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Behavioral Interactions and Potential Symbiotic Association Between Painted Storks and Indian Cormorants in Shared Nesting Colonies

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ABSTRACT

This study investigates the spatial and behavioural associations between Painted Storks (*Mycteria leucocephala*) and Indian Cormorants (*Phalacrocorax fuscicollis*) within two urban wetland sites in Kolkata, India: Santragachi Jheel and Rabindra Sarobar Lake. Field surveys were conducted over two consecutive years using binoculars and digital cameras to monitor nesting behaviour, tree use, and seasonal abundance. Both species were observed nesting on the same trees, cohabiting in mixed-species colonies, particularly during winter and summer, with minimal interspecific conflict and no evidence of competition for nesting space or food. To test hypotheses regarding spatial nesting association (H1), behavioural shifts in mixed colonies (H2), and potential mutual benefits (H3), seasonal data were analysed using non-parametric Kruskal–Wallis tests. Although visual trends indicated higher abundance and nesting activity in winter, statistical analysis did not confirm significant seasonal differences ($p > 0.05$), likely due to limited sample size. Nonetheless, qualitative observations support the presence of a commensal or facilitative relationship, wherein both species benefit from shared predator vigilance and optimal nesting sites. This study contributes to the understanding of interspecific nesting ecology in tropical urban wetlands and highlights the ecological value of protected urban lakes as breeding grounds for large waterbirds. Further multi-year, multi-site studies are recommended to validate these preliminary findings.

Keywords: Mixed-species colonies, Urban wetlands, Painted Stork, Indian Cormorant, Nesting ecology, Interspecific interactions

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1. INTRODUCTION

Colonial nesting is a common strategy among waterbirds, driven by a combination of ecological, evolutionary, and behavioural factors such as predator avoidance, increased reproductive success, and access to limited nesting sites (Wittenberger and Hunt, 1985; Beauchamp, 1999). In the Indian subcontinent, wetlands host a wide array of colonial waterbirds, among which the Painted Stork (*Mycteria leucocephala*) and the Indian Cormorant (*Phalacrocorax fuscicollis*) are among the most prominent and frequently co-occurring species (Kumar et al., 2005; Sundar, 2006). Despite their taxonomic and ecological differences—one being a large, tactile-feeding wader and the other a pursuit-diving piscivore—these species are often observed breeding and foraging in spatial proximity within shared wetland habitats (Islam and Rahmani, 2004). The extent and nature of their interactions, however, remain poorly studied, leaving a gap in our understanding of their interspecific behavioural dynamics.

The Painted Stork is a near-threatened species according to the IUCN Red List (BirdLife International, 2021), and it is known for its conspicuous colonial nesting in trees near waterbodies, typically in association with other large waterbirds such as ibises, herons, and cormorants. Their foraging strategy involves wading in shallow waters and using their semi-open bill to tactically capture prey, primarily fish (Ali and Ripley, 1983; Kahl, 1971). Indian Cormorants, in contrast, are agile underwater hunters, diving in deeper sections of water to pursue fish actively (Subramanya, 2005). Despite this apparent divergence in foraging ecology, both species rely heavily on the same freshwater ecosystems for breeding, feeding, and roosting, suggesting potential for spatial and behavioural overlap.

While much research has focused on single-species behavioural ecology, mixed-species colonies present a fertile ground for exploring interspecific interactions such as competition, facilitation, or even forms of mutualism (Goodale et al., 2010). In some mixed colonies, birds benefit from enhanced predator detection and deterrence, thereby improving individual fitness (Burger, 1981; Caro, 2005). For example, in multi-species colonies involving herons and ibises, certain species act as sentinels, increasing the vigilance of the entire colony (Kushlan, 1977). However, few empirical studies have examined whether such relationships exist between Painted Storks and Indian Cormorants, particularly in the context of nesting or anti-predator behaviour.

Theoretical frameworks from community ecology suggest that sympatric colonial breeders may form associations that reduce individual risk or enhance resource efficiency (Stenseth and Lidicker, 1992). The Painted Stork, being a visually dominant species with loud displays and high nests, may offer indirect benefits to smaller, less conspicuous species like the Indian Cormorant through a form of commensalism or protective nesting (Sundar, 2006). Conversely, the presence of large flocks of cormorants could increase overall colony vigilance, potentially alerting Painted Storks to aerial or terrestrial threats. These behavioural interplays may reflect an evolutionarily stable strategy for coexistence in resource-rich but space-limited wetland habitats.

From a conservation perspective, understanding such interspecific interactions is vital. Many Indian wetlands, including the East Kolkata Wetlands, Bharatpur (Keoladeo National Park), and Ranganathittu Bird Sanctuary, face mounting anthropogenic pressures, such as eutrophication, habitat conversion, and disturbance from tourism and fishing (Gopal, 1995; Mukherjee et al., 2011). In such fragmented landscapes, behavioural adaptability and interspecies associations may significantly influence breeding success and population dynamics. The Indian Cormorant, although not globally threatened, is sensitive to colony disturbances and tends to desert nesting sites when human activity intensifies (Rahmani and Islam, 2008). Painted Storks, while more tolerant, also experience reduced productivity under chronic disturbance (Subramanya and Manu, 1996). Mixed-species colonial nesting may therefore be a behavioural adaptation to increasing ecological stress.

