

# Odonata Across Different Habitat Types: A Review

Doshita Dass<sup>\*1</sup>, Ritu Sharma<sup>2</sup>

<sup>\*1</sup>Research Scholar, Department of Zoology, Raja Shankar Shah University, Chhindwara, Madhya Pradesh, India

<sup>2</sup>Assistant Professor, Department of Zoology, Pradhan Mantri College of Excellence, Government Autonomous Post Graduate College, Chhindwara, Madhya Pradesh, India

DOI: <https://doi.org/10.51244/IJRSI.2026.1308000316>

Received: 07 September 2026; Accepted: 12 September 2026; Published: 23 September 2026

## ABSTRACT

Odonates (dragonflies and damselflies) act as key ecological indicators of aquatic as well as terrestrial ecosystems. Owing to their two life stages (aquatic larva and aerial/terrestrial adult form) and response to habitat fragmentation, water pollution, radiation, and urban stress, they play an important role in assessing the ecological health of their surroundings. This review highlights the importance of odonates as bioindicators from the existing literature globally and the regional literature on the subject. It is clear that habitat diversity, riparian vegetation cover, and various physicochemical factors (DO, BOD, conductivity, pH, etc.) have a huge effect on the species richness and evenness of the odonate community. Generalist species, such as *Orthetrum sabina*, *Pantala flavescens*, *Brachythemis contaminata*, etc., tend to prevail in disturbed/polluted habitats, whereas stenotopic species act as markers of conserved microhabitats. In Central India, i.e., the Madhya Pradesh region, seasonality and water scarcity pose a unique problem in the study of odonates, which makes the study of seasonally occurring water bodies and urban refugia of great importance for the region. Therefore, understanding the diversity, distribution, and habitat preferences of odonate species is essential for assessing ecosystem health and developing effective conservation strategies.

## INTRODUCTION

Odonata (dragonflies and damselflies) are widely recognized as important components of freshwater and terrestrial ecosystems and have gained attention as potential bioindicators of environmental quality. Odonata can be useful as bioindicators, but mainly as one among a mosaic of correlated habitat (and especially microhabitat) attributes that together correlate with “water quality” and stages of ecological succession, including degradation caused by human impact [7]. Sensitive bioindicator taxa, particularly Odonata (dragonflies and damselflies), have exhibited declines in fragmented landscapes, reflecting the deterioration of habitat quality and freshwater ecosystems [25]. Their presence and diversity often reflect the ecological condition of aquatic habitats, making them valuable in monitoring environmental changes.

There are 6,442 species of Odonata that have been documented all around the world [20]. Odonata play various roles in the ecosystem, such as predators and prey, during both their larval and adult life stages [19]. They occur across a wide range of habitats, including both lotic (flowing water) and lentic (standing water) systems [30], which further strengthens their applicability as indicators of habitat quality.

### Terrestrial And Semi-Natural Habitats

Although odonates rely on water bodies to complete their larval development, adults interact extensively with surrounding terrestrial habitat for foraging and reproduction. Consequently, the quality and structure of neighboring terrestrial vegetation strongly influence odonate diversity.

Habitat quality and forest disturbance affected odonate communities in the Sungai Wain Protection Forest, Borneo [11], by comparing intact primary forest, slightly degraded forest, secondary forest, and heavily degraded or non-forest habitats. Researchers sampled dragonflies and damselflies from various freshwater environments,

such as streams, swamps, rivers, lakes, and reservoirs, using standardized surveys in two seasons. The study recorded 88 odonate species, finding that intact primary forests had the highest species richness, endemic species, and habitat specialists. In contrast, species diversity and specialist taxa declined gradually with increasing habitat degradation. Disturbed habitats were dominated by widespread, disturbance-tolerant species. Multivariate analyses confirmed that habitat degradation significantly impacted odonate community composition, respond predictably to habitat disturbance and forest alterations, making them effective indicators of habitat quality. The study also emphasizes the need to preserve intact forest cover and riparian vegetation to maintain both odonate diversity and overall freshwater biodiversity. Therefore, tracking changes in odonate groups can serve as a practical and cost-effective means to assess habitat degradation and guide conservation and habitat restoration efforts.

Odonate diversity and abundance in the ICAR Research Complex for NEH Region, Umiam, Meghalaya [4], to assess habitat suitability for dragonflies and damselflies. The survey from March to August 2014 documented 33 odonate species, including 24 Anisoptera and 9 Zygoptera. The Libellulidae family was the most dominant with 21 species, followed by Gomphidae (2 species), Aeshnidae (1 species), and Coenagrionidae (9 species). Analysis of relative abundance showed that five species were very common, thirteen were common, ten were occasional, three were rare, and two were very rare. The high odonate diversity was attributed to the presence of grasslands, shrubs, and small freshwater bodies, which offer suitable breeding, feeding, and resting spots. The authors noted that institutional campuses with varied vegetation and aquatic habitats could serve as important refuges for odonates and long-term sites for environmental monitoring. Additionally, they recommended habitat conservation through protected areas, pollution control, sustainable land use, ecological research, and public awareness to maintain odonate diversity. Despite documenting odonate diversity and highlighting habitat heterogeneity, the study primarily provides a qualitative assessment of habitat quality. The lack of quantitative analyses of physicochemical water parameters (e.g., pH, dissolved oxygen, conductivity, turbidity, and nutrient levels) and statistical relationships between habitat variables and odonate groups limits its capacity to establish direct ecological links. Therefore, combining biodiversity assessments with environmental and water quality evaluations would offer a better understanding of habitat quality. It indicates that habitat complexity, including aquatic areas and surrounding vegetation, is essential for determining odonate diversity and abundance. This also supports using odonates as ecological indicators for evaluating habitat quality and monitoring environmental shifts.

Habitat quality significantly impacts odonate diversity and composition [26]. Rice field habitats supported a greater diversity of Odonata, including both Zygoptera and Anisoptera, while stream habitats had fewer species from only three families. This variation suggests that habitat diversity, availability of aquatic vegetation, and suitable breeding sites boost odonate richness. The study also evaluated habitat quality using biological indices such as the Family Biotic Index (FBI), Biological Monitoring Working Party (BMWP), and Shannon Diversity Index, showing that odonate groups can effectively reflect the health of freshwater ecosystems and water quality. However, the study mainly relied on species composition and biological indices, while important habitat factors like physicochemical characteristics (e.g., pH, dissolved oxygen, conductivity, temperature), riparian vegetation, and human disturbances were not examined in detail

Recently, the idea of ethodiversity has been examined as a new aspect of biodiversity for evaluating human impacts using Odonata. Researchers analyzed the behavior of 120 male damselflies (*Mnesarete pudica*) across two different habitats: a conserved ecological reserve and an impacted one [14]. They observed behaviors like harassment, courtship, contest, chase, and patrol using the focal animal method, where each individual was watched for 15 minutes. These behaviors were classified into ecological functions, including mate acquisition, mate searching, and competitive interactions. Statistical methods, including Spearman's correlation, principal component analysis (PCA), and PERMANOVA, were used to investigate behavioral patterns and their differences between habitats. The results highlighted distinct behavioral organization between conserved and impacted sites. Populations in conserved areas showed stronger behavioral integration, with notable correlations among behavioral traits. This indicated more structured and stable behavioral patterns. In contrast, impacted habitats displayed fewer behavioral correlations, suggesting disruption. PCA results revealed that chase and patrol behaviors were most impacted, showing higher expression in disturbed environments. Furthermore, PERMANOVA confirmed that habitat type significantly affects behavioral traits.

