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Comparative Population Biology of Black (*Francolinus francolinus*) and Grey (*F. pondicerianus*) Francolins Under Lal Suhanra National Park (Pakistan) Conditions*

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Abstract: Strip transect (2.5 X 0.04 km^2) data on sighting of black francolin and grey francolin was simultaneously collected from 10 francolin favourable habitat stands of the Lal Suhanra National Park (South Punjab, Pakistan) for two consecutive days in each calendar month (1993-2004). Average population densities of black (8.40±1.39 birds/ km^2; range 3 – 13/ km^2) and grey (6.20±1.52 birds/ km^2; range 3 – 10/ km^2) was not significantly different (t = 0.5629, df = 159, p > 0.05). Significant differences in individual stand densities of two species and a negative correlation (r^2 = - 0.333, p > 0.05) indicated habitat exclusion. Both the species followed identical pattern of density variations, with minimum populations during winter (November-February) and peak in late summer (July-August), but there was a rapid rise in February-March in black and in July-August in grey francolin. Distribution of juveniles in the populations (black: 0.32±0.09 juvenile/ female, 0.14±0.03 juvenile/ adult; grey: 0.32±0.07 juvenile/ female, 0.15±0.03 juvenile/adult) is not significant different (t= 0.24, df = 14, p = 0.05), suggesting equal breeding potentials. Preponderance of males was recorded in Black (male/female ratio 1.31, α^2 15.42, df = 1, p<0.001) and grey (ratio 1.21, α^2 9.14, df 1, p< 0.001). Black francolin population exhibited a significant heterogeneity in distribution of sexes in both spatial (α^2 20.76, df = 5, p<0.05) and seasonal (α^2 21.76, df 10, p<0.05) samples, while heterogeneity was not significant for grey francolin population (stands: α^2 13.61, df = 9, p>0.05, seasons: α^2 `3.36, df = 10, p>0.05). Average size of covey was smaller (1.88±0.15, range 1-5) in black compared to grey (1.94±0.18, range 1-7) francolin. Black francolin (0.60±0.09) tended more towards a uniform dispersion compared with grey (0.78±0.11).

Key words: Population density, seasonal fluctuation, annual fluctuation, age structure, sex structure, dispersion.

INTRODUCTION

Black (*Francolinus francolinus*) and grey (*F. pondicerianus*) francolins are popular medium-sized resident game birds of the Indus Plain (Roberts, 1991; Islam, 1999). Both these species are associated with man as pet (Fuller e*t al.*, 2000; Santiapillai *et al.*, 2003), favourite game birds and table delicacy (Long, 1981; Mian, 1995), biological control agent for insect pests of agricultural crops (Beg and Qureshi, 1972; Khan, 1989) and having impact on culture of the area (Lum, 1986). Global populations of these species are stable, considered as Least Concerned (IUCN, 2007; Birdlife, 2007), but concern is frequently expressed in Pakistan regarding a gradual decline in their populations (Roberts, 1991), attributed to hunting (Mann and Chaudhry, 2000) and habitat loss (Khan, 2010).

Both black and grey francolins are of almost same size (Roberts, 1991). Black francolin inhabits thicker cover of vegetation (Baker, 1932-35; Whistler, 1941; Craft, 1966; Cramp and Simmons, 1980; Johnsgard, 1988; Roberts, 1991; Charalambides, 1994), roosting on ground in thick growth of tall grasses and often mounts up on branches of trees for calling (Bump and Bump, 1964; Ali and Ripley, 1983; Roberts, 1991; Khan and Mian, 2013). Grey francolin is better adapted to sustain arid conditions, living under sparse growth of vegetation (Roberts, 1991). Presence of populations of black and grey francolins over sympatric range of distributions under considerably protected conditions of Lal Suhanra National Park (LSNP) allowed us to undertake the present study on comparative population biology variables of these two species with the hypothesis that difference in their habitat requirements has an influence on their population biology parameters. For this purpose a long term (1993-2004) study was

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designed where population biology variables of the two species were simultaneously studied using identical sampling techniques.

