Nesting tree characteristics of heronry birds of urban ecosystems in peninsular India: implications for habitat management

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Abstract

Wetland ecosystems, particularly the mangrove forest, are the primary wild habitat of heronry birds. However, urban ecosystems have become a favorite breeding habitat of these birds. To provide inputs into the habitat management for conservation of these birds, we investigated the quantitative and qualitative characteristics of nesting trees of heronry birds in the urban environment of the North Kerala region of peninsular India. Census on nesting trees was done in 3 major microhabitats of the urban ecosystem: avenues of national highways and towns, nonresidential plots, and residential areas apart from the mangrove islets in the peri-urban locality. The study found that 174 trees of 22 species hosted 1,928 heronry bird nests in the urban habitats; mangrove forests, although plentiful in the study area, hosted only about 20% of the total nests encountered in the study. Rain trees Samanea saman (43.7%) were the most available nesting tree. The greatest number of nests and nesting trees were encountered on the roads of urban areas, followed by nonresidential areas and residential areas. The differences in the observed frequencies of nesting trees in 3 microhabitats and in 3 types of roads (national highways > state highways > small pocket road) were significant. Canopy spread, girth size, and quality of the trees predicted the tree selection of the heronry birds in urban environments. Therefore, we recommend proper management and notification of the identified nesting trees as protected sites for the conservation of heronry birds.

Key words: avenue trees, heronry, management, urban ecosystem.
Kerala has about 15 species of resident and breeding waterbirds nesting in various heronries across the state (Sashikumar et al. 2011). Little cormorant Microcarbo niger, Indian cormorant Phalacrocorax fuscicollis, Oriental darter Anhinga melanogaster, Indian pond-heron Ardeola grayii, black-crowned night-heron Nycticorax nycticorax, little egrets Egretta garzetta, intermediate egrets Ardea intermedia, great egrets Ardea alba, purple heron Ardea purpurea, and grey heron Ardea cinerea are the 10 species that are found nesting in North Kerala region (Roshnath et al. 2014).

We used historical bird census data (Sashikumar and Jayarajan 2007, 2008; Sashikumar et al. 2011; Roshnath et al. 2013, 2014) and the citizen responses to our newspaper advertisements for heronry bird sites to select the nesting sites for the present investigation. We followed Sutherland’s (1996) method of counting nests in heronry sites to select the nesting sites for the present investigation.

A total of 52 heronry sites were identified in Kannur and Kasaragod districts of North Kerala, which include both the human-influenced areas, such as roads in urban and rural towns, residential and nonresidential areas, and the wild habitats, such as mangrove islets (Figure 1). These heronries were visited during the peak breeding period (monsoon months of June–August 2015) to identify the composition of the birds in the heronries, and to record the characteristics of the nesting trees. Nesting bird species were identified using binoculars (Celestron’s Nature DX 8 × 42) and a standard field guide (Ali 2003). The number of nests of each species was recorded in each heronry. Wherever possible an aerial survey was made on trees in urban and residential sites from the terrace of the adjacent tallest buildings. Based on the long-term data we identified following “microhabitat” types for sampling the nesting trees and to study the tree characteristics: road, residential area, nonresidential public places, wetland, and riverside (Figure 1). Whenever a nesting tree was located tree characteristics (tree species, tree height, girth at breast height [GBH] of the tree, and tree crown spread) and the age of the heronry (only for those trees that were occupied by the birds as seen in the historical data) were recorded.

The tree height was measured using a 1-m graded pole (Datta and Pal 1993; Gopi and Pandav 2011); electricity poles of 2 standard lengths (7 and 9 m) were used as the references. The GBH, canopy length (Lc), and breadth (B) were estimated using a meter tape. Average canopy spread (hereafter canopy spread) was estimated using the formula $L + B)/2$ (Blozan 2006).

Trees were assigned qualitative scores based on the sum score obtained from the scores assigned to following qualitative variables of the nesting trees: canopy’s adequate space (canopy spread area) for nest placement, and suitable branching pattern, which supports nests, offers nesting materials, and protects nests from rain, wind, and predators (Table 1).

