Indian Forester, **143** (10) : 975-984, 2017
http://www.indianforester.co.in

ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

ROLE OF HERBACEOUS VEGETATION IN HABITAT UTILIZATION BY CRITICALLY ENDANGERED GREAT INDIAN BUSTARD *ARDEOTIS NIGRICEPS* (VIGORS) IN THE INDIAN THAR DESERT

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ABSTRACT

With an objective to enhance the inviolate area, fresh closures were made adjacent to old closures in Thar desert landscape as part of managerial inputs based on *in situ* conservation guidelines for critically endangered great Indian bustard *Ardeotis nigriceps* (Vigors). This newly enclosed area was partly mowed and ploughed just before the onset of rains in July which resulted in profuse regeneration of herbaceous vegetation. Preference for these newly made closures by the bustard was noted as compared to old closures. In order to understand causes of such preference, the vegetation of both old and freshly made closures was compared. High richness and abundance of ephemerals and low height of herbaceous vegetation in newly made closures providing better opportunities of feed and enhanced sight distance to detect approaching predators attracted more number of great Indian bustard. Mowing and ploughing the open areas in mosaic pattern breaks the crust laden hard surface allowing regeneration of herbaceous vegetation that improves the habitat for the species. Carrying out this activity annually just before the onset of rains without disturbing the local sewan *Lasiurussc indicus* and other perennial grasses, shrubs and trees of old closures of bustard range areas emerged as a key management strategy for *in situ* conservation of great Indian bustard in the Indian part of Thar desert.

Key words: Abundance, Bustard, *Ardeotis nigriceps*, Desert, Diversity, Endangered, Ephemerals, Richness, Vegetation.

Introduction

The great Indian bustard *Ardeotis nigriceps*-known to all Indian ornithologists by its initials-is in deep trouble (Collar *et al*., 2015). With a remaining population of ~200 birds (IUCN, 2011), it is most threatened among all bustards and was listed as Critically Endangered in IUCN red list (IUCN, 2011). The great Indian bustard is a grassland species and is restricted to Rajasthan and Gujarat with some birds in Maharashtra, Andhra Pradesh-Karnataka and Andhra Pradesh. Their populations have dwindled due to historical human exploitation (hunting and egg collection during British Raj) and are currently threatened by habitat loss (intensive agriculture and infrastructural development in grasslands) and human-induced deaths (fatal collisions with power lines and passive hunting) (Dutta *et al*., 2011). Rajasthan State in India holds the largest population and is prime hope for saving the species (Dutta *et al*., 2011). As the range states across the country are developing species' recovery plans (Dutta *et al*., 2013), baseline information on current distribution, abundance and habitat relationships are scanty. Such information is essential for conservation planning and subsequently assessing the effectiveness of management actions in respect of species like great Indian bustard. In view of this it is essential for the natural resource managers to keep in their mind about the observations in field as outcome from their managerial inputs to draw out subsequent strategy plan for future managerial actions. More sightings of great Indian bustard *Ardeotis nigriceps* (Vigors) in the newly made closure as compared to old closures in Thar desert of India, attracted the attention of park managers to know the reason of such preference of the new closure. In order to investigate this, a floristic survey was carried out and attempts were made to compare vegetation in different closures both, old and new in Jaisalmer district namely Sudasiri ACD, Sudasiri new, Tikhi Magri, Ramdeora and also open areas of Khara and Loharki of bustard range area. Aim was to understand factors responsible for biased habitat preference of great Indian bustard for new closures amongst different landscape units so as to arrive at future managerial directions as part of the already initiated *in situ* conservation measures for great Indian bustard.

High richness and abundance of herbaceous vegetation in newly closed degraded grasslands from livestock grazing were observed to be the main factors for increased congregation of Great Indian Bustard *Ardeotis nigriceps* in Sudasiri area of Desert National Park.

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Material and Methods

The study was done in Sudasiri closures (Sudasiri ACD, Tikhi Magri and Sudasiri new closure) raised in agro-pastoral dominated areas of Desert National Park and Ramdeora ABC closure and adjoining areas that form a part of Desert Bio-geographic Zone (Rodgers *et al*., 2002) with super arid conditions (Fig.1 and 2).

