Home range size, habitat use and nesting success of Swamp Francolin *Francolinus gularis* on agricultural land in northern India

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Summary

Swamp Francolin *Francolinus gularis* is considered Vulnerable to extinction as its native grassland habitat is converted to agricultural land. However, there are virtually no life history data available to allow the impact of these changes on the species to be assessed. Thirteen birds were radio-tracked during the breeding season on agricultural land near Dudwa National Park in Uttar Pradesh, northern India. The study area was dominated by sugar-cane fields, but also contained other crops and natural wet grassland. Home range size varied from 273 m² to 2,687 m² and was significantly correlated with tracking duration. We did not detect significant patterns in overall use of habitats at either the home-range level ($P = 0.14$) or at the radio-location level ($P = 0.13$). However, some individual habitats appeared to be used in proportions that differed from random expectations. At the home range level, birds appeared to favour tall sugar-cane and grassland whilst at the individual location level, grassland and wet areas were most used. Radio-tagged birds made six nests, of which only two hatched young. One was in an old sugar-cane field and the other on grassland. Although we did not detect statistical significance, we believe that developing an appropriate management regime for this species is so urgent that the results are sufficient to manage adaptively the species' habitat at least on an experimental scale. These data suggest that a matrix of habitats, including agricultural land, can supply the necessary components to satisfy the various requirements of Swamp Francolin. However, some natural grassland habitat associated with wet areas appears to be critical. The crucial challenge is to make sure that agricultural landscapes have these habitats present in the right proportions and spatial arrangements to support viable populations of Swamp Francolin.

Introduction

Swamp Francolin *Francolinus gularis* is considered Vulnerable to extinction because of drainage and conversion to agriculture of its wet grassland habitat in northern India (McGowan *et al.* 1995, BirdLife International 2000, Fuller *et al.* 2000, Hilton-Taylor, 2000). Its distribution is limited to the low-lying *terai* belt that lies between the Himalayan foothills to the north and the Indo-Gangetic plains to the south (Ali and Ripley 1983). This belt runs along the Indo-Nepalese border eastwards to the north-east Indian state of Assam and is characterized by

Sal *Shorea robusta* forests and large expanses of wet grassland (see Anon. 1990 and Rahmani *et al.* 1991 for further information on the vegetation of the *terai*). Much of the forest in the *terai* has now been felled and the grasslands are being replaced with sugar-cane fields.

Swamp Francolin typically inhabits swampy areas around seasonal marshes (*taals*), which lie in the flood-plains of major rivers. It is not known how the species is faring in this much-changed landscape, but it is assumed that its habitat has become reduced and fragmented. Despite this, recent surveys have identified populations in both India (McGowan *et al.* 1996, Javed *et al.* 1999) and Nepal (Dahal 2001, Shakya *et al.* 2001, see also Kalsi *et al.* 2001). A particular concern is whether this species is able to survive in the now extensive sugar-cane fields that surround the marshy areas that they still inhabit. If the species can use these fields and breed successfully, then its chances of survival may be far better than is currently thought. If, however, they cannot, then there should be considerable cause for concern, as sugar-cane farming is continuing to dominate much of this region. The sugar-cane is harvested during the Swamp Francolin's breeding season, adding further uncertainty to its value for the species.

As there is no reliable information upon which to predict the likely survival of increasingly isolated Swamp Francolin populations, we set out to determine the size of individual home ranges and habitat use during the breeding period, as well as nesting success.

