



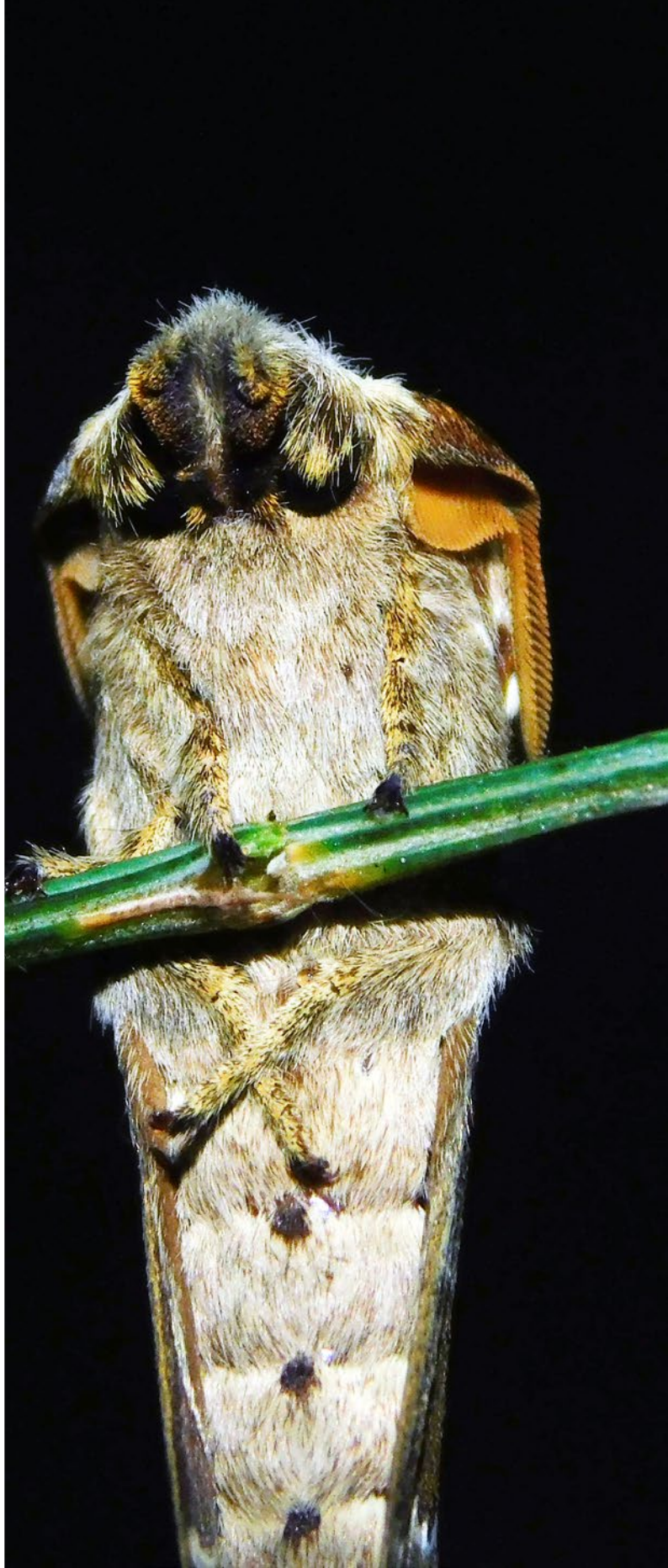
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Unveiling The Avian Tapestry: Study Of Bird Diversity In Kuttichal, Aryanadu, Thiruvananthapuram, Kerala

Geethu Prasannan¹, Razeena Karim. L², Jean Jose. J³, Meera George⁴ and Reji Chandran⁵

¹Research Scholar, Mar Ivanios College, Thiruvananthapuram, Kerala, India. Geethuprasannan1999@gmail.com

²Head of Department and Assistant Professor, Department of Zoology, Christian College, Kattakkada, Kerala, India. razeenakarim@gmail.com

³Assistant Professor, Department of Zoology, St. Gregorios College, Kottarakkara, Kerala, India. jeanlincy@gmail.com

⁴Principal and Assistant Professor, Department of Zoology, Mar Ivanios College, Thiruvananthapuram, Kerala, India. Meera.george@mic.ac.in

⁵WWF Volunteer. Itsreji.chandran@gmail.com

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Abstract:

Understanding bird diversity is a key aspect of ornithology, offering valuable insights into ecosystem health, habitat quality, and biodiversity conservation. A year-long avifaunal survey conducted from December 2023 to December 2024 in Kuttichal, Aryanadu, Thiruvananthapuram documented 59 bird species spanning 14 orders. During the survey a total of 748 birds were recorded, representing a rich diversity of species. The order Coraciiformes was notably abundant, primarily due to high populations of bee-eaters, particularly the Chestnut-headed Bee-eater (*Merops leschenaulti*). Families such as Corvidae, Meropidae, Dicruridae, and Ardeidae were well-represented, with species like the House Crow (*Corvus splendens*), Large-billed Crow (*Corvus macrorhynchos*), Drongos (*Dicrurus macrocerus*), White-cheeked Barbet (*Megalaima viridis*), and Black-hooded Oriole (*Oriolus xanthornus*) recorded in significant numbers. The sightings included Little Egret (*Egretta garzetta*, n=4), Cattle Egret (*Bubulcus ibis*, n=7), Indian Pond Heron (*Ardeola grayii*, n= 4), Purple Heron (*Ardea purpurea*, n= 3), House Crow (*Corvus splendens*, n=75), Jungle Babbler (*Argya striata*, n=8), Rufous Treepie (*Dendrocitta vagabunda*, n=12), Purple-rumped Sunbird (*Cinnyris asiaticus*, n=9), Loten's Sunbird (*Cinnyris lotenius*, n=9), Black Drongo (*Dicrurus macrocerus*, n=5), Ashy Drongo (*Dicrurus leucophaeus*, n=2), Greater Racket-tailed Drongo (*Dicrurus paradiseus*, n=5), Common Myna (*Acridotheres tristis*, n=6), Large-billed Crow (*Corvus macrorhynchos*, n=30), Red-whiskered Bulbul (*Pycnonotus jocosus*, n=14), Crimson-backed Sunbird

(*Leptocoma minima*, n=5), Indian Paradise Flycatcher (*Terpsiphone paradisi*, n=4), Common Tailorbird (*Orthotomus sutorius*, n=6), Malabar Whistling Thrush (*Myophonus horsfieldii*, n=1), Pale-billed Flowerpecker (*Dicaeum erythrorhynchos*, n=5), Golden-fronted Leafbird (*Chloropsis aurifrons*, n=1), Gray Wagtail (*Motacilla cinerea*, n=7), Fork-tailed Drongo-Cuckoo (*Surniculus dicruroides*, n=3), Common Iora (*Aegithina tiphia*, n=6), Blyth's Reed Warbler (*Acrocephalus dumetorum*, n=4), Green Warbler (*Phylloscopus nitidus*, n=8), Indian Golden Oriole (*Oriolus kundoo*, n=3), Black-hooded Oriole (*Oriolus chinensis*, n=4), Asian Brown Flycatcher (*Muscicapa dauurica*, n=3), Little Spiderhunter (*Arachnothera longirostra*, n=2), Indian Pitta (*Pitta brachyura*, n=1), Large-billed Leaf Warbler (*Phylloscopus magnirostris*, n=1), Blue-throated Flycatcher (*Cyornis rubeculoides*, n=1), Nilgiri Flowerpecker (*Dicaeum concolor*, n=1), Ashy Woodswallow (*Artamus fuscus*, n=3), Oriental Magpie Robin (*Copsychus saularis*, n=2), White-throated Kingfisher (*Halcyon smyrnensis*, n=8), Common Kingfisher (*Alcedo atthis*, n=3), Stork-billed Kingfisher (*Pelargopsis capensis*, n=6), Chestnut-headed Bee-eater (*Merops leschenaultii*, n=289), Black Kite (*Milvus migrans*, n=21), Brahminy Kite (*Haliastur indus*, n=18), Shikra (*Accipiter badius*, n=3), Oriental Honey-buzzard (*Pernis ptilorhynchus*, n=1), Rock Pigeon (*Columba livia*, n=27), Spotted Dove (*Spilopelia chinensis*, n=3), Grey-fronted Green Pigeon (*Treron affinis*, n=1), Greater Coucal (*Centropus sinensis*, n=12), Asian Koel (*Eudynamis scolopaceus*, n=15), White-cheeked Barbet (*Megalaima viridis*, n=16), Black-rumped Flameback (*Dinopium benghalense*, n=5), Asian Palm Swift (*Cypsiurus balasiensis*, n=12), Jungle Owlet (*Glaucidium radiatum*, n=8), White-breasted Waterhen (*Amaurornis phoenicurus*, n=6), Little Cormorant (*Microcarbo niger*, n=11), Indian Cormorant (*Phalacrocorax fuscicollis*, n=2), Malabar Grey Hornbill (*Ocyrceros griseus*, n=9), Rose-ringed Parakeet (*Psittacula kramera*, n=8) and Little Grebe (*Tachybaptus ruficollis*, n=2).

The presence of nesting sites for Chestnut-headed Bee-eaters highlights the ecological importance of the area as a breeding habitat. The prevalence of insectivorous species, including drongos, bee-eaters, and ground feeders such as Jungle Babblers and Common Mynas, indicates a robust and balanced ecosystem. Observations also revealed complex trophic interactions, underscoring the ecological richness and biodiversity of the region.

Keywords

Bird diversity, Aryanadu, Distribution of birds.

Introduction

Birds are an integral component of ecosystems worldwide, playing a vital role in maintaining biodiversity and ecosystem health (Singh et al., 2018). As sensitive indicators of environmental changes, birds contribute significantly to various ecological functions, including pollination, seed dispersal, and disease regulation (Stevenson & Fanshawe, 2002). Their ecological importance extends to biomass recycling, waste reduction, and ecosystem resilience, underscoring the crucial role birds play in maintaining the delicate balance of ecosystems.

Free-ranging birds, including migratory species, may act as long-distance carriers of diverse microorganisms capable of transmission to humans (Nuttall PA., 1997). Birds serve as bioindicators of healthy ecosystems, reflecting environmental quality and providing valuable insights into the overall health of ecosystems (Mistry et al., 2008; Slabbekoorn & Ripmeester, 2008). Insectivorous species and raptors regulate disease vectors, such as mosquitoes and rodents, which helps to maintain ecosystem balance. Scavenger birds contribute to biomass recycling and waste reduction, highlighting the importance of these birds in maintaining ecosystem cleanliness. Frugivorous birds facilitate seed dispersal, allowing plant species to propagate and maintain ecosystem diversity. Sunbirds, with their specialized beaks, participate in plant pollination, demonstrating the intricate relationships between birds and plants in maintaining ecosystem health (Judd et al., 2008).

As human activities continue to impact ecosystems, understanding the complex relationships between birds and their environments is critical for developing effective conservation strategies. Human activities, such as urbanization, habitat destruction, and pollution, pose significant threats to bird populations worldwide (Butchart et al., 2010). Understanding ecological factors controlling bird population stability is crucial for conservation efforts, as these factors can inform strategies aimed at maintaining ecosystem balance and promoting biodiversity (Mola et al., 2021). Urbanization, in particular, affects avian populations, with industrial agents, human behavior, and ecological factors influencing ecological processes and impacting bird populations (Altaf et al., 2012).

Semi-natural ecosystems, formed by human activities, retain significant native elements and are crucial for biodiversity conservation (IUCN, 2000). These ecosystems, which include agricultural landscapes and urban green spaces, provide vital habitat for bird species and support ecosystem services essential for human well-being. The Indian Subcontinent, with its rich cultural and ecological heritage, is home to 1,340 bird species (Ali & Ripley, 1987), highlighting the importance of conservation efforts in this region. Avifaunal diversity studies are essential ecological tools, providing valuable insights into habitat health and fulfilling ecological importance (Helm, 2002). By examining bird populations and their relationships with their environments, researchers can gain a deeper understanding of ecosystem dynamics and develop effective conservation strategies. Ornithological research contributes significantly to scientific advancement, with birds serving as indicators of ecosystem health and providing valuable insights into the impacts of environmental change (Bilgrami, 1995).

Baseline information, such as faunal checklists, is essential for conservation planning and policy-making (Kumar et al., 2005). By documenting bird species and their habitats, researchers can identify areas of high conservation value and develop effective strategies for protecting these areas. Bird counting and monitoring are crucial for predicting ecological health and productivity, providing valuable insights into the impacts of environmental change and informing conservation efforts (Unfi et al., 2005).

Understanding bird distribution and abundance is crucial for effective conservation strategies, as this information can inform habitat management and restoration efforts. This study investigates avian diversity in Aryanad, an agricultural village, providing valuable insights into the ecological importance of bird populations in this region. This study endeavors to shed light on the unexplored avifauna of this region.

Materials And Methods

Study Area

Aryanadu

Aryanad, a rural region situated within the Aryanadu Grama Panchayat, under the administrative jurisdiction of Nedumangad Taluk in Thiruvananthapuram District,

Kerala, India, serves as the study area for this research. Geographically, Aryanad is positioned between 8.556° - 8.677° N latitude and 77.071° - 77.224° E longitude, and is characterized as an agricultural village located at the foothills of the Agasthyamalai range of the southern Western Ghats. The region's landscape is dominated by agricultural lands, with coconut, rubber, banana, and various vegetables being the predominant crops. Aryanad's proximity to the Peppara Wildlife Sanctuary adds to its conservation significance, and the Karamana River, which originates in the Western Ghats and flows through the village, serves as a primary source of drinking water for Thiruvananthapuram city. The Aryanad Panchayath shares borders with several neighboring panchayaths, including Uzhamalakkal, Vellanad, Poovachal, Kuttichal, Vithura, and Tholickode, further emphasizing the region's unique cultural and ecological characteristics.

Methodology

A comprehensive field study was conducted in Aryanad from December 2023 to December 2024 to investigate the bird diversity of the selected area, with multiple field visits scheduled throughout each month to ensure thorough data collection. Visual observations, counting and photographing birds were the primary field activities, carried out between 7:30 am and 10:30 am to coincide with peak bird activity, using the naked eye for monitoring and preliminary field identification with color charts from previous research findings. Birds were monitored visually, with undisturbed movements practiced to minimize disturbance, and identifications were confirmed on-site using the field guide published by WWF India, while photographs were taken using a digital camera (Nikon Z6 II) to aid in identification and documentation. Accurate records of observations were maintained, and the data was subsequently submitted to the international bird register, eBird, for further analysis and documentation.

Result

The study, conducted over a 12-month period from December 2023 to December 2024 in Kuttichal, Aryanadu, Thiruvananthapuram, yielded a total of 59 bird species belonging to 14 orders. The sightings included Little Egret (*Egretta garzetta*, n=4), Cattle Egret (*Bubulcus ibis*, n=7), Indian Pond Heron (*Ardeola*

grayii, n=4), Purple Heron (*Ardea purpurea*, n=3), House Crow (*Corvus splendens*, n=75), Jungle Babbler (*Argya striata*, n= 8), Rufous Treepie (*Dendrocitta vagabunda*, n=12), Purple-rumped Sunbird (*Cinnyris asiaticus*, n=9), Loten's Sunbird (*Cinnyris lotenius*, n=9), Black Drongo (*Dicrurus macrocerus*, n=5), Ashy Drongo (*Dicrurus leucophaeus*, n= 2), Greater Racket-tailed Drongo (*Dicrurus paradiseus*, n=5), Common Myna (*Acridotheres tristis*, n=6), Large-billed Crow (*Corvus macrorhynchos*, n=30), Red-whiskered Bulbul (*Pycnonotus jocosus*, n=14), Crimson-backed Sunbird (*Leptocoma minima*, n=5), Indian Paradise Flycatcher (*Terpsiphone paradisi*, n=4), Common Tailorbird (*Orthotomus sutorius*, n=6), Malabar Whistling Thrush (*Myophonus horsfieldii*, n=1), Pale-billed Flowerpecker (*Dicaeum erythrorhynchos*, n=5), Golden-fronted Leafbird (*Chloropsis aurifrons*, n=1), Gray Wagtail (*Motacilla cinerea*, n= 7), Fork-tailed Drongo-Cuckoo (*Surniculus dicruroides*, n=3), Common Iora (*Aegithina tiphia*, n= 6), Blyth's Reed Warbler (*Acrocephalus dumetorum*, n=4), Green Warbler (*Phylloscopus nitidus*, n=8), Indian Golden Oriole (*Oriolus kundoo*, n=3), Black-hooded Oriole (*Oriolus chinensis*, n=4), Asian Brown Flycatcher (*Muscicapa dauurica*, n=3), Little Spiderhunter (*Arachnothera longirostra*, n=2), Indian Pitta (*Pitta brachyura*, n=1), Large-billed Leaf Warbler (*Phylloscopus magnirostris*, n=1), Blue-throated Flycatcher (*Cyornis rubeculoides*, n=1), Nilgiri Flowerpecker (*Dicaeum concolor*, n=1), Ashy Woodswallow (*Artamus fuscus*, n=3), Oriental Magpie Robin (*Copsychus saularis*, n=2), White-throated Kingfisher (*Halcyon smyrnensis*, n=8), Common Kingfisher (*Alcedo atthis*, n=3), Stork-billed Kingfisher (*Pelargopsis capensis*, n=6), Chestnut-headed Bee-eater (*Merops leschenaultii*, n=289), Black Kite (*Milvus migrans*, n=21), Brahminy Kite (*Haliastur indus*, n=18), Shikra (*Accipiter badius*, n=3), Oriental Honey-buzzard (*Pernis ptilorhynchus*, n= 1), Rock Pigeon (*Columba livia*, n= 27), Spotted Dove (*Spilopelia chinensis*, n=3), Grey-fronted Green Pigeon (*Treron affinis*, n= 1), Greater Coucal (*Centropus sinensis*, n=12), Asian Koel (*Eudynamis scolopaceus*, n=15), White-cheeked Barbet (*Megalaima viridis*, n=16), Black-rumped Flameback (*Dinopium benghalense*, n=5), Asian Palm Swift (*Cypsiurus balasiensis*, n=12), Jungle Owlet (*Glaucidium radiatum*, n=8), White-breasted Waterhen (*Amaurornis phoenicurus*, n=6), Little Cormorant (*Microcarbo niger*, n=11), Indian

Cormorant (*Phalacrocorax fuscicollis*, n=2), Malabar Grey Hornbill (*Ocyrceros griseus*, n=9), Rose-ringed Parakeet (*Psittacula krameria*, n=8) and Little Grebe (*Tachybaptus ruficollis*, n=2). (Table 1). Notably, the order Coraciformes was found to be abundant, largely due to the presence of a large number of bee-eaters. Furthermore, families such as Corvidae, Meropidae, Dicuridae, and Ardeidae were also well-represented, with species like *Corvus splendens*, *Merops leschenaultii*, *Dicrurus macrocerus*, and *Megalaima viridis*, being recorded in abundance .

