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Observation on distribution and habitat characteristics of Gugal (*Commiphora wightii*) in the arid region of Kachchh, Gujarat (India)

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Abstract : Generation of ecological information about the rare and endangered species is the prerequisite for their conservation. 'Gugal' (*Commiphora wightii*), overexploited for various medicinal and cosmetic use-values, is one of the threatened plants of Indian arid regions, with very little ecological knowledge. This paper examines its abundance, distribution pattern and associations with different species in coastal side of Kachchh district of Gujarat State. During this study, 286 circular plots of 0.1 ha size were sampled where all the woody plants were counted and the main habitat characteristics recorded. Spatial variation in the abundance of *C. wightii* was clearly evident within the area. Topography, soil type, soil depth and biotic pressures were found as the major controlling factors. A positive association was recorded with species like *Acacia nilotica, Acacia senegal* and *Euphorbia nivullia*, while, negative association was recorded with *Cassia auriculata*. The study reveals that *Prosopis juliflora* - an exotic weed, has no influence on the abundance of *C. wightii*. As one of the few conservation measures, study recommends the establishment of small reserves in the north-eastern part of the study area.

Resumen: La generación de información ecológica acerca de de las especies raras y en peligro es prerequisito para su conservación. El "Gugal" (*Commiphora wightii*), sobreexplotado por sus variados usos medicinales y cosméticos, es una de las plantas amenazadas de las regiones áridas de la India, con muy poco conocimiento ecológico. Éste articulo examina su abundancia, patrones de distribución y asociaciones con diferentes especies en la zona costera del distrito kachchh del estado Gujarat. Durante éste estudio, 286 parcelas circulares de 0.1 ha de tamaño fueron muestreadas, se contaron las plantas leñosas y se registraron las principales características del habitat. La variación especial en la abundancia de *C. wightii* fue claramente evidente en el area de estudio. Se encontró que la topografía, tipo de suelo, profundidad del suelo y las presiones bióticas fueron los principales factores controladores. Se registró una asociación positiva con especies como *Acacia nilotica*, *Acacia senegal* y *Euphorbia nivullia*, mientras que se registró una asociacion negativa con *Cassia auriculata*. El estudio revela que *Prosopis juliflora,* una maleza exótica, no tiene influencia sobre la abundancia de *C. wightii*. Como una de las pocas medidas de conservación, el estudio recomienda el establecimiento de pequeñas reserves en la parte noreste del area de estudio.

Resumo: A produção de informação ecológica sobre as espécies raras e em risco é um prérequisito para a sua conservação. A "Gugal" (*Commiphora wightii*), sobre explorada para vários usos medicinais e de cosmética, é uma das expécies ameaçadas nas regiões indianas áridas, sobre as quais há um reduzido conhecimento ecológico. Este trabalho examina a sua abundância, padrões de distribuição e associações com diferentes espécies na orla costeira do distrito de Kachchh do Estado do Gujarat. Durante este estudo foram amostradas 286 parcelas circulares de 0,1 ha e onde todas as plantas lenhosas foram contadas e as principais carac-

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terísticas do hábito foram registadas. A variação especial da abundância de *C. wightii* foi claramente evidente na área. A topografia, tipo e profundidade do solo e as pressões bióticas foram os principais factores de controlo encontrados. Registou-se uma associação positiva com espécies como a *Acacia nilotica, Acacia senegal* e *Euphorbia nivullia*, enquanto foi registada uma associação negativa com a *Cassia auriculata*. O estudo revelou que a *Prosopis juliflora* – uma infestante exotica – não tem influência na abundância da *C. wightii*. Como uma das poucas medidas conservacionistas, o estudo recomenda o estabelecimento de pequenas reserves na partenorte-oriental da área em estudo.

Key words : Density, association, conservation, *Prosopis juliflora*, habitat gradients.

Introduction

Species is the most commonly used biological unit in defining and conserving the biodiversity (Heywood 1995). Among the species, however, major concern for the conservation is focussed towards those species, which are identified as rare, endemic or threatened (Given 1994; Soule & Wilcox 1980). A threatened condition may be defined when natural regeneration of a species is not able to keep pace with its exploitation or destruction by anthropogenic or natural means, and as a consequence there is serious decline in the population (Jain 1992). Destructive harvesting for pharmaceutical and industrial uses is one major cause of such decline in plant population (Rao *et al*. 1983). While, the number of threatened species increases worldwide, understanding of various ecological parameters, controlling their population and distribution, is a necessary precondition for the species conservation efforts (Cancino *et al*. 1995; Cropper 1993; Synge 1981).

