Abundance of grey junglefowl *Gallus sonneratii* at Theni Forest Division, Western Ghats, India: implications for monitoring and conservation

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Abstract The distance sampling line transect method was used to determine the abundance of grey junglefowl *Gallus sonneratii* in five different forest habitats in the Gudalur Range, Western Ghats, India. Surveys conducted across all seasons during 2004-2005 revealed distinctive habitat-wise and seasonal patterns in grey junglefowl abundance. Density estimates were consistently higher in Southern Deciduous Scrub Forest and lowest in Southern Sub-Tropical Hill Forest over the two-year period. Density estimates from all five habitats, and across seasons (except the post-monsoon season), were also consistently higher in 2005 than in 2004. However, temporal (between-year) differences in junglefowl abundance between habitats and seasons were not significant. Our analysis revealed that the most beneficial time of year to survey grey junglefowl populations was during the breeding season (December-May), corresponding to the post-monsoon and summer seasons. We suggest that conservation efforts for grey junglefowl populations in the Western Ghats should be prioritized around Southern Deciduous Scrub Forest habitats.

Keywords *Gallus sonneratii*, distance sampling, line transects, density estimates, Western Ghats

Introduction

Providing an understanding of the abundance and distribution of bird species is fundamental to successful conservation management (Conroy & Noon, 1996). Basic knowledge of abundance patterns exhibited by bird species enables conservation managers to assess their status, assess the impact of a range of conservation management options, and identify further research priorities (e.g. Lambert, 1992; Lee & Marsden, 2008). Few data exist for the majority of Galliformes, which constitute one of the most threatened bird families in the world (Fuller et al., 2003). Whilst there is an obvious need for more quantitative work for the most threatened Galliformes species, we know surprisingly very little (quantitatively) regarding patterns of abundance for some of the more common, widespread Galliformes (but see Fernandes et al., 2009). Such data are important since some populations of these species are locally threatened (and presumed to be declining) due to anthropogenic pressures on their habitats.

The grey junglefowl *Gallus sonneratii* is a widespread and distinctive gamebird species endemic to central and southern India (Madge & McGowan, 2002). The species is known to occur in a variety of lowland habitats throughout its range, including lowland forests, secondary forests, and forest edge habitats (Collias & Collias, 1967; Madge & McGowan, 2002). Research conducted in 1988 has revealed that the species shows a preference for wooded areas with low to moderate canopy vegetation, and moderate to high scrub cover interspersed with areas of low or no grass cover (Sathyakumar, 2006). It is now widely believed that several populations of grey junglefowl appear to be in decline (Zacharias, 1993; Sathyanarayana, 1997), possibly linked to anthropogenic habitat loss and degradation (McGowan & Garson, 1995). Consequently, the species' range across India is now highly fragmented due to agricultural encroachment and other developmental activities. Few data exist to help determine accurately the species' conservation status (Kaul & Garson, 1993). Quantitative surveys of any grey junglefowl population would make a significant contribution towards determining its conservation status and help predict possible consequences of ongoing habitat fragmentation.

The goal of this present study is to examine habitat-wise and temporal patterns of distribution and abundance of grey junglefowl in the Western Ghats, India, to help inform long-term conservation management of the species. We examine abundance data between different habitats and across seasons over a two-year period, and discuss the implications of these data for the conservation status of the species and future surveys for this and other *Gallus* species.

Methods

Study area

We conducted surveys at the Theni Forest Division, Gudalur Range (9º37'N, 77º16'E), southern Western Ghats, Tamilnadu, south India (FIG. 1 - 2). The topography of the area is mostly flat and the altitude ranges from 300 to 1,965 m. The Gudalur Range regularly experiences extreme climatic conditions, with temperature range from 25-38ºC during the summer and 9-26ºC in winter. Average rainfall varies from 598 mm during June and August (southwest monsoon), to 766 mm from October to December (northeast monsoon). Based on these climatic patterns, four distinct seasons are generally recognized for the region: pre-monsoon (June-August), monsoon (September-November), post-monsoon (December-February) and summer (March-May). The Gudalur range is dominated by five principal habitat types (see Subramanian (2003): Southern Deciduous Scrub Forest (SDSF); Plantation Forest (PF); Southern Dry Mixed Deciduous Forest (SDMDF), Southern Moist Mixed Deciduous Forest (SMMDF); and Southern Sub-Tropical Hill Forest (SSTHF). Detailed descriptions of these habitats are shown in TABLE 1.

