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Ecological niche modeling, population status and regeneration of *Coscinium fenestratum* colebr. (Menispermaceae): a medicinally important liana of the central Western Ghats

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Abstract: Distribution, population status, and regeneration of *C. fenestratum* in its natural habitats were studied in the central Western Ghats of Karnataka, India. DIVA - GIS, was adopted to identify the areas suitable for the growth of *C. fenestratum*. Only a tiny band of high rainfall hilly slopes of the central Western Ghats in Karnataka was predicted to be highly suitable for the species, suggesting a high habitat-specificity and restricted distribution of *C. fenestratum*. A total of 163 adult individuals and 975 regenerating individuals were enumerated in all the eight natural populations studied. Only in three populations both adult and regeneration structure was healthy; large deficiencies of higher size class of adults and of individuals in class I (< 40 cm height) regeneration were observed in other five populations. The density of saplings per plot was positively associated with the number of adult individuals per plot. Species recovery programme could be the best way to protect this species from local extinction due to over exploitation and habitat loss.

Resumen: Se estudió la distribución, el estado de la población y la regeneración de Cosciniumfenestratum en sus hábitats naturales en la porción central de los Gates Occidentales de Karnataka, India. Se adoptó el SIG - DIVA para identificar las áreas adecuadas para el crecimiento de *C. fenestratum*. La predicción indica que sólo una pequeña banda de laderas de colinas con precipitación elevada delaporción central de los Gates Occidental en Karnataka sería muy adecuada para la especie, lo que sugiere una alta especificidad de hábitat y una distribución restringida de *C. fenestratum*. Se registraron en total 163 individuos adultos y 975 individuos en regeneración en las ocho poblaciones naturales estudiadas. Sólo en tres poblaciones tanto la estructura de los adultos como la de regeneración eran sanas; en otras cinco poblaciones se observaron deficiencias grandes de la categoría de mayor tamaño de los adultos y de los individuos de la clase de regeneración I (< 40 cm de altura). En cada parcela la densidad de plantas jóvenes (brinzales) se asoció positivamente con el número de individuos adultos. Un programa de recuperación de la especie podría ser la mejor manera de proteger a esta especie de la extinción local ocasionada por la sobrexplotación y la pérdida de hábitat.

Resumo: A distribuição, estado da população, e regeneração da C. fenestratum nos seus habitats naturais foram estudados na região central dos Gates ocidentais de Karnataka, na Índia. A identificação das áreas adequadas para o crescimento de *C. fenestratum* foi efectuada com recurso a GIS - DIVA. Apenas numa pequena faixa de alta queda de chuva em encostas montanhosas do centro dos Gates ocidentais, em Karnataka, foi previsto ser altamente

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adequada para a espécie, o que sugere uma alta especificidade de habitat e uma distribuição restrita de *C. fenestratum*. Um total de 163 indivíduos adultos e 975 indivíduos em regeneração foram enumerados em todos as oito populações naturais estudadas. Somente em três populações adultas a estrutura da regeneração era saudável; grandes deficiências na classe de maior tamanho dos adultos e dos indivíduos na classe I de regeneração (< 40 cm de altura) foram observadas em cinco outras populações. A densidade de plântulas por parcela foi positivamente associada com o número de indivíduos adultos por parcela. Um programa de recuperação da espécie pode ser a melhor maneira de a proteger da extinção local, devido à sobre-exploração e à perda de habitat.

Key words: *C. fenestratum*, conservation, endangered, medicinal plant, stand structure, Western Ghats.

Introduction

Coscinium fenestratum (Gaertn.) Colebr., (Family: Menispermaceae), is a critically endangered dioecious liana found in the semi-evergreen and evergreen forests of the Western Ghats, India (Tushar *et al*. 2008). Synonyms of the species include *Menispermum fenestratum* Gaertn., *Coscinium peltatum* Merr., *C. wallichianum* Miers, *C. maingayi* Pierre, *C. usitatum* Pierre, *C. blumeanum* Miers var. *epeltatum* Boerl., *C. wightianum* Miers, *C. fenestraum* var. *macrophyllum* Yamamoto, *C. fenestratum* var. *ovalifolium* Yamamoto, *Pereiria medica* Lindl (Forman 1978; Tushar *et al*. 2008). The species is widely used in Ayurvedic and Siddha formulations to treat digestive disorders, chronic fevers, wounds and ulcers. Ramasubbu *et al.* (2012) have reported that the species is used in over 62 different Ayurvedic preparations. It is also an important ingredient in folk medicine of Oorali tribes of Kerala against rheumatism, jaundice and skin diseases (Udayan *et al*. 2005). An alkaloid, berberine, shown to be an important molecule with anti-diabetic and anti-bacterial properties, is extracted from woody stem barks in large quantities (Malhotra *et al.* 1989; Ramesh Babu *et al*. 2012; Siwon *et al*. 1980). Today it has become one of the high-value metabolite yielding species, and it is estimated that about 114 t of woody stem bark of this species is extracted annually from the Western Ghats (Ved & Goraya 2007). In a recent estimation it is reported that 2000 t of extract from *C. fenestratum* was used by Indian pharmaceutical industry in 2011 to prepare a wide range of formulations and the demand for its extract has reached unsustainable levels (Rashme Sehgal 2012). This high industrial demand is believed to be the major cause of destruction of natural populations of *C. fenestratum*. For the same reason, Foundation for Revitalization of Local Health and Tradition (FRLHT), Bengaluru has assigned "critically endangered" status to the species through its CAMP assessments (Ravikumar & Ved 2000) and globally it is listed as endangered (Augusta 2003; Trans & Zeigler 2001). Despite its criticality and pharmaceutical importance, there are substantial gaps in our understanding of its population and regeneration status which is a pre-requisite for effective conservation.