The survey recorded 75 individuals of the House Crow (*Corvus splendens*), indicating its strong presence in the area. The Chestnut-headed Bee-eater (*Merops leschenaultii*) was the most abundant single species with a remarkable 289 individuals. Among drongos, the Black Drongo (*Dicrurus macrocerus*) numbered 5 individuals, while the White-cheeked Barbet (*Megalaima viridis*) showed a healthy count of 16 individuals.

The study site was also found to be home to a variety of bird species, including the Chestnut-headed bee-eater, House crow, Large-billed crow, and White-cheeked barbet, which were among the major avian representatives in Aryanadu. Additionally, nesting sites of the Chestnut-headed bee-eater were identified in the area.

Observations show the Chestnut-headed Bee-eater (*Merops leschenaultii*) as the most abundant species (289 individuals), reflecting the availability of open areas and perches suitable for aerial insectivores. Dietary guilds were classified as graminivorous, frugi-/nectarivorous, insectivorous, and carnivorous/scavenger: Graminivorous: House Crow (75), Large-billed Crow (30), Rock Pigeon (27), Spotted Dove (3) → 4 key species. Frugi-/nectarivorous: Sunbirds and Flowerpeckers (*Cinnyris asiaticus*, *C. lotenius*, *Leptocoma minima*, *Dicaeum erythrorhynchos*, *D. concolor*) → 5 species. Insectivorous: Drongos, Tailorbirds, Flycatchers, Ioras, Warblers (e.g., *Dicrurus macrocerus*, *Orthotomus sutorius*, *Muscicapa dauurica*, *Phylloscopus nitidus*) → 18 species. Carnivorous/Scavengers: Kites, Shikra, Cormorants (*Milvus migrans*, *Haliastur indus*, *Accipiter badius*, *Microcarbo niger*, *Phalacrocorax fuscicollis*) → 5 species.

The abundance of insectivorous bird species, such as bee-eaters, drongos, and ground feeders like Jungle babblers and Common mynas, indicated a



healthy ecosystem. The recorded bird species exhibited complex food web relationships, which were observed throughout the study period.

Simpson index = $1 - D = 1 - 0.167627041 = 0.8323$

The Simpson biodiversity index of the site was calculated to be 0.8323 (Table 2), indicating a high level of bird richness in Kuttichal, Aryanadu, Thiruvananthapuram.

WHAT ARE THE VALUES FOR OTHER

BIODIVERSITY INDICES INCLUDING RICHNESS

Additional Biodiversity Indices: Shannon–Wiener index (H') = 2.84, Species richness (S) = 59, Pielou's evenness (J) = 0.70.

Graph 1:

Graph showing order wise distribution of birds recorded during study period at Aryanadu, Thiruvananthapuram.

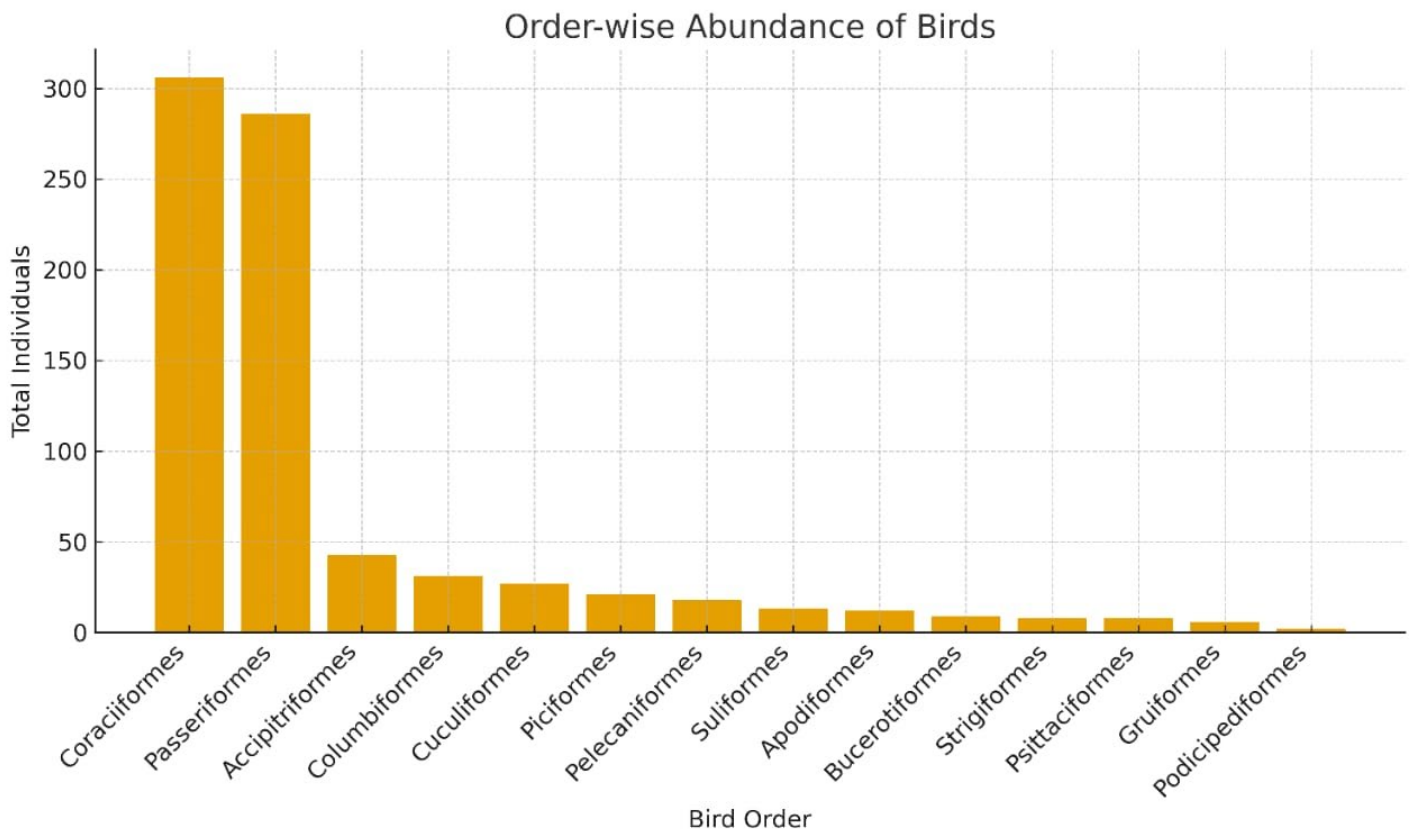


Table 1 showing order,common name, scientific name and distribution of birds during the study period in Aryanadu ,Thiruvananthapuram

Sl no	Order	Common name	Scientific name	Pre monsoon count	Monsoon count	Post monsoon count	Total
1	Pelecaniformes	Little Egret	<i>Egretta garzetta</i>	2	0	2	4
		Cattle Egret	<i>Bubulcus ibis</i>	3	0	4	7
		Indian Pond Heron	<i>Aedeola grayii</i>	1	0	3	4
		Purple Heron	<i>Ardea purpurea</i>	1	0	2	3
2	Passeriformes	House Crow	<i>Corvus splendens</i>	14	5	56	75
		Jungle Babbler	<i>Argya striata</i>	1	0	7	8
		Rufous Treepie	<i>Dendrocitta vagabunda</i>	4	1	7	12
		Purple-rumped Sunbird	<i>Cinnyris asiaticus</i>	3	2	4	9
		Loten's Sunbird	<i>Cinnyris lotenius</i>	4	0	5	9
		Black Drongo	<i>Dicrurus macrocerus</i>	2	1	2	5
		Ashy Drongo	<i>Dicrurus leucophaeus</i>	0	0	2	2
		Greater Racket- tailed Drongo	<i>Dicrurus paradiseus</i>	0	1	4	5
		Common Myna	<i>Acridotheres tristis</i>	0	1	5	6
		Large-billed Crow	<i>Corvus macrorhynchos</i>	3	1	26	30
		Red-whiskered Bulbul	<i>Pycnonotus jacosus</i>	4	0	10	14
		Crimson-backed Sunbird	<i>Leptocoma minima</i>	1	1	3	5
		Indian paradise Flycatcher	<i>Terpsiphone paradisi</i>	1	0	3	4
		Common Tailor Bird	<i>Orthotomus sutorius</i>	1	1	4	6
		Malabar Whistling Thrush	<i>Myophonus horsfieldii</i>	0	0	1	1
		Pale-billed Flowerpecker	<i>Dicaeum erythrorhynchos</i>	2	1	2	5
		Golden- fronted Leaf bird	<i>Choropsis aurifrons</i>	0	0	1	1
		Gray Wagtail	<i>Motacilla cinerea</i>	0	0	7	7
		Fork -tailed Drongo Cuckoo	<i>Surniculus dicruroids</i>	0	0	3	3
		Common Iora	<i>Aegithina tiphia</i>	2	0	4	6
		Blyth's Reed Warbler	<i>Acrocephalus dumetorum</i>	2	0	2	4
		Green Warbler	<i>Phylloscopus nitidus</i>	3	0	5	8
		Indian Golden Oriole	<i>Oriolus kundoo</i>	1	0	2	3
		Black Hooded Oriole	<i>Oriolus chinensis</i>	1	1	2	4
		Asian Brown Flycatcher	<i>Muscicapa dauurica</i>	0	0	3	3
		Little Spider Hunter	<i>Arachnothera longirostra</i>	0	0	2	2
		Indian Pitta	<i>Pitta brachyura</i>	0	0	1	1
		Large- billed Leaf Warbler	<i>Phylloscopus magnirostris</i>	0	0	1	1
Blue -throated Flycatcher	<i>Cyornis rubeculoides</i>	0	0	1	1		
Nilgiri Flowerpecker	<i>Dicaeum concolor</i>	0	0	1	1		
Ashy Woodswallow	<i>Artamus fuscus</i>	3	0	0	3		

Sl no	Order	Common name	Scientific name	Pre monsoon count	Monsoon count	Post monsoon count	Total
		Oriental magpie -Robin	<i>Copsychus saularis</i>	0	0	2	2
3	Coraciformes	White-throated Kingfisher	<i>Halycon smyrnensis</i>	3	1	4	8
		Common Kingfisher	<i>Alcedo atthis</i>	1	1	1	3
		Stork -billed Kingfisher	<i>Pelargopsis capensis</i>	2	1	3	6
		Chestnut Headed Bee eater	<i>Merops leschenaultia</i>	100	2	187	289
4	Accipitriformes	Black Kite	<i>Milvus migrans</i>	18	0	3	21
		Brahminy Kite	<i>Haliastur indus</i>	8	1	10	18
		Shikra	<i>Accipiter badius</i>	0	0	3	3
		Oriental Honey Buzzard	<i>Pernis ptilorhynchus</i>	0	0	1	1
5	Columbiformes	Rock Pigeon	<i>Columba livia</i>	2	1	24	27
		Spotted Dove	<i>Spilopelia chinensis</i>	0	0	3	3
		Grey-fronted green pigeon	<i>Treron affinis</i>	0	0	1	1
6	Coculiformes	Greater Coucal	<i>Centropus sinensis</i>	3	1	6	12
		Asian Koel	<i>Eudynamys scolopaeceus</i>	4	1	10	15
7	Piciformes	White -cheeked Barbet	<i>Megalaima viridis</i>	5	1	10	16
		Black Rumped Flameback	<i>Dinopium benghalense</i>	1	1	3	5
8	Apodiformes	Asian Palm Swift	<i>Cypsiurus balasiensis</i>	0	0	12	12
9	Strigiformes	Jungle Owlet	<i>Glaucidium radiatum</i>	2	0	6	8
10	Gruiformes	White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	3	0	3	6
11	Suliformes	Little Cormorant	<i>Microcabo niger</i>	2	0	9	11
		Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	1	0	1	2
12	Bucerotiformes	Malabar Gray Hornbill	<i>Ocyrceros griseus</i>	3	0	6	9
13	Psittaciformes	Rose -ringed Parakeet	<i>Psittacula krameria</i>	0	1	7	8
14	Podicipediformes	Little Grebe	<i>Tachybaptus ruficollis</i>	0	0	2	2

Table 2 showing Simpson index of birds recorded during study period in Aryanadu, Thiruvananthapuram.

Sl no	Common name	Total	n/N	(n/N) ²
1	Little Egret	4	0.0053475935828	0.000028596751
2	Cattle Egret	7	0.0093582887700	0.000012511081
3	Indian Pond Heron	4	0.0053475935828	0.000028596751
4	Purple Heron	3	0.0040106951871	0.000016085675
5	House Crow	75	0.1002673796791	0.010053547427
6	Jungle Babbler	8	0.0106951871657	0.000114387028
7	Rufous Treepie	12	0.0160427807486	0.000257370814
8	Purple-rumped Sunbird	9	0.0120320855614	0.000144771108
9	Loten's Sunbird	9	0.0120320855614	0.000144771108
10	Black Drongo	5	0.0066844919786	0.000044682433
11	Ashy Drongo	2	0.0026737967914	0.000007149189
12	Greater Racket- tailed Drongo	5	0.0066844919786	0.000044682433
13	Common Myna	6	0.0080213903743	0.000064342703
14	Large -billed Crow	30	0.0401069518716	0.001608567588
15	Red whiskered Bulbul	14	0.0187165775401	0.000350310274
16	Crimson -backed Sunbird	5	0.0066844919786	0.000044682433
17	Indian Paradise Flycatcher	4	0.0053475935828	0.000028596751
18	Common Tailor Bird	6	0.0080213903743	0.000064342703
19	Malabar Whistling Thrush	1	0.0013368983957	0.000001787297
20	Pale -billed Flowerpecker	5	0.0066844919786	0.000044682433
21	Golden -fronted Leaf bird	1	0.0013368983957	0.000001787297
22	Gray Wagtail	7	0.0093582887700	0.000012511081
23	Fork -tailed Drongo Cuckoo	3	0.0040106951871	0.000016085675
24	Common Iora	6	0.0080213903743	0.000064342703
25	Blyth's reed Warbler	4	0.0053475935828	0.000028596751
26	Green Warbler	8	0.0106951871657	0.000114387028
27	Indian Golden Oriole	3	0.0040106951871	0.000016085675
28	Black Hooded Oriole	4	0.0053475935828	0.000028596751
29	Asian Brown Flycatcher	3	0.0040106951871	0.000016085675

Sl no	Common name	Total	n/N	(n/N) ²
30	Little Spider Hunter	2	0.0026737967914	0.000007149189
31	Indian Pitta	1	0.0013368983957	0.000001787297
32	Large -billed leaf warbler	1	0.0013368983957	0.000001787297
33	Blue Throated Flycatcher	1	0.0013368983957	0.000001787297
34	Nilgiri Flowerpecker	1	0.0013368983957	0.000001787297
35	Ashy woodswallow	3	0.0040106951871	0.000016085675
36	White- throated Kingfisher	8	0.0106951871657	0.000114387028
37	Common Kingfisher	3	0.0040106951871	0.000016085675
38	Stork -billed Kingfisher	6	0.0080213903743	0.000064342703
39	Chestnut -headed bee-eater	289	0.3863636363	0.1492768594
40	Black Kite	21	0.0280748663101	0.000788198118
41	Brahminy Kite	18	0.0240641711229	0.000579084331
42	Shikra	3	0.0040106951871	0.000016085675
43	Oriental Honey Buzzard	1	0.0013368983957	0.000001787297
44	Rock Pigeon	27	0.0360962566844	0.001302939746
45	Spotted Dove	3	0.0040106951871	0.000016085675
46	Grey-fronted green pigeon	1	0.0013368983957	0.000001787297
47	Greater Coucal	10	0.0133689839	0.000178729730
48	Asian Koel	15	0.0200534759358	0.000402141897
49	White- cheeked barbet	16	0.0213903743315	0.000457548114
50	Black- rumped flameback	5	0.0066844919786	0.000044682433
51	Asian Palm Swift	12	0.0160427807486	0.000257370814
52	Jungle Owlet	8	0.0106951871657	0.000114387028
53	White -breasted waterhen	6	0.0080213903743	0.000064342703
54	Little Cormorant	11	0.0147058823529	0.000216262975
55	Indian Cormorant	2	0.0026737967914	0.000007149189
56	Malabar Gray Hornbill	9	0.0120320855614	0.000144771108
57	Rose -ringed parakeet	8	0.0106951871657	0.000114387028
58	Little Grebe	2	0.0026737967914	0.000007149189
59	Oriental magpie- robin	2	0.0026737967914	0.000007149189
Total		748		0.167627041

Photographs showing the family wise important birds in the site

Family: Corvidae



Rufous Treepie
(*Dendrocitta vagabunda*)

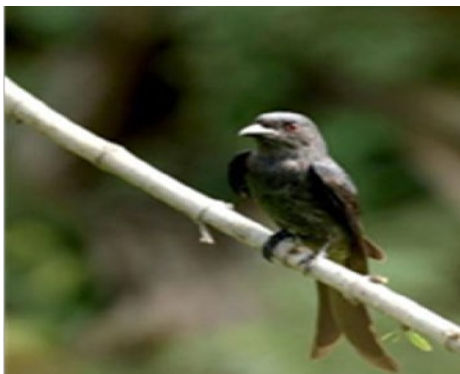


House crow
(*Corvus splendens*)

Family: Dicruroidae

Family: Meropidae

Family: Ardeidae



Ashy drongo
(*Dicrurus leucophaeus*)



Chestnut headed bee eater
(*Merops leschenaultia*)



Indian Pond Heron
(*Ardeola grayii*)

Family: Cuculidae



Greater Coucal
(*Centropus sinesnsis*)



Asian koel
(*Eudynamys scolopaceus*)

Family: Accipitridae



Shikra
(*Accipiter badius*)



Brahminy kite
(*Haliastur indus*)

Family: Sturnidae



Common myna
(*Acridotheres tristis*)

Discussion

A comprehensive avifaunal survey conducted in Kuttichal, Aryanadu, Thiruvananthapuram, yielded a total of 59 bird species belonging to 14 orders. The calculated Simpson's biodiversity index (0.8323) indicates a high level of avian diversity at the study site in Kuttichal, Aryanadu. Similarly, the Shannon–Wiener index ($H' = 2.84$) reflects substantial species heterogeneity, while a Pielou's evenness value of 0.70 suggests a moderately balanced distribution of individuals among the 59 recorded species. Collectively, these indices demonstrate that the site supports a rich and relatively evenly distributed bird community. The dietary preferences of birds in our study are encompassing four primary categories: graminivorous; frugi and nectarivorous; and carnivorous and scavengers.