Study area

The study was conducted around Ghola Taal (i.e. marsh), which lies just outside Dudwa National Park in Uttar Pradesh, northern India (Figure 1). Specifically, land lying along the southern and south-eastern edges of the *taal*, closest to the village was used (see McGowan *et al.* 1996). The *taal* had limited open water, which was surrounded by marshy vegetation, grassland and fields of sugar-cane and other crops, such as pulses, mustard, rice and vegetables. The area is inundated for four to five months during and after the monsoon each year. Seven habitat categories were used in this study:

i), ii) *Sugar-cane* covers much of the study area, mostly as tall crops (3 m or more), which were mature and ready for harvest, but also as younger crops including recently planted stems. To allow for this considerable variation, two size classes were used: ''short'' (less than 150 cm tall) and ''tall'' (greater than 150 cm tall).

iii) *Old sugar-cane* fields were those that had previously been used for growing this crop but were not currently in use. They were dominated by stems of uncultivated sugar-cane and wet grasses such as *Phragmites karka*, *Arundo donax* and *Saccharum* spp. Typically this vegetation reached 100–200 cm in height.

iv) *Other crops* that were cultivated included pulses, mustard, rice and vegetables.

v) *Seasonal waterbodies* were present either as standing water (e.g. in open areas of the taal itself), or in channels and streams.

vi) *Marshes* next to these waterbodies were characterized by the sedges *Typha angustifolia* and *Cyperus rotundus*.
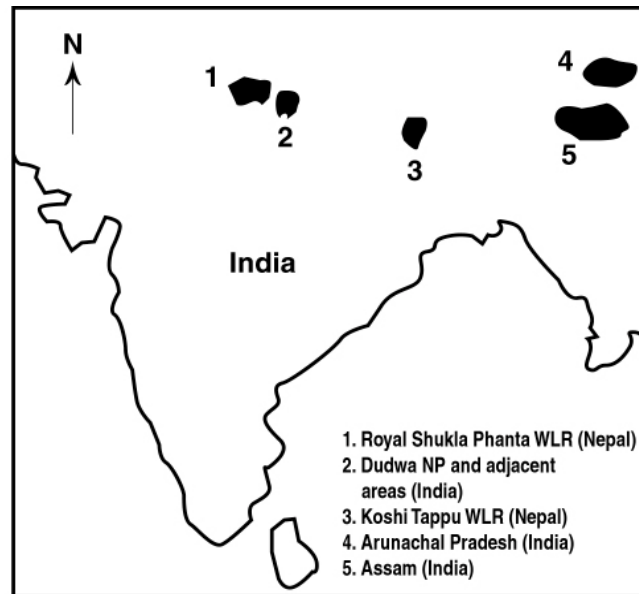
Figure 1. Known distribution of Swamp Francolin in northern India and southern Nepal. The location of Dudwa National Park is shown (from Kalsi *et al.* 2001).

vii) *Grassland* areas around the taal were dominated by *Saccharum spontaneum*, which was 100–300 cm tall. Other grass species present included *Saccharum munja*, *Phragmites karka*, *Arundo donax* and *Vetiveria zizaniodes*.

Much of the native grassland habitat in this area has been converted to sugar-cane agriculture. During the study, 42% of the study area was covered in tall sugar-cane, old sugar-cane made up 19% of the area, and short sugar-cane comprised 4% of the area. However, these are rather ephemeral habitats and changed in availability during the study (February–June) as tall sugar-cane was harvested and replaced with short stems planted to produce the following year's crop. Grasslands comprised 22% of the study area; seasonal water, marshes and other crops each covered 4% (see Figure 2).