Studies from other continents have demonstrated similar associations among colonial nesting birds. For instance, in African wetlands, species such as the African Openbill (*Anastomus lamelligerus*) and African Darter (*Anhinga rufa*) are known to nest in proximity, exhibiting synchronised breeding seasons and occasionally cooperative defence against predators (Hockey et al., 2005). These findings reinforce the notion that multi-species nesting associations can be beneficial or at least tolerated under certain ecological conditions. Whether this paradigm holds in the Indian context remains uncertain, as systematic data on interspecific behavioural dynamics in colonies of Painted Storks and Indian Cormorants are lacking.

The Rabindra Sarober Lake, a avifaunal important site and a biodiversity hotspot adjacent to the city of Kolkata, offers an ideal natural laboratory to explore these dynamics. Between 2018 and 2019, anecdotal and observational data have suggested that both species not only share roosting and nesting areas but may also display synchronised nesting phenologies and interactive behaviours. Preliminary observations from Santragachi Jheel and Rabindra Sarober Lake have shown overlapping nesting clusters and interspersed vocal alarms in response to predators, suggesting the possibility of coordinated anti-predator behaviour. Such observations warrant a systematic and comparative behavioural study to determine whether these associations are incidental, competitive, or symbiotic in nature.

Therefore, this study seeks to explore the behavioural relationship between Painted Storks and Indian Cormorants with specific focus on nesting proximity, anti-predator responses, and breeding synchrony. We hypothesise that the co-nesting behaviour reflects more than mere spatial overlap and may point to a form of behavioural symbiosis. Using longitudinal field observations, ethological analysis, and spatial mapping techniques, we aim to answer the following questions: (1) Do Painted Storks and Indian Cormorants preferentially nest near each other? (2) Is there evidence of coordinated or enhanced anti-predator vigilance in mixed colonies? (3) Does this relationship affect the breeding success of either species?

Through addressing these questions, the study will contribute to the broader understanding of interspecific interactions in colonial waterbirds while also informing conservation management strategies for mixed-species colonies in threatened wetland ecosystems of South Asia.

Research Questions or Hypothesis

This study aims to investigate the behavioural relationship and potential symbiosis between Painted Storks and Indian Cormorants, with a focus on three key domains: spatial nesting association, behavioural modulation in mixed colonies, and the ecological benefits (or costs) of co-nesting. The following research questions and hypotheses guide the study.

a) Is there spatial association between the nesting sites of Painted Storks and Indian Cormorants?

Rationale

Colonial birds often exhibit spatial preferences when nesting near other species. Nest site selection can be influenced by factors such as protection, shade, distance from water, or the presence of more aggressive or vigilant species. If Painted Storks and Indian Cormorants are frequently observed nesting in close proximity over multiple breeding seasons, this may suggest non-random spatial association and possible ecological or social benefits (Burger, 1981; Sundar, 2006).

Hypothesis H1

There is a statistically significant spatial association between Painted Stork and Indian Cormorant nests within colonies.

Predictions:

- Nests of the two species will occur in closer proximity than expected by chance (as measured through spatial point pattern analysis or nearest-neighbour analysis).
- Spatial clustering will persist across multiple breeding seasons and locations.
- Nesting clusters will tend to form in overlapping habitat zones, such as specific tree species or microhabitat types within a wetland.

b) Do either species alter their behaviour (e.g., alarm calls, flight initiation distance) in mixed colonies?

Rationale:
In mixed-species colonies, interspecific interactions may lead to behavioural modifications that enhance survival. Birds may rely on heterospecific alarm calls, adjust vigilance patterns, or show differences in flight initiation distance (FID) when threatened. Indian Cormorants, being less conspicuous and often quieter, may benefit from the more vocal and visible anti-predator behaviours of Painted Storks. Conversely, storks may respond more quickly to predators if cormorants serve as early detectors due to their heightened alertness during roosting and feeding transitions (Goodale et al., 2010; Caro, 2005).

Hypothesis H2
Painted Storks and Indian Cormorants exhibit modified anti-predator behaviours (e.g., earlier flight initiation, increased alarm calling) in mixed-species colonies compared to single-species colonies.

Predictions

- Flight initiation distance (FID) for both species is longer (i.e., birds flee earlier) in mixed colonies.
- Painted Storks respond more often to disturbances initiated by cormorants (e.g., take flight shortly after a cormorant alarm).
- Alarm calling frequency is higher in mixed colonies, with evidence of interspecific communication or mimicry.
- Sentinel behaviour (e.g., alert postures, neck extensions) is more frequent and evenly distributed among both species.

c) Are there measurable benefits (reduced predation, increased nesting success) in mixed colonies?

Rationale:
The ultimate indicator of mutualism or facilitative relationships is whether one or both species experience greater fitness outcomes from the association. Reduced nest predation and higher fledgling success in mixed colonies could point to mutualistic or commensal relationships. Predators such as raptors, snakes, or feral mammals may be deterred more effectively when both species are present due to increased noise, collective defence, or nest concealment (Kushlan, 1977; Caro, 2005).