With this backdrop we studied the natural distribution, population structure and regeneration status of the species in the Central Western Ghats adopting ecological niche-modeling and standard vegetation analysis techniques.

Material and methods

Study area

The study was undertaken in the central Western Ghats region of Karnataka, India which covers little over 40,000 sq. km of area spread over 12 districts of the state. The study was restricted to floristically rich wet-evergreen primary forests, disturbed ever-green forests, semi-evergreen and moist-deciduous forest types of Uttara Kannada, Dakshina Kannada, Udupi, Shimoga, Chickmagalur, Hassan and Kodagu districts of Karnataka. Low (< 600 m) and medium elevation (600 - 1400 m) forests were considered wherein the temperature of the coldest month varied between 17 °C to 22 °C. The dry season among the forest types ranged from 4 to 6 months from December to May. Reconnaissance survey for natural populations of *C. fenestratum* was undertaken in 35 forest ranges. The geo-coordinates and elevation of

all natural populations were recorded using Global Positioning System (Make: GARMIN, GPSMAP 60 CSx) to the nearest 20 m.

Ecological niche modeling

Secondary data on the distribution of *C. fenestratum* was collected from various sources including forest department records, published literature, and also interaction with the forest officials. This information was used in preparing the type localities, which was used as base for further explorations. The ecological niche model was adopted to develop the potential geographic distribution map of *C. fenestratum* across the central Western Ghats region following Ganeshaiah *et al*. (2003). The program DIVA-GIS ver 5.0.02 with the Bioclim classic model was used to predict the distribution of the species in the entire range (Anderson *et al.* 2002). DIVA - GIS model was implemented with the following bio-climatic variables, *viz*., annual mean temperature, mean monthly temperature range, isothermality, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, temperature annual range, mean temperature of wettest quadrant, mean temperature of driest quadrant, mean temperature of warmest quadrant, mean temperature of coldest quadrant, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation seasonality (CV), precipitation of wettest quarter, precipitation of driest quarter, precipitation of warmest quarter, precipitation of coldest quarter to identify the potential geographical distribution of *C. fenestratum*. A total of 15 geo coordinate points obtained from the primary and secondary sources were used to run the program (www.diva-gis.org). Based on the habitat suitability the software categorizes the area in different colours as excellent, medium and poor habitats. The algorithm attaches 0 to 2.5 percentile for areas of low suitability, 2.5 to 5.0 percentile for areas of medium suitability, 5 to 10 percentile for areas of high suitability, 10 to 20 percentile for areas of very high suitability and 20 to 40 percentile is for the areas that are excellent in terms of habitat match.

Demographic plots

Following Bullock (1996), 10 plots of the size 10 m x 10 m were randomly laid on a transect line of 0.5 to 1.0 km in each of the representative habitats to assess the population status and to study the ecological constraints, if any, that limit population build up in its natural habitats. Overall eighty plots were laid for enumeration for demographic studies. The demographic profile of plots was recorded adopting standard vegetation survey methods (Ganeshaiah *et al.* 2012; Tadwalkar *et al.* 2012). All lianas rooted-in within the study plots were systematically enumerated. In every plot, number of adult individuals, number of regenerating individuals, associated species, phenological stage of every liana and the disturbance were recorded. Point of measurement for diameter of lianas, its classification into adult and regeneration classes and counting of multiple stems were done as per the standard protocol for liana census, following Gerwing *et al.* (2006). Liana measurement points included: (a) lianas that simply ascend into the canopy were measured at 130 cm along the stem from the main rooting point; (b) twining lianas were measured at 130 cm from the rooting point measured along the stem of the liana; (c) lianas that branch below 130 cm from the rooting point were measured from the 20 cm below the branching point. Since the species shows cylindrical stem, diameter was measured using digital calipers to the nearest 0.01 mm. Only a few lianas with fruits were encountered during the survey hence the sex of all the individuals could not be ascertained. Population status and regeneration status was analyzed using size class distribution. Considering the size class, individuals that are rooted within the plot with more than 1.0 cm diameter were considered as adult individuals (Gerwing *et al*. 2006). Regenerating individuals were classified under the following four different classes based on the length and diameter of the stem *viz*. class I (< 40 cm height), class II (40 - 100 cm height), class III (> 100 cm height, < 0.5 cm diameter), and class IV (> 100 cm height with 0.5 - 1.0 cm diameter).

