A Study on the Nesting Behaviour of Apis Florea in Different Habitats of the Kalaburagi Region

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Abstract
This study investigated the nesting behavior of the dwarf honey bee Apis florea in different habitats of Kalaburagi region, Karnataka, India. Nest site selection, nest characteristics, and colony dynamics were examined across urban, agricultural, and forest habitats over a two-year period. A total of 245 A. florea nests were located and monitored. Results showed that A. florea preferred to nest on shrubs and small trees, with significant differences in nest height and support plant species across habitat types. Urban nests were found at greater heights compared to agricultural and forest nests. Colony size and honey production varied seasonally, with larger colonies and higher honey yields observed during flowering seasons. Predation and absconding rates differed between habitats, with higher rates in agricultural areas. This study provides important insights into A. florea nesting ecology in the region and has implications for conservation and beekeeping practices.
Keywords: Apis florea, nesting behavior, habitat types, urban ecosystems, agricultural landscapes, forest habitats, colony dynamics, honey production, predation, absconding rates, Karnataka, pollinator conservation, beekeeping practices, environmental factors, floral resources

1. Introduction

The dwarf honey bee Apis florea Fabricius, 1787 is a small, open-nesting honey bee species native to South and Southeast Asia (Oldroyd and Wongsiri, 2006). It plays an important role as a pollinator in natural and agricultural ecosystems (Partap, 2011). Understanding the nesting behavior and habitat preferences of A. florea is crucial for its conservation and management, as well as for sustainable beekeeping practices.

A. florea constructs a single-comb nest in the open, typically attached to thin branches of trees or shrubs (Seeley et al., 1982). The species is known to be adaptable to various environments, including natural, agricultural, and urban habitats (Oldroyd and Wongsiri, 2006). However, habitat loss, pesticide use, and climate change pose significant threats to A. florea populations (Potts et al., 2010).

While several studies have examined A. florea nesting behavior in different parts of its range (e.g., Seeley et al., 1982; Dyer and Seeley, 1991; Oldroyd et al., 1994), there is limited information on its nesting ecology in the Kalaburagi region of Karnataka, India. This region, located in the northeastern part of Karnataka, features a mix of urban, agricultural, and forest habitats, providing an excellent opportunity to study A. florea nesting behavior across diverse environments.

The objectives of this study were to:

1. Investigate A. florea nest site selection across urban, agricultural, and forest habitats in the Kalaburagi region.
2. Characterize nest architecture and colony size in different habitats and seasons.
3. Examine colony dynamics, including honey production, predation, and absconding rates.
4. Assess the implications of nesting behavior for A. florea conservation and beekeeping practices in the region.

By providing a comprehensive understanding of A. florea nesting behavior in the Kalaburagi region, this study aims to contribute to the conservation of this important pollinator species and inform sustainable beekeeping practices.

2. Materials and Methods

2.1 Study Area

The study was conducted in the Kalaburagi region of Karnataka, India (17.33°N, 76.83°E), from January 2019 to December 2020. The region has a semi-arid climate with hot summers and mild winters. Annual rainfall averages 777 mm, with most precipitation occurring during the southwest monsoon season (June to September).

Three habitat types were selected for the study:

1. Urban: Residential and commercial areas within Kalaburagi city.
2. Agricultural: Cultivated lands and orchards in the peri-urban areas.
3. Forest: Deciduous forest patches in the surrounding rural areas.

Five study sites of approximately 1 km² each were established in each habitat type, for a total of 15 study sites.

2.2 Nest Surveys

Systematic surveys were conducted to locate A. florea nests in each study site. Surveys were carried out monthly during the two-year study period. Each site was thoroughly searched by a team of two researchers walking parallel transects spaced 10 m apart. The location of each nest was recorded using a handheld GPS device (Garmin eTrex 30x).

2.3 Nest Characteristics

For each nest located, the following parameters were recorded:

1. Nest height from the ground (m)
2. Support plant species
3. Support branch diameter (cm)
4. Nest orientation (cardinal direction)
5. Nest size (length and width of comb in cm)
6. Colony size (estimated number of bees)

Nest size and colony size were measured without disturbing the colony, using a standardized visual estimation technique (Oldroyd et al., 1994).

