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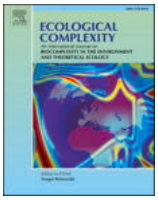

Co-breeding involving herons and a potential egg predator, the Indian House Crow (*Corvus splendens*), in Peninsular India

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ABSTRACT

Association between species may strengthen the fitness of the species involved It is not rare that avian species associate on the breeding and feeding grounds. However, a species associated with a potential egg predator is less common. In this study, a synchronized breeding of Indian House Crow (*Corvus splendens*) and breeding Indian Pond Herons (*Ardeola grayii*) in urban conditions is reported. Both the crow abundance and the crow nest abundance increased with the number of heronry nests on sites. Crows were mostly observed when flying over or when resting nearby, but they also attempted egg predation from heronry nests. Crows also used the heronry sites for collecting nesting resources, such as twigs, scavenging dead chicks and for stealing the food brought to feed the heronry chicks. A dearth of suitable nesting places and provisions in an urban environment may be the reason why these birds share nesting trees. Vigilant breeding crows, despite their ability to depredate heron nests, may be more beneficial to herons as they are known to mob and distract heron predators, but a full cost-benefit analysis needs to be undertaken.

1. Introduction

In mixed-species foraging flocks, different species of birds may cooperate and select the same habitat for the mutualistic benefits such as improved feeding efficiency or better protection from predators (Sridhar et al., 2009). Similar to mixed-species foraging flocks, there are 'mixed species nesting associations' (Slagsvold 1980; Mönkkönen et al., 1999). Here, the species share same habitat for breeding. Two major hypotheses are put forward to explain mixed-species breeding (Quinn et al., 2003): (1) the predator protection hypothesis (Koskimies 1957) and (2) the similar habitat hypothesis (Orians and Wilson 1964). While the former hypothesis suggests that individuals of one species opt to nest with individuals of another for gaining protection from predators, the latter hypothesis suggests that the species associate because their habitat requirement is the same, although by chance some protection from predators may still be gained (Quinn et al., 2003). Sometimes, the nesting association occurs between a non-aggressive species and an aggressive species (Ueta 1998). Here, the protected species benefits to nest near protective species and often benefit in ways such as egg protection (Quinn and Ueta 2008). Although rare, instances are available for a predator species nesting near to its potential colonial prey species where the prey species is benefitted more than the losses incurred. For instance, Buff-necked Ibis (*Theristicus caudatus*) nests with different raptors as they take advantages of intra and inter specific tolerance of raptors as this benefit will overcome the small amount of loss (chick loss) resulting from a single pair of raptor nesting within the colony (Donázar et al. 1996). Similarly, co-breeding of Common Kestrels (*Falco tinnunculus*) near the colony of Eurasian Curlews (*Numenius arquata*) was reported beneficial for the curlews (Norrdahl et al., 1995). Here, we report a case of the Indian House Crow (*Corvus splendens*; here after crow) where this species preferred to nest near heronries of districts of North Kerala, India in urban ecosystems. We examined the kind of interaction existing between them and tried to portrait the costs and benefits the two species incurred and received through this interaction.

Crows are both solitary and occasional colonial nesters with a colony of two or more nests (Sengupta 1969). Usually the species constructs nests on large, well-branched dense canopy trees close to human settlements and also on man-made structures (Dutta and Raut 2013). Generally, the crow prefers human-influenced habitats due to the availability of larger amounts of anthropogenic food found in these places (Lim and Sodhi 2009). In India, where the regional weather conditions differ from west coast to east coast of southern peninsula, from south to central and north India, the crows are known to breed throughout the year (Akhter et al., 1994). According to Grimmett et al.

