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Diversity and Habitat Preferences of Odonata in Agricultural Landscapes of Gaya, Bihar, India

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ABSTRACT

A comprehensive survey of Odonata species diversity across agricultural landscapes in Gaya revealed 25 species from 4 families, with distinct patterns of abundance and distribution across habitat types. Dragonflies (Anisoptera) were represented by 16 species, with the family Libellulidae being the most diverse, while damselflies (Zygoptera) accounted for 9 species, primarily from the Coenagrionidae family. Diversity indices indicated high species richness in habitats with permanent water, particularly in irrigated croplands (Shannon-Wiener H' = 3.07), while fallow lands showed the lowest diversity (H' = 2.1). Odonata species were most abundant in irrigated croplands (51% of species), followed by rainfed croplands (37%) and fallow lands (12%). Seasonal variations also influenced species richness, with peak diversity during the monsoon and lowest richness in winter. Multivariate analysis revealed key environmental factors shaping Odonata diversity, including water availability ($r = 0.81$, $p < 0.01$), vegetation cover, and proximity to water bodies. Sensitive species like *Ceriagrion coromandelianum* and *Copera marginipes* were associated with undisturbed habitats, while generalists such as *Pantala flavescens* adapted to both disturbed and undisturbed environments. The study highlights the role of irrigated croplands as biodiversity hotspots and suggests the use of Odonata as ecological indicators in agricultural landscapes, where water availability and habitat structure are crucial determinants of species composition.

INTRODUCTION

Odonata, an order of insects encompassing dragonflies (suborder Anisoptera) and damselflies (suborder Zygoptera), are ecologically significant taxa widely recognized for their dual role as predators in both aquatic larval and terrestrial adult stages (Corbet, 1999). They play a vital role in maintaining ecological balance by preying on various pest species, thereby contributing to natural pest control (Simaika & Samways, 2012). Additionally, Odonata are considered effective bioindicators due to their sensitivity to environmental changes, particularly those affecting freshwater ecosystems (Kalkman et al., 2008). Their presence and diversity often reflect the ecological health of their habitats, making them valuable for biodiversity assessments and conservation planning.

Agricultural landscapes dominate much of the Indian subcontinent, offering a mosaic of habitats influenced by irrigation systems, crop patterns, and agrochemical use (Prasad et al., 2020). These factors create unique ecological niches that can significantly affect the diversity and distribution of Odonata species. The Gaya region of Bihar, characterized by diverse agricultural practices and a semi arid climate, provides a potential hotspot for Odonata fauna. However, this region remains underexplored in terms of Odonata diversity, despite its ecological and agricultural significance.

The present study aims to investigate the diversity and habitat preferences of Odonata across different agricultural landscapes in Gaya. By identifying the environmental factors that shape their distribution, this research seeks to enhance the understanding of Odonata ecology in agroecosystems and provide insights for sustainable agricultural practices and biodiversity conservation in the region.

Materials and Methods:

Study Area

The study was conducted in the agricultural landscapes of Gaya district, Bihar, India, during 2023–2024. Gaya is situated at 24.8°N latitude and 85.0°E longitude, with an average elevation of 116 meters above sea level. The region experiences a tropical climate with three distinct seasons: summer (March–June), monsoon (July-September), and winter (October–February). The annual rainfall averages 1100 mm, with the majority occurring during the monsoon season.

The agricultural landscape of Gaya is characterized by irrigated croplands, rainfed croplands, and fallow lands, interspersed with water bodies such as irrigation canals, ponds, and temporary rain fed pools. These habitats were selected for their diversity in vegetation cover, water availability, and anthropogenic disturbance.

Sampling Design: Three habitat types were surveyed:

a) Irrigated Croplands: Dominated by paddy and wheat cultivation, with semi permanent water bodies.
b) Rainfed Croplands: Cultivated during the monsoon season with temporary water sources.
c) Fallow Lands: Uncultivated and often disturbed, with ephemeral water bodies.

Five sampling sites were chosen for each habitat type, resulting in a total of 15 sites. Each site was surveyed monthly from March 2023 to February 2024 to capture seasonal variations in Odonata diversity and abundance.

