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Running out of time? The great Indian bustard *Ardeotis nigriceps*—status, viability, and conservation strategies

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Abstract The endemic great Indian bustard (GIB) is evolutionarily trapped between open nesting and *k*-selection that endangers its persistence under prevailing levels of habitat loss and hunting. A global population of about 300 birds is further fragmented into eight populations in the states of Rajasthan (shared with Pakistan), Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Madhya Pradesh in India. The largest population of 100–125 birds exists in Jaisalmer, Barmer, and Bikaner districts of Rajasthan. Remaining populations number less than 35 birds each. Prevalent GIB conservation strategies use legislation to (a) secure traditional breeding areas by declaring small Protected Areas (PA) or (b) protect vast areas with varied human land uses. The vagrant nature of GIB reduces the benevolent effect of small PAs, while large reserves alienate people by curbing legitimate subsistence rights through strict legislation. These factors along with ill-informed habitat management challenge the current PA approach, even causing local extinctions. Population viability analysis shows that GIB populations of ≤35 birds can persist only under unrealistic conditions of first year mortality ≤40%, and no human caused mortality of adult birds. Even the largest population (≥100 birds) is sensitive to additional loss of adult birds to human causes. With current levels of hunting in Pakistan, extinction is a real threat. A landscape conservation strategy using conservation/community reserve concept that includes controlled traditional land uses with GIB-friendly infrastructural development is needed. The declining rate of GIB populations calls for immediate commencement of *ex situ* conservation breeding programs.

Keywords Endangered · Environmental stochasticity · *Ex situ* conservation · Grassland · Poaching · Population viability analysis

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Current status

The family Otididae is an obligate grassland taxa highly specialized with *k*-selected traits and an open nesting system (Lack 1954), rendering them vulnerable to extinction when faced with environmental changes or direct threats. The endangered great Indian bustard (GIB, *Ardeotis nigriceps*) faces serious threat of extinction from habitat conversion to agriculture, infrastructural development, and hunting (Rahmani 1989; IUCN 2008). The population, which was roughly estimated in 1969 at about 1,260 individuals (Dharmakumarsinhji 1971) ranging over the western half of India, dwindled down to about 745 individuals by 1978 (Dharmakumarsinhji 1978a). Around 600 individuals survived at the turn of this millennium (BirdLife International 2001), and currently 300–350 (Rahmani 2006) are left, restricted to fragmented pockets in six states of India (Fig. 1).

In Rajasthan, the Desert National Park in the districts of Jaiselmer and Barmer along with the agro-pastoral land-

