The hatching success of ground- and roof-nesting Red-wattled Lapwing *Vanellus indicus* in Haridwar, India

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We studied hatching success of Red-wattled Lapwing *Vanellus indicus* in ground- and roof-nests during 2006–07 in rural and suburban habitats of district Haridwar (29°55′N 78°08′E), Uttarakhand state, India. The mean number of eggs that hatched successfully per nest in roof-nests (2.2±1.2) was significantly higher than in the ground-nests (1.0±1.5). This was because the number of egg losses in roof-nests was significantly lower than in ground-nests, not because of a difference in clutch size between nest-types. Hatching success as computed by the Mayfield method was 0.30 (n = 70) and 0.67 (n = 25) in ground- and roof-nests respectively. Different factors, namely predation, nest damage and hatching failure, were responsible for egg loss in both nest-types. However, egg loss due to predation was significantly higher in ground-nests (59.21%) than those on the roofs (15.38%). In spite of common threats operating on both nest-types, results clearly revealed that roof-nests had more successful hatch-rates than ground-nests.

INTRODUCTION

The Red-wattled Lapwing *Vanellus indicus* is currently classified as Least Concern according to the IUCN Red List (Birdlife International 2009) and is a common and widespread wading bird of the Indian Subcontinent. The species, in common with other Charadriidae, lays 3–4 eggs on the ground, in a small natural depression or scrape. Typical nesting habitat includes open country, grazing land, fallow fields, dry beds of village tanks, and islets in rivers (Ali & Ripley 1998). The incubation period ranges from 28 to 30 days and both sexes perform incubation duties (Desai & Malhotra 1976, Ali & Ripley 1998). Eggs are lost to an array of predators (e.g. mongooses, crows, kites, dogs), to human activities (e.g. ploughing) and to trampling by grazing animals (Naik *et al.* 1961). Desai & Malhotra (1976) studied the nesting success of ground-nesting Red-wattled Lapwing and observed that out of 74 eggs laid 39 (52.70%) hatched successfully, and ultimately 30 young fledged, leading to an overall nesting success of 40.54%.

Additionally, this species has occasionally been observed to nest on flat pebbled roofs in urban environments (Gole & Mundkur 1980, Patnaik 1980, Tehsin & Lokhandwala 1982, Mundkur 1985, Grimmett *et al.* 1998). Roof-nesting has been observed in a number of ground-nesting avian species in other parts of the world such as the United States, Canada and South Africa (Goodnight 1957, Fisk 1978, Blokpoel & Smith 1988, Gore & Kinnison 1991, Dwyer *et al.* 1996, Crawford & Dyer 2000). In some countries populations of roof-nesting birds (e.g. terns and gulls) have significantly increased or even outnumbered those on the ground (Ludwig 1974, Hovis & Robson 1989, Vermeer 1992). Use of flat roofs for nesting has been suggested as an adaptive response of ground-nesting birds to the loss of traditional nest sites and habitats subjected to rapid urbanisation (Fisk 1978, Toland 1992, Baumann 2006). Additionally, roofs have been suggested to be more protected from humans, most mammalian predators and grazing animals when compared to open ground (Douglass *et al.* 2001).

Loss of natural habitat has been suggested as a possible reason for roof-nesting by Red-wattled Lapwing (Mundkur 1985). However, no studies have so far been conducted to ascertain the reasons causing such a shift in the species's nesting habitat. This paper aims to study productivity of roof-nests of Red-wattled Lapwing relative to those on the ground through comparing hatching success between nest-types.

MATERIALS AND METHODS

The study was undertaken in April–June 2006 and 2007, which coincides with the peak breeding season of the Red-wattled Lapwing. Observations were made using 10×50 binoculars and field scope (75×) in rural and urban habitats of district Haridwar (29°55′N 78°08′E), Uttarakhand state, India.

Ground-nests were located by noting typical breeding behaviour such as nest building, incubating birds or alarm calling. Roof-nests were searched for by climbing to a vantage point and scanning the roofs of nearby buildings. Field observations reveal that Red-wattled Lapwings are generally not present on roofs outside the breeding season. Thus, frequent sightings of bird(s) on a building during the breeding period were suggestive of the presence of a breeding pair there.

Most observations were made during midday hours when, due to high temperatures, nests were never left unattended and at least one of the birds was incubating. Searches for nests were done systematically and we were equally likely to find nests regardless of location, i.e. all parts of the study area were searched thoroughly and repeatedly during the breeding season. The incubation period of Red-wattled Lapwing lasts 28–30 days (Desai & Malhotra 1976, Ali & Ripley 1998). Thus, nests found prior to clutch completion were inspected every 2–5 days followed by more frequent visits during the expected date of hatching. Nests found after clutch completion were nearly always inspected on alternate days. In addition, local inhabitants such as children, farmers and building owners were regularly quizzed regarding the occurrence of nest(s) of Red-wattled Lapwing on their premises or in nearby areas.

