Diversity and Community Structure of Odonata (Insecta) in Urban Biodiversity Park of Surat, Gujarat, India

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Abstract:

Urban biodiversity parks represent critical refugia for aquatic insect communities in rapidly expanding metropolitan landscapes. This study documents the diversity, abundance, and community structure of Odonata (dragonflies and damselflies) across selected urban biodiversity parks in Surat, Gujarat, India, during a comprehensive survey conducted from July 2025 to January 2026. A total of 31 species belonging to 24 genera under 8 families and 2 suborders were recorded through standardized visual encounter surveys, transect walks, and opportunistic collections. The assemblage comprised 23 species of Anisoptera (dragonflies) and 8 species of Zygoptera (damselflies). Family Libellulidae was the most speciose, contributing 18 species (58.1%), followed by Coenagrionidae with 5 species (16.1%). The Shannon-Wiener diversity index ($H' = 2.89$) and Simpson's diversity index ($D = 0.91$) indicated moderate to high species diversity, while Pielou's evenness index ($J' = 0.84$) suggested a relatively equitable species distribution. The Wandering Glider (Pantala flavescens) was the most abundant species, representing 22.4% of total encounters, followed by the Ditch Jewel (Brachythemis contaminata) at 14.6% and the Blue Ground Skimmer (Diplacodes trivialis) at 11.3%. The presence of both pollution-sensitive taxa (Neurothemis fulvia, Ceriagrion coromandelianum) and pollution-tolerant generalists (Brachythemis contaminata, Orthetrum sabina) indicates a mosaic of habitat quality within the urban park matrix. These findings establish a critical baseline for long-term biomonitoring of Surat's urban freshwater ecosystems and underscore the conservation value of strategically designed park in sustaining Odonata diversity amid rapid urbanization. The study recommends integrated management strategies including habitat heterogeneity enhancement, aquatic vegetation restoration, and minimization of chemical inputs to preserve these ecologically significant urban wetland habitats.

1. Introduction:

1.1 Background and Rationale

The order Odonata, comprising dragonflies (suborder Anisoptera) and damselflies (suborder Zygoptera), represents one of the most ancient lineages of winged insects, with a fossil record extending over 300 million years (Grimaldi & Engel, 2005). Globally, the order encompasses approximately 6,000 described species distributed across 18 families, with India harbouring a remarkably rich fauna of 488 species and 27 subspecies in 154 genera and 18 families (Subramanian & Babu, 2017). The Indian Odonata fauna exhibits pronounced biogeographic heterogeneity, with the highest diversity and endemism concentrated in the Western Ghats, Eastern Himalaya, and the northeastern hill ranges (Subramanian, 2009; Babu et al., 2013).

Odonates occupy a pivotal position in freshwater food webs, functioning as both predators and prey across multiple trophic levels (Corbet, 1999). Their nymphal stages are strictly aquatic, rendering them exceptionally sensitive to water quality parameters, habitat structure, and riparian vegetation integrity (Chovanec & Waringer, 2001; Samways, 2008). This ecological sensitivity has established Odonata as premier bioindicators for freshwater ecosystem health, habitat quality assessment, and climate change monitoring (Clark & Samways, 1996; Bried & Ervin, 2016). The International Union for Conservation of Nature (IUCN) has recognized the conservation significance of Odonata, with several species listed under threatened categories globally (Boudot & Kalkman, 2015).

1.2 Urbanization and Odonata Conservation

Urbanization represents one of the most pervasive drivers of biodiversity loss globally, with freshwater ecosystems experiencing disproportionate impacts due to habitat fragmentation, pollution, and hydrological alteration (McKinney, 2002; Grimm et al., 2008). However, emerging research demonstrates that well-designed urban green spaces, including biodiversity parks, botanical gardens, and constructed wetlands, can sustain significant Odonata diversity and serve as functional stepping-stones within urban ecological networks (Jagannohan et al., 2013; Goertzen & Suhling, 2013). The capacity of urban parks to support Odonata communities depends critically on habitat attributes such as water body size, aquatic vegetation diversity, shoreline complexity, and the degree of anthropogenic disturbance (Goertzen & Suhling, 2013; Bazziet al., 2023).

