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Nesting Ecology of the Oriental Darter (*Anhinga melanogaster*) in a Multi-Species Colonial Waterbird Assemblage at Sur Sarovar Bird Sanctuary, Agra

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Abstract

This study examines the nesting ecology of the Oriental Darter (*Anhinga melanogaster*) in a multispecies colonial waterbird assemblage at Sur Sarovar Bird Sanctuary, Agra, Uttar Pradesh. The present study documents the nesting occurrence of Oriental Darter within a multi-species colonial nesting assemblage comprising 13 waterbird species, providing a comparative framework to assess its relative nesting abundance, dominance, and ecological constraints. The breeding ecology of habitat-specialist waterbirds within multispecies colonies provides important insights for wetland conservation.

Surveys conducted during the breeding season in year 2025 recorded seven active breeding sites; however, Oriental Darter nesting was restricted to a single large riparian site dominated by Prosopis juliflora. This site supported 1,239 nests belonging to 13 waterbird species, indicating high species richness but uneven nesting distribution. The Eastern Cattle Egret was the numerically dominant species, contributing 56.1% of total nests, followed by Little Egret (18.7%). In contrast, the Oriental Darter accounted for only 1.5% (19 nests) of the nesting population, reflecting low numerical abundance but strong habitat specialization. Diversity analysis using Shannon–Wiener and Simpson indices revealed moderate species diversity with low evenness, supported by a high Berger–Parker dominance value (d = 0.56). All Oriental Darter nests were located in the upper canopy of Prosopis juliflora trees, emphasizing the importance of vegetation structure, canopy height, and hydrological stability in breeding site selection. The restriction of 100% of darter nesting activity to a single breeding site highlights the species' vulnerability to localized habitat disturbance. These findings underscore the need for site-specific conservation measures focused on protecting structurally complex riparian habitats to sustain breeding populations of the Oriental Darter within multispecies colonial systems.

Keywords-Oriental Darter, breeding ecology, multispecies nesting colony, riparian wetland, Prosopis juliflora, nesting site selection, species dominance.

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Introduction

Colonial nesting is a characteristic reproductive strategy among waterbirds, particularly in wetland ecosystems where suitable nesting substrates and foraging resources are spatially concentrated. Multispecies colonial assemblages represent structurally complex breeding systems in which interspecific interactions, habitat heterogeneity, and resource partitioning collectively influence nesting success and population stability. Investigating nesting ecology within such assemblages provides critical insights into species-specific habitat.

The Oriental Darter (*Anhinga melanogaster*), a large piscivorous waterbird belonging to the family Anhingidae, is widely distributed across South and Southeast Asia and is closely associated with inland freshwater wetlands, reservoirs, and slow-flowing river systems. The species typically nests colonially on trees situated in or adjacent to water bodies and frequently associates with herons, egrets, cormorants, and other piscivorous birds. Despite its broad distribution, the Oriental Darter is categorized as Near Threatened due to ongoing population declines resulting from wetland degradation, hydrological modifications, loss of nesting habitats, and increasing anthropogenic disturbances at breeding sites. Consequently, detailed, site-specific studies on its nesting ecology are essential for understanding its breeding strategies and informing conservation management.

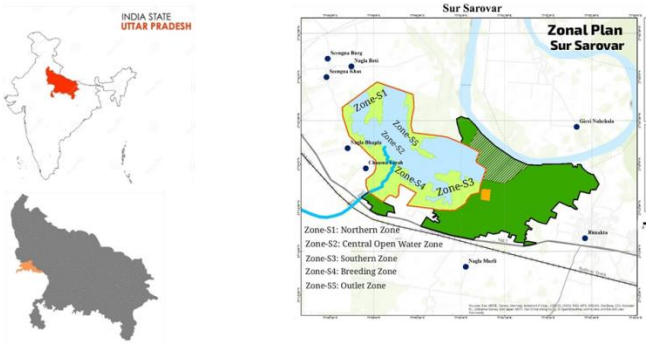
Sur Sarovar Bird Sanctuary constitutes an important inland wetland supporting diverse assemblages of resident and migratory waterbirds. The sanctuary provides favourable breeding conditions through the availability of perennial water, heterogeneous tree cover, and extensive foraging habitats. During the breeding season, Sur Sarovar sustains large multispecies nesting colonies dominated by egrets, cormorants, and darters, thereby functioning as a significant regional breeding site for colonial waterbirds.