---

## Role Of Odonates In Wetland Ecosystem: -

Odonata play a vital role in wetland ecosystems as key predators in both larval and adult stages, contributing significantly to nutrient cycling and food web dynamics.

The researchers investigated the spatial distribution of dragonfly assemblages to evaluate their usefulness as indicators for the design and management of conservation ponds in KwaZulu-Natal, South Africa [22]. The study was conducted at Airtons' Dam, where the habitat was divided into four biotopes: a pond, a forest stream, a grassland stream, and a downstream stream section. Thirty-two standardized sample units were established along the water's edge, and mature male Odonata were recorded at approximately fortnightly intervals from April 1988 to May 1989. Habitat variables, including water current, shade, vegetation cover, rocks, grasses, sedges, and herbs, were measured for each sampling unit. Species associations and habitat preferences were analysed using rank-abundance analysis, species covariance, niche overlap indices, TWINSpan classification, and Canonical Correspondence Analysis (CCA). A total of 23 Odonata species were recorded, comprising 8 Zygoptera and 15 Anisoptera. The study revealed distinct spatial patterns in species distribution, with different dragonfly species exhibiting strong preferences for specific microhabitats and environmental conditions. Habitat heterogeneity was identified as a key factor supporting high species diversity, while niche overlap among closely related species was generally low, indicating resource partitioning.

A standardized assessment approach for evaluating the ecological integrity of aquatic ecosystems using dragonfly (Odonata) communities as bioindicators in accordance with the draft European Union Water Framework Directive (EUWFD) [6]. The study was conducted at two artificial ponds in Austria, Tritonwasser and Priessnitz Pond, which were monitored through repeated field surveys between April and November. Adult dragonflies were identified through direct observation, photography, and occasional hand-net capture, while evidence of reproduction, including larvae, exuviae, and breeding behaviour, was used to confirm autochthonous populations. The assessment considered species richness, abundance, the proportion of autochthonous and habitat-specialist (stenoecious) species, endangered species, and dragonfly community composition. Ecological status and ecological potential were classified into five categories ranging from high/maximum to bad based on deviations from reference communities. Tritonwasser supported 31 species, including 25 autochthonous and 10 endangered species, whereas Priessnitz Pond recorded 26 species, 18 autochthonous species, and 3 endangered species. Both ponds exhibited high habitat heterogeneity with abundant aquatic macrophytes, supporting diverse dragonfly assemblages and high abundances of characteristic species. Tritonwasser achieved the maximum ecological potential, while Priessnitz Pond also exhibited good ecological quality.

The author of the paper created the Odonate River Index (ORI) to assess the ecological integrity of river corridors using odonate groups as bioindicators [13]. The study covered six Alpine rivers in northern Italy, showcasing different channel shapes and various levels of human disturbance. Researchers recorded 5,570 odonate specimens, including adults, larvae, and exuviae, representing 41 species. The results indicated that odonate diversity was greatly influenced by habitat quality. Key environmental factors affecting species composition included aquatic and riparian vegetation, flow speed, substrate size, and channel shape. The ORI effectively detected habitat degradation and reflected ecological conditions across different river types. However, it showed limitations in rivers with average annual water temperatures below 10°C and may require regional adjustment before use in other climate zones. This study emphasizes that habitat quality is crucial in shaping odonate communities, not just water quality. It demonstrates that dragonflies respond to both physical habitat structure and environmental changes, supporting their role as reliable indicators of freshwater ecosystems. It stresses that assessing habitat quality should consider multiple environmental factors like riparian vegetation, substrate characteristics, flow regime, and channel shape, in addition to species diversity. Moreover, the Odonate River Index offers a standardized framework that can be adapted and validated for freshwater ecosystems in other regions, including tropical countries like India

The potential of Odonata diversity as an indicator of water quality at four freshwater sites in Pala Municipality, Kerala, India [17]. They conducted monthly surveys from September 2014 to March 2015. They assessed water quality using the Water Quality Index (WQI), based on physicochemical parameters. They evaluated Odonata diversity with Simpson's Diversity Index. The researchers recorded a total of 49 Odonata species from 10 families, including 26 dragonfly species and 23 damselfly species. The Libellulidae family was the dominant

group of dragonflies, while Coenagrionidae was the most common family of damselflies. Sites with better water quality showed higher species richness and diversity. In contrast, polluted sites had fewer species and were mostly made up of pollution-tolerant species like *Brachythemis contaminata*.

The feasibility of bioindication of wetland ecosystems through dragonflies and damselflies by studying odonate diversity in 30 ponds of Meenachil Taluk, Kerala [18], based on the varying quality of water of these ponds. The quality of water was measured based on fourteen physicochemical parameters and the Water Quality Index (WQI), while biological assessment was carried out using odonate diversity, species richness, and Simpson's Diversity Index. Sixty-seven species of odonates belonging to eleven families were reported from this study. It was found that ponds with high and medium water quality showed high diversity of odonates, but degraded ponds had mainly pollution-tolerant species. It was interesting to note that the authors found that species composition and species richness were better indicators of wetland conditions than overall diversity. Some polluted ponds also had higher diversity of odonates since there were disturbance-tolerant taxa.

A Study on Dragonfly (Odonata) Diversity as Bioindicator for Water Quality in Mount Muria Region, Central Java [16]. This study aims to assess the diversity of dragonflies (Odonata) as a bioindicator of water quality in the Mount Muria area, Central Java. The study used a quantitative descriptive research design. This research was conducted in three watershed stations that represented different freshwater habitats. Surveying of dragonflies was done with visual day-flying method in the morning (07.00-10.00 WIB), while water quality was analyzed by physical (temperature, light intensity, and humidity) and chemical parameters (pH, Biochemical Oxygen Demand, and Chemical Oxygen Demand). Identification of the specimens was carried out using standard taxonomic keys. The calculated ecological indices were the index of relative abundance, Shannon-Wiener diversity index, index of dominance, index of evenness, and Family Biotic Index. There were ten odonate species found, consisting of six species of Anisoptera and four species of Zygoptera. *Euphaea variegata* was the most abundant species (51.39%), and the second was *Enallagma signatum* (28.47%). The high value of the relative abundance indicates that these species were highly adapted. The total Shannon-Wiener diversity index ( $H = 1.36$ ) showed that the community was relatively moderate and unstable, and the evenness index ( $E = 0.56$ ) indicates that species were distributed moderately. According to the Family Biotic Index ( $FBI = 5.60$ ) and the standards of Indonesia's water quality, the river was classified as moderately polluted and in fair condition. Odonata communities showed a strong correlation with the freshwater habitat quality and confirmed that they can be used as reliable indicators.