MATERIALS AND METHODS

LSNP (29^o 24' N, 71^o 01' E; 110-125 m above sea line; national park established in 1972; Chaudhry and Khan, 2002) is located in southern Punjab (Pakistan). It is located in the northwestern parts of the Cholistan Desert/Greater Indian Thar Desert, and is a hot desert (average temperatures: summer 46.7^{o}C, winter 3.5^{o}C; sporadic precipitation and low relative humidity) with alternating sand dunes and interdunal flats (Rao *et al.*, 1989). During the study period, severe drought (18-51 mm/year; 1993 and 1996), was followed by high (460-569 mm/year, 1997-2000) and moderate (112-141 mm/year, 2001-2004) precipitation spells. Two blooms, i.e., spring (February-March) and post-monsoon (August-September) are witnessed by the area. Bahawal Canal irrigates northwestern parts of the park, where swamp vegetation and irrigated plantation has developed.

Each of the 23 stands (stretches having reasonably uniform physic-biotic conditions) established over LSNP was extensively searched for direct/indirect sighting of black and grey francolins during 1993 and stands (n = 10) having francolin populations were selected for present population studies. A permanent strip transect line (2.5 km) was established using walk trails, trying to keep of diagonal disposition and including all microhabitat variation (Khan and Mian, 2012). Each transect line was walked through at normal speed (2-3 km/ hour) by 3-4 workers moving together and talking at normal pitch during morning (starting half an hour before sun rise) and evening (starting half an hour before dusk) sessions to count the number of black and grey francolin observed. Transect sampling was exercised for two consecutive days (on almost same dates) during each calendar month between 1993 and 2004. Sex (male, female) and age (juvenile, adult) of each sighted bird; and the number of birds seen together were recorded. Initial studies revealed that present transect sampling covered a strip of 80 m (40 m on each side of transect line), which was regarded as transect width for the present study.

Stand population densities (per km^2) of black and grey francolins were separately calculated for each sample by dividing number of the sighted birds by 0.2 (transect area = length x width, 2.5 x 0.08 km^2), and average densities worked out for different stands, calendar months and years for analysis of seasonal /annual population fluctuations. Variance and standard error of mean (SEM) were calculated, t-test (unpaired) used for significance of differences (0.05 significance level) and Pearson's coefficient of linear correlation calculated for judging association between density and other variables (Sokal and Rohlf, 2000). Number of adults of two sexes recorded in transect sightings were used for calculation of sex ratios for different stands, seasons and years. α^2 test was used for significance of difference to 1:1 sex ratio, and heterogeneity α^2 used for testing uniformity of data collected under different sets. Transect data on number of juveniles and adult females/ birds sighted were used to calculate juvenile: adult ratios. Number of birds of black or grey francolin seen together during transect sampling were considered as a group (covey). Individual group size data was used for calculation of dispersion index (variance/mean: 1 = random dispersion, <1 = uniform, <1 = clumped; Odum, 1971).

RESULTS

Density

Average densities (Table I) of black (8.40±1.39 SEM birds/ km²; range = 3 – 13/ km²) and grey (6.20±1.52 SEM birds/ km²; range = 3 – 10/ km²) francolins were not significantly different ($t = 1.81$, df = 2558, $p > 0.05$) from one another. Average densities of two francolin species were, however, significantly different ($t = 1.96$, df = 318, $P < 0.05$) in majority of individual stands. Negative correlation ($r^2 = -0.333$, df = 2558, $p > 0.05$, not significant) between distribution of population densities of grey and black francolins in individual stands indicated habitat segregation between species.

Seasonal fluctuation

Average crude densities of two francolin

Table I.- **Population density (mean ± SEM, per km²) of black and grey francolins in different stands of LSNP having favourable francolin habitat. Number of transects (n = 160) and the transect area (32 km²) remained constant in all stands. t (df = 158, P = 0.05) = 1.96.**