The area is flat with slight undulations with scarce and erratic rainfall, with mean annual precipitation of 100-500 mm that decreases from east to west (Pandeya *et al*., 1977). The climate is characterized by very hot summers (temperature rising up to 50°C), relatively cold winter (temperature dropping below 0°C), and large diurnal temperature range (Sikka 1997). Thar is the most populated desert (Rahmani, 1997a), inhabited by 85 persons/km^2 that largely stay in small villages and dhanis (clusters of 2-8 huts), and depend mainly on pastoralist and dry farming for livelihoods. Realizing the continuous degradation and destruction of this landscape due to recent infrastructure activities like roads, power transmission and especially much talked Indira Gandhi Canal in the region, it was felt necessary that a representative of this unique ecosystem should be preserved as such, a beginning was made in 1980 when an area of 3162 km^2 was brought under the umbrella of Protected Area Network as desert wildlife sanctuary with an objective of conservation of unique biological diversity, along with aesthetic beauty and cultural heritage of this desert ecosystem with various ecological processes and also great Indian bustard as flagship species. One of the main purpose for the establishment of this large protected area was to conserve the critically endangered great Indian bustard apart from conserving the desert biota. Though it has not been notified as National Park, the name of this protected area still continues as Desert National Park. An estimated human population of around hundred thousand with a livestock more than three hundred thousand, residing in 73 villages is located in DNP which is viewed as a threat to the wilderness and biological elements of the landscape. An approximate area of around 135 km^2 in DNP and ~35 km^2 outside DNP was covered with closures in last 36 years. Closures (fenced areas) in DNP as well as in Ramdeora area are the management units of local park authorities fenced for the purpose of checking encroachment and livestock grazing in the closures. During breeding season of GIB, these closures, especially in Sudasiri area of DNP and of Ramdeora area can be viewed as "maternity wards" for the species. The vegetation of the area is thorny scrub, characterized by open woodlot dominated by *Prosopis cineraria* and *Salvadora persica* scrubland dominated by *Capparis decidua*, *Zizyphus mauritiana*, *Salvadora oleoides*, *Leptadenia pyrotechnica, Aerva pseudotomentosa, Haloxylon salicornicum* and *Crotalaria burhia* as shrubs, and the dominant grasses include *Lasiurus scindicus, Octhocloa indica, Dactyloctenium scindicum, Enneapogon cenchuroides*, *Cymbopogon jwarancusa*, *Aristida depressa,* etc. Notable fauna, apart from the ones mentioned before, include mammals like chinkara (*Gazella bennetti*), desert fox (*Vulpes vulpes*), Indian fox (*Vulpes bengalensis*), desert cat (*Felis silvestris*), birds like Macqueen's bustard (*Chlamydotis macqueenii*), cream-colored courser (*Cursorius cursor*), sandgrouses (*Pterocles* spp.), larks, and several species of birds of prey.

Fig. 1: Map showing Desert National Park in Jaisalmer district of Rajasthan

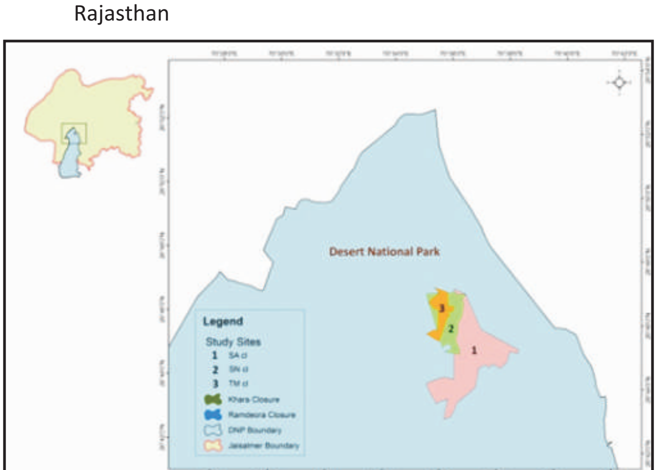

Fig. 2: Map showing closures studied in Desert National Park where study was conducted

The frequent occurrence of great Indian bustard in newly made Sudasiri new closure (SN cl), that was made in 2015 and negligible sighting of the birds in old Sudasiri ACD (SA cl) closure in post breeding season in October-November 2015 (Fig. 3) compelled the lead author to assume that it is the vegetation that determines the habitat preference by the bird when the human induced disturbance factors are minimum and similar in both of the closures. Closures selected for this study were Sudashiri

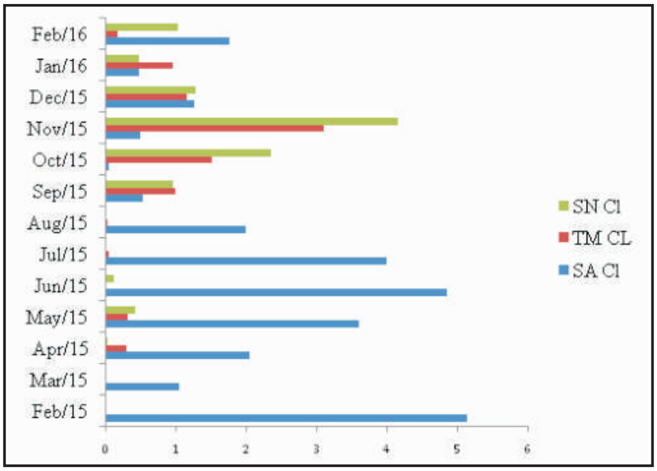

Fig. 3: Bar chart showing the average monthly sighting of great Indian bustard in three closures (SA cl, TM cl and SN cl) as observed from February 2015 to February 2016 in Desert National Park

ACD closure (SA cl), Tikhi Magri Closure (TM cl), Sudasiri new closure (SN cl), Ramdeora closure (RA cl), Khara open area and Loharki open area. The Sudasiri closures are located in north of the DNP while the Ramdeora closure is located outside the DNP. The Khara and Loharki areas are outside the closures in close proximity to Ramdeora Closure ABC.