The study documented 59 bird species comprising 748 individuals across 14 orders in Kuttichal, Aryanadu. Observations show the Chestnut-headed Bee-eater (*Merops leschenaultii*) as the most abundant species (289 individuals), reflecting the availability of open areas and perches suitable for aerial insectivores. Dietary guilds were classified as graminivorous, frugi-/nectarivorous, insectivorous, and carnivorous/scavenger: Graminivorous: House Crow (75), Large-billed Crow (30), Rock Pigeon (27), Spotted Dove (3) → 4 key species. Frugi-/nectarivorous: Sunbirds and Flowerpeckers (*Cinnyris asiaticus*, *C. lotenius*, *Leptocoma minima*, *Dicaeum erythrorhynchos*, *D. concolor*) → 5 species. Insectivorous: Drongos, Tailorbirds, Flycatchers, Ioras, Warblers (e.g., *Dicrurus macrocerus*, *Orthotomus sutorius*, *Muscicapa dauurica*, *Phylloscopus nitidus*) → 18 species. Carnivorous/Scavengers: Kites, Shikra, Cormorants (*Milvus migrans*, *Haliastur indus*, *Accipiter badius*, *Microcarbo niger*, *Phalacrocorax fuscicollis*) → 5 species.

Conclusion

Avian diversity study in Aryanadu recorded a total of 59 species belonging 15 families and 14 orders. Simpson's biodiversity index was calculated as 0.8323 where as Shannon-Wiener index $H' = 2.84$. Pielou's evenness value was found to be 0.70. The abundance analysis showed that Chestnut-headed Bee-eater is found to be prominent in the study area. These quantitative findings highlights the richness and diversity of bird communities in the agricultural

landscape of Aryanadu.

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Spatial Distribution and Diversity of Avian Communities in Prayagraj, India: Influence of Land Use Patterns

Shimant Mehta^{1*}, Ekta Pathak Mishra², Anuj Kumar Banarya³

¹Department of Forest Biology, Tree Improvement and Wildlife Sciences, College of Forestry, SHUATS, Prayagraj.

²Assistant Professor, Department of Environmental Sciences, College of Forestry, SHUATS, Prayagraj.

³Department of Forest Biology, Tree Improvement and Wildlife Sciences, College of Forestry, SHUATS, Prayagraj.

*shimantmehta4@gmail.com (Corresponding Author)

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Abstract

The study records the spatial distribution and the bird diversity found in a variety of land use categories in Prayagraj, Uttar Pradesh, India. The research was conducted by point count and line transects methods performed at seven sites with different disturbance levels. A total of 113 bird species were observed, belonging to 18 orders and 48 families.

A total of 113 bird species belonging to 48 families and 18 orders were recorded, with the highest richness observed in moderately disturbed habitats such as Arail and Jagdishpur. Together, PC1 and PC2 explained approximately 78% of the total variation, indicating strong community structuring along disturbance gradients. Redundancy Analysis (RDA) identified canopy cover and water proximity as the most influential environmental variables, collectively explaining 58.9% of the total variation ($p < 0.05$). Sites with greater canopy cover and proximity to water supported higher species richness, whereas sites with increased human disturbance had lower diversity.

These findings demonstrate the role of the riparian and semi-natural habitats in the sustenance of the urban biodiversity and the need for the protection of moderately disturbed areas and reducing identified disturbance in the rapidly expanding urban outskirts.

These findings demonstrate the role of riparian and semi-natural habitats in sustaining urban biodiversity and emphasize the need to protect moderately disturbed areas while mitigating anthropogenic disturbances in the rapidly expanding urban outskirts.

Introduction

Urban expansion is widely perceived to be one of the main causes of habitat degradation and biodiversity

loss due to its disruption of ecological connectivity and change in composition of biological communities (Joshi, 2001; Kath *et al.*, 2009). Birds, highly diverse in ecology, tropically specialized and sensitive to change in the environment, are powerful bio-indicators of habitat quality and anthropogenic disturbance (Bezzel, 1985). Habitat fragmentation, green space availability, and urban edge effects have direct effects on the avian diversity, usually favoring generalist and invasive species in place of specialists (Weiss *et al.*, 2003; Piorek *et al.*, 2014).

This present study was carried out in the culturally and ecologically important Prayagraj city of Uttar Pradesh, India, which is situated at the junction of two rivers, Ganga and Yamuna. Prayagraj was chosen because it comprises disturbed urban areas, agricultural edges and riparian corridors that provide important stopover sites for migratory water birds and habitat for threatened species such as Indian Skimmer (*Rynchops albicollis*) and Egyptian Vulture (*Neophron percnopterus*). The riverine systems and the surrounding floodplains support critical nesting and foraging habitat for the city's high avian diversity.

The objective of this study is to investigate the relationship between habitat structure, land use patterns, and human disturbance with bird species composition and richness in Prayagraj. Specifically, the objectives aimed were to assess avian species richness and composition along a gradient of seven different habitat types, quantify diversity using ecological indices such as Shannon Diversity Index, Simpson Index, and Evenness and determine the role of environmental variables such as canopy cover, proximity to water, and human activity in shaping community structure through multivariate statistical tools such as Principal Component Analysis (PCA) and Redundancy Analysis (RDA).

This research helps in understanding biodiversity dynamics in rapidly urbanizing regions and highlights the ecological importance of riparian buffers in urban planning and conservation strategies (Fontana, 2011; Abdar, 2013) by focusing on disturbed urban zones as well as relatively undisturbed semi-natural habitats.

Materials and Methodology

Study Area

The study was carried out in the city of Prayagraj,

Uttar Pradesh, India (24°47'N, 81°19'E) a culturally and ecologically important city at the confluence of the Ganga and Yamuna rivers. Riverbanks, institutional campuses, public parks and peri-urban landscapes were selected as seven habitats across the city.

Seven distinct habitat types were selected to represent the range of land-use patterns across Prayagraj: (1) Arail River Bank, (2) Sangam, (3) Jagdishpur, (4) Phaphamau, (5) Sam Higginbottom University of Agriculture, Technology and Sciences Campus, (6) Minto Park, and (7) Company Garden. These sites encompass riverine, semi-natural, peri-urban, and urban green spaces that collectively represent the city's major ecological gradients.

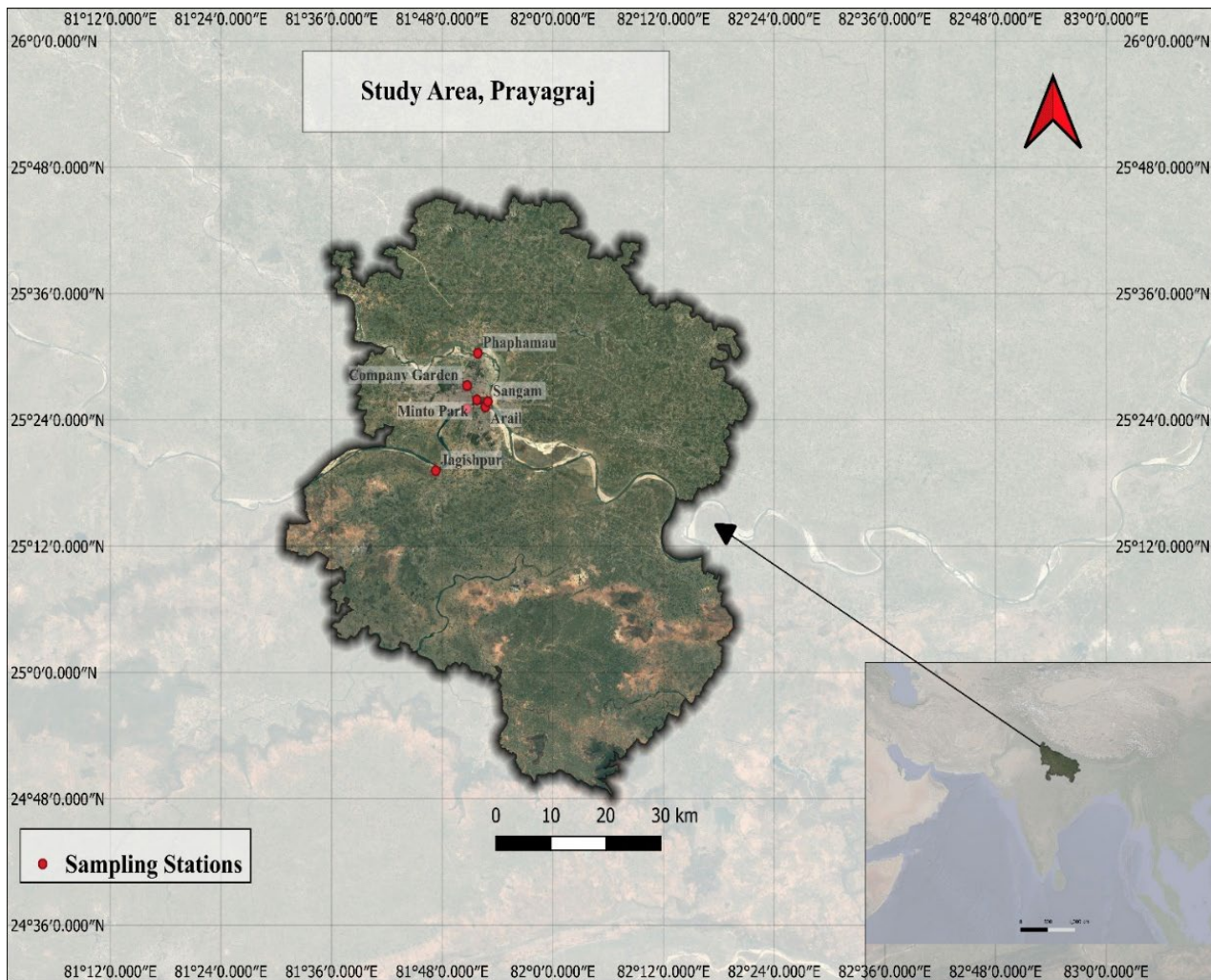
Three environmental variables i.e., canopy cover (%), human disturbance and proximity to water bodies (Shitri *et al.*, 2014) were used to categorize these sites into moderately disturbed (e.g. Arail River Bank, Jagdishpur, Phaphamau) and highly disturbed (e.g., Minto Park, Company Garden, SHUATS Sam Higginbottom University of Agriculture, Technology and Sciences Campus, Sangam) habitats. Study area illustration can be seen within (Fig. 1.).

Disturbance levels were categorized based on three measured variables: canopy cover (%), human disturbance score, and proximity to water bodies (m). Canopy cover was recorded using a spherical densiometer at each sampling point and averaged per site.

Human disturbance was quantified by counting the number of people and vehicles within a 50 m radius during each survey period. Scores were standardized on a 0–10 scale (0 = no activity, 10 = extremely high activity). Proximity to water was calculated using GPS-based distance measurements to the nearest permanent water source. Sites with canopy cover >30% and disturbance score ≤6 were classified as moderately disturbed (Arail, Jagdishpur, Phaphamau), while those with canopy cover <30% and disturbance score >6 were classified as highly disturbed (Minto Park, Company Garden, Sam Higginbottom University of Agriculture, Technology and Sciences Campus).

Data Collection

Point count and line transect surveys were carried out between February and April 2022, as described by (Bibby *et al.*, 2000). Four times, in the morning, mid-morning, afternoon, and evening, each habitat was



(Fig. 1). - Geographical location of Prayagraj and the distribution of seven avian sampling habitats across riverine, semi-natural, and urban landscapes.

surveyed to capture diurnal variation in bird activity. For point counts, a fixed 50m radius was used and point counts made for 10 minutes per point; for line transects, line transects were 3.2– 4.4 km in length and covered broader spatial gradients across the sites.

Each site was surveyed multiple times per month between February and April 2022, resulting in a total of twelve visits per site and 84 site visits overall. Sampling effort varied slightly among months, with 26 surveys in February, 30 in March, and 28 in April, depending on weather conditions and site accessibility. Surveys were conducted during morning, mid-morning, afternoon, and evening sessions to capture daily variation in species activity. This distribution ensured adequate temporal coverage across the study period while maintaining consistency among sites. Visual and acoustic birds were identified with Nikon 10×50 binoculars and Nikon D5600 DSLR camera with a 70–

300mm lens. The species identified were verified from field guides such as Salim Ali's Book of Indian Birds (13th ed.) and (Grimmett *et al.*, 2011). Observational data as well as environmental parameters such as canopy density and water proximity were recorded at each of the points. Canopy density was measured with a spherical densiometer at each sampling point and averaged per site. Proximity to water was measured using a handheld GPS and distances computed to the nearest permanent water body in ArcGIS.

Data Analysis

Standard ecological indices such as Shannon Wiener Index (H'), Simpson's Index (1-D), Evenness (Pielou's Index) and Dominance Index (D) were used to calculate diversity metrics and assess community structure. Margalef's and Menhinick's Indices were used to evaluate species richness.

Bird community structure was analyzed in relation to environmental gradients using OriginPro 2023 (student version) and Principal Component Analysis (PCA) and Redundancy Analysis (RDA). The Principal Component Analysis (PCA) was conducted using three standardized environmental variables recorded across all study sites: canopy cover (%), human disturbance score, and proximity to water (m). These variables were selected for their strong ecological relevance to avian habitat structure and disturbance gradients in the urban-rural landscape of Prayagraj. All variables were standardized (Z-score transformation) before analysis to ensure comparability. To obtain dimensionality reduction, and major patterns in species distribution independent of external variables, PCA was applied as a widely used unconstrained ordination technique (Legendre & Legendre, 1998). Summarizing the variance in fewer principal axes helps in visualizing site level similarities based on species composition (Sharma *et al.*, 2017).

However, RDA, a constrained ordination method, was used to evaluate the amount of variation in avian community composition that could be explained by measured environmental factors such as canopy cover, human disturbance, and water proximity. RDA is a combination of several regression and principal component analysis and is therefore suitable for ecological data when the species–environment relationships are of interest (Ter Braak & Šmilauer, 2002). It provided the key environmental gradients to explain bird assemblages in Prayagraj across habitats.

Results & Discussion

Species Richness and Composition:

A total of 113 bird species was recorded across seven Prayagraj habitats, distributed in 48 families and 18 orders with the Passeriformes being the most dominant. Common generalist species, such as Common Myna (*Acridotheres tristis*), House Crow (*Corvus splendens*), Black Drongo (*Dicrurus macrocercus*), and Asian Koel (*Eudynamys scolopaceus*) were seen frequently in the highly disturbed areas, such as Company Garden and Minto Park. Whereas, Arail River Bank, Jagdishpur, and Phaphamau habitats exhibited a greater diversity of insectivorous, granivorous and aquatic birds due to better vegetation structure and less disturbance. Indian Skimmer (*Rynchops albicollis*), a globally vulnerable species, found its niche in the Arail–Sangam River

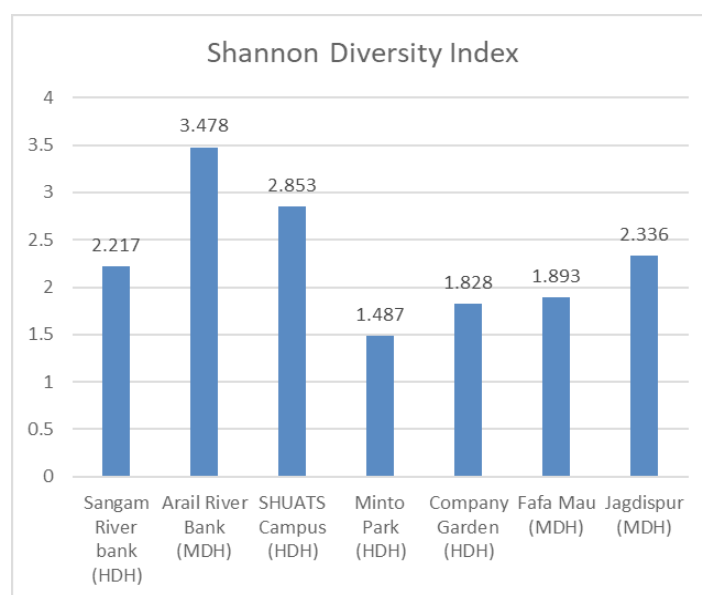
corridor as a key riparian zone. The ecological value of these moderately disturbed sites was additionally indicated by the record of the Egyptian Vulture (*Neophron percnopterus*) near SHUATS and Arail. These results highlight the value of semi natural and riverine habitats for species richness and conservation priority birds in urbanizing landscapes. Below is a full checklist of recorded species and their taxonomic classification. (Table 1)

Abundance Patterns

The House Crow House Crow (*Corvus splendens*) was the most abundant species with 263 individuals, with high concentrations in Jagdishpur and SHUATS Campus due to its strong urban association. Widely distributed across all sites, the Common Myna Common Myna (*Acridotheres tristis*) followed with 130 individuals. The Black Drongo Black Drongo (*Dicrurus macrocercus*) had moderate and consistent presence, favoring semi open habitats like Arail and SHUATS, with 33 individuals. The patterns highlighted here indicate the adaptability of generalist species in disturbed landscapes.