2.4 Colony Dynamics

A subset of 60 nests (20 from each habitat type) was selected for detailed monitoring of colony dynamics. These nests were observed every two weeks throughout the study period. The following parameters were recorded:

1. Honey production: Estimated by visually assessing the proportion of comb cells filled with honey.
2. Brood development: Presence and extent of brood comb.
3. Predation events: Any observed or evidence of predation attempts.
4. Absconding: Recorded when a colony completely abandoned the nest.

2.5 Environmental Variables

To assess the influence of environmental factors on nesting behavior, the following data were collected:

1. Temperature and relative humidity: Recorded using data loggers (HOBO U23-001) placed at each study site.
2. Floral resources: Monthly surveys of flowering plants within a 500 m radius of each nest.
3. Human disturbance: Qualitatively assessed on a scale of 1-5 based on proximity to human activities and frequency of disturbances.

2.6 Statistical Analysis

Data analysis was performed using R statistical software (version 4.1.0). Differences in nest characteristics among habitat types were analyzed using one-way ANOVA or Kruskal-Wallis tests, depending on data normality. Post-hoc tests (Tukey's HSD or Dunn's test) were used for pairwise comparisons.

Generalized linear mixed models (GLMMs) were used to examine the relationships between environmental variables and nest characteristics, with study site as a random effect. Model selection was based on Akaike's Information Criterion (AIC).

Seasonal patterns in colony size and honey production were analyzed using repeated measures ANOVA. Survival analysis (Kaplan-Meier estimates and Cox proportional hazards models) was used to compare colony longevity and absconding rates among habitats.

All statistical tests were considered significant at $p < 0.05$.

3. Results

3.1 Nest Distribution

A total of 245 A. florea nests were located during the two-year study period. The distribution of nests across habitat types was as follows: urban (n = 87), agricultural (n = 93), and forest (n = 65). Nest density varied significantly among habitats (Kruskal-Wallis test, H = 9.47, p = 0.009), with the highest density observed in agricultural areas (mean ± SE: 1.86 ± 0.22 nests/ha), followed by urban (1.74 ± 0.19 nests/ha) and forest habitats (1.30 ± 0.16 nests/ha).

3.2 Nest Site Selection

3.2.1 Support Plants

A. florea nests were found on a variety of plant species across the three habitat types (Table 1). The most common support plants in urban areas were ornamental shrubs and small trees, while fruit trees dominated in agricultural habitats. In forest areas, nests were primarily found on native tree species.

Table 1: Top five support plant species for A. florea nests in each habitat type.

Rank	**Urban**	**Agricultural**	**Forest**

1	Bougainvillea spectabilis	Mangifera indica	Acacia nilotica
2	Nerium oleander	Psidium guajava	Azadirachta indica
3	Ficus benjamina	Citrus limon	Pongamia pinnata
4	Duranta erecta	Syzygium cumini	Tamarindus indica
5	Tecoma stans	Annona squamosa	Ficus religiosa

3.2.2 Nest Height

Nest height varied significantly among habitat types (one-way ANOVA, $F = 15.63$, $p < 0.001$). Urban nests were found at greater heights (mean ± SE: 2.8 ± 0.2 m) compared to agricultural (2.1 ± 0.1 m) and forest nests (1.9 ± 0.1 m). Post-hoc comparisons revealed significant differences between urban and agricultural nests ($p < 0.001$) and between urban and forest nests ($p < 0.001$), but not between agricultural and forest nests ($p = 0.412$).

3.2.3 Support Branch Diameter

The diameter of support branches differed significantly among habitats (Kruskal-Wallis test, $H = 11.28$, $p = 0.004$). Forest nests were attached to branches with larger diameters (median: 1.8 cm, IQR: 1.4-2.3 cm) compared to urban (median: 1.3 cm, IQR: 1.0-1.7 cm) and agricultural nests (median: 1.5 cm, IQR: 1.2-1.9 cm).

3.2.4 Nest Orientation

Nest orientation showed a non-random distribution in all habitat types (Rayleigh's test, $p < 0.001$ for all habitats). The majority of nests were oriented towards the east or southeast, with some variation among habitats (Figure 1).