The bird observation data was continuously recorded from February 2015 to February 2016. Vegetation sampling and plant observation was done in Nov.-Dec. 2015. Vegetation sampling was done using quadrates of 5x5m size laid randomly in the study areas. A total of 200 of quadrates were laid in Sudasiri ACD (n=30), Sudasiri Tikhi Magri (n=30), Sudasiri new (n=30), Ramdeora closure (n=71), Loharki area (n=19) and Khara area (n=20). Plant species as observed in the quadrates were recorded and their heights were also measured. Based on habit, plants were also grouped into trees, herbs, shrubs and grasses. The data were analyzed using the Biodiversity *Pro* version 2.0. We chose a set of five diversity indices to test for differences in floristic diversity among different six sites cited above. These include species richness, Shannon diversity index, Shannon evenness index, Simpsons diversity index, Alpha diversity and Berger-Parker index. While the richness in a sample represents number of species, the Berger-Parker index is a measure of the degree to which a single species is dominant. We are usually interested not just in the diversity of a single site, but in comparing biodiversity levels across sites.

Results and Discussion

Results

Floristic analysis

A total of 47 plant species belonging to belonging to 25 families were observed in all study sites. Five plant species (sample 1 to 5) could not be identified (Table 1). Based on the encounter rate of the plant species (species present or absent) in the pooled data of all sample plots, grasses emerged as dominant in the study sites (45%) followed by herbaceous plants (39%), shrubs (13%). While the trees (*Ziziphus mauritiana* and *Capparis decidua*) constituted only 2% of total encounter rate of the different

Table 1: Name of the plant species arranged alphabetically as observed in all sites along with local name and habit.

S.No.	Scientific name	Common name	Habit
1	*Aerva pseudotomentosa*	Bhui	Shrub
2	*Aristida depressa*	Lapla	Grass
3	*Arnebia hispidissima*	Chhota Jhad	Herb
4	*Benincasa fistulosa*	Tisandi	Herb
5	*Blepharis sindica*	Bhangari	Herb
6	*Boerhaava diffusa*	Santhi	Herb
7	*Calotropis procera*	Akra	Bush
8	*Capparis decidua*	Kair	Shrub
9	*Cenchrus ciliaris*	Dhaman	Grass
10	*Citullus colocynthis*	Tumba	Scrambler
11	*Convolvulus prostratus*	Shankhpushpi	Scrambler
12	*Corchorus olitorius*	Cham ghass	Grass
13	*Corchorus trilocularis*	Corchorus	Herb
14	*Crotalaria burhia*	Senia	Herb
15	*Cucumis melo-agrestis*	Kaachri	Bel
16	*Cyamopsis tetragonoloba*	Gowar	Herb
17	*Cymbopogon jwarancusa*	Bhurat	Grass
18	*Cyperus rotundus*	Moth	Herb
19	*Dactyloctenium aegypticum*	Ubri	Grass
20	*Dactyloctenium sindicum*	Ganthil	Herb
21	*Dipterygium glaucum*	Phel	Herb
22	*Enneapogon cenchuroides*	Kiria	Grass
23	*Eragrostis minor*	Lampla	Grass
24	*Euphorbia hirta*	Doodheli	Herb
25	*Fagonia cretica*	Dhamasa	Herb
26	*Gisekia pharnaceoides*	Chhapar	Herb
27	*Haloxylon salicornicum*	Lanna	Bush
28	*Heliotropium strigosum*	Bafuli	Herb
29	*Indigofera cordifolia*	Bekar	Herb
30	*Indigofera sessiliflora*	Bekaria	Herb
31	*Lasiurus scindicus*	Sewan	Grass
32	*Lepidagathis trinervis*	Kanta wala	Herb
33	*Leptadenia pyrotechnica*	Khinp	Shrub
34	*Mollugo cerviana*	Chiria-ro-khet	Herb
35	*Mushrooom*	Mushroom	Thallus
36	*Octhocloa indica*	Narad	Grass
37	*Salvadora oleoides*	Jal	Tree
38	Sample 1	Bawal	Herb
39	Sample 2	Sample 2	Herb
40	Sample 3	Behoni	Herb
41	Sample 4	Gogoni	Herb
42	Sample 5	Shamsama	Herb
43	*Solanum surretense*	Nili Kateli	Herb
44	*Tephrosia falciformis*	Tephrosia	Herb
45	*Tribulus terrestris*	Kanti (Gokhru)	Herb
46	*Ziziphus mauritiana*	Ber	Tree
47	*Ziziphus nummularia*	Jharber	Bush