### Statistical analysis

Number of nests per tree was used as a measure of nest tree occupancy and as the response variable in the analyses to study the effect of urban habitat type and nesting tree species on heronries. Since an accurate number of nests per mangrove tree was not available, mangrove habitat is not included in the analyses. We also studied the effect of road type (national highway, state highway, and pocket road) on the number of nests of the heronries per tree. We used generalized linear mixed models (GLMM) with Poisson error as the distribution to compare the effects of habitat (road, residential site, and

| Parameters                              | High | Medium | Low |
|-----------------------------------------|------|--------|-----|
| Protection from predators               | 3    | 2      | 1   |
| Nesting materials acquired within the tree | 3    | 3      | 1   |
| Suitable branching pattern              | 3    | 2      | 1   |
| Adequate space (canopy)                 | 3    | 2      | 1   |
| Withstand wind (chance of nest not to be fallen) | 3    | 2      | 1   |
| Protection from rain (chances of nest not getting wet) | 3    | 2      | 1   |
nonresidential site) and the road type (streets in the cities, state highways, and national highways) on the heronries using the lm4 package in R 3.2.1 (R Core Team 2014); the location, sites, and tree species were used as the random factors in the analysis. Assuming that the large trees could affect the nesting tree selection, GBH of the tree was used as a covariate in the analysis. We used log-linear models for simple contingency tables (= chi-square test) to test whether the observed number of trees occupied by the heronries was statistically different for the 5 most preferred nesting tree species, which were identified using the qualitative score obtained to the tree species as per the calculation given above, and the local abundance of the species. These tree species were rain tree Samanea saman (score = 16), copper pod Peltophorum terocarpum (score = 16), banyan tree Ficus bengalensis (score = 16), mango tree Mangifera indica (score = 13), and jackfruit Artocarpus heterophyllus (score = 11), which together contributed to about 82% of the total trees occupied by the heronries, and hosted 85.13% of the total nests counted in the study. These 5 species together constituted about 40% of the total avenue trees in the 146-km stretch of the National Highway 17 in Kasaragod–Kannur region (Manoj K. and Sinu P.A, unpublished data).

Nest abundance was recorded for each nesting tree in a given site, which was considered as a response variable in the models to predict the variables affecting the nest tree selection. Nest abundance per tree was plotted against each of the tree characteristics in a scatter plot to find out the kind of relationships that exist between them. The significance of the relationship was tested using Spearman’s rank order correlation test. Wherever a nonlinearity in the interaction was expected, it was tested using a polynomial regression, and compared the results with the linear models using 1-way Analysis of variance (ANOVA). We used GLMM with Poisson error as distribution to study the effect of different tree characteristics on the nest abundance in tree. Tree height, canopy spread, GBH, and qualitative score were used as the fixed factors; the locations, sites, and tree species were used as the random factors in the analysis. Before arriving to the final predictive variables to use in the model simplification, we compared the models that were built on different variables using the model.sel function available in MuMIn package in R. Models built using age of herony (i.e., the number of years since occupied by the birds as accounted for past 10 years) as a fixed factor were not significant. Model with lowest Akaike’s information criterion was selected as the best model.

**Results**

A total of 9 species belonging to 2 families, Ardeidae (7 species) and Phalacrocoracidae (2 species), participated in the heronries (Table 2). The abundance of little egrets, intermediate egrets, great egrets, purple heron, and grey heron was greater in the heronries of wetland habitats than in the city. However, little cormorant, Indian cormorant, black-crowned night-heron, and Indian pond-heron participated more in the heronries of the city than in the wetlands. Heronries were found on 174 trees of 22 species. The highest number of nesting trees was recorded along the road (n = 130) followed by residential areas (n = 22), non-residential areas (n = 20), river (n = 1), and woodland (n = 1) (Table 3). Trees along the motor highways (National Highway 17) and the other major roads in the towns and city had maximum records of nests (n = 1,549); trees in nonresidential public places such as railway stations, forts, and temple premises had 285 nests; and trees in residential areas (Lakshimpuram, Kadavathur, Nuchiayad, Kottakapara, and Moolakandam) had 80 nests. A tree in riverine habitat in Mannor had 13 nests, whereas another tree in Parapuram, a wetland habitat had only 1 nest. Mangrove islets had 495 nests. However, the number of nests per tree was not affected by the habitat type (Figure 2a). The road type also had no significant effect on the number of nests per tree (Figure 2b), but the frequency of nesting trees was significantly different between the road types (log-linear chi-square model, z = 42.97, P < 0.0001).