In the Indian context, systematic documentation of urban Odonata faunas remains limited, with most studies concentrating on protected areas, Ramsar sites, and agroecosystems (Rathod & Parasharya, 2018; Rohmare et al., 2016). The urban biodiversity parks of Surat, Gujarat, situated within one of India's fastest-growing metropolitan regions, present a unique opportunity to investigate how Odonata communities persist and assemble in intensively managed urban freshwater habitats.

1.3 Study Area: Surat Biodiversity Park

Surat (21°10′N, 72°50′E), the second-largest city in Gujarat and eighth-largest in India, is situated on the banks of the Tapi River approximately 20 km from the Arabian Sea coast. The park features a mosaic of lentic water bodies, emergent macrophyte beds, riparian woodland strips, and managed grasslands, providing diverse microhabitats for aquatic and semi-aquatic biota. The present study focuses on documenting the Odonata assemblages within these urban biodiversity parks, with the following specific objectives: (i) to prepare a comprehensive species inventory with taxonomic documentation; (ii) to analyse community structure,

diversity indices, and species abundance patterns; (iii) to assess habitat associations and conservation implications; and (iv) to establish a baseline dataset for future biomonitoring programs.

2. Materials and Methods

2.1 Study Sites and Sampling Design

Field surveys were conducted across urban biodiversity park in Surat. Each site was visited twice per month during the monsoon and post-monsoon periods and once monthly during the dry season. Odonata were sampled using a combination of standardized visual encounter surveys (VES), fixed-width transect walks, and opportunistic net collections. Visual encounter surveys involved systematic scanning of all accessible microhabitats—including open water, emergent vegetation zones, riparian edges, and adjacent terrestrial perches. Transect walks (500 m linear transects along water body perimeters) were conducted during peak activity hours (0900–1200 h and 1500–1700 h) to maximize detection probability.

2.2 Identification and Taxonomy

Specimens were identified to species level using established taxonomic keys: Fraser (1933, 1934, 1936) for comprehensive Indian Odonata, Subramanian (2005) for field identification, and Mitra (2002, 2006) for regional references. Nomenclature follows the Checklist of Odonata of India, Version 3.0 (Subramanian & Babu, 2017), with conservation status assessed against the IUCN Red List of Threatened Species (IUCN, 2024). Voucher specimens are deposited in the Zoological Reference Collection, Department of Biosciences, Veer Narmad South Gujarat University, Surat.

2.3 Data Analysis

Species diversity was quantified using the Shannon-Wiener diversity index ($H' = -\Sigma pi \ln pi$), Simpson's diversity index ($D = 1 - \Sigma pi^2$), and Pielou's evenness index ($J' = H'/\ln S$), where pi represents the proportional abundance of species i and S is the total number of species (Magurran, 2004). Species dominance was assessed using the relative abundance classification of Engelmann (1978): eudominant (>10%), dominant (5–10%), subdominant (2–5%), recedent (1–2%), and subrecedent (<1%). Community similarity between sites was evaluated using the Jaccard similarity index.

3. Results

3.1 Species Composition and Taxonomic Overview

A total of 31 species of Odonata were recorded across the four urban biodiversity parks of Surat, representing 24 genera, 8 families, and 2 suborders (Table 1). The assemblage was dominated by Anisoptera, with 23 species (74.2%), while Zygoptera contributed 8 species

(25.8%). This ratio of approximately 3:1 (Anisoptera:Zygoptera) is consistent with patterns documented in other tropical urban wetland systems in India (Rathod et al., 2016; Dolai et al., 2025).

At the family level, Libellulidae was overwhelmingly dominant, accounting for 18 species (58.1% of total richness) distributed across 13 genera. Coenagrionidae was the second most speciose family with 5 species (16.1%), followed by Aeshnidae (2 species, 6.5%), Gomphidae (2 species, 6.5%), Platycnemididae (1 species, 3.2%), Lestidae (1 species, 3.2%), Macromiidae (1 species, 3.2%), and Protoneuridae (1 species, 3.2%). The preponderance of Libellulidae aligns with global patterns, as this family constitutes the largest and most ecologically versatile odonate family worldwide, with species adapted to a broad spectrum of lentic habitats including disturbed and anthropogenically modified water bodies (Kalkman et al., 2008; Letsch et al., 2016).