Diversity Indices

Shannon Diversity Index (H') varied across sites, and the maximum was found in Arail River Bank (3.47) and minimum in Minto Park (1.40), implying greater species richness and evenness in moderate disturbance habitats. (Fig. 2). This trend was supported



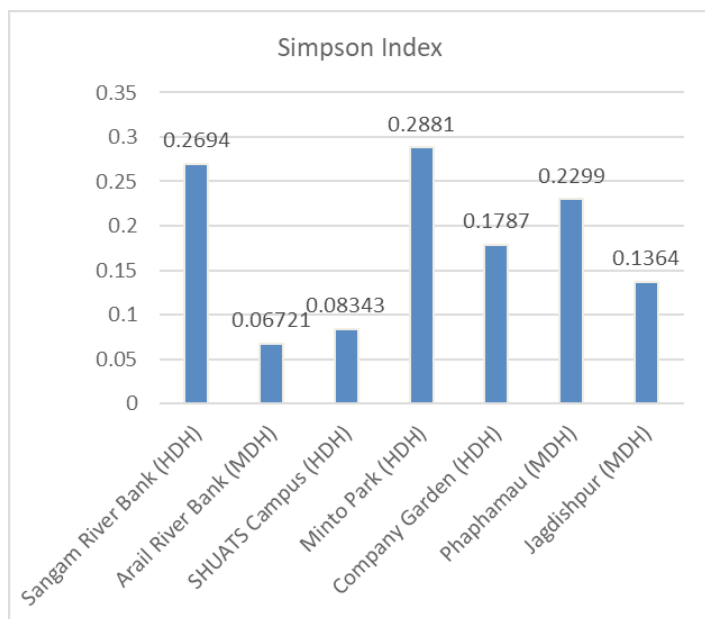
(Fig.2). - Shannon – Wiener Diversity Index across Different Landscapes

S.No.	Common name	Scientific name	Order	Family	Count	Status	S.No.	Common name	Scientific name	Order	Family	Count	Status
1	Ashy Prinia	<i>Prinia socialis</i>	Passeriformes	Cisticolidae	4	LC	58	Grey-throated Martin	<i>Riparia chinensis</i>	Passeriformes	Hirundinidae	3	LC
2	Asian Koel	<i>Eudynamis scolopaceus</i>	Cuculiformes	Cuculidae	7	LC	59	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	Anseriformes	Anatidae	4	LC
3	Black Drongo	<i>Dicurus macrocerus</i>	Passeriformes	Dicruidae	33	LC	60	Spotted Owlet	<i>Athene brama</i>	Strigiformes	Strigidae	8	LC
4	Bank Myna	<i>Acridotheres ginginianus</i>	Passeriformes	Sturnidae	123	LC	61	Plum-headed Parakeet	<i>Psittacula cyanocephala</i>	Psittaciformes	Psittaculidae	1	LC
5	Common Myna	<i>Acridotheres tristis</i>	Passeriformes	Sturnidae	130	LC	62	Brown-headed Barbet	<i>Megalaima zeylanica</i>	Piciformes	Megalaimidae	1	LC
6	Black-headed Gull	<i>Chroicocephalus ridibundus</i>	Charadriiformes	Laridae	1550	LC	63	Yellow-crowned Woodpecker	<i>Leiopicus mahrottensis</i>	Piciformes	Picidae	2	LC
7	Black-hooded oriole	<i>Oriolus xanthornus</i>	Passeriformes	Oriolidae	6	LC	64	Rock Pigeon	<i>Columba livia</i>	Columbiformes	Columbidae	35	LC
8	Bonelli's Eagle	<i>Aquila fasciata</i>	Accipitriformes	Accipitridae	2	LC	65	Eurasian Collared Dove	<i>Streptopelia decaocto</i>	Columbiformes	Columbidae	15	LC
9	Yellow-wattled lapwing	<i>Vanellus malabaricus</i>	Charadriiformes	Charadriidae	8	LC	66	Laughing Dove	<i>Spilopelia senegalensis</i>	Columbiformes	Columbidae	16	LC
10	Long-legged Buzzard	<i>Buteo rufinus</i>	Accipitriformes	Accipitridae	3	LC	67	Spotted Dove	<i>Spilopelia chinensis</i>	Columbiformes	Columbidae	40	LC
11	Common Kingfisher	<i>Alcedo atthis</i>	Coraciiformes	Alcedinidae	5	LC	68	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	Coraciiformes	Alcedinidae	17	LC
12	Paddy Field Pipit	<i>Anthus rufulus</i>	Passeriformes	Motacillidae	8	LC	69	Pied kingfisher	<i>Ceryle rudis</i>	Coraciiformes	Alcedinidae	25	LC
13	Baya Weaver	<i>Ploceus philippinus</i>	Passeriformes	Ploceidae	4	LC	70	Asian Pied Starling	<i>Gracupica contra</i>	Passeriformes	Sturnidae	8	LC
14	Pied Bush Chat	<i>Saxicola caprata</i>	Passeriformes	Muscicapidae	7	LC	71	Little Swift	<i>Apus affinis</i>	Apodiformes	Apodidae	12	LC
15	Large Grey Babbler	<i>Turdoides malcolmi</i>	Passeriformes	Leiothrichidae	8	LC	72	Cattle Egret	<i>Bubulcus ibis</i>	Pelecaniformes	Ardeidae	250	LC
16	Oriental White-eye	<i>Zosterops palpebrosus</i>	Passeriformes	Zosteropidae	13	LC	73	Shikra	<i>Athene brama</i>	Strigiformes	Strigidae	1	LC
17	Greenish Warbler	<i>Phylloscopus trachiloides</i>	Passeriformes	Phylloscopidae	4	LC	74	Red-vented Bulbul	<i>Pycnonotus cafer</i>	Passeriformes	Pycnonotidae	40	LC
18	Indian Roller	<i>Coracias benghalensis</i>	Coraciiformes	Coraciidae	24	LC	75	Jungle Babbler	<i>Turdoides striata</i>	Passeriformes	Leiothrichidae	270	LC
19	House Swift	<i>Apus nipalensis</i>	Apodiformes	Apodidae	160	LC	76	Indian Robin	<i>Saxicoloides fulicatus</i>	Passeriformes	Muscicapidae	1	LC
20	Grey Wagtail	<i>Motacilla cinerea</i>	Passeriformes	Motacillidae	4	LC	77	Oriental Magpie-Robin	<i>Copsychus saularis</i>	Passeriformes	Muscicapidae	8	LC
21	Pied Avocet	<i>Recurvirostra avosetta</i>	Charadriiformes	Recurvirostridae	13	LC	78	Common Hawk-Cuckoo	<i>Hierococcyx varius</i>	Cuculiformes	Cuculidae	1	LC
22	Brown-headed Gull	<i>Chroicocephalus brunicephalus</i>	Charadriiformes	Laridae	400	LC	79	Brahminy Starling	<i>Sturnia pagodarum</i>	Passeriformes	Sturnidae	4	LC
23	Pallas's Gull	<i>Ichthyophaga ichthyophaga</i>	Charadriiformes	Laridae	3	LC	80	Common Iora	<i>Aegithina tiphia</i>	Passeriformes	Aegithinidae	4	LC
24	Grey Heron	<i>Ardea cinerea</i>	Pelecaniformes	Ardeidae	22	LC	81	Wire-tailed Swallow	<i>Hirundo smithii</i>	Passeriformes	Hirundinidae	2	LC
25	Alexandrine Parakeet	<i>Psittacula eupatria</i>	Psittaciformes	Psittaculidae	2	LC	82	Red-rumped Swallow	<i>Cecropis daurica</i>	Passeriformes	Hirundinidae	6	LC
26	Black kite	<i>Milvus migrans</i>	Accipitriformes	Accipitridae	28	LC	83	Indian Silverbill	<i>Euodice malabarica</i>	Passeriformes	Estrildidae	13	LC
27	Ruddy Shelduck	<i>Tadorna ferruginea</i>	Anseriformes	Anatidae	102	LC	84	Black Shaheen Falcon	<i>Falco peregrinus peregrinator</i>	Falconiformes	Falconidae	3	LC
28	Little Ringed Plover	<i>Charadrius dubius</i>	Charadriiformes	Charadriidae	9	LC	85	Egyptian Vulture	<i>Neophron percnopterus</i>	Accipitriformes	Accipitridae	13	EN
29	Temminck's Stint	<i>Calidris temminckii</i>	Charadriiformes	Scolopacidae	18	LC	86	Ashy-crowned Sparrow-Lark	<i>Eremopterix griseus</i>	Passeriformes	Alaudidae	15	LC
30	Painted Stork	<i>Mycteria leucocephala</i>	Ciconiiformes	Ciconiidae	15	NT	87	Purple-rumped Sunbird	<i>Leptocoma zeylanica</i>	Passeriformes	Nectariniidae	5	LC
31	Great Cormorant	<i>Phalacrocorax carbo</i>	Suliformes	Phalacrocoracidae	179	LC	88	Jungle Prinia	<i>Prinia sylvatica</i>	Passeriformes	Cisticolidae	14	LC
32	Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	Suliformes	Phalacrocoracidae	23	LC	89	Barn Owl	<i>Tyto alba</i>	Strigiformes	Tytonidae	2	LC
33	White-browed wagtail	<i>Motacilla maderaspatensis</i>	Passeriformes	Motacillidae	9	LC	90	Common Kestrel	<i>Falco tinnunculus</i>	Falconiformes	Falconidae	1	LC
34	White Wagtail	<i>Motacilla alba</i>	Passeriformes	Motacillidae	7	LC	91	Red Avadavat	<i>Amandava amandava</i>	Passeriformes	Estrildidae	4	LC
35	Intermediate Egret	<i>Ardea intermedia</i>	Pelecaniformes	Ardeidae	22	LC	92	Crested Lark	<i>Galerida cristata</i>	Passeriformes	Alaudidae	6	LC
36	Little Cormorant	<i>Microcarbo niger</i>	Suliformes	Phalacrocoracidae	132	LC	93	Greater Coucal	<i>Centropus sinensis</i>	Cuculiformes	Cuculidae	13	LC
37	Little Egret	<i>Egretta garzetta</i>	Pelecaniformes	Ardeidae	110	LC	94	Common Hoopoe	<i>Upupa epops</i>	Bucerotiformes	Upupidae	25	LC
38	Green Bee-eater	<i>Meropis orientalis</i>	Coraciiformes	Meropidae	32	LC	95	Common Redshank	<i>Tringa totanus</i>	Charadriiformes	Scolopacidae	35	LC
39	Brown Rock-chat	<i>Cercomela fusca</i>	Passeriformes	Muscicapidae	4	LC	96	Asian Woolly-necked Stork	<i>Ciconia episcopus</i>	Ciconiiformes	Ciconiidae	19	NT
40	Common Babbler	<i>Turdoides caudata</i>	Passeriformes	Leiothrichidae	65	LC	97	Small Pratincole	<i>Glareola lactea</i>	Charadriiformes	Glareolidae	70	LC
41	Indian Grey Hornbill	<i>Ocyrocerus birostris</i>	Bucerotiformes	Bucerotidae	8	LC	98	Gadwall	<i>Mareca strepera</i>	Anseriformes	Anatidae	45	LC
42	Indian Peafowl	<i>Pavo cristatus</i>	Galliformes	Phasianidae	26	LC	99	Common Pochard	<i>Aythya ferina</i>	Anseriformes	Anatidae	67	LC
43	House Crow	<i>Corvus splendens</i>	Passeriformes	Corvidae	300	LC	100	White-breasted Kingfisher	<i>Halcyon smyrnensis</i>	Coraciiformes	Alcedinidae	9	LC
44	Indian Pond-Heron	<i>Ardeola grayii</i>	Pelecaniformes	Ardeidae	25	LC	101	Sarus Crane	<i>Antigone antigone</i>	Gruiformes	Gruidae	4	LC
45	River Lapwing	<i>Vanellus duvaucelii</i>	Charadriiformes	Charadriidae	170	LC	102	White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	Gruiformes	Rallidae	58	LC
46	Black-tailed Godwit	<i>Limosa limosa</i>	Charadriiformes	Scolopacidae	6	NT	103	Common Moorhen	<i>Gallinula chloropus</i>	Gruiformes	Rallidae	23	LC
47	Wood Sandpiper	<i>Tringa glareola</i>	Charadriiformes	Scolopacidae	29	LC	104	Osprey	<i>Pandion haliaetus</i>	Accipitriformes	Pandionidae	2	LC
48	Asian Openbill	<i>Anastomus oscitans</i>	Ciconiiformes	Ciconiidae	40	LC	105	Eurasian Sparrowhawk	<i>Accipiter nisus</i>	Accipitriformes	Accipitridae	1	LC
49	Red-naped Ibis	<i>Pseudibis papillosa</i>	Pelecaniformes	Threskiornithidae	13	LC	106	Crested Serpent Eagle	<i>Spilornis cheela</i>	Accipitriformes	Accipitridae	1	LC
50	House Sparrow	<i>Passer domesticus</i>	Passeriformes	Passeridae	259	LC	107	Indian Skimmer	<i>Rynchops albigallus</i>	Charadriiformes	Laridae	300	EN
51	Rose-ringed Parakeet	<i>Psittacula kramera</i>	Psittaciformes	Psittaculidae	30	LC	108	Yellow-footed Green-Pigeon	<i>Treron phaeocephalus</i>	Columbiformes	Columbidae	4	LC
52	Taiga Flycatcher	<i>Ficedula albicilla</i>	Passeriformes	Muscicapidae	2	LC	109	Indian Golden Oriole	<i>Oriolus kundoo</i>	Passeriformes	Oriolidae	2	LC
53	Marsh Sandpiper	<i>Tringa stagnatilis</i>	Charadriiformes	Scolopacidae	2	LC	110	Scaly-breasted Munia	<i>Lonchura punctulata</i>	Passeriformes	Estrildidae	16	LC
54	Common Greenshank	<i>Tringa nebularia</i>	Charadriiformes	Scolopacidae	1	LC	111	Purple Sunbird	<i>Cinnyris asiaticus</i>	Passeriformes	Nectariniidae	9	LC
55	Little Stint	<i>Calidris minuta</i>	Charadriiformes	Scolopacidae	11	LC	112	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	Pelecaniformes	Threskiornithidae	11	LC
56	Paddyfield Warbler	<i>Acrocephalus agricola</i>	Passeriformes	Acrocephalidae	2	LC	113	River Tern	<i>Sterna aurantia</i>	Charadriiformes	Laridae	200	LC
57	Western Yellow Wagtail	<i>Motacilla flava</i>	Passeriformes	Motacillidae	5	LC							

Table 1. Checklist of bird species recorded across seven study sites in Prayagraj, classified by their common names, scientific names, taxonomic order, family, and IUCN status

Abbreviations: LC=Least Concern, NT=Near Threatened, VU=Vulnerable, CR= Critically Endangered, EN= Endangered





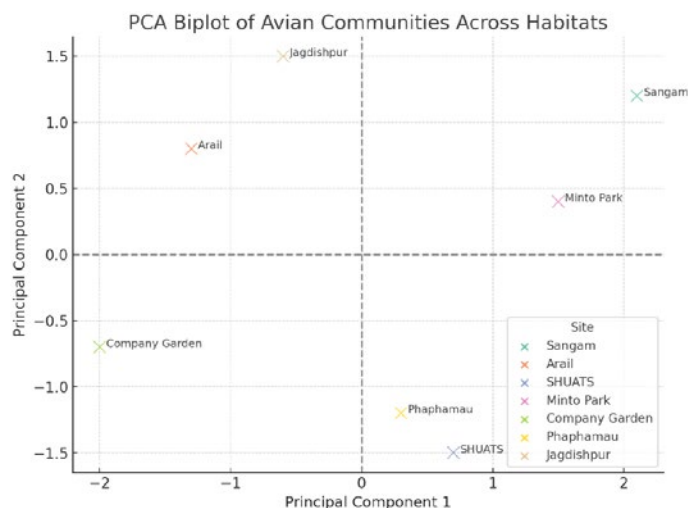
(Fig. 3). - Simpson Index across Different Landscapes

by the Shannon Evenness Index, which ranged from 0.88 (Arail) to 0.62 (Minto Park), indicating that less disturbed sites had less balanced species distribution. These patterns were further confirmed by the Simpson Index which revealed that Arail (0.93) and SHUATS (0.91) had the highest probabilities of species diversity and Minto Park (0.71) had the least. The observed trend is depicted in (Fig. 3). The Dominance Index was also highest (0.29) at Minto Park and lowest (0.07) at Arail, where generalist species dominated highly disturbed environments. Together, these indices clearly show that the bird communities in moderately disturbed habitats (Arail, SHUATS, and Jagdishpur) are more diverse and evenly distributed than those in highly disturbed urban parks.

Multivariate Analyses

Principal Component Analysis (PCA)

Distinct ecological clustering across habitats was revealed by PCA. Arail, Jagdishpur and Phaphamau were grouped closely with a higher proportion of sensitive or habitat-dependent species. By contrast, Company Garden and Minto Park separated from one another, driven by dominance of generalist urban adapted birds. Together, PC1 and PC2 explained roughly 78% of the total variation, suggesting strong community structuring across disturbance gradients. The spatial separation in the bi-plot illustrates how environmental variation and disturbance gradients

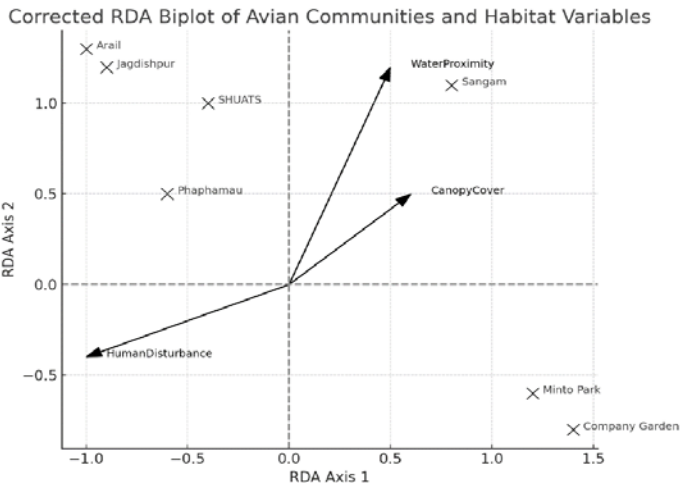


(Fig. 4). - PCA bi-plot showing variation in bird communities across habitats in Prayagraj. Sites cluster by disturbance level and species composition.

shape avian community structure across the urban-rural mosaic of Prayagraj. This trend is illustrated below. (Fig. 4)

Redundancy Analysis (RDA)

Results of Redundancy Analysis (RDA) showed that Water Proximity, Canopy Cover and Human Disturbance had significant influence on avian community composition across study sites. Water Proximity and Canopy Cover were predominantly found in Arail, Jagdishpur and Phaphamau, with Charadriiformes, Gruiformes, and Piciformes order birds showing higher representation which is expected in riparian zones and forest edge habitats. Water Proximity also clustered near Sangam or confluence, near the Sangam area, indicating the location of birds which are dependent on water and particularly from Pelecaniformes and Ciconiiformes. In contrast, Minto Park and Company Garden were aligned with Human Disturbance, possessing orders such as Passeriformes (e.g. Sturnidae, Corvidae) that were urban adapted. SHUATS Campus was centrally occupied, where vegetation structure and human activity had a moderate influence over Passeriformes and Columbiformes. The strength of influence of the environmental vectors was indicated by the direction and length of environmental vectors and Water Proximity was the most important factor in shaping community variation. This demonstrates how



(Fig. 5). - RDA bi-plot showing how habitat variables influence bird community structure across sites in Prayagraj.

environmental gradients shape distribution of avian taxonomic groups under different habitat conditions in Prayagraj. The graphical representation in (Fig. 5) supports this observation.

Conclusion

The results of this study show how the diversity of birds is influenced by habitat structure and disturbance in seven separate habitats within Prayagraj. The species were recorded from a total of 113 bird species, belonging to 48 families and 18 orders; moderately disturbed habitats such as Arail, Jagdishpur and Phaphamau supported higher species richness and evenness, including ecologically sensitive and riparian groups. In contrast, Minto Park and Company Garden urban parks were characterized by lower diversity and were comprised of generalist species from Passeriformes that were strongly influenced by human disturbance. In addition, multivariate analyses supported that Water Proximity and Canopy Cover positively influenced avian community composition and Human Disturbance was correlated with the presence of disturbance tolerant taxa. These findings support the ecological value of riparian corridors and semi natural green spaces in urban landscapes and emphasize the importance of habitat sensitive urban planning and targeted conservation efforts to conserve avian diversity in rapidly urbanizing environments.