Examining the parameters as nest-site selection, vertical and horizontal nest stratification, tree species preference, colony composition, and spatial associations within a multispecies context is crucial for assessing interspecific interactions, habitat sharing mechanisms, and ecological niche differentiation.

The present study examines the nesting ecology of the Oriental Darter within a multispecies colonial waterbird assemblage at Sur Sarovar Bird Sanctuary, Agra. By analyzing nesting patterns, colony structure, and species associations, this study aims to generate baseline ecological data that will contribute to long-term monitoring and conservation planning for colonial waterbirds in inland wetland ecosystems of the Upper Gangetic Plains.

Methods and Material

Study site:-Sur Sarovar Bird Sanctuary (Ramsar site) lies between N27º 14' 4″ and N27º 31' 51″ and longitude E77º 49' 38″ and E77º 52' 40″. The Sanctuary falls administratively under Kiraoli tehsil in Agra revenue district of Uttar Pradesh State. The sanctuary falls under the semi-arid biogeographic division of the Indian subcontinent.



Map of Study Site Sir Sarovar Bird Sanctuary

Survey Timings: Visits were made to the selected sampling site in study area from 15th May-2025 to 15th September 2025 in one shift 8:00 am to 11:00 am in the morning simultaneously after 15-15 days difference.

Survey Techniques: To survey for identifying the nesting site we have applied boating survey method and walking survey method.

The following steps were followed:

Species Identification: Whenever a breeder avifaunal species was observed or heard, its species name was recorded. The assistance of field guides

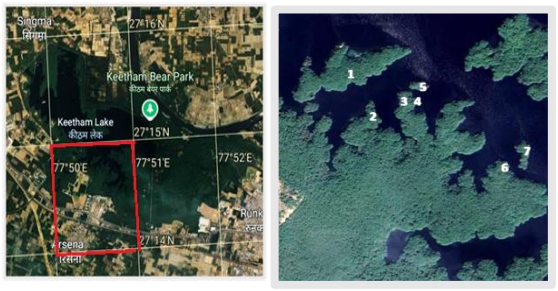
(Grimmett & Inskipp, 2003) and audio recordings was utilized to identify species accurately. Breeder avifaunal species were identified based on their appearance, size, shape, and behaviour. Photographs and video recordings were captured for later analysis.

Visual Observations: Researchers carefully observed the selected nesting sites of study area. Binoculars and DSLR camera were used to aid in identifying birds and count the nest at a distance without disturbing the breeder species.

Nest count: Nest count is theoretically the best measure of breeding population as per Boyd and King (1959) quoted in (Narayanan & Vijayan, 2007). Nests in the heronry were counted for adult bird's presence with or without activities, egg presence and chick presence. Vantage point count method was adopted for breeding bird census in present study.

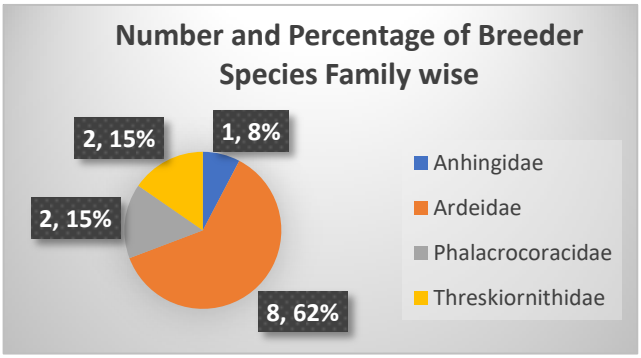
Results and Discussion

Breeding Site Distribution and Species-Specific Nesting



Surveys conducted across Sur Sarovar Bird Sanctuary identified 7 active breeding sites of colonial waterbirds in Zone-S4 of zonal plan of study area during the study period. However, nesting by the Oriental Darter (*Anhinga melanogaster*) was confined to a single breeding site, accounting for 14.3% of the total breeding sites available within the sanctuary. The remaining six sites (85.7%) lacked darter nests and were occupied exclusively by other colonial species.

