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Odonata Unveiled: A Differential Diagnosis of Recent Odonata Species Discovered in India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Odonata, commonly known as dragonflies and damselflies, represent a fascinating and diverse order of insects found throughout the world, with a rich evolutionary history dating back hundreds of millions of years. Odonates are diverse group of insects with around 6407 valid species throughout the world, out of which 498 species have been recorded in India. These insects are characterized by their striking, often vibrant, colors, large compound eyes, and elongated bodies. This review provides a concise overview of the various new Odonata species discovered in recent years in India. Odonata, like all living organisms, continue to evolve because evolution is a fundamental and ongoing process in the natural world. Several factors contribute to why Odonata, along with all species, are still evolving. In recent years different species have been discovered from both the suborders that is, Anisoptera and Zygoptera of the order Odonata. Different species have been mainly discovered from Kerala, and Maharashtra. The species are identified on the basis of their

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external features, markings and similarities and dissimilarities from the similar species. This also covers the importance of newly found species, their ecological value and their importance in the environment as a wetland marker.

Keywords: Odonata; species discovery; diversity; anisoptera; zygoptera; ecological value; wetland marker.

ABBREVATIONS

Sp. : Species
B. : Burmagomphus
E. : Epithemis
P. : Protosticta

1. INTRODUCTION

Odonata is an insect order that includes dragonflies and damselflies. They are large, colorful, and easily observable. They are popular with both amateur and professional entomologists. They have two pairs of narrow, transparent wings, a sloping thorax, a long slender body, an abdomen that is almost always longer than any of the wings, chewing mouthparts, very short antennae and muscles with a high proportion of sarcoplasmic reticulum. Odonata shows a very distinct mechanism of flying. They have strong flight muscles which not only helps them in flying but also enables them to glide swiftly in the air [1].

They are also considered as voracious feeders, both as nymphs and adults, they feed upon mosquito larvae, small insects, fish fingerlings and fish spawns etc. [2].

The mating behavior of dragonflies involves a variety of fascinating rituals, it forms a heart or wheel like shape during mating known as "mating wheel" a specific behavior observed during dragonfly courtship. This phenomenon is also known as a copulatory wheel. Male dragonflies often perform intricate flight displays to attract females. Once a female is interested, the male grasps the female behind her head using claspers at the end of his abdomen [3]. According to recent data there are 6,407 reported Odonata species in the world [4]. In India there are approximately 498 species and 27 subspecies in 154 genera and 18 families that are currently reported from different states [5]. There are 276 species under 94 genera and 8 families in the Suborder Anisoptera, 211 species under 59 genera and 9 families in the Suborder Zygoptera, and one species under one genera and one family in the Suborder Anisozygoptera.

The order Odonata holds a special place in assessing the health of the fresh water ecosystem. Odonata are highly dependent on the water for their growth and development. From laying eggs to completing their larval form, Odonata directly rely on water and the quality of water. Hence, they act as a bio-indicator of quality of the water and health of the environment [6].

Along with ecological importance, Odonata also holds cultural significance. In a study conducted in Sebu Lake situated at Mindanao in Philippines, an ethno-linguistic group known as T'boli, revealed the cultural significance of Odonata [7]. This ethno-linguistic group uses the larvae of family Libellulidae and Aeshnidae as dietary source. Along with the dietary source, they also consider the Odonata larvae as antidote for various diseases. During an interview with T'boli people, they also mentioned the folk songs and lullabies associated with the Odonata, for spreading their beliefs to the young generation, emphasizing on the importance of Odonata in the nature and how to live in the nature with harmony.

Odonata are also considered as bio-control agent as they feed upon various small insects like mosquito and their larvae. The nymphs of Odonata are highly voracious feeders and they feed upon the larvae of the mosquitoes present in the water [8].

This review discusses about the three new species recorded in India. These species have been recorded in Kerala and Maharashtra. Out of three species two of them belongs to the suborder Anisoptera and one belongs to the suborder Zygoptera. In the suborder Zygoptera, *Protosticta sexcoloratus* sp. was discovered in the year 2023 and in the suborder Anisoptera, *Burmagomphus chaukulensis* sp. in the year 2022 and *Epithemis wayanadensis* sp. in the year 2023 were discovered. These species were reported and were compared morphologically to the similar species residing in the similar habitat. On carrying out the in-depth analyzation of the

species, these species were considered as new species. All three newly species found have their own importance and significance.

2. RECENT ODONATA SPECIES DISCOVERED IN INDIA

Chandran along with his team [9] discovered a new population of *Protosticta sexcoloratus* Chandran, Muneer, Madhavan, Jose, which was different from the early existing species. It belongs to the suborder Zygoptera (Damselfly) and family Platystictidae. This family is distributed throughout South America, Central America and Asia [10].