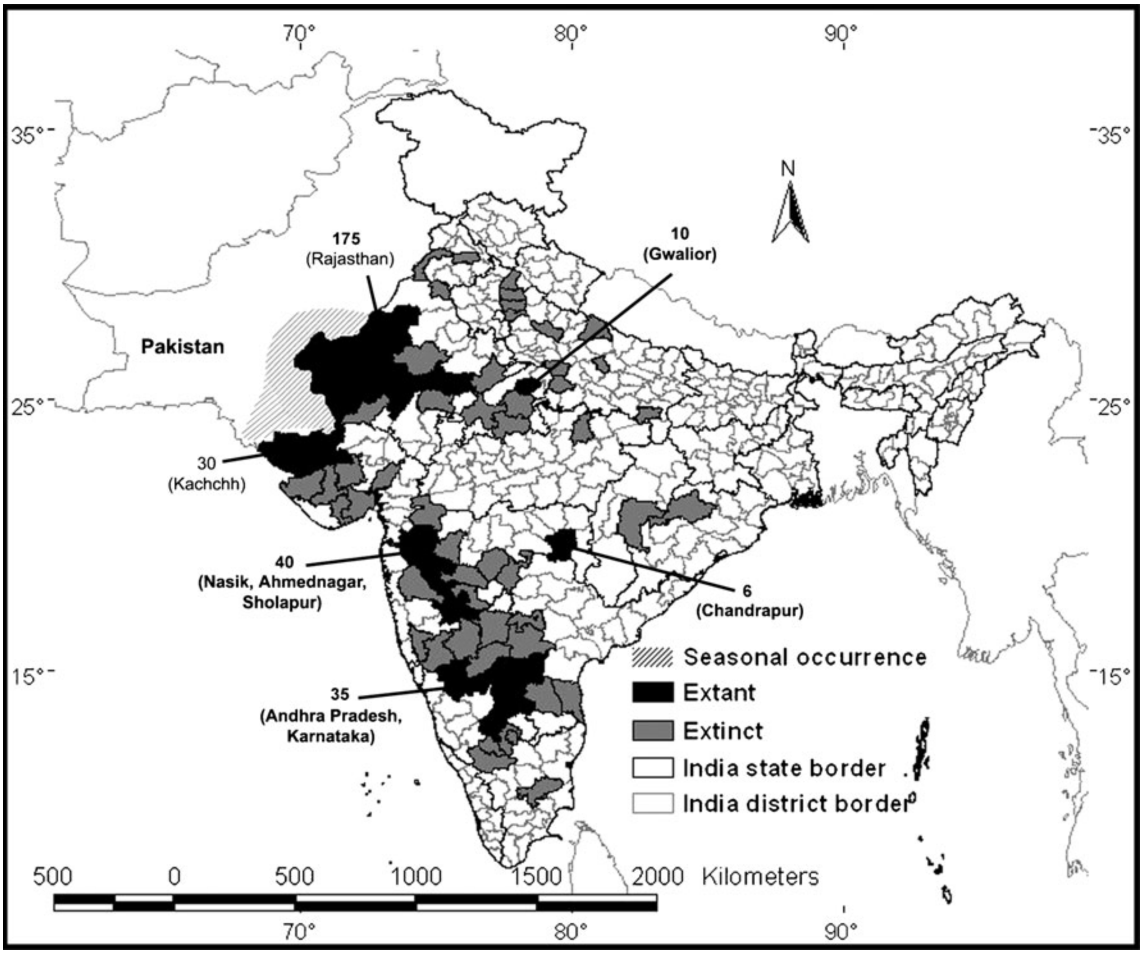

Fig. 1 Current (2008) and historical distribution of great Indian bustard within districts of India and occurrence of summer visitors in Pakistan. The *numbers* are the estimated maximum populations

scapes of Bikaner holds the largest global population of the GIB currently numbering between 100 and 125 birds, along with another 25–50 birds in Ajmer, Pali, and Tonk districts (Rahmani 2006). All other populations number less than 35 birds each (BirdLife International 2001). These populations are located within the states of (a) Maharashtra, at the Bustard Sanctuary of Sholapur and Ahmednagar districts having 30–35 birds, Nasik district having five to eight birds, and Chandrapur district having four to six birds (Thosar et al. 2007); (b) Andhra Pradesh, at Rollapadu Sanctuary of Kurnool district and its adjoining areas of Anantpur district having about 30 birds (Rao and Javed 2005; Rahmani 2006); (c) Gujarat, in Abdasa tehsil of Kachchh district having 25–30 birds (Singh 2001); (d) Karnataka, where the population status is poorly known, but few birds (2–4) have recently been reported from Sirguppa tehsil of Bellary district (Ahiraj 2008); and (e) Madhya Pradesh, where the GIB population has faced a stark decline (Rahmani 2006) and numbers in Gwalior district are likely to be less than 10 birds. The Rajasthan and Kachchh populations are probably shared with eastern Pakistan where sporadic, seasonal occurrences of 15–20 bird sightings have been recorded (Khan et al. 2008).

The last two decades have seen a drastic reduction in the range occupancy and population size of the GIB in India (Fig. 1). For instance, within the state of Gujarat, GIB was recorded from Surendranagar, Jamnagar, Bhavnagar, Rajkot, Kheda, Amreli, and Kachchh districts (Rahmani 1989; Rahmani and Manakadan 1990), but currently a single population survives in Kachchh with rare transients reported in Bhavnagar, Jamnagar, and Surendranagar districts. Similar trends are reported across the GIB range (Fig. 1).

Ecological requirements of the species

Bustards originated 77 million years ago in Africa and speciated over discreet ranges of the Old World grasslands (Johnsgard 1991). They have subsequently coevolved with wild ungulates and depend on grazers to maintain a suitable habitat structure. Since the last thousand years, community of wild grazers has been steadily replaced by domestic livestock in most of the bustards' range outside Africa (Skarpe 1991). GIB flocks vagrantly use wide, sparse grass–scrub landscapes with low intensity cultivation (Rahmani 1989) in the non-breeding season. They have a broad omnivorous diet chiefly consisting of fruits like *Zizyphus*, insects like grasshopper and beetle, reptiles, and seasonally available food crops like ground nut and millet (Rahmani 1989). During mid-summer and monsoon, they congregate at traditional areas to breed and avoid human disturbance (Rahmani 1989; Johnsgard 1991). Organized in a polygynous exploded lek mating system, dominant males show site fidelity to their display stations. This behavior has been recognized as one of the crucial factors in designing conservation strategies for the species (Rahmani and Manakadan 1986; Rahmani 1989; Johnsgard 1994).

Prevalent conservation strategies

Natural resource conservation is guided by two dichotomous approaches: sustainable use (IUCN 1991) regulated by traditional institutions (Gadgil 1992) or preservationism through complete cessation of resource extraction (Kramer et al. 1997). Alerted by naturalists about the decline of GIB and the need to conserve grassland resources (Tyabji 1952; Ali and Ripley 1969; Dharmakumarsinhji 1978b), State Governments of India declared eight bustard Sanctuaries in post-1980s, with a belief that establishment of "Protected Areas" (PAs) might hold the best hope for saving the species (Rahmani and Manakadan 1987). Most of these PAs were either too small, targeting traditional breeding patches following the preservationist approach (Kramer et al. 1997), or very large, covering entire agro-pastoral landscape inclusive even of large townships. Within these reserves, the recommendation was to maintain small, scattered (>100 to <500 ha) refuges with large buffers (Rahmani 1989) that should preferably be traditional breeding spots and protected during the breeding season (Rahmani 1989; Chauhan 2006) to exclude cattle. Refuges were recommended to be managed so as to provide habitat requirements for crucial activities such as lekking, nesting, chick rearing, and foraging (Rahmani 1989), and could be rotated over the PA through ≥5-year periods (Chauhan 2006).