habits of plant species. While the Sudasiri new closure (SN cl) was observed to be dominated by herbaceous plants (67%), followed by grasses (24%); the old Sudasiri ACD closure (SA cl) was dominated by grasses (59%) with the herbaceous plants contributing only of 34%. In Ramdeora closure (RA cl) grasses constituted 78% of the total plants and the herbs contributed only 18%. Relatively not very old closure, Tikhi Magri (TM cl) was observed to be dominated by herbs (46%), grasses (44%) and shrubs (10%) (Fig. 4). Similarly, based on the pooled data of actual count of vegetation in sample plots, the percentage of herbaceous plants was observed to be dominated in SN cl (73%) than grasses (23.2%) and shrubs (3.8%). While the percentage of grasses in SA cl was observed to maximum (70%) as compared to herbs (27.7%), the percentage of herbs and grasses remained 39.7 and 57.8 in TM cl. (Fig. 5). Grasses like *Lasiurus scindicus*, *Octhocloa indica*, *Dactyloctenium scindicum,* etc were observed to be main components of flora in SA cl. The more abundant herbaceous vegetation in the order of dominance in SN cl was observed to be represented by *Fagonia cretica*, *Molluga cerbiana*, *Indigofera cordifolia*, *Crotalaria burhia* and *Aerva pseudotomentosa*. Similarly, *Dactyloctenium scindicum*, *Octhocloa indica*, *Lasiurus scindicus* are the dominating grasses in TM cl and *Fagonia cretica*, *Indigofera cordifolia*, *Molluga cerbiana*, *Crotolaria bhuria* and *Aervap seudotomentosa* are the important herbaceous species of TM cl (Table 2).

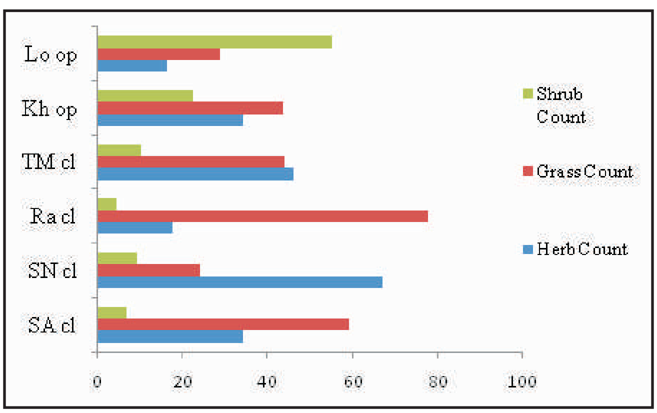

Fig. 4: Bar chart showing the presence of herbs, shrubs and grasses in different sites studied based on the pooled data of encounter rate of floristic species in all sample plots

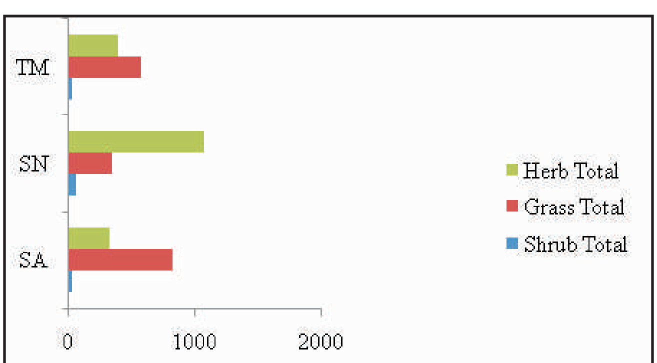

Fig. 5: Bar chart comparing the percentage of grasses, herbs and shrubs based on actual pooled data all counts of plants in different sample plots in three closures (SA cl, SN cl and TM cl) of desert national park.

The average height of the ground vegetation was observed to be maximum (43cm) in SA cl while it was only 28 cm in SN cl. It was observed as only 28.8 cm in TM cl and RA cl. The observed height of ground vegetation was 32.12 cm in Khara open (Kh op) area and 37.4 in Loharki area (Lo op) (Fig. 6).

Diversity indices

Based on encounter rate of different plant species across different quadrates in different closures and open areas, we computed different diversity indices with Biodiversity Pro and foundmaximum richness of floristic species in Sudasiri new closure SNCl (Hills number H^0=31) followed by Sudasiri old ACD SAcl (H^0=21), Tikhi Magri TMcl (H^0=20), Ramdeora closure RAcl (H^0=20). Extremely low species richness (H^0=12) was observed in open areas of Khara and Loharki. Shannon diversity index was observed to be maximum (H'=1.35) in Sudasiri new closure (SNcl), followed by just adjacent closure Tikhi Magri (TM cl) with a Shannon index of 1.15, Sudasiri Old ACD closure (H'=1.14). Ramdeora Closure (Ra cl) showed Shannon diversity index as 0.99. It was observed minimum in open areas like Loharki (H'=0.98) and Khara (H'=0.89) revenues areas. Similarly species evenness, Shannon evenness index (J') was observed maximum (J'=0.91) in Sudasiri new closure (SN cl), followed by Tikhi Magri (TM cl) with a J' of 0.88, 0.86 in Sudasiri old ACD (SA cl) and only 0.76 in Ramdeora closure (RA cl). Though subjected to all kinds of anthropogenic pressures area the Loharki area showed considerably higher species evenness (J'=0.90) as compared to Khara area (J'=0.83). Similarly, Alpha index was also observed maximum in SNCl (α=9.22). It was recorded as 6.18 in RAcl followed by TM cl (6.08), 5.55 was in RAcl, 3.81 in Kh op and 3.77 in Lo op areas (Table 3).