The role of Odonata communities as bioindicators for assessing stream quality regarding various land-use practices in northern Argentina, including natural reserve, forested, plantation/livestock, and urban [23]. Habitat quality was evaluated according to the Habitat Integrity Index (HII) along with environmental factors such as water temperature, turbidity, conductivity, and nitrate concentration. Altogether, 42 Odonata species were detected, 23 of which belonged to Zygoptera and 19 to Anisoptera. While there was no significant difference in the number of species between habitat types, the species composition varied significantly based on the habitat conditions. Conserved streams harbored species like *Argia croceipennis* and *Argia albistigma*, while degraded streams contained species like *Oxyagrion basale* and *Acanthagrion lancea*.

The diversity of Odonata as environmental indicators in spring ecosystems around Malang Raya, East Java, Indonesia [15]. The research took place from October to December 2019, using the Visual Encounter Survey (VES) method. Researchers observed Odonata along transects on both sides of the springs, with each site surveyed twice. They photographed individuals for identification based on features like wing color, wing size and shape, body color and shape, and flight behavior. Along with the Odonata observations, they recorded environmental factors like air temperature, light intensity, humidity, and wind speed. They assessed Odonata diversity using the Shannon-Wiener diversity index ( $H'$ ). The findings showed that the eastern and southern spring sites had higher Odonata diversity and species richness compared to the northern and western sites, suggesting better environmental quality. The dominant genera included *Euphaea*, *Vestalis*, *Orthetrum*, and *Neurothemis*.

The diversity of dragonfly species as bioindicators of water quality at Science Techno Park (STP) spring located in Beleknehe Village, Kupang District, Indonesia [24]. Insect specimens were sampled using nets and hand-sorting methods and identified following taxonomic identification keys. Physicochemical characteristics of

water quality, including conductivity, total dissolved solids (TDS), iron, hardness, sulfate, manganese, nitrate, and nitrite, were used in determining water quality. Four odonate species from three families were observed at STP spring and were recorded as *Neurothemis stigmatizans*, *Coenagrion lunulatum*, *Megalagrion sp.*, and *Orthetrum pruinsum*. The parameters of water quality met the standards of the Indonesian Ministry of Health, thereby signifying good ecological conditions at the spring. The observation of these odonate species, especially those from families Libellulidae and Coenagrionidae, indicated a fairly undisturbed habitat capable of hosting these sensitive insects.

The habitat quality, especially the condition of riparian vegetation, greatly affects odonate groups in Ozark Spring streams [5]. The study categorized streams into minimally, moderately, and highly impacted riparian habitats based on the amount of natural vegetation and human disturbance. Habitat quality was assessed through various environmental parameters like water physicochemical characteristics (temperature, dissolved oxygen, pH, conductivity, nutrients), stream flow, substrate composition, canopy cover, emergent vegetation, and riparian conditions at both local and landscape levels. Odonates were sampled across three seasons using nymphs, exuviae, and adults for an accurate assessment of resident species. Multivariate analyses revealed that the composition of odonate communities strongly responded to riparian habitat condition. Streams with intact riparian vegetation supported greater species richness and clearer assemblage patterns than degraded sites. In contrast, heavily disturbed streams with less woody vegetation and altered stream margins supported fewer resident species.

The study conducted the first odonatan survey in the Sungai Chiling Fish Sanctuary in Selangor, Malaysia, which showed that Odonata diversity can effectively assess habitat quality [1]. Researchers used sweep net sampling over three days and recorded 48 individuals from 15 species and 6 families. There was no significant difference in species richness and abundance across various river crossings. High values of species diversity, evenness, and distribution suggested good water quality. However, slight disturbances were noted near the entrance based on the presence of disturbance-associated dragonfly and damselfly species. Overall, Odonata diversity is high in Malaysia, with around 342 species, including both Zygoptera and Anisoptera, and a significant number of endemic species (Yule & Yong, 2004).

The researchers investigated the diversity of Odonata as a bioindicator of water pollution in the Batang Harau watershed, Tanah Datar District, West Sumatra, Indonesia [3]. The study was conducted between December 2022 and January 2023 across three habitat types, namely natural, rice field, and disturbed habitats, using the Visual Encounter Survey (VES) method with modified 20 × 10 m transects. Observations were carried out during the peak activity periods of dragonflies (07:00–09:00 and 15:00–17:00), while environmental parameters, including temperature, humidity, dissolved oxygen (DO), and pH, were recorded at each sampling site. A total of 280 individuals representing 12 species from seven families were documented, with the highest species richness and diversity recorded in the natural habitat. The Shannon–Wiener diversity index was highest in the natural habitat ( $H' = 1.62$ ) and lower in rice field ( $H' = 0.92$ ) and disturbed habitats ( $H' = 0.85$ ), indicating a decline in odonate diversity with increasing habitat disturbance. Similarly, the species richness index was greatest in the natural habitat (1.67), whereas the dominance index was relatively low (0.24), reflecting a more balanced community structure. In contrast, disturbed habitats exhibited higher dominance values and lower diversity, suggesting that environmental disturbance favors a few tolerant species such as *Orthetrum sabina* and *Pantala flavescens*. The measured abiotic parameters showed only slight variation among habitats, with natural habitats maintaining the highest dissolved oxygen concentration (8.54 mg L<sup>-1</sup>), which likely supported greater odonate diversity.

The researchers studied dragonfly diversity to indicate water quality in the Mangkol River, Central Bangka Regency, Indonesia [33]. They conducted dragonfly surveys and assessed water quality at four sampling stations along the river, covering upstream, midstream, and downstream areas. Water quality was measured using physicochemical parameters, the Family Biotic Index (FBI), and the Pollution Index (IP). The team recorded 12 dragonfly species, totaling 104 individuals, including 10 Anisoptera and 2 Zygoptera species. The upstream station had clear water, dense riparian vegetation, and little human impact, which led to the highest species diversity. In contrast, downstream stations affected by illegal tin mining displayed reduced diversity and were dominated by pollution-tolerant species like *Orthetrum sabina*. The study found that dragonfly diversity depends

on habitat quality, riparian vegetation, and human activities. This highlights the value of Odonata as reliable indicators of freshwater ecosystem health.

Collectively, these studies demonstrate that odonate assemblages are reliable indicators of wetland ecosystem health because they respond consistently to variations in habitat quality, water quality, and anthropogenic disturbance. Across different wetland habitats, including ponds, springs, rivers, streams, and watersheds, higher odonate diversity, greater species richness, and the presence of habitat-specialist or pollution-sensitive species were consistently associated with ecologically intact wetlands, whereas degraded habitats were characterized by reduced diversity and dominance of pollution-tolerant taxa. The reviewed studies further indicate that species composition, community structure, and the occurrence of autochthonous populations often provide more sensitive measures of ecological integrity than diversity indices alone. In addition, habitat attributes such as riparian vegetation, aquatic macrophytes, habitat heterogeneity, hydrological conditions, and physicochemical water characteristics jointly influence odonate assemblages, highlighting the importance of integrating biological and environmental assessments. Although several investigations successfully demonstrated the bioindicator potential of Odonata, some studies relied primarily on descriptive analyses or diversity indices without establishing robust statistical relationships between odonate communities and environmental variables. Therefore, future wetland assessments should adopt a comprehensive approach that combines odonate diversity, species composition, habitat-specialist taxa, physicochemical water quality parameters, and habitat characteristics to achieve more accurate evaluations of wetland ecological integrity. Integrating Odonata diversity with physicochemical parameters (such as pH, dissolved oxygen, conductivity, and temperature), riparian vegetation characteristics, habitat complexity, and other environmental variables can provide a more comprehensive and accurate evaluation of habitat quality. The findings also emphasize the importance of conserving riparian vegetation and maintaining habitat complexity to sustain odonate diversity. Overall, the available evidence strongly supports the application of dragonflies and damselflies as cost-effective and scientifically robust bioindicators for monitoring wetland ecosystems, detecting environmental degradation, and guiding wetland conservation and restoration programmes.