Limitations of current conservation strategies

The prevalent legal system in the 1980s–1990s governing PAs was not sufficiently flexible to permit implementation of even these simple recommendations. While declaration, many GIB Sanctuaries were inclusive of, or surrounded by privately owned lands, exemplified by Karera Bustard Sanctuary in Madhya Pradesh and the Bustard Sanctuary of Maharashtra which included the township of Sholapur. Due to enhanced protection and restricted livestock grazing in the Karera Bustard Sanctuary (202 km^2), the residing small blackbuck population exploded resulting in crop depredation in adjoining private agricultural lands. Blackbuck being a Schedule I species [Wildlife (Protection) Act 1972] could not be hunted. This antagonized local agro-pastoral communities (Rahmani 2003) resulting in a backlash by the communities that caused the local extinction of GIB and reduction of blackbuck population through poaching. In another case, the Bustard Sanctuary of Maharashtra which covers an area of 8,496 km^2 has faced rapid industrialization and increase in human population during the last 30 years. There is also a shift in agricultural practices from monsoonal crops such as *Sorghum* and millet to sugarcane and grapes—crops not suitable to bustards resulting in severe habitat loss for GIB. The remaining suitable habitat consists of small and scattered grassland patches protected under the Drought Prone Areas Programme. The total aggregate area of these scattered patches is not more than 400 km^2, the biggest patch being near a village called Nannaj, about 20 km north of Sholapur town. Traditionally, grasslands and scrub have been considered as "wasteland" and the Forest Department policy, until recently, has been to convert them to "forests" with plantation of fuel/fodder shrub/tree species, even exotics like *Prosopis juliflora*, *Gliricidium*, and *Eucalyptus* spp., under social forestry and compensatory afforestation schemes [Indian Forest Act 1927; Forest (Conservation) Act 1980] resulting in further loss of GIB habitat. The large expanse of this Sanctuary (much of it being non-GIB habitat) has restricted private land owners therein to use their lands freely and profitably, as the stringent Indian legislation is extremely restrictive about land use in legally gazetted Protected Areas [Wildlife (Protection) Act 1972]. This again has generated bitterness among the local populace. Currently, the government of Maharashtra is proposing to rationalize the boundary of this Sanctuary to accommodate the concerns of private land owners. The cumulative impact of all these land-use policies and attitude changes is that there is a declining population of GIB in the Bustard Sanctuary of Maharashtra.

On the other end of large Sanctuaries lie some extremely small conservation areas targeting lekking or nesting patches as in Sonkhaliya (17 km^2) in Rajasthan, Gaga-Bhatiya (2 km^2) and Lala-Naliya (17 km^2) in Gujarat, and Rollapadu (6 km^2) in Andhra Pradesh. Some of these GIB refuges have been subjected to well-intended but ill-informed management interventions such as development of large water bodies, network of roads, delineation of "reserve grasslands" through trenching-cum-mounding and plantation. Such managerial practices have resulted in severe habitat alteration (Pande and Pathak 2005) and are considered to have caused local extinction of the species from Ranibennur and Gaga-Bhatia Sanctuaries, and decreased usage of Lala Sanctuary.

Since both these strategies, (a) creation of large PAs inclusive of private lands and (b) implementation of "minimum conservation area for breeding", have failed to address all the ecological requirements of the species and achieve the objective of GIB conservation, the decline in density (estimated 20–29%, see BirdLife International 2001) and range (estimated 90%, see Rahmani 2001) of the species have continued unabated. Hence, the prevalent conservation strategies need to be re-evaluated and rectified.

Population viability assessment

To understand the interactions between the inherent *k*-selected demographic traits of GIB with environmental stochasticity, habitat management, anthropogenic influences, and their effects on the viability of different size GIB populations, we conducted a population viability analysis (PVA) (Boyce 1992) using published demographic parameters of GIB and related species (Ena et al. 1986; Rahmani 1989; Alonso and Alonso 1992; Johnsgard 1994; del Hoyo et al. 1996; Combreau et al. 2000; Morales et al. 2001; Osborne and Osborne 2001; Hallager and Boylan 2004; Rao and Javed 2005; see Table 1). We used the program *VORTEX version 9.72* (Lacy et al. 2007) and ran 500 iterations for each of the following scenarios. We considered (a) the best case scenario where the initial population was 100 birds mimicking the Rajasthan population, (b) a scenario with the initial population of 40 birds, and (c) initial population of 25 birds representing most other populations, and (d) a scenario where the initial population was 10 birds mimicking the remaining few small, scattered populations. Since some of the life-history parameters were ill-known, we built "optimistic" and "pessimistic" models for each scenario to estimate extinction probabilities in 20, 50, and 100 years, using different combinations of first and second year mortality rates, carrying capacities, adult harvests, and catastrophic drought incidences occurring once in 5 (20%) years or 10 (10%) years (Fig. 2, also see supporting material—Appendix S1). During a catastrophe year, the survival and fecundity were reduced by 10% and 80%, respectively. GIB, though legally protected as a Schedule I species under Wildlife (Protection) Act (1972), has been a prized game bird and is occasionally poached. Poaching and accidental deaths due to human causes were simulated as "harvest" of one bird of either sex in alternate years from the modeled population (Fig. 2, also see models 1–113 in supporting material—Appendix S1 and Table 1 for PVA model inputs).