Gugal (*Commiphora wightii*) is a threatened plant species of Indian arid region (GEC 1996; WCMC 1994) which is reported from the States of Gujarat and Rajasthan with restricted distribution. In Gujarat, the species is mainly found in Kachchh and some parts of Saurashtra regions (Sabins & Rao 1983; Shah 1978). Due to its fragrant oleo-gum resin the Indian Bdellium-the species has high use-value to pharmaceutical and perfume industries and is subjected to over exploitation (Atal *et al*. 1975). While, the species is well documented for its use-values (Hocking 1993; Kirtikar & Basu 1935) and associated anatomical characteristics (Nair *et al*. 1981; Shah *et al*. 1982) the ecological information is lacking completely. This paper aims at filling this gap of information by evaluating *C. wightii* in terms of its distribution pattern, habitat preferences, association with other plant species and potential threats in near-coastal parts of Kachchh district. Based on this study, we suggest some conservation measures for the species. The data generated for this paper emerged from a larger study aimed at biodiversity appraisal for environmental impact assessment of a water resource development project in the study area (GUIDE 1997).

Materials and methods

Study area

The study area lies in Kachchh district of Gujarat between the 22°45 to 23°15 N latitude and of 69°15 to 69°50 E longitude, and covers about 1568 km^2 area of Mandvi, Mundra and Bhuj talukas. Topographically, the area is predominantly undulating with some small hills in the northern parts. The southern part is basically coastal surrounded by Gulf of Kachchh. The entire area is covered within the catchment of five ephemeral rivers viz., Rukmavati, Khari, Nagwanti, Phot and Bhukhi (Fig. 1) and supports sandy loam and stony gravel soil. The rainfall is low and erratic with high coefficient of variation (>60%). In the three talukas, average annual rainfall varies between 327 mm (at Bhuj) to 434 mm (at Mundra). The temperature ranges from 4.6°C in winter to 45°C in summer. Due to high temperature, low humidity and high wind speed, evapo-transpiration rates are quite high. More importantly, the area is facing severe problem of salinity intrusion due to over exploitation of ground water (Anon 1997).

According to the forest classification of Champion & Seth (1968), study area is predominantly

represented by Sub-group '6B' - northern tropical thorn forest. However, Gaussen *et al*. (1968) includes the area within physiognomic forms of discontinuous thorny thickets and scattered shrubs of *Salvadora oleoides-Prosopis spicigera* series. The area is dominated by *Acacia nilotica, A. senegal, Prosopis juliflora* and *Euphorbia nivullia*. Some small isolated patches of mangroves, dominated by *Avicennia marina*, are also recorded near the Mundra coast.

Methodology

This work emerges from a larger EIA study, where methods are specifically designed to sample plant communities at large, not the population of *C. wightii* alone. Since, the study area lacks in obvious ecological gradients like altitude and moisture, it is assumed that distance from the coast, due to some non-apparent underlying factors, controls the trends and patterns in vegetation. Based on this assumption, the study area was delineated into seven parallel zones : Zone-1 was near the coastline while Zone-7 was farthest from the coast in the inland (Fig. 1). While, the four zones near the coastal areas were delineated with about 5-km width, other three zones were of about 10 km each. In each zone, sampling sites were identified *a priori* on 1:50,000 scaled Survey of India toposheets. These sites were selected to account the natural variability in the area on the basis of physical features noted on the toposheets like hills, plateau or valleys; drainage pattern and broad habitat types like scrub or open and dense forests etc. Biotic pressure, especially the livestock grazing, surrogated by distance to human settlement, was also considered while selecting these sites.

In each selected sampling location, one circular plot of 0.1 ha area (17.85 m radius) was laid. In order to account more number of less common species, a 0.1 ha plot has been widely used for different vegetation studies in arid and semi-arid condi-

