura bicolor (Roxb. ex Wild. ) DC. | Asteraceae | -                      | SFD, CE               | SFD, CE           | -                 |
| Habenaria foliosa A. Rich var. foliosa | Orchidaceae | SRA                    | SRA                   | -                 | SRA               |
| Habenaria grandifloriformis Blatt. & McC. | Orchidaceae | SCA                    | SCA                   | -                 | SCA               |
| Habenaria heyneana Lindl. | Orchidaceae   | SCA                    | SCA                   | SCA               | SCA               |
| Habenaria longicorniculata J.Graham | Orchidaceae | -                      | -                     | SRA               | -                 |
| Habenaria pangchongmosens Santapau & Kapadia | Orchidaceae | -                      | -                     | -                 | RC                |
| Habenaria rariflora A.Rich | Orchidaceae   | SCA                    | SCA                   | SCA               | SCA               |
| Hedysitis aspera Heyne ex Roth | Rubiaceae | SCA                    | -                     | -                 | -                 |
| Hedysitis stockii (Hook.f. & Thomson) R.S.Rao & Hemadri | Rubiaceae | -                      | Naneghat             | -                 | ERS, B            |
| Heliotropium indicum L.   | Boraginaceae   | -                      | SRA                   | -                 | -                 |
| Hypoxis aurea Lour        | Hypoxidaceae   | SRA                    | SRA                   | SRA               | SRA               |
| Impatients azaulas Arn.   | Balsaminaceae  | -                      | -                     | -                 | -                 |
| Impatients balsamina L.   | Balsaminaceae  | SRA, SFD               | SRA, SFD              | SRA, SFD          | SRA, SFD          |
| Impatients lawii Hook. f. & Thomson | Balsaminaceae | SFD, RC                | SFD, RC               | SFD, RC           | SFD, RC           |
| Impatients minor (DC.) Bennet | Balsaminaceae | RC, SG                 | -                     | RC                | RC                |
| Impatients oppositifolia L. | Balsaminaceae | SFD                   | SFD                   | SFD               | SFD               |
| Indigofera dalzellii T. Cooke | Fabaceae | -                      | -                     | SFD, CR           | SFD, CR           |
| Iphegenia indica (L.) A.Gray ex Kunth | Colchicaceae | SCA                    | -                     | -                 | -                 |
| Iphegenia stellata Blatt. | Colchicaceae   | SCA                    | SCA                   | SCA               | -                 |
| Isachne elegans Dalz. ex Hook.f. | Poaceae | SCA                    | -                     | -                 | SCA               |
| Jansenella graftiflora (M.II.Hal) Bor | Poaceae | -                      | SFD                   | SFD               | -                 |
| Jansenella neglecta Yadav, Chivalkar & Gosavi | Poaceae | SCA                    | -                     | -                 | SCA               |
| Justicia betonica L.      | Acanthaceae    | SRA, SG                | SRA, SG               | -                 | SRA               |
| Justicia glaucesc Rottl.  | Acanthaceae    | SRA, SG                | SRA, SG               | -                 | SRA               |
| Lavandula bipinnata Kuntze | Lamiaeae      | ERS                    | ERS                   | -                 | ERS               |
| Linum mysurensis B. Heyne ex Benth. | Linaceae | SCA                    | -                     | SFD               | SFD               |
| Momordica dioica Wall.    | Cucurbitaceae  | RC, SFD                | RC, SFD               | RC, SFD           | SFD               |
| Murdannia lanuginosa G. Brückn | Commelinaceae | -                      | -                     | -                 | RC                |
| Murdannia semiteres (Dalzell) Santapau | Commelinaceae | ERS                    | ERS                   | ERS               | ERS               |