To relocate nests quickly and reduce the chance of attracting predators (see Salek & Smilauer 2002), nests were marked by a stone placed on a brick within 1.5 m. To minimise disturbance we did not spend more than 10 seconds near the nest during inspection. When a nest was found empty, the contents were carefully scrutinised and recorded. Nests were recorded as successful when at least one of the following criteria was apparent: small fragments of eggshell were present in the nest lining; at least one chick was seen; behaviour of the adults indicated presence of a brood. A nest was classed as successful if at least one egg hatched. A nest was assumed to have failed if it was found to be empty before the expected hatch date (and did not comply with the above criteria), or if there was evidence of predation (i.e. large egg fragments, disturbed nest lining, etc.) (Galbraith 1988).

During each visit, nests, eggs and chicks were counted and sorted by nest-type (ground or roof). In a number of nests, asynchronous hatching was observed, i.e. all eggs did not hatch simultaneously and it took 20–43 hours until the complete clutch hatched. In those nests, the young started moving out of nests within a couple of hours and concealed themselves in nearby vegetative cover. Such nests were observed at either midday or dawn because parents were always observed sitting over the eggs and young during these periods. Along with two local inhabitants, we observed individual nests for longer continuous periods (up to four hours) from a hide or vehicle in order to spot fleeing chicks, and we searched vegetation for hiding chicks. Roofs provided less cover for chicks than ground sites, thus offering better opportunities to locate the chicks. In both nest-types we observed most chicks before they left the nest.

Hatching success was calculated with the Mayfield method (Mayfield 1975) as well as with the traditional method (% of eggs that hatched successfully out of total eggs laid). Numbers of eggs and chicks that hatched in ground- and roof-nests were compared using two-tailed t-test (Zar 1984). The mean values were presented with the standard deviation (±SD).

RESULTS

A total of 40 (29 on ground and 11 on roof) and 55 (41 on ground and 14 on roof) nests of Red-wattled Lapwing were found in 2006 and 2007 respectively. In both nest-types (ground and roof) the clutch size and mean number of eggs hatched per nest did not differ significantly between years and thus the data from both years were pooled (Table 1). Average clutch sizes for ground- and roof-nests were nearly identical (3.6±0.6 SD and 3.6±0.4 SD respectively; t-test: $t = 0.02$, $df = 59$, $P = 0.982$).

Using the Mayfield method, the mortality rate for the incubation period of Red-wattled Lapwing was 0.039 (45 failures/1,134 nest-days) and 0.013 (5 failures/374.5 nest-days) failures per nest-day for ground- and roof-nests respectively. The probability of survival was 0.961 (1-0.039) and 0.987 (1-0.013) per nest-day for ground- and roof-nests respectively. Hence, with an incubation period of 30 days, the probability of survival of a nest with young was 0.30 (0.961^{30}) and 0.67 (0.987^{30}) for ground- and roof-nests respectively. The mean number of eggs that hatched successfully in roof-nests was significantly greater than those from ground-nests (2.2±1.2 and 1.0±1.5 respectively; $t = 3.95$, $df = 50$, $P = 0.0002$).

On comparing the hatching success between nest-types with the traditional method, the proportion of eggs that hatched in roof-nests (62.6%) was higher than in ground-nests (28.6%) (Table 2). Loss of eggs was greater in ground-nests (71.3%) than those on the roofs (37.3%). Different factors, namely predation, nest damage and hatching failure, affected hatching success in both the nest-types, but with different loss rate in each group (Table 2). Only 15.3% of roof-nest eggs were predated compared to 59.2% of ground-nest eggs. Roof-nests may primarily have been predated by aerial predators, ground-nests by both terrestrial and aerial predators. Grazing animals caused nest damage in ground-nests leading to a 9.8% loss of eggs, whereas roof-nests were damaged mostly by intentional and unintentional human interference during building construction, renovation or cleaning, resulting in an egg loss of 19.7%. Individual eggs remained unhatched in both nest-types. Loss of eggs due to hatching failure was almost equal in ground- (2.3%) and roof-nests (2.1%).

DISCUSSION

Nest survival and hatching success of Red-wattled Lapwings were higher on roofs than in typical habitat on the ground. The main difference in hatching success between nest-types was mainly due to higher predation rate on the ground than on roofs. Those nests on the ground were susceptible to a greater array of predators such as domestic dogs, pigs, snake, mongoose, House Crow *Corvus splendens*, Jungle Crow *C. macrorhynchos*, Greater Coucal *Centropus sinensis*, Black Kite *Milvus migrans* and Shikra *Accipiter badius*, whereas nests located on roofs were susceptible to a smaller range of primarily aerial predators such as crows and raptors (no terrestrial predators were noticed on the roofs). Similar differences in nesting success between roof- and ground-nests have been reported in other ground-nesting species (Fisk 1978, Gore & Kinnison 1991). These differences have been partly attributable to the different types of predators that ground- and roof-nests are exposed to (Fisk 1978, Massey & Fancher 1989, Gore & Kinnison 1991).