Methods

There are practical difficulties in assessing Swamp Francolin's response to land-use change. These include its secretive nature and the tall dense grassland that it inhabits, both of which make the species difficult to detect. Furthermore, its natural habitat is now mostly confined to protected areas that include tiger *Panthera tigris* and/or rhinoceros *Rhinoceros unicornis* and so moving about on foot can be unwise. McGowan *et al.* (1996) found that dawn and dusk call counts detected more birds at a site than visits at other times of the day and they identified a site where an intensive study of habitat use on agricultural land was practical. In order to study habitat use in detail, however, the movements of individuals must be sampled without disturbing them and this requires the
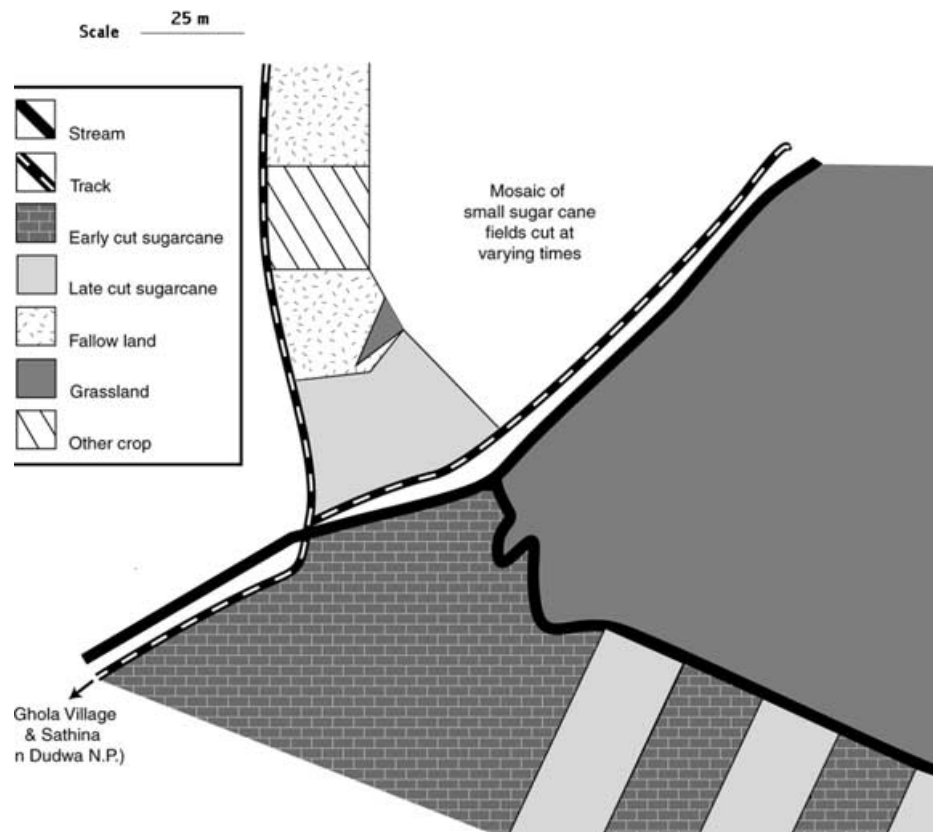
Figure 2. Sketch of study area and habitats in Ghola Taal outside Dudwa National Park, Uttar Pradesh, India.

attachment of radio-tags and subsequent tracking. The boundaries of the study area were defined by the radio-tagged birds.

Trapping and radio-tracking

Birds were trapped between February and early April 1998 by driving them into mist-nets. A line of mist-nets was erected at one end of a sugar-cane field that was then driven from the other end. This was done slowly along most of the length of the field and rapidly towards the end so that any birds would be flushed into the nets. Each trapped individual was fitted with a necklace transmitter that weighed less than 2% of body weight.

Tagged birds were located once each day from the date of capture until the onset of the monsoon on 25 June or until loss or death. Individuals were located at randomly selected times each day between 06h00 and 21h00. Their positions were located by triangulating from at least three points that were marked on a map of the study area. Transmitter ranges were typically less than 250 m, and

so birds were routinely approached very closely so that each location could be reliably assigned to a patch of habitat. Triangulation errors were therefore small. Minimum convex polygon ranges were then calculated for each tagged bird.