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Author Contribution: Shimant Mehta: Conceived and designed the study, carried out fieldwork, analyzed data, and drafted the manuscript. Dr. Ekta Pathak Mishra: Supervised the research, contributed to methodology, and critically reviewed the manuscript. Anuj Kumar Banarya: Assisted in field surveys, data compilation, and supported result interpretation.

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Appendix

Plates of Avian Species Photographed During Field Surveys



Fig. S1. Indian Skimmer (Rynchops albicollis) in flight over Arail River Bank. A globally vulnerable species dependent on undisturbed sandbanks.

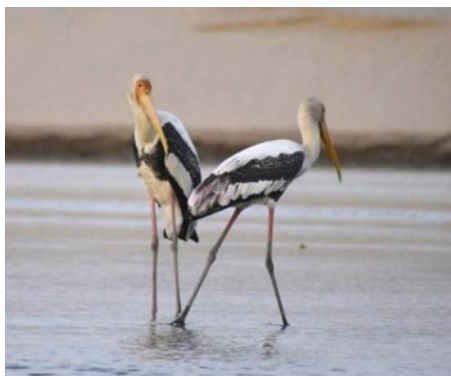


Fig. S2. Painted Stork (Mycteria leucocephala) wading in wetland areas near Sangam.



Fig. S3. Egyptian Vulture (Neophron percnopterus) recorded near Arail Riverbank. Globally Endangered scavenger species.



Fig. S4. Black-headed Ibis (Threskiornis melanocephalus) observed in groups at Sangam sandbars.

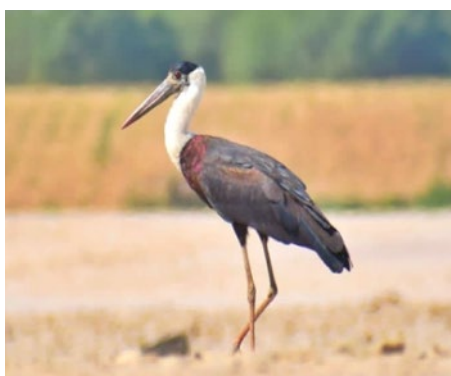


Fig. S5. Woolly-necked Stork (Ciconia episcopus) seen foraging on exposed riverbed habitat near Arail Riverbank.



Fig. S6. Pied Kingfisher (Ceryle rudis) in flight over riverine habitat in Phaphamau.

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Reproductive phenology of trees in tropical dry evergreen forests, Nagapattinam, South India

Muthulingam Udayakumar^{1*}, Jhonson Evitex-Izayas¹ and Thangavel Sekar²

¹ Department of Plant Science, Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli – 627 012, Tamil Nadu, India.

² Department of Environmental Science, Indira Gandhi National Tribal University, Amarkantak, Anuppur – 484 887, Madhya Pradesh, India.

*Corresponding author: udayakumar@msuniv.ac.in

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Abstract

Vegetative, flowering, fruiting, and synchronous (flowering cum fruiting) phenophases of trees were recorded in tropical dry evergreen forests (TDEF) of Nagapattinam district in Tamil Nadu, South India. The present study concentrated on 55 tree species spread in 50 genera and 27 families. A total of 550 trees (ten individuals each per tree) were labelled with consecutively numbered aluminium tags to record vegetative, flowering, fruiting, and synchronous phenophases of trees. Karl Pearson's simple correlation test was employed to assess relationship between environmental factors (temperature, rainfall and monthly rainy days) and phenophases (flowering and fruiting) in study area. 37 species were at vegetative phenophase during the month of September followed by October (35) and November (27). Flowering phenophase peaked during January-February (close to dry period). 36 species were at fruiting phenophase during May. It was observed that temperature had an influence on flowering ($r = .59, p < .005$) and fruiting ($r = .61, p < .005$). Rainfall also correlated with both flowering ($r = .08, p < .025$) and fruiting ($r = -.82; p < .001$). Similar to temperature and rainfall, rainy days of a month also had an association with flowering ($r = 0.30, p < .005$) and fruiting ($r = -.74, p < 0.001$). Trees of TDEFs showed an annual phenological pattern except *Memecylon umbellatum*, which showed biannual pattern (produced flowers and fruits two times in a year). Generally, fruit is available throughout the year in the study area. This study contributes considerable amount of information to phenological pattern of trees in TDEFs.

Keywords: floral characters; fruit types; fruit colour; plant sexuality; Tamil Nadu

Introduction

Phenology is the study of growth of buds, leaf flushing, flowering, fruiting and leaf fall in relation to seasons or years with climatic factors (Linnaeus 1751). Plant phenological studies are important for a better understanding of the ecological adaptations of plant species and community level interactions. The knowledge of phenology of plants has helped to understand the influence of phenological events on feeding, movement patterns, and sociality of insects, birds and mammals. The scope of phenology is wide and it gives valuable baseline information to global climate change studies (Pioa et al. 2019).

Parmesan and Yohe (2003) carried out a meta-analysis with plants (woody and herbaceous) and animals (Amphibians, birds, insects and fishes) and found an alteration in spring events (advancement of phenological events 2.3 days decade⁻¹ for about 60% of species) and correlated those changes to increasing temperature. Impacts of climate change on natural ecosystem is also studied (Walther et al. 2002).

Tropical forest ecosystems have more diverse and complex phenological patterns than temperate forests (Borchert 1983, Rathcke and Lacey, 1985). Phenological studies explain plant growth patterns, impacts of environmental factors and selective pressure on reproduction of life forms (Root et al. 2003). Additionally, phenological events have a close link with plant development, weather and climate, thereby serving as a cost-effective detector of changes in biosphere (Koch et al. 2005). In addition, phenological patterns of plants are widely used to characterise vegetation type (Shimwell 1972; Opler et al. 1980). Effects of climate change on forest ecosystems can be easily deduced with phenological studies, changing climate affects the length of growing seasons in tropical forests (Singh and Kushwaha 2005). Besides, variations in phenological patterns are recognised as indicators of global climate change (Menzel and Fabian 1999; Penuelas et al. 2002; Menzel, 2003).

The complex interaction between environmental and genetic factors determines phenological dynamics (Ruml and Vulic 2005). The air temperature is believed to be a dominant factor that governs the timing of flowering and other phenological events (Galan et al. 2001). Photoperiod is regarded as a key factor in phenophases (Friedel et al. 1993; Morellato and Haddad 2000). In addition, soil also influences (soil temperature, water

content, soil type and nutrient supply) phenological events to some extent (Wielgolaski 2001). According to Keatley (2000) rainfall regime plays a significant role in phenology of the tropical and subtropical regions.

Trees may produce flowers at definite (periodic flowering) or indefinite interval (mast flowering), (Longman and Jenik 1987; Yap and Chan 1990). The frequency of flowering periods vary from a minimum of 3-4 months to a maximum of 10-15 years (Longman and Jenik 1987). Information on type of reproduction has implications for preservation and management of forest ecosystems. Most tropical trees have cross pollination (strongly out-crossed; Pollen of one individual fertilizes the flowers of another individual of the same species) (Bawa 1992). Over exploitation of trees increases the distance among individuals of the same species thereby reduce the chance of out-crossings in species.

Phenological studies are important to know about timing and duration of flowering, fruiting and seeding. The timing or frequency of flowering and production of seeds are widely considered as important characteristics of reproductive ecology because these features have crucial roles in conservation and management practices of forest ecosystems. With phenological data one can easily collect seeds either for enrichment plantings or conservation purposes (e.g. seed storage, plantations, expansion of forest area, afforestation etc.). Studies on flowering and fruiting phenology of trees are limited for tropical dry evergreen forests (TDEFs). Further, phenological information is not available for TDEFs of Nagapattinam region. Thus, the present investigation concentrated on TDEFs of Nagapattinam district located on the southern Coromandel Coast of India. Objectives of the present study are (a) observation of phenophases of trees in tropical dry evergreen forests; (b) assessment of relationship between phenophases and rainfall, and phenophases and temperature; and (c) to record important floral and fruit traits of trees in study area.

Materials and Methods

The study was conducted in forested regions of Nagapattinam district in Tamil Nadu, South India (Table 1, Figure 1). The forest type of study area known as tropical dry evergreen forest (TDEF), have moderate tree density, diversity, species richness and biomass (Parthasarathy et al. 2008; Udayakumar and Parthasarathy 2010; Udayakumar 2018). Trees

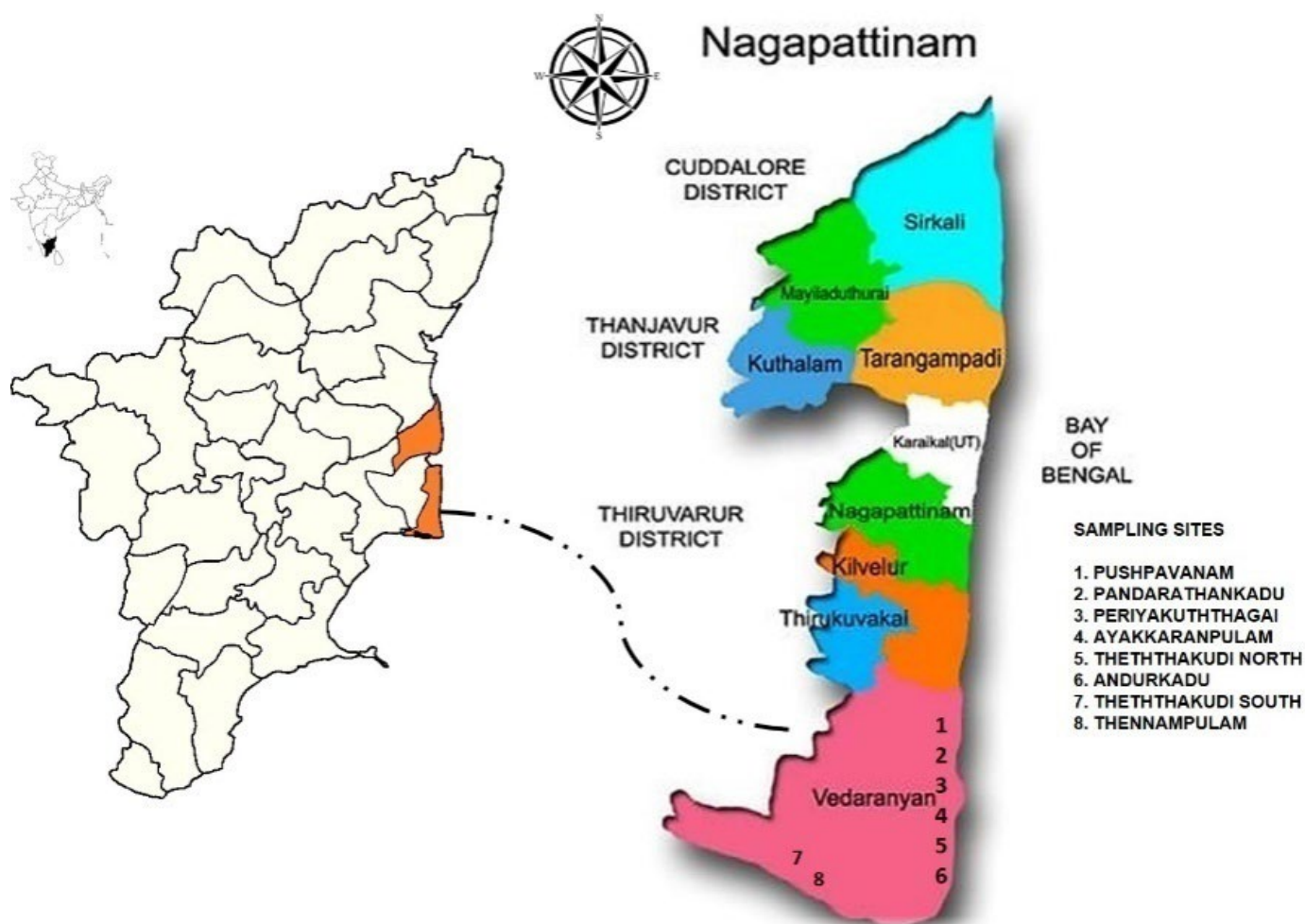


Figure 1. Map of study area wherein phenology study conducted.

Table 1. Study sites and their geographical coordination

Name of study area	Geographical coordinates
Ayakkaranpulam	10°27'2.88"N; 79°50'39.84"E
Andurkadu	10°23'9.60"N; 79°48'56.16"E
Pandaraththankadu	10°27'2.88"N; 79°50'39.84"E
Periyakuththagai	10°25'06.75"N; 79°49'47.18"E
Pushpavanam	10°29'29.99"N; 79°50'19.60"E
Thennampulam	10°26'55.52"N; 79°50'19.60"E
Theththakudi North	10°24'08.17" N; 79°49'47.18"E
Theththakudi South	10°26'20.35"N; 79°48'47.18" E

have short bole, reach up to 9m height. Ground flora constituted by some geophytes (e.g., *Typhonium* spp.; *Amorphophallus* spp.) and perennial succulents (e.g., *Sanseiviera roxburghiana* Schult. & Schult. f.). Annuals appear during wet season and complete their lifecycle before the onset of dry season. Cauliflory is very rare (Champion and Seth 1968).

This study was concentrated on 55 tree species spread in 50 genera and 27 families. A total of 550 trees, ten individuals each per species were labelled with consecutively numbered aluminium tags to record vegetative, flowering, fruiting, and synchronous phenophases of trees. All the marked individuals were observed fortnightly for the period of one year. As these forests are protected as sacred groves by local community, all the aluminium tags were intact throughout the study period. For upper storey trees binocular observations were made for phenological studies. The records were maintained every month for the number of species found in four stages vegetative, flowering, fruiting and synchronous. The trees without any reproductive parts such as flowers and fruits (immature, tender and mature) were considered as 'vegetative'. Trees which had flowers were considered as 'flowering'. Species showed synchronous phases

have been added to both flowering and fruiting for computing monthly flowering and fruiting of trees in study area. They were considered as ‘fruiting’ when had fruits (immature, tender and mature), while they were considered as ‘synchronous’ when had both flowers and fruits at a time. Information on important traits namely, leaf type, flower colour, fruit colour, flower type, and sexuality were recorded on the field and confirmed with regional floras (Gamble and Fischer 1921-1935; Matthew 1995; Pallithanam 2001). Karl Pearson’s simple correlation test was employed to assess the relationship between environmental factors (temperature, rainfall and monthly rainy days; <https://mausam.imd.gov.in/chennai/>) and phenophases (flowering and fruiting) in study area.

Results

Vegetative phenophase

A maximum of 37 species were at vegetative phenophase during the month of September followed by October (35) and August (30), whereas minimum number of species showed vegetative phenophase during April (10 species) and May (11). *Crateva magna* and *Sapium insigne* showed long vegetative phenophase of 8 months, 11 species exhibited 7 months, while two species had 0 month (Figure 2). Each species had 4.98

± 1.83 months of vegetative phenophase. Large number of species showed vegetative phenophase during September (37 species, 67.27%) followed by October (35 species; 63.64%) and August (30 species; 54.55%), whereas a small number of species showed vegetative phenophase on April (10 species, 18.19%), May (11, 20%) and March (15, 27.27%) in study area.

Reproductive phenophase

Most of the trees showed reproductive phenophase during April (45 species, 81.82%), May (44 species, 80%), and March (40 species; 72.73%), while a least number of species showed reproductive phenophase on September (18 species, 32.73 %) and October (20 species, 36.36 %). On average, in a month 58.18% (32 species) species either fruited or flowered in study area.

Flowering phenophase

Flowering phenophase peaked during January-February (24 and 23 species, respectively; close to dry period) while just nine species flowered during July and September. A maximum duration (4 months) of flowering period was observed in *Euphorbia antiquorum*, *Glycosmis mauritiana*, *Morinda coreia* and *Pavetta indica* (Figure 2). Each species had 1.89 ± 0.92 months of flowering phenology.

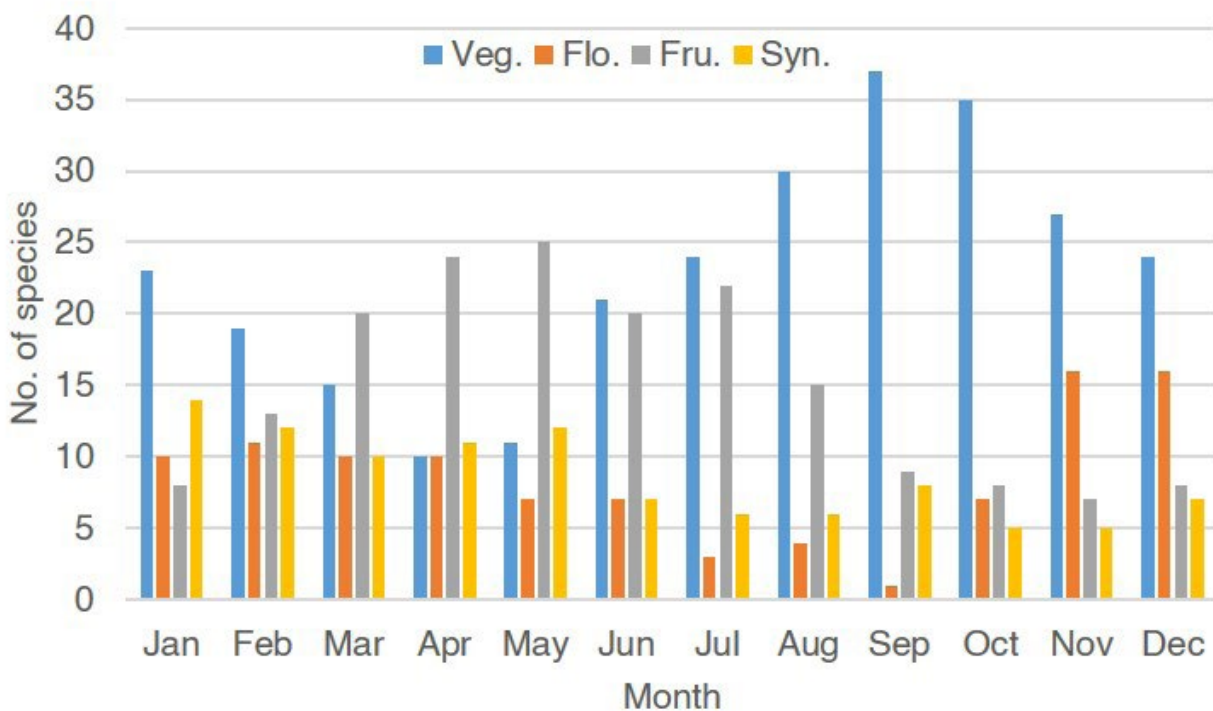


Figure 2. Month-wise vegetative, flowering, fruiting and synchronous phenophases of trees in study area.