Apart from predation, ground-nesting Red-wattled Lapwings faced the risk of nest damage by grazing animals. In two instances we witnessed a herd of grazing sheep trampling the eggs of ground-nesting Red-wattled Lapwings. Also, on a number of occasions ground-nesting parents were observed aggressively attacking grazing animals near their nests. Damage to eggs in ground-nests by grazing animals has been reported by other workers also (Beintema & Muskens 1987, Hart *et al.* 2002).

Unlike ground-nests, losses in roof-nests were more frequently caused by human activities (Table 2). Most of the property owners were unaware of the presence of nests of Red-wattled Lapwing on their roofs, and thus nearly all damage to nests occurred unintentionally during the unloading of building material like cement, bricks and wood on the roofs. In two cases, property owners were observed trying to protect nests of Red-wattled Lapwing from direct sunlight by providing artificial shade. In another instance, the property owner relocated the nest (with four eggs and stone pebbles) of a Red-wattled Lapwing 6 m from its original position as it was disturbing construction. It was interesting to note that the

Table 1. Clutch size and average number of eggs hatched in Red-wattled Lapwing *Vanellus indicus* between study years (2006 vs 2007) and nest-types (ground vs roof).

Nest-type	Clutch size [mean±SD] 2006	2007	Number of eggs hatched [mean±SD] 2006	2007
Ground	3.62±0.72 (N = 29)	3.65±0.65 (N = 41)	0.89±1.44 (N = 29)	1.14±1.57 (N = 41)
t-test value	t = 0.22, df = 56, P = 0.824		t = 0.68, df = 63, P = 0.495	
Roof	3.63±0.50 (N = 11)	3.64±0.49 (N = 14)	2.36±1.28 (N = 11)	2.21±1.31 (N = 14)
t-test value	t = 0.03, df = 21, P = 0.974		t = 0.28, df = 22, P = 0.777	

Table 2. Productivity in ground- and roof-nests of Red-wattled Lapwing *Vanellus indicus*.

				Hatching success (%) calculated by		Causes of nest loss (%) due to		
Nest-type	Nests observed	Eggs laid	Eggs hatched	Mayfield method	Traditional method	Predation	Nest damage	Hatching failure
Ground	70	255	73	30.31	28.63	59.21	9.80	2.35
Roof	25	91	57	67.53	62.63	15.38	19.78	2.19

bird initially arranged the stone pebbles and later incubated the eggs in its new position and that all the eggs hatched successfully. Dwyer *et al*. (1996) have reported the loss of 50% roof-nesting colonies of gull species due to human activities, but contrary to our study, they were all subjected to an intentional roof-nesting removal programme.

We observed instances of hatching failure of individual eggs in both nest-types at almost the same rate. Hatching failure due to infertility or embryo mortality is an important cause of reduced breeding success in birds and has commonly been reported for a number of avian species (Gonzalez 1996, Seixas & Mourão 2002).

There are reports indicating that roof-nesting by colonies of ground-nesting birds may cause economic, safety and health problems for the property owners, through (i) noise caused by their calls and footsteps, (ii) mess and fouling caused by their droppings, (iii) blockage of gas flues and gutters by nesting materials, (iv) holding moisture by nesting materials, and (v) diving and swooping on pets and people, etc. (Blokpoel & Scharf 1991, Belant 1993), and various techniques have been trialled to reduce or eliminate these factors (Blokpoel & Tessier 1992). In the present study, however, nesting by Red-wattled Lapwings on roofs did not cause any trouble to property owners because the species does not breed in colonies and in only one instance did we find two active nests on a single roof (area: 230 m^2). Most property owners were merely aware of the presence of Red-wattled Lapwing pairs but not of their nests on their roofs. These observations also suggest that the distribution and extent of roof-nests of Red-wattled Lapwing in our study area is not as great as reported for other ground-nesting birds in other countries.

In spite of common threats operating on both nest-types, it is clear from the results that roof-nests had higher hatching success than ground-nests. The intensity of predation on adult birds and their nests has been presumed to be one of the determining forces for the evolution of avian reproductive strategies (Lack 1968, Ricklefs 1969). It has also been suggested that if prey cannot defend itself against predators there should be selection for predator avoidance adaptations, for instance, concealment of the nest and its contents, nesting at lower densities and breeding in inaccessible sites or in safer habitats (e.g. Lack 1968, Collias & Collias 1984).

It is worth mentioning here that in one of our studies carried out in the same study area, we found the Spotted Munia *Lonchura punctulata* occurring in urban habitat solely during the breeding period and nesting significantly more successfully in this urban habitat than in forest, owing to reduced predation rate on the urban nests (Sharma *et al*. 2004). It could be argued that roof-nesting by Red-wattled Lapwings is also a strategy to increase breeding output by minimising predation pressure. Alternatively, roof-nesting by Red-wattled Lapwing may also be a response in a locally increasing population to loss of traditional habitat and to the abundance of gravel roofs in the study area. Although roof-nesting appears to give Red-wattled Lapwings a selective advantage of higher hatching success, chick survival could be constrained on roofs due to restricted food supply, lack of cover, and falls. Further investigations are needed on ringed individuals over consecutive years to ascertain causes and consequences of roof-nesting.

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