Results and discussion

Habitat structure

All the eight natural populations of *C. fenestratum* identified in the central Western Ghats region of Karnataka occurred in the areas with slope > 15 % -habitats of floristically rich wet-evergreen/disturbed wet - evergreen/semi - evergreen forest types (Fig. 1; Table 1). All the populations were found in the low elevation habitats except that of Maani dam site (P_4) which was only 46 m above the cut-off limit of the low elevation forest types. Floristically these forests showed disturbed

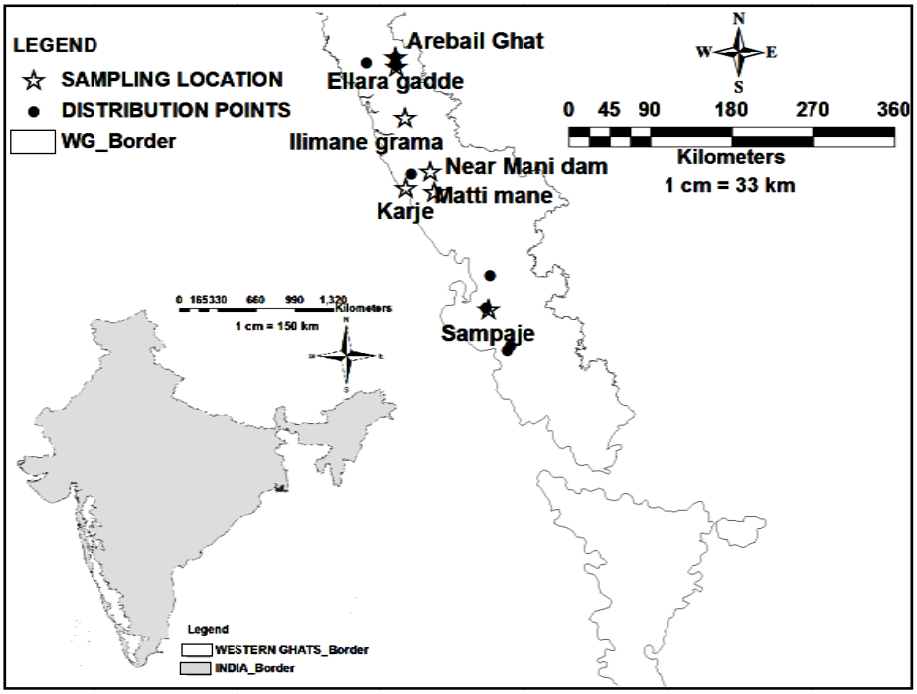

Fig. 1. Map of the *C. fenestartum* populations distributed along the Central Western Ghats region of Karnataka, India. Arebail Ghat (P_1); Ellara Gadde (P_2); Ilimane grama (P_3); Near Maani Dam (P_4); Matti mane (P_5); Sampaje (P_6).

Table 1. Characteristics of the *C. fenestratum* populations in the Central Western Ghats region of Karnataka, India.

Population I.D.	Forest locality	Forest range & Forest division	Geo Co-ordinates; ºN latitude and ºE longitude	Altitude (m above msl)	Total number of lianas enumerated	Adults	Habitat type and disturbance
P_1	Arebail Ghat	Idugundhi/Yellapura	14.902472, 74.652694	499	212	36	Semi evergreen
P_2	Ellara Gadde	Idugundhi/Yellapura	14.991194 74.644306	570	217	44	Semi evergreen
P_3	Ilimane Grama	Kyadhagi/Sirsi	14.391194 74.745194	484	231	46	Disturbed evergreen
P_4	Maani Dam	Nagara/Shimoga	13.488917 75.024500	646	109	19	Disturbed evergreen
P_5	Matti Mane	Nagara/Sagara	13.858597 74.994200	585	327	11	Disturbed evergreen
P_6	Sampaje	Madikere/Madikere	13.699972 74.750000	183	22	4	Evergreen
P_7	Makut	Madikere/Madikere	12.489897 75.5753	146	3	3	Disturbed evergreen
P_8	Karje	Brahmavar/Mangalore	12.660861 75.000163	200	3	-	Evergreen

Table 2. Associated indigenous woody plants with natural populations of *C. fenestratum*. + indicates the presence of the species in a specific population.

Associated species	Population I.D. *					
	P_1	P_2	P_3	P_4	P_5	P_6
Knema attenuata	+	+	+	+	+	-
Holigarna grahamii	+	+	-	+	+	-
Gnetum ula	-	+	+	-	-	-
Olea dioca	+	-	+	-	-	-
Anamirta cocculus	+	+	+	-	+	+
Hopea ponga	-	+	-	+	+	+
Glycosmis pentaphylla	+	-	-	-	-	-
Mesua ferrea	-	+	-	+	+	+
Nothapegia racemosa	-	+	+	+	+	+
Mimusops elengi	+	+	-	+	+	+
Chrysophyllum roxburghii	-	-	-	+	+	+
Derris scandens	-	+	-	+	+	+
Lea indica	-	+	+	+	+	+

*Please refer to Table 1 for the details on the Population I.D.

formations with common associated species such as *Knema attenuata, Holigarna grahmii, Nothopegia racemosa, Anamirta cocculus* (a liana which is very similar to *C. fenestratum*) and *Lea indica* (Table 2). Where ever found, the individuals of *C. fenestratum* accurred in aggregations. There were not many differences in the habitat structure where the natural populations of the species are found along the central Western Ghats. However, the populations were highly fragmented from each other and showed signs of disturbance through out central Western Ghats region. Kathriarachchi *et al*. (2004) have reported that in Sri Lanka, *C. fenestratum* survives under a varied range of light levels and regenerates naturally well in slightly disturbed sites than the un-disturbed sites. However, Muthukumar & Parthasarathy (2000) have reported a good population of *C. fenestratum* with a density of 48 individuals per ha in an undisturbed 'west coastal tropical evergreen forest' of *Dipeterocarpus-Mesua-Palaquium* type.