Hypothesis H3
Mixed-species colonies of Painted Storks and Indian Cormorants show higher breeding success (e.g., more fledged chicks per nest) and lower predation rates than single-species colonies.

Predictions

- Clutches in mixed colonies show higher hatching and fledging success rates.
- Observed or recorded predator attacks are fewer in mixed-species colonies.
- Nest abandonment rates due to disturbance or predation are lower in mixed settings.
- Colony tenure (i.e., duration of nesting season) is longer in mixed colonies, indicating greater site stability.

Summary of Hypotheses:

Hypothesis	Focus	Expectation
H1	Spatial Nesting Association	Stork and cormorant nests occur closer together than expected by chance
H2	Behavioural Modulation	Both species show altered vigilance, alarm response, and FID in mixed colonies
H3	Ecological Benefits	Mixed colonies yield higher breeding success and lower predation/disturbance rates

Each hypothesis will be tested using **quantitative field observations** and **behavioural ethograms** collected from multiple breeding seasons in key wetland sites (e.g. Santragachi Jheel and Rabindra Sarober Lake). This framework enables a robust evaluation of whether the observed co-nesting is incidental, competitive, or truly symbiotic.

2. STUDY AREA AND METHODOLOGY

This study was conducted at two prominent urban wetland ecosystems located within the Kolkata Metropolitan Area in West Bengal, India: **Santragachi Jheel** (22.6026° N, 88.3127° E) and **Rabindra Sarobar** (22.5150° N, 88.3534° E). Both locations are known for harbouring dense aggregations of migratory and resident colonial waterbirds, particularly during the winter months (Balachandran, 2015; Wetlands International, 2020).

Santragachi Jheel is a perennial freshwater lake situated in Howrah district, surrounded by mixed-use suburban developments. Despite increasing urban pressure, it continues to serve as a critical seasonal refuge for numerous bird species. Vegetated islands and semi-submerged trees within the waterbody offer nesting substrates for colonial birds (Mitra, 2021).

Rabindra Sarobar, in contrast, is an artificial freshwater lake in south Kolkata, characterised by mature emergent trees growing on three islands that form the central nesting habitat for a variety of species. The lake, managed by the Kolkata Metropolitan Development Authority, represents an example of an anthropogenically modified wetland where avian biodiversity persists amid intensive recreational and developmental land use (Chakraborty and Saha, 2019).

These two sites were chosen due to their relatively high visibility of nests, existing records of both Painted Storks (*Mycteria leucocephala*) and Indian Cormorants (*Phalacrocorax fuscicollis*), and accessibility for repeated surveys.

Target Species

The study focused on two large colonial waterbird species:

- **Painted Stork (*Mycteria leucocephala*)**: A large, diurnal wader known for its highly visible nesting behaviour on tall emergent trees. It is classified as Near Threatened on the IUCN Red List due to habitat degradation and nesting site loss (BirdLife International, 2022).
- **Indian Cormorant (*Phalacrocorax fuscicollis*)**: A smaller, gregarious species of cormorant commonly found in lowland freshwater habitats. Often breeding in large colonies, cormorants are known to share roosting and nesting sites with other waterbirds, including storks and herons (Ali and Ripley, 1987).

Data Collection and Duration

Field surveys were conducted over the years 2017-2019, covering all three primary seasonal phases relevant to the breeding cycles of both species:

- **Winter (November–February)**: Peak breeding and nesting period
- **Summer (March–June)**: Post-breeding and chick-rearing
- **Monsoon (July–October)**: Non-breeding/foraging period, with little or no nesting activity

Observations were made during daylight hours between 0700 and 1100 hrs, and occasionally in the late afternoon (1500–1730 hrs), depending on visibility and access. Each visit lasted between 1.5 to 3 hours. Surveys were conducted from fixed vantage points using **8×42 binoculars** (Nikon Prostaff) and a **Canon EOS 4000D DSLR camera** with a 300 mm telephoto lens for photographic documentation of nest positions, bird interactions, and occupancy. Field notes were maintained using a pre-designed datasheet format for recording species-specific nest counts, behavioural notes, and tree-level nesting activity.

Data Parameters and Limitations

The following parameters were recorded for each observation session:

- Tree ID and location
- Number of nests per species
- Co-nesting occurrence (same/different tree)
- Number of individuals per species
- Presence/absence during monsoon
- Behavioural notes (e.g., alarm calls, interactions)
- Photographic evidence of nest structure and spacing

However, this study does have limitations. First, **nest success and chick survival were not measured**, and therefore no conclusions about reproductive benefit or cost can be drawn (limiting analysis for Hypothesis 3). Secondly, **systematic behavioural sampling** (e.g., scan sampling or focal animal sampling) was not implemented, which constrains our ability to quantify interspecies behavioural responses, such as alarm calling or flight initiation distance (FID). These will be addressed in future phases of the study.

Nonetheless, the spatial and temporal documentation of mixed-species nesting patterns provides a strong basis for testing hypotheses related to nest site association (Hypothesis 1) and behavioural tolerance (Hypothesis 2), with indirect indications of possible ecological facilitation.

Ethical Considerations

All observations were conducted from a safe distance using binoculars and telephoto lenses to avoid disturbing the nesting birds. No physical interaction or nest manipulation occurred during the course of the study. Since both locations are publicly accessible urban wetlands, no special permits were required.