Simpson's Index (D) with a mathematical expression of $\Sigma n(n-1)/N(N-1)$) measures that two individuals randomly selected from a sample will belong to the same species ranges between 0 to 1 (while 0 represents infinite diversity and 1, no diversity. We overcome this problem of the counter-intuitive nature of Simpson's Index by replacing it with Simpson's Reciprocal Index (1/D) where the maximum value is number of species in the sample. Maximum SRI (1/D) was observed in Sudasiri new closure (SN cl*)* (1/D=20.12) followed by closures Tikhi Magri

Table 2: The plant species as observed in three closures in the order of decreasing abundance.

Plant species in Sudasiri ACD old closure (SA cl)	% of total pooled samples (N=1172)	Plant species in Sudasiri New Closure (SN cl)	% of total pooled samples (N=1467)	Plant species in Tikhi Magri New Closure (TM cl)	% of total pooled samples (N=992)
Lasiurus sindicus	23.21	*Fagonia cretica*	24.88	*Dactyloctenium scindicum*	26.71
Octhocloa indica	14.93	*Mollugo cerviana*	13.02	*Octhocloa indica*	22.78
Dactyloctenium scindicum	13.74	*Indigofera cordifolia*	10.02	*Fagonia cretica*	15.62
Cymbopogon jwarancusa	11.69	*Octhocloa indica*	8.99	*Indigofera cordifolia*	9.37
Indigofera cordifolia	8.53	*Crotalaria burhia*	6.34	*Mollugo cerviana*	7.66
Blepharis sindica	6.22	*Boerhaavia diffusa*	4.02	*Lasiurus sindicus*	4.74
Fagonia cretica	5.55	*Lasiurus sindicus*	3.88	*Crotalaria burhia*	4.33
Aristida depressa	5.124	*Cenchrus ciliaris*	3.07	*Eragorstis minor*	2.31
Enneapogon cenchuroides	1.70	*Aerva pseudotomentosa*	2.86	*Aerva pseudotomentosa*	1.81
Heliotropium strigosum	1.62	*Citrullus colocynthis*	2.79	Sample 2	1.00
Aerva pseudotomentosa	1.53	*Euphorbia hirta*	2.52	*Citrullus colocynthis*	0.91
Tribulus terrestris	1.36	*Heliotropium strigosum*	2.25	*Cymbopogon jwarancusa*	0.60
Mollugo cerviana	0.94	*Dactyloctenium sindicum*	2.11	*Aristida depressa*	0.50
Indigofera sessiliflora	0.77	*Eragorstis minor*	1.98	*Dipterygium glaucum*	0.50
Cenchrus ciliaris	0.68	*Aristida depressa*	1.90	*Ziziphus nummularia*	0.40
Lepidagathis trinervis	0.68	*Indigofera sessiliflora*	1.50	*Leptadenia pyrotechnica*	0.20
Eragorstis minor	0.60	*Tribulus terrestris*	1.50	*Tribulus terrestris*	0.20
Crotalaria burhia	0.43	*Cymbopogon jwarancusa*	1.23	*Cucumis melo agrestis*	0.10
Leptadenia pyrotechnica	0.43	*Cyamopsis tetragonoloba*	1.02	*Enneapogon cenchuroides*	0.10
Citrullus colocynthis	0.17	*Cucumis melo agrestis*	0.95	*Haloxylon salicornicum*	0.10
Calotropis procera	0.085	*Dipterygium glaucum*	0.95	*Arnebia hispidissima*	
		Haloxylon salicornicum	0.89		
		Arnebia hispidissima	0.27		
		Corchorus trilocularis	0.27		
		Benincasa fistulosa	0.20		
		Blepharis sindica	0.20		
		Solanum surretense	0.14		
		Convolvulus prostratus	0.07		
		Tephrosia falciformis	0.07		
		Ziziphus nummularia	0.07		

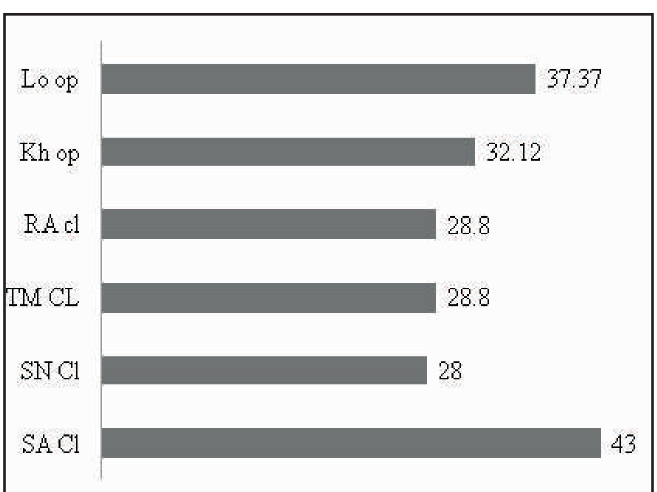

Fig. 6: Bar chart showing average height of ground vegetation in centimeters as observed in different sites during study period.