We found that populations of 10 individuals were in imminent risk of extinction (Fig. 2a, also see models 1–25

Table 1 Details of input parameters in population viability analysis models

PVA input parameters	Values and range
Initial population size	(a) 10, (b) 25, (c) 40, (d) 100
Reproductive system and rate	
Age of first offspring	3 years (♀) and 4 years (♂)
Max. age of reproduction	20 years
Max. no of progeny/year	1
Sex ratio at birth	1♀:1♂
% Adult ♀ breeding/year	50±10[a]
% ♂ in breeding pool	25
Mortality rate	
1st year	30±6% 40±8% & 50±10%
2nd year	10±2% and 18±4% (♀) and 16±3% and 22±4.5% (♂)
Adults	5±1% (♀) and 8±1.5% (♂)
Catastrophe	
Frequency	(a) 10% and (b) 20% of years
Severity	Fecundity reduced by 80% and survival reduced by 10%
Harvest	(a) nil and (b) 1 adult ♂ and 1 adult ♀ in 2 years

[a] Estimated as the mean ratio of breeding (nesting/chick rearing) females to total females in various populations obtained from published literature (1, 2) and field observations during current study. Average sex ratio was used to calculate number of females in cases where there was no separate mention of female and male birds in the population. Literature from where PVA input parameters were obtained: Ena et al. 1986; Rahmani 1989 (1); Alonso and Alonso 1992; Johnsgard 1994; del Hoyo et al. 1996; Combreau et al. 2000; Morales et al. 2001; Osborne and Osborne 2001; Hallager and Boylan 2004; Rao and Javed 2005 (2); Dutta and Jhala, unpublished data