Nest-Site Selection and Vegetation Association: All Oriental Darter nests were recorded on Prosopis juliflora, a dominant riparian tree species at the occupied breeding site. Statistically, 100% of darter nests were associated with this vegetation type.



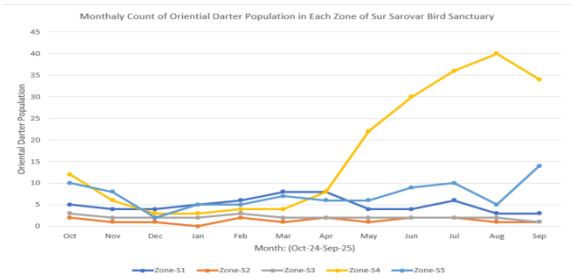
Colony Composition, Nest Abundance, and Dominance Structure

The primary breeding site Zone-S4 supported a multispecies assemblage of 13 waterbird species, with a cumulative total of 1,239 nests, a strong interspecific variation, reflecting a skewed dominance structure typical of mixed colonial systems. The Eastern Cattle Egret (*Ardea coromanda*) was numerically dominant with 695 nests, contributing 56.1% of the total nesting population. The Little Egret (*Egretta garzetta*), with 232 nests, accounted for 18.7%, forming the second most dominant species. Together, these two species comprised 74.8% of all nests, indicating high numerical dominance and a steep rank–abundance gradient. Other species contributed comparatively smaller proportions, including Indian Cormorant (63 nests; 5.1%), Eurasian Spoonbill (55 nests; 4.4%), Grey Heron (53 nests; 4.3%), and Black-crowned Night Heron (49 nests; 4.0%). Minor contributors included Great White Egret (1.9%), Medium Egret (1.4%), Black-headed Ibis (1.2%), and Purple Heron (0.2%). The Oriental Darter, with 19 nests, represented only 1.5% of the total nesting assemblage, its low numerical abundance.

Spatial Organization and Interspecific Associations

Vertical nest stratification was evident within the colony. Oriental Darter nests were primarily positioned in upper canopy strata, frequently overlapping with Indian Cormorant nests (5.1% of total), while smaller-bodied egrets dominated lower and intermediate layers. This spatial segregation reflects effective niche partitioning, reducing direct interspecific competition despite high nesting density.

Breeding Synchrony and Hydrological Stability



Breeding phenology of the Oriental Darter coincided with peak nesting activity of dominant species, indicating temporal synchrony across >90% of the nesting assemblage. This synchrony corresponded with periods of hydrological stability at the Zone-S4 riparian site, ensuring sustained fish availability for piscivorous species.

Constraints on Breeding Site Expansion

Despite the presence of multiple breeding sites, Oriental Darter nesting was restricted to one site (14.3%), suggesting strong ecological constraints on site expansion. Factors likely include insufficient canopy height, low colony size, and reduced structural complexity at other sites.

Nesting Frequency and Relative Contribution of Oriental Darter

The 19 Oriental Darter nests represented approximately 1.5% of the total nesting assemblage, indicating a low relative nesting density compared to dominant ardeids. Despite this limited numerical representation, the consistent presence of Oriental Darter nests confirms the suitability of the study wetland as a breeding habitat for this specialized piscivore.

