Contributions of vulnerable hydrogeomorphic habitats to endemic plant diversity on the Kas Plateau, Western Ghats

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Abstract

Background: The Western Ghats of India are known to be a major biological hotspot that supports plant diversity and endemism. On the Kas Plateau, a lateritic plateau of the northern Western Ghats, we examined mesoscale distributions of endemic, rare, or locally significant plant species in forest habitats or on the plateau and its escarpments, and assessed the edaphic and hydrological parameters of seasonal plateau microhabitats.

Findings: Almost two thirds of over 100 phytogeographically significant species occur on the plateau top; these represent 26 plant families and 43 genera. About 80% of the species are restricted to the upper plateau and its escarpments.

Conclusion: Since botanically critical plateau habitats are generally small, dependent on seasonal monsoon moisture, and determined by drainage-related parameters that can be altered by anthropogenic activities, they are highly vulnerable. Maintenance of appropriate microhabitats should be a key consideration for conservation of regionally significant plant biota.

Keywords: Lateritic plateau, Endemism, Microhabitats, Seasonal habitats, Biological hotspots

Background

Biological “hotspots” (Reid 1998; Myers et al. 2000; Anand et al. 2010) have captured considerable public attention since conservation biologists first proposed the concept. The Western Ghats, or Sahyadri Mountains, which represent the edge of the Deccan Plateau of western India, are among the well-known global hotspots recognized for exceptional biotic diversity and endemism (Chandran 1997; Daniels 1997; Mittermeier et al. 1999; Myers et al. 2000; Padhye and Ghate 2002; Wawte 2003; Bossuyt et al. 2004; Punekar and Kumaran 2005; Gunawardene et al. 2007; Daniels and Vencatesan 2008) accompanied by an alarming level of habitat loss (Davadar et al. 2007; Panigrahy et al. 2010). Due to their exceptional biota, the Western Ghats have recently been recognized by UNESCO as a World Heritage Site (United Nations Educational, Scientific, and Cultural Organization 2012).

Most conservation attention has focused on the forested regions of the Western Ghats, where recent estimates suggest that less than 7% of the original forest habitat remains (Davadar et al. 2007; Panigrahy, Kale, Dutta et al. 2010; Anand et al. 2010) while agricultural expansion and extraction of resources continue to threaten the native biota (Cincotta et al. 2000; Davadar et al. 2007). In addition to the remaining forested areas, the northern Western Ghats also encompass higher plateau tablelands that have received less conservation attention (Wawte 2003; Porembski and Wawte 2005), although studies suggest these ecological subsets of the Western Ghats mega-hotspot provide their own noteworthy and unique biological components such as uncommon vegetation (Porembski and Wawte 2005; Lekhak and Yadav 2012), new species (Yadav et al. 2008; Malpure and Yadav 2009; Randive and Punekar 2011), endemism (Wawte 2003; Joshi and Janar thanam 2004) or complex pollination interactions (Hobbhahn et al. 2006). While less heavily impacted than the forests, the plateaus are also subject to uses such as grazing, mineral extraction, and increasingly, tourist
visitation, all of which are activities with high potential to alter and degrade habitats.

Our study examined botanically significant habitats on the Kas Plateau of the northern Western Ghats (Satara district, Maharashtra State). Like other plateaus of the Western Ghats known for their rare flora (Joshi and Janarthanam 2004; Punekar and Kumaran 2005), the upper Kas Plateau is capped with red lateritic crusts (Wavve 2003; Ollier and Sheth 2008) that provide arid habitats except during the monsoon season. The Kas Plateau receives over 2000 mm of rain per year, mainly from June to September, and daily mean temperatures are over 22°C (Hobbhahn et al. 2006). These monsoonal rains have been recognized as a critical impetus for the appearance and flowering of endemic herbaceous taxa and ephemeral flush communities (Porembski and Wavve 2005) on comparable edaphic islands throughout the tropics and other Western Ghat plateaus (Wavve 2003; Joshi and Janarthanam 2004, Lekhak and Yadav 2012).