(1/D=12.72) and Sudasiri Closure SA cl (1/D=11.87). It was observed only 6.22 in Ramdeora closure.

Discussion

Frequent occurrence of great Indian bustard outside the closures along with livestock during post breeding season can be due to functional evolutionary benefit that the species is taking through some functional advantages which has already been studied for other species too (Morse, 1977; Berner and Grubb, 1985; Terborgh, 1990; Stensland, *et al*., 2003; Sridhar *et al.*, 2009). Functional explanations usually fall within two major, non-exclusive categories: foraging advantages (individuals benefit from the mixed species association by summing up their capacities to locate patchy food resources; Krebs 1973; Stensland *et al*., 2003) and anti-predator benefits (individuals benefit from the association by increasing their abilities to detect and deter predators;

Table 3: Different diversity indices computed with biodiversity Pro based on encounter rate of different plant species across different quadrates in different closures.

S.No.	Index	SA cl	SN cl	TM cl	RA cl	Lo op	Kh op
1	Shannon H' Log Base 10.	1.14	1.35	1.15	0.99	0.98	0.89
2	Shannon H*max* Log Base 10.	1.32	1.50	1.30	1.30	1.08	1.08
3	Shannon J'	0.86	0.91	0.88	0.76	0.90	0.83
4	Alpha	6.18	9.22	6.08	5.55	3.77	3.81
5	Simpsons Diversity (D)	0.08	0.05	0.08	0.16	0.11	0.15
6	Simpsons Diversity (1/D)	11.87	20.12	12.72	6.22	8.84	6.65
7	Hill's Number H0	21	31	20	20	12	12
8	Hill's Number H1	63.65	127.50	65.75	38.37	36.9	28.01
9	Hill's Number H2	0	0	0	0	0	0
10	Berger-Parker Dominance (d)	0.15	0.10	0.13	0.33	0.22	0.24
11	Berger-Parker Dominance (1/d)	6.63	10.28	7.85	3.02	4.58	4.25
12	Berger-Parker Dominance (d %)	15.08	9.73	12.74	33.17	21.84	23.53

Fig. 7: Great Indian bustard in a closure with chain linked fence behind the species.

Fig. 8: Great Indian bustard in new closure. The herbaceous vegetation that has come up after the rains is clearly visible with one medium sized tree of kair *Capparis deciduas.*

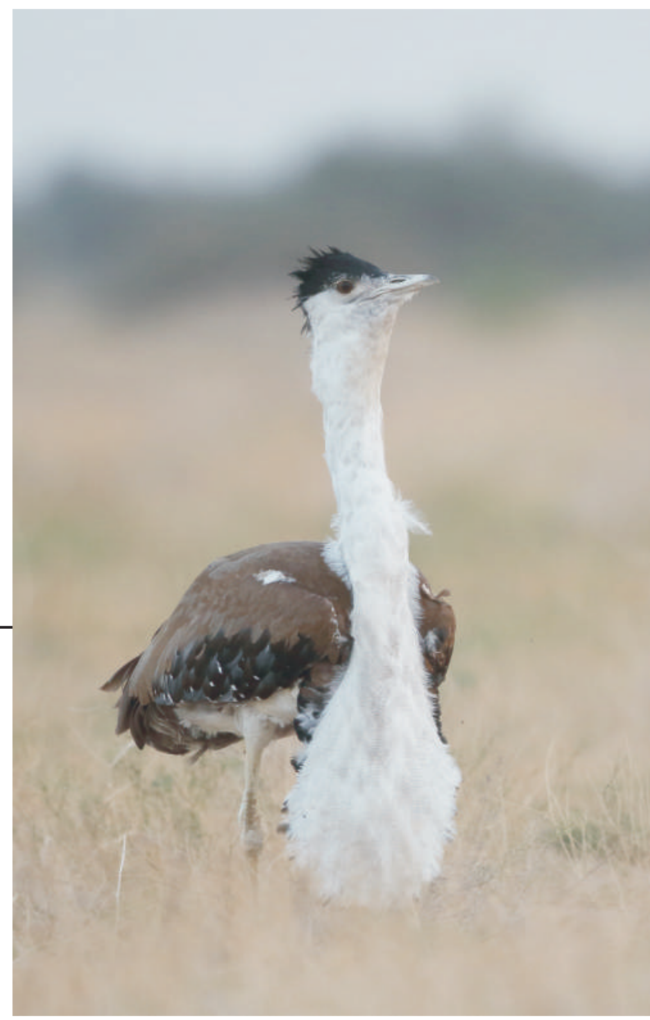

Fig. 9: A portrait of great Indian bustard *Ardeotis nigriceps*.