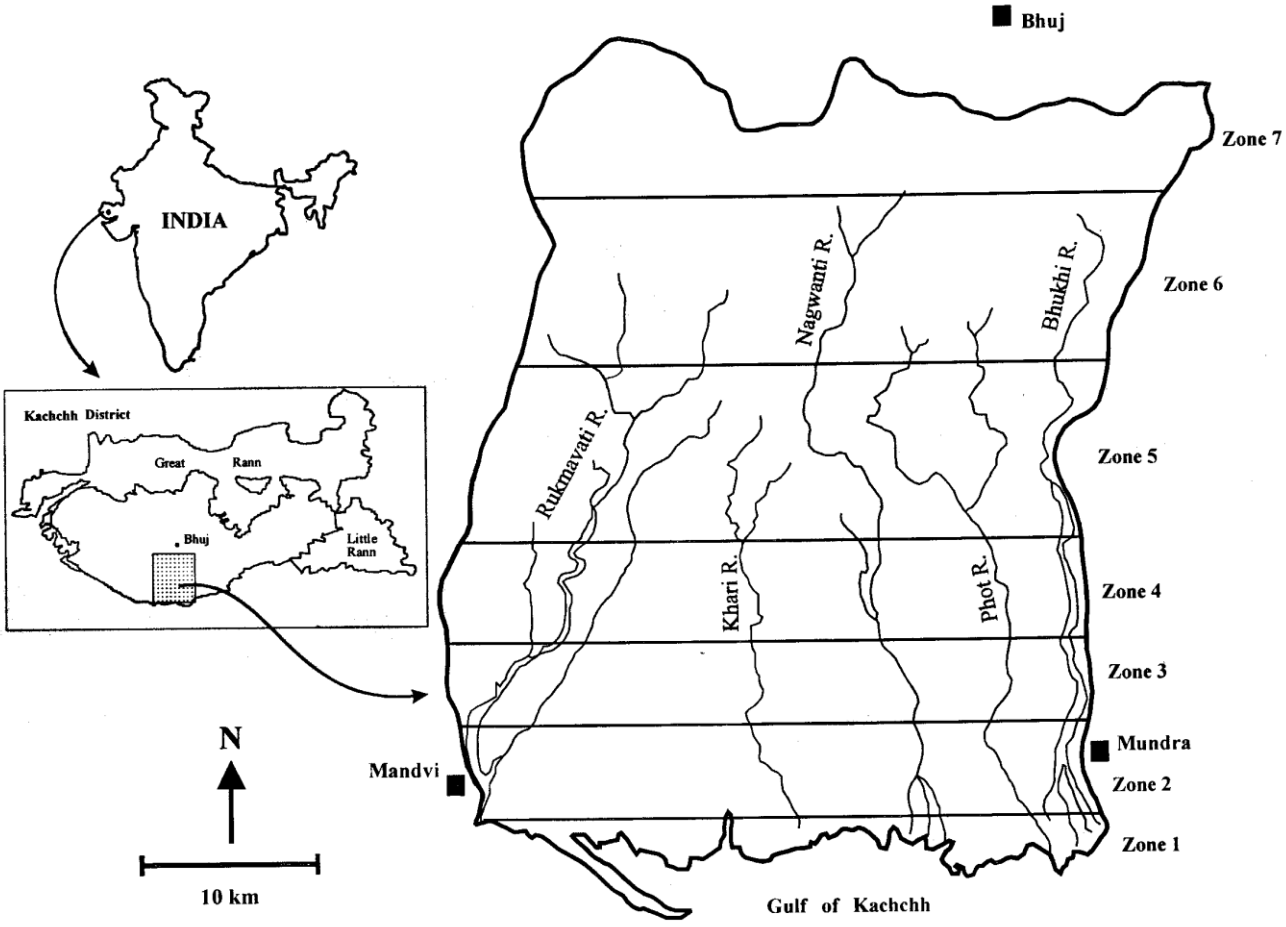

Fig. 1. Location of Study Area. Zones were delineated based on distance from the coastline.

tions (McAuliffe 1990; Meyer *et al*. 1992; Ward *et al*. 1993). A total of 286 such plots were sampled between November 1996 and February 1997. From each sampling plot, species wise number of trees and shrubs were recorded. Canopy cover for woody species was recorded ocularly at the interval of 5% cover classes. Different habitat variables like terrain type, soil type, soil depth and nature of surface were also recorded in each sampling plot.

The data recorded from the sample plots were analyzed for the density and frequency following the methods described by Misra (1968) and Mueller-Dombois & Ellenberg (1974). For the association analysis, Chi-square test from 2 x 2 contingency table was employed (Kent & Coker 1992).

Results and discussion

Distribution and habitat characterization

Out of 286 plots sampled, *C. wightii* was recorded in125 plots (43.7%) with an average density of about 49 plants ha^{-1}. Across the delineated zones, *C. wightii* was not recorded near the coastal zones i.e. Zone-1 to Zone-3. The species first appeared in Zone-4 (density 16.9 plants ha^{-1}) with a continuous increase towards the mainland zones (Zone-7 density 127.1 plants ha^{-1}). The frequency of occurrence followed the same trend, as the species was recorded in about 84% sample plots in Zone-7 and 23.6% in Zone-4 (Table 1). This indicates that the distribution and abundance of *C. wightii* was strongly correlated with the distance from the coast. However, this effect of distance from the coast could be attributed to variations in the micro-topography (terrain, altitude) and other physical environmental conditions (like ground water salinity, geological substratum) across the zones (Table 2).