While investigating the Odonata diversity of the Western Ghats of Kerela, a population of *Protosticta* was found in Vellarimala, Wayanad which was morphologically quite different from the previously existing *Protosticta* species. Individuals were collected and were deeply studied with respect to their morphological characters and these characters were compared with the detailed description of the all the *Protosticta* species found in the Western Ghats. This detailed comparison concluded that the population found in Vellarimala, Wayanad is a new species.

Materials and methods: The specimen of *Protosticta sexcoloratus* were collected with the help of insect net. Total five specimens were collected, out of which three were male and two were female. The collected specimens were then preserved by both wet (absolute ethanol) and dry method. Along with that the specimens of *P. gravelyi* Lidlaw , 1915 and *P. mortoni* Fraser, 1924 were also collected and preserved for the comparative study. The photographs of the species present in the field were captured using a Sony a7III mirrorless digital camera. The preserved specimens were dissected under stereomicroscope for the further studies of their genital ligulae. Measurements were taken using digital vernier caliper.

Morphological features: The most distinct characteristic of the reported species was that the color of male and the color of female was quite different, which was not seen earlier in any other similar species from the same group. Presence of a fine bluish mid-dorsal crania present in the male. It was also observed that both male and female were of same size, which was again considered as a distinct feature. Along with this the prothorax was pale purple in color with black color markings. The S9 was devoid of any sort of markings and cerci was found to be rounded in this species. The size of the species was way smaller as compared to the similar species. It was also seen that the posterior lobe of the prothorax was spine deficient. The paraprocts were not bifurcated and sub basal spines were quite noticeable. When observed carefully the shape of the caudal appendages were observed to be little different from the other species. The presence of small dorsal spine was noticed on the cerci after its bifurcation. In the third segment the bifurcated tips were round in shape while in other species it was observed to be shovel shaped.

A new species belonging to the genus *Epithemis* was recorded in the Wayanad plateau, Kerela in October, 2023 [11]. The genus *Epithemis* was taken into account as monotypic and was represented by a single species *Epithemis mariae* Laidlaw,1915. This genus was found to be endemic to the Western Ghats region of India [12]. During the research and field work going on in Kerala, a specimen was found which was quite similar to the *Epithemis mariae* but had some morphological differences. The new specimen found appeared to be darker in color, abdomen had red coloration which was restricted, and absence of yellow colored antehumeral stripes made it look different from the *Epithemis mariae*.

List 1. *Protosticta sexcoloratus* sp.

Order	Odonata
Suborder	Zygoptera
Superfamily	Platystictoidea
Family	Platystictidae
Genus	*Protosticta*
Type species	*Protosticta gravelyi*

Area: Vellarimala, Meppadi Forest Range, Wayanad, Kerala

Table 1. Differential diagnosis of *Protosticta sexcoloratus* with other species

S.No.	Species	Observation
1.	*Protosticta mortoni*	1) Quite similar caudal appendages in both the species. 2) Different position of dorsal spine present on the cerci. 3) Pale blue color of prothorax in *P. mortoni* while its pale purple in case of *P. sexcoloratus*. 4) *In P. mortoni* the posterior lobe of prothorax was black in color dorsally with blue color spot, while in *P. sexcoloratus* prothorax was pale purple colored and posterior lobe shows curved stripe marking of black color which further goes into the middle lobe. 5) Bifurcated tip in the third segment was rounded in *P. sexcoloratus* while in *P. mortoni* it was hook shape ends.
2.	*Protosticta gravelyi*	1) Quite similar caudal appendages in both the species. 2) Different position of dorsal spine present on the cerci.
3.	*Protosticta hearseyi* Fraser, 1922	1) Pale purple colored prothorax in *P. sexcoloratus* while in *P. hearseyi* it was pale blue. 2) No marking in S9 in *P. sexcoloratus* while marking present in S9 in *P. hearseyi*. 3) Rounded tip cerci in *P. sexcoloratus*, square shaped tip in *P. hearseyi*. 4) Similar mid dorsal crania in both *P. hearseyi* and *P. sexcoloratus*
4.	*Protosticta sholai* Subramanian & Babu, 2020	1) It was bigger than *P. sexcoloratus*. 2) S9 has yellow marking, while it was unmarked in *P. sexcoloratus*. 3) Square shaped tips in cerci, while in case of *P. sexcoloratus* are round in shape.
5.	*Protostict amonticola* Emiliyamma & Palot, 2016	1) Both the species have same size. 2) *P. monticola* has prothorax in brown and white color, while the prothorax in *P. sexcoloratus* was pale purple in color.
6.	*Protosticta sanguinostigma* Fraser,1922	1) Bigger in size. 2) *P. sanguinostigma* has bottle green colored eyes while *P. sexcoloratus* has bright blue colored eyes. 3) Pterostigma was blood red in colored in case of *P. sanguinostigma* while in *P. sexcoloratus* it was dark brown in color. 4) In case of *P. sanguinostigma* the cerci was long with pointed spines, while in case of *P. sexcoloratus* the cerci was short with inward curved spines present in sub basal region.