The Kas Plateau region, covering ca. 1800 ha in total, encompasses several mesoscale habitat types. On the plateau top (ca. 13 km² at 1200 m asl), variation in seasonal moisture inhibits growth of woody species that otherwise comprise the lower forest communities, allowing the plateau vegetation to be primarily herbaceous, where members of the Acanthaceae, Poaceae, Cyperaceae, Eriocaulaceae, Lentibulariaceae and Balsaminaceae (Wavve 2003, Joshi and Janarthanam 2004; Dessai and Janarthanam 2011) are prominent. Although monocots dominate the vegetation, topographic, hydrological and edaphic heterogeneity promote overall floristic diversity and endemism in both Monocots and Dicots. Kas Lake, the only major aquatic habitat, is an artificial reservoir situated at ca. 800 m in a valley within the plateau region. Additional major habitats include the rocky escarpment just below the plateau (Figure 1) that intergrades into subtropical broadleaf hill forests (Mishra and Singh 2001).

The objective of this study was to assess the relative significance of small-scale plateau and forest habitats for plant diversity, in particular, as critical habitats for endemic and rare plant species. Previous studies elsewhere in the Western Ghats (Joshi and Janarthanam 2004, Lekhak and Yadav 2012) have suggested that significant plant biota on the plateau tops are linked to the seasonal appearance of habitats created by monsoon moisture. In particular, the Ephemeral Flush Vegetation (EFV) that occurs on a broad scale across the expanse of rocky areas where moisture seeps through the soil during the wet months and shapes expanses of a short term meadow-like community (Porembski and Wavve 2005; Wavve 2008) has been recognized as a signature component of the Western Ghat plateaus. Beyond the EFV meadows, however, the edaphic matrix of the plateau top provides smaller scale habitats with hydrogeomorphic anomalies that support significant plant taxa in restricted spaces. Using the Kas region as a model lateritic plateau, we assessed its significant flora and habitats at two scales: mesoscale distributions in major ecological zones of the plateau and its subtending slopes, and microscale distributions on the plateau in seasonal habitats defined by hydrogeomorphic parameters that included moisture content, short term or seasonal water retention capacity, soil profile, topographic variation (e.g. crevice, depression, elevated tableland), soil depth, soil texture, and micro-elevational gradients. On the mesoscale level, we further defined forests as Protected (those with greater than 50% of the land still covered by trees and under active management by the Indian Forest Department) or Degraded (those retaining less than 50% of the original tree cover, and still heavily utilized for grazing or agriculture). The perimeter of the protected forests (PF) that formed the transient zone between the degraded forests (DF) and the protected forests (PF) were categorized as hedges. While not prominent in area to be regarded as a separate mesohabitat, plants founds in this zone have been identified in Table 1 and 2.

These assessments allowed us to compare the relative contributions of different habitats for supporting plant diversity of phytochorographic or conservation interest. Our focus was on restricted habitats that contain regionally endemic plant taxa.