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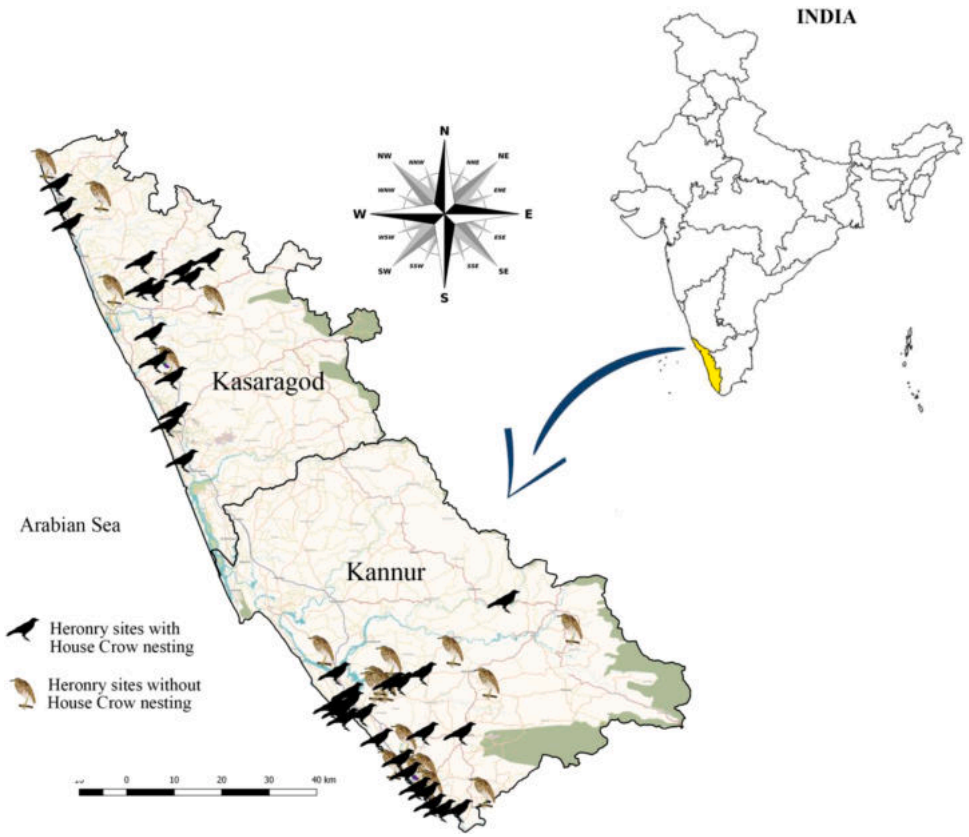

Fig. 1. Map of India (inset) and Northern Malabar part of the state of Kerala showing heronry sites with and without crow nests.

(2016), the breeding season extends from January to September, while Ali and Reply (1972) suggest that peak nesting period varies with local environmental conditions. Nevertheless, it is known that the crow prefers warmer and drier months rather than heavy monsoon months to nest (Ali 1972; Nordin and Yousuf 1980).

In our study, we found some crows nesting during peak rainy months (July-August) along with the heronry birds, which normally nest during wet months in the state of Kerala. Similar to crows, heronry birds are also roosting and breeding on large trees in urban sites (Roshnath and Sinu 2017). Less nest predation and high availability of nesting trees in urban ecosystems are suggested to be the reasons for the heronry birds preferring urban ecosystems for breeding (Ryder et al., 2010; Møller 2012; Roshnath et al., 2019). Thus, crows and heronry birds share the same habitat and there might be a plausible trade-off between them in the urban ecosystem. We specifically asked 1) whether the crow abundance and the crow nest abundance increase with the heronry nest abundance and 2) what are the different activities of crows in the vicinity of heronries. We used this activity chart to discuss the activities that are useful and detrimental for heronries.