### Urban Odonate Communities

In urban areas, odonates also play a crucial role as bioindicators of environmental health and habitat quality within fragmented city landscapes. In a rapidly urbanizing environment, their diversity and assemblage pattern reflect the impact of anthropogenic stress, thermal variation, and the health of artificial or degraded aquatic ecosystems.

The patterns of distribution of dragonfly (Odonata) species in urban landscapes in Central Europe were investigated to assess the effects of urbanization on biodiversity and habitat quality [32]. Data from 22 cities were collected through a review of scientific literature that met specific criteria of species inventory and sufficient sampling effort. In addition, six cities were considered individually in order to evaluate the effect of urbanization on species richness along the urban-rural continuum. The species were divided into groups by their habitat type and origin, which were either native, Eurasian or Mediterranean, and further into habitat specialists and generalists. Using GLMs and GLMM statistical analysis, the authors identified 64 species of native Odonata, with an average number of 32.6 species per city. There is a positive relationship between species richness and the size of the city, as well as some climate factors such as temperature amplitude and July temperature. Besides, species richness increases significantly from urban towards rural parts of the city, with a larger abundance of habitat specialists and generalists found in rural habitats. Thus, habitat heterogeneity, presence of various aquatic ecosystems, and lower urban disturbances are essential factors influencing the biodiversity of Odonata.

Odonata diversity as bioindicators of habitat quality in the urban landscape at the Tripura University campus, northeast India [10]. The study was carried out from March 2024 to February 2025 using a point-based sampling technique. In this approach, 33 random sampling points were repeatedly surveyed through direct observation and visual inspection. Sample collection was done during odonates' activity hours, which are between 7:00–10:00 a.m. and 3:00–5:00 p.m., with minimal impact on natural habitats. Species identification was done using standard taxonomic keys and the Indian Odonata Database, whereas the analysis for diversity was done using PAST and BioDiversity Pro software. During the survey, 33 species of Odonata belonging to 25 genera and five families were found to be present, which accounts for 44% of the total odonate diversity of Tripura. Out of 33

species, 23 species belonged to Anisoptera, whereas 10 species were Zygoptera. The higher number of species found on the university campus, an urban landscape, suggests that heterogeneous habitats such as wetlands, tree plantations, and green patches can act as a habitat for diverse species of odonates.

The above-mentioned studies prove that urban landscapes can be quite species-rich if they possess heterogeneous habitats, including wetlands, ponds, riparian vegetation, green spaces, and other semi-natural freshwater habitats. In other words, the research suggests that habitat quality in urban landscapes, and not the process of urbanization per se is the main driver of odonate diversity and species composition. It means that urban areas with high connectivity and heterogeneity of aquatic habitats, as well as vegetation richness, host more odonate species, while highly urbanized and fragmented areas tend to have mostly widespread and disturbance-tolerant species. Overall, the presented studies highlight the importance of habitat heterogeneity, availability of freshwater habitats, and low anthropogenic disturbance for ensuring ecological integrity in urban landscapes. Consequently, assemblages of odonates can serve as an effective and sensitive indicator of habitat quality and biodiversity of urban landscapes.

### Odonates As Bioindicator Of Radioactivity

Odonates serve as valuable bioindicators for monitoring radioactive contamination and radionuclide bioaccumulation in aquatic and terrestrial ecosystems. Consequently, assessing radionuclide burden and physiological stress in Odonata provides vital insights into environmental radiation dynamics, ecological risk assessment, and long-term ecosystem health in radiation-impacted habitats.

The potential use of dragonflies (Odonata) as bioindicators for environmental radioactivity was evaluated by assessing the accumulation of the radionuclide cesium-137 ( $^{137}\text{Cs}$ ) in dragonflies and river water from the Mura–Drava–Danube Biosphere Reserve in Croatia [31]. In all, 11 composite samples of dragonflies and the associated river water were analyzed for  $^{137}\text{Cs}$  content using high-resolution gamma spectrometry with the ORTEC HPGe detector. The  $^{137}\text{Cs}$  content in river water was in the range of 4 to 13 Bq m<sup>-3</sup>, while the dragonfly samples contained 1.7–3.0 Bq kg<sup>-1</sup> of  $^{137}\text{Cs}$ , indicating concentrations that were more than 100 times higher than in the surrounding water. This shows how highly efficient the bioaccumulation of the radionuclides by dragonflies in the freshwater ecosystems is, and makes dragonflies better biomonitors than the water alone. Thus, the research proved that dragonflies may be used as very good bioindicators of ionizing radiation and environmental radioactivity, and can be useful as biomonitors for long-term radiological monitoring of freshwater ecosystems. It was also emphasized that more research should be carried out on radionuclide accumulation in different stages of development of Odonates.

### Odonata Larvae As Indicator Of Environmental Quality

The relationship between developmental instability in odonatan larvae and water quality in the Serdang River, Malaysia, using fluctuating asymmetry (FA) to assess water quality parameters [2]. The experiment involved monthly sampling of Odonata larvae from January to June 2008 using a modified kick sampling method on a 300 m stretch of the river. Two dominant Odonata genera, *Onychothemis* (Libellulidae) and *Pseudagrion* (Coenagrionidae) were identified using a taxonomic key. Water quality was measured using physicochemical parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, nitrate, phosphate, ammonium nitrogen, total suspended solids (TSS), and Water Quality Index (WQI). The morphological fluctuating asymmetry was calculated using selected larval structures, and the relationship between FA and environmental variables was tested using two-way ANOVA and Redundancy Analysis (RDA). The results showed that there is fluctuating asymmetry in both genera, but no directional asymmetry was found. Fluctuating asymmetry increases with increases in BOD, temperature, nutrients, and suspended solids, while the Water Quality Index negatively correlated with composite fluctuating asymmetry.

The usefulness of Odonata nymphs as bioindicators for measuring the quality of aquatic ecosystems in the Trashigang District in the east of Bhutan through a study involving the analysis of differences in larval communities in lentic (lakes) and lotic (streams) ecosystems [12]. Odonata nymphs were collected in both pre-monsoon and post-monsoon seasons using standardized methods of kick net and dip-net sampling methods, whereas the following nine physicochemical factors were analyzed to determine habitat quality: water

temperature, pH, dissolved oxygen, conductivity, total dissolved solids, turbidity, alkalinity, hardness, and chloride. In total, 222 Odonata nymphs belonging to seven families were captured: Coenagrionidae, Aeshnidae, Gomphidae, Libellulidae, Lestidae, Epiophlebiidae, and Euphaeidae, and Coenagrionidae was identified as the most prevalent family among all of them. Differences in the Shannon diversity and community composition of odonates were observed between lentic and lotic ecosystems, although family richness and abundance were not statistically significant. The NMDS analysis and ANOSIM provided additional evidence of the distinctness of odonate larval assemblages in both habitats as habitat quality affects the structure of the odonate community. PCA proved that physicochemical factors affected the differentiation of habitat quality and larval community structure.