Predictive map

The predictive distribution map developed for Karnataka state adopting DIVA-GIS, in general, agreed with the observed distributional pattern of the species. Only a tiny band of high rainfall hilly slopes of the central Western Ghats in Karnataka was predicted to be suitable for the species (Fig. 2). This suggests the high habitat-specificity and restricted distribution of *C. fenestratum*. A tiny spot near Yellapura area was predicted to be an excellent niche for the occurrence of *C. fenestratum* (red spot), which was indeed corroborated by the field study and corresponded to the population # 1. Apart from these, hill slopes of Sirsi, Supa, Sagara, Thirthahalli, Soraba and in Hosanagara taluks were also predicted to be of high-suitability (Orange colour). One of the basic assumptions of the ecological niche modeling is that the areas identified as 'highly suitable niche' support better growth and regeneration of the species in question. Using DIVA-GIS, Yethish (2006) has shown that this hypothesis holds good with respect to *Myristica malabarica, Knema attenuata, Dysoxylum malabaricum*, and *Vateria indica*. The present study also indicated that population # 1 was the best in terms of age structure (see next sections). Very high niche suitability was also predicted in a tiny spot in Supa taluk although the population was could not be identified in the field study. However, a report of the state forest department did mention about a natural population of *C. fenestratum* in Anshi near Dandeli wildlife sanctuary to consist of three adult individuals which corresponds to the predicted area (Anonymous 2010). Perhaps because of extremely low population size, the population could not be identified in the field. However, the DIVA-GIS failed to predict the occurrence of *C. fenestratum* in Kodagu district, though two highly disturbed populations were observed in the district during the survey. These predictions offer opportunities to undertake finer scale exploration of these areas and to identify remnant populations of *C. fenestratum*, if any, and use the same as a source of germplasm for a possible *ex situ* or *in situ* conservation before they become locally extinct.

Population status

A total of 163 adult and 975 regenerating individuals were enumerated in all the eight natural populations studied. Perhaps this is the largest sample size ever considered in any population study of this critically endangered species (Table 1). Populations P_1, P_2 and P_3, showed least signs of disturbance such as cut stumps (less than 30 % of population), root digging and climber cutting. The average canopy cover in these populations was around 66.67. However, the canopy in P_4, P_5 and P_6, more open (average canopy of 46.67 %), with