Bird surveys

Surveys were conducted every month from January 2004 to December 2005 but only on days of suitable weather. We used the distance sampling line-transect method (Burnham et al., 1980) to survey the grey junglefowl. Transects were positioned randomly with respect to the available habitat (Buckland et al., 2001) and separated by a minimal distance of 200 - 300 m. The total number (n = 15) and length of transects (each transect = 1 km) was a compromise between the area of available habitat (e.g. number and size of habitat patches), journey time between transects (i.e. sampling effort) and the number of transects necessary to obtain a sufficient sample of records for estimating junglefowl abundance (FIG. 3). Transects were surveyed immediately after sunrise between 06.00 and 08.00 hrs. An observer walked transects at a constant speed (0.8 - 1.0 km/hr) and was trained in distance estimation and familiar with all known vocalizations of the grey junglefowl. The order of transects surveyed and the direction of travel along transects during repeat visits was rotated to counter the bias of bird activity associated with time of day (Bibby et al., 2000).

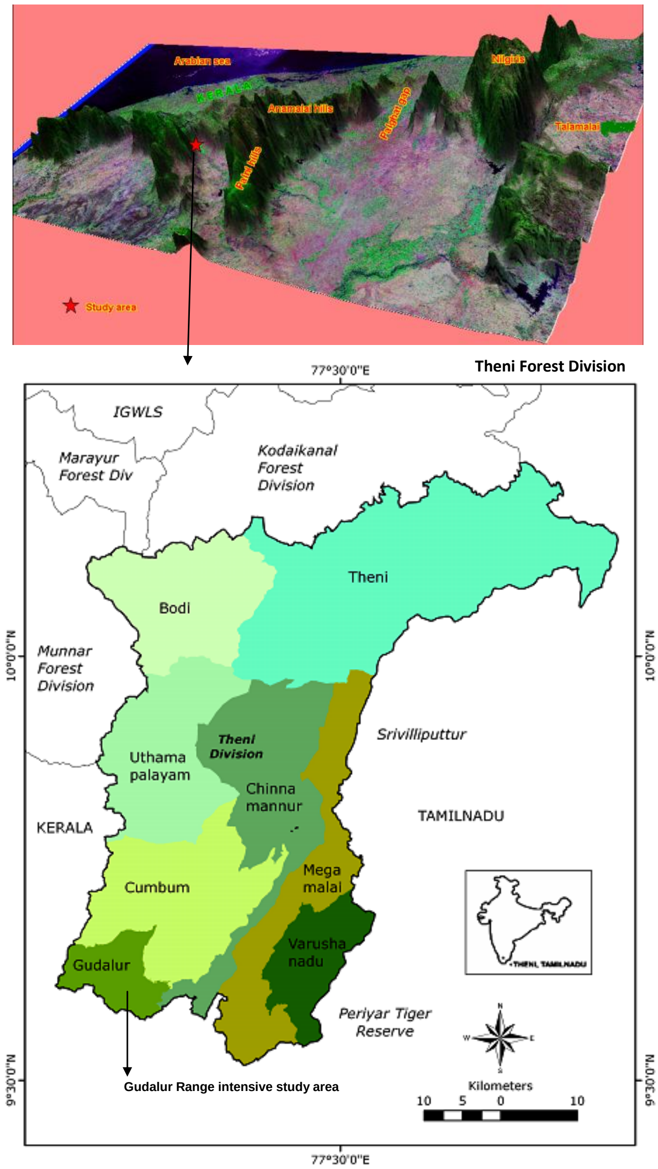

FIG. 1 The Gudalur Mountain Range.

The counting unit for grey junglefowl was the group of individuals. For each bird group contact we recorded the date, time of day, number of individuals, and, where possible, the age and sex of the individuals. We also measured perpendicular distance between the geometric centre of the bird group contact and the line transect. The position of the observer along the transect and location of the bird was marked using coloured tape, sighting angles were made using a standard field compass, and the distance was recorded using a tape measure.

Data analysis

We defined the breeding season as occurring between December and May, and the non-breeding season occurring between June and November. Climatic seasons were defined as pre-monsoon, monsoon, post-monsoon and summer (see above). Univariate statistical analysis was conducted using SPSS version 10.0 (SPSS Inc, 2000). Bird data were examined for normality using Kolmogorov-Smirnov tests. Differences between density estimates across breeding and non-breeding seasons, and habitats, were examined using non-parametric Kruskal-Wallis tests.