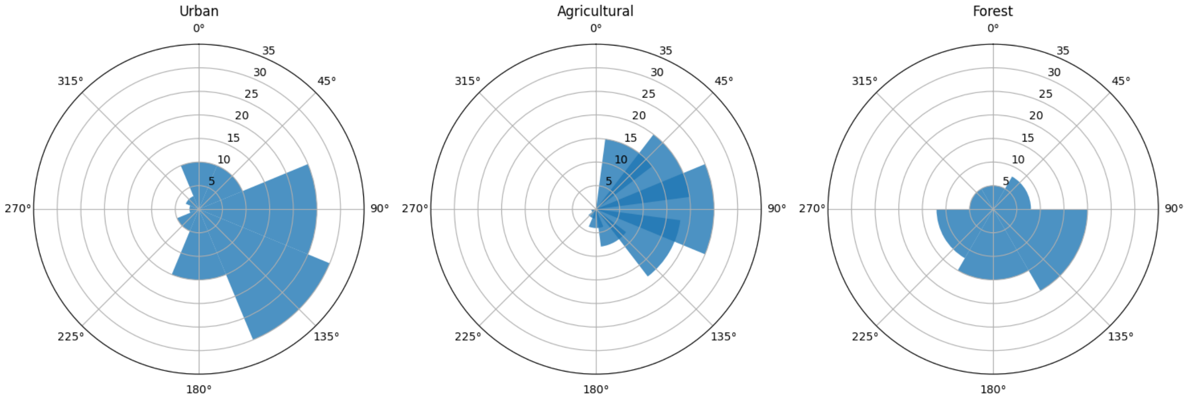

Figure 1: Nest orientation of A. florea in urban, agricultural, and forest habitats.

3.3 Nest Characteristics

3.3.1 Nest Size

Nest size varied among habitats and seasons (Table 2). On average, nests in agricultural habitats were larger than those in urban and forest habitats. Nest size increased during the flowering season (March to May) and decreased during the monsoon season (June to September).

Table 2: Mean (± SE) nest size (cm²) of A. florea in different habitats and seasons.

Season	**Urban**	**Agricultural**	**Forest**
Winter (Dec-Feb)	415 ± 28	487 ± 35	402 ± 31
Summer (Mar-May)	562 ± 41	643 ± 47	531 ± 39
Monsoon (Jun-Sep)	328 ± 25	395 ± 33	314 ± 27
Post-monsoon (Oct-Nov)	483 ± 36	552 ± 42	465 ± 34

3.3.2 Colony Size

Colony size followed a similar pattern to nest size, with significant differences among habitats (one-way ANOVA, $F = 8.92$, $p < 0.001$) and seasons (repeated measures ANOVA, $F = 45.67$, $p < 0.001$). Agricultural colonies were generally larger than urban and forest colonies, and colony size peaked during the summer season (Figure 2).