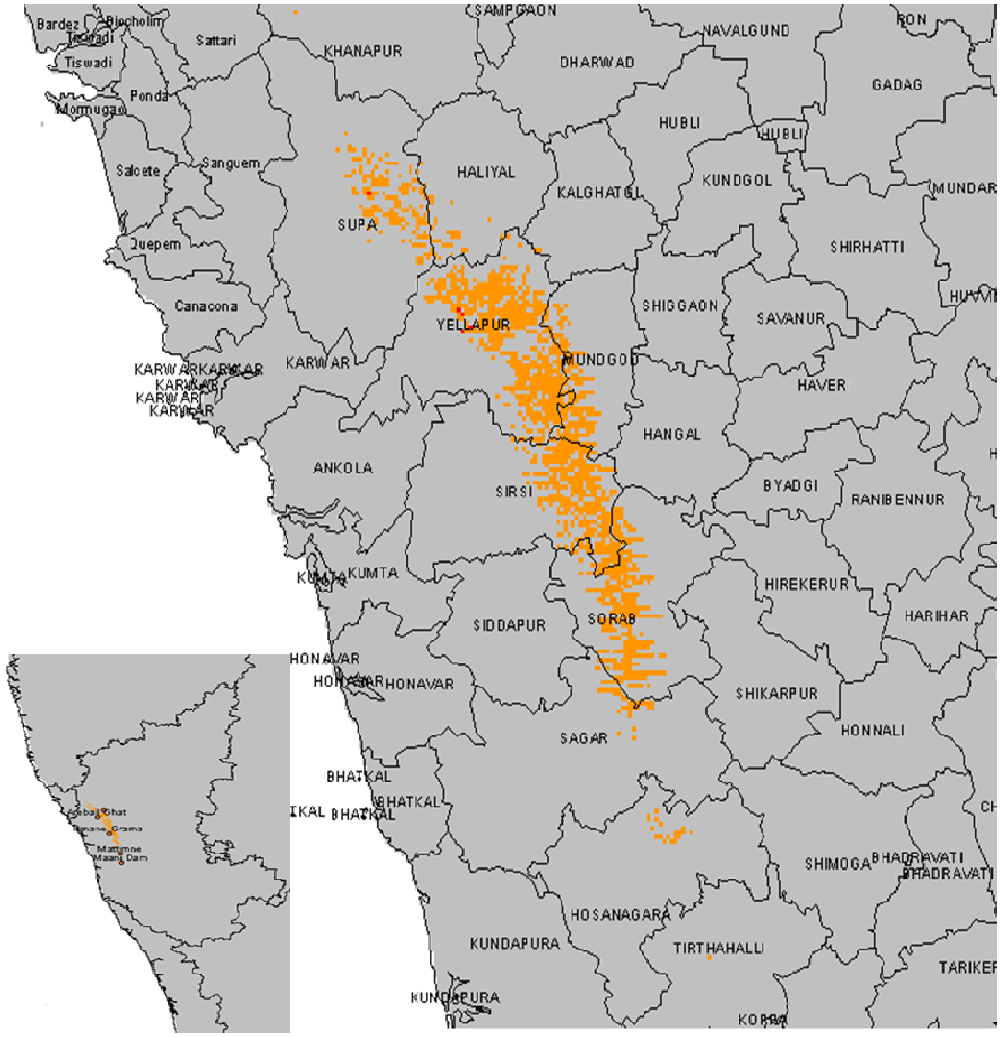

Fig. 2. Predicted potential distribution of *C. fenestratum* in Central Western Ghats of India using DIVA –GIS. The Red dots represent the locations with highest potentiality.

Table 3. Density, Variance to Mean ratio, of adults and regenerating individuals of *C. fenestratum* in different locations.

Population	Location	Density of adult individuals per 100 sq m Mean ±S.D.	Density of regeneration per 100 sq m Mean ±S.D.	Variance to Mean ratio for adult individuals	Variance to Mean ratio for regeneration	Regeneration per adult
P_1	Arebail Ghat	4.30 ± 2.31	17.60 ± 9.19	1.24	4.80	4.31 ± 4.79
P_2	Ellara Gadde	4.40 ± 2.76	17.50 ± 6.15	1.73	2.16	6.15 ± 8.77
P_3	Ilimnae Grama	4.60 ± 2.67	19.90 ± 10.42	1.56	5.45	3.95 ± 3.19
P_4	Mani Dam	1.50 ± 1.69	11.30 ± 8.93	1.90	7.01	3.59 ± 4.64
P_5	Mattimane	1.10 ± 0.88	31.60 ±15.30	0.70	7.41	15.5 ± 12.18
P_6	Sampaje	0.57 ± 0.79	5.14 ± 5.81	1.08	6.57	2.62 ± 4.99

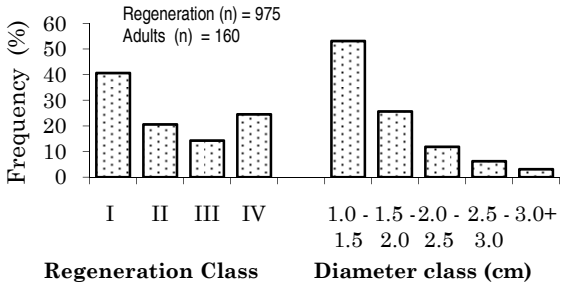

Fig. 3. Overall size structure of *C. fenestratum* populations, Data pooled over all populations. Frequency has been computed for adults and regeneration separately. Please refer text for the classification of regeneration.

higher values for cut stumps (67.0 % of population), root digging and climber cutting. In population P_5 we encountered large number of cut stumps suggesting destructive harvesting of the species in the past. Populations P_7 and P_8 had less than five individuals and exhibited a very high level of habitat disturbance, hence were not included for status study. Among the six populations considered, the mean adult and regeneration density per plot of *C. fenestratum* was highly variable with values ranging from 1.10 (P_5) to 4.60 (P_3) for adults and from 5.14 (P_6) to 31.60 (P_5) for regenerating individuals. The number of juveniles/recruits per adult was also highest in P_4 site. Except in populations P_7 and P_8, in all other sites, the species showed active recruitment under natural conditions where the sapling abundance being invariably higher than adult abundance (Table 3).

The density of saplings per plot was positively associated with the number of adult individuals per plot (Spearman's correlation, $r_s = 0.44$; $P < 0.05$); however, saplings per adult did not correlate with number of adults per plot (Spearman's correlation $r_s = -0.003$; ns). As analyzed by the variance : mean ratio, the spatial patterns of the saplings was highly clumped. Since the species shows very active root sprouting, a large number of regenerating individuals could be originated from the root sprouts at different distances from the main stem. Highly clumped spatial dispersion pattern exhibited by the saplings also suggest that these could be root sprouts. For the same reason higher rate of recruitment observed should be viewed more cautiously since increased root sprouting would not increase the level of genetic diversity of the population. This information is crucial for a better assessment of species conservation status through the establishment of optimal *in situ* conservation and sustainable management programs.