List 2. *Epithemis wayanadensis* sp.

Order	Odonata
Suborder	Epiprocta
Infraorder	Anisoptera
Family	Libellulidae
Genus	*Epithemis*
Type species	*Epithemis mariae*

Area: Wayanad, Kerala

Material and Methods: Two male specimens of *Epithemis wayanadensis* were collected with the help of butterfly net. Out of two specimens one was preserved in alcohol while other was preserved dry. For the comparative study one male of *E. mariae* was collected. All the specimens were photographed using mirror-less digital camera. For detailed data of morphology stereomicroscope was used. Measurements were taken using digital Vernier caliper.

Morphological Features: During the investigation, two male specimens of *Epithemis wayanadensis* sp. were collected. For the comparative study, *E. mariae* male specimen was collected from village Kuttampuzha,

Anamalai hills, Western Ghats. Both the specimens were photographed using high resolution cameras. *E. wayanadensis* had pitch black color. S3 is red colored on the dorsum and the color was limited to one third of the basal. The labium was completely black in color. Labrum had a black colored smoky spot at center and on the anterior side a narrow black color border was present. The end of each postclypeus had thick black hairs. Legs were completely black in color. Cerci was short with thick spines. The length of epiproct was same as the length of cerci. In secondary genitalia the lamina had thick and sturdy hamules and the lobes of genitalia were boot shaped. The total length of male was 27mm, with 20mm abdomen length.

In *Burmagomphus* genus the current number of species are 29 [13], out of these 29 species around 6 species are reported in India [14]. *Burmagomphus chaukulensis* Joshi, Ogale & Sawant is considered as a new species found in Maharashtra located in the Western Ghats of India. This new species is discovered by [15] in Chaukul village located in Sindhudurg district, Maharashtra. The species was found to be morphologically different from the similar species located in that area. The recorded specimen was observed to have unique shape of the caudal appendages, markings on the thoracic region and distinctive hamuli.

Materials and methods: The specimens were photographed in the field using Canon EOS 7D Mark II DSLR camera. They were then collected insect net. The specimens were then brought to the laboratory and were further photographed using Leica stereomicroscope with inbuilt camera.

Table 2. Differential diagnosis of *Epithemis wayanadensis* with *Epithemis mariae*

S.No.	Species	Observation
1.	*Epithemis. mariae*	1) Black was the predominant color in *E. wayanadensis* while it was brownish black in case of *E. mariae*. 2) S3 dorsum was red colored and limited to its one third in *E. wayanadensis* while it was spread over more than three fourth of basal in case of *E. mariae*. 3) Labium was completely black in case of *E. wayanadensis* while labium was creamy white with blackish fume type at the base in vase of *E. mariae*. 4) In *E. wayanadensis* labrum had a hazy blackish spot in the middle and the anterior margin had black color border, while in case of *E. mariae* color of labrum was completely creamish white. 5) Postclypeus of *E. wayanadensis* had thick tuft of hairs, while in case of *E. mariae* it was absent. 6) Length of cerci was short in case of *E. wayanadensis* while in case of *E. mariae* the length of cerci was long with tapered spines. 7) Length of epiproct was same as length of cerci in case of *E. wayanadensis* while, the length of epiproct was shorter than the length of cerci in case of *E. mariae*. 8) The lamina of secondary genitalia was thick, hamules were thick and genital-lobes were boot shaped in case of *E. wayanadensis*, while the lamina was pointy, hamules were thin and the genital-lobes were square shaped in case of *E. mariae*.

List 3. *Burmagomphus chaukulensis* sp.