**Results and discussion**

**Mesoscale distribution**

We found that a large component of the regionally significant plant species occur on the plateau top and escarpments (Table 1). Of 103 species identified as being of local significance for the Kas Plateau region (primarily due to local or regional endemism or general rarity), ca.
| Family         | Species                                      | Mesohabitat(s) & distribution               |
|----------------|----------------------------------------------|---------------------------------------------|
| **DICOTS**     |                                              |                                             |
| Acanthaceae    | *Barleria gibsonii* Dalzell                  | Hedges, PF; END India                       |
|                | *Haplanthes verticillatus* (Roxb.)RB. Majumbar | DF; ETH; END W Ghats                        |
|                | *Justicia trinervia* Vahl                    | PT; END W Ghats                             |
|                | *Neuracanthus sphaerostachyus* (Nees)Dalzell | E, PT; END W Ghats                          |
|                | *Pseuderanthemum malabaricum* (C.B,Clarke)Gamble | DF; hedges, PF; END W Ghats                |
|                | *Strobilanthes callosa* Nees                 | DF, hedges, PF; END W Ghats                |
|                | *Strobilanthes sessilis* Nees var. *nitcho* C.B. Clarke | PT; END W Ghats |
| Apiaceae       | *Heracleum grande* (Dalzell & Gibson)P.K. Mukh | Hedges PF; END W Ghats                      |
|                | *Pinda concanensis*Dalzell/PK Mukh. & Constance | PT; DF; END W Ghats                        |
|                | *Pimpinella wallichiana* (Miq. ex Hohen)K.N.Gandhi | DF; ETH                                    |
| Apocynaceae    | *Ceropegia jainii* Ansari & B.G.P.Kulk. (CE) | PT; END NW Ghats                           |
|                | *Ceropegia vincaefolia* Hook.(EN)            | PT; hedges PF; END W Ghats                 |
| Asteraceae     | *Adenanthera indica* Dalzell                 | PT; END W Ghats                            |
|                | *Boccharoides lilacinia* (Dalzell)M.R.Almeida | Hedges DF; END W Ghats                     |
|                | *Senecio arachnoidea* (C.B.Clarke)M.R. Almeida | PT; DF                                    |
|                | *Tricholepis glaberrima* DC                  | PT; E; END W Ghats, C India                |
| Balsaminaceae  | *Impatiens dalzellii* Hook. F. & Thomson (EN) | PT; END W Ghats                           |
|                | *Impatiens lawii* Hook.f. & Thomson (EN)    | PT; END W Ghats                           |
|                | *Impatiens minor* (DC)Bennet                 | DF; END W Ghats                           |
|                | *Impatiens oppositiflora* L                 | DF; PT (distribution uncertain)            |
| Begoniaceae    | *Begonia crenata* Dryand                    | PT; END W Ghats                           |
| Begoniaceae    | *Begonia hirsuta* Dalzell                   | PT; END W Ghats                           |
| Boraginaceae   | *Adelocaryum coelestinum* (Lindl.)Brand      | PT; E; END W Ghats                        |
|                | *Adelocaryum malabaricum* Brand             | PT; E; END W Ghats                        |
| Celastraceae   | *Amicratea grahamii* (Wight) N, Halle       | PF                                        |
| Convolvulaceae | *Argyreia boseana* Santapau & V. Patel (EN) | PT; END W Ghats                           |
|                | *Argyreia cuneata* (Willdl.)Ker.-Gawl        | DF; END NW Ghats                          |
|                | *Argyreia sericea* Dalzell&A. Gibson         | DF; END W Ghats                           |
| Crassulaceae   | *Kalanchoe olivacea* Dalzell & A.Gibson     | PT; E; END W Ghats                        |
| Euphorbiaceae  | *Euphorbia panchganiensis* Blatt. & McCann  | PT; END W Ghats (Conservation status uncertain) |
| Fabaceae       | *Cajanusr secorea* (Benth.ex Baker)Maesen  | DF; END India                             |
|                | *Caesalpinia spicata* Dalzell               | PF, DF; END W Ghats                       |
|                | *Crotalaria leptostachya* Benth             | DF; END W Ghats                           |
|                | *Dalbergia horrida* (Dennst,)Mabb           | DF; END W Ghats                           |
|                | *Flemingia nilgheriensis* (Baker) Wight ex Cooke (EN) | PT; END W Ghats |
|                | *Indigofera dalzellii* Cooke (R. Sharma et al. 1996) | PT; END W Ghats |
|                | *Smithia agharkani* Hernadri (VU)           | PT; DF; END W Ghats                       |
|                | *Smithia bigemina* Dalzell                  | PT; DF; END W Ghats                       |
|                | *Smithia hirsuta* Dalzell                   | PT; DF; END W Ghats                       |
|                | *Smithia salvuginea* Hance                  | PF; DF                                    |
### Table 1 Noteworthy plant taxa and their mesoscale habitats in the Kas Plateau region, Western Ghats