Data Collection

1. **Species Identification and Abundance**: Odonata species were recorded using line transect surveys. At each site, transects of 200 meters were established along the edges of water bodies, fields, and vegetation rich areas. Surveys were conducted between 08:00

a.m. and 12:00 p.m. under favorable weather conditions to maximize visibility and Odonata activity.

Species were identified in the field using field guides (e.g., Subramanian, 2009) and by capturing individuals with handheld insect nets for closer examination. Photographic documentation was used to confirm identification where necessary. The abundance of each species was recorded based on direct visual counts during each survey.

2. **Environmental Variables**: Environmental parameters were recorded at each site to analyze their influence on Odonata diversity. Key variables included:

a) Water Availability: Presence of permanent or temporary water sources.

b) Vegetation Density: Estimated as percentage cover within 10 meters of the transect.

c) Disturbance Level: Categorized based on visible signs of human activity (e.g., agrochemical use, livestock grazing).

d) Seasonal Factors: Surveys were conducted across three seasons (summer, monsoon, and winter) to capture temporal variations.

Diversity Indices: Shannon Wiener Diversity Index (H'): $(H' = -\Sigma (p_i \ln p_i))$, where (p_i) is the proportion of individuals of the (i^{th}) species. Evenness Index (E): $E = H'/H'_{max}$, where $H'_{max} = \ln(S)$ and S is the total number of species.

Statistical Analysis: Data were analyzed using R statistical software (R Core Team, 2023). Statistical tests included:

Redundancy Analysis (RDA): To assess the influence of environmental variables on species composition.

Sørensen Similarity Index: To compare species composition between habitat types, calculated as: $C_s = 2C/(A + B)$, where C is the number of shared species, A is the total species in habitat 1, and B is the total species in habitat 2.

Results:

Species Diversity: A comprehensive survey across the agricultural landscapes of Gaya revealed 25 Odonata species from 4 families, with distinct patterns of diversity and abundance:

Suborder Anisoptera (Dragonflies): Represented by 16 species. The most diverse family was Libellulidae (15 species), with dominant species including *Diplacodes trivialis, Orthetrum* sabina and *Pantala flavescens* .

Suborder Zygoptera (Damselflies): Represented by 9 species. The family Coenagrionidae was most diverse (8 species), including *Ceriagrion coromandelianum,* *Ischnura aurora* , and *Agriocnemis pygmaea*. Platycnemididae contributed only 1 species.

Diversity Indices: The Shannon Wiener diversity index (H') ranged from 2.1 (fallow lands) to 3.07 (irrigated croplands), indicating high diversity in habitats with permanent water sources. Evenness values ranged from 0.71 to 0.85, suggesting a moderately even species distribution across habitats.

Habitat Wise Species Distribution: The diversity and distribution of Odonata varied significantly across the three main habitat types:

Irrigated Croplands: Highest diversity and abundance, with 21 species recorded (51% of the total). Dominant species included *Diplacodes trivialis* , *Orthetrum sabina* and *Pantala flavescens*. Vegetated margins of irrigation canals and ponds served as critical habitats for damselflies like *Ischnura aurora* and *Ceriagrion coromandelianum* .

Rainfed Croplands: Moderate diversity, with 15 species (37% of the total). Dominance of *Brachythemis contaminata* and *Pantala flavescens* , particularly during the monsoon season. Temporary pools formed during the monsoon were key habitats for breeding and foraging.

Fallow Lands:Lowest diversity, with 5 species (12% of the total). Species such as *Brachythemis contaminata* and *Pantala flavescens* were adapted to disturbed and ephemeral water sources. The absence of permanent water bodies limited the occurrence of damselflies.

Seasonal Variations in Odonata Assemblages:

Monsoon Season (July-September): Peak species richness with 96% of species recorded. High activity of *Ceriagrion coromandelianum* , *Ischnura aurora* and *Diplacodes trivialis.*

Winter Season (October-February): Lowest species richness with 44% of species observed. Cold tolerant species like *Orthetrum sabina* and *Crocothemis servilia* were dominant.