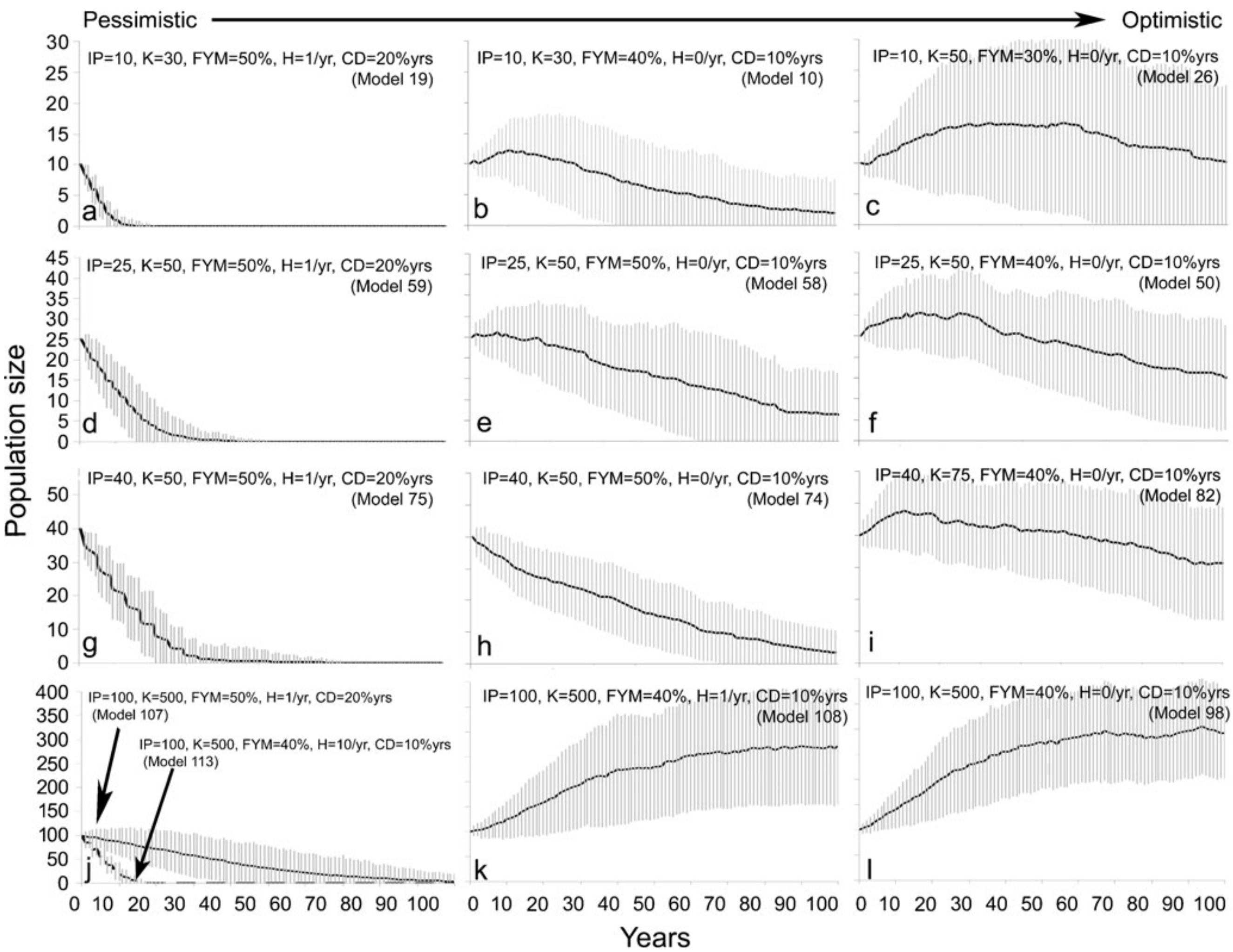

Fig. 2 Population viability analysis model predictions for GIB populations of initial sizes (*IP*) 10 (*first horizontal panel*—**a**, **b**, **c**), 25 (*second horizontal panel*—**d**, **e**, **f**), 40 (*third horizontal panel*—**g**, **h**, **i**), and 100 birds (*fourth horizontal panel*—**j**, **k**, **l**), under pessimistic (*left vertical panel*—**a**, **d**, **g**, **j**) and optimistic scenarios (*right vertical panel*—**c**, **f**, **i**, **l**) of various combinations of potential carrying capacity (*K*), first year mortality rate (*FYM*), human caused adult bird loss (*H*), and catastrophic drought incidence (*CD*) during the next 100 years

and 27–48 in supporting material—Appendix S1) facing a likely extinction probability of 10% in 20 years, with 43% population trajectories becoming extinct within 50 years and 80% extinction probability in 100 years (Fig. 2b, also see model 10 in supporting material—Appendix S1). These populations had low chance of persistence (62% survival probability in 100 years) even under most optimistic (but unrealistic) conditions when first year mortality was below 30%, second year mortality was 10% for females and 16% for males, potential carrying capacity was ≥50 individuals, human caused adult loss was totally controlled, and catastrophe was less frequent (Fig. 2c, also see model 26 in supporting material—Appendix S1).

Populations of 25 individuals also showed high risks of extinction (67–100% extinction probability in 100 years, see Fig. 2d, also see models 49, 51–53, and 54–64 in supporting material—Appendix S1). Under realistic conditions, these populations faced extinction probability of 16% in 50 years (Fig. 2e, also see model 58 in supporting material—Appendix S1). These populations could only persist (70% survival probability in 100 years) under optimistic (but unrealistic) conditions when first year mortality was below 40%, second year mortality was 10% for females and 16% for males, potential carrying capacity was ≥50 individuals, human caused adult loss was totally controlled, and catastrophe was less frequent (Fig. 2f, also see model 50 in supporting material—Appendix S1).

Populations of 40 individuals had fair chances of persistence (>80% survival probability in 100 years, see Fig. 2i, also see models 82 and 86 in supporting material—Appendix S1) provided first year mortality was ≤40%, potential carrying capacity was ≥75 birds, and catastrophe was less frequent. However, when we assumed a pessimistic situation of higher nesting and fledgling mortality (50%) along with low carrying capacity (50 birds) and more frequent catastrophes, extinction probabilities in 100 years jumped to 37%, 63% and 84%, respectively (Fig. 2h, also see models 74, 89 and 90 in supporting material—Appendix S1). Poaching or accidental additional death of one adult every year threatened these populations (extinction probability 6–37% in 20 years) with 99–100% population trajectories facing extinction within 100 years (Fig. 2g, also see models 67, 68, 71, 72, 75, 76, 79, 80, 83, 84, 87, 88, 91, 92, 95, and 96 in supporting material—Appendix S1).

The population of 100 individuals had a high probability of persistence (>70%) for the next 100 years even under realistic nesting and fledgling mortality (≥40%), higher second year mortality rate, and more frequent catastrophe (Fig. 2l, also see models 97, 98, 100–102, 104, 106, and 110 in supporting material—Appendix S1). But persistence of even this "large" population was sensitive to loss of an additional adult bird every year to human causes (extinction probability 50–100% in 100 years, see Fig. 2j and k, also see models 99, 103, 107, 108, 111, and 112 in supporting material—Appendix S1).

Sensitivity analysis is often used to asses the relative importance of parameters in model-based inference (McCarthy et al. 1995; Heinsohn et al. 2004). Some of our parameter estimates were obtained from related species and some others were not known with reasonable certainty. The number of adult females in the breeding pool each year, second year mortality, frequency of catastrophes, and potential carrying capacity were examples of parameters which were fuzzily estimated from literature. We include these along with first year and adult mortality in our sensitivity analysis, wherein each of the parameters was altered by 10% of its original value, and the PVA models rerun to asses its effect on persistence of the GIB population for 50 years.