Population size class structure

The overall size class structure as shown in Fig. 3 depicts a typical reverse J pattern both for the adult and regenerating individuals suggesting a healthy regeneration although less disturbed populations contributed to this pattern. A pattern of size class distribution was also similar in the three populations (*viz.* P_1, P_2 and P_3) where there was low incidence of disturbance. However, among the disturbed sites (*viz.*, P_4, P_5 and P_6) large deficiencies in adult size classes was observed (Fig. 4). For instance, in P_5 and P_6 none of the observed lianas had diameter more than 1.5 cm and large deficiencies of class I regeneration was also observed. A comparison of size class distribution of less disturbed sites (pooled over P_1, P_2 and P_3) and disturbed sites (pooled over P_4, P_5 and P_6) showed statistically significant differences between the two, both with respect to the regeneration and adult as suggested by the KS test (Kolmoronov - Smirnov test; D_{max} values for the comparison of regeneration = 0.265; $P < 0.05$; and for adults = 0.413; $P < 0.05$; Fig. 5). It is surprising that in all the eight populations, none of the individuals recorded diameter more than 3.5 cm, although the previous records of forest department suggests the existence of lianas that were larger than 25.0 cm diameter. While systematic record of is largely absent, it may be conjectured that the growth rate of *C. fenestratum* is very slow and as a consequence, a long duration is needed for the build up of natural populations.

Conservation implications

Several biological features and pressure of harvesting have contributed to the critical population status of the species. Firstly inherent properties such as high habitat specificity (restricted to the high rainfall hill slopes), vulnerable liana life form (which necessitates a host species for establishment), slow growth rate of lianas (need about 15 years of growth to reach the adult stage (Ramesh Babu *et al.* 2012), lack of active seed dispersal (Parthasarathy *et al.* 2004) have restricted its geographic occupancy to smaller areas. The liana is dioecious in nature with a small time-window of blooming and depends on animal vectors for effective pollination as well as for dispersal (Ravikumar & Ved 2000). Further, the species possess very low seed germination percentage;

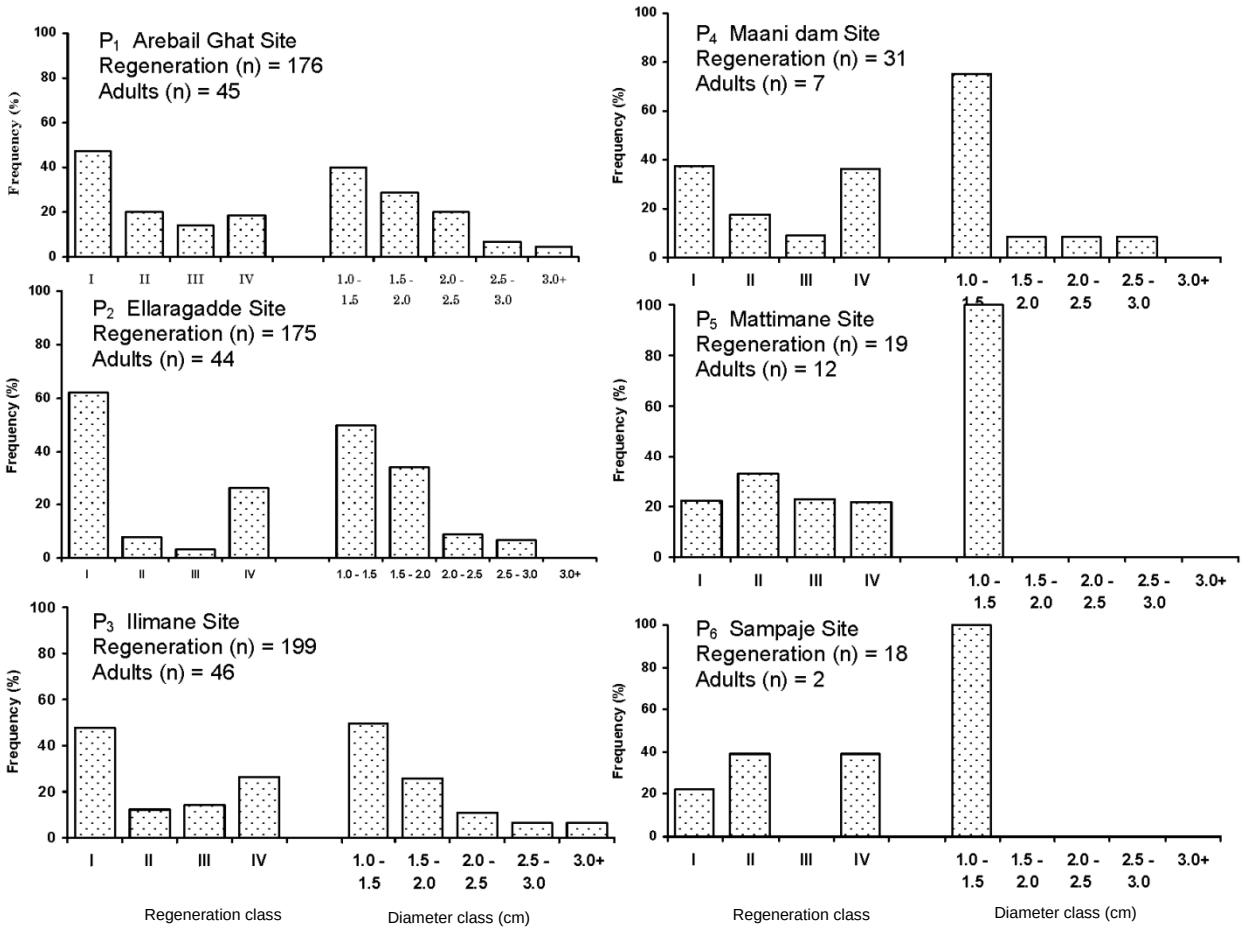

Fig. 4. Size structures of six populations of *C. fenestratum* studied. Frequency has been computed for adults and regeneration separately in each site. Please refer text for the classification of regeneration.

consequently, the natural regeneration through sexual reproduction is rather poor (Forman 1978). Perhaps the strongest reason for its rarity is the unsustainable harvesting practices followed by collectors. Since the root and lower part of stem have highest berberine content, unsustainable harvesting such as root digging, branch cutting has been practiced. Perhaps the populations today represent the remnant part of the original bigger populations that have been subjected to severe exploitation. This has raised concerns for the immediate species recovery initiatives.