The suitability of odonate larvae as bioindicators of pesticide pollution in the Sunagawa River system of Yamagata Prefecture, Japan [27]. Odonate larvae were sampled from eight sampling sites situated in various sections of the river that receive different degrees of pesticide pollution due to rice farming. Samples of odonate larvae were collected through the use of hand nets at four different times of the year from June 1989 to March 1990 while concurrently measuring water temperature, pH, electrical conductivity, and pesticide residues. Residues of different pesticides such as butachlor, chlorfenvinphos, diazinon, fenitrothion, fenthion, malathion, pretilachlor, simetryn, and thiobencarb were detected at various sampling sites, with high pesticide contamination being recorded downstream of the agricultural area. Five species of odonate larvae were identified, and the distribution of these larvae differed based on the degree of pesticide contamination. High species richness was recorded in sampling sites with low pesticide pollution, but only one species of larvae was observed in the highly polluted downstream sampling stations. It was evident that pesticide pollution affected the species composition of odonate larvae, thus making odonate larvae sensitive to agricultural pesticides.

The researchers conducted an experiment to assess the predatory efficacy of odonate nymphs as biocontrol agents of mosquito larvae in a controlled laboratory environment in Malaysia [21]. Odonata nymphs were obtained from lakes, drains, and small streams in both urban and suburban areas, while *Aedes aegypti*, *Aedes albopictus*, and *Culex quinquefasciatus* fourth instar larvae served as the prey. Three main dragonfly nymph species, *Neurothemis fluctuans*, *Orthetrum chrysis*, and *Orthetrum sabina*, were tested for feeding efficacy under uniform environmental conditions. According to author, *O. sabina* was the most efficient predator of *Aedes aegypti*, but *O. chrysis* was relatively more efficient in feeding on *Culex quinquefasciatus*. All three species of odonate nymphs fed on the mosquito larvae through the duration of the experiment, although there was significantly greater feeding activity during daylight hours compared to nighttime hours; therefore, it is likely that prey recognition depended on visual cues only. While predation rates among dragonflies were not significantly different, the mosquito species significantly affected predation efficacy. Since the abundance, survival, and predatory performance of odonate larvae are closely associated with healthy aquatic habitats, their occurrence can also indirectly reflect habitat quality and ecological integrity. Therefore, larval odonates not only contribute to biological control of disease vectors but also serve as valuable indicators of freshwater ecosystem health and environmental quality.

Together, these studies indicate that odonate larvae (nymphs) are very efficient bioindicators of freshwater ecosystem health due to spending most of their life cycle in aquatic habitats and being a constant reflection of ecological conditions. Differences in larval richness, composition, fluctuating asymmetry, and species distribution have been consistently correlated with differences in water quality, physicochemical properties, habitat state, and contamination with pesticides. Compared to adults, odonate larvae are better indicators of environmental quality since they respond directly to the cumulative effect of ecological stressors over a long period. Also, the sensitivity of odonate larvae to pollution, habitat degradation, and agricultural chemicals is an important characteristic allowing them to be used for the detection of subtle ecological disturbances that do not manifest on an ecosystem scale yet. Moreover, the ecological significance of odonate larvae as natural predators of mosquito larvae is one more reason why these organisms are important for the maintenance of freshwater ecosystem functioning and indirectly reflect the habitat state.

### Odonatofaunal studies in Madhya Pradesh

A protected dry and moist deciduous forest ecosystem in central India can be considered as a region with a significant distribution of odonata species.

The dragonfly fauna in the campus of PMCoE Government Autonomous Post Graduate College, Chhindwara, Madhya Pradesh [9]. There was a total of 26 dragonfly species were found in the families Aeshnidae, Cordulegastridae, and Libellulidae, out of which the family Libellulidae was the most dominant. The availability of green spaces, dense forestation, the presence of shrubs, flowering plants, and semi-permanent water sources had enabled several common species to exist, while the rare and very rare species indicated the importance of the existence of semi-natural microhabitats within urban settings. The study findings indicated that conservation of campus flora, along with maintenance of habitat diversity and minimal anthropogenic interference, is crucial for conservation of dragonflies.

The research was conducted in three tiger reserves, Kanha, Pench, and Bandhavgarh, which are located in Madhya Pradesh [8]. The study revealed that 47 species of Odonata belonging to 31 genera and 7 families can be found in the area. Notably, the family Libellulidae was the most widely represented, accounting for 26 species, followed by Coenagrionidae with 10 species. The most species were found in Kanha ( $n = 44$ ), while Bandhavgarh and Pench had  $n = 41$  and  $n = 37$ , respectively. However, 35 species were discovered in all three reserves. Das et al. (2013) revealed that the distribution of odonata species in the area is seasonal, as *Orthetrum sabina*, *Diplacodes trivialis*, and *Pantala flavescens* were the most commonly observed during the summer, while *Agriocnemis pygmaea*, *Ceragrion coromandelianum*, and *Ischnura senegalensis* were more widespread in winter. The authors explained that scarce water resources during the season are the primary reason why odonata species aggregate around available water sources. Therefore, their distribution pattern can be disrupted due to microhabitat loss, which is triggered by summer forest fires and anthropogenic activities in central India.

Providing a baseline for the Central India region, the researchers studied odonate diversity in various water bodies and surrounding reserve forests, including lakes, dams, lotic and lentic waters, in Madhya Pradesh and Chhattisgarh Provinces [28]. Their survey, conducted in 2008-2010, identified 106 species of odonates belonging to 53 genera and 12 families. As a result, 14 new species were added to the regional list of odonates. Consistent with the findings of local surveys conducted in central India, the number of species from the families Libellulidae (39 spp.), Coenagrionidae (29 spp.) was found to be the greatest. Other families included Gomphidae (10 spp.), Lestidae (6 spp.), and Protoneuridae (5 spp.). In turn, the number of species from Calopterygidae, Aeshnidae, Chlorocyphidae, Platynemididae, Macromiidae, Euphaeidae, and Corduliidae was lower (1 to 3 spp. each). The study conducted by Tiple and Chandra (2013) enhanced the knowledge about the odonate species in the tableland of Madhya Pradesh and serves as an essential baseline for surveying their distribution patterns in this region.