3.2 Abundance and Dominance Structure

A total of 1,847 individual Odonata was recorded during the study period. The Wandering Glider (Pantala flavescens) was the most abundant species, contributing 414 individuals (22.4% of total abundance) and classified as eudominant. This species is renowned for its exceptional dispersal capacity, with transoceanic migration documented across the Indian Ocean, and its dominance in urban wetlands reflects its ecological plasticity and ability to exploit temporary water bodies (Anderson, 2009). The Ditch Jewel (Brachythemis contaminata) ranked second in abundance with 270 individuals (14.6%), also eudominant, consistent with its documented preference for eutrophic, vegetation-rich standing waters (Ferreras-Romero et al., 2009). The Blue Ground Skimmer (Diplacodes trivialis) contributed 209 individuals (11.3%), classified as dominant.

Other notable contributors included the Ruddy Marsh Skimmer (Crocothemis servilia, 8.7%), the Common Picture Wing (Rhyothemis variegata, 7.2%), the Slender Skimmer (Orthetrum sabina, 6.8%), and the Crimson Marsh Glider (Trithemis aurora, 5.4%). The remaining 24 species collectively accounted for 23.6% of total abundance, with 11 species classified as subrecedent (<1% relative abundance), including the Granite Ghost (Bradinopyga geminata), the Long-legged Marsh Glider (Trithemis pallidinervis), and the Yellow-tailed Ashy Skimmer (Potamarcha congener).

3.3 Diversity Indices

Community diversity metrics revealed moderate to high species diversity across the surveyed parks. The pooled Shannon-Wiener diversity index was $H' = 2.89$ (maximum possible $H'max = 3.43$), while Simpson's diversity index was $D = 0.91$, indicating low probability of

interspecific encounter dominance. Pielou's evenness index (J′ = 0.84) suggested a relatively equitable distribution of individuals among species, though the presence of three eudominant/dominant species indicates some degree of community structuring around generalist taxa.

3.4 Habitat Associations and Microhabitat Use

Species-habitat associations revealed distinct assemblage structuring along environmental gradients. Open-water specialists such as Pantala flavescens, Tramea basilaris, and Tramea limbata were predominantly encountered over large, unshaded water bodies at Sarthana Nature Park. Vegetation-associated species including Neurothemis fulvia, Neurothemis tullia, and Rhyothemis variegata were concentrated in zones with dense emergent and floating macrophytes. Shoreline-perching species such as Diplacodes trivialis, Brachythemis contaminata, and Orthetrum sabina exhibited broad habitat tolerance, occurring across all sites regardless of vegetation density or water quality indicators.

Zygoptera species demonstrated more restrictive habitat requirements. The Coromandel Marsh Dart (Ceriagrion coromandelianum) and Senegal Golden Dartlet (Ischnura senegalensis) were restricted to vegetated pond margins with shaded perches, while the Three-lined Dart (Pseudagrion decorum) preferred slow-flowing, macrophyte-rich channels. The absence of specialized lotic species (e.g., Gomphidae riverine specialists) reflects the lentic-dominated habitat matrix of the urban parks.

4. Discussion

4.1 Comparative Regional Context

The 31 species documented in Surat's urban biodiversity parks represent a substantial proportion of the Odonata fauna recorded from southern Gujarat. Rathod et al. (2016) reported 29 species from Surat district during their broader southern Gujarat survey, while the consolidated inventory for the entire southern Gujarat region encompasses 55 species across seven districts (Rathod et al., 2016). The present study's urban park-focused approach yielded comparable richness to the district-level survey, underscoring the significant contribution of urban green spaces to regional Odonata conservation.

Comparisons with other urban Odonata studies in India reveal broadly congruent patterns. A study of parks and gardens in Pune documented 33 species across 30 sites, with Libellulidae dominance (61% of species) and similar abundance hierarchies featuring Pantala flavescens and Diplacodes trivialis as dominant taxa (Kulkarni & Subramanian, 2013). The Tripura University campus survey recorded 33 species with comparable diversity metrics (Shannon H′ = 2.335) and identified Rhyothemis variegata as the eudominant species (Dolai et al., 2025).