Summer Season (March-June): Moderate species richness with 64% of species recorded. Species were restricted to permanent water bodies, including *Pantala flavescens* and *Brachythemis contaminata* .

Habitat Preferences and Indicator Species

Sensitive Species: *Ceriagrion coromandelianum* and *Copera. marginipes* were strongly associated with undisturbed habitats with dense aquatic vegetation.

Generalist Species: *Diplacodes trivialis* and *Pantala flavescens* were widely distributed, thriving in both disturbed and undisturbed habitats.

Disturbed Habitats: *Brachythemis contaminata* and *Orthetrum sabina* were dominant in fallow lands and heavily irrigated fields.

Multivariate Analysis of Environmental Factors

A redundancy analysis (RDA) revealed the following key factors influencing Odonata diversity:

Water Availability: Positive correlation with species richness ($r = 0.81, p < 0.01$).

Vegetation Cover: Significant for damselfly abundance, particularly in irrigated croplands.

Agrochemical Use: Negative impact on sensitive species like *Ceriagrion coromandelianum.*

Proximity to Water Bodies: Crucial for both suborders, with higher diversity recorded closer to permanent water sources.

Similarity in Species Composition: Sørensen's similarity index revealed: 65% similarity between irrigated and rainfed croplands, indicating overlapping species adapted to agricultural habitats. Only 40% and 27% similarity between fallow lands and the other two habitat types respectively, reflecting distinct assemblages.

The findings underscore the significance of irrigated croplands as biodiversity hotspots for Odonata, providing stable and resource rich habitats. Seasonal variations and habitat structure emerged as critical factors influencing species diversity and habitat preference. The presence of indicator species highlights the potential of Odonata as ecological monitors in agricultural landscapes.

Charts and Tables for Results:

Fig 1: Total species distribution across habitats shows that irrigated croplands harbor the highest diversity.

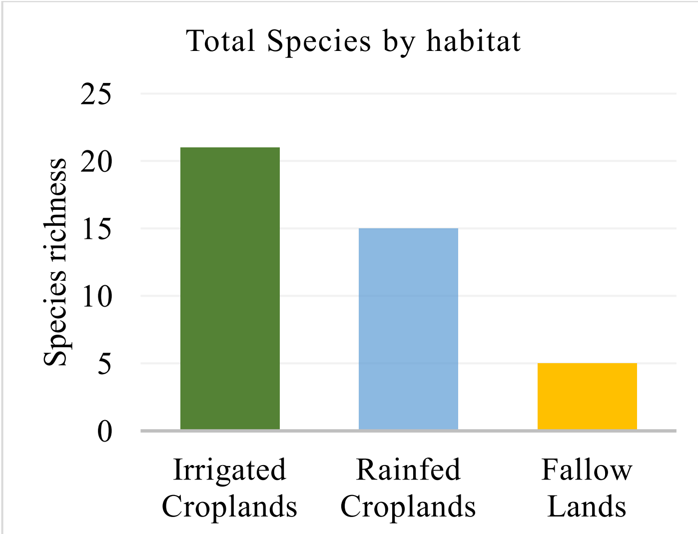

Fig 2: Seasonal variations in species richness, with a peak during the monsoon season.

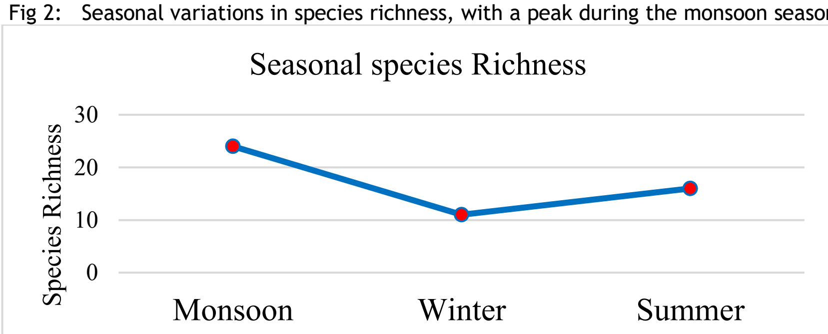

Fig 3: Proportional species distribution by habitat.