(Continued)

| Family                  | Species Description                                      | Habitat       |
|-------------------------|----------------------------------------------------------|---------------|
| Gentianaceae            | *Smithia setulosa* Hance                                  | DF; E; END W Ghats |
|                         | *Vigna khadakensis* (Santapau)Sundararagh. & Wadhva (VU) | DF; E; END NW Ghats |
| Lamiaceae               | *Exacum lawii* C.B.Clarke                                 | PT; DF; END W Ghats |
|                         | *Exacum pumilum* Griseb                                  | DF; END W Ghats |
|                         | *Swertia densifolia* (Griseb.) Kashyapa                  | PT; END W Ghats |
| Lentibulariaceae        | *Lavandula lawii* Wight                                   | DF; END W Ghats |
|                         | *Plectranthus mollis* (Alton)Spreng                      | DF; ETH       |
| Gentianaceae            | *Utricularia praeterita* Taylor                           | PT; END Maharashtra & Goa |
|                         | *Utricularia purpurascens* J. Graham                     | PT; END NW Ghats |
|                         | *Utricularia albo-caerulea* Dalzell                      | PT; END NW Ghats |
| Lythraceae              | *Rotala fimbriata* Wight                                  | PT; END S India |
| Malpighiaceae           | *Aglaia lawii* (Wight) C.J.Saldanha                       | PF; END India |
| Piperaeae               | *Piper trichostachyon* (Miq.)C. DC                        | PF; END W Ghats |
| Ranunculaceae           | *Arisaema ghaticum* (Sardesai et al.) Punekar & Kumaran (CE) | PT; END NW Ghats |
|                         | *Arisaema murrayi* (J. Graham)Hook                        | PT; Hedges PF, DF; END W Ghats |
|                         | *Cryptocoryne spiralis* (Retz.)Fisch. Ex Wydler           | PT; END NW Ghats |
|                         | *Cryptocoryne cognata* Schott                            | PT; END NW Ghats |
|                         | *Iphegenia stellata* Blatt. (VU)                          | PT; END NW Ghats |
|                         | *Iphigenia pallida* Baker                                 | Hedges; DF; ETH; END S India |
| Colchicaceae            | *Cyanotis fasciculata* (B. Heyne)Shult. & Shultf          | PT; END NW Ghats |
|                         | *Murdannia lanuginosa* (Wall. Ecx C.B. Clarke) G. Bruckn. (EN) | PT; END W Ghats |
|                         | *Murdannia vaginata* Breckn                              | PT; END NW Ghats |
|                         | *Murdannia versicolor* (Dalz.)Bruckn                      | PT; END NW Ghats |
|                         | *Murdannia lanuginosa* (Wall. Ecx C.B. Clarke) G. Bruckn. (EN) | PT; END NW Ghats |
|                         | *Eriocaulon brevicaespum* Körn                           | PF; Distribution uncertain (Almeida, 2009) |
|                         | *Eriocaulon epiperunculatum* Potdar et al.                | PT; END NW Ghats |
|                         | *Eriocaulon sedgwickii* Tyson                            | PT; END W Ghats |
|                         | *Eriocaulon tuberiferum* A.R.Kulk. & Desai (EN)           | PT; END NW Ghats, Maharashtra |
| Hyacinthaceae (Liliaceae) | *Dipcadi maharashtrenseDeb & S. Dasgupta (CE)             | PT; END NW Ghats, Maharashtra (Liliaceae) (Tetali et al. 2000) |
|                         | *Drimia polyantha* Ansari & Sundaragh                     | PT; END W Ghats |
| Musaceae                | *Ensete superbum* (Roxb.)Cheesm                          | PT |
| Orchidaceae             | *Aerides crispa* Lindl                                    | PF; DF; END Peninsular & E India |
|                         | *Aerides maculosa* Lindl                                 | PF; END IndIA |
|                         | *Bulbophyllum bimbriatum* (Lindl.)Rchb.f                  | PF; END W Ghats |
two-thirds occur entirely or partially on the plateau top; of these, over 80% are restricted to the upper plateau and 22 have conservation concerns as ranked by the International Union for the Conservation of Nature (IUCN). In comparison, approximately one third of the species inhabit only protected or degraded forest habitats (or both); of these, two have an IUCN conservation concern. The plateau top thus contributes greatly to the botanical diversity of phytogeographic and conservation interest of the larger plateau region. The noteworthy regional flora represents 33 different plant families of which 21 are Dicotyledoneae and 12 are Monocotyledoae, and 68 genera (Table 1). The largest infra-familial diversity occurs in the Acanthaceae (six genera of which three occur on the plateau; eight species, four on the plateau), the Fabaceae (eight genera, of which three occur on the plateau; 12 species, five on the plateau), the Asteraceae (four genera overall, three on the plateau; four species, three on the plateau), and the Orchidaceae (five genera overall, two on the plateau; nine species, five on the plateau), and the Poaceae (seven genera and species overall, all on the plateau). Highly represented genera include Impatiens (Balsaminaceae) encompassing six species, with five occurring on the plateau, Smithia (Fabaceae) with five species (three on the plateau), Habenaria (Orchidaceae) with four species, all on the plateau, Eriocaulon (Eriocaulonaceae), four species, all on the plateau, Ultricularia (Lentibulariaceae), three species on the plateau, and Murdannia (Commelinaceae), with four species on the plateau.