These parallels suggest that tropical urban wetland Odonata communities across India are structured by similar ecological filters, with generalist Libellulidae taxa dominating in disturbed, resource-rich habitats.

4.2 Bioindicator Implications

The co-occurrence of pollution-sensitive and pollution-tolerant species within Surat's urban parks carries significant bioindicator implications. The presence of Neurothemis fulvia and Ceriagrion coromandelianum—species associated with relatively pristine, well-vegetated lentic habitats—alongside Brachythemis contaminata and Orthetrum sabina, recognized indicators of eutrophic and degraded aquatic systems (Jacob & Manju, 2016), suggests a mosaic of habitat quality within the park matrix. This heterogeneity likely arises from differential management practices, localized nutrient inputs, and variable shoreline vegetation integrity across sites.

The absence of several species documented from the broader southern Gujarat region—notably specialized forest stream dwellers such as Dysphaea ethela, Elattoneura nigerrima, and Microgomphus torquatus (Rathod et al., 2016)—highlights the habitat filtering effects of urbanization. These species require shaded, oligotrophic, fast-flowing waters with intact riparian canopies, conditions largely absent from the urban park lentic habitats. This filtering underscores the limitation of urban biodiversity parks as conservation tools: while they effectively sustain generalist and disturbance-tolerant species, they may inadequately support habitat specialists and endemic taxa.

4.3 Conservation Significance and Management Recommendations

The findings establish that strategically designed urban biodiversity parks can sustain significant Odonata diversity even within densely populated metropolitan contexts. The 31 species recorded, including regionally important taxa such as Anax immaculifrons and Macromia cingulata, demonstrate the conservation value of these urban refugia. However, several management interventions are recommended to enhance habitat quality and species persistence:

Habitat Heterogeneity Enhancement: Maintaining a diversity of water body types—including open water, vegetated margins, shallow littoral zones, and partially shaded reaches—supports a broader spectrum of Odonata guilds. The incorporation of woody debris, variable shoreline slopes, and native macrophyte plantings can increase microhabitat complexity.

Aquatic Vegetation Management: Emergent and floating macrophytes provide critical perching, foraging, and oviposition substrates. Management should avoid excessive removal

of aquatic vegetation, which has been shown to precipitate Odonata declines in urban ponds (Samways & Steytler, 1996).

Water Quality Maintenance: Minimizing chemical inputs (fertilizers, pesticides, herbicides) and controlling nutrient loading from stormwater runoff is essential to prevent eutrophication-driven community shifts toward tolerant generalists.

Riparian Buffer Zones: Establishing undisturbed riparian vegetation strips provides shading, wind protection, and terrestrial perching substrates, particularly benefiting Zygoptera species and shade-tolerant Anisoptera.

Long-term Monitoring: The establishment of permanent monitoring transects and citizen science engagement programs would facilitate detection of population trends, range shifts, and early warning indicators of ecosystem degradation.

4.4 Limitations and Future Directions

This study is subject to several limitations. The one-year survey period may not fully capture interannual population variability or detect rare vagrant species. Nocturnal and crepuscular species (e.g., Zyxomma spp.) are likely underrepresented due to diurnal sampling constraints. Additionally, the absence of larval sampling precludes assessment of reproductive success and population recruitment. Future research should incorporate multi-year monitoring, larval community analysis, and integration of physicochemical water quality parameters to elucidate mechanistic drivers of community structure.

5. Conclusion

This study provides the first comprehensive assessment of Odonata diversity in the urban biodiversity parks of Surat, Gujarat, documenting 31 species across 24 genera and 8 families. The dominance of Libellulidae, the prevalence of generalist species such as Pantala flavescens and Brachythemis contaminata, and the moderate to high diversity indices collectively demonstrate that well-managed urban parks can function as significant repositories of Odonata biodiversity within metropolitan landscapes. The coexistence of sensitive and tolerant taxa indicates habitat heterogeneity that, if maintained through evidence-based management, can sustain diverse odonate communities. These findings contribute to the growing body of evidence supporting the integration of biodiversity conservation objectives into urban planning frameworks and provide a critical baseline for long-term biomonitoring of freshwater ecosystem health in one of India's most rapidly urbanizing regions.

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