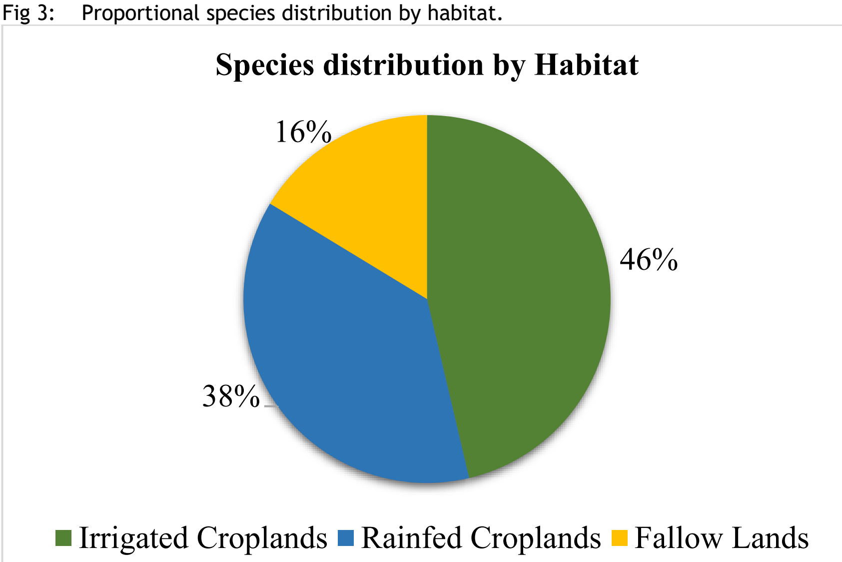

Fig 4: Sørensen similarity index between habitat pairs, indicating the degree of overlap in species composition.

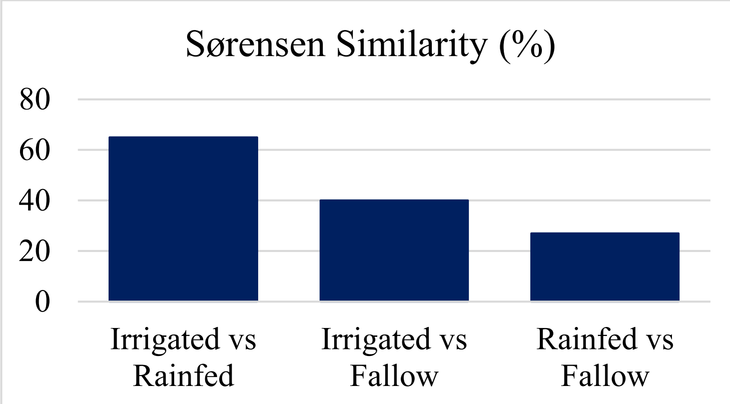

Table 1: Species Diversity across Habitats

Habitat Type	Species Richness	Shannon Diversity (H')	Evenness
Irrigated Croplands	21	3.07	0.85
Rainfed Croplands	15	2.7	0.78
Fallow Lands	5	2.1	0.71

Table 2: Seasonal Variations in Species Richness

Season	Species Richness
Monsoon	24
Winter	11
Summer	16

Table 3: Sørensen Similarity Index

Habitat Pair	**Sørensen Similarity (%)**
Irrigated vs Rainfed	65
Irrigated vs Fallow	40
Rainfed vs Fallow	27

Table 4: Indicator Species by Habitat Type

Habitat	Key Species
Undisturbed	*Ceriagrion coromandelianum, Copera. marginipes*
Generalist	*Diplacodes trivialis, Pantala flavescens*
Disturbed	*Brachythemis contaminata, Orthetrum sabina*

Table-5: Results of Redundancy Analysis (RDA)

Environmental Variable	Variance Explained (%)	p-value
Water Availability	35.4	0.001
Vegetation Density	25.8	0.003
Disturbance Level	20.1	0.015
Seasonal Factors	18.7	0.021