Stand No.	Black francolin #	Black francolin Density	Grey francolin #	Grey francolin Density	t-value
4	510	13.28±2.25	155	4.04±0.98	2.21
15	487	12.68±2.32	123	3.20±0.54	2.88
5	431	11.22±2.11	132	3.44±0.74	2.52
7	190	4.95±1.03	358	9.32±2.11	2.1
3	186	4.84±1.02	387	10.08±2.12	2.78
18	132	3.44±0.88	252	6.56±1.11	1.75
22	-	-	234	4.66±0.96	-
11	-	-	179	6.09±1.06	-
12	-	-	238	6.20±1.14	-
13	-	-	323	8.41±1.35	-
Overall		8.40±1.39		6.20±1.52	1.81

species during different calendar months (Table II) were not significantly different (t<1.96, df = 318, P>0.05), except for August and September, where densities of grey francolin were significantly higher than those of black francolin (t>1.96, df = 318, P<0.05). Two species followed identical patterns of seasonal fluctuation, maintained low densities during winter (November–March) which started rising gradually after March. Densities of black francolin showed an abrupt rise between February and March, followed by a slow gradual rise till July followed by a rapid decline in August Densities of grey francolin started showing a slow gradual rise between March and June and a steep rise between June and August followed by a rapid decline between August and October (Figure 1).

Annual fluctuations

Average population densities of black and grey francolins during different years (Table III) suggested no significant difference (t < 1.96, df = 312, P > 0.05). Two species followed similar pattern of annual fluctuation. Average densities of both species were maintained at lower levels during 1993-96 (drought hit years; black francolin: 4.03±1.12 to 4.44±1.23 birds/km², grey francolin: 5.34±1.37 to 5.72±1.88 birds/km²). Densities increased between 1998 and 1999 (heavy rainfall years; black francolin: 5.97±2.06 and 5.56±2.18 birds/km²; grey francolin: 7.25±1.80 and 7.53±1.92 birds/ km²), which declined with low densities in 2003 (black francolin: 4.31±1.19 birds/km²; grey francolin: 5.56±1.13 birds/km²). Annual precipitation is significantly correlated with Grey (r = 0.7938, df = 10, P < 0.01) and black (r = 0.6529, df = 10, P < 0.05) francolin population densities.

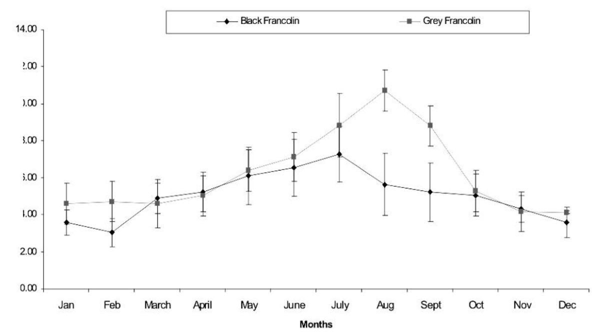

Fig. 1. Fluctuations in the average densities (per km²) of black and grey francolins during different calendar months (1993 – 2004) in LSNP.

Table II.- **Population density (mean ± SEM, per km²) of black and grey francolins in LSNP during different calendar months (1993-2004). Number of transects (n=160) and transect area (32 km²) remained constant for different months. t (df = 158, P = 0.05) = 1.96.**

Months	Black francolin #	Black francolin Density	Grey francolin #	Grey francolin Density	t-value
January	115	3.6±1.11	147	4.6±0.68	0.54
February	97	3.0±1.09	151	4.7±0.77	0.63
March	157	4.9±1.31	147	4.6±0.82	0.40
April	168	5.2±1.09	161	5.0±1.07	0.24
May	195	6.0±1.11	205	6.4±1.55	0.20
June	209	6.5±1.30	228	7.1±1.56	0.51
July	233	7.3±1.72	283	8.8±1.51	0.63
August	180	5.6±1.11	343	10.7±1.67	2.59
September	167	5.2±1.09	282	8.8±1.57	2.78
October	162	5.1±1.11	169	5.3±1.12	0.45
November	138	4.3±1.08	133	4.2±0.71	0.37
December	115	3.6±.0.78	132	4.1±0.83	0.41

Table III.- Black and grey francolin during different years for the favourable Francolin tract of the Lal Suhanra National Park. Number of transect (n = 160) and transect area (32 km²) remained constant for different years. t (df = 318, P = 0.05) = 1.96.