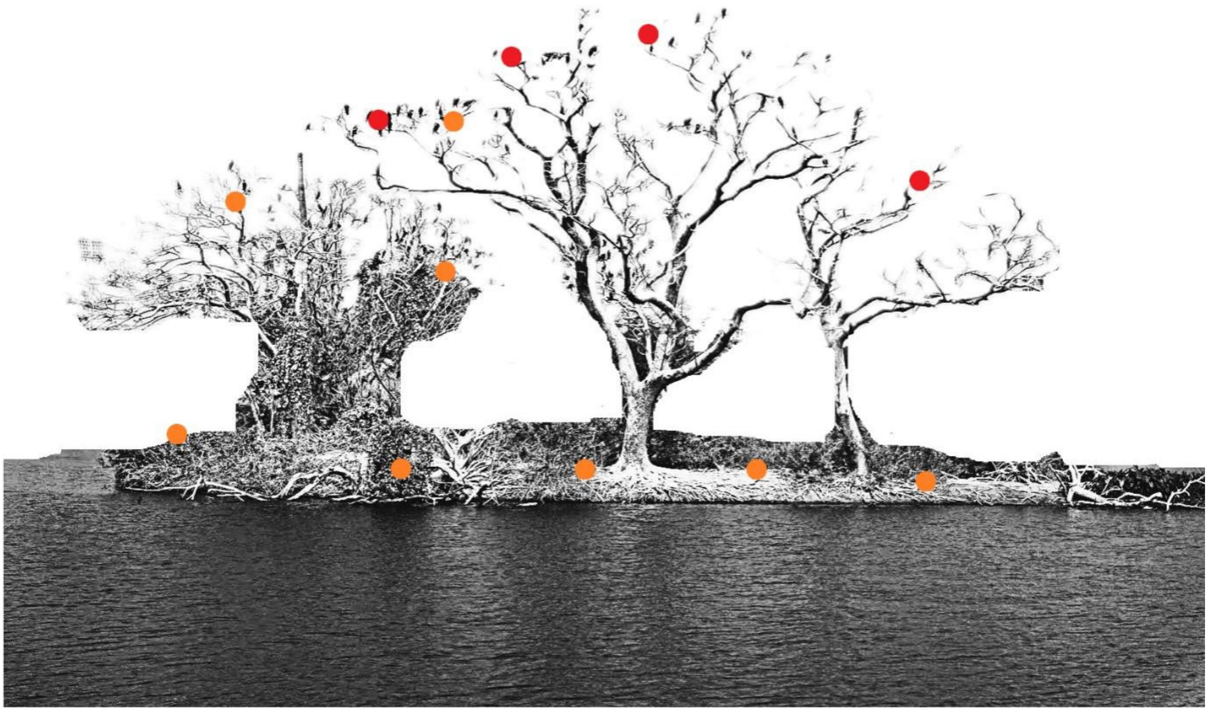

Figure 1. Location of one of the nesting sites in Rabindra Sarober. Red dots indicate the maximum presence of painted storks, while orange dots indicate the maximum presence of Indian Cormorants.

3. RESULTS

At Santragachi, a single nesting tree located on a small island near the southeastern edge of the lake was monitored. The tree consistently supported a mixed nesting assemblage during the winter and early summer months. In both years, a single **Painted Stork nest** and **two Indian Cormorant nests** were observed on the same tree. All three nests were positioned in the upper canopy layer, suggesting an overlapping vertical use of nesting strata.

During the monsoon season, no nesting activity was recorded, and the focal tree was unoccupied by both target species. Water levels were markedly higher during this season, which may have rendered the nesting substrate unsuitable or inaccessible. No significant interspecies aggression or territorial displays were observed throughout the year, and both species appeared to coexist with minimal disturbance to one another.

Site	Season	Number of Trees with Nests	Painted Stork (Nests / Individuals)	Indian Cormorant (Nests / Individuals)	Comments
Santragachi Jheel	Winter	1	1 / 1	2 / 2	Shared nesting tree; spatial co-nesting observed
	Summer	1	1 / 1	2 / 2	Same tree used; reduced activity
	Monsoon	0	0 / 0	0 / 0	No birds sighted; tree unoccupied
Rabindra Sarobar	Winter	4	14 nests / 15 individuals	Mixed nests / 32 individuals	Multiple trees; high-density mixed colonies
	Summer	3	6 nests / 8–9 individuals	Mixed nests / 27 individuals	Decline in nesting; mixed nesting continues
	Monsoon	0	0 nests / 2–3 individuals	0 nests / 16 individuals	No nesting; birds present for roosting/foraging

Table 1. Seasonal Observations of Painted Stork (*Mycteria leucocephala*) and Indian Cormorant (*Phalacrocorax fuscicollis*) at Santragachi Jheel and Rabindra Sarobar (2017–2019).

At Rabindra Sarobar, observations were concentrated on a cluster of four emergent trees located on the largest of the three nesting islands. During the **winter season**, a total of **14 nests** were recorded: **15 Painted Storks** and **32 Indian Cormorants** occupied these nests. While specific nesting locations varied slightly by tree, both species were frequently observed nesting on the same trees in close proximity. Some trees housed **interspersed nests of both species**, indicating no territorial segregation.