A total of 22 species of nesting trees (excluding mangrove species) were recorded in the city during the study period (Table 4); rain trees (43.7%; 76 trees), copper pod (13.2%; 24 trees), mango (10.3%; 18 trees), jackfruit (8%; 14 trees), and banyan tree (5.7%; 10 trees) were the major trees selected by heronry birds for nesting. The log-linear model showed that observed frequency of trees occupied by the heronry birds in different species was significant (log-linear chi-square model, z = 39.65; P < 0.0001).

The average height, GBH, and canopy spread of the nesting trees were 9.82 (±0.16 SE), 2.09 (±0.15 SE), and 22.58 m (±1.06 SE), respectively. Nest abundance in trees increased with canopy spread (r = 0.25, P = 0.004) and qualitative score of the trees (r = 0.23, P = 0.002); GBH (r = 0.16, P = 0.06), and height of the tree (r = 0.11, P = 0.14) were relatively weakly correlated with the nest abundance (Figure 3). The nest abundance in trees was predicted by the GBH (z = 2.855, P = 0.004), canopy spread (z = –2.939, P = 0.003), qualitative value of the tree species (z = –2.044, P = 0.03), and the interaction between these factors (see Table 5 for the best model predicting the nest abundance in trees).

**Discussion**

The aim of the present study was to elucidate the kinds of trees and the tree characteristics that predicted the nesting tree selection and nest abundance in trees, and to provide inputs into the habitat management for the conservation of heronry birds. The study was conducted in North Malabar region of Kerala state, and covered 36 sites in Kannur and 16 sites in Kasaragod districts. The study finds a total of 1,928 nests on 174 trees of 22 species in human-altered habitats, and 495 nests in mangrove forests of 3 sites. Although 22 tree species were hosting the nests of heronry birds, 85.15% of the nests were occupied on 5 species of trees (rain tree, copper pod, mango, jackfruit, and banyan tree); therefore, they become the crucial nesting trees of the heronry birds in the urban areas. Rain tree, due to its vast canopy expanse, is the most preferred avenue shade tree for the landscape practitioners. Rain tree was the most common tree selected for nesting by the heronry birds, probably because this is the most common and suitable shade tree available in the avenues of highways and towns. Although the banyan tree F. bengalensis is also an equally common avenue tree in the national highways and streets of towns of Malabar region (Manoj and Sinu, unpublished data), and have the same qualitative features as that of rain trees (e.g., the canopy spread and tree height) (Table 4), they host relatively few nests. This shows that heronry birds have a strong fidelity to rain trees due to additional qualitative features, such as availability of the nesting materials from within the tree, and optimum nesting spaces (branching pattern). All tree characteristics individually and in interaction with each other predicted the occupancy and the abundance of nests in trees, which is in agreement with the findings of previous studies (Post 1990; Ranglack et al. 1991; Minias and Kaczmarek 2013). Previous studies suggest that the average height of the nesting trees of heronry birds is 6–11 m (Telfair 1983; Hilaluddin et al. 2006; Sashikumar and Jayarajan 2007), which might vary with the habitat (Telfair 1983, 1994; Narayanan 2014).
In the present study, the heronries were also observed in trees at different heights between 6 and 12 m and of different girth sizes between 0.45 and 7 m.

Our decade-long monitoring of the heronry sites showed that even though other trees with desired characters are present in the vicinity, birds choose to nest in trees that were selected previously (Kelsall and Simpson 1980; Visser et al. 2005). This was even applicable to the most preferred host species, such as rain trees. For example in Ayikkara heronry, although large rain trees were present, birds preferred to nest every year on relatively smaller trees of Gulmohar and Changing rose. In Nadal, pond-herons nest in small rain tree with less-extent canopy, even though large canopied rain trees were abundant.