One of the important applications of predictive maps to rare and endangered species management has been their ability to guide reintroduction and restoration efforts. Today the *C. fenestartum* populations are located in fragmented populations of Karnataka. Hill slopes of six taluks *viz.*, Sirsi, Supa, Sagara, Thirthahalli, Soraba and in Hosanagara taluks have been predicted to be highly-suitable but seems to be unoccupied by the species. Hence immediate efforts should be undertaken to introduce the species to newer locations and re-introduce to historically known locations as well as to augment the existing disturbed populations following forest gene bank model (Gunaga *et al.* 2013; Ravikanth *et al.* 2010; Uma Shaanker & Ganeshaiah 1997). Specific recovery plan recommendations for *C. fenestratum* are: (1) conduct genetic analysis adopting robust DNA markers on all the populations to identify sites with high levels of diversity; (2) research genetic relatedness, breeding systems and patterns of gene flow to improve or develop management plans; (3) create a forest gene bank through introduction of individuals from all other sites to a target site; (4) implement *ex situ* seed storage and propagation necessary to preserve representatives of populations that are vulnerable.

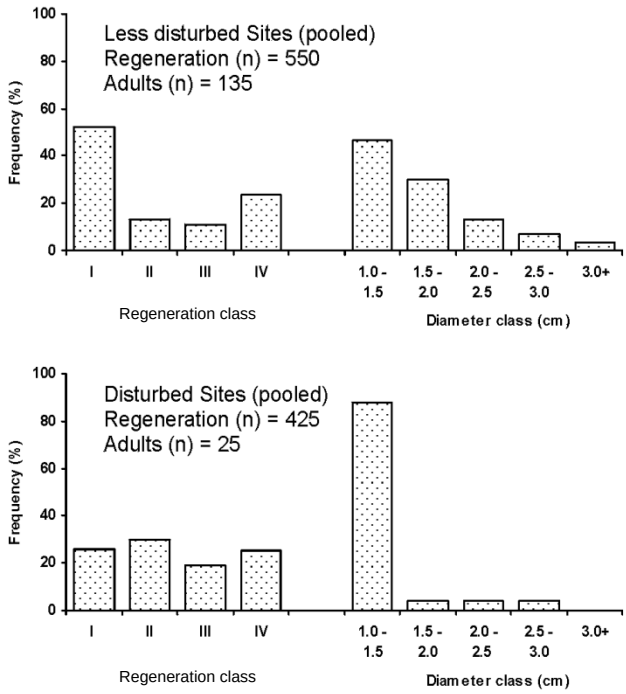

Fig. 5. Size structure of *C. fenestratum* populations pooled over less disturbed and disturbed sites. Frequency has been computed for adults and regeneration separately. Kolmoronov - Smirnov test D_{max} values for the comparison of regeneration = 0.265 ($P < 0.01$) and for adults = 0.413 ($P < 0.05$). Please refer text for the classification of regeneration.

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References

Augusta, A. 2003. *Coscinium fenestratum* (Gaertner) colebr. Medicinal poisonous plants. pp. 139-140. *In*: R. M. H. J. Lemens & Bunyapraphatsara (eds.) *Natural Plant Resources*. South East Asia.

Anderson, R. P., A. T. Peterson & G. M. Laverde. 2002. Using niche-based GIS modeling to test geographical predictions of competitive exclusion & competitive release in South American pocket mice. *Oikos* **98:** 3-16.

Anonymous. 2010. *Report on National Programme on Promoting Conservation of Medicinal Plants and Traditional Knowledge for Enhancing Health and Livelihood Security*. Department of Forests, Government of Karnataka.

Bullock, J. 1996. Plants. *Ecological Census Techniques: a Handbook*. pp. 111-138 *In*: W. J. Sutherland (ed.) Cambridge University Press, Cambridge.

Forman, L. L. 1978. A review of the tribe *Coscinieae* Hook. f. & Thoms. (Menispermaceae). *Kew Bulletin* **32**: 323-338.

Ganeshaiah, K. N., R. Ganesan, R. Vasudeva, C. G. Kushalappa, A. R. R. Menon, Ankur Patwardhan, S. R. Yadav & R. Uma Shaanker. 2012. *Plants of Western Ghats* Vol. 1. School of Ecology and Conservation. University of Agricultural Sciences, Bangalore. Bengaluru.

Ganeshaiah, K. N., Narayani Barve, Nilima Nath, K. Chandrashekar, M. Swamy & R. Uma Shaanker. 2003. Predicting the potential distribution of the sugarcane wooly aphid using GARP and DIV-GIS. *Current Science* **85:** 1526-1528.