Fruiting phenophase

A maximum of 36 species had fruiting phenophase during May followed by April (34) and March (30), and least number (12 species) of species were at fruiting phenophase during November. *Pterospermum canescens* had eight months of fruiting phenophase; *Tamarindus indica* had seven months; *Atalantia monophylla* and *Catunaregam spinosa* had six months each (Figure 2). Each species had 3.27 ± 1.63 months of flowering phenophase.

Synchronous phenophase

Fourteen species had both flowers and fruits (synchronous phenophase) in January, while the number reduced to five on October and November. *Thespesia populnea* and *Phyllanthus reticulatus* produced flowers and fruits throughout the year. *Ficus benghalensis* and *F. hispida* had 5 months of synchronous phenophase, whereas 6 species showed 0 values (tree species which never showed synchrony). Each species had 1.85 ± 2.28 months of synchronous phenophase (Figure 2).

Temperature, rainfall and phenophases

It was observed that temperature had an influence on flowering ($r = 0.59$, $p < 0.005$) and fruiting ($r = 0.61$, $p < 0.005$). Rainfall also correlated with both flowering ($r = 0.08$, $p < 0.025$) and fruiting ($r = -0.82$, $p < 0.001$). Similar to temperature and rainfall, rainy days of a month also had an association with flowering ($r = 0.30$, $p < 0.005$) and fruiting ($r = -0.74$, $p < 0.001$).

Inflorescence

Of 55 species, 27 had racemose inflorescence, 10 produced mixed type, 16 formed cymose inflorescences, remaining two had a special type. Among cymose inflorescence producers six species produced axillary cyme; one each formed corymbose cyme, cymose cluster and paniced cyme; two had simple cyme; three formed cymose panicle; and, two produced polychasial cyme. Likewise, among racemose inflorescence producers, six species had simple raceme; nine formed panicle; five produced corymb; two species each formed catkin, head and umbel; and, one species each formed spadix and spike (Table 2).

Flower colour

Twenty eight species produced white coloured flowers; it was yellow in ten species; six were green;

three species each produced pink and cream; two species each developed greenish yellow and greenish white; while a single species' produced brown coloured flowers (Table 2).

Flower scent

Faintly scented flowers were formed by twenty-one species, 18 species produced fairly scented flowers, while remaining 16 species produced strongly scented flowers (Table 2).

Tree sexuality

Hermaphrodite type of sexuality was present in 31 species, while eight species each were showed dioecious, monoecious and polygamous type of sexuality in study area (Table 2).

Fruit type

Among fruit types, drupe was dominant (25; 45.45%) followed by berry (17; 30.1%) and capsule (6; 10.1%), while pod was produced by four species, syconia by two and nut by just single species in study area (Table 2).

Fruit colour

Among 55 species, seventeen (30.1%) produced yellow fruits; 12 (21.82%) species produced black; it was red in 11 (20%) species; brown in ten (18.19%); violet in two (3.67%); and green, orange and white coloured fruits was produced by just single species each (Table 2).

Leaf type

In this study two third of species had simple leaves (37; 67.27%), remaining 18 species had compound leaves (32.73%), (Table 2).

Discussion

Flowering phenophase

The pattern observed in study area (peak flowering close to dry season) is similar to the patterns reported in the tropical dry forests of India (Bhat 1992; Singh and Singh 1992; Murali&Sukumar, 1994; Bhat and Murali 2001); Costa Rica (Opler et al. 1980) and Africa (Burger 1974). Earlier, Kikim and Yadava (2001) recorded a peak flowering during April (beginning of warm and dry season) in subtropical forest sites of Manipur, India; Nath (2012) recorded a peak flowering

Table 2. Botanical name, family, physiognomy, inflorescence, flower colour, scent, sexuality, leaf type, fruit type and colour of trees in TDEFs.

(PHY[@]-Physiognomy, E-Evergreen, D-Deciduous; FLC^s -Flower colour, Gw-Greenish white, Gy-Greenish yellow; FSC[&]-Flower scent, St-Strong, Fr-Fair, Ft-Faint; SEX[^]-Sexuality, Her-Hermaphrodite, Pol-Polygamous, Dio-Dioicous, Mon-Monoicous; LT[#]-Leaf type, S-Simple, C-Compound; FRT[%]-Fruit type; FRC⁺-Fruit colour, Y-Yellow, R-Red, Bk-Black, Br-Brown, G-Green, O-Orange, V-Violet, W-White)

Botanical name	Family	PHY [@]	Inflorescence	FLC ^s	FSC ^{&}	SEX [^]	LT [#]	FRT [%]	FRC ⁺
<i>Aglaia elaeagnoidea</i> (A. Juss.) Benth.	Meliaceae	E	Terminal panicle	Y	St	Her	C	Drupe	Y
<i>Albizia lebbek</i> (L.) Benth.	Mimosaceae	D	Head	Gw	St	Her	C	Pod	Y
<i>Allophylus serratus</i> (Hiern) Kurz	Sapindaceae	E	Raceme	W	Fr	Pol	C	Berry	R
<i>Anacardium occidentale</i> L.	Anacardiaceae	D	Terminal panicle	P	Ft	Pol	S	Nut	G
<i>Atalantia monophylla</i> DC.	Rutaceae	E	Umbel	W	St	Her	C	Berry	Y
<i>Azadirachta indica</i> A. Juss.	Meliaceae	D	Cymose panicle	W	St	Her	C	Drupe	Y
<i>Benkara malabarical</i> (Lam.) Tirveng.	Rubiaceae	E	Corymbose cyme	W	St	Her	S	Drupe	R
<i>Borassus flabellifer</i> L.	Arecaceae	E	Spadix	G	Fr	Dio	C	Drupe	Bk
<i>Breynia vitis-idaea</i> (Burm. f.) C.E.C. Fisch.	Euphorbiaceae	D	Axillary cyme	G	Ft	Mon	C	Drupe	R
<i>Calophyllum inophyllum</i> L.	Clusiaceae	E	Terminal panicle	W	Fr	Pol	S	Drupe	Y
<i>Canthium coromandelicum</i> Alston	Rubiaceae	E	Cyme	Gw	Ft	Her	S	Drupe	Y
<i>Canthium dicocum</i> (Gaertn.) Merr.	Rubiaceae	E	Polychasial cyme	W	St	Her	S	Drupe	Bk
<i>Carmona retusa</i> (Vahl) Masam.	Boraginaceae	E	Axillary cyme	C	Ft	Her	S	Drupe	R
<i>Cassia fistula</i> L.	Caesalpiniaceae	D	Raceme	Y	Ft	Her	C	Pod	Br
<i>Catunaregam spinosa</i> (Thunb.) Tirveng.	Rubiaceae	E	Solitary	Y	Fr	Her	S	Drupe	Y
<i>Chionanthus zeylanicus</i> L.	Oleaceae	E	Terminal panicle	W	St	Her	S	Drupe	Bk
<i>Commiphora caudata</i> Engl.	Burseraceae	D	Panicled cyme	C	Ft	Pol	C	Drupe	R
<i>Crateva magna</i> (Lour.) DC.	Capparidaceae	D	Corymb	W	St	Her	S	Drupe	R
<i>Diospyros ebenum</i> J. König	Ebenaceae	E	Terminal corymb	W	Fr	Pol	C	Berry	Y
<i>Diospyros ferrea</i> (Willd.) Bakh.	Ebenaceae	E	Axillary cyme	Gy	Fr	Dio	S	Berry	Y
<i>Diospyros montana</i> Roxb.	Ebenaceae	E	Axillary fascicle	Y	Fr	Dio	S	Berry	O
<i>Diospyros peregrina</i> Gurke	Ebenaceae	E	Axillary fascicle	Gy	Fr	Dio	S	Berry	R
<i>Drypetes sepiaria</i> Wight & Arn.	Euphorbiaceae	E	Axillary fascicle	Y	Fr	Dio	S	Berry	Br
<i>Ehretia pubescens</i> Benth.	Boraginaceae	E	Axillary fascicle	W	Ft	Dio	S	Drupe	R
<i>Euphorbia antiquorum</i> L.	Euphorbiaceae	E	Cyme	C	Ft	Mon	S	Capsule	Br
<i>Ficus benghalensis</i> L.	Moraceae	D	Hypanthodium	G	Ft	Mon	S	Syconia	R
<i>Ficus hispida</i> L. f.	Moraceae	E	Hypanthodium	G	Ft	Mon	S	Syconia	Y
<i>Flacourtia indica</i> (Burm. f.) Merr.	Flacourtiaceae	E	Raceme	W	St	Dio	S	Drupe	Bk

Botanical name	Family	PHY ⁷ @	Inflorescence	FLC ^S	FSC ^{&}	SEX [^]	LT [#]	FRT [%]	FRC ⁺
<i>Garcinia spicata</i> Hook.	Clusiaceae	E	Fasicle	W	Ft	Mon	S	Berry	Y
<i>Glycosmis mauritiana</i> Tanaka	Rutaceae	E	Panicle	W	St	Her	C	Berry	R
<i>Gmelina asiatica</i> L.	Verbenaceae	D	Raceme	Y	Fr	Her	C	Drupe	Y
<i>Ixora pavetta</i> Andrews	Rubiaceae	E	Polychasial cyme	W	St	Her	S	Drupe	B
<i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	D	Catkin	W	Ft	Pol	C	Drupe	R
<i>Lepisanthes tetraphylla</i> (Vahl.) Radlk.	Sapindaceae	E	Panicle	W	Fr	Pol	C	Drupe	Y
<i>Madhuca longifolia</i> L.	Sapotaceae	D	Fasicle	Br	Fr	Her	S	Berry	Y
<i>Manilkara hexandra</i> (Roxb.) Dubard	Sapotaceae	E	Axillary solitary	W	Fr	Her	S	Berry	Y
<i>Maytenus emarginata</i> (Willd.) Ding Hou	Celastraceae	E	Cymose panicle	W	Ft	Her	S	Capsule	B
<i>Memecylon umbellatum</i> Burm. f.	Melastomataceae	E	Fascicle	Pi	Fr	Her	S	Berry	V
<i>Morinda coreia</i> Buch. -Ham.	Rubiaceae	D	Head	W	St	Her	S	Berry	B
<i>Ochna squarrosa</i> L.	Ochnaceae	D	Panicle	Y	Ft	Her	S	Drupe	B
<i>Pamburus missionis</i> (Wight) Swingle	Rutaceae	E	Axillary raceme	W	St	Her	C	Berry	Y
<i>Pavetta indica</i> L.	Rubiaceae	E	Corymb	W	Fr	Her	S	Berry	Bk
<i>Phyllanthus reticulatus</i> Poir.	Euphorbiaceae	D	Fascicle	G	Ft	Mon	S	Berry	V
<i>Pongamia pinnata</i> (L.) Merr.	Papilionaceae	D	Racemose panicle	Pi	Ft	Her	C	Pod	Br
<i>Premna latifolia</i> Roxb.	Verbenaceae	D	Corymb	W	St	Her	S	Drupe	Bk
<i>Pterospermum canescens</i> Roxb.	Sterculiaceae	D	Cymose cluster	W	Ft	Her	S	Capsule	Br
<i>Sapindus emarginatus</i> Vahl	Sapindaceae	D	Terminal panicle	W	Fr	Pol	C	Drupe	Bk
<i>Sapium insigne</i> (Royle) Benth. & Hook. f.	Euphorbiaceae	D	Spike	Y	Ft	Mon	S	Capsule	Br
<i>Securenaga leucopyrus</i> (Willd.) Muell.-Arg.	Euphorbiaceae	D	Fascicle	G	Ft	Mon	S	Drupe	W
<i>Streblus asper</i> Lour.	Moraceae	E	Cluster	W	Ft	Dio	S	Drupe	Y
<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	D	Cymose panicle	W	St	Her	S	Berry	Bk
<i>Tamarindus indica</i> L.	Caesalpiniaceae	E	Raceme	Y	Fr	Her	C	Pod	Br
<i>Tarenna asiatica</i> Kuntze ex K. Schum.	Rubiaceae	E	Umbel	W	St	Her	S	Drupe	Bk
<i>Terminalia arjuna</i> Wight & Arn.	Combretaceae	D	Catkin	W	Fr	Her	S	Capsule	Br
<i>Thespesia populnea</i> (L.) Sol. ex Corrêa	Malvaceae	D	Solitary	Y	Ft	Her	S	Capsule	Br

phenophase during March in a subtropical forest site in northeast India; Yadav and Yadav (2008) found a peak flowering on March to April in a tropical dry deciduous forest in Rajasthan, India; Sundarapandian et al. (2005) observed a peak flowering during February-May in moist deciduous forest of India Western Ghats. In TDEFs of other regions, for example Venkateswaran (2004) found this pattern of flowering i.e. peak community flowering on close to dry months in two TDEF sites in Villupuram, Tamil Nadu. According to Morellato et al. (1989) increase of photoperiod encourage the commencement of flowering phenophase. In this study flowering is correlated with temperature. Earlier, many researchers found correlation between flowering and temperature in tropical forests (Ashton et al. 1988; Morellato and Haddad 2000; Marques et al. 2004; Corlett and Lafrankie 1998; Tutin and Fernandez 1993; Stevenson 2004). Photoperiod also has been related with flowering phenophases (Sloan et al. 2007).

Deciduous trees such as *Albizia lebbbeck*, *Cassia fistula*, *Crateva magna*, *Lannea coromandelica* and *Pongamia pinnata* flowered close to the summer, while many evergreen species flowered in pre-monsoon and wet monsoon period in study area. Since deciduous trees remain leafless during dry season, they also have an advantage to present flowers to pollinators (Arthur-Selwyn and Parthasarathy 2007). Many species of dry evergreen forests flower close to the months of low rainfall and high temperature, when insect activity is probably greatest (Janzen 1967; van-Schaik 1986) and it is believed to attract several pollinating insects.

Fruiting phenophase

An average of 3.27 ± 1.64 months of fruiting phenophase prevailed for each species in present study area. This result is not in conformity with the observations of Arthur-Selwyn and Parthasarathy (2007). They reported a mean fruiting phenophase of 3.6 months for a TDEF site in Coromandel Coast of Tamil Nadu. Tree species of present study showed no specific seasonality in fruiting, which is in agreement to reports on other forests (Frankie et al. 1974; Prasad and Hegde 1986; Murali and Sukumar 1994). Most of the species fruited during May (36 species). This observation is in-line with the results of Nath (2012) who observed peak fruiting period during May-June in a subtropical forest site, northeast India. However, the observed peak is not in agreement with Kikim and

Yadava (2001), who found fruiting peak on September to October (wet period) in subtropical forest sites of Manipur.

Fruiting is positively associated with temperature and negatively correlated with rainfall. The relationships found between phenophases and environmental factors are in agreement with Venkateswaran (2004) who observed same relationships in two TDEF sites along Coromandel Coast. In addition, Okullo et al. (2004) also found dry season flowering in tropical forests. Temperature has been found to affect flowering in many tropical forests (van-Schaik et al. 1993; Chapman et al. 1999).

Generally, fruit is available throughout the year in study area. This pattern assures continuous food supply to frugivores and other animals in TDEFs. Fruiting year-round in TDEFs follows the trend of many tropical forests. If seeds are dispersed during wet period, due to high soil moisture content they germinate quickly and establish (van-Schaik et al. 1993). Fruits produced at the end of dry season could avoid water stress because forthcoming rainy season provide moisture and create conducive environment for seed germination (Hamann 2004). By producing fruits year-round, species of dry evergreen forests use both south-west as well as north-east monsoonal wet seasons for seed germination.

Phenological pattern

Flowering and fruiting occurred throughout the year. Trees of TDEFs showed an annual phenological pattern except *Memecylon umbellatum*, it showed biannual pattern (produced flowers and fruits two times in a year). Earlier, Venkateswaran (2004) and Arthur-Selwyn and Parthasarathy (2006) observed unimodal phenological pattern in most of the species in TDEF sites on Coromandel Coast. They also found bimodal phenological pattern in predominant, characteristic TDEF species i.e., *Memecylon umbellatum*.

Flower colour

The most common flower colour of the present study area was white (50.9%). Same results were reported earlier from tropical forest regions, such as, Coromandel Coast of Tamil Nadu (Arthur-Selwyn and Parthasarathy 2007); Western Ghats, India (Devy and Davidar 2003); Sarawak region of Malaysia (Momose et al. 1998); dry forests of Cerrado, Brazil (Oliveira and Gibbs 2000), and caatinga, north-east Brazil (Machado and Lopes

2004). In general, white coloured flowers are moth-pollinated (Rausher 2008). A phenological study on TDEF also observed this relationship (Arthur-Selwyn and Parthasarathy 2006). Bird pollinated flowers are rare (usually red or orange with elongated floral tubes, reduced floral limbs). Bee and moth pollinated flowers (flowers with inserted stigmas) are abundantly present in study area; hence species of TDEFs are highly depending upon insects for their successful pollination, consecutively, seed and fruit formation.

Flower scent

Flower scent acts as a long-distance attractant (Endress 1994) or as a close range orientation guide within the flowers (Dobson et al. 1997). Faintly scented flowers were produced by 38.20% of species, 32.73% of species produced fairly scented flowers, remaining 20.1% of species produced strongly scented flowers, and these results are to certain extent similar to the reports of Arthur-Selwyn and Parthasarathy (2007), they reported 48% of species formed faintly scented flowers. However, they studied phenology of all life forms including tree, liana and herb but present study concentrated only on trees. White coloured and scented flowers are syndromes of moth pollinated flowers. In this study more than 50% of species produced white coloured flowers, more than 60% species produced scented flowers. These observations indicated that moth pollination is prevalent in TDEFs. Previously, Arthur-Selwyn & Parthasarathy (2006, 2007) found insects as a major pollinator in two TDEF sites of Tamil Nadu.

Fruit type

Drupe was the most common type (45.45%) of fruit in present study area followed by berry (30.1%) and capsule (10.1%). Arthur-Selwyn and Parthasarathy (2007) reported 36% of drupes and 34% of berries from two TDEF sites in Coromandel Coast. The proportion of species with fleshy fruits obtained in this study (80%) is similar to reports from tropical regions such as Costa Rica (Frankie et al. 1974); La Selva (Levey et al. 1994); Brazil (Funch et al. 2002); New Caledonia (Carpenter et al. 2003); and, China (Du et al. 2009). Most of the species produced fleshy fruits (80%). Fleshy fruits are dispersible by avian frugivores (Darwin 1859). High quantity of fleshy fruits supports life of many birds.