2. Material and methods

2.1. Study area

Heronry sites were identified and observed in Kannur and Kasaragod districts of North Kerala (Fig. 1), where 80% of the nest were recorded in urban areas such as roads in urban and rural towns, residential and non-residential areas, and 20% of nests were recorded in mangrove islets. In urban heronries, birds generally nest in avenue trees with average height 9.82±0.16 m, girth at breast height (GBH) 2.09±0.15 m and canopy spread of 22.58±0.06 m (Roshnath and Sinu 2017). While the Little Cormorant (*Microcarbo niger*), Indian Cormorant (*Phalacrocorax fuscicollis*), Little Egret (*Egretta garzetta*), Great Egret (*Ardea alba*), Intermediate Egret (*Ardea intermedia*), Black-crowned Night Heron (*Nycticorax nycticorax*), and Indian Pond Heron (*Ardeola grayii*) share heronries in the mangrove islets, Little Cormorant, Indian Cormorant, Black-Crowned Night Heron, and Indian Pond Heron (here after herons) participate in the heronries of the urban areas.

This study was carried out in the peak breeding period of heronry birds from June to August for three consecutive years from 2015 to 2017 in the Kannur (11° 52′ 8.04″ N, 75° 21′ 19.66″ E) and Kasaragod district (12° 30′ 0″ N, 75° 0′ 0″ E) of north Kerala in peninsular India. This period, coincides with the south-west monsoon in the state of Kerala (July-September). The northern districts of the state (Kasaragod, Kannur, Calicut, Wayanad and Malapuram) receive annual rainfall of the range 1600–2900 mm, and 65% of the annual rainfall in the northern districts happen during the south-west monsoon (Nair et al., 2014).

2.2. Sampling method

In the survey, each heronry was visited and the information on the nesting species, number of nests of each species, number of nesting trees, and species of nesting trees were recorded. Geographical co-ordinates of the location were recorded using Global Positioning System (GPS). In each of our site visits, we recorded the numbers of individuals of crow (abundance), and crow nests (nest abundance) within a 100-m radius of the heronry. We recorded crow abundance (50 heronries) and crow nest counts (38 heronries) on the same day of heronry counts in Kannur-Kasaragod districts during 2015–2017.

To study the activity pattern of crows, we selected two heronry sites (one each in urban and mangrove habitat) and monitored them twice a week from 1 June to 31 August 2016. This yielded a total of 20 observation days. We made observations from 08:00–17:00 hr on heronries to study the behavior of crows. We divided the whole observation time of a day into 15-min blocks with a break of 5 min. During each 15-min observation, we counted the number of crows approaching our focal