Years	Black francolin		Grey francolin		t-value
	#	Density	#	Density	
1993	139	4.34±0.87	182	5.69±0.76	0.89
1994	129	4.03±0.75	174	5.44±0.84	1.06
1995	137	4.28±0.67	183	5.72±0.88	0.92
1996	142	4.44±0.91	171	5.34±1.12	0.69
1997	154	4.81±0.65	195	6.09±1.10	0.99
1998	191	5.97±0.78	232	7.25±1.18	0.66
1999	210	5.56±0.81	241	7.53±1.14	0.96
2000	204	6.38±1.10	221	6.91±1.10	0.29
2001	187	5.84±0.87	214	6.69±1.11	0.59
2002	157	4.91±0.79	197	6.16±1.10	1.09
2003	138	4.31±0.89	178	5.56±1.13	1.08
2004	148	4.63±0.94	193	6.03±1.10	1.10

Age structure

Distribution of juveniles in the populations of black francolin (0.32±0.09 juveniles/female, 0.14±0.03 juvenile/adult birds) and the grey francolin (0.32±0.07 juvenile/female, 0.15±0.03 juveniles/ adult) is not significant different (t= 0.24, df = 14, p = 0.05) (Table IV).

Juvenile of grey francolin were not recorded in two stands which were holding irrigated plantation and those of black francolin in two other stands having tropical thorn forests, despite the fact that adult birds were present in such stands. This suggests that non-breeding range of habitat distribution in both the species was wider than the ranges of breeding birds.

No juveniles were recorded during October-February for black and during October-March for grey francolins (Table V). Juvenile to adult ratio showed an almost identical pattern of seasonal change with maximum values appearing in August followed by a decline in September.

Sex structure

Pooled data on distribution of two sexes in adult populations in different stands (Table VI) and calendar months (Table VII) suggest a general skewness in favour of males in both the species. The preponderance of male is slightly higher in black francolin (male/female ratio 1.31, α^2 15.42, df 1, p<0.001) compared to grey francolin (ratio 1.21, α^2 9.14, df 1, p< 0.001). Population of black francolin exhibited a significant heterogeneity in distribution of sexes in both spatial (α^2 20.76, df 5, p<0.05) and seasonal (α^2 21.76, df 10, p<0.05), while grey francolin population showed non-significant heterogeneity (Stands: α^2 13.61, df 9, p>0.05, seasons: α^2 `3.36, df 10, p>0.05) suggesting a wider variation in sex ratios in black compared to grey francolin.

Dispersion

Values of dispersion index for Black (0.60± 0.09) and grey (0.78±0.11) francolins suggest a general random distribution with a tendency of maintaining some degree of uniform dispersion (Table VIII). Black is prone towards a more uniform distribution compared to grey francolin. This pattern is exhibited in yearly (Table VIII) and all seasonal (Table IX) samples. Average size of covey was also smaller (1.88±0.15, range 1-5) in black francolin compared to that of grey francolin (1.94±0.18, range 1-7). Majority of individuals appeared as singles (black 52.39%, grey 50.18%), and the frequencies of groups of larger size gradually decreased with increase in covey size (Table X).

DISCUSSION

Density

Non-significant difference in density distribution of grey and black francolins was expected, because of their having almost same biomass and feeding habits, requiring same amounts of food energy. Higher densities of black francolin compared to grey francolin can be attributed to selection of thicker vegetation as its habitat by the black francolin, where potentially higher food energy is available (Faruqi *et al*., 1960).

Significant difference in densities of two species in individual study stands can be attributed to variation in habitat available in different stands. Negative correlation between distributions of populations in different stands indicates some degree of habitat exclusion between black and grey francolins. Two species are, thus, not in direct habitat competition with one another even

Table IV.- Distribution of juvenile in the population of black and grey francolin in different stands established in the LSNP.

Stand (#)	Black francolin Adult (#)	Black francolin Juvenile (#)	Black francolin Juvenile/female	Black francolin Juvenile/Adult	Grey francolin Adult (#)	Grey francolin Juvenile (#)	Grey francolin Juvenile/Female	Grey francolin Juvenile/Adult
3	186	-	-	-	317	70	0.46	0.32
4	423	87	0.46	0.21	147	8	0.12	0.05
5	378	53	0.31	0.14	132	0	-	-
7	190	-	-	-	297	61	0.44	0.21
11	-	-	-	-	168	11	0.14	0.07
12	-	-	-	-	219	19	0.19	0.09
13	-	-	-	-	249	74	0.67	0.3
15	412	75	0.44	0.18	123	-	-	-
18	112	20	0.51	0.18	209	43	0.49	0.21
22	-	-	-	-	218	16	0.17	0.07
Overall	1701	235	0.32±0.09	0.14±0.03	2079	302	0.32±0.07	0.15±0.03

Table V.- Distribution of juveniles in the population of black and grey francolin during different months in LSNP.