Focus on the urban and peri-urban landscape matrix of Central India: the odonate diversity in Jabalpur city and its surroundings for an extended period of time (2008-2019) [29]. Overall, 75 species of odonates in 9 families were registered. Among them, 21 species were added to the district's faunal list, while 4 species (*Ictinogomphus distinctus*, *Rhyothemis triangularis*, *Onychargia atrocyana*, *Anax indicus*) were found new to the state of Madhya Pradesh. The family Libellulidae was the most species-rich (32 spp.), followed by Coenagrionidae (17 spp.), while Gomphidae and Platynemididae had 9 and 6 species, respectively. In terms of conservation status, 37% of recorded species were classified as very common/abundant, while 28% of them were rare/very rare (among them *Aethriamanta brevipennis*, *Agriocnemis pieris*, *Caconeura ramburi*). The researchers emphasize the importance of the urban wetlands and natural hillocks acting as refuges for the regional odonate diversity, which is under threat from anthropogenic activities. The survey covered a wide range of potential microhabitats, from the natural reserves (Dumna Nature Reserve) to the Narmada River basin.

The authors concluded that the dry deciduous forests of Central India provided a suitable habitat for odonates only during the rainy season, while the summer season often resulted in their local extinction due to the depletion of permanent water bodies initiated by forest fires and human activities.

Table 1: Summary of reviewed studies on odonatan species diversity, habitat heterogeneity and ecosystem health

| S. No. | Author                 | Country | Habitat type                                        | Parameter evaluated                    | Finding summary                                                                                |
|--------|------------------------|---------|-----------------------------------------------------|----------------------------------------|------------------------------------------------------------------------------------------------|
| 1.     | Takamura et al. (1991) | Japan   | Riverine/freshwater habitat (Sunagawa River system) | Pesticide residues, water temperature, | Odonate larvae of different species distribution according to pesticide contamination. Species |

|    |                              |                                      |                                                                  |                                                                               |                                                                                                                                                                                |
|----|------------------------------|--------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |                              |                                      |                                                                  | pH, electrical conductivity                                                   | richness was higher at low-pollution sites, whereas only one species was recorded at highly polluted sites.                                                                    |
| 2. | Samways et al. (1996)        | South Africa                         | Wetland (Ponds, streams, forests)                                | Microhabitat preference, species association, rank-abundance                  | Intact habitat heterogeneity supports high species diversity and resource partitioning among odonates.                                                                         |
| 3. | Chovanec (2000)              | Austria                              | Artificial ponds                                                 | Ecological integrity, autochthonous species, community structure              | Artificial ponds with rich aquatic vegetation can achieve high ecological potential and support endangered odonate species.                                                    |
| 4. | Dolny' et al. (2011)         | Indonesia (Borneo)                   | Primary, secondary and degraded forests.                         | Species richness, endemism, community composition                             | Primary Forests harbor high specialists and endemic species; habitat degradation reduces specialist taxa and favors generalists.                                               |
| 5. | Willigalla & Fartmann (2012) | Central Europe                       | Urban landscapes                                                 | Species richness, abundance along urban-rural continuum                       | Odonate richness increase towards rural gradients; larger cities with higher aquatic habitat complexity support more species,                                                  |
| 6. | Das et al. (2013)            | India (Madhya Pradesh)               | Protected Tiger Reserves                                         | Species richness, family composition, seasonal occurrence.                    | Recorded 47 species across dry deciduous forests and identified seasonal aggregation around drying water sources, highlighting vulnerability to forest fires and habitat loss. |
| 7. | Tiple & Chandra (2013)       | India (Madhya Pradesh & Chattisgarh) | Reverse forests, dams, lakes, lotic and lentic water bodies      | Species richness, family representation, new regional records.                | Documented 106 species (adding 14 new regional records), establishing baseline odonate diversity in Central India dominated by Libellulidae and Coenagrionidae.                |
| 8. | Al-Shami et al. (2014)       | Malaysia                             | River ecosystem (Serdang river)                                  | Morphological Fluctuating Asymmetry (FA) in larvae, WQI, BOD, suspended solid | Larval Fluctuating asymmetry increased proportionally with BOD, nutrient, and suspended solid, demonstrating that developmental instability in nymphs reflects aquatic stress. |
| 9. | Bora and Meitei (2014)       | India (Meghalaya)                    | Institutional campus, grassland, shrubs, small freshwater bodies | Species richness, family composition relative abundance categories            | Documented 33 species and showed that heterogenous vegetation and small aquatic bodies within institutional                                                                    |

|     |                        |                          |                                                                  |                                                                                             |                                                                                                                                                                                              |
|-----|------------------------|--------------------------|------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     |                        |                          |                                                                  |                                                                                             | campuses act as vital refuges for odonate conservation.                                                                                                                                      |
| 10. | Golfieri et al. (2016) | Italy                    | Alpines river corridors along disturbance gradients              | Odonate River Index (ORI), channel structure, flow speed, substrate, riparian vegetation    | Physical habitat structure and channel shape strongly influenced odonate communities, validating the Odonate River Index (ORI) as a reliable tool for assessing river degradation.           |
| 11. | Jacob & Manju (2016)   | India (Kerala)           | Freshwater river/pond sites across Pala Municipality             | Water Quality Index (WQI), physicochemical parameters, Simpson's Diversity Index            | Higher water quality positively correlated with odonate species richness, while severely polluted sites were dominated by pollution-tolerant taxa like <i>Brachythemis contaminata</i>       |
| 12. | Siregar (2016)         | Indonesia                | Rice fields and lotic stream habitats                            | Diversity indices (Shannon), Family Biotic Index (FBI), BMWP index.                         | Rice fields with dense aquatic vegetation supported greater odonate diversity than stream habitat, demonstrating that biological indices effectively reflect freshwater ecosystem health.    |
| 13. | Jacob et al. (2017)    | India (Kerala)           | 30 lentic ponds across Meenachil Taluk                           | 14 physicochemical parameters, Water Quality Index (WQI), species composition               | Species composition and richness proved to be more sensitive indicators of wetland degradation than overall diversity indices, as disturbed ponds housed tolerant generalists.               |
| 14. | Hidayat et al. (2019)  | Indonesia (Central Java) | Watershed Stations in Mount Muria region                         | Physicochemical factors (DO, BOD, COD, pH), Shannon-Wiener index, Family Biotic Index (FBI) | Water quality parameters correlated strongly with odonate community structure, classifying the river as moderately polluted and confirming odonates as reliable water quality bioindicators. |
| 15. | Dorji & Nidup (2020)   | Bhutan                   | Lentic(lakes), lotic (Streams) ecosystem                         | Larval community structure, Shannon index, 9 physicochemical water parameters, PCA, NMDS    | Water physicochemical factors significantly structured larval assemblages, creating distinct communities between lentic and lotic habitats, with Coenagrionidae as the dominant family.      |
| 16. | Schroder et al. (2020) | Argentina                | Streams under varied land uses (reserve, forest, pasture, urban) | Habitat Integrity Index (HII), water temperature, turbidity, nitrate,                       | While species richness remained similar, species composition changed drastically across land-use types, replacing sensitive                                                                  |