Sensitivity analysis revealed that persistence was most sensitive to proportion of females breeding each year (Table 2). This was followed by juvenile and adult mortality as the next most sensitive parameters. The PVA was not sensitive to 10% changes in second year mortality, potential carrying capacity and frequency of catastrophes with population persistence changing marginally by less than 9%.

Of the above three most sensitive parameters, we had reasonably reliable data on adult and juvenile mortalities. However, proportion of breeding females in the population was not as reliable and was based on anecdotal reports (Rahmani 1989; Rao and Javed 2005) and field data for only 2 years in Kachchh (Dutta and Jhala unpublished data). An incorrect estimation of this parameter would change our PVA results numerically, but our inferences on conservation actions would largely remain unaffected. An underestimation of 10% of the proportion of females in the breeding pool would overestimate the probability of extinction by 30–70%, while an overestimate of 10% of proportion of females in the breeding pool would underestimate the extinction probability by 31–46%. Similarly, 10% decrease in first year mortality would increase population persistence by 34% and 10% increase in the same would reduce population persistence by 55%, while 10% decrease in adult mortality would increase population persistence by 21% and 10% increase in the same would reduce population persistence by 18%. Interestingly, changes in the potential carrying capacity did not alter model results, suggesting that GIB were restricted not by habitat availability but more by direct threats to their survival (Table 2). This model outcome could be misinterpreted to suggest that ample habitat was available for GIB populations. However, this is not true since crucial habitat requirements for lekking and nesting that are not reflected in the potential carrying capacity would act by limiting breeding success, and survival of juveniles as well as that of adult birds. The potential carrying capacity reflects the size of bustard habitat and food availability which were probably not limiting.

Effects of environmental stochasticity on breeding area use by GIB: a case study

Spatial variation in precipitation at local scales of a few square kilometers is a common phenomenon in arid landscapes where GIB occur. In the Abdasa tehsil (one tenth of a district) of district Kachchh, grasslands interspersed with scrub and crop fields stretch along the coastline for nearly 45 km forming a continuum of ca. 200 km^2 of prime GIB habitat between Virachia (23.25°N, 69.11°E) and Lala (23.18°, 68.76°E) villages. In this habitat, a 17-km^2 patch has been proposed as Naliya Bustard Sanctuary. This patch has been the traditional lekking and nesting area for the GIB population of Abdasa. Typical breeding habitat of GIB occurs in undisturbed grasslands (at least 2–3 km away from the nearest village) characterized by a mosaic of less grazed ($6.5_{\mathrm{Mean}}\pm0.6_{\mathrm{SE}}$ livestock sign 10 m^{-1}) and relatively tall grass ($45_{\mathrm{Mean}}\pm2_{\mathrm{SE}}$ cm height) preferred by nesting females (13 nest sites sampled), interspersed with well-grazed ($13.3_{\mathrm{Mean}}\pm3.8_{\mathrm{SE}}$ livestock sign 10 m^{-1}) and short grass ($17_{\mathrm{Mean}}\pm2_{\mathrm{SE}}$cm height) preferred by displaying males (12 display sites sampled) (Dutta and Jhala unpublished data). Although males of this species show site fidelity to display arenas in traditional lekking grounds (Rahmani 1989), our observations suggest that site fidelity can at times be compromised as a consequence of local spatial shift in rainfall provided such typical breeding habitats are available in adjoining patches. Intensive monitoring between 2007 and 2009 revealed that during 2008, GIB did not form their traditional lek in Naliya grassland patch but instead showed a shift in display stations with sporadic displays spread over

Table 2 Sensitivity testing of population viability analysis wherein parameters estimated with less certainty and/or parameters of critical importance were modified by 10% of original values to asses the corresponding percentage change in population extinction over next 50 years [%ΔP(E)50] for initial populations (IP) of 10, 25, 40, and 100 birds

Modified parameter	Change (%)	IP	%ΔP(E)50
Percentage adult female in breeding pool each year	−10	10	57
	+10		−31
	−10	25	54
	+10		−44
	−10	40	30
	+10		−38
	−10	100	69
	+10		−46
First year mortality	−10	10	−14
	+10		24
	−10	25	−23
	+10		36
	−10	40	−38
	+10		34
	−10	100	−62
	+10		126
Adult mortality	−10	10	−21
	+10		17
	−10	25	−15
	+10		21
	−10	40	−11
	+10		11
	−10	100	−38
	+10		23
Second year mortality	−10	10	−12
	+10		10
	−10	25	−5
	+10		10
	−10	40	−4
	+10		6
	−10	100	−18
	+10		5
Frequency of catastrophes	−10	10	−10
	+10		0
	−10	25	−5
	+10		5
	−10	40	−9
	+10		6
	−10	100	−13
	+10		15
Carrying capacity	−10	10	5
	+10		10
	−10	25	8
	+10		−5
	−10	40	−11
	+10		2
	−10	100	18
	+10		−13