Distance data were analyzed using the program DISTANCE v. 5.0 Beta (Thomas et al., 1998). Three key functions (uniform, half-normal and hazard rate all with cosine series adjustment) were considered for each analysis. Key function selection was evaluated using Akaike's Information Criteria (AIC) and chi-square statistics were used to assess the 'goodness of fit' of each function (Buckland et al., 2001). Percentage CV and confidence intervals were calculated empirically (e.g. Lloyd, 2008). Repeated transects increased species sample sizes, providing a more precise estimate of variance and increasing the reliability of the detection function (Buckland et al., 2001). Shape criteria were examined for heaping or cluster bias and any outliers were right-hand truncated where necessary (Buckland et al., 2001). Determination of actual values for truncation and subsequent grouping of records into transect walked as an estimate of relative abundance, were calculated for the species in distance bands followed visual inspection of detection histograms (Buckland et al., 2001). Encounter rates (number of individuals per km transect walked) were calculated where the minimum sample size (n = 40) criterion was not met.

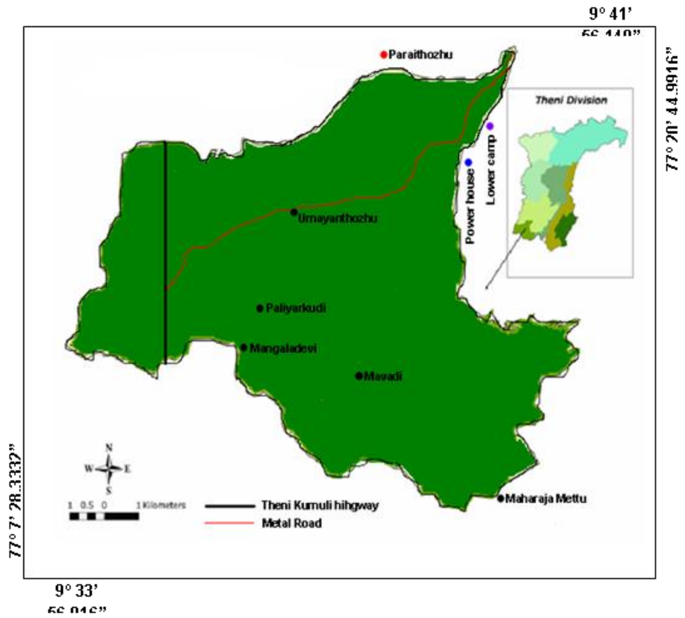

FIG. 2 Study area (Theni Forest Division) located within the Gudalur Range.

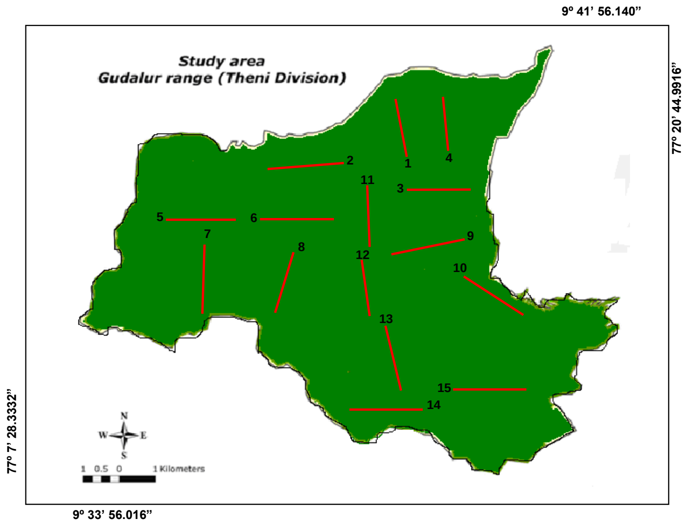

FIG. 3 Transect routes positioned throughout the study area.

Results

We completed 360 transect repeats during the study period (n = 96 for SDSF, n = 96 for PL, n = 48 for SDMDF, n = 72 for SMMDF, n = 48 for SSTHF). This resulted in 294 and 362 sightings of grey junglefowl in 2004 and 2005 respectively (TABLE 2). Repeat transect sample sizes between different habitats were uneven (because of the limiting influence of habitat topography and area) but a number of general comparisons can be made.