(Terborgh 1990; Sridhar *et al*., 2009). High abundance and richness of ephemerals post monsoon from September to February (winters) is one explanation for increased occurrence of GIB (Fig 1) in newly made closure (SN cl). Dietary observations made by Bhushan (1985); Rahmani and Manakadan (1988); Rahmani (1989) have revealed that the species is omnivorous feeding on orthopteran and coleopteran insects, lizards and rodents, berries of *Zizyphus* species, kair *Capparis decidua*, piloo of *Salvadora persica* and even foliage herbaceous plants like dhamasa *Fagoniacretica*, bekar *Indigofera cordifolia*. Local staff has also observed the species feeding on the grains of a number of members of Poaceae including kiria *Enneapogon cenchruoides*, sewan *Lasiurus scindicus* and even bhurat *Cymbopogon jwarancusa*; agricultural crops such as millets and legumes; Many times the great Indian bustard has been observed feeding on larvae of insects from the fruits of kacchri *Cucumis melo-agrestis* and matira *Citrullus colocynthis*. Bustards in general are opportunistic omnivores and in the wild their diet reflects the local and seasonal abundance of plants and animals (Schutz and Seddon, 1996; Tigar and Osborne, 2000). Vegetation appear to be a more important source of food for Houbara Bustard during winter and early spring while animals, mostly invertebrates and small vertebrates are more likely to be consumed in late spring and summer (Cramp and Simmons, 1987; Johnsgard, 1991). Field studies of the gut contents of bustards have shown that vegetation constitutes a very significance proportion of their diet (Collar, 1996). Based on faecal analysis of great bustards (*Otis t. tarda*) in Spain, Lane *et al*. (1999) showed the diet composition by dry weight of green plant material remained 48.4%, 40.9% invertebrates and 10.6% seeds by in august (late spring and summer) and almost all green material between December and March (winter and early spring).

Great Indian bustard prefers open, semi-arid agro-grass habitats that support many other faunal species like chinkara *Gazella bennettii*, spiny-tailed lizard *Saara hardwickii* and also potential predators like desert fox *Vulpes vulpes pusilla*, Indian fox *Vulpes bengalensis*, desert cat *Felis sylvestris*, common grey mongoose *Herpestes edwardsii*, Monitor lizard *Varanus* spp. and many birds of prey. In addition to foraging advantages, the association of chinkara and livestock with the bustard in Thar landscape can be viewed as a defense mechanism against predation. Mixed species groups can be larger than single-species ones, and could allow earlier detection, more efficient defenses and increased safety in numbers (Jullien and Clobert, 2000; Arroyo *et al*., 2001; Stensland *et al*., 2003). One species could also benefit from the better vigilance behaviour of the other, for instance when they differ in morphology, size or behaviour (Sridhar *et al*., 2009).

Apart from many factors responsible for the habitat selection by a species including the presence of hetero-specifics, including predators (Wootton, 1992; Pitt, 1999; Forstmeier and Weiss, 2004; Bongi *et al*., 2008; Morosinotto *et al*., 2010) and competitors (Svardson, 1949; Cody, 1981; Robinson and Terborgh, 1995; Petit and Petit, 1996; Aunapuu and Oksanen, 2004; Boyer and Rivault, 2006), the role vegetation complexity is very important especially among the large birds like the members of Otididae. The low height of the ground vegetation in freshly closed SN cl (28 cm) as compared to older SA cl (43 cm) can also be viewed as one of the reason for more occurrence of GIB in SN cl. The preference for freshly made closure by GIB can be viewed as anti-predatory strategy as the low height of ground vegetation will enable the species to detect the approaching predator. Habitat studies done in the past also reveal the preference of GIB for plain areas with short grasses (30-50 cm) interspersed with isolated patches of tall grass (*c*. 75 cm) or shrubs and non-intensive dry land agriculture (Manakadan, 1986; Rahmani and Manakadan, 1986, Rahmani, 1989; Dutta *et al*., 2010). Low height of the ground perennials also favors the growth of ephemerals post rainy season.

The high abundance and richness of vegetation in freshly made closure SN cl (H'=1.35; H^o=31 and α=9.22) as compared to old SA cl (H'=1.14; H^o=21 and α=6.18) can be attributed to growth of more ephemerals in the freshly made closure. The exposure of bare ploughed closed land of the SN cl to rain shower resulted in growth of more annuals, thus increasing the floristic richness. These annuals and low spreading herbaceous perennial palatable species, as emerged by the rain shower resulted into a noticeable difference in composition, structure and diversity in freshly closed closures (Paddocks). The reason behind for this can be attributed to seasonal and herbaceous perennials that can draw water from whole soil profile throughout the growing seasons where as climax grasses withdraw water from deeper layers of 2-5 m during droughts (Snyman, 1998). Such a partitioning of resource utilization actually increases the diversity of feed for the GIB. As already observed that functional wet seasons habitats dominated by short, nutritious grasses facilitate optimum intake of nutrients and energy for lactating females, for optimal calf growth and building body stores (Fynn, 2012). Importance of heterogeneity in vegetation composition has also been mentioned for achieving optimum grazing use by McGranahan and Krikman (2013). This will also take into account the spatial patterns of landscape created by patches of seasonal vegetation and temporal patterns of biomass (=productivity) availability of seasonal (ephemerals) in post monsoon and perennials in winter and summer, as evident from the present study. Similar conclusions were also arrived at in decade-long detailed grazing experiments conducted earlier in rangelands in Jaisalmer in Indian Thar desert by Mertia (1984). Fynn (2012) also concluded that grazing based on spatial and temporal variability in forage quality and quantity best supported the livestock. And this would hold true for wildlife such as GIB foraging on these resources. This would allow seasonal grazing and seasonal rests for more effective recovery periods, a conclusion also reached by Mertia (1984). Singh *et al.* (2006) also proved that seasonal vegetation has higher crude protein than perennial grasses and therefore meets the nutritional needs of foraging animals including wildlife.