a much wider area (Kanauthia Daun) to the east of and outside the proposed Sanctuary (Fig. 3). The probable reason for this shift was low rainfall in the traditional breeding area (Naliya Daun) in relation to Kanauthia Daun about 12 km east. We indexed this difference in precipitation by the geometric mean ratio of green to dry vegetation cover and found a 4-fold difference between Naliya ($2.6_{Mean}\pm0.64_{SE}$) and Kanauthia ($11.3_{Mean}\pm0.89_{SE}$). This plasticity in behavior of GIB is a likely response to the inherent nature of semi-arid stochastic systems they inhabit. In the non-breeding season, GIB disperse to cover an area of several thousand square kilometers of semi-arid grassland–scrub–agricultural landscape in Kachchh (Dutta, Jhala, and Sharma unpublished data). Thus, a strategy of only declaring small "traditional" breeding areas as preserves may not suffice for conserving the species.

Conservation implications

Results of PVA models have shown that GIB populations are extremely sensitive to removal of adult birds. Even the largest population can plummet to extinction with a constant additional loss of one adult to human causes each year. Historically, GIB have been hunted as game bird (Hume and Marshall 1878; Ali 1927; Rahmani 1989) and continue to be hunted in neighboring Pakistan (Khan et al. 2008). Low intensity poaching still persists within India as well. The western Rajasthan and Kachchh populations are probably shared with Cholistan desert and Sindh of Pakistan, where 49 birds were hunted out of 63 that were sighted over a period of 4 years (Khan et al. 2008). Given the life history traits of GIB, this level of removal is unsustainable and threatens the extinction of the largest global western Indian population within next 15–20 years (Fig. 2j, also see PVA model 113 in supporting material—Appendix S1). Increasing unfriendly infrastructural development within the GIB habitats intensifies chances of fatal bird strikes against high-tension electric wires, fast-moving vehicles, and other structures like wind-power generators. Conservation strategies must try to minimize loss of adult birds from poaching and other human causes like infrastructural development.

The PVA models also show that ≥50% nesting and fledgling mortalities can jeopardize the persistence of GIB populations substantially. GIB are known to abandon nests