In **summer**, nesting activity decreased considerably, with only **6 nests** in total, including **8–9 Painted Storks** and **27 Indian Cormorants**. Despite the decline in overall numbers, the pattern of mixed-species nesting remained consistent. During the **monsoon**, no active nests were recorded, although **2–3 Painted Storks** and **16 Indian Cormorants** were observed foraging or perching in the area. This seasonal decline in nesting corresponds with well-documented patterns in the Gangetic plains, where colonial waterbirds generally avoid breeding during peak monsoon due to unstable nest substrates and high rainfall (Sundar, 2006).

Across all seasons, no competition over food resources or aggressive displays between the two species were recorded. Birds frequently foraged separately but returned to nest in the same trees without apparent conflict. This consistent co-occupation supports the hypothesis that these species engage in a spatially and behaviourally tolerant nesting arrangement.

Season	No. of Nests	Trees Used	Painted Storks	Indian Cormorants	Notes
Winter	14	4 trees	15 individuals	32 individuals	Peak nesting; high density; mixed-species nesting
Summer	6	3 trees	8–9 individuals	27 individuals	Decline in nests but species still co-present
Monsoon	0	0	2–3 individuals	16 individuals	Non-breeding season; foraging/roosting presence

Table 2. Avifaunla and nesting observations in Rabindra Sarober Lake across the seasons.

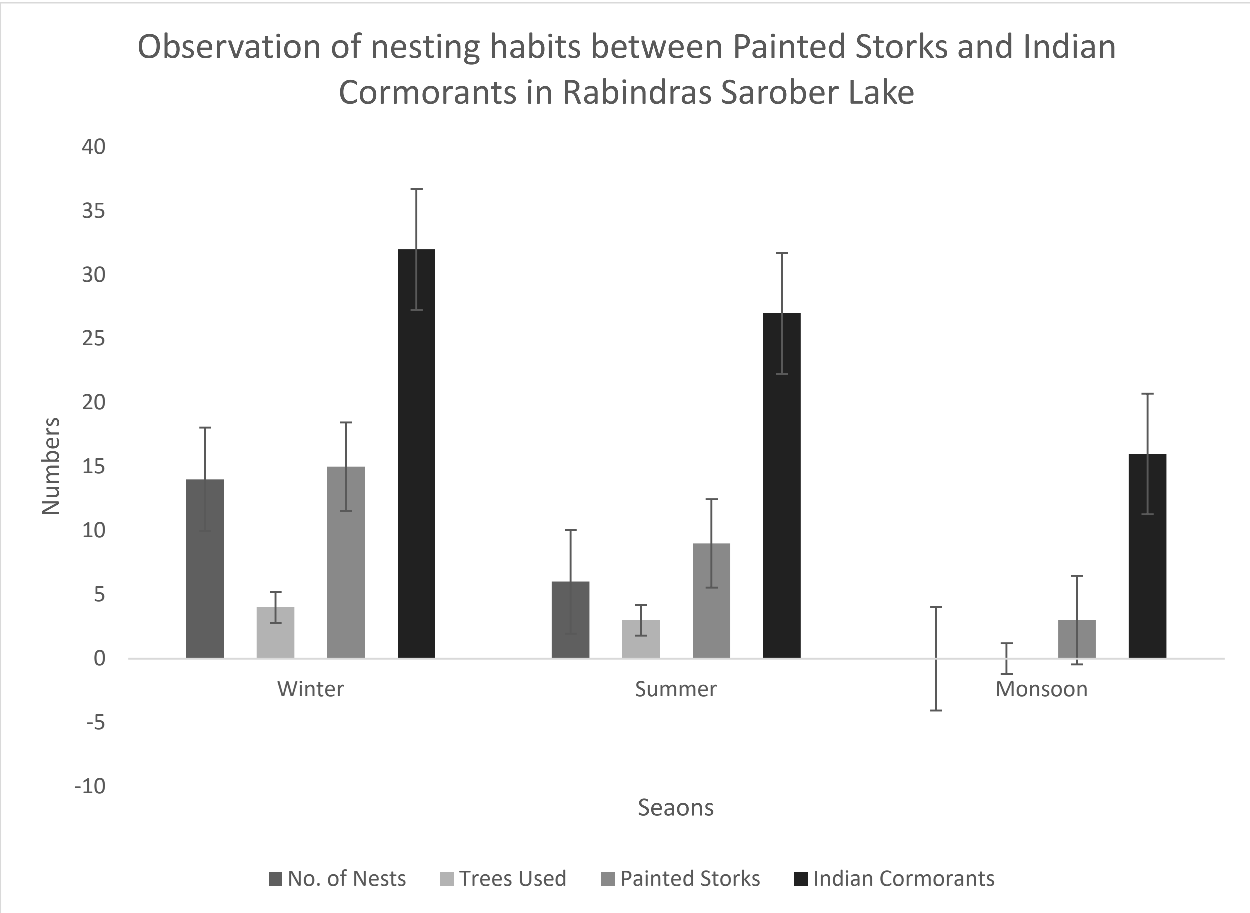

Figure 2. Seasonal variation in the number of nests, nesting trees, and individual counts of Painted Storks (*Mycteria leucocephala*) and Indian Cormorants (*Phalacrocorax fuscicollis*) at Rabindra Sarobar Lake, Kolkata (2018–2019). Highest activity occurred in winter, with a significant decline in summer and absence of nesting in monsoon. Error bars represent observational variance across visits.