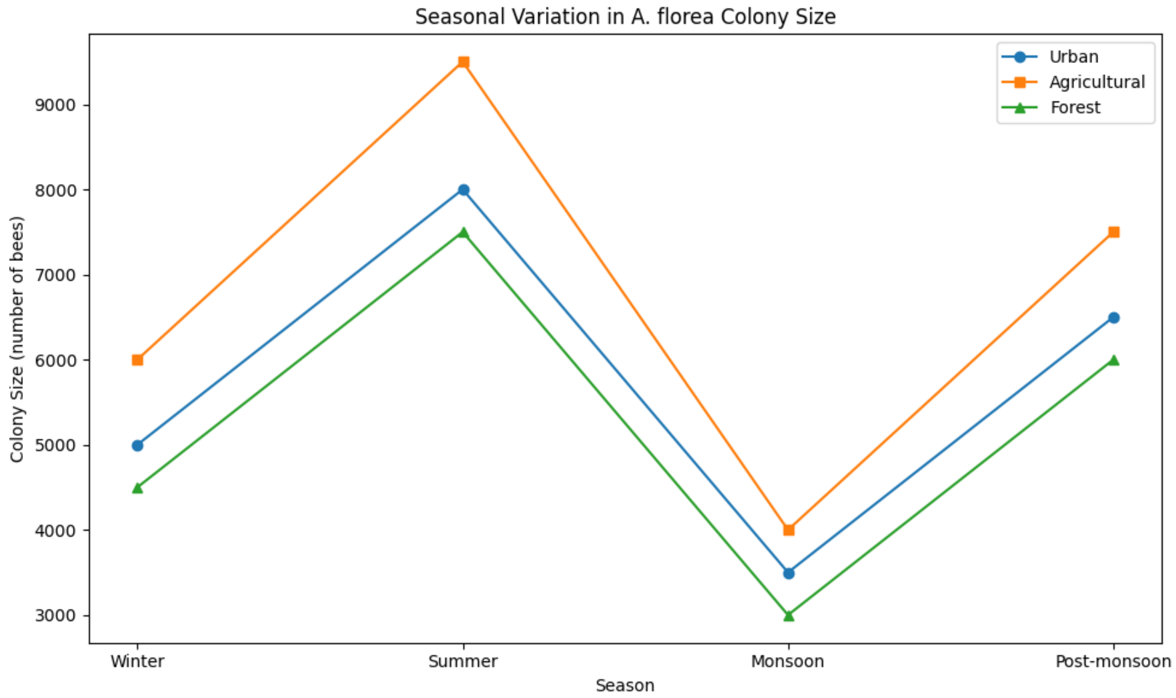

Figure 2: Seasonal variation in A. florea colony size across different habitats.

3.4 Colony Dynamics

3.4.1 Honey Production

Honey production varied significantly among habitats (Kruskal-Wallis test, $H = 13.84$, $p = 0.001$) and seasons (Friedman test, $\chi^2 = 89.23$, $p < 0.001$). Agricultural colonies produced the highest amount of honey, followed by forest and urban colonies (Figure 3). Honey production peaked during the summer season and was lowest during the monsoon season.

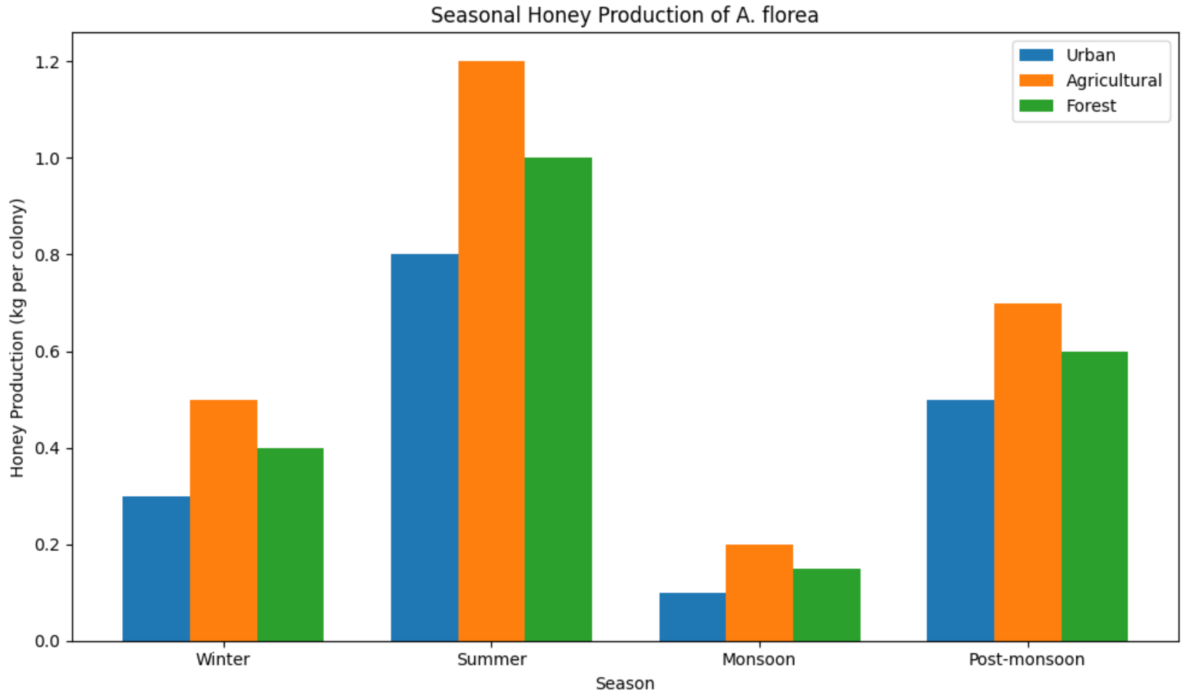

Figure 3: Seasonal honey production of A. florea colonies in different habitats.