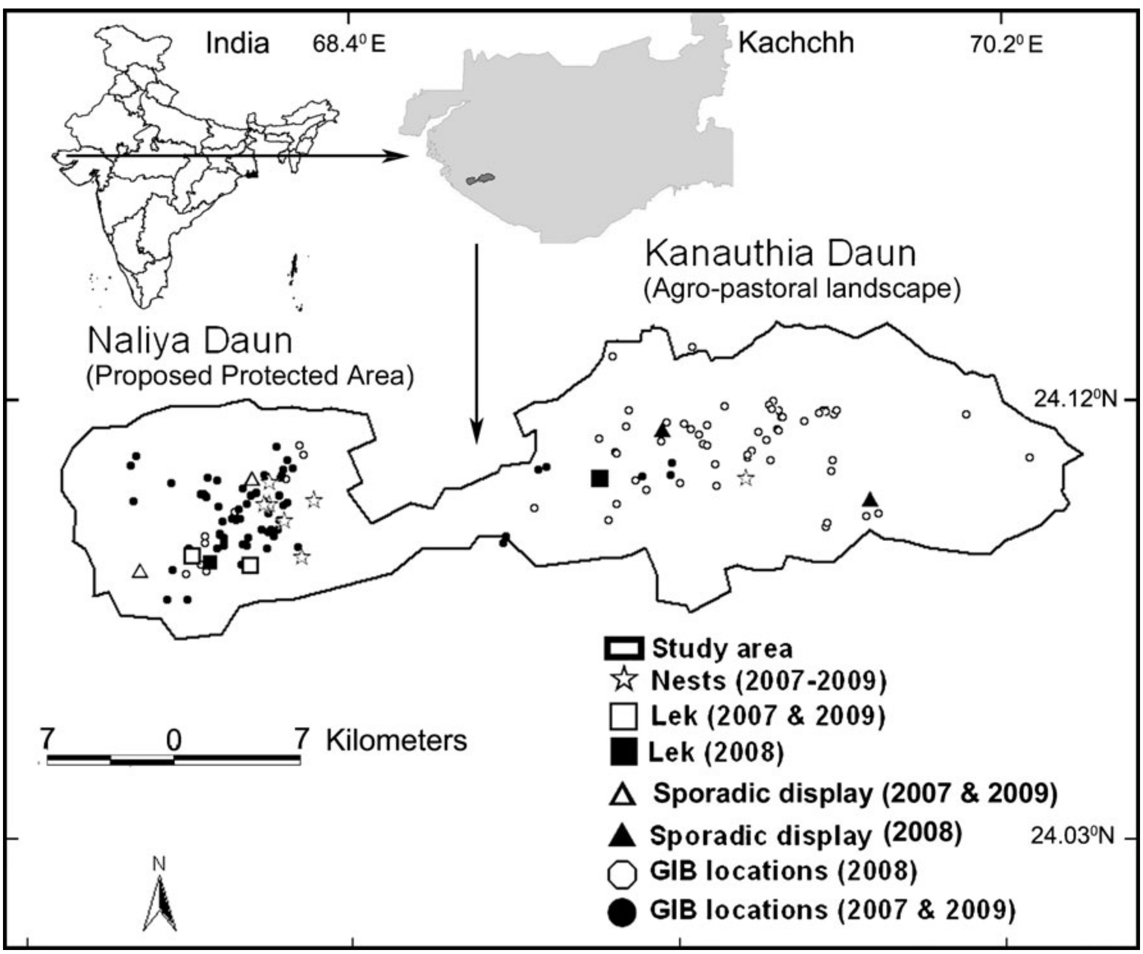

Fig. 3 Great Indian bustard breeding habitat in Kachchh showing variation in spatial use during breeding seasons of 2007–2009

due to human disturbance (Rao and Javed 2005). Since this species is extremely site-specific restricted area breeders, it is possible to enhance nesting and fledging success by creating disturbance-free zones during the breeding season. In populations of less than 30 birds, additional efforts may be needed to actively control predators (feral dogs, feral cats, jackals, and foxes) from these sites prior to and during the breeding season. Such predator control though controversial is essential and doable within these small breeding areas. Also, predator control within these small areas of a few square kilometers will not affect their populations adversely since they occur at reasonably moderate densities across the GIB landscapes. We believe that removal of significant source of mortality during the nesting and fledging stages (most vulnerable stage in the life history of GIB), along with supplementation of adult birds from a captive bred stock, may reverse the extinction trajectory of these small (≤30) populations.

GIB requires a landscape level conservation policy. Its habitat occurs in areas where human-induced changes in the landscape are most rapid due to intensive agriculture and industrialization, making it difficult to create protected areas that encompass GIB landscapes. Moreover, some form of traditional land uses like dry farming and controlled grazing are beneficial to GIB. Thus, its conservation is not entirely incompatible with some forms of human use of the landscape which requires minimal infrastructural development. The new categories of PAs introduced in Indian legislation such as (a) Conservation Reserve, (b) Community Reserve, and (c) Ecologically Sensitive/Fragile Area [Section 31A of Wildlife (Protection) Amendment Act 2002 (2003); Section 5 of Environment (Protection) Act 1986] can better protect bustards and their habitats on lands having government/private mixed ownerships (also see Gray et al. 2007). Such procedures will not require land acquisition or people displacement but will allow sustainable use of larger areas with participation from local communities and essential intervention of the Government (Rahmani 2006). GIB-friendly grassland management regime will benefit local communities in the long run as it will enhance productivity for livestock and prevent overgrazing. A major threat today to bustard habitat is not so much from pastoral use of GIB landscape but rather its conversion to other land uses such as intensive agriculture and industry, along with their associated infrastructural developments. Such land use changes rarely benefit local communities, and therefore it will be relatively easy to bring in reforms which are both economically beneficial for local people, as well as being GIB friendly. Appropriate incentive-driven legislation and policy reforms have to be implemented in collaboration with local NGOs to achieve this dual goal.

Although the bird requires strict protection measures, its wide-ranging nature makes implementation of protection difficult without public support (Rahmani 2003). Publicity and awareness campaigns should ensue to generate support among the local populace like the ones undertaken by the Bombay Natural History Society in Rajasthan and Maharashtra (Rahmani 2006). A profitable and equitable mechanism to share revenues generated from eco-tourism with local communities (Narain et al. 2005) may go a long way in harnessing support for GIB conservation.

In spite of all these measures, owing to the extinction-prone, *k*-selected nature of the species and threat from hunting, GIB is in urgent need for *ex situ* conservation and subsequent supplementation of existing small *in situ* populations. Although a few unscientific attempts to breed GIB in captivity have failed in the past (Putman 1976; Sankhala 1977; Rahmani 1986), scientific execution of conservation breeding is possible (Collar 1983) along the lines of successful breeding programs of houbara *Chlamydotis undulata* (Lawrence et al. 2008), great bustard *Otis tarda* (Great Bustard Group 2006–2007), and kori bustard *Ardeotis kori* (A.R. Rahmani personal observation). Within India, like many other developing countries, there is migration of rural people to urban centers in search of better livelihood and in response to better economies (Okpara 1983; Gugler 1988). This is likely to reduce human pressures on the GIB habitat in the future. At such times in the future, it may be possible to restore GIB to their former range from captive stock. There are discussions in the Indian conservation circles and the Government to reintroduce the cheetah *Acinonyx jubatus* in India (Ranjitsinh and Jhala 2010). This would require consolidating large protected habitats which would be beneficial for GIB as well as other endangered fauna of the arid and semi-arid regions. If we fail to act now in promoting both *in situ* and *ex situ* measures for conserving the GIB, we are likely to witness the extinction of this species within a span of generations.

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