Gerwing, Jeffrey J., Stefan A. Schnitzer, Robyn J., Burnham, Frans Bongers, Jéróme Chave, Saara J. Dewalt, Corneille E. N. Ewango, Robin Foster, David Kenfack, Miguel Martinez-Ramos, Marc Parren, N. Pathasarathy, Diego R. Pérez-Salicrup, Francis E. Putz & Duncan W. Thomas. 2006. A standard protocol for liana censuses. *Biotropica* **38:** 256-261.

Gunaga Srikanth, N. Rajeshwari & R. Vasudeva. 2013. Tree diversity and disturbance of Kaan forests: Relics of a community protected climax vegetation in the central Western Ghats. *Tropical Ecology* **54**: 117-131.

Kathriarachchi, H. S., K. U. Tennakoon, C. Gunatilleke I. Gunatilleke & P. Ashton. 2004. Ecology of two selected liana species of utility value in a lowland rain forest of Sri Lanka: Implications for management. *Conservation and Society* **2**: 273-288.

Malhotra, S., S. C. Taneja & K. L. Dhar. 1989. Minor alkaloid from *Coscinium fenestratum*. *Phytochemistry* **28**: 1998-1999.

Muthukumar, S. & N. Parthasarathy. 2000. Alpha diversity of lianas in a tropical evergreen forest in the Anamalais, Western Ghats, India. *Diversity and Distribution* **6**: 1-14.

Parthasarathy, N., S. Muthukumar & M. Sridhar Reddy. 2004. Patterns of liana diversity in tropical evergreen forests of peninsular India. *Forest Ecology and Management* 190: 15-31.

Ramasubbu, R., A. Chandra & Kumuthakalavalli. 2012. Seed biology of *Coscinium fenestratum* (Gaertn.)

Colebr. - A critically endangered medicinal plant of Western Ghats. *Journal of Medicinal Plants Research* **6**: 1094-1096.

Ramesh Babu, H. N., H. N. Thriveni & R. Vasudeva. 2012. Influence of drying methods and extraction procedures on the recovery of berberine content in *Coscinium fenestratum*. *Journal of Natural Products and Plant Resources* **2**: 540-544.

Rashme Sehgal. 2012. Indian medicinal plant faces extinction, The Asian Age, Published on 2nd October. Available for download on http//www.asianage.com/india/Indian-medicinal-plants-face-extinction-771.

Ravikanth, G., R. Vasudeva, K. N. Ganeshaiah & R. Uma Shaanker. 2010. Garcinia forest gene banks: an alternative approach for the conservation of garcinia genetic resources of the Western Ghats. pp. 1-13. *In*: R. Vasudeva, B. S. Janagoudar, B. M. C. Reddy, Bhuwon Sthapit & H. P. Singh (eds.) *Garcinia Genetic Resources*: *Linking Diversity, Livelihood and Management*, College of Forestry, Sirsi.

Ravikumar, K. & D. K. Ved. 2000. *100 Red-listed Medicinal Plants of Conservation Concern in Southern India.* Foundation for Revitalization of Local Health Traditions (FRLHT), Bangalore.

Siwon, J., R. Verpoorte, G. F. A. Van Essen & A. B. Svendsen. 1980. Studies on Indonesian medicinal plants-III. The alkaloids of *Coscinium fenestartum*. *Planta Medica* **38**: 24-32.

Tadwalkar, M. D., Amruta M. Joglekar, Monali Mhaskar, Radhika B. Kanade, Bhanudas Chavan, Aparna V. Watve, K. N. Ganeshaiah & Ankur A. Patwardhan. 2012. Dispersal modes of woody species from the northern Western Ghats, India. *Tropical Ecology* **53**: 53-67.

Trans, T. A. & S. Ziegler. 2001. Utilization of medicinal plants in Bach Ma National Park, Vietnam. Newsletter Med. Plant Specialist Group IUCN Species. *Survey Communication* **7**: 3-4.

Tushar, K. V., Satheesh George, A. B. Remashree & Indira Balachandran. 2008. *Coscinium fenestratum* (Gaertn.) Colebr. - A review on this rare, critically endangered and highly-traded medicinal species. *Journal of Plant Sciences* **3**: 133-145.

Udayan, P. S., S. George, K. V. Tushar & I. Balachandran. 2005. Medicinal plants used by the Kaadar tribes of Sholayar forest, Thrissur district, Kerala. *Indian Journal of Traditional Knowledge* **4**: 159-163.

Uma Shaanker, R. & K. N. Ganeshaiah. 1997. Mapping genetic diversity of *Phyllanthus emblica*: Forest gene banks as a new approach for in situ conservation of genetic resources. *Current Science* **73**: 163-168.

Ved, D. K. & G. S. Goraya. 2007. *Demand and Supply of Medicinal Plants in India*. NMPB, New Delhi & FRLHT, Bangalore, India.

Yethish. 2006. *Mapping the Distribution of Selected RET (Rare Endangered and Threatened) Tree Species of Central Western Ghats using Ecological Niche Modeling*. Dissertation, University Agricultural Sciences, Bangalore.

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