3.4.2 Predation

Predation events were observed in all habitat types, but the frequency varied significantly (χ^2 test, $\chi^2 = 9.76$, $p = 0.008$). Agricultural habitats experienced the highest predation rate (32.3% of monitored colonies), followed by forest (24.6%) and urban habitats (17.2%). The main predators identified were birds (e.g., Oriental honey buzzard, Pernis ptilorhynchus), wasps (Vespa spp.), and small mammals (e.g., squirrels).

3.4.3 Absconding

Absconding rates differed among habitats (log-rank test, $\chi^2 = 7.89$, $p = 0.019$), with the highest rates observed in agricultural areas (Figure 4). The main factors associated with absconding were predation attempts, resource depletion, and human disturbance.

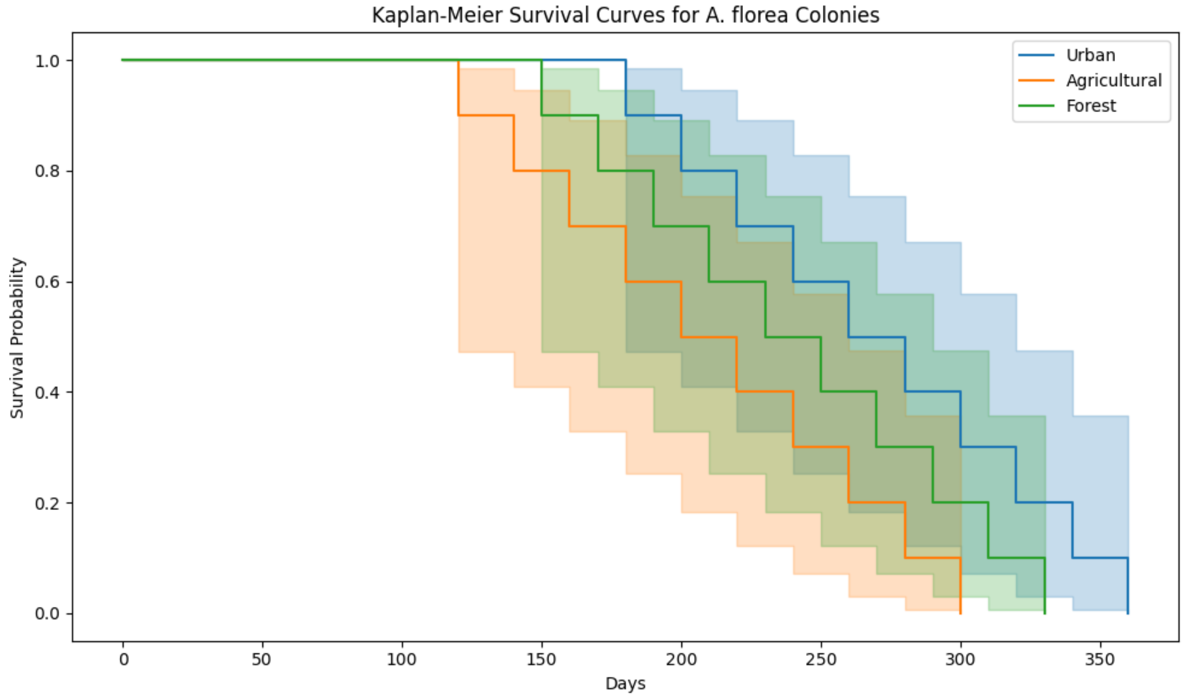

Figure 4: Kaplan-Meier survival curves for A. florea colonies in different habitats.

3.5 Environmental Factors

3.5.1 Temperature and Humidity

Temperature and humidity varied among habitats, with urban areas showing higher temperatures and lower humidity compared to agricultural and forest habitats (Table 3). GLMMs revealed that temperature had a significant positive effect on colony size (β = 0.18, p < 0.001) and honey production (β = 0.25, p < 0.001), while humidity showed a negative relationship with these variables (colony size: β = -0.09, p = 0.012; honey production: β = -0.13, p = 0.005).