Fruit colour

According to Arthur-Selwyn and Parthasarathy (2007) red was the common (25%) fruit colour, followed by black (20%) and brown (19%) in TDEFs of Coromandel coast, India. However, the present study recorded a different observation, common fruit colour as recorded in present study area was yellow (30.1%) followed by black (21.82%) and red (20%). In addition, proportion of fruit colour obtained in the present study is not in-line with that of tropical evergreen forest of China, where Du et al. (2009) reported brown (30%) as a predominant fruit colour followed by black (15%), red (11%) and yellow (4%). Fruit colour plays important role in propagule dispersal (seed, fruit) in forest ecosystem. With contrasting colours, fruits advertise their presence to their dispersers (Morton 1973; Janzen 1975). Darwin (1859) and Ridley (1930) believed colours increase the conspicuousness of fruits thereby attract dispersers that eat fruits and disperse enclosed seeds. Production of clumps of mature fruits during leafless period (as happens in *Lannea coromandelica*) is believed to serve as a long distance signal (Stiles 1982). In general, fruits change their colour from green to yellow, red, brown, black etc. Conspicuous colouration of fruits is believed to evolve to attract dispersers (Ridley 1930). In this study a good proportion (45%) of species produced avian dispersible fruits (red and black). According to Janson (1983), Wheelwright and Janson (1985) and Willson and Whelan (1990) bird dispersible fruits are red or black in colour. Based on distribution of fruit colours Willson et al. (1989) recognized frequent, consistent relationship between bird and fruit colours (red and black fruits).

Dual colour changes in fruits as present in *Memecylon umbellatum* are common in Neotropics (Corner 1966). Fruit colour of *M. umbellatum* changes from green to yellow, then turns yellow to red, finally appear as violet on complete maturation. The colour of fruits acts as a stimulus to resident birds. Resident frugivores regularly search plants for mature fruits, remove matured fruits immediately. This action of resident birds largely avoids infections of microbes and insects, as actions of microbes and insects could destroy fruits and seeds (Janzen 1977).

Tree sexuality

It was observed that hermaphrodite type of plant sexuality was present in more number of species.



Hermaphrodite kind of sexuality is primitive than monoecious and dioecious types of plant sexuality (Naik 1984) hence, the forest ecosystem under study is belongs to old-growth and primitive types of forest. Bawa (1992) found hermaphroditic flowers as predominant (60-65%) followed by dioecious (23-26%) and monoecious (11-14%) flowers in tropical lowland rain forests. Data on sexuality of trees serve as useful tool in conservation measures. They largely help conservation practitioners to decide the minimum area for forest reserves. Cross pollination enhances genetic variations in forest trees (Bawa 1992). The information on prevalence of dioecism in forest ecosystem is important to determine minimum area for successful and effective conservation. Dioecious plants broadly need larger areas than hermaphrodite or monoecious ones. The chances of nearby tree is being opposite sex is reduced to 50% for dioecious plants, whereas, the chances are 100% for hermaphroditic or monoecious plants. If dioecious trees do not find their opposite sex then they will fail to reproduce and in extreme situation such species will altogether disappear once for all (become extinct).

Leaf type

Simple leaves are primitive than compound leaves (Naik 1984). In the study area simple leaves were present in 67.27% of trees, whereas compound leaves were found in 32.63% of trees only, these findings shows that the tree community of the study area is dominated by evolutionarily primitive species.

Conclusions

Flowering and fruiting patterns observed in this study are in agreement with earlier studies concentrated on phenology of tropical forests. Also, the relationship found between temperature and flowering, and temperature and fruiting is in line with findings reported earlier by various authors. Information gathered in this study strengthening the phenological database of TDEF. Trees in study area highly depends on moths for a successful pollination. Diversity of insects including moths need to be studied in TDEFs. Reproductive success of species can influence ecosystem stability and other vital ecological processes. Hence, investigation is needed to quantify the relationship between plant and pollinators (especially moths). This study collected information on phenological behaviour of species for

the period of one year; if data gathered for long period then impacts of climate change on TDEFs could be addressed. Research on plant-seed disperser interaction is scanty in TDEF. To fill this gap studies can be conducted. Plant sexuality and leaf types of TDEF species demonstrated that the tree communities in the study area dominated by evolutionarily primitive trees.

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Inventory of Moths observed in Waghire College campus during Corona pandemic period

Bhagyashri S. Madbhavikar

Assistant Professor

Department of Zoology, P.D.E. A's Waghire College, Saswad,

Tal. Purandar, Dist. Pune, Maharashtra, India (412301).

bhagyashrimane24@gmail.com

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Abstract

72 moth species belonging to 11 families, 27 sub-families and 68 genera were observed in the Waghire College campus in Saswad town of Purandar taluka, Pune, Maharashtra. These moths were observed mainly during Corona Pandemic i.e. from June 2021 to June 2023. Erebidae family dominated with 29 moth species followed by Geometridae (5 species), Crambidae and Noctuidae (3 species each) and other families like Bombycidae, Nolidae, Pyralidae, Saturniidae, Sphingidae, Uranidae and Yponomeutidae with one species each. This is a first comprehensive inventory of moths occurring in the College campus and also a first study on moths of Purandar taluka, Pune district. Although a minor investigation, this study serves to contribute to the database for generating larger regional inventory on moth diversity.

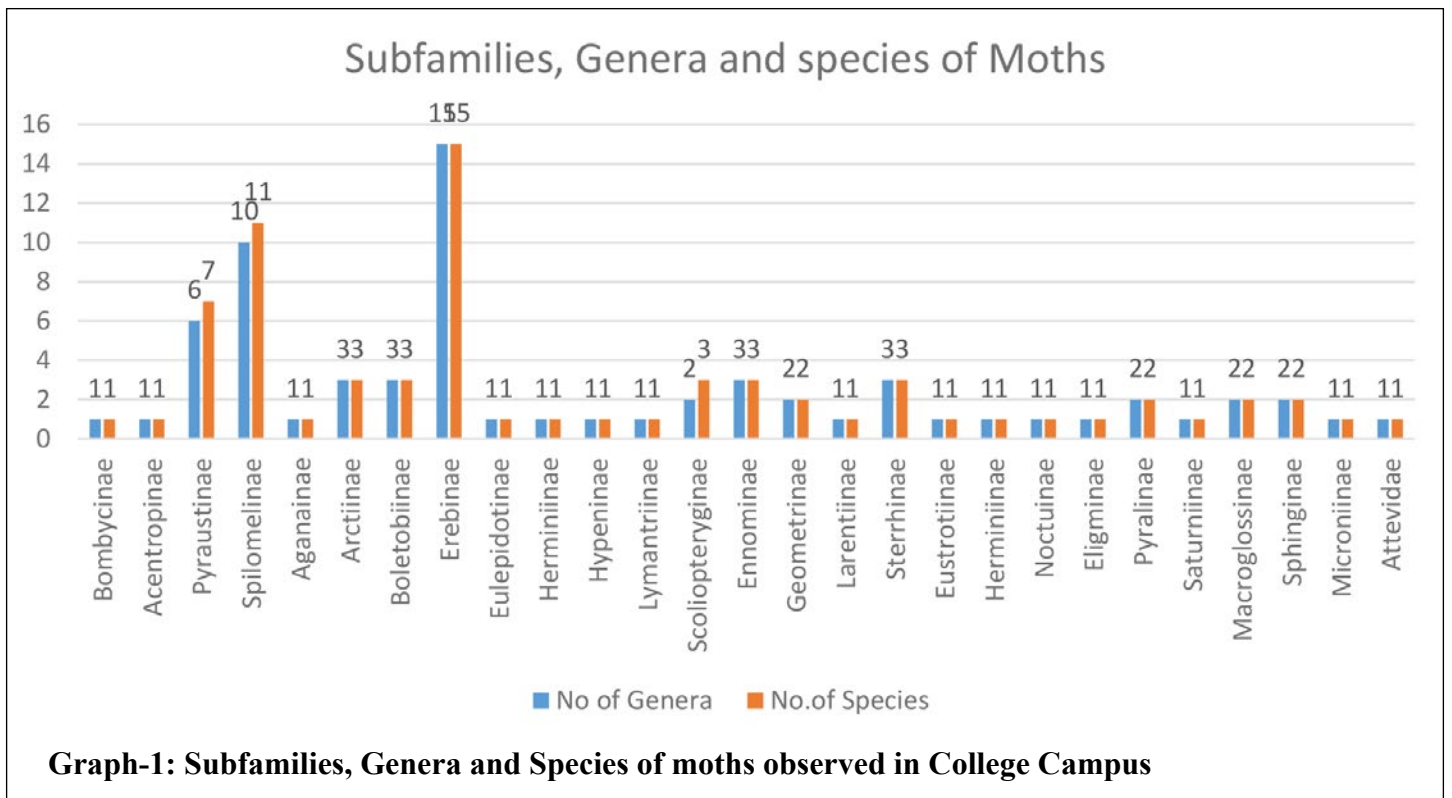
Keywords: Moths, ladies staff washroom, corona pandemic period

Introduction

P.D.E. A's Waghire College of Arts, Commerce and Science is an educational institute located in the drought prone Saswad, a developing town known for fig and custard apple production in the historical Purandar taluka of Pune district, Maharashtra. Moths, the nocturnal counterparts of butterflies play a role of pollinators and agricultural pests in ecosystem. But sadly, these have not been extensively studied as in the case of butterflies. During the Corona pandemic period when the whole world had come to a standstill and humans suffered, nature was getting healed. It was during this period few moths were noticed on the walls of the ladies' staff washroom of the college. Occurrence of these moths during the corona period in and around



Map -1: Waghire College, Saswad



the college campus led preparation of the inventory on moths. To the best of my knowledge, this is a first comprehensive inventory of moths occurring in college campus.

Study area map and Study Method

Waghire College of Arts, Commerce and Science, Saswad (Lat. 18.35436°N and Long. 74.02508° E) is a located on 11 acres’ area in Saswad town, on route the NH 47 Hadapsar- Baramati road. Its infrastructure

Table-1: Inventory of Moths observed in Waghire College Campus during Corona Pandemic period

Sr. No.	Common name	Scientific name	Family	Sub-family	Season	Observation date	iNaturalist UID	RG/NRG
1	Banded Achaea Moth	<i>Achaea catella</i>	Erebidae	Erebinae	Monsoon	28-09-2021	96461242	RG
2	Eastern Death's Head Hawkmoth	<i>Acherontia styx</i>	Sphingidae	Sphinginae	Monsoon	12-10-2021	97992108	RG
3	Agassiziella Moth	<i>Agassiziella picalis</i>	Crambidae	Acentropinae	Winter	06-01-2022	104460482	RG
4	Convolvulus Hawk Moth	<i>Agrius convolvulii</i>	Sphingidae	Sphinginae	Monsoon	17-08-2021	125050588	RG
5	Tropical Anomis Moth	<i>Anomis flava</i>	Erebidae	Scoliopteryginae	Winter	11-01-2022	104958908	RG
6	Angled Gem Moth	<i>Anomis sabulifera</i>	Erebidae	Scoliopteryginae	Monsoon	20-10-2020	95015033	RG
7	South Indian Small Tussore Moth	<i>Antheraea paphia</i>	Saturniidae	Saturniinae	Monsoon	29-07-2020	95119017	RG
8	Owl Moth	<i>Anticarsia irrotata</i>	Erebidae	Eulepidotinae	Winter	31-12-2021	123940058	RG
9	White Underwing Artena Moth	<i>Artena dotata</i>	Erebidae	Erebinae	Monsoon	29-09-2022	136899255	RG
10	Oruza Moth	<i>Ataboruza divisa</i>	Erebidae	Boletobiinae	Monsoon	09-08-2021	95514277	RG
11	White tube moth	<i>Atteva niphocosma</i>	Yponomeutidae	Attevidae	Summer	08-03-2021	123993452	RG
12	Variiegated Avatha Moth	<i>Avatha discolor</i>	Erebidae	Erebinae	Monsoon	14-07-2021	95516119	RG
13	Bastilla Moth	<i>Bastilla simillima</i>	Erebidae	Erebinae	Monsoon	09-07-2021	97534179	RG
14	Botyodes asialis Moth	<i>Botyodes asialis</i>	Crambidae	Spilomelinae	Winter	06/10/2022	137846978	RG
15	Bradina Moth	<i>Bradina admixtalis</i>	Crambidae	Spilomelinae	Monsoon	20-07-2021	125050912	RG
16	Chabula Moth	<i>Chabula acamasalis</i>	Crambidae	Spilomelinae	Winter	08-01-2022	104566633	RG
17	Chiasmia Moth	<i>Chiasmia emersaria</i>	Geometridae	Ennominae	Monsoon	21-09-2021	95638219	RG
18	Chrysocraspeda Moth	<i>Chrysocraspeda olearia</i>	Geometridae	Sterrhinae	Monsoon	05-08-2021	95514770	RG
19	Red Edged Aquarium Moth	<i>Comostola pyrrhogona</i>	Geometridae	Geometrinae	Monsoon	14-07-2021	95166302	RG
20	Cyana Moth	<i>Cyana puella</i>	Erebidae	Arctiinae	Winter	28-10-2022	140268415	RG
21	Oleander Hawk Moth	<i>Daphnis nerii</i>	Sphingidae	Macroglossinae	Winter	28-09-2021	96484845	RG
22	Cucumber Moth/ Cotton caterpillar	<i>Diaphania indica</i>	Crambidae	Spilomelinae	Summer	03-12-2021	102403541	RG
23	Dasyboarmia Moth	<i>Dasyboarmia isororpha</i>	Geometridae	Ennominae	Winter	31-12-2021	104022588	NRG
24	Carissa tiger Moth	<i>Digama machalii</i>	Erebidae	Aganainae	Monsoon	19-06-2021	95516421	RG
25	Dinumma Moth	<i>Dinumma spp</i>	Erebidae	Scoliopteryginae	Monsoon	15-07-2021	124877493	NRG
26	Ailanthus Defoliator Moth	<i>Eligma narcissus</i>	Nolidae	Eligminae	Winter	16-11-2021	101261448	RG
27	Endotricha Moth	<i>Endotricha mesenterialis</i>	Pyalidae	Pyalinae	Winter	04-01-2021	125048529	RG
28	Common Owl moth	<i>Erebus macrops</i>	Erebidae	Erebinae	Winter	22-02-2021	95515958	RG
29	Lined Eublemma Moth	<i>Eublemma baccalix</i>	Erebidae	Boletobiinae	Winter	22-02-2022	123937601	RG
30	Yellow Blotched Pearl Moth	<i>Eurrhyarodes bracteolalis</i>	Crambidae	Pyraustinae	Monsoon	20-08-2021	95514470	RG
31	Glyphodes Moth	<i>Glyphodes canthusalis</i>	Crambidae	Spilomelinae	Winter	01-11-2022	140748832	RG
32	Double Striped Pug Moth	<i>Gymnoscelis ruffasciata</i>	Geometridae	Larentiinae	Monsoon	07-09-2021	95122060	RG
33	Hamodes Moth	<i>Hamodes propitia</i>	Erebidae	Erebinae	Winter	01-11-2022	140747263	RG
34	Hemithea Moth	<i>Hemithea tritonaria</i>	Geometridae	Geometrinae	Monsoon	04-08-2021	95529700	RG
35	Tropical Grass Webworm Moth	<i>Herpetogramma licarsisalis</i>	Crambidae	Spilomelinae	Monsoon	31-07-2021	95527388	RG

Sr. No.	Common name	Scientific name	Family	Sub-family	Season	Observation date	iNaturalist UID	RG/NRG
36	Dusky Grass Webworm Moth	<i>Herpetogramma phaeopteralis</i>	Crambidae	Spilomelinae	Monsoon	13-07-2021	124754105	RG
37	Hipoepa	<i>Hipoepa fractalis</i>	Noctuidae	Herminiinae	Winter	07-01-2022	104567075	RG
38	Hydrillodes	<i>Hydrillodes lentalis</i>	Erebidae	Herminiinae	Winter	04-01-2022	104268269	RG
39	Ornate Hydriris	<i>Hydriris ornatalis</i>	Crambidae	Spilomelinae	Winter	06-01-2022	104460482	RG
40	Spotted Beet Webworm moth	<i>Hymenia perspectalis</i>	Crambidae	Pyraustinae	Monsoon	09-07-2021	97534481	RG
41	Lantana Defoliator	<i>Hypena laceratalis</i>	Erebidae	Hypeninae	Monsoon	20-10-2020	95015643	RG
42	Hypophyra	<i>Hypophyra vespertilio</i>	Erebidae	Erebinae	Summer	12-04-2021	95519715	RG
43	Black Looper	<i>Hyposidra talaca</i>	Geometridae	Ennominae	Winter	11-11-2021	100850266	RG
44	Brinjal Fruit and Shoot Borer	<i>Leucinodes orbonalis</i>	Crambidae	Spilomelinae	Monsoon	20-07-2021	95664373	RG
45	Mung Bean Moth	<i>Maruca vitrata</i>	Crambidae	Pyraustinae	Monsoon	22-07-2021	102403449	RG
46	Grey Swallowtail Moth	<i>Micronia aculeata</i>	Uranidae	Microniinae	Summer	15-03-2021	123988140	RG
47	Sugarcane Looper Moth	<i>Mocis frugalis</i>	Erebidae	Erebinae	Winter	20-10-2021	98779227	RG
48	Brown Striped Semilooper Moth	<i>Mocis undata</i>	Erebidae	Erebinae	Winter	11-01-2022	104960618	RG
49	Crepuscular hawk Moth	<i>Nephele hespera</i>	Sphingidae	Macroglossinae	Winter	06-10-2022	138700761	RG
50	Footman Moth	<i>Nepita conferta</i>	Erebidae	Arctiinae	Winter	10-02-2021	95527046,	RG
51	Nygmia Moth	<i>Nygmia icilia</i>	Erebidae	Lymantriinae	Winter	17-02-2022	106917264	RG
52	Olepa Moth	<i>Olepa sp</i>	Erebidae	Arctiinae	Monsoon	16-09-2021	95014096	NRG
53	Green drab Moth	<i>Ophiusa tirhaca</i>	Erebidae	Erebinae	Monsoon	04-10-2021	97150988	RG
54	Pagyda Moth	<i>Pagyda salvalis</i>	Crambidae	Pyraustinae	Winter	07-10-2022	13784056	RG
55	Pearl Grey Moth	<i>Poliobotys ablactalis</i>	Crambidae	Spilomelinae	Monsoon	06-12-2021	102600994	RG
56	Polydesma Moth	<i>Polydesma boarmoides</i>	Erebidae	Erebinae	Monsoon	18-09-2021	95238512	RG
57	Pseudozarba Moth	<i>Pseudozarba bipartita</i>	Noctuidae	Eustrotiinae	Monsoon	01-07-2022	124204560	RG
58	Painted Mealmoth	<i>Pyralis pictalis</i>	Pyralidae	Pyralinae	Monsoon	16-09-2021	95523997	RG
59	Phoenician pyrausta/ Perilla leaf moth	<i>Pyrausta phoenicealis</i>	Crambidae	Pyraustinae	Monsoon	20-08-2021	95529745	RG
60	Raspberry pyrausta Moth	<i>Pyrausta signatalis</i>	Crambidae	Pyraustinae	Winter	04-01-2022	125052631	RG
61	Banded Pearl Moth	<i>Sameodes cancellalis</i>	Crambidae	Spilomelinae	Monsoon	04-08-2021	124753553	RG
62	Scopula Moth	<i>Scopula fibulata</i>	Geometridae	Sterrhinae	Monsoon	25-09-2021	96070899	RG
63	Simplicia Moth	<i>Simplicia cornicalis</i>	Erebidae	Herminiinae	Monsoon	07-08-2021	95541738	RG
64	Spirama Moth	<i>Spirama helicina</i>	Erebidae	Erebinae	Monsoon	08-07-2021	96485419	RG
65	Indian Owlet Moth	<i>Spirama retorta</i>	Erebidae	Erebinae	Summer	08-03-2021	97535181	RG
66	Oriental leafworm Moth	<i>Spodoptera litura</i>	Noctuidae	Noctuinae	Monsoon	29-06-2022	124098817	NRG
67	Hawaiian Beet Webworm Moth	<i>Spoladea recurvalis</i>	Crambidae	Pyraustinae	Monsoon	09-07-2021	97534344	RG
68	Yellow underwing Moth	<i>Thyas coronata</i>	Erebidae	Erebinae	Winter	08-12-2021	102710135	RG
69	Thyas Moth	<i>Thyas honesta</i>	Erebidae	Erebinae	Monsoon	25-09-2021	96054776	RG
70	Greenish Silk Moth	<i>Trilocho varians</i>	Bombycidae	Bombycinae	Winter	02-11-2020	126176194	RG
71	Tramunda Moth	<i>Tramunda mundissa</i>	Geometridae	Sterrhinae	Monsoon	15-07-2021	97534928	RG
72	Zurobata Moth	<i>Zurobata vacillans</i>	Erebidae	Boletobiinae	Monsoon	15-07-2021	124752459	RG

Abbreviation: RG – Research grade and NRG- Non Research grade as per identified by iNaturalist app.