Habitat use

A habitat map of the area used by all of the radio-tagged birds was prepared by plotting the size and shape of each field and patch of natural vegetation. Compositional analysis was used to compare the birds' use of the habitats present with their availability. This technique assesses whether habitats are used in the same proportions as they occur. The analysis was done at two levels (Aebischer *et al.* 1993). First the proportion of each habitat in the study area was compared with that found in the convex polygon home range of each radio-tagged individual. Second, the proportion of each habitat within each home range was compared with the proportion of radio-locations in that habitat. Mac-Comp 0.90 (J.P. Carroll unpubl. package) was used to determine use of all habitats simultaneously using multivariate analysis of variance (MANOVA). Paired comparisons of all habitats were then carried out using *t*-tests to obtain a ranking matrix (Aebischer *et al.* 1993). These were then used to generate a rank order that described how the habitats were used compared with their availability.

Nesting

For any radio-tagged pair that built a nest, the habitat in which it was located was recorded. Clutch size was also noted and nest success monitored. Specific attempts were made to encounter broods so that the number of chicks could be counted. This was done by waiting for chicks to emerge into open areas when radio-tracking indicated that birds were in or near habitats where sightings would be possible.

Results

Thirteen birds in adult plumage were radio-tagged. One female was predated within three days and so was not used in any analyses. Of the remaining 12, five were males and seven were females and they were tracked for between 36 and 130 days (Table 1). Two further females were lost during radio-tracking (see Table 3), leaving 10 birds tracked from capture until the onset of the monsoon.

Home range size

Range size was significantly correlated with duration of radio-tracking ($r = 0.727$, $P = 0.008$; Figure 3). There was no significant difference in the number of days tracked between males and females (Mann–Whitney $U = 10.0$, $P = 0.22$). Mean range size was 1,050 m^2 ($n = 12$, SE = 209.88). Male home ranges ($n = 5$, mean = 1,396 m^2, SE = 418.13) averaged larger than female's ($n = 7$, mean = 822 m^2, SE = 185.51; Table 1), although this difference was not significant (Mann–Whitney $U = 10.5$, $P = 0.26$).

It is striking that the mean range size is very small indeed and comparison of

Table 1. Home range sizes of radio-tagged Swamp Francolins in Ghola Taal, near Dudwa National Park, northern India.

	Male				Female		
Bird	Date trapped	Days tracked	Home range (m²)	Bird	Date trapped	Days tracked	Home range (m²)
M1	13 Feb	130	604	F1*	13 Feb	130	1,634
M2*	4 Mar	106	2,024	F2	9 Apr	73	852
M3	9 Apr	73	852	F3	7 Apr	75	828
M4*	21 Feb	63	679	F4	26 Mar	88	1,272
M5	13 Feb	127	2,687	F5*	20 Feb	49	460
				F6	30 Mar	36	273
				F7	8 Apr	39	436

* Denotes non-nesting birds. M3 and F2 formed a pair and were trapped at the same time, and M5 and F7 also formed a pair but were trapped at different times. The success or reason for failure of nesting birds is given in Table 3. As one location was taken each day for each radio-tagged bird, the number of days also corresponds to the number of radio-locations used in the analysis.
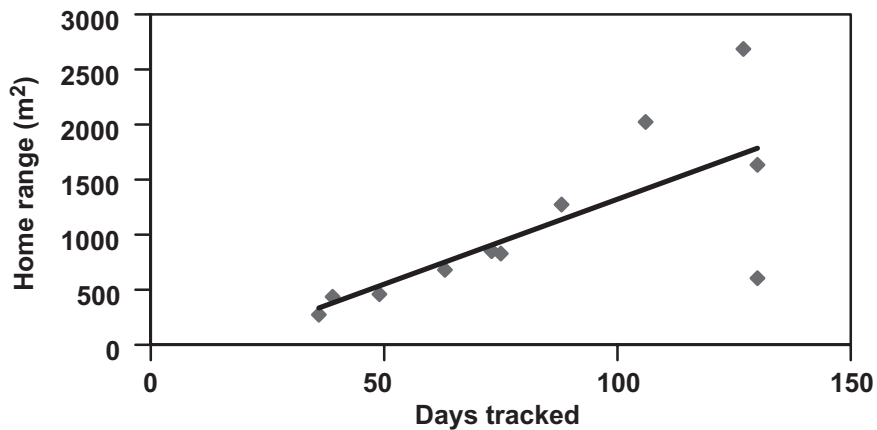

Figure 3. Correlation ($r = 0.727$, $P = 0.008$) between home range size and number of days tracked for 12 radio-tagged Swamp Francolin. One pair (M3 and F2) moved together throughout the study and thus used the same area (see Table 1).