|     |                         |                        |                                                                      | species composition                                                                          | taxa(Argia spp.) with tolerant species in degraded streams.                                                                                                                                 |
|-----|-------------------------|------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 17. | Guillermo & Juen (2021) | Brazil                 | Conserved vs. impacted ecological reserves                           | Ethodiversity, behavioural function (courtship, chase, patrol, contest), PCA, PERMANOVA      | Conserved sites exhibited stable and integrated behavioral patterns in male damselflies, whereas habitat degradation disrupted behavioral structure and increased chase/patrol interaction. |
| 18. | Hasanah & Rohman (2021) | Indonesia (East Java)  | Spring ecosystem (Malang Raya)                                       | Shannon-Weiner diversity index ( $H'$ ), species richness, microclimate variables            | Spring sites with intact surrounding vegetation and favorable microclimates maintained significantly higher odonate diversity and species richness.                                         |
| 19. | Ramlee et al. (2022)    | Malaysia               | Urban/Suburban aquatic habitats & laboratory assays                  | Predatory efficacy of nymphs on mosquito larvae (Aedes, Culex), diurnal activity             | Nymphs proved to be highly effective visual predators of disease vector ( <i>O. sabina</i> , <i>O. Chrysis</i> ), linking healthy nymph habitat to natural biological pest control.         |
| 20. | Tiple et al. (2022)     | India (Madhya Pradesh) | Urban and peri-urban matrix (Jabalpur, Dumna Reverse, Narmada Basin) | Long-term species richness (2008-2019), state records, conservation status                   | Identified 75 species (adding 4 new state records) and highlighted urban wetland and hillocks as crucial refuges against expanding anthropogenic pressure.                                  |
| 21. | Cheri & Finn (2023)     | USA                    | Ozark spring streams across a riparian degradation gradient          | Riparian vegetation conditions, physicochemical factors, canopy cover, community composition | Streams with intact riparian buffer zones supported significantly greater resident odonate richness and stable assemblages<br><br>structures compared to degraded riparian zones            |
| 22. | Semium et al. (2023)    | Indonesia (Kupang)     | Spring ecosystem (Science Techno Park)                               | Physicochemical parameters (TDS, conductivity, nitrates, metals), species richness           | Identified 4 odonate species whose presence aligned with water standards, confirming a clean, relatively undisturbed spring habitat.                                                        |
| 23. | Abdullah & Mamat (2024) | Malaysia               | Sanctuary river system (Sungai Chiling)                              | Species richness, abundance, diversity indices, spatial river crossing comparison            | High species diversity and evenness reflected healthy aquatic conditions, though localized human entry points were detected by the presence of disturbance-associated species.              |

|     |                        |                           |                                                         |                                                                                            |                                                                                                                                                                                             |
|-----|------------------------|---------------------------|---------------------------------------------------------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 24. | Berliana et al. (2024) | Indonesia (West Sumatra)  | Natural, rice field and disturbed habitats              | Shannon-Weiner index ( $H'$ ), dominance index, abiotic factors (DO, pH, temp)             | Natural habitats with high dissolved oxygen maintained maximum odonate diversity ( $H' = 1.62$ ), whereas disturbed habitats were dominated by tolerant species ( <i>Orthetrum sabina</i> ) |
| 25. | Dey & Das (2025)       | India (Tripura)           | University campus urban landscape                       | Species richness, generic/family distribution, diversity indices                           | Recorded 33 species (44% of state diversity), demonstrating that heterogeneous urban green spaces and campus ponds serve as vital biodiversity refuges.                                     |
| 26. | Vukoja et al. (2025)   | Croatia                   | River ecosystem in Mura-Drava-Danube Biosphere Reserve  | Radionuclide Cesium-137 ( $^{137}\text{Cs}$ ) concentration in water vs. adult dragonflies | Dragonflies bioaccumulated $^{137}\text{Cs}$ at levels over 100 times higher than surrounding river water, proving their efficacy as biomonitors for environmental radioactivity.           |
| 27. | Zunnikah et al. (2025) | Indonesia (Central Banka) | River gradient from upstream to downstream mining areas | Physicochemical parameters, Family Biotics Index (FBI), Pollution index (IP)               | Undisturbed upstream stations showed high species richness, whereas downstream sites impacted by tin mining exhibited low diversity dominated by pollution-tolerant species.                |
| 28. | Dass & Sharma (2026)   | India (Madhya Pradesh)    | College campus semi-natural/urban microhabitat          | Species richness, family dominance, microhabitat availability                              | Documented 26 species dominated by Libellulidae, emphasizing the role of campus flora and semi-permanent water bodies as urban micro-refuges                                                |

## CONCLUSION

The Odonata are one of the most useful orders of insects for ecological assessments in various habitats. From the analysed papers, it can be seen that odonate diversity, composition, abundance, and behaviour are dependent on such factors as habitat parameters, physicochemical properties, and anthropogenic activities. It has been found that more diverse habitats with natural conditions and high environmental quality had higher odonate diversity, whereas disturbed habitats were dominated by disturbance-tolerant odonates. Moreover, besides adult odonates, the larvae of the group turned out to be a very reliable indicator of environmental quality due to their aquatic life cycle and direct dependence on the environment. Finally, recent works have shown the possibility of using dragonflies for monitoring of radioactive contamination of the environment via radionuclide accumulation. Nevertheless, some of the analysed studies are based only on diversity indices without taking into account physicochemical parameters and ecological factors. Thus, future studies should take a multidisciplinary approach towards ecological assessments involving not only taxonomic diversity but also odonate larvae, behaviour, and environmental factors.

## REFERENCE

1. Abdullah, M. I., & Mamat, N. (2024). First Odonata survey and utilization of Odonata diversity as bioindicator for Sungai Chiling habitat quality. *International Journal of Research and Innovation in Applied Science*, 9(7), 675–683. <https://doi.org/10.51584/IJRIAS.2024.907056>