**Journal of Threatened Taxa | www.threatenedtaxa.org | 26 August 2019 | 11(10): 14334–14348 | 14347**
| Species                                                                 | Family          | Durgawadi microhabitat | Naneghat microhabitat | Amba microhabitat | Zenda microhabitat |
|------------------------------------------------------------------------|-----------------|------------------------|------------------------|-------------------|-------------------|
| 95 Murdannia simplex (Vahl) Brenan                                     | Commelinaceae   | -                      | -                      | SFD               | -                 |
| 96 Murdannia spirata L.                                                 | Commelinaceae   | -                      | -                      | ERS               | ERS               |
| 97 Murdannia versicolor G. Brückn.                                      | Commelinaceae   | -                      | -                      | SFD, SCA          | RC                |
| 98 Neoaea calycina (Wall. ex Hook.f.) W.H. Lewis                       | Rubiaceae       | SRA, RC, SFD           | SRA, RC, SFD           | SRA, RC, SFD      | SRA, RC, SFD      |
| 99 Neomaxa foetida (Dalzell) W.H. Lewis                                | Fabaceae        | SCA                    | SCA                    | SCA               | SCA, SRA          |
| 100 Nervilia aragoana Gaudich.                                          | Orchidaceae     | -                      | -                      | -                 | Amba              |
| 101 Nicandra physaloides (L.) Gaertn.                                   | Solanaceae      | SRA                    | SRA                    | -                 | SRA               |
| 102 Nilgirianthus reticulatus (Stapf) Bremek.                           | Acanthaceae     | CE, SRA                | CE, SRA                | SRA               | CE, SRA           |
| 103 Nilgirianthus reticulatus (Stapf) Bremek.                           | Acanthaceae     | -                      | -                      | -                 | -                 |
| 104 Nymphoides indica (L.) Kunze                                       | Menyanthaceae   | SP                     | -                      | -                 | SP                |
| 105 Panicum antidotale Retz.                                            | Poaceae         | SRA                    | SRA                    | SRA               | SRA               |
| 106 Paspalum canareae (Steud.) Veldk. var. canareae                   | Poaceae         | ERS, SFD               | ERS                    | ERS               | SFD               |
| 107 Pimpinella adsendens Dalzell                                       | Apiaceae        | RC, CE                 | RC, CE                 | RC, CE            | RC, CE            |
| 108 Pinda concanensis (Dalzell) P.K.Mukh. & Constance                  | Apiaceae        | SFD, SCA               | SFD, SCA               | -                 | SFD, SCA          |
| 109 Pogostemon decanensis (Panigrahi)                                  | Lamiaceae       | SP                     | SP                     | SP                | SP                |
| 110 Remusatia vivipara (Rosx) Schott                                   | Araceae         | SFD, SG                | -                      | -                 | SFD               |
| 111 Rhamphicarpa longiflora bentth.                                     | Scrophulariaceae| SP, SEP                | SP, SEP                | SP, SEP           | -                 |
| 112 Rostellaria diffusa (Nees.) Nees                                    | Acanthaceae     | -                      | -                      | -                 | -                 |
| 113 Rotala densiflora Koehne                                           | Lythraceae      | SP, SEP                | SP, SEP                | SP, SEP           | SP, SEP           |
| 114 Senecio bombayensis N.P. Balakr.                                    | Asteraceae      | CE, RC, SFD            | CE, RC, SFD            | CE, RC, SFD       | CE, RC, SFD       |
| 115 Senecio dalzellii C.B. Cl.                                          | Fabaceae        | SCA, SFD, RC           | SCA, SFD, RC           | SCA, SFD, RC      | SCA, SFD, RC      |
| 116 Smithia bigemina Dalzell                                           | Fabaceae        | SCA                    | SCA                    | SCA               | SCA               |
| 117 Smithia hirsuta Dalzell                                            | Fabaceae        | SCA                    | SCA                    | SCA               | SCA               |
| 118 Smithia purpurea Hook                                               | Fabaceae        | SRA, SEP, RC,          | SRA, SEP, RC           | -                 | -                 |
| 119 Smithia racemosus B. Heyne                                         | Fabaceae        | SRA                    | SRA                    | SRA               | SRA               |
| 120 Smithia sensitiva Aiton                                             | Fabaceae        | SRA                    | SRA                    | -                 | SRA               |
| 121 Solanum anguivi Lam.                                               | Solanaceae      | SCA                    | -                      | SCA               | SCA               |
| 122 Sonerila scopigera Dalzell                                         | Melastomataceae | B, RC                  | B, RC                  | B, RC             | B, RC             |
| 123 Sopubia delphinifolia G. Don                                       | Scrophulariaceae| SP, SEP                | SP, SEP                | SP, SEP, SCA      | SP, SEP, SCA      |
| 124 Sphacanthus indicus L                                               | Asteraceae      | -                      | -                      | -                 | -                 |
| 125 Striga gesnerioides (Wild.) Vatke                                   | Scrophulariaceae| SCA                    | -                      | -                 | SCA               |
| 126 Swertia densifolia (Griseb.) Kashyapa                               | Gentianaceae    | SRA, SFD               | -                      | -                 | SRA, SFD          |
| 127 Swertia minor Knoeb.                                                | Gentianaceae    | SCA, SEP               | SCA, SEP               | SCA, SEP          | SCA, SEP          |
| 128 Thunbergia laevis Wall. & Nees                                      | Acanthaceae     | SRA, SG                | SRA, SG                | -                 | SRA, SG           |
| 129 Torenia indica C.J. Saldantha                                      | Scrophulariaceae| PTC                    | -                      | -                 | PTC               |
| 130 Utricularia graminifolia Vahl                                       | Lentibulariaceae| SP, SEP                | -                      | SEP               | -                 |
| 131 Utricularia praeterea P. Taylor                                     | Lentibulariaceae| -                      | -                      | -                 | SP, SEP           |
| 132 Utricularia purpurescens Grah.                                      | Lentibulariaceae| SP, SEP, B,            | SP, SEP, B,            | SP, SEP, B,       | SP, SEP, B,       |
| 133 Utricularia striatula J.E. Sm.                                      | Lentibulariaceae| SP, SEP                | SP, SEP                | SP, SEP           | SP, SEP           |
| 134 Vigna vexillata (L.) A.Rich                                        | Fabaceae        | SFD, RC, SCA           | SFD, RC, SCA           | SFD, RC, SCA      | SFD, RC, SCA      |
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The status of waterbird populations of Chhaya Rann Wetland Complex in Porbandar, Gujarat, India – Dhwalkumar Vargiya & Anita Chakraborty, Pp. 14268–14278