Tables 1 and 3 indicate that nesting may influence home range size. The two smallest range sizes were those of females that were killed on the nest (F6 and F7). In contrast the four largest range sizes were birds that either were not taking part in nesting or which were disturbed during nesting (M2, M5, F1 and F4). For example, M5 was paired with F7, which was trapped on the nest by poachers. The female's range size was amongst the smallest recorded and the male's was the largest.

Habitat use

Our radio-telemetry data on habitat use failed to detect significant patterns in the overall use and availability of habitats at both the study area–home range

level (Wilks' $\lambda = 0.22$, $P = 0.14$) and the home range–individual location level ($\lambda = 0.25$, $P = 0.13$). Inspection of the matrices did, however, reveal some significant relationships at both levels (Table 2A, B). At the study area–home range level, there was a significant preference for tall sugar-cane when compared with both marsh areas and short sugar-cane and the preference for tall sugar-cane over waterbodies approached formal significance ($P = 0.068$). At the home range–individual location level, however, grassland was preferred significantly over both tall sugar-cane and other crops.

Overall, both tall sugar-cane and grassland appeared to be the most favoured habitats at the study area–home range level (i.e. rank values of 1 and 2 in Table 2A), with waterbodies and marsh least favoured (i.e. rank values of 6 and 7 in Table 2A). At the home range–radio-location level seasonal waterbodies and grassland appeared to be most favoured (i.e. rank values of 1 and 2 in Table 2B) and marsh and short sugar-cane the least preferred (i.e. rank values of 6 and 7 in Table 2B).

Nesting success

Eight of the 12 radio-tagged birds took part in breeding in six pairs (Table 3) and all six nests were found. Mean clutch size was 5.4 (range 4–7; $n = 5$), and only two pairs completed incubation successfully. One nest was made in a sugar-cane field and was lost when the cane was harvested. Two other nesting females were caught, one by a village dog and one by poachers (Table 3).

Discussion

The range sizes recorded during this study were remarkably small. Birds involved in nesting and the early stages of chick-rearing appeared to range over a very limited area. In contrast, the largest range sizes observed, which were still small compared with other Galliformes, were those individuals that had either not attempted nesting, or whose attempts had been disturbed. The relationship between the number of days that a bird was radio-tagged and its range size, would, therefore, seem likely to be a consequence of birds moving further once nesting was completed. It is probable, therefore, that this range size would continue to increase for nesting birds. It is less clear whether the range size of non-nesting birds, or those individuals that had their nesting disrupted would continue to increase.

During the calling and nesting period, Swamp Francolins that were radio-tracked in this study appeared to be using some habitats in different proportions to those in which they were available. However, the relationships were not significant. This may have been due to at least four factors. First, the sample size here was small, so that only the largest of differences would have been detected and any more subtle effects would not be shown. There was considerable variation among individuals in the use of habitats and so it is all the more difficult to detect anything other than large differences within our small sample size. Second, the overall study area was defined by the radio-tagged birds. Therefore comparisons of habitat proportions at the study area–home range level were conservative because areas containing no birds (and probably poorer habitat) would not have

Table 2. Matrix of the proportions of habitat available in the study area compared with those present in Swamp Francolin home ranges (A) and home range proportions compared to radio-locations (B) at Ghola Taal, near Dudwa National Park, northern India.