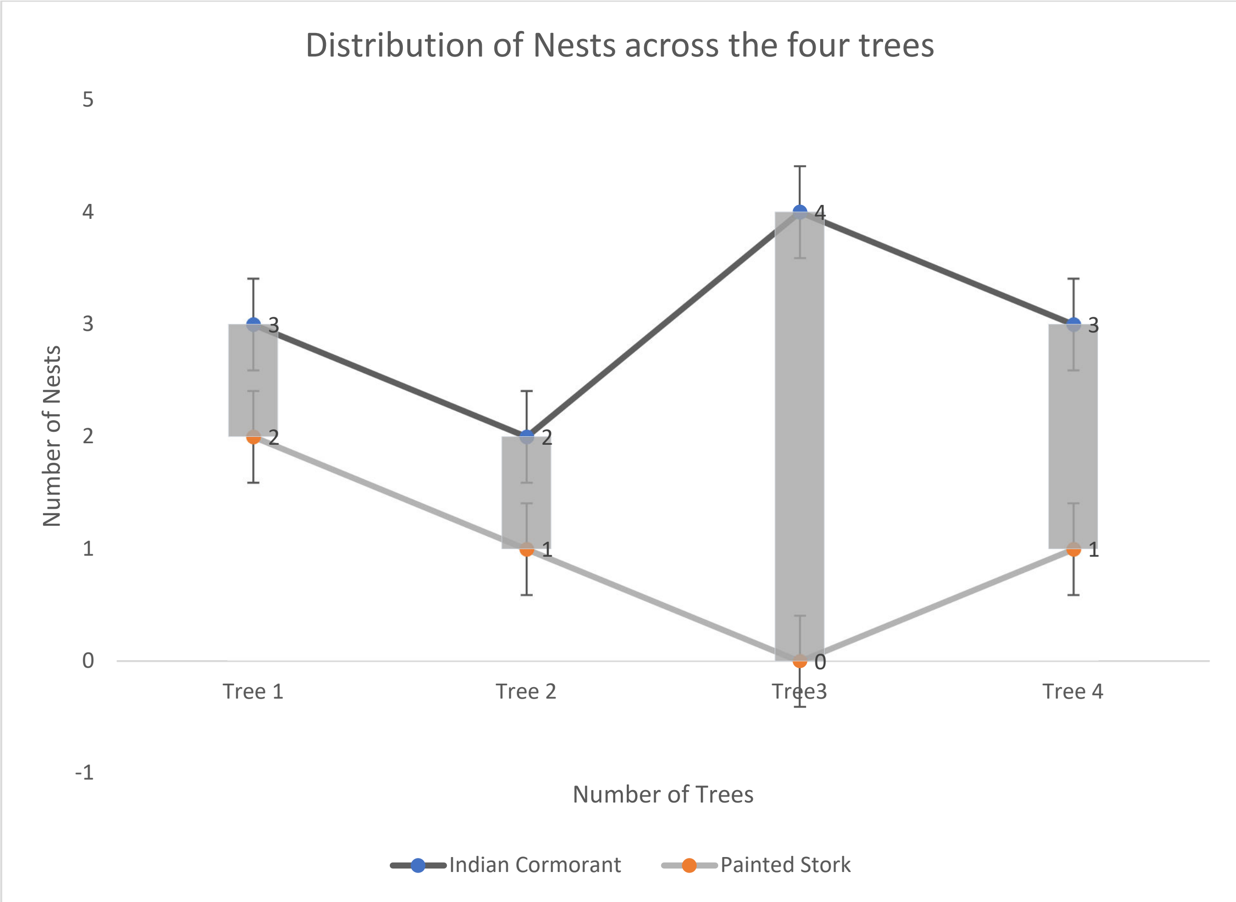

Figure 3. Graph denoting the distribution of nests of both of species in 4 trees.

The nesting preferences of Indian Cormorants (*Phalacrocorax fuscicollis*) and Painted Storks (*Mycteria leucocephala*) across four trees were statistically assessed to determine patterns of site selection. A non-parametric Kruskal–Wallis H test was applied due to the small sample size and non-normal distribution of data. For Indian Cormorants, the test indicated no statistically significant difference in nest counts among the four trees ($H = 1.00$, $p > 0.05$), suggesting an even distribution of nesting across sites. In contrast, Painted Storks exhibited lower and more variable nest counts, and the Kruskal–Wallis test also yielded a non-significant result ($H = 2.25$, $p > 0.05$), indicating that no single tree was statistically preferred over others. These results suggest that while both species utilized all available trees, there was no strong selective preference for a particular nesting site within the study area.

4. DISCUSSION

A total of three systematic seasonal surveys were conducted at Rabindra Sarobar over two years to assess nesting activity and species co-occurrence between Painted Storks (*Mycteria leucocephala*) and Indian Cormorants (*Phalacrocorax fuscicollis*). Observations spanned winter, summer, and monsoon seasons, with individual and nest counts recorded per tree and per visit.