Street trees are important habitats for birds and other urban taxa (Nagendra and Gopal 2010). The study finds that the majority of nesting trees are located in national highways, nonresidential areas including towns, railway stations, and temple premises, and residential plots (Subramanya 1996; Sashikumar and Jayarajan 2007). In contrast, only few nesting trees were located in their native habitats, such as wetlands and mangrove islets, despite an abundance of these habitats in the study area. The affinity of heronry birds to towns and cities was also reported previously in other parts of India (Subramanya 1996; Sashikumar and Jayarajan 2007; Urﬁ 2010), and elsewhere (Des Granges and Reed 1981; Henny et al. 1989; Vennesland and Butler 2004; Vergara et al. 2006).

Heronry birds’ nests have differential predatory pressure from the birds of prey, snakes, and mouse in the urban and wild natural habitats (King 1983; Walasz 1990; Gliwicz et al. 1994). Since the last breeding period (June–October 2016), we have been studying the predator composition and predatory pressure on heronry bird nests in the city of Kannur and in the mangrove islets, and we found that the predatory pressure is relatively low in the heronries of cities (Roshnath R et al., unpublished data). Greater abundance of suitable large trees, low predation pressure, and additional foraging places in the close neighborhood (e.g., fish markets) might have set the city a preferred breeding ground for the heronry birds.

Although heronry birds are highly acclimated to the disturbed environments such as urban areas (Urﬁ 2006, 2010; Möller 2008), vertical and horizontal expansion of cities, and irresponsible solid waste management are sources of concern for the continued conservation of this important functional group of birds in wetland and urban ecosystems. The study sites have already experienced decline in the heronry bird nests in recent years (Roshnath et al. 2013, 2014). The present study found that 76.92% of the nesting trees were located in the national highways; therefore, road expansion and urbanization will be directly affecting these birds. While horizontal expansion may have a direct effect on the nesting tree density and natural feeding grounds, vertical expansion is likely to affect the behavior of the heronry birds. We find that heronry birds abandon

Table 2. Species participating in the heronries observed in the study

| Family            | Common name       | Scientific name         | No. of nests |
|-------------------|-------------------|-------------------------|--------------|
| Phalacrocoracidae | Little cormorant  | Microcarbo niger         | 721          |
|                   | Indian cormorant  | Phalacrocorax fuscicollis| 48           |
| Ardeidae          | Little egret      | Egretta garzetta        | 55           |
|                   | Great egret       | Ardea alba               | 5            |
|                   | Intermediate egret| Ardea intermedia        | 58           |
|                   | Black-crowned night-heron | Nycticorax nycticorax | 111          |
|                   | Indian pond-heron | Ardeola grayii           | 1,422        |
|                   | Grey heron        | Ardea cinerea           | 2            |
|                   | Purple heron      | Ardea purpurea           | 1            |

Table 3. Number of trees and number of nests in different habitats

| Habitat            | No. of trees | No. of nests |
|---------------------|--------------|--------------|
| Road                | 130          | 1,549        |
| Residential area    | 22           | 80           |
| Nonresidential area | 20           | 285          |
| River               | 1            | 13           |
| Wetland             | 1            | 1            |
| Mangrove            | —            | 495          |
| Total               | —            | 2,423        |

Figure 2. Box plots show the nest abundance in (A) 3 microhabitats and (B) 3 road types in the city. nh, national highway; pocket.rd, small streets inside the town and residential plots; sh, state highway.
the age-old heronries in sites, where over bridges and fly-over bridges are being constructed as vehicular traffic at the tree canopy level is a major disturbance for the birds (personal observation). Since most of the nesting trees are located along the road, development and expansion of roads will lead to the felling of these centuries' old trees, which will have a direct impact on the population of nesting heronry birds. Hence, prioritization should be given for conservation of nesting sites to conserve these waterbirds. Although the abundance of heronries in wetland and mangrove system is relatively lower, these wild habitats are still preferred by little