		Tall sugar-cane	Grass-land	Old sugar-cane	Water-bodies	Marsh	Short sugar-cane	Other
A								
Tall sugar-cane	x		(n.s.)	(n.s.)	(n.s.)	−1.7451	−1.9328	(n.s.)
	SE					0.5854	0.7405	
	P					0.0200	0.0380	
Grassland	x	(n.s.)		(n.s.)	(n.s.)	(n.s.)	(n.s.)	(n.s.)
	SE							
	P							
Old sugar-cane	x	(n.s.)	(n.s.)		(n.s.)	(n.s.)	(n.s.)	(n.s.)
	SE							
	P							
Waterbodies	x	(n.s.)	(n.s.)	(n.s.)		(n.s.)	(n.s.)	(n.s.)
	SE							
	P							
Marsh	x	1.7451	(n.s.)	(n.s.)	(n.s.)		(n.s.)	(n.s.)
	SE	0.5854						
	P	0.0200						
Short sugar-cane	x	1.9328	(n.s.)	(n.s.)	(n.s.)	(n.s.)		(n.s.)
	SE	0.7405						
	P	0.0380						
Other	x	(n.s.)	(n.s.)	(n.s.)	(n.s.)	(n.s.)	(n.s.)	
	SE							
	P							
Rank		1	2	4	6	7	5	3
B								
Tall sugar-cane	x		0.8745	(n.s.)	(n.s.)	(n.s.)	(n.s.)	(n.s.)
	SE		0.3722					
	P		0.0400					
Grassland	x	−0.8745		(n.s.)	(n.s.)	(n.s.)	(n.s.)	−3.2948
	SE	0.3722						1.1477
	P	0.0400						0.0480
Old sugar-cane	x	(n.s.)	(n.s.)		(n.s.)	(n.s.)	(n.s.)	(n.s.)
	SE							
	P							
Waterbodies	x	(n.s.)	(n.s.)	(n.s.)		(n.s.)	(n.s.)	(n.s.)
	SE							
	P							
Marsh	x	(n.s.)	(n.s.)	(n.s.)	(n.s.)		(n.s.)	(n.s.)
	SE							
	P							
Short sugar-cane	x	(n.s.)	(n.s.)	(n.s.)	(n.s.)	(n.s.)		(n.s.)
	SE							
	P							
Other	x	(n.s.)	3.2948	(n.s.)	(n.s.)	(n.s.)	(n.s.)	
	SE		1.1477					
	P		0.0480					
Rank		4	2	3	1	6	7	5

x, mean logratio differences (negative means indicate that the row habitat was used more than the column habitat and a positive value indicates the opposite); SE, standard error; *P*, probability that differences are obtained by random chance.

Table 3. Nesting habitat and breeding success of radio-tagged Swamp Francolins at Ghola Taal near Dudwa National Park in northern India.

Male	Female	Habitat	Clutch size	No. hatched	Reason for failure*
M5	F7	Grassland	7	0	Female trapped by poachers
M3	F2	Old sugar-cane	5	5	–
Untagged	F4	Tall sugar-cane	5	0	Field harvested during incubation and eggs taken
Untagged	F3	Old sugar-cane	4	0	Unknown, presumably natural as incubation was completed
Untagged	F6	Old sugar-cane	6	0	Female preyed upon by village dog
M1	Untagged	Grassland	Not known	4	–

* Unless noted, all birds survived until the end of tracking on 25 June when the monsoon broke.

been included in this analysis. Third, there may have been no real difference in habitat use, with birds using the habitats in the proportions that they were available, and our results were simply chance. Fourth, the harvesting of sugar-cane during the study period may have masked any preference, especially in the change from tall sugar-cane, which appeared to be an important habitat, to short sugar-cane, which was not.

This last reason is an important consideration as it indicates that our results were conservative: i.e. the harvesting made it difficult to accurately track quantifiable changes in habitat availability and thus detect significant differences in habitat preference. We suggest, however, that there were trends at both levels, which, when combined with our information on nest sites and success, indicated that some habitats were more important than others to Swamp Francolin during the breeding season. At the study area–home range level, home ranges tended to be sited in tall sugar-cane and grassland rather than in the other habitats. The proportion of these in individual home ranges varied considerably, and may suggest that not all home ranges were of equal quality, with better home ranges containing more of a preferred habitat (tall sugar-cane and grassland). Other habitats were less preferred.