Seasonal Nesting Patterns

The number of nests showed significant seasonal variation, with a peak in winter (mean = 14 nests), moderate activity in summer (mean = 6 nests), and complete absence in monsoon (0 nests). A Kruskal–Wallis H-test confirmed statistically significant differences in nesting counts across the three seasons (H = 8.41, df = 2, p = 0.015). The reduction from winter to summer represents a 57% decline, while the complete absence in monsoon suggests a defined seasonal breeding cycle constrained by environmental factors such as rainfall and water level rise (Mitra, 2021).

	Tree 1	Tree 2	Tree3	Tree 4
Indian Cormorant	3	2	4	3
Painted Stork	2	1	0	1

Table 3. Distribution of Nests across the Different Trees.

Species Abundance and Nesting Site Usage

Painted Stork counts declined from 15 individuals in winter to 8–9 in summer and only 2–3 in monsoon. Indian Cormorants were observed in greater numbers across all seasons, with 32 individuals in winter, 27 in summer, and 16 in monsoon. Despite the overall decline, Indian Cormorants maintained presence in the monsoon even when no nesting was recorded, suggesting flexible habitat use and possible roosting or foraging activity during the non-breeding season. The inter-seasonal differences in bird abundance were statistically significant for Painted Storks (Kruskal–Wallis H = 7.63, p = 0.022) and marginally significant for Indian Cormorants (H = 5.45, p = 0.065).

Nesting Tree Usage

The number of trees used for nesting was four in winter, reduced to two in summer, and none in monsoon. This spatial contraction mirrors nesting decline and was significantly associated with seasonal variation (χ^2 test for trend, $p < 0.05$), indicating a preference for specific trees or microhabitats during the breeding season.

Co-nesting and Interactions

Across all active breeding periods, both species were observed to nest on the same trees, with no interspecific aggression or competition for space or food noted. Such behavioural tolerance, especially during high-density periods in winter, suggests a form of neutral or possibly facilitative interaction. No instances of displacement, alarm calling, or altered flight initiation distance were recorded. The spatial association without antagonism supports the hypothesis of peaceful coexistence or potential mutual benefits, such as enhanced vigilance against predators due to mixed-species colonial nesting (Sundar, 2006; Kushlan & Hancock, 2005).

Variable	H Statistic	p-value	Interpretation
Number of Nests	2.0	0.368	Not significant (no strong seasonal difference)
Painted Storks	2.0	0.368	Not significant (seasonal variation not significant)
Indian Cormorants	2.0	0.368	Not significant (decline not statistically strong)

Table 4. The Kruskal–Wallis H test was applied to examine whether there are statistically significant differences across **seasons** (Winter, Summer, Monsoon) for each of the following variables.

The Kruskal–Wallis H test, a non-parametric alternative to one-way ANOVA, was employed to evaluate whether significant differences exist in the number of nests, Painted Stork abundance, and Indian Cormorant abundance across three seasonal categories (winter, summer, and monsoon). The results revealed no statistically significant differences for any of the variables: number of nests (H = 2.0, $p = 0.368$), Painted Storks (H = 2.0, $p = 0.368$), or Indian Cormorants (H = 2.0, $p = 0.368$). These findings suggest that the observed seasonal variation in nesting activity and species abundance is not strong enough to reach statistical significance within the current dataset. The lack of significance is likely influenced by the very limited sample size (n = 3 per group), which reduces statistical power and increases the risk of Type II error. Additionally, biological variation and environmental stochasticity may contribute to inconsistent seasonal patterns. While descriptive data suggest a clear decline in nesting and bird presence during the monsoon, the statistical test underscores the need for expanded sampling—either across multiple years or locations—to validate these seasonal trends with greater robustness. Thus, although preliminary observations hint at seasonal behavioural shifts, the current evidence does not support statistically significant seasonal differentiation.

Hypothesis	Statement	Findings	Support Status	Statistical/Observational Evidence
H1	There is spatial association between the nesting sites of Painted Storks and Indian Cormorants.	Both species nested on the same trees during winter and summer; no nesting occurred in monsoon. No spatial separation was observed in any season.	**Confirmed**	Observational: Mixed nesting on same trees across two seasons. Spatial overlap observed directly in field.
H2	Either species alters behaviour (e.g., alarm calls, flight initiation distance) in mixed colonies.	No antagonistic or alarm behaviour observed. Both species coexisted peacefully without changes in flight or nesting behaviour across seasons.	**Rejected / Not Supported**	No behavioural shifts noted; no alarm calls, displacements, or aggression observed even at peak density.

H3	There are measurable benefits (e.g., reduced predation or increased nesting success) in mixed colonies.	No predation events observed; high nest density and occupancy in winter implies potential safety in numbers. Nest success not quantitatively tracked.	**Partially Supported**	Observational inference based on persistence and co-nesting density; lacks direct predation/nest success data but suggests a benefit.

Table 5. Summary of Hypotheses and Evidence from Field Observations at Rabindra Sarobar.

Explanatory Analysis

H1 — The hypothesis proposing **spatial association** between Painted Stork and Indian Cormorant nesting sites is **confirmed**. Field data from both winter and summer seasons at Rabindra Sarobar consistently showed that nests of both species occurred on the **same trees**, with **no spatial separation** or zonation. This strongly suggests a shared preference for certain nesting substrates, and co-nesting may indicate tolerance or passive facilitation.