Diversity and temporal variation of the bird community in paddy fields of Kadhiramangalam, Tamil Nadu, India – Chaitara Shree Jayasimhan & Padmanabhan Pramod, Pp. 14279–14291

First videos of endemic Zanzibar Servaline Genet Genetta servalina archeri, African Palm Civet Nandinia binotata (Mammalia: Carnivora: Viverridae) and other small carnivores on Unguja Island, Tanzania – Helle V. Goldman & Martin T. Walsh, Pp. 14292–14300

The identification of pika and hare through tricho-taxonomy (Mammalia: Lagomorpha) – Manokaran Kamalakannan, Kailash Chandra, Joy Krishna De & Chinnadurai Venkatraman, Pp. 14301–14308

Palynological analysis of faecal matter in African Forest Elephants Loxodonta cyclotis (Mammalia: Proboscidea: Elephantidae) at Omo Forest Reserve, Nigeria – Okwong John Walter, Olusola Helen Adekamibi & Omonu Clifford, Pp. 14309–14317

Avitourism opportunities as a contribution to conservation and rural livelihoods in the Hindu Kush Himalaya - a field perspective – Nishikant Gupta, Mark Everard, Ishaan Kochhar & Vinod Kumar Belwal, Pp. 14318–14327

Pollination in an endemic and threatened non-oecious herb Begonia satrapis C.B. Clarke (Begoniaceae) in the eastern Himalaya, India – Subhankar Gurung, Aditya Pradhan & Arun Chettri, Pp. 14328–14333

Multivariate analysis of elements from the microhabitats of selected plateaus in the Western Ghats, Maharashtra, India – Prit Vinayak Aphaile, Dhananjay C. Meshram, Dyanesh M. Mahajan, Prasad Anil Kulkarni & Shraddha Prasad Kulkarni, Pp. 14334–14348

Diversity of butterflies of the Shettihalli Wildlife Sanctuary, Shivamogga District, Karnataka, India – M.N. Harisha, Harish Prakash, B.B. Hosetti & Vijaya Kumara, Pp. 14349–14357

First record of two rare brachyuran crabs: Drachiella mormarata and the Asiatic Golden Cat Catopuma temminckii (Mammalia: Carnivora: Felidae) from the community forests surrounding the Dzükou Valley in Nagaland, India – Bhavendu Joshi, Biang La Nam Syiem, Rokohebi Kuotsu, Arjun Menon, Jayanta Gogoi, Varun Rshav Goswami & Divya Vasudev, Pp. 14363–14367

Diversity of butterflies of the eastern Ghats of Tamil Nadu, India – Kothandapani Raman, Sivangnanabooathipposs Vimalraj, Bawa Mothilal Krishnakumar, Natesan Balachandran & Abhishek Tomar, Pp. 14373–14376

Some recent evidence of the presence of the Critically Endangered Gyps vulture populations in northern Shan State, Myanmar – Sai Sein Lin Oo, Nang Lao Kham, Kyaw Myo Naing & Swen C. Renner, Pp. 14377–14380

Two new locations for the Vulnerable Black-necked Crane Grus nigricollis (Przewalsky, 1876) (Aves: Gruiformes: Gruidae) in Arunachal Pradesh, India – Rohan Krish Menzies, Megha Rao & Abhinav Kumar, Pp. 14381–14384

Aquilaria malaccensis (Malvales: Thymelaeaceae): a new host plant record for Deudorix epijarbas cinnabarus (Lepidoptera: Lycaenidae) in Malaysia – Kah Hoo Lau & Su Ping Ong, Pp. 14385–14387