Order	**Odonata**
Suborder	Anisoptera
Family	Gomphidae
Genus	*Burmagomphus*
Species	*chaukulensis*

Area: Chaukul, Sindhudurg, Maharashtra

Table 3. Differential diagnosis of *Burmagomphus chaukulensis* with other species

S.No.	Species	Observation
1.	*Burmagomphus divaricatus* Fraser, 1924	1) *B. divaricatus* male had dorsal and antehumeral stripes which were fused, but in case of *B. chaukulensis* male these stripes were short and separated.
2.	*Burmagomphus pyramidalis* Laidlaw, 1922	*1) B. pyramidalis male* had dorsal and antehumeral stripes which were fused, but in case of *B. chaukulensis* male these stripes were short and separated. *2) B. pyramidalis differs from B. chaukulensis by the shape of hamuli on the posterior end. The hamuli of B. chaukulensis* had spines on both ends.
3.	*Burmagomphus hasimaricus* Fraser,1924	1) *B. hasimaricus* male had dorsal and antehumeral stripes which were fused, but in case of *B. chaukulensis* male these stripes were short and separated.
4.	*Burmagomphus laidlawi* Fraser, 1924	1) Both *B. laidlawi* and *B. chaukulensis* had dorsal and antehumeral stripes which were short and separated. 2) The markings on the thorax is quite similar in both the species. 3) The hamuli in case of *B. laidlawi* had spines which was only present on the anterior side, while the hamuli in case of *B. chaukulensis* the spines were present on posterior side on both ends. 4) In *B. laidlawi* V4 was small and saddle like in shape and had slim apical filaments, while on the other hand in *B. chaukulensis* the V3 and V4 were tubular in shape and the apical filament was chunky at base. 5) The cerci were curved inwardly with tiny spines at base at apices in *B. laidlawi,* in case of *B. chaukulensis* the cerci were pointy and had a bi-lobed base at apices. 6) The stripe present on the mesepisternum was rounded and wide in *B. laidlawi,* and in *B. chaukulensis* the stripe on mesepisternum was sharp and pointy towards anterior side and was also reduced.

Morphological features: In the field the specimens were captured and clicked using high resolution camera lens. The living male specimen was appeared to be black in color with yellowish to pale green type of markings. Eyes were greenish in color and the face was black in color with yellow markings. The labium was yellow colored and the labrum had yellow spots on it. The prothorax was black in color with yellow color markings on it. The pterothorax had yellow-colored markings on it with mesothoracic collar. Abdomen was black with yellow color markings on it. S1 had triangular markings present on the dorsal side, and markings on the S2 were broad at the posterior end and were thin and tapered and were ending before the margin on the posterior side. The S3 to S7 had basal rings which were posteriorly pointing on the dorsum of S2 to S3. S9 was comprised of having a big size tri-lobed marking at the posterior margin. In case of accessory genitalia, the anterior hamuli was quite short and was wide at the base. The hamuli was tapered at the apices and was dark brown colored and was swathed with dense setae at the apices. The posterior hamuli was almost rectangular in shape, it was quite broad with an apical ridge and acute pointed spines on both posterior and anterior ends. Caudal appendages were both black in color, bifurcated and curved to inside. Cerci was broad towards the base; apices were sharp and curved inwardly. Paraproct was longer than cerci.

3. POTENTIAL THREATS TO THE SURVIVAL OF ODONATA AND CONSERVATION MEASURES

Odonata are highly sensitive to the changes in the environment. A little alteration in the environment, affects the entire life cycle of the Odonata. Since the Odonata are dependent upon the water bodies for their growth and development, any difference in water standards clearly impacts the Odonata residing there [16].

Various human activities pollute the water resources, which in result alters the pH, alkalinity, transparency and size of the water course etc. [17]. These changes in the water standards act as potential threats to the survival of the Odonata species.

The major reason behind the Odonata species getting endangered is the destruction in the wetlands. According to the IUCN Red List of Threatened Species there are many species who are now marked as endangered because of the wetland destruction caused by humans. Loss in the marshes, swamps and free flowing water bodies are caused by reckless expansion of agricultural land, urbanization in the whole world [18].

Pollution from agricultural runoff, industrial discharge, pesticides, herbicides, and household chemicals can degrade water quality and affect Odonata larvae, which are sensitive to changes in water chemistry [19].

Alterations in temperature and precipitation patterns can disrupt Odonata breeding cycles and habitat availability. Shifts in climate may also affect the distribution of species and lead to changes in community composition.

Artificial light sources near aquatic habitats can disrupt Odonata behavior, including mating and foraging, and may attract predators or competitors [20].