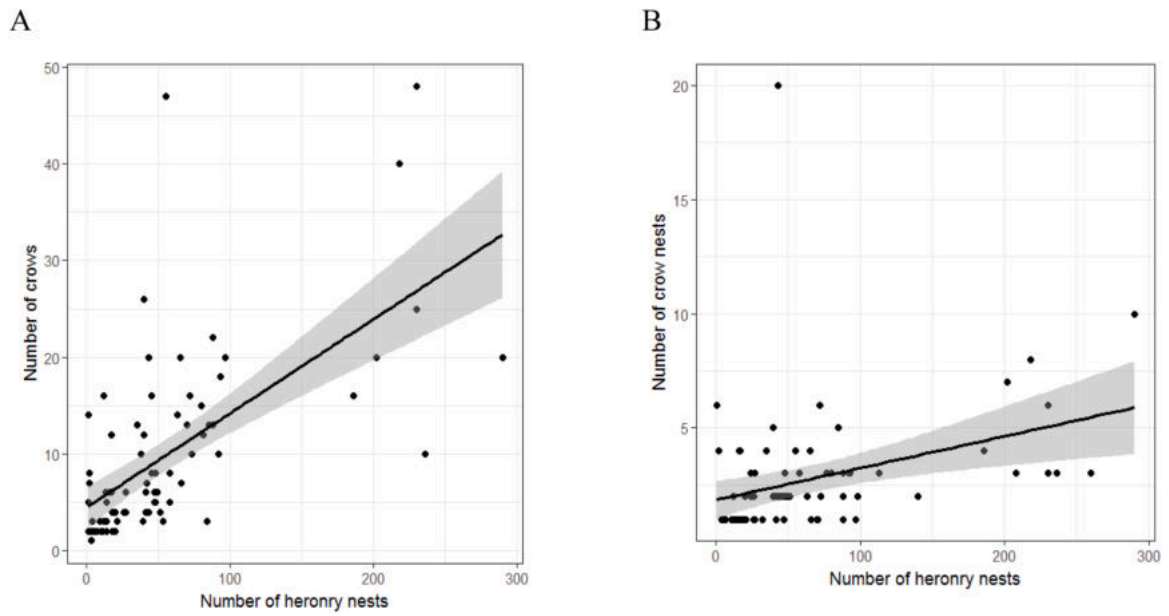

Fig. 2. The crow abundance (GLM: $z = 7.0$, $p<0.0005$ (A)) and crow nest abundance (GLM: $z = 3.6$, $p = 0.0003$ (B)) increase with the heron nest abundance in heronries.

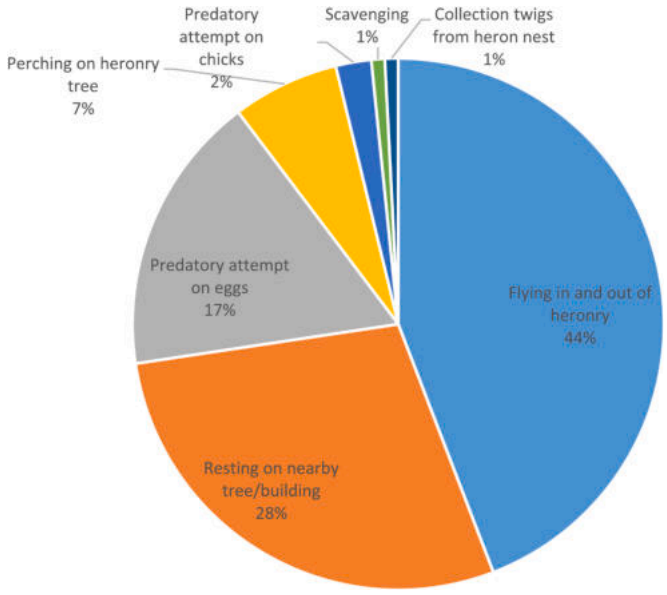

Fig. 3. Percentage composition of different activities showed by crows in the heronries of study area.

heronry site, and recorded specific activities. The activities observed were number of times at which crows were found flying in and out of heronry or patrolling over the heronries, number of incidence where they perched on nearby trees/buildings and on the nesting trees. We also looked for the predatory attempts on eggs and chicks separately. We used 8 × 45 Celestron binoculars to watch Crows and their activity.

2.3. Statistical analysis

We studied the effect of heronry nest abundance on crow abundance and crow nest abundance using two Generalized Linear Models (GLM). In the model, we fitted heronry nest abundance as the predictive variable, crow abundance or crow nest abundance as response variable, and negative binomial distribution as the error type. The proportion of different activities of crows/day was studied using a binomial test for proportions. The number of heronry sites in three years was compared using a χ2-test. Binomial test (prop.test) for contingency tables was used to compare the proportion of heronry sites having crow nests in their vicinity for three years. All analyzes were performed in R version 3.2.3.

3. Results

A total of nine species belonging to two families - Ardeidae (Black-crowned Night Heron, Indian Pond Heron, Little Egrets, Intermediate Egrets, Great Egrets, Purple Heron; *Ardea purpurea*, and Grey Heron; *Ardea cinerea*) and Phalacrocoracidae (Little Cormorant and Indian Cormorant) - were present in the heronries of study area. The number of heronry sites (average $N = 45.3$) was consistent across the three years of study ($\chi^2 = 0.41$, df = 2, $P = 0.8$). 63% of the heronries had crow nests in their close vicinity, however, the number of crow nest-occupied heronries (average $N = 24.6$) was different between the years ($\chi^2 = 11.1$, df = 2, $P = 0.003$). Both the crow abundance (GLM: $z = 7.0$, $p<0.0005$) and the crow nest abundance (GLM: $z = 3.6$, $P = 0.0003$) increased with the number of heronry nests on trees (Fig. 2).