Management Implications

It is therefore important to realize that seasonal vegetation that provides heterogeneity and complexity prolonged the period of range use and delayed the onset of degradation. Managing this heterogeneity and complexity in order to enhance resilience thus becomes an important management priority for arid rangeland (Vetter, 2009) for sustained population build up of critically endangered great Indian bustard in the Indian Desert. In order to achieve this objective, a very simple management strategy emerged from this study suggesting mowing and to plough the open areas in mosaic pattern for breaking the crust laden hard surface without disturbing the local grass sewan *Lasiurus scindicus* and other perennial grasses, shrubs and trees of old closures like SA cl and RA cl in GIB range areas annually just before onset of rains. While the mowing can be used to lower vegetation height and control woody vegetation (Sample and Hoffman 1989), the selective ploughing will bring out the stored seed bank of annuals on to the surface enabling them to use moisture of the very first rain and germinate to grow further in subsequent rains. Sprinkling the ploughed fields with leguminous species like alfalfa *Madicago sativa* (Lanne *et al*., 1999) in the closures is another management intervention that the study recommends. In fact, such slight amount of disturbance is known to increase diversity in all dryland ecosystems and is a desirable management intervention for the conservation of critically endangered great Indian bustard.

Acknowledgements

Authors thank to G.V. Reddy, V.K. Bissa, P. Patil, Y.V. Jhala, S. Dutta, M. Rathod and H. Singh. We are indebted to Rajasthan Forest department and frontline staff of Desert National Park for providing continuous support and help in the study.

भारतीय थार रेगिस्तान में नाजुक रूप से संकटापन्न ग्रेट इंडियन बस्टर्ड *आर्डिओटिसनाइग्रिसेप्स* (वाइगोर्स) द्वारा आवास उपयोग में शाकीय वनस्पति की भूमिका

गोविन्द सागर भारद्वाज, के.आर. अनूप, प्रेरणा शर्मा एवं सुरेश कुमार

सारांश

अदूषित क्षेत्र बढ़ाने के उद्देश्य के साथ नाजुक रूप से संकटापन्न ग्रेट इंडियन बस्टर्ड *आर्डिओटिस नाइग्रिसेप्स* (ताइगोर्स)के लिए स्व–स्थाने संरक्षण दिशा निर्देशों पर आधारित प्रबंधकीय निवेशों के भाग के रूप में थार रेगिस्तान भूदृश्य में पुराने बाड़ों के समीपस्थ नए बाड़ों का निर्माण किया गया। इस नए परिबद्ध क्षेत्र की जुलाई में वर्षा के आगमन से ठीक पहले आंशिक रूप से जुताई कर दी गई, जिसके फलस्वरूप शाकीय वनस्पति का प्रचुर मात्रा में पुनर्जनन हुआ। पुराने बाड़ों की तुलना में बस्टर्ड द्वारा इन नए तैयार किए बाड़ों के लिए पसन्द को नोट किया गया। इस तरह की पसन्द के कारणों को जानने के लिए पुराने और नए तैयार बाड़ों दोनों की वनस्पति की तुलना की गई। आसन्न परभक्षियों का पता लगाने के लिए वर्धित साइट दूरी और संभरण के बेहतर सुअवसर उपलब्ध कराकर नए तैयार बाड़ों में शाकीय वनस्पति की निम्न ऊँचाई और अस्थायी प्रचुरता एवं उच्च समृद्धता ने ज्यादा संख्या में ग्रेट इंडियन बस्टर्ड को आकर्षित किया। मोजैक पैटर्न में खुले क्षेत्रों के कर्तन एवं जुताई से पपड़ीदार कठोर सतह टूट जाती है, जिससे शाकीय वनस्पति का पुनर्जनन सुगम हो जाता है और जो प्रजाति के लिए आवास में सुधार लाता है। स्थानीय सीवान *लेजिरूसक इंडिकस* तथा अन्य बारहमासी घासों, झाड़ियों और बस्टर्ड रेंज क्षेत्रों के पुराने बाड़ों के वृक्षों को विक्षुब्ध किए बिना वर्षा के आगमन के ठीक पहले सालाना यह कार्यकलाप करना थार रेगिस्तान के भारतीय भाग में ग्रेट इंडियन बस्टर्ड के स्व–स्थाने संरक्षण के लिए एक मुख्य प्रबंध रणनीति के तौर पर उभरा है।

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