Table -2: Number of Families, Sub-families, Genera and Species of Moth

Family	No. of Subfamilies	No of Genera	No .of Species
Bombycidae	Bombycinae	1	1
Crambidae	Acentropinae	1	1
	Pyraustinae	6	7
	Spilomelinae	10	11
Erebidae	Aganainae	1	1
	Arctiinae	3	3
	Boletobiinae	3	3
	Erebinae	15	15
	Eulepidotinae	1	1
	Hermiinae	1	1
	Hypeninae	1	1
	Lymantriinae	1	1
Geometridae	Scoliopteryginae	2	3
	Ennominae	3	3
	Geometrinae	2	2
	Larentiinae	1	1
Noctuidae	Sterrhiinae	3	3
	Eustrotiinae	1	1
	Hermiinae	1	1
Noctuidae	Noctuinae	1	1
	Noctuinae	1	1
Nolidae	Eligminae	1	1
Pyralidae	Pyralinae	2	2
Saturniidae	Saturniinae	1	1
Sphingidae	Macroglossinae	2	2
	Sphinginae	2	2
Uranidae	Microniinae	1	1
Yponomeutidae	Attevidae	1	1

comprises of massive ground, college building, botanical garden, apiary cum butterfly garden and is surrounded by residential houses (Map-1). Around the premises are large trees like Peepal, Jamun, Gulmohar, Tamarind, Ashoka, Millingtonia, Acacia, Nilgohar, Banyan, Wild almond, Mango and lots of grasses. *Ficus religiosa*, *Syzygium cumini*, *Delonix regia*, *Tamarindus indica*, *Saraca asoca*, *Millingtonia hortensis*, *Vachellia nilotica*, *Jacaranda mimosifolia*, *Ficus benghalensis*, *Sterculia fetida*, *Mangifera indica*. During the corona pandemic period from June 2021 to June 2023, the moths were observed as and when spotted. Moth observed after June 2023 have not been included in this checklist. Observed moths were merely photographed with an android phone OPPO A53s 5G model CPH2321 and identified with the help of a moth

guide book by V. Shubhalakshmi [1] and android apps -Insect identifier and iNaturalist app [2,3].

Result and Discussion

India is a hotspot for faunal diversity. Out of the 1,42,000 moths observed in the world, 12,000 moth species occur in India. However, not all have been identified and recorded. Hence, although the moth population is much greater in number than the butterfly population, not much information or data is available in textual form.



So far, extensive study on moths has not been conducted in Purandar nor Saswad. This inventory serves as a first report of occurrence of moths in Saswad town. During the study period, 72 species of moths belonging to 11 families, 27 sub-families and 68 genera were observed mainly in the ladies' staff washroom. The Table-1 depicts the common name, scientific name, families and subfamilies of the observed moths while Table -2 reflects the families, sub families, genera and species of moths observed. Table-3 shows the photographs of observed moths. In this study, Erebidae family dominated with 29 moth species followed by Geometridae (5 species), Crambidae and Noctuidae (3 species each) and other families with one species each. Although a minor investigation, this study serves to contribute to the database for generating larger regional inventory on moth diversity.
















During the study by Phadatare et. al. in Baramati region, a total 188 specimens of moths were collected from two sites viz- Kambleshwar (75 moth species) and Nimbodi (113 species) by using night trap methods. 17 species were common between both the sites and seven lepidopteron families like Nymphalidae, Bombycidae, Sphingidae, Noctuidae, Arctiidae, Hyblaeidae, and Pyralidae were recorded. Also, in a study on moths from Western ghats region by V. Shubhalaxmi [5], 418 species of moths from 28 families belonging to 15 superfamilies, were recorded by light trapping at eight sites in northern Western Ghats, India. Of the species recorded, 11 new species were new records and 25 species were endemic to India. The dominant families observed were Erebidae, Geometridae, Sphingidae and Crambidae. In yet another study of moths in Ahmednagar college campus by Ahire and Khobragade [6], 34 moth species belonging to 07 families and 15 subfamilies. Here, the families Erebidae and Geometridae dominated in the study area followed by Sphingidae, Noctuidae,





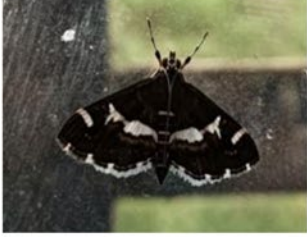





Table -3: Photographs of Moths observed

		
<i>Achaea catella</i>	<i>Acherontia styx</i>	<i>Agassiziella picalis</i>
		
<i>Agrilus convolvulii</i>	<i>Amata cyssea</i>	<i>Anomis flava</i>
		
<i>Anomis sabulifera</i>	<i>Antheraea paphia</i>	<i>Anticarsia irrotata</i>
		
<i>Artena dotata</i>	<i>Ataboruza divisa</i>	<i>Atteva niphocosma</i>
		
<i>Avata discolor</i>	<i>Bastilla simillima</i>	<i>Botyodes asialis</i>

		
<i>Bradina admixtalis</i>	<i>Chabula acamasalis</i>	<i>Chaismia emersaria</i>
		
<i>Chrysocraspeda olearia</i>	<i>Comostola pyrrhogona</i>	<i>Cyana puella</i>
		
<i>Daphnis nerii</i>	<i>Diaphania indica</i>	<i>Dasyboarmia isorrhopa</i>
		
<i>Digama marchalii</i>	<i>Dinumma sps</i>	<i>Eligma narcissus</i>
		
<i>Endotricha mesenterialis</i>	<i>Erebus macrops</i>	<i>Eublemma baccalix</i>

		
<i>Eurrhyarodes bracteolalis</i>	<i>Glyphodes canthusalis</i>	<i>Gymnoscelis rufifasciata</i>
		
<i>Hamodes propitia</i>	<i>Hemithea tritonaria</i>	<i>Herpetogramma licarsisalis</i>
		
<i>Herpetogramma phaeopteralis</i>	<i>Hipoepa fractalis</i>	<i>Hydrillodes lentalis</i>
		
<i>Hydriris ornatalis</i>	<i>Hymenia perspectalis</i>	<i>Hypena laceratalis</i>
		
<i>Hypopyra vespertilio</i>	<i>Hyposidra talaca</i>	<i>Leucinodes orbonalis</i>
		
<i>Maruca vitrata</i>	<i>Micronia aculeata</i>	<i>Mocis frugalis</i>

		
<i>Mocis undata</i>	<i>Nephele hespera</i>	<i>Nepita conferta</i>
		
<i>Nygmia icilia</i>	<i>Olepa sp.</i>	<i>Ophiusa tirhaca</i>
		
<i>Pagyda salvalis</i>	<i>Poliobotys ablactalis</i>	<i>Polydesma boarmoides</i>
		
<i>Pseudozarba bipartita</i>	<i>Pyralis pictalis</i>	<i>Pyrausta phoenicealis</i>
		
<i>Pyrausta signatalis</i>	<i>Sameodes cancellalis</i>	<i>Scopula fibulata</i>

		
<i>Simplicia cornicalis</i>	<i>Spirama helicina</i>	<i>Spirama retorta</i>
		
<i>Spodoptera litura</i>	<i>Spoladea recurvalis</i>	<i>Thyas coronata</i>
		
<i>Thyas honesta</i>	<i>Trilocha varians</i>	<i>Tramunda mundissa</i>
		
<i>Zurobata vacillans</i>		

Crambidae, Eupterotidae and Notodontidae. Similar findings were observed in Wardha district moth diversity study by Wankhade et.al [7] where in total 64 species of moths belonging to 14 families and 31 subfamilies were recorded from different sites. Here too family Erebidae (22 species) dominated, followed by Geometridae (11 species), Cambridae (10 species) Noctuidae (07 species), Sphingidae (4 Species), Cossidae (3 Species) and 1 species each from family Eupterotidae, Pterophoridae, Saturnidae, Uranidae, Bombycidae, Lasiocampidae and Scythrididae. In a moth study in Kerala by Chembakassery et.al [8] 503 species of moths (343 belonging to 371 genera under 42 families were observed at Kavvai River basin, northern Kerala, India from 2015 to 2017. Erebidae followed by Crambidae, Geometridae, Noctuidae, and Pyraliade were the dominant families as in earlier studies. An inventory of moths of SPPU, Pune by Pujari [9] reveals 189 unique genera along with 154 unique species belonging to 26 families viz. Erebidae (234), Geometridae (147), Crambidae (117), Noctuidae (86) and Pyralidae (23).

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First record of the Jujube Lappet Moth *Streblote siva* (Lefèbvre, 1827) from Raigad District, Konkan Division, Maharashtra, India

Javed Ahmed^{1*}, Bhushan Jadhav², Mattis Michel³, Chris Cathrine⁴, Rajashree Khalap⁵.

^{1*}Corresponding Author: Jai Gopi Krishna CHSL, A-Wing, Flat No 102, 1, Patil Wadi, Govandi (East), Mumbai 400088, Maharashtra, India. Email: curiocritters@gmail.com

²A-4, Plot no. 82, Aasra Co-operative Housing Society, Near Swami Vivekanand School, Gorai-1, Borivali (West), Mumbai 400091, India. Email: bhushanjadhav7604@gmail.com

³Naturalist, Belgium. Email: matvierkant@outlook.com

⁴Office 2 and 3, Craigarnhall, Bridge of Allan, Stirling, FK9 4NG, Scotland.
Email: chris.cathrine@caledonianconservation.co.uk

⁵45-A, Sagar Sangeet, 58 Shahid Bhagat Singh Marg, Colaba, Mumbai 400005, India.
Email: rajashree.khalap@gmail.com

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The Jujube Lappet Moth *Streblote siva* (Lefèbvre, 1827) is widely distributed, being found in India, Nepal, Burma, Myanmar, Iraq, Pakistan, Iran, Jordan, Bahrain, Oman, Saudi Arabia, United Arab Emirates, and Yemen. Reportedly present across India (Fletcher, 1925), it has been recorded from our country from West Bengal, Southern India, North-West Himalayas, Rajasthan, and the semi-arid zones. In the state of Maharashtra, in Western India, it has only been recorded from the Mumbai region, from Sanjay Gandhi National Park, the Mumbai Suburban Region, and from the adjacent Thane District. (Sondhi et al., 2025; Joshi et al., 2023; Esfandiari et al., 2013; De Prins & De Prins, 2011–2021; Subhalakshmi, 2018; Subhalakshmi et al., 2011).

The only other species of *Streblote Hübner*, [1820] recorded from the state of Maharashtra is *Streblote dorsalis* Walker, 1866 - recorded in Mumbai by Rishi et al., (2019) as *Streblote helpsi* Holloway (a junior synonym of *S. dorsalis*), in Amravati by Gadhikar et al. (2015), and in Nashik by Gurule and Nikam (2013) who list it as uncommon.

S. siva was formerly known only from two district localities in Maharashtra (Sondhi et al., 2025; Subhalakshmi et al., 2011), and the present report establishes a new distributional record for the species from Nagaon village, Vasant Wadi, near Nagaon Beach, as the first record of the species from Raigad District, in Konkan Division, and the third known distributional record from the state of Maharashtra (Figure 1).

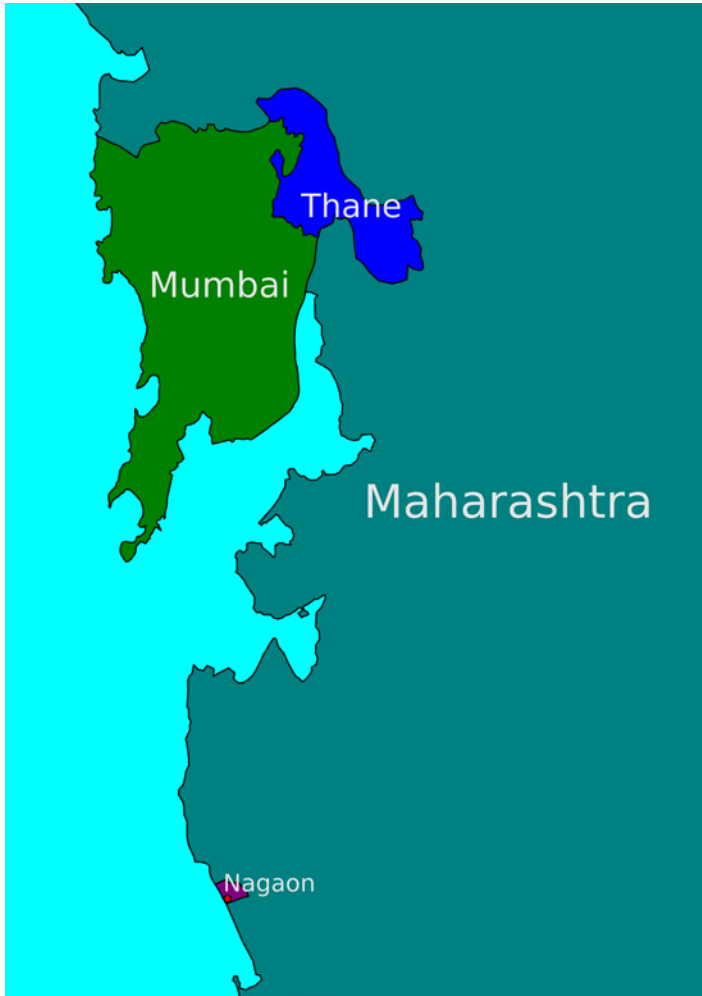


Figure 1 - Distribution records of *Streblote siva* from Maharashtra

The moth was photographed on 5 April 2023 at 00:33 am. during a nocturnal field excursion to the seasonal marshland/salt scrub running parallel to Nagaon Beach, and adjoining the property of one of the authors (R. Khalap).

Identification was based on the diagnostic features provided by Hampson (1893), furnished herewith, along with a few personal observations noted in the specimen photographed, namely; tegula ochreous red, abdomen white, sometimes tinged with red-brown. Fore-wing grey, base of which with a red-brown white ringed spot, and a yellow-brown sub-basal patch. Medial line distinct (though can be less distinct than the post-medial line, and even partially broken in some specimens), angling inwards below the cell. Cell with (a highly irregular) red-brown 'spot' (much more akin to a blotch, which can sometimes even be entirely missing, or present as a light impression in some



Figure 2 - *Streblote siva*, Dorso-lateral view



Figure 3 - *Streblote siva*, Dorsal view

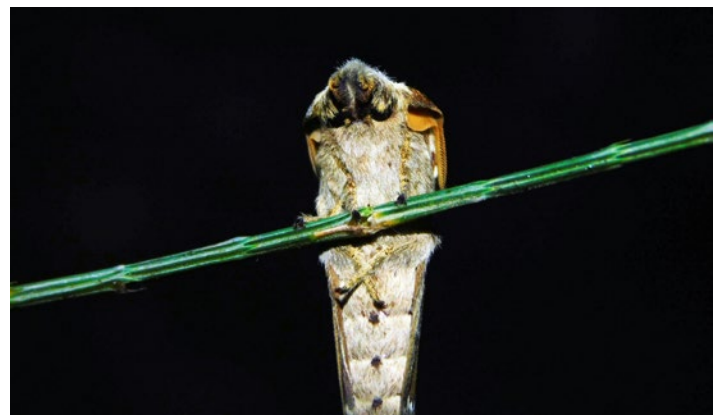


Figure 4 - *Streblote siva*, Ventral view

specimens), protruding beyond the lower angle of the cell as a streak (or more accurately, a dark smudge). White post-medial line distinct, and very irregular. Abdomen white (Figures 2-4). This species diagnosis was further bolstered by the color plates presented by Subhalakshmi (2018), in 'Field Guide to Indian Moths', and the excellent, curated selection of verified images of the species furnished on (the respective species page

of) the Moths of India database - a digital archive of reference quality images for Indian moths.

S. siva is a polyphagous species, and while the complete list of known larval host plants is beyond the scope of this publication, the species can be a pest on several commercially important plants, including *Moringa oleifera* Lam (Joshi et al., 2018), *Psidium guajava* L. (Mitra, 1945), *Dalbergia sissoo* Roxb. (Kalia & Lal, 1999), *Tecomella undulata* (Sm.) Seem. (Kalia et al., 2014), *Tamarindus indica* L. 1753 (Joshi & David, 2018), *Zizyphus jujuba* Miller, and *Rosa* L. spp. (Rajmohana et al., 2024). Hence, the diagnosis and distribution of this species are important for economic reasons.

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