Microscale distributions

On the plateau top, we identified 11 microhabitat types (Table 2; Figure 2) that support plant species of phytogeographic significance. Although it was not possible to assess ecological parameters for all of the known plateau endemics, these microhabitats typify critical components of ephemeral niches. During the monsoon season, the plateau consists of a mosaic of floristically different habitats determined by hydrogeomorphic factors; for many of these habitats, the occupied area is very small in extent and seasonally ephemeral. Some are correlated with soil texture or depth that temporarily change drainage and provide water availability (Table 2; Category I habitats), some are correlated with slight elevation gradients that provide more mesic habitat than nearby saturated soils (Category II habitats), and some are temporary aquatic sites (Category III habitats). Micro-elevational gradients that provide more drainage during the wet season are critical for the support of endemics such as Dipcadi maharashtrensis (Tetali et al. 2000), while fully aquatic habitats support endemics such as Aponogeton satarenensis, locally common in seasonal standing or flowing water (Figure 3) and the carnivorous genus

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**Table 1 Noteworthy plant taxa and their mesoscale habitats in the Kas Plateau region, Western Ghats**

| Family             | Species                                                                 | Habitat Description                  | Conservation Status   |
|--------------------|--------------------------------------------------------------------------|--------------------------------------|-----------------------|
| Poaceae            | *Chrysopogon castaneus* Veldkamp & C.B, Salunkhe (EN)                    | PT; END W Ghats                      |                       |
|                    | *Coelochne minutu* Bor. (EN)                                              | PT; END W Ghats                      |                       |
|                    | *Eulalia shirangii* Salunkhe & Potdar                                     | PT; END NW Ghats, Maharashtra?       | Distribution and conservation status uncertain |
|                    | Glyphochloa divergens (Hack)Clayton                                       | PT; END W Gha                        |                       |
|                    | *Indopoa paupercula* (Stapf) Bor.                                        | PT; END W Ghats                      |                       |
|                    | *Isachne lisboa* Hook. f. (EN)                                             | PT; END W Ghats, Maharashtra         |                       |
|                    | Jansenella neglecta S.R. Yadav, Chvalkar & Gosavi                        | PT; END W Ghats                      |                       |
| Zingiberaceae      | Curcuma caulina J.Graham (VU)                                              | END NW Ghats, Maharashtra            |                       |
|                    | Zingiber cernum Dalzell                                                   | Hedges, PF; END W Ghats              |                       |
|                    | Zingiber neesanum (J. Graham) Ramamoorthy                                 | Hedges, PK                           |                       |