At the home range–individual location level, birds tended to associate with seasonal waterbodies and grassland probably because these habitats usually occurred together. Although marshes also tended to be associated with waterbodies and grassland it might be that we were seeing greater use of tall vegetation at the end of the dry season when the waterbodies contained no water. Tall sugar-cane and disused sugar-cane fields may also have been important.

Much of the study area was covered in tall sugar-cane that was harvested by the local farmers during the study period and so became less available to the birds than it was at the start of radio-tracking. This seems likely to have influenced the birds' use of habitats within their home ranges: the proportions of tall sugar-cane in each home range would have decreased and that of short sugar-cane increased as the study progressed. This would have led to the replacement of a habitat that was important to Swamp Francolin with one that was used much less, and this trend increased as the breeding season progressed.

These results suggest that tall sugar-cane and grassland may be important habitats for Swamp Francolin and their presence is necessary in this part of the *terai*. However, only one of six nests was located in currently used sugar-cane fields (comprising < 40% of the study area), suggesting that whilst tall sugar-cane is extensively used by Swamp Francolin, it does not appear to be used much for nesting and we speculate, therefore, that its benefit to recruitment into the population would be limited to use for chick-rearing cover, if at all. Although unused sugar-cane fields comprised only 20% of the study area, three of the six nests were found in this habitat. Altogether, this indicates that unused sugar-cane fields close to currently used sugar-cane fields may be important for Swamp Francolin. Therefore, a matrix of habitats, including tall crop fields and native grassland, is likely to be necessary during the breeding season.

The study period covered four-and-a-half months and it took nearly two months to trap 12 birds. Given the variability between individuals in habitat use, our results indicate that larger sample sizes may be required to describe fully habitat use during this period. Therefore, it was not possible to subdivide the study period into shorter periods that would allow habitat use and availability to be quantified on a finer time scale.

Although we have not detected statistically unequivocal evidence of an overall selection of some habitat types, we believe that there is sufficient indication that some habitats are being preferred to justify using these results to initiate a planned programme of adaptive management (see Walters 1986, Salafsky *et al.* 2001). Adaptive management is simply the incorporation of research into conservation action such that design, management and monitoring is used to test systematically assumptions in order to adapt and learn (Salafsky *et al.* 2001). This is appropriate in this case, because we urgently need to find out which habitat management regimes are most likely to ensure that individual, isolated Swamp Francolin populations do not become extinct. The results suggest that this process should start by ensuring that patches of tall native grassland remain within the sugar-cane matrix. Farmers could be encouraged to leave patches of native grassland between sugar-cane fields. Leaving some sugar-cane fields out of production periodically would add further nesting cover to the habitat mosaic on agricultural land.

The results from habitat analysis at two levels, and the siting of nests, indicated that the habitats present were used for different activities. Therefore, there is a need to ensure that the habitats are available in suitable proportions and are arranged appropriately with respect to each other and at a spatial scale appropriate to the range sizes of individuals. For example, whilst tall sugar-cane fields may be important, the evidence presented here suggests that they are unlikely to support successful nests. Add to this the dynamism of habitat availability as the sugar-cane is harvested and there is clearly a challenge to ensure that the matrix present at any time meets all of the needs of Swamp Francolin.

There is clearly a need to understand the dynamics of Swamp Francolin populations in both agricultural land and natural habitats. This will determine the extent to which man-made habitats are adequate or necessary for some parts of the Swamp Francolin's life history, or will indicate that they are simply a sink for populations from natural habitats. In Ghola Taal, the wet grasslands in adjacent areas of Dudwa National Park could be the sources for such birds.

Acknowledgements

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