Table 4. Number and mean (±SD) height of host trees of different species encountered in the study

| Common name          | Scientific name          | Number | Mean tree height | SD   |
|----------------------|--------------------------|--------|------------------|------|
| Rain tree            | Samanea saman            | 76     | 10.50            | 2.51 |
| Copper pod           | Peltophorum terocarpum   | 23     | 8.82             | 1.69 |
| Mango                | Mangifera indica         | 18     | 8.33             | 1.81 |
| Jackfruit            | Artocarpus heterophyllus | 14     | 8.07             | 1.14 |
| Indian banyan        | Ficus bengalensis        | 10     | 9.65             | 1.85 |
| Coconut              | Cocos nucifera           | 6      | 12.5             | 0.83 |
| Peepal               | Ficus religiosa          | 5      | 11               | 1.41 |
| Badam                | Terminalia catappa       | 4      | 11               | 1.63 |
| Cashew               | Anacardium occidentale   | 2      | 7.5              | 0.70 |
| Golden shower tree   | Cassia Fistula           | 2      | 7.5              | 0.70 |
| Tamarind             | Tamarindus indica        | 2      | 8.5              | 2.12 |
| Uppilla              | Macaranga peltata        | 2      | 7.5              | 0.70 |
| Changing rose        | Hibiscus mutabilis       | 1      | 9                | 0    |
| Ilippa               | Madhuca neriifolia       | 1      | 6                | 0    |
| False Ashoka         | Polyalthia longifolia    | 1      | 11               | 0    |
| Kite tree            | Casuarina equisetifolia  | 1      | 11               | 0    |
| Mahagoni             | Svetenia mahagoni        | 1      | 11               | 0    |
| Mangrove trumpet tree| Dolichandrone spathacea  | 1      | 9                | 0    |
| Pala                 | Alstonia scholaris       | 1      | 12               | 0    |
| Sheemakonna          | Gliricidia sepium        | 1      | 8                | 0    |
| Snake wood (Kanjiram)| Strychnos nux-vomica    | 1      | 7                | 0    |
| Teak                 | Tectona grandis          | 1      | 10.7             | 0    |

Figure 3. Scatterplots show the relationship between the nesting tree characteristics, such as (A) height, (B) canopy spread, (C) GBH, and (D) qualitative value, and the nest abundance of the heronry birds.
Table 5. The best predictive model (GLMM) of nest abundance of heronry birds in trees

| Variable                  | \( \varepsilon \) value | \( P \) value |
|---------------------------|--------------------------|---------------|
| GBH                       | 2.855                    | 0.004         |
| Canopy spread             | -2.939                   | 0.003         |
| Qualitative value         | -2.044                   | 0.04          |
| Tree height               | -0.5                     | 0.61          |
| GBH*canopy spread         | -2.93                    | 0.003         |
| GBH*qualitative value     | -2.499                   | 0.01          |
| Canopy spread*qualitative value | 3.868               | 0.0001        |
| GBH*tree height           | -2.762                   | 0.005         |
| Canopy spread*tree height | 2.264                    | 0.02          |
| Qualitative value*tree height | 1.679               | 0.09          |
| GBH*canopy spread*tree height | 3.721               | 0.0001        |
| GBH*qualitative value*tree height | 2.071              | 0.03          |
| Canopy spread*qualitative value*tree height | -3.22             | 0.001         |

Note: Qualitative value—scores assigned to tree based on different variables stated in Table 1.

egrets, intermediate egrets, great egrets, purple heron, and grey heron. Therefore, the conservation of mangrove forests is also required for the conservation of heronry birds. Notifying the nesting trees as protected sites and proper management of identified nesting trees could help in conservation of these breeding birds. Posters regarding the nesting bird species could be posted under the trees to draw public attention and create awareness. If removing the nesting trees is inevitable for the expansion of the cities, we recommend selective removal of the non-nesting trees in the vicinity first. Local governments may consider erecting heronry guards above the bus waiting shelters if nesting trees are located in such places (Sashikumar C, personal communication). To help town planners, this study has provided a comprehensive map of the nesting tree locations and the nesting tree species of the heronry birds in the 2 districts of North Kerala, which may be found useful during landscape planning.

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