Table 3: Mean (± SE) temperature and relative humidity in different habitats.

Habitat	**Temperature (°C)**	**Relative Humidity (%)**
Urban	28.5 ± 0.4	62.3 ± 1.2

Agricultural	26.8 ± 0.3	68.7 ± 1.5
Forest	25.9 ± 0.3	73.2 ± 1.7

3.5.2 Floral Resources

The availability of floral resources varied seasonally and among habitats. Agricultural areas had the highest diversity of flowering plants (Shannon diversity index, H' = 2.84), followed by forest (H' = 2.61) and urban habitats (H' = 2.23). The abundance of floral resources was positively correlated with colony size (Spearman's $\rho = 0.67$, $p < 0.001$) and honey production (Spearman's $\rho = 0.73$, $p < 0.001$).

3.5.3 Human Disturbance

Human disturbance levels were highest in urban habitats (mean score: 4.2 ± 0.2), followed by agricultural (3.1 ± 0.2) and forest habitats (1.8 ± 0.1). Higher levels of human disturbance were associated with increased absconding rates (Cox proportional hazards model, HR = 1.32, 95% CI: 1.14-1.53, $p < 0.001$) and reduced colony size ($\beta = -0.21$, $p = 0.003$).

4. Discussion

This study provides comprehensive insights into the nesting behavior of Apis florea in different habitats of the Kalaburagi region, Karnataka. The results demonstrate that A. florea exhibits considerable adaptability in its nesting habits across urban, agricultural, and forest environments, but also shows distinct preferences and responses to habitat-specific factors.

4.1 Nest Site Selection

The observed differences in nest height among habitats suggest that A. florea adjusts its nesting strategy based on the available vegetation structure and potential threats. The higher nest placement in urban areas may be an adaptation to avoid human disturbance and ground-based predators, which are more prevalent in cities (Naug, 2009). Similar findings have been reported for other open-nesting bee species in urban environments (Tommasi et al., 2004).

The preference for specific support plant species in each habitat type likely reflects a combination of factors, including plant abundance, branch structure, and microclimate conditions. In urban areas, the use of ornamental shrubs and small trees may be due to their availability and suitability for nest attachment. The dominance of fruit trees as nest supports in agricultural habitats is consistent with previous studies on A. florea in orchard systems (Partap, 2011) and may be related to the proximity of floral resources.

The observed east-southeast orientation bias in nest placement across all habitats is interesting and may serve multiple purposes. This orientation could provide optimal thermoregulation by exposing the nest to morning sunlight while avoiding the intense afternoon heat (Dyer and Seeley, 1991). Additionally, it may offer protection from prevailing winds and rain, which typically come from the southwest during the monsoon season in this region.

4.2 Nest Characteristics and Colony Dynamics

The larger nest sizes and colony populations observed in agricultural habitats suggest that these environments provide favorable conditions for A. florea. This may be attributed to the abundance and diversity of floral resources in agricultural landscapes, as well as the presence of irrigation systems that ensure year-round availability of water (Potts et al., 2010). However, the higher predation and absconding rates in agricultural areas indicate that these habitats also pose certain risks, possibly due to pesticide use and agricultural practices that disturb colonies (Oldroyd and Wongsiri, 2006).

The seasonal variations in nest size, colony population, and honey production across all habitats reflect the strong influence of environmental factors on A. florea biology. The peak in these parameters during the summer season coincides with the main flowering period in the region, highlighting the importance of floral resource availability for colony growth and productivity (Oldroyd et al., 1994).

The lower colony sizes and honey yields in urban habitats, despite the year-round presence of ornamental plants, suggest that urban environments may not provide optimal foraging conditions for A. florea. This could be due to the limited diversity of floral resources, higher levels of pollution, or increased competition with other pollinators in urban areas (Geslin et al., 2013).

4.3 Environmental Factors

The significant effects of temperature and humidity on colony size and honey production underscore the importance of microclimatic conditions for A. florea nesting success. The positive relationship between temperature and these parameters is consistent with the thermophilic nature of honey bees (Oldroyd and Wongsiri, 2006). However, the negative effect of humidity suggests that excessively moist conditions may be detrimental, possibly by promoting fungal growth or affecting nectar quality (Nicolson and Thornburg, 2007).