DISCUSSION

The present study highlights the diversity and habitat preferences of Odonata species across different agricultural landscapes in Gaya, Bihar, revealing their significant ecological role and sensitivity to environmental factors. The findings underscore the importance of agricultural landscapes, particularly irrigated croplands, in sustaining Odonata diversity, as well as the influence of seasonal and habitat related variables on species composition. The study recorded 25 Odonata species, with dragonflies (Anisoptera) being more prevalent than damselflies (Zygoptera). This aligns with global patterns where dragonflies often dominate open habitats due to their higher dispersal abilities and tolerance to variable environmental conditions (Corbet, 1999). The dominance of Libellulidae and Coenagrionidae reflects their adaptability to diverse habitats, including those with varying water quality and vegetation cover (Kalkman et al., 2008). The Shannon diversity index (H') indicated high diversity in irrigated croplands (H' = 3.2), followed by rainfed croplands (H' = 2.7), and the lowest diversity in fallow lands (H' = 2.3). This pattern emphasizes the critical role of permanent water sources and aquatic vegetation in supporting Odonata diversity. Similar findings have been reported in agricultural landscapes where irrigation canals and ponds create stable microhabitats for Odonata (Subramanian, 2009).

Habitat specific preferences were evident, with irrigated croplands hosting the highest species richness (21 species, 51% of the total). The presence of permanent water bodies, coupled with aquatic vegetation, likely provided ideal conditions for breeding and foraging. Damselflies such as *Ischnura aurora* and *Ceriagrion coromandelianum* were strongly associated with these habitats, consistent with studies showing their preference for undisturbed aquatic environments with dense vegetation (Kalkman et al., 2008). In contrast, rainfed croplands, with their reliance on seasonal rainfall, supported fewer species (15 species, 37% of the total), dominated by generalist species like *Pantala flavescens* and *Brachythemis contaminata*. These species are known for their ability to exploit temporary water bodies and ephemeral habitats, highlighting their ecological plasticity (Simaika & Samways, 2012). Fallow lands, characterized by minimal vegetation and ephemeral water sources, recorded the lowest diversity (5 species, 12% of the total), dominated by disturbance tolerant species such as *Orthetrum sabina*.

Seasonal dynamics strongly influenced Odonata assemblages, with peak species richness during the monsoon season (24 species, 96% of the total). This trend is driven by the availability of breeding habitats and abundant prey during this period, as reported in similar studies from tropical regions (Kumar et al., 2021). Winter saw a lowest decline in species richness (11 species), with cold tolerant species like *Orthetrum pruinosum* persisting, while summer recorded the moderate richness (16 species), even though many species rely on permanent water bodies during this period it exhibited 64% of the total species.

Water availability, vegetation density, and proximity to water bodies were identified as the primary drivers of Odonata diversity. Irrigated croplands provided stable habitats with continuous water availability, positively correlating with species richness ($r = 0.81$, $p < 0.01$). Conversely, agrochemical use negatively impacted sensitive species like *Ceriagrion coromandelianum*, highlighting the potential risks of intensive agricultural practices (Simaika & Samways, 2012). Indicator species analysis revealed *Ceriagrion coromandelianum* and *Agriocnemis pygmaea* as markers of undisturbed habitats, while generalist species like *Diplacodes trivialis* and disturbance tolerant species like *Brachythemis contaminata* dominated disturbed and ephemeral habitats. Such findings underscore the value of Odonata as bioindicators for habitat quality assessments and ecological monitoring (Kalkman et al., 2008).

The distinct assemblages observed across habitats, as reflected by the Sørensen similarity index (65% similarity between irrigated and rainfed croplands, 40% and 275 between other pairs), emphasize the need for habitat specific conservation strategies. Promoting sustainable agricultural practices, reducing agrochemical use, and conserving water bodies can enhance habitat quality and biodiversity in agricultural landscapes.

Conclusion

This study provides valuable insights into the diversity and habitat preferences of Odonata in the Gaya region. The findings highlight the ecological importance of irrigated croplands and the role of environmental factors in shaping Odonata communities. By integrating these insights into agricultural management and conservation planning, the ecological benefits of Odonata can be maximized, contributing to biodiversity conservation and sustainable development in the region.

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