2. Al-Shami, S. A., Che Salmah, M. R., Abu Hassan, A., Madziatul Rostam, K., & Nor Zalipah, M. (2014). Fluctuating asymmetry of Odonata larvae as a biomarker of water quality in Serdang River, Malaysia. *Life Science Journal*, 11(7), 153–162.
3. Berliani, N., Rozi, F., & Jabang, N. O. (2024). Species diversity of Odonata as a bioindicator of water pollution in the Batang Harau watershed, Tanah Datar District, West Sumatra. *IOP Conference Series: Earth and Environmental Science*, 1346(1), 012026. <https://doi.org/10.1088/1755-1315/1346/1/012026>
4. Bora, A., & Meitei, L. R. (2014). Odonates (Dragonflies and Damselflies) of Indian Council of Agricultural Research (ICAR), Research Complex for NEH Region Campus, Umiam, Meghalaya, India. *Journal of Entomology and Zoology Studies*, 2(6), 16–21.
5. Cheri, C. R., & Finn, D. S. (2023). Odonata as indicators? Dragonflies and damselflies respond to riparian conditions along Ozark Spring streams. *Hydrobiology*, 2(1), 260–276. <https://doi.org/10.3390/hydrobiology2010017>
6. Chovanec, A. (2000). Dragonflies (Insecta: Odonata) as indicators of the ecological integrity of aquatic systems—A new assessment approach. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie*, 27(2), 887–890. <https://doi.org/10.1080/03680770.1998.11901366>
7. Corbet, P. S. (1993). Are Odonata useful as bioindicators? *Libellula*, 12(3–4), 91–102.
8. Das, S. K., Sahoo, P. K., Dash, N., Marathe, S., Mahato, S., Dashahare, A., Mishra, P. S., Prasad, A., & Rana, R. (2013). Odonates of three selected tiger reserves of Madhya Pradesh, Central India. *Check List*, 9(3), 528–532. <https://doi.org/10.15560/9.3.528>
9. Dass, D., & Sharma, R. (2026). A checklist of dragonfly (Odonata: Anisoptera) diversity in the campus of Government Autonomous Post Graduate College, Chhindwara, Madhya Pradesh, India. *Journal of Entomology and Zoology Studies*, 14(1), 40–44. <https://doi.org/10.22271/j.ento.2026.v14.i1a.9673>
10. Dey, A., & Das, D. (2025). Odonata diversity as a bioindicator of habitat quality in an urban landscape: Insights from Tripura University campus, Northeast India. *Acta Entomology and Zoology*, 6(2), 157–165. <https://doi.org/10.33545/27080013.2025.v6.i2c.244>
11. Dolný, A., Bárta, D., Lhota, S., Rusdianto, & Drozd, P. (2011). Dragonflies (Odonata) in the Bornean rain forest as indicators of changes in biodiversity resulting from forest modification and destruction. *Tropical Zoology*, 24(1), 63–86.
12. Dorji, T., & Nidup, T. (2020). Study of nymphs of Odonata (Anisoptera & Zygoptera) as a bio-indicator for aquatic ecosystem: A case study in Trashigang District. *Sherub Doenme: The Research Journal of Sherubtse College*, 13, 1–16.
13. Golfieri, B., Hardersen, S., Maiolini, B., & Surian, N. (2016). Odonates as indicators of the ecological integrity of the river corridor: Development and application of the Odonate River Index (ORI) in northern Italy. *Ecological Indicators*, 61(Part 2), 234–247. <https://doi.org/10.1016/j.ecolind.2015.09.022>
14. Guillermo-Ferreira, R., & Juen, L. (2021). Odonate ethodiversity as a bioindicator of anthropogenic impact. *International Journal of Odonatology*, 24(1), 149–157. [https://doi.org/10.23797/2159-6719\\_24\\_11](https://doi.org/10.23797/2159-6719_24_11)
15. Hasanah, M., Rohman, F., & Susanto, H. (2021). Environmental indicators based on Odonata diversity around the springs in Malang Raya, East Java. *AIP Conference Proceedings*, 2353(1), 030035. <https://doi.org/10.1063/5.0052980>
16. Hidayat, S., Husnia, F., Rohmah, E., & Mukhlisoh, S. (2019). Study on diversity of dragonfly (Odonata) as a bioindicator of water quality in Mount Muria area, Central Java. *Journal of Natural Sciences and Mathematics Research*, 5(2), 53–61.
17. Jacob, S., & Manju, E. K. (2016). Potential of Odonate (dragonflies and damselflies) diversity as a bioindicator of water quality. *International Journal of Science and Research*, 5(7), 2033–2038.
18. Jacob, S., Thomas, A. P., & Manju, E. K. (2017). Odonata (Dragonflies and Damselflies) as bio indicators of water quality. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(9), 19464–19472. <https://doi.org/10.15680/IJIRSET.2017.0609144>
19. Luke, S., Dow, R., Butler, S., Khen, C., Aldridge, D., Foster, W., & Turner, E. (2017). The impacts of habitat disturbance on adult and larval dragonflies (Odonata) in rainforest streams in Sabah, Malaysian Borneo. *Freshwater Biology*, 62(3), 491–506. <https://doi.org/10.1111/fwb.12880>
20. Paulson, D., Schorr, M., & Deliry, C. (2025). World Odonata list. OdonataCentral, University of Puget Sound. <https://www.odonatacentral.org>

21. Ramlee, S., Norma-Rashid, Y., & Mohd-Azirun, M. S. (2022). Odonata nymphs as potential biocontrol agent of mosquito larvae in Malaysia. *Southeast Asian Journal of Tropical Medicine and Public Health*, 53(4), 426–430.
22. Samways, M. J., Caldwell, P. M., & Osborn, R. (1996). Spatial patterns of dragonflies (Odonata) as indicators for design of a conservation pond. *Odonatologica*, 25(2), 157–166.
23. Schröder, N. M., Rippel, C. G., Walantus, L. H., Zapata, P. D., & Pessacq, P. (2020). Odonata assemblages as indicators of stream condition: A test from northern Argentina. *International Journal of Odonatology*, 23(4), 117–130. [https://doi.org/10.23797/2159-6719\\_23\\_09](https://doi.org/10.23797/2159-6719_23_09)
24. Semiun, C. G., Mamulak, Y. I., Pani, E., & Stanis, S. (2023). The study of dragonfly (Odonata) diversity as bioindicator of water quality in Science Techno Park Spring-Beleknehe Village. *Jurnal Biologi Tropis*, 23(1), 174–178. <https://doi.org/10.29303/jbt.v23i1.4477>
25. Sharma, R. (2024). Impact of climate change and habitat fragmentation on the biodiversity of Chhindwara District, Madhya Pradesh: A comprehensive review. *International Journal of Recent Development in Engineering and Technology*, 15(4), 12–19.
26. Siregar, A. Z. (2016). The use of Odonata as bioindicator in environmental systems. *Universitas Sumatera Utara*.
27. Takamura, K., Hatakeyama, S., & Shiraishi, H. (1991). Odonate larvae as an indicator of pesticide contamination. *Applied Entomology and Zoology*, 26(3), 321–326. <https://doi.org/10.1303/aez.26.321>
28. Tiple, A. D., & Chandra, K. (2013). Dragonflies and damselflies (Insecta, Odonata) of Madhya Pradesh and Chhattisgarh states, Central India. *Care4Nature*, 1(1), 2–12.
29. Tiple, A., Sharma, V., & Padwad, S. V. (2022). Dragonflies and damselflies (Insecta: Odonata) of Jabalpur, Madhya Pradesh, India. *Journal of Threatened Taxa*, 14(3), 20740–20746. <https://doi.org/10.11609/jott.7306.14.3.20740-20746>
30. Vilenica, M. (2017). Ecological traits of dragonfly (Odonata) assemblages along an oligotrophic Dinaric karst hydrosystem. *Annales de Limnologie – International Journal of Limnology*, 53, 377–389. <https://doi.org/10.1051/limn/2017019>
31. Vukoja, A., Bogdanović, T., Rašeta, D., Miljanić, N., Ivanišić Risek, I., Ilić, K., Pavičić, I., Marjanović Čermak, A. M., & Petrinc, B. (2025). Dragonflies (Odonata) as bioindicators of radioactivity. *Isotopes in Environmental and Health Studies*, 61(2), 230–238. <https://doi.org/10.1080/10256016.2024.2425070>
32. Willigalla, C., & Fartmann, T. (2012). Patterns in the diversity of dragonflies (Odonata) in cities across Central Europe. *European Journal of Entomology*, 109(2), 235–245. <https://doi.org/10.14411/eje.2012.030>
33. Zunnikah, Hadisusanto, S., & Nurjani, E. (2025). Diversity of dragonflies (Odonata) as bioindicators of water quality in Mangkol River, Terak Village, Simpang Katis Subdistrict, Central Bangka Regency. *BIOMA: Berkala Ilmiah Biologi*, 27(2), 60–67.