Months	Black francolin Adult (#)	Black francolin Sub-adult (#)	Black francolin Sub-adult /Adult	Grey francolin Adult (#)	Grey francolin Sub-adult (#)	Grey francolin Sub-adult /Adult
January	115	-	-	147	-	-
February	97	-	-	151	-	-
March	140	17	0.12	247	-	-
April	147	21	0.14	144	17	0.12
May	172	23	0.13	174	31	0.18
June	167	42	0.25	180	48	0.27
July	178	55	0.31	219	64	0.29
August	123	57	0.46	355	88	0.35
September	147	20	0.14	228	54	0.24
October	162	-	-	169	-	-
November	138	-	-	133	-	-
December	115	-	-	132	-	-

Table VI.- Distribution of two sexes in the adult population of black and grey francolins in different stands of LSNP from 1993 to 2004 (χ^2 for df = 1 at 0.05 = 135)

Stand #	Black francolin ♂	Black francolin ♀	Black francolin ♂ / ♀ ratio	Black francolin $\chi^2_{(1:1)}$	Grey francolin ♂	Grey francolin ♀	Grey francolin ♂ / ♀ ratio	Grey francolin $\chi^2_{(1:1)}$
3	101	85	1.18	1.38	165	152	1.09	0.53
4	232	191	1.22	3.97	81	66	1.23	1.53
5	205	173	1.19	2.71	82	50	1.64	7.76
7	113	77	1.47	6.82*	159	138	1.15	1.48
11	-	-	-	-	91	77	1.28	1.17
12	-	-	-	-	116	103	1.28	0.77
13	-	-	-	-	138	111	1.24	2.93
15	243	169	1.44	13.29*	69	54	1.28	1.83
18	71	41	1.73	8.04*	115	94	1.22	2.11
22	-	-	-	-	121	97	1.25	2.64
Overall	965	736	1.31	15.42*	1137	942	1.21	9.44

Table VII.- **Distribution of two sexes in the adult population of black and grey francolins in LSNP during different calendar months (χ^2 for df = 1 at 0.05 = 135).**

Months	Black francolin					Gran francolin				
	♂	♀	♂ : ♀ ratio	$\chi^2_{(1:1)}$	P	♂	♀	♂ : ♀ ratio	$\chi^2_{(1:1)}$	P
January	68	47	1.45:1	3.83	0.05	90	57	1.57:1	2.41	0.06
February	59	38	1.55:1	4.55	0.03	85	66	1.29:1	2.39	0.12
March	79	61	1.30:1	2.31	0.13	80	67	1.19:1	1.15	0.28
April	83	64	1.30:1	2.46	0.12	83	61	1.36:1	3.36	0.07
May	93	79	1.18:1	1.14	0.29	90	84	1.07:1	0.21	0.64
June	96	71	1.35:1	3.74	0.05	98	82	1.20:1	1.42	0.23
July	91	87	1.05:1	0.09	0.76	111	109	1.02:1	0.02	0.89
August	65	58	1.12:1	0.40	0.53	133	122	1.09:1	0.47	0.49
September	86	61	1.41:1	3.65	0.06	125	103	1.21:1	2.12	0.15
October	95	67	1.42:1	4.84	0.03	91	78	1.17:1	1.00	0.32
November	78	60	1.30:1	2.35	0.13	70	63	1.11:1	0.37	0.54
December	72	43	1.68:1	7.31	0.007	82	50	1.64:1	7.56	0.01

Table VIII.- **Dispersion index (variance/mean) of the populations of black and grey francolin in the LSNP during different years.**