Conservation strategies for Odonata aim to address the various threats facing these species and their habitats. Here are some effective conservation strategies:

1. Habitat Conservation and Restoration: Protect and restore natural habitats, including wetlands, ponds, streams, and riparian zones, which are essential for Odonata breeding, feeding, and development.
2. Establish protected areas, reserves, and conservation easements to safeguard Odonata habitats from development and habitat degradation.
3. Water Quality Management: Implement measures to reduce water pollution from agricultural runoff, industrial discharge, and urban sources to maintain suitable habitat conditions for Odonata. Promote best management practices for land use to minimize the impacts of pollution on aquatic ecosystems.
4. Climate Change Adaptation: Develop and implement adaptive management strategies to address the impacts of climate change on Odonata habitats and populations. Identify and protect climate refugia that may provide suitable habitat for Odonata species under future climate scenarios.
5. Community Engagement and Education: Raise awareness about the importance of Odonata and their habitats through public

outreach, education programs, and citizen science initiatives. Engage local communities, landowners, and stakeholders in conservation efforts, including habitat restoration and monitoring programs.

6. Research and Monitoring: Conduct research on Odonata ecology, distribution, population trends, and habitat requirements to inform conservation planning and management. Implement long-term monitoring programs to track Odonata populations and assess the effectiveness of conservation interventions.
7. Policy and Legislation: Advocate for the inclusion of Odonata and their habitats in environmental policies, land-use planning, and conservation regulations. Support the development and enforcement of laws and regulations to protect Odonata species and their habitats from threats such as habitat destruction, pollution, and overexploitation.
8. Collaboration and Partnerships: Foster collaboration among government agencies, non-governmental organizations, academic institutions, and local communities to coordinate conservation efforts and leverage resources effectively. Establish partnerships with private landowners, businesses, and industry stakeholders to promote sustainable land management practices and habitat conservation on private lands.

By implementing these conservation strategies, we can help conserve Odonata species and ensure the long-term health and resilience of their habitats.

4. DISCUSSION

Numerous Odonata species are threatened by habitat loss brought on by urbanization, agriculture, and climate change. The necessity for focused conservation efforts is highlighted by the discovery of new species. Preserving these recently discovered species requires actions to support sustainable land use and safeguard wetland ecosystems. A growing number of citizen science projects have contributed to the documentation of Odonata species in India. Databases are populated by enthusiasts and researchers who map species ranges and track changes over time. Further taxonomic research and genetic analysis are necessary to reveal additional latent diversity in the Odonata. Working together, ecologists, taxonomists, and conservationists will help us gain a thorough understanding of these species. More respect for Odonata and their environments can be fostered by educating the public about their significance. Local communities can be involved in conservation initiatives through educational programs. The health and sustainability of ecosystems can be improved by including Odonata conservation into more general biodiversity and water management plans. Recognizing their place in freshwater systems is part of this.

5. CONCLUSION

In conclusion, the discovery of a new Odonata species in India represents a significant contribution to our understanding of biodiversity and ecosystem dynamics. This newfound species adds to the rich tapestry of India's natural heritage and underscores the importance of continued exploration and documentation of its diverse flora and fauna. The circumstances surrounding the discovery, including the collaboration among researchers and the meticulous process of identification and description, highlight the dedication and expertise required to unveil new species in today's rapidly changing world.

As we celebrate this discovery, it's essential to recognize the broader implications for conservation and ecosystem management. By protecting and restoring habitats, addressing threats such as habitat loss, pollution, and climate change, and engaging local communities in conservation efforts, we can safeguard not only the newly discovered Odonata species but also the entire web of life that depends on healthy ecosystems.

Furthermore, the discovery of new species serves as a reminder of the countless mysteries that still await discovery in the natural world. It underscores the need for continued scientific research, exploration, and conservation efforts to unravel these mysteries and ensure the preservation of Earth's biodiversity for generations to come.

In essence, the discovery of a new Odonata species in India is not just a scientific milestone but also a call to action—an invitation to explore, understand, and protect the wonders of our natural world.

6. STATEMENTS AND DECLARATIONS

- Both the authors, Shweta Bhatia and Neelam Kumari has carried out this work in collaboration between both authors. Both authors read and approved the final manuscript.
- Both the authors, Shweta Bhatia and Neelam Kumari made substantial contributions to the
- conceptions and design of the work, analysis and interpretation of the data.
- Both the authors, Shweta Bhatia and Neelam Kumari have no relevant financial or non-financial interests to disclose.
- The authors Shweta Bhatia and Neelam Kumari have no competing interests to declare that are relevant to the content of this article.
- Both the authors, Shweta Bhatia and Neelam Kumari have no financial or proprietary interests in any material discussed in this article.

7. AVAILABILITY OF DATA AND MATERIALS

Data citation: All the citations are included with the DOI, and is included in the reference list.

DISCLAIMER (ARTIFICIAL INTELLIGENCE).

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPLOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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