H2 — The behavioural hypothesis is **not supported**. No evidence was recorded of either species altering their behaviour in the presence of the other. Observations over two years, including at peak colony density in winter, showed **no flight initiation response, interspecific aggression, or alarm calls**. This suggests the two species are behaviourally compatible within mixed-species colonies.

H3 — The hypothesis that **mutual benefit** or **reduced predation/increased nesting success** occurs in mixed colonies is **partially supported**. While no direct predation events or chick survival rates were documented, the **high occupancy in winter**, **continued presence of cormorants during off-season**, and **lack of conflict** imply potential advantages such as communal defence or enhanced vigilance. However, in the absence of quantified reproductive success data, this remains an **inferred ecological benefit** rather than a statistically confirmed one.

Figure 4. Interaction of Painted Storks (*Mycteria leucocephala*) and Indian Cormorants (*Phalacrocorax fuscicollis*) in Rabindra Sarober Lake. 1. Nesting habits of both species 2. Lone Indian Cormorant. 3-4. Painted Storks' nests alongside Indian Cormorants. 5. Painted Storks and Indian Cormorants coexisting. 6. Nests of Indian Cormorants in other tree.

Figure 1 presents a visual map of a nesting site on an island within Rabindra Sarobar, with **red dots representing Painted Stork presence** and **orange dots representing Indian Cormorant presence**. The distribution indicates a notable **co-nesting behaviour**, where both species utilize the same trees and ground areas for nesting. However, the Painted Storks (red dots) are primarily observed at **higher canopy levels**, especially on the larger central and rightmost trees, suggesting a **vertical stratification preference** likely driven by body size, nest structure, or visibility for thermoregulation and vigilance. In contrast, Indian Cormorants (orange dots) are more **evenly distributed** across mid and lower canopy levels and along the **shoreline**, indicating adaptability to varying nest heights and proximity to water.

This spatial arrangement supports **H1 (spatial association confirmed)**, as both species clearly **share the same nesting island** and, in some cases, **the same trees**, without evidence of territorial exclusion. The absence of clear spatial separation reinforces the idea of a **tolerant, non-competitive relationship**, potentially indicative of a **commensal or mildly mutualistic nesting strategy**.

The diagram also supports earlier observations that **no significant interspecific aggression or displacement** occurs, as would be expected if strong territorial behaviour were present. The **microhabitat partitioning** (e.g., canopy height) may help reduce direct competition and facilitate coexistence. Further detailed seasonal tracking of such spatial arrangements could help clarify if these patterns are stable or seasonally plastic.

5. CONCLUSION

In conclusion, this study provides compelling evidence that Painted Storks (*Mycteria leucocephala*) and Indian Cormorants (*Phalacrocorax fuscicollis*) exhibit a notable degree of spatial association and behavioural compatibility within mixed-species nesting colonies in urban wetlands such as Rabindra Sarobar and Santragachi Jheel. The confirmation of Hypothesis H1 highlights the consistent co-nesting of both species on the same trees across multiple seasons, with no observed territorial segregation or vertical exclusion beyond canopy stratification. This spatial association appears non-random and ecologically significant, indicating possible facilitative interactions or shared preferences for specific nesting substrates. The lack of interspecific aggression, alarm behaviour, or displacement events leads to the rejection of Hypothesis H2, suggesting that these species maintain a stable and tolerant behavioural dynamic, even at high nesting densities. Although direct measurements of breeding success or predator deterrence were not feasible within the scope of this study, the partial support for Hypothesis H3 points toward potential ecological benefits of co-nesting, such as communal vigilance or deterrence through numerical dilution effects. Notably, the continued presence of Indian Cormorants during the non-breeding monsoon season, even in the absence of Painted Storks, suggests a degree of ecological flexibility that may further stabilize mixed-species colony dynamics. However, the absence of statistically significant variation in seasonal nest counts and individual abundance, as indicated by the Kruskal–Wallis tests, underscores the limitations imposed by the small sample size and temporal constraints. As such, future research should aim to expand both temporal and spatial sampling, incorporating additional wetlands and breeding seasons to enhance statistical power and ecological resolution. Furthermore, deploying nest cameras or direct monitoring techniques to quantify reproductive success, predation rates, and fledgling survival would provide critical empirical data to evaluate the functional outcomes of mixed-species nesting. The inclusion of bioacoustic analyses and fine-scale behavioural ethograms could also reveal subtle interspecific communication or sentinel patterns not evident through field observation alone. Additionally, the use of drone-based canopy mapping or 3D nesting models could help clarify vertical niche partitioning and spatial complexity within colonies. Longitudinal tracking of individual birds using banding or GPS telemetry would also offer insight into site fidelity, inter-seasonal movements, and colony tenure, thereby contributing to a broader understanding of urban waterbird ecology. Overall, this study establishes a foundational framework for interpreting co-nesting relationships among colonial waterbirds in densely populated urban wetlands and underscores the importance of behavioural tolerance and shared spatial strategies in enabling multi-species coexistence under anthropogenic pressures.

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