	Black francolin				Grey francolin			
Years	n	Mean	Variance	Index	n	Mean	Variance	Index
1993	77	1.17	0.25	0.21	86	1.71	1.20	0.70
1994	73	1.90	0.76	0.40	69	1.55	0.64	0.41
1995	104	1.50	0.88	0.58	90	1.52	0.84	0.55
1996	85	1.81	1.16	0.64	98	1.73	0.87	0.50
1997	113	1.38	0.72	0.52	118	1.86	0.93	0.50
1998	152	2.11	1.93	0.91	139	2.36	2.07	0.87
1999	124	1.57	1.03	0.65	185	2.37	3.39	1.43
2000	122	1.88	1.36	0.72	160	1.88	2.27	1.20
2001	117	1.30	0.22	0.16	124	1.54	0.69	0.44
2002	86	1.54	1.47	0.95	103	1.31	0.56	0.42
2003	84	2.11	1.36	0.64	88	1.50	0.61	0.40
2004	73	1.54	0.87	0.56	69	1.26	0.31	0.24
Overall	1210	1.6	0.97	0.60±0.09	1329	1.74	1.37	0.78±0.11

Table IX.- **Dispersion index (variance/mean) of the populations of black and grey francolin in the LSNP during different months.**

Months	Black francolin				Grey francolin			
	n	Mean	Variance	Index	n	Mean	Variance	Index
					62	1.15	0.14	0.12
January	120	1	-	-	85	1.2	0.17	0.14
February	109	1.17	0.15	0.12	104	1.66	0.65	0.39
March	96	1.71	0.37	0.21	110	1.85	1.23	0.66
April	80	1.9	0.76	0.4	126	1.86	1.02	0.54
May	84	2.09	1.29	0.61	136	2.09	1.67	0.79
June	92	2.92	1.41	0.48	160	2.32	2.29	0.98
July	124	2.16	1.91	0.88	182	2.13	2.75	1.29
August	100	2.33	1.66	0.71	133	1.6	1.28	0.80
September	96	1.28	0.22	0.17	90	1.21	0.17	0.14
October	100	1.06	0.06	0.05	71	1.21	0.18	0.15
November	98	1.08	0.08	0.07	70	1.13	0.12	0.10
December	111	1	-	-				

Table X.- Frequencies of the coveys of different sizes in the populations of black and grey francolin in LSNP.

Covey size	Black francolin		Grey francolin	
	n	%	n	%
1	634	52.39	667	50.18
2	301	25.08	323	24.30
3	108	9.00	148	11.14
4	125	10.41	112	8.43
5	42	3.50	53	3.98
6	-	-	16	1.20
7	-	-	10	0.75

in otherwise sympatric tracts. No previous study focused distribution of these two species over a sympatric range, but the collective consideration of results of two separate studies conducted in the same area (Faisalabad, Pakistan) at almost same time indicated that black francolin preferred cropland (Khan, 1989), while grey francolin was more frequent in sandy scrubs (Ullah, 1991). Such habitat exclusion lowers direct competition between species falling at the same trophic level and goes in the advantage of both the species (Odum, 1971). Competitive exclusion was also indicated in food consumed by black and grey francolins (Khan and Mian, 2012).

Seasonal fluctuations

Identical pattern of seasonal density fluctuations in the populations of black and grey francolins can be expected under similar pattern of population recruitment and chick/juvenile loss, 70-80% chicks coming in February-May and low level of breeding continuing till July (Black)/August (Grey) (Khan, 2010). Stable and low population densities during winter indicate limited winter caused mortalities in both species, which can be ascribed to mild winter temperatures, low avian predation (Khan, 2010, Mian and Ghani, 2007) and higher survival potentials of adult francolins. Winter low populations may also reflect chances of some population movements to the surrounding agricultural fields (black) and desert tracts (grey). Wider ecological amplitude is expected during non-breeding season (Odum, 1971). Chick/ juvenile/ sub-adult mortalities without population recruitment explains rapid decline in population densities between July/August and November. Natural adult mortality of around 4% per month is expected for the adult bird with an average age of about two years (Robert, 1991).

Higher summer population densities, as reflected under the present study, can also be artifacts caused due to increased activities of the birds during breeding season, which render them more prone to appear in transect sampling. Not much literature is available to support or otherwise refute this possibility and further studies are required to explore this aspect. Higher summer male mortalities, as reflected by lowered proportion of the males during summers, may also hint towards increased male activity and thence facing higher predation (Khan and Mian, 2012,a,b).