It is understood that distribution and abundance of plants are governed by two major factors, (a) the suitability of habitat which is again the product of different factors and (b) level and pattern of biotic pressure (Given 1994). In this context it is important to identify the key habitat parameters that control the distribution and abundance of species in the study area. Further, it is important to assume here that, in the past, a valuable and specific resource like *C. wightii* was subjected to a uniform level of exploitation across the entire area, rather than to selective removal of plants from better habitats. Therefore, today's variation in density of *C. wightii* could largely be attributed to the different sets of habitat parameters prevailing in the area. Obviously, high densities of plants are recorded in more suitable habitat conditions. In the present study, therefore, predominant habitat characteristics in high density plots could be considered as key habitat parameters for the *C. wightii*. Keeping the above in view, habitat characterization was done in two population situations *i.e.* sample plots with low (up to 100 plants ha^{-1}) and high density (>100 plants ha^{-1}) of *C. wightii*. Sample plots with high density of *C. wightii* were recorded more in undulating (41.2%)

Table 1. Density and frequency of *C. wightii* in different zones.

Zone	N	Mean Density (Number ha^{-1})	Frequency (%)
1	7	0.0	0.0
2	34	0.0	0.0
3	34	0.0	0.0
4	55	16.9	23.6
5	49	57.1	59.2
6	62	73.4	72.6
7	45	127.1	84.4
Entire Area	286	49.0	43.7

Table 2. Physical characteristics of study area.

Zone	Topography	Altitude (m)	Ground water salinity (TDS in ppm)	Geological substratum
1	Flat	1-22	2800-4800	Alluvium
2	Flat	10-27	1600-4000	Shale, Mottled Sandstone
3	Undulating	20-44	800-2400	Shale, Mottled Sandstone
4	Undulating	40-74	400-3200	Shale, Laterite Clay
5	Undulating	60-137	800-2400	Basalt
6	Hilly	80-286	1200-2800	Basalt, Sandstone, Shale, Fossiliferous limestones
7	Hilly	140-295	800-2400	Sandstone, Shale, Fossiliferous limestones

and hilly (23.5%) terrain; loamy (41.2%) and gravelly (31.4%) soil type; shallow depth of soil (78.4%) and, pebbly (49.0%) and rocky (37.3%) substratum (Table 3).

Apparently, spatial variability (heterogeneity), in terms of micro-topography and soil characteristics is the major factor controlling the distribution and abundance of *C. wightii* in the study area. While, the responses of micro-topographical variation in characterization of communities in arid environment has received scant attention (Meyer *et al*. 1992; Ward *et al*. 1993), the role of spatial heterogeneity in terms of soil and other resources is well documented (Belsky 1995; Breshears & Barnes 1999). Based on the above, we tentatively suggest some broad habitat parameters and their gradients controlling the distribution and abundance of *C. wightii* (lower to higher density) in the study area (Table 4). Of these, soil type depth, substratum type, terrain and ground water salinity seems to have high degree of spatial variability across the zones and thus record strong affinity with the distance from the coast.

Table 3. Habitat characteristics of *C. wightii* under different density classes.

Habitat Parameters	Areas with Low Density of *C. wightii* (upto 100 plants ha^{-1}) n = 74	Areas with High Density of *C. wightii* (>100 plants ha^{-1}) n = 51
Terrain[1]		
Undulating	40.5	41.2
Flat	36.5	17.6
Hilly	9.5	23.5
Dry River Beds	13.6	17.6
Soil Type[1]		
Sandy	24.2	19.6
Loamy	41.9	41.2
Clayey	8.1	7.8
Gravelly	25.7	31.4
Soil Depth[1]		
Deep	32.4	7.8
Medium	25.7	13.7
Shallow	41.9	78.4
Substratum[1]		
Soil	45.9	13.7
Pebbles	40.5	49.0
Rocky	13.5	37.3
Signs of Moderate to High Grazing Pressure[1]	43.2	33.3
Woody Species Canopy Cover[2]	28.7	22.9

1= % of sample plots, presented in two density situations.
2 = Average cover (%), presented in two density situations.