1 Taxonomy follows Sharma et al. (1996), Singh and Karthikeyan (2000) and Singh et al. (2001), or International Plant Names Index as appropriate. * Indicates a species recognized as being of conservation concern for Maharashtra State according to Mishra and Singh (2001), or Singh et al. (1996). Classifications for conservation concern follow IUCN classifications of Critically Endangered (CE), Endangered (EN), or Vulnerable (VU) as indicated in Mishra and Singh (2001) or Singh et al. (1996). Endemics (END) may represent India, the Western Ghats, the northern Western Ghats, or Maharashtra State, following Sharma et al. (1996), Singh and Karthikeyan (2000), Singh et al. (2001), Almeida (2009), and Dessai and Janarthanam (2011). Habitats are described in the text and abbreviated as follows: Protected Forest (PF), Degraded Forest (DF), Plateau Top (PT), Escarpment (E). ETH indicates a species with Ethnobotanical uses.
| Category | Code and Name | Description | Examples of noteworthy species |
|----------|---------------|-------------|------------------------------|
| I. Defined by soil composition | MH1. Rock Crevices | Cracks between rocks with 3–6 cm soil depth. Individual microhabitats confined to area of 60 x 91 cm. | Indigofera dalzellii Ceropegia jainii* Pinda concanensis |
| | MH2. Rock Depressions | Rock depressions with 3–6 cm of soil. | Indigofera dalzellii Utricularia purpurascens |
| | MH3. Gravel Patches | Coarse gravel and lateritic pebbles-dominated patches found intermittently with MH4. | Ceropegia jainii* Pinda concanensis Utricularia purpurascens Cyanotis fasciculaae Murdannia vaginata Glyphochloa divergens |
| II. Defined by micro-elevation & topographic position | MH4. Pleocaulis ritchiei (Acanthaceae) Tableland | Dominated by Pleocaulis ritchiei and lacking stagnant water; most common microhabitat on plateau top. | Iphigenia stellata* Adenoon indicum Justicia trinervia *Flemingia nilgheriensis Murdannia vaginata |
| | MH5. Elevated Tableland | Similar to MH4 but dominated by Habenaria grandifloriformis and Iphigenia stellata. | Dipcadi maharashtraensis* Ceropegia vinacefolia* Iphigenia stellata* Adenoon indicum *Smithia agharkani Smithia salugrina Swertia densifolia Utricularia albocaerulea Murdannia vaginata Habenaria rariflora *Chrysopogon castaneus *Coelachne minuta Glyphochloa divergens |
| | MH6. Plateau Edges | Rock faces of the escarpments; steep slope lacking water retention. | Vigna kahandalensis*, Pinda concanensis*, Impatiens dalzellii*, Hitchenia caulina* *Ceropegia vincaefolia Pinda concanensis Smithia agharkarii Smithia salsuginea Swertia densifolia Utricularia albocaerulea Habenaria rariflora *Chrysopogon castaneus *Coelachne minuta Glyphochloa divergens |
| III. Defined by moisture saturation | MH7. Shallow Streamlets | Streamlets that cross plateau top; 3–10 cm deep and 90-50cm wide. | Aponogeton satarensis* |
| | MH8. Streamlets Bank | Marshy shoulders of streamlets; 30–110 cm wide. | Aponogeton satarensis* Utricularia purpurascens Cryptocoryne cognata |
| | MH9. Marshy Patches | Ground depressions with 2–4 cm of water. | Habenaria panchaganiensis* Ericaulon tuberiferum* Utricularia purpurascens Utricularia albocaerulea |
| | MH10. Marshy Crevices | Rainwater-saturated soil in crevices between rocks; 2-8cm deep. | Aponogeton satarensis* Cryptocoryne cognata |
| | MH11. Temporary Puddles | Rainwater-filled depressions or ditches. 2–12cm deep and 60–121 cm wide. | Aponogeton satarensis* Cryptocoryne cognata |
Utricularia. Since the lateritic caprock crusts on the plateau do not retain moisture well, most of these microhabitats dry out and disappear in non-monsoon months. Soil moisture has been recognized as the primary determinant of endemic plant phenology in the Western Ghats (Joshi and Janarthanam 2004), and the botanical diversity of plateau habitats is only apparent while monsoon moisture persists.