Annual fluctuations

Rainfall, especially under arid conditions, directly controls sprouting of ephemerals (Walker, 1963; Mian, 1985) ensuring food, for predominantly herbivore (Faruqi *et al*., 1960; Khan and Mian, 2011, 2012a), and shelter for cursorial (Ali and Ripley, 1969; Roberts, 1991; Khan 2010) francolins, which explains significant positive correlation between precipitation and population densities of grey and black francolins. A stronger correlation of grey francolin (0.79) population density compared with that of black francolin (0.65) with annual precipitation suggests a higher control of precipitation over population levels of grey francolin, which is adapted to survive under more arid condition. Canal irrigation provides support to vegetation in stands holding black francolin population, which slightly reducing the direct effect of lower precipitation.

There are persistent reports of illegal hunting and trapping of both these francolin species in LSNP (Anonymous, 2007). No reliable estimates are available, however it appears that human predation is fully sustained by populations of these species. It is difficult to conclude whether these stable populations are at carrying capacity levels of the habitat, changing with the change in vegetative cover/habitat conditions. However, the fact that population fluctuations of the two species were following precipitation pattern indirectly indicate that populations of these francolins were maintained at carrying capacity levels of the habitat. Under such circumstances human predation is claiming the part of the population falling above carrying capacity level and controls intra-specific competition.

Age structure

Presence of chicks/juveniles and maintenance of almost similar juvenile: female ratios in the populations of both the species suggest that these species are breeding, and the two species were not significantly different in their recruitment potentials. Absence of sub-adults of grey francolin in two stands having irrigated plantation, and those of black francolin in two stands with thorn forest plantation reflects adaptation of grey francolin to more arid conditions compared to black francolin which is adapted to thicker swamp vegetation. This also suggests wider ecological amplitude for habitat of non-breeding population compared to breeding population in both these species. Adoption to narrow range of tolerance during breeding season has been generally suggested for all living species (Odum, 1971).

Sex structure

Skewed in favour of males, as suggested for the populations of these francolin species, appears in many other phasianid populations (Islam and Crawford, 1993; Donald, 2007), especially in medium-sized phasianids (Djibouti Francolin, *Francolinus ochropechus*, 67 males : 6-10 females, Bealey *et al.*, 2006; Grey partridge, *Perdix perdix*, 19 males : 5 females, Novoa *et al.*, 2002). No explanation is available to explain such a sex biased skewness. Higher possible genomic mortality of heterogametic (ZW) females compared with homogametic males (ZZ) allows the males of these species to offer sacrifice to save the females, which has the responsibility of rearing the brood. This has a special value for species survival compensating the earlier loss of females.

Dispersion

Dispersion pattern has a value in species survival. Uniform dispersion decreases intraspecific competition and group protection to biotic/abiotic environment hazards (Odum, 1994). Black francolin, surviving under thicker vegetative cover can find protection of thicker vegetative cover is exposed to lower level of environmental hazards and hence is prone towards more uniform dispersion, as compared with grey francolin, which survives in habitat having a low vegetative cover and hence requiring more of group protection.

Dispersion also varies with the season. Black francolin exhibited an almost uniform dispersion during the winter (December and January) and an almost random dispersion during July (dispersion index 0.88). A similar pattern was also exhibited in grey francolin and a tendency of having a slightly clumped dispersion appeared during August and a complete uniform dispersion appearing during winter (December = 0.10, January = 0.12). The breeding activities, pair bonds and development of family groups during summer are collectively responsible for the increased size of covey and a reduced level of uniform distribution.

Both black and grey francolins shared a common character of showing trend of a more uniform dispersion during low rainfall years (drought, black = 0.45 ± 0.05, grey = 0.54 ± 0.04; moderate precipitation; black = 0.57 ± 0.06; grey = 0.38 ± 0.04) as compared with the years receiving higher precipitation (black = 0.70 ± 0.05, grey = 0.78 ± 0.06). Grey francolin even exhibited a slightly random dispersion during some of the high rainfall years. The tendency of having a higher degree of aggregation during the years of higher rainfall can be expected as higher availability of the food with increasing rainfall lowers the interspecific or intraspecific competition for food and shelter. The increased aggregation may also be a character of a higher population levels especially when food and shelter are not acting as limiting factor and population remains below the carrying capacity of the habitat.

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