Table 4. Major habitat gradients controlling the abundance of *C. wightii*.

Habitat Gradient	Low Density	High Density
Salinity level	High	Low
Terrain	Flat-Undulating	Hilly
Soil type	Loamy	Gravelly
Soild depth	Deep	Shallow
Substratum type	Soil	Rocky
Grazing pressure	High	Low
Canopy cover	Dense	Open
Distance from coast	Near	Far

Association with other species

Analysis of distribution pattern and habitat characterization revealed the association of *C. wightii* with other major plant species. The Chi-square value, an index of association, showed that all the major species were significantly associated with *C. wightii* (Table 5). *C. wightii* generally exhibited stunted growth (average height 0.5 m), however, inside the thickets of *E. nivullia*, it showed interesting association by growing up to 1-2 m height (Pers. Obsv.). Such association of *Euphorbia* has also been reported for another endangered plant species *Frerea indica* (Tetali *et al*. 1997). While all the species were positively associated with *C. wightii* and sharing the similar habitats, *C. auriculata* showed negative association (X^2 = 60.3, P > 0.001) suggesting relatively higher degree of habitat (niche) separation. It was apparent in spatial distribution that *C. wightii* was more frequent and abundant in the mainland (Zone-4 to Zone-7) and *C. auriculata* was mostly confined to the coastal region i.e. up to Zone-3 (Fig. 2). However, record of both the species in Zone-4 suggests some degree of niche overlap and presence of transitional habitats.

Table 5. Association of *C. wightii* with other major species.

Species	Observed frequency of joint occurrence	Expected frequency of joint occurrence	^{2}	Association
Acacia nilotica	102	94	4.3[c]	+ ve
Acacia senegal	97	66	54.5[a]	+ ve
Zizyphus nummularia	99	87	8.9[b]	+ ve
	86	44	109.2[a]	+ ve
Euphoriba nivullia	95	94	.0007[d]	+ ve
Prosopis juliflora	81	66	12.0[a]	+ ve
Capparis decidua	103	62	95.0[a]	+ ve
Grewia tenax	15	46	60.3[a]	- ve
Cassia auriculata				

a, b, c and d are P>0.001, P>0.01, P>0.02 and P>0.95, respectively.

Effect of Prosopis juliflora

In the early 1960's, *P. juliflora* was planted in the area to arrest the coastal erosion, which subsequently encroached into large tract of fertile lands of Kachchh (GEC 1994) and thus adversely affected the communities of natural vegetation (Pandya & Sidha 1982). During this study, therefore, specific attempt is made to determine the effect of *P. juliflora* on the abundance of *C. wightii*. To understand this, density of *P. juliflora* was considered as causative factor while response was seen on density of *C. wightii*. It was found that density of *C. wightii* was almost equal in the plots with or without *P. juliflora* (Table 6). Further, it

Table 6. Effect of *P. juliflora* on *C. wightii* in study area.

Parameters	Density of *C. wightii* (No. ha^{-1})	
Density of *P. juliflora* (No ha^{-1})		
1 to 100 (n=54)	136.7	20.5
101 to 200 (n=16)	67.5	16.1
201 to 300 (n=5)	194.0	94.5
301 to 400 (n=5)	98.0	56.0
>400 (n=15)	56.7	11.3
Plots with *P. juliflora* (n=95)	113.4	13.7
Plots without *P. juliflora* (n=30)	107.7	17.4

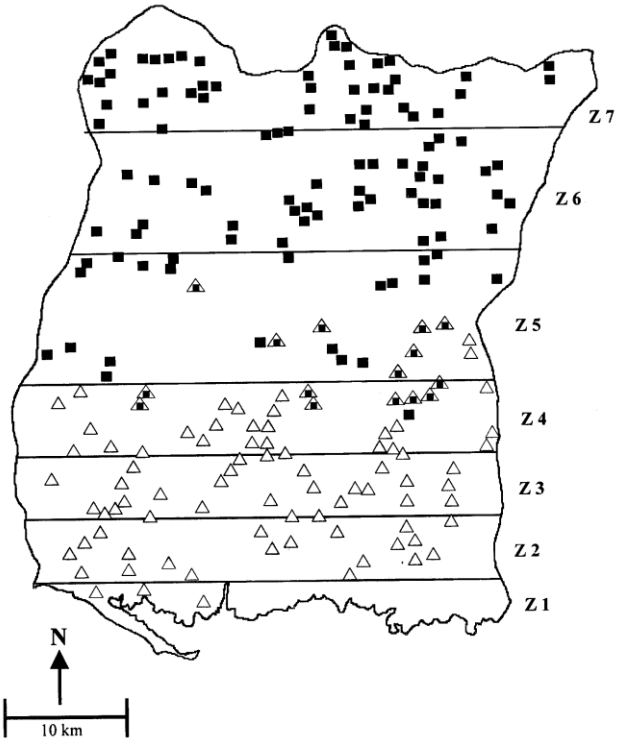

Fig. 2. Distribution of *C. wightii* (■) and *C. auriculata* ( ) in different zones of study area. Also showed the plots with the presence of both species ( ).