TABLE 1 Description of habitats and position of study transects in five different habitats, Theni Forest Division, Gudalur Range, Western Ghats. Habitats are: Southern Deciduous Scrub Forest (SDSF), Plantation Forest (PF), Southern Dry Mixed Deciduous Forest (SDMDF), Southern Moist Mixed Deciduous Forest (SMMDF), Southern Sub-Tropical Hill Forest (SSTHF).

Transect	**Orientation**	**Habitat and elevation (m)**	**Description**
1 Elavankadu 2 Pulichikkadu 3 Vandipadhai 4 Pulichi Plot	South-north East-west West-east South-north	SDSF, 325-350	Flat terrain, characterized by open canopy cover (50%). Dominated by tree species *Toona ciliata*, *Anogeisus latifolia*, *Hardwickia binata*, *Santalum album*, *Hopea parviflora*, *Albizia amara*, *Ailanthus excelsa* and *Acacia chundra*. Shrub cover (60%) dominated by *Lantana camara* and *Acacia torta* and fairly dense ground leaf litter cover (55%). Cattle grazing common. Total area = 7.5 km²
5 Pulikkadu 6 Pulikkadu 7 Mangaladevi 8 Thekkuthottam	West-east West-east North-south North east-south west	PL, 350-375	Generally flat terrain with occasional low hills. Original habitat previously clear felled and replaced with plantations of softwood trees *Schleichera oleosa*, *Ailanthus excelsa*, *Salmalia malabarica*, and *Bombax* spp. with 60% canopy cover. Shrub cover (40%) dominated by *Lantana camara* and *Acacia torta*. Total area = 3.5 km²
9 Vannathiparai East 10 Minnilayam	East-west North west-south east	SDMDF, 375-400	Consists of hilly and flat terrain. Dominated by *Ailanthus excelsa*, *Albizia amara*, *Trema orientalis*, *Santalum album*, *Capparis grandiflora*, *Grewia tillifolia*, *Hopea parviflora*, *Streblus asper*, *Sterculia urens* and *Anogeissus latifolia.* Dense (70%) canopy cover. Shrub cover (40%) dominated by *Lantana camara* and *Acacia torta*. Total area = 2.0 km²
11 Sethuvaikkal 12 Mungil Pannai 13 Anaikaltheri	North-south North-south North-south	SDMDF, 625-700	Undulating hilly terrain dominated by *Chuckrasia tabularis*, *Trema orientalis*, *Diospyros buxifolia*, *Anogeissus latifolia*, *Lannea coromandelica*, *Atalantia monophylla*, *Acacia chundra*, *Ehretia levis*, *Capparis glauca* and *Diospyros melanoxylon*. Dense canopy cover (70%). Shrub cover (50%) dominated by *Lantana camara* and *Acacia torta*. Dense cover of ground leaf litter (60%). Total area = 6.3 km²
14 Madatheri 15 Uchikadu	East-west West-east	SSTHF, 825-950	Hilly, undulating terrain dominated by *Grewia tillifolia*, *Hopea parviflora*, *Anogeissus latifolia*, *Mallotus philippensis*, *Pteracarpus marsupium*, *Capparis divaricata*, *Diospyros montana*, *Terminalia paniculata*, *Trema orientalis* and *Syzygium cumini*. Dense canopy cover (70%). Shrub cover (60%) with understory dominated by *Abutilon indicum* and *Mundulea sericea*. *Elettaria cardamomum* common whilst *Lantana camara* and *Acacia torta* are scarce. Dense ground leaf litter cover. Total area = 3.8 km²

TABLE 2 Density estimates (number of individuals per unit area of habitat) ± SE of grey junglefowl in five habitats, Theni Forest Division, Gudalur Range, Western Ghats, across the two-year study period. Figures in parentheses represent 95% CI. n = sample sizes. ***** represents encounter rates (number of individuals per km transect walked).