Crows exhibited seven types of activities (Fig.. 3). Flying in and out of the heronry for plausible predation of eggs (44% of total activities) was the major activities of crows followed by either perching on trees/buildings nearby heronries (28%) or on the heronry trees itself (7%). Crows were found attempting to depredate more on eggs (17%) than chicks (2%). Of the total predatory attempts on eggs ($N = 63$), crows were successful in predating 15 eggs. We found crow predation only in heron nests even though other species were present. Crows were also found to scavenge on dead chicks/fallen prey and stealing twigs from heron nests. The daily average number of different activities varied significantly ($\chi^2 = 86.8$, df = 8, $p <0.00005$; Fig. 3).

4. Discussion

Even though the crow nests year round in some parts of India, they prefer hotter months prior to the onset of monsoon in peninsular India (Ali 1972; Nordin and Yousuf 1980). Our observations in heronry sites found nests of crows during heronry season i.e. peak southwest monsoon months. We assume that the crows might have benefited from this, in particular by finding food (remains) and nesting materials from

heronries. We found the heronry birds nesting before the crows, therefore, the choice of nesting is with the crows. Thus, the predator protection hypothesis might have less relevance in shaping this interaction. Since the crow and the herons are sharing similar habitat for nesting, our study might support the similar habitat hypothesis (Orians and Wilson 1964; Quinn et al., 2003).

Crows are opportunistic foragers; they forage on insects, birds, mammals, and scavenge on food waste and carcases (Chhotabhai 2012). We found the crows scavenging on fallen fish/ preys that the herons feed their chicks, and also on dead heron chicks. Crows lift eggs from bird nests whenever the nests are unguarded (Ekanayake et al., 2015; Roshnath et al., 2019). Crows were also found to benefit by stealing twigs from heron nests and use in their own nests.

The association of timid species with a diurnal raptor has been frequently reported, but the advantage for the timid species has been shown in only a few cases (Wiklund 1982; Ueta 1994; Blanco and Tella 1997). Generally nesting with an opportunistic predator gives no benefits to the birds. But according to the predator protection hypothesis, nesting along with another aggressive species is advantageous as the neighbouring predator will defend its nest, thereby providing the other species nest protection against other predators (Ebbinge and Spaans, 2002). Crows are known to show high aggressive nest defence behavior which evolved though strong selective and learning processes (Knight et al., 1987). Crows defend their nest against the intrusion of crows from other colonies and against birds of prey (Sengupta 1969; Sharma 1979; Rohitashwa and Choudhary 2011) and even humans (Vijayaraghavan 2002). Response to alarm calls of the protective species increase survivability of protected species (Nuechterlein 1981; Burger 1984). As crows react to any intruders including humans, information parasitism is another benefit that heronry birds get from this unusual interaction.

In short, by nesting along with the potential preys, the breeding crows are benefited directly in terms of availability of food and nest materials at low cost. With abundant anthropogenic food, our previous study found disproportionate low nest predation by crows in urban heronries than mangrove heronries (Roshnath et al., 2019). Since the crows chased other larger birds of prey (personal observations), the co-breeding herons also might been benefited. The shortcomings of the present studies are, we did not look for the crow nests elsewhere apart from the heronries during the nesting period. Future studies should investigate other proximate factors that might have affected the co-breeding decision of the crows. For instance, the nest traits (number of eggs/ nest; type of nesting material, crow activities) and nest success of crows that are breeding with the herons and not with the herons can throw more lights on this evolving interaction.

Author statement

R Roshnath designed and conducted the study. PA Sinu conducted all statistical analyses. All authors contributed to the writing and editing of the manuscript. All the authors have read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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