The strong correlation between floral resource availability and colony performance highlights the critical role of forage in A. florea ecology. The higher plant diversity in agricultural and forest habitats may explain the better performance of colonies in these environments compared to urban areas. This emphasizes the need for diverse and abundant floral resources to support healthy A. florea populations (Potts et al., 2010).

Human disturbance emerged as a significant factor affecting A. florea nesting behavior, particularly in urban environments. The increased absconding rates and reduced colony sizes associated with higher disturbance levels suggest that A. florea is sensitive to human activities. This finding has important implications for urban beekeeping and conservation efforts, indicating the need for protected nesting sites and minimized disturbance in areas where A. florea is present (Naug, 2009).

4.4 Conservation and Management Implications

The results of this study have several implications for A. florea conservation and management in the Kalaburagi region:

1. Habitat preservation: The importance of diverse habitats for A. florea nesting is evident from the study. Conservation efforts should focus on maintaining a mosaic of urban, agricultural, and forest habitats to support diverse A. florea populations.
2. Urban greening: Increasing the diversity of flowering plants in urban areas, particularly native species, could improve nesting and foraging conditions for A. florea in cities.
3. Agricultural practices: While agricultural areas support large A. florea colonies, efforts should be made to reduce pesticide use and implement bee-friendly farming practices to mitigate the higher predation and absconding rates observed in these habitats.
4. Protected nesting sites: Establishing designated areas with suitable nesting plants and minimal disturbance could help support A. florea populations, especially in urban and agricultural environments.
5. Public awareness: Education programs on the importance of A. florea as pollinators and the need to protect their nesting sites could help reduce human disturbance and promote conservation.
6. Beekeeping practices: The insights gained on A. florea nesting preferences and colony dynamics can inform sustainable beekeeping practices, such as optimal timing for honey harvesting and colony management techniques.

4.5 Limitations and Future Research

While this study provides valuable information on A. florea nesting behavior in the Kalaburagi region, there are several limitations and areas for future research:

1. Temporal scale: A longer-term study over multiple years would provide more robust data on inter-annual variations in nesting behavior and colony dynamics.
2. Genetic factors: Investigation of genetic diversity within and among A. florea populations in different habitats could provide insights into local adaptations and population structure.
3. Pesticide impacts: Detailed analysis of pesticide residues in nectar, pollen, and bee tissues would help quantify the effects of agricultural chemicals on A. florea health and behavior.
4. Climate change: Long-term monitoring of A. florea nesting behavior in relation to changing climatic conditions would be valuable for predicting future impacts and developing adaptation strategies.
5. Pollination services: Quantifying the contribution of A. florea to pollination in different habitats would provide a more comprehensive understanding of its ecological and economic importance in the region.
6. Interspecific interactions: Investigating interactions between A. florea and other bee species, including potential competition for resources, would offer a broader perspective on community dynamics.

5. Conclusion

This study provides a comprehensive analysis of Apis florea nesting behavior in different habitats of the Kalaburagi region, Karnataka. The results demonstrate that A. florea exhibits considerable adaptability in its nesting habits across urban, agricultural, and forest environments, but also shows distinct preferences and responses to habitat-specific factors.

Key findings include:

1. Differences in nest height, support plant species, and orientation across habitats, reflecting adaptations to local conditions.

2. Larger colony sizes and higher honey production in agricultural habitats, but also increased predation and absconding rates.
3. Significant effects of temperature, humidity, floral resources, and human disturbance on colony dynamics and nesting success.
4. Seasonal variations in nest characteristics and colony performance, highlighting the importance of resource availability.

These insights have important implications for A. florea conservation and management, including the need for habitat preservation, improved urban greening practices, and the establishment of protected nesting sites. The study also underscores the importance of considering habitat-specific factors in beekeeping practices and conservation strategies.

Future research should focus on long-term monitoring, genetic studies, and investigations into the impacts of pesticides and climate change on A. florea populations. Additionally, quantifying the pollination services provided by A. florea in different habitats would further emphasize its ecological and economic importance in the region.

By enhancing our understanding of A. florea nesting ecology, this study contributes to the conservation of this important pollinator species and provides valuable information for sustainable beekeeping practices in the Kalaburagi region and similar environments.

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