Habitat	2004	2005	Pooled data set
Southern Deciduous Scrub Forest (SDSF)	32.1 ± 3.6 (25.0 - 45.1) n=101	36.9 ± 4.5 (28.7 - 52.2) n=132	35.8 ± 6.3 (22.1 - 62.2) n=233
Plantation Forest (PF)	22.3 ± 2.9 (14.25 - 33.41) n=79	28.6 ± 3.2 (11.6 - 40.2) n=85	25.4 ± 5.2 (15.4 - 35.6) n=164
Southern Dry Mixed Deciduous Forest (SDMDF)	13.8 ± 1.5 (7.4 – 28.6) n=45	21.8 ± 4.2 (13.4 - 29.4) n=61	19.4 ± 3.1 (13.3 - 28.5) n=106
Southern Moist Mixed Deciduous Forest (SMMDF)	23.6 ± 2.8 (8.8 – 38.4) n=57	27.8 ± 4.2 (17.4 - 37.6) n=72	23.1 ± 6.0 (18.5 - 38.1) n=129
Southern Sub-Tropical Hill Forest (SSTHF)	0.15 ± 0.02 * (0.08 - 0.21) n=12	0.27 ± 0.11 * (0.20 - 0.35) n=12	0.20 ± 0.08 * (0.16 - 0.26) n=24

Across the five different habitats, density estimates from both years and pooled estimates were consistently highest in SDSF habitat and lowest in SDMDF habitat (TABLE 2). Density estimates from all five habitats were also consistently higher in 2005, with the most noticeable difference recorded from SDMDF habitat. Similarly, encounter rates of grey junglefowl in SSTHF were higher in 2005 than in 2004. However, temporal differences in density estimates were not significantly different ($X^2 = 1.5$, $P = 0.38$).

We identified distinctive seasonal-wise patterns of abundance, with density estimates varying between seasons and between the same seasons across both years (TABLE 3). Overall, seasonal density estimates were highest in 2005, with the exception of those from the post-monsoon season. During 2004, estimated densities were highest in the post-monsoon season, and during the monsoon season in 2005. Density estimates were consistently lowest during the pre-monsoon season across both years, whereas the pooled density estimates were highest during the summer season. Similarly, grey junglefowl density estimates were higher during the breeding than non-breeding season across both years, but not for the pooled data-set (TABLE 3). Temporal differences in density estimates between the four seasons ($X^2 = 0.9$, P = 0.47) and between breeding and non-breeding seasons ($X^2 = 0.6$, df = 3, $P = 0.42$) were not significantly different.

TABLE 3 Density estimates (number of individuals per unit area of habitat) ± SE of grey junglefowl across four climate seasons and breeding/non-breeding seasons, Theni Forest Division, Gudalur Range, Western Ghats, across the two year study period. Figures in parenthesis represent 95% CI. N = sample sizes.

Season	2004	2005	Pooled data set
Pre-monsoon (June-Aug)	6.5 ± 1.7 (3.9-10.8) n=53	8.9 ± 4.2 (05.4 - 19.2) n=76	11.2 ± 5.3 (6.4 - 16.4) n=129
Monsoon (Sept-Nov)	17.5 ± 3.8 (11.5- 26.6) n=77	21.6 ± 4.7 (10.5 - 38.2) n=86	15.4 ± 4.2 (8.9 - 22.1) n=136
Post-monsoon (Dec-Feb)	19.0 ± 3.6 (13.1- 27.5) n=97	17.9 ± 5.7 (9.3 - 25.2) n=113	22.0 ± 6.9 (15.3 - 35.1) n=210
Summer (March-May)	13.0 ± 2.9 (8.4-20.1) n=67	20.9 ± 6.2 (12.4 - 28.9) n=101	27.5 ± 6.3 (15.5 - 42.3) n=168
Breeding (Dec-May)	32.1 ± 4.4 (24.5 - 42.0) n=164	38.6 ± 6.5 (23.2 - 55.4) n=180	32.3 ± 9.5 (23.4 - 41.9) n=344
Non-breeding (June-Nov)	22.4 ± 4.5 (15.1 - 33.2) n=130	26.3 ± 7.3 (19.9 - 33.3) n=152	38.3 ± 6.8 (22.3 - 54.3) n=282

Discussion

Patterns of grey junglefowl abundance

Our density estimates of grey junglefowl showed distinct habitat-wise variations, with the species being more abundant in SDSF habitat and less abundant in SSTHF habitat (TABLE 2).