Rediscovery of Nilgiri Mallow Abutilon neelgerrense var. fischeri T.K. Paul & M.P. Nayar (Malvaceae) after a century from southern India – Varsha Vilasrao Nimbalkar, Arun Prasanth Ravichandran & Milind Madhav Sardesai, Pp. 14388–14390

Communications

Species diversity and spatial distribution of amphibian fauna along the altitudinal gradients in Jigme Dorji National Park, western Bhutan – Bal Krishna Koirala, Karma Cheda & Tshering Penjor, Pp. 14249–14258

First videos of endemic Zanzibar Servaline Genet Genetta servalina archeri, African Palm Civet Nandinia binotata (Mammalia: Carnivora: Viverridae) and other small carnivores on Unguja Island, Tanzania – Helle V. Goldman & Martin T. Walsh, Pp. 14292–14300

The identification of pika and hare through tricho-taxonomy (Mammalia: Lagomorpha) – Manokaran Kamalakannan, Kailash Chandra, Joy Krishna De & Chinnadurai Venkatraman, Pp. 14301–14308

Palynological analysis of faecal matter in African Forest Elephants Loxodonta cyclotis (Mammalia: Proboscidea: Elephantidae) at Omo Forest Reserve, Nigeria – Okwong John Walter, Olusola Helen Adekamibi & Omonu Clifford, Pp. 14309–14317

Avitourism opportunities as a contribution to conservation and rural livelihoods in the Hindu Kush Himalaya - a field perspective – Nishikant Gupta, Mark Everard, Ishaan Kochhar & Vinod Kumar Belwal, Pp. 14318–14327

Pollination in an endemic and threatened non-oecious herb Begonia satrapis C.B. Clarke (Begoniaceae) in the eastern Himalaya, India – Subhankar Gurung, Aditya Pradhan & Arun Chettri, Pp. 14328–14333

Multivariate analysis of elements from the microhabitats of selected plateaus in the Western Ghats, Maharashtra, India – Prit Vinayak Aphaile, Dhananjay C. Meshram, Dyanesh M. Mahajan, Prasad Anil Kulkarni & Shraddha Prasad Kulkarni, Pp. 14334–14348

Notes

Range extension of the Gooty Tarantula Poecilotheria metallica (Araneae: Theraphosidae) in the Eastern Ghats of Tamil Nadu, India – Kothandapani Raman, Sivangnanabooathipposs Vimalraj, Bawa Mothilal Krishnakumar, Natesan Balachandran & Abhishek Tomar, Pp. 14373–14376

Some recent evidence of the presence of the Critically Endangered Gyps vulture populations in northern Shan State, Myanmar – Sai Sein Lin Oo, Nang Lao Kham, Kyaw Myo Naing & Swen C. Renner, Pp. 14377–14380

Two new locations for the Vulnerable Black-necked Crane Grus nigricollis (Przewalsky, 1876) (Aves: Gruiformes: Gruidae) in Arunachal Pradesh, India – Rohan Krish Menzies, Megha Rao & Abhinav Kumar, Pp. 14381–14384

Aquilaria malaccensis (Malvales: Thymelaeaceae): a new host plant record for Deudorix epijarbas cinnabarus (Lepidoptera: Lycaenidae) in Malaysia – Kah Hoo Lau & Su Ping Ong, Pp. 14385–14387

Rediscovery of Nilgiri Mallow Abutilon neelgerrense var. fischeri T.K. Paul & M.P. Nayar (Malvaceae) after a century from southern India – Varsha Vilasrao Nimbalkar, Arun Prasanth Ravichandran & Milind Madhav Sardesai, Pp. 14388–14390

Short Communications

Diversity of butterflies of the Shettihalli Wildlife Sanctuary, Shivamogga District, Karnataka, India – M.N. Harisha, Harish Prakash, B.B. Hosetti & Vijaya Kumara, Pp. 14349–14357

First record of two rare brachyuran crabs: Drachiella mormarata and the Asiatic Golden Cat Catopuma temminckii (Mammalia: Carnivora: Felidae) from the community forests surrounding the Dzükou Valley in Nagaland, India – Bhavendu Joshi, Biang La Nam Syiem, Rokohebi Kuotsu, Arjun Menon, Jayanta Gogoi, Varun Rshav Goswami & Divya Vasudev, Pp. 14363–14367

Rediscovery of Calanthe daviddii (Orchidaceae) after 11 decades in the western Himalaya, India – Ashutosh Sharma, Nidhan Singh & Pankaj Kumar, Pp. 14368–14372