The Kas Plateau exemplifies the general profile of plant biodiversity on the lateritic plateaus of the Western Ghats: in a small area, there is a strong endemic component prominent in the vegetation (Porembski and Watve 2005; Lekhak and Yadav 2012) and flora associated with seasonal monsoon moisture availability. These endemics occur in a variety of ephemeral microhabitats associated with edaphic features of the plateau. The flora here and elsewhere in the Western Ghats encompasses unique and diverse genomes across multiple taxonomic levels from plant families to species. It not only represents locally high species diversity overall, the “alpha” diversity consideration for conservation hotspots, but also locally high “beta” diversity (Le Gendre et al. 2005; Whitaker 1972): variation in species composition among habitats. On the Western Ghats plateaus, the critical dependence of these habitats on the maintenance of monsoonal hydrologic regimes and edaphic conditions easily affected by anthropogenic activities at small and large scales render them extremely vulnerable to alteration, and pose significant threats to their biota.

Human use of the Western Ghats plateaus dates back several millennia (Chandran 1997) and today, the Kas Plateau is utilized for grazing, resource extraction, and tourism. Relatively easy road access enhances the likelihood of landscape level impacts from habitat conversion, trampling, trails, and tourist services such as teashops, uses that could have direct or indirect impacts on floristic diversity. Following the declaration of Kas Plateau as a UNESCO heritage site, there has been an effort by the Forest Service to raise fences in order to discourage anthropogenic impacts (Times of India, 24 May 2012). However, implementing such action can bear negative consequences that include habitat fragmentation, hindrance in the passage of fauna that may help with pollination or seed dispersal, and the possibly of invasion by exotic species that inadvertently get transported in with the river sand brought for building the fences. Utilization of plant resources for economic reasons may diminish the presence of commercially valuable species such as Iphigenia stellata (Colchicaceae), known for its anticancer compounds and subject to unregulated local harvest. Human activities that affect microhabitats could have potentially broader impacts, especially on endemics that depend on ephemeral niches determined by specific hydrogeomorphic conditions. Clogging streams with effluents, diversion of stream channels from social trails or roads, and general alteration of topography or drainage patterns that determine plant microhabitats are of particular concern.

Larger issues of drastic seasonal changes in moisture amounts or timing from long term climate change would also profoundly affect persistence of critical habitats. Considerable attention is currently being given to the impact that global warming could have on the South Asian monsoonal system and cyclonic disturbances (Murugavel et al. 2012; Patwardhan et al. 2012). These
weather systems are fundamental to the maintenance of habitats in the Western Ghat hotspot, and more broadly, to the interactive human-ecological systems of the region. While the systems are complex and no clear predictive models yet exist, any alteration would bring serious impacts on multiple human and biological levels.

Conclusions
For many reasons, within the context of the Western Ghat mega hotspot, the Kas Plateau exemplifies the unique contributions and vulnerabilities of higher elevation microhabitats with their small populations of rare and endemic species that depend on critical amounts and timing of moisture. Protection of these precarious habitats and the biota they support deserve a high profile and careful focus as key components in the long-term conservation of globally significant flora and vegetation.

Methods
Fieldwork was conducted during the monsoon months (June-September) of 2010 (Bhattarai 2010). We utilized literature reports to determine local distributions and ecology of regionally significant species (Mishra and Singh 2001 and references listed in Table 1), surveyed the forests and plateau top for the occurrence of these species, and established ecological profiles of preferred habitats for these species in the study range. At the mesoscale level, we determined the habitat distribution for notable plant species as occurring on the plateau top, on the subtending escarpments, in Kas Lake, and/or in two types of forest on the slopes categorized as protected or degraded depending on the level of forest vegetation remaining through visual inspection in the field. At the microscale level, we utilized field studies to divide the plateau top into microhabitats based on key edaphic parameters that contribute to the support of uncommon or locally significant plant species.

Endnotes
*The paper by Lekhak and Yadav appeared in print while our paper was in review and represents a parallel study to ours in a broader context. We were unaware of the work being done by these authors. We and the editors at SpringerPlus have discussed the overlap in our respective papers and we believe they represent complementary investigations leading to similar conclusions.

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