Previous studies have also shown that the species is more abundant in SDSF habitat across other parts of the Theni Forest Division (e.g. Sathyanarayana et al., 2000; Subramanian, 2003; Ramesh & Sathyanarayana, 2007). This may be related to the presence of Kusum (*Schleichera oleosa*) trees with a dense cover of *Lantana camara* and

Acacia torta bushes that are essential for nesting (Ramesh, 2007). Grey junglefowl may be less abundant in SSTHF habitat because of habitat features such as the higher elevation, dense canopy cover and low density of *L. camara* and *A. torta* bushes.

Interestingly, these habitat-wise patterns appear not to be representative of the species in other areas throughout southern India. Evidence from other studies suggests there is pronounced geographic variation in patterns of grey junglefowl abundance. At Mundanthurai Plateau, Tamilnadu, the grey junglefowl is more abundant in open woodland habitat with low to moderate canopy vegetation cover, and containing a mosaic of moderate scrub cover interspersed with low or no grass cover (Sathyakumar, 2006). At the Mudumalai Wildlife Sanctuary, the grey junglefowl is more abundant in scrub forest habitat (e.g. Gokula, 1998; Gokula & Vijayan, 2000), whereas it is more abundant in mixed dry deciduous forest within the Anaikatti Hills (Nirmala & Lalitha, 2002). The species appears to be scare in other higher elevation habitats at a number of locations including the Periyar Tiger Reserve (Zacharias, 1997), Srivilliputtur Grizzled Giant Squirrel Wildlife Sanctuary (Ramesh, 1994), and the Mundanthurai Plateau (Sathyakumar, 2006).

With the exception of the post-monsoon season, densities estimated for all habitats and seasons from 2005 were higher than those estimated for 2004 although these differences were not significant. The between-season differences are almost certainly a reflection of seasonal variations in species detectability rather than true differences in density - a common problem when surveying Asian Galliformes (Gaston, 1978; 1980). Whereas differences in density estimates between seasons in the same year is somewhat understandable, differences in density estimates between years merits further investigation. It is tempting to suggest that the 2005 estimates represent true increases in abundance between years, but this seems less likely since the differences were not significant. We suspect that the differences may again be related to differences in detectability but further data regarding variation in vegetation cover between years is required to confirm this.

Variation in the density estimates between habitats may, in part at least, be a reflection of the uneven sampling across habitats. We were only able to sample fewer transects in two of our target habitats because of the small overall area of available habitat (SDMDF), or undulating, hilly terrain (SSTHF). Transect length (1 km) was also a reflection of the extent and conditions of the five habitat types. Some authors suggest that only transects > 9.8 km in length are sufficient to obtain reliable estimates of *Gallus* density (e.g. Fernandes et al., 2009). In reality however, the exact length and number of transects used is entirely site-dependent (e.g. Bibby et al., 2000). At the Theni Forest Division, the number of bird registrations and the density estimate confidence intervals indicate that for four of the five habitats at least, the number and length of transects used was sufficient to reliably estimate grey junglefowl density in those habitats. We stress however, that this sampling effort may not be adequate for other sites for the species throughout southern India and recommend that, where possible, future surveys consider sampling a greater number of longer transects.

Implications for monitoring grey junglefowl

Ideally, bird population surveys should always be conducted when the target species are most detectable in order to collect as much data as possible (Bibby et al., 2000). Our study shows that the most beneficial time of year to survey the species in the Western Ghats using distance sampling line transect surveys is during the breeding season (December to May) which corresponds to the post-monsoon and summer seasons. During these seasons, the species becomes more conspicuous and easier to record because subadults tend to separate from adult females and live apart, and established pairs tend to forage in more open vegetation. Importantly, our results also demonstrate that surveys should not be conducted during the pre-monsoon season (June and August). During this period, individual birds are less conspicuous since adult females and their chicks for most of the time remain in dense vegetation cover, whilst adult males also prefer to remain in dense vegetation cover and tend not to vocalize frequently.

Implications for conservation

Throughout its range the grey junglefowl appears to tolerate a number of different woodland habitats, so species-specific conservation measures, in terms of priority habitats for conservation management, should reflect this variation in abundance and habitat selection. Our results show that in the Gudalur range of the Western Ghats, the conservation of

Southern Deciduous Scrub Forest habitat (SDSF) will be an important step to preserving significant regional populations of grey junglefowl. Complementary to this, efforts to conserve Plantation Forest (PL), Southern Dry Mixed Deciduous Forest (SDMDF), and Southern Moist Mixed Deciduous Forest (SMMDF) should also prove to be highly beneficial for the species.

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