was also observed that density of *P. juliflora* does not have any significant correlation with the density of *C. wightii* (r^2 = -0.009, P >0.27, n = 125). Therefore, it can be argued that the present level of *P. juliflora* spread has no significant bearing on of *C. wightii* in the study area. Lack of any significant association between these two species (Table 5) further substantiates the above view.

Threats

The species has high use-value especially for medicinal purpose. Each mature plant of *C. wightii* gives an average of about 250-500 gm of gum during one extraction season *i.e.* November and December (Atal *et al.* 1975). Between 1963 and 1970, forest department alone has collected a total of about 43 tonnes of Gugal gum from the entire Kachchh (Table 7) (Anon. 1972). However, this figure underestimated the total production of Gugal in Kachchh. Atal *et al.* (1975) reported that during the same period, annually 300 to 400 tonnes of Gugal were sold from Bhuj market, highlighting the potential of the area, in terms of number of mature plants. It is important to note here that

Table 7. Gugal gum collection in Kachchh by forest department.

Year	Collection in Tonnes
1963 – 64	30.00
1964 – 65	10.20
1965 – 66	4.00
1966 – 67	1.10
1967 – 68	0.43
1968 – 69	0.33
1969 – 70	0.75
1994 – 95	4.60
1995 – 96	1.70
1996 – 97	1.30
1997 – 98	2.28
1998 – 99	2.42

local people normally followed very crude methods of gum extraction from *C. wightii*, which leads to high mortality of the plants. It is presumed, therefore, that during such a high level of gum collection, there could be death of large number of mature plants, which subsequently reduces the gum collection. Sharp decline in forest department's collection between 1962 to 1970 could be attributed to such mass destruction of plants. However, unlike in 1960s, the increase in gum collection during 1990s may not be attributed to the improved population of *C. wightii* in the wild, but to organized and controlled collection by forest department alone.

Grazing and browsing by sheep and goats seems to have some bearing on the abundance of *C. wightii*. Although no empirical data is available to establish this, but two general observations indicate this effect. First, during the survey, hardly any seedlings and samplings of *C. wightii* were recorded from the study area, which could be linked to overgrazing. Second, the low density of *C. wightii* corresponds with more frequent evidences of livestock grazing (43%), which is less (33%) in high density plots (Table 2).

Interestingly, *C. wightii* demonstrated one of the most generic problems of conservation where the species is initially subjected to very high degree of organized extermination and when left with small population, exposed to continuing anthropogenic pressures like grazing and browsing which ultimately arrest the new recruitment. The records of very few mature or fruit bearing plants and almost negligible degree of new recruitment highlights the vulnerability of the population of this species in the study area.

Conclusion

This is the first study on the micro-habitat requirements, natural associations and distribution pattern of threatened *C. wightii*. The study reveals that abundance and distribution of the species in the coastal areas of Kachchh (Gujarat) follows a distinct environmental gradient directed by the topography and salinity. Undulating and hilly areas appear to be the most suitable habitats for this species, which showed highest density (127.1 plants ha^{-1}). The species has undergone heavy exploitation for its valuable gum in the past and currently it faces chronic stress in the form of livestock grazing and cutting irrespective of distance from the human habitation. Based on the information collected during this study we recommend the following conservation measures for the species : (i) multiplication through nursery as well as tissue culture techniques (*ex-situ* conservation) and plantation in the suitable habitats, (ii) establishment of a small reserve in the north-eastern part of the study area including zones 5 to 7 (*in-situ* conservation) in which biotic pressure should be regulated, (iii) developing standard and better gum extraction techniques in order to minimize mortality of the plants, (iv) involvement of local communities in the conservation of species. Although *Prosopis juliflora* (an exotic species) is confined to small pockets at present, it could be a potential threat to *C. wightii* in future if it spreads more rapidly. Therefore, regular monitoring of both the species (spread of the former and response of the latter) would be desirable.

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