Shannon–Wiener Diversity and Evenness of Nesting Waterbirds

Using species-wise nest abundance data of 13 colonial waterbird species (N = 1,239 nests), diversity and evenness indices were calculated as follows:

Shannon–Wiener Diversity Index (H′), Calculated Values: H′ = 1.52

Pielou's Evenness Index (J′)- Calculated Values: J′ = 0.59

Species-wise Nest Abundance and Diversity Indices of Colonial Waterbirds

Parameter: Value-Total nesting species (S): 13, Total nests recorded (N): 1,239 ± 20

Shannon–Wiener diversity index (H′): 1.52

Maximum possible diversity (ln S): 2.56

Pielou's evenness index (J′) 0.59

Dominance Structure and Competitive Environment

The dominance pattern of the nesting assemblage was quantified using Simpson's dominance index (D = 0.36) and the Berger–Parker dominance index (d ≈ 0.56), both of which indicate high dominance by a single species, namely the Cattle Egret. Such dominance is characteristic of large colonial breeding sites where habitat conditions strongly favor opportunistic, disturbance-tolerant species. From the perspective of Oriental Darter nesting ecology, high dominance exerts dual and contrasting influences:

Nesting Niche Partitioning

Nesting niche overlap is similarly minimized through vertical stratification of nesting sites. Oriental Darter nests were typically placed at moderate to upper canopy levels, often above dense ardeid nesting layers. This spatial separation: Reduces aggressive encounters, Minimizes nest usurpation, Enhances chick survival through improved microclimate and reduced disturbance. Such structural partitioning allows Oriental Darter to persist even under conditions of extreme numerical dominance by ardeids.

Interpretation for breeding ecology of Sur Sarovar Bird Sanctuary:

The calculated Shannon–Wiener diversity index (H′ = 1.52) indicates a moderate level of nesting diversity, reflecting the presence of multiple breeding species within the study area. However, this moderate diversity value is constrained by the disproportionately high nesting contribution of a few dominant species, particularly Bubulcus ibis and Egretta garzetta.

The Pielou's evenness index (J′ = 0.59) suggests moderate to low evenness in nest distribution, indicating that nesting abundance is unevenly shared

among species. This pattern is characteristic of colonial waterbird assemblages, where ecologically flexible and opportunistic breeders dominate nesting sites, while specialized or disturbance-sensitive species occur at lower densities. The gap between observed diversity (H′ = 1.52) and maximum potential diversity (ln S = 2.56) further highlights the dominance-driven community structure of the nesting assemblage. Such dominance is ecologically significant, as it reflects optimal breeding conditions for generalist species supported by favorable hydrology, prey availability, and nesting substrates. Shannon–Wiener (H′)= 1.52 (Moderate diversity), Shannon Evenness (E)=0.59 (Low–moderate evenness), Simpson's Dominance (D)= 0.36 (High dominance), Berger–Parker (d)= 0.56 (Strong single-species dominance)

Nest occupancy and hatching period by Oriental Darter

At the breeding site of study area Oriental Darter demonstrated prolonged nest occupancy duration of approximately 80–85 days. Observations of all 19 active nests showed that clutch size varied between three and six eggs. The incubation period of Oriental Darter recorded between 25–30 days, and male and female adults both were regularly recorded to attending the nests during the incubation period. During the parenting care the male adults were present near the nest. This biparental participation during incubation and parental caring shows a cooperative breeding strategy adopted by the Oriental Darter in the nesting site of study area.

A. Nesting site no-1 of Oriental Darter in Zone-S4

B. Nesting of Oriental Darter showing Hatching and Parental Caring

Conservation and Ecological Implications

Statistical dominance by generalist egret species, coupled with low proportional representation of the Oriental Darter, highlights the need for habitat-focused conservation strategies rather than species-count-based management. Protection of the primary breeding site, maintenance of mature Prosopis juliflora stands, and stabilization of riparian water regimes are essential for sustaining darter breeding populations. The Oriental Darter's 1.5% nesting contribution, combined with 100% site dependence, positions it as a sensitive bioindicator of wetland structural integrity within Sur Sarovar Bird Sanctuary.

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