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BIODIVERSITY AND ECOLOGICAL DISTRIBUTION OF ANISOPTERA (DRAGONFLIES) AND ZYGOPTERA (DAMSELFLIES) IN DIR LOWER

Original Article

Fawad Khan[1]*, Kiran Fatima[2], Sabeeka Zaffar[3], Farkhanda Manzoor[4], Farman Ali[5], Akhtar Badshah Khan[6], Kamran Nawaz[7], Samina Yasmin[8]

[1]Medical Entomologist, Health Department Kp. / Entomology Department, Abdul Wali Khan University Mardan, Pakistan.
[2]Department of Zoology, Wildlife and Fisheries University of Agriculture Faisalabad. Pakistan.
[3]School of Zoology, Faculty of Basic Sciences and Mathematics, Minhaj University, Lahore, Pakistan.
[4]Dean of Scientific Research and Development, Minhaj University, Lahore, Pakistan.
[5]Professor, Entomology Department, Abdul Wali Khan University Mardan, Pakistan.
[6]Department of zoology GPGC Timergara Dir Lower Affliation Malakand University Chakdra Dir L, Pakistan.
[7]Department of Chemical and Life Science, Qurtuba University of Science and Information Technology Peshawar, Pakistan.
[8]Lecturer, Zoology Department, Hazara University, Mansehra, KPK, Pakistan.

Corresponding Author: Fawad Khan, Medical Entomologist, Health Department Khyber Pakhtunkhwa / Entomology Department, Abdul Wali Khan University Mardan, Pakistan. medicalentomologist94@gmail.com

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ABSTRACT

Background: Odonates, including dragonflies and damselflies, play a crucial role in freshwater ecosystems, serving as bioindicators of environmental health and natural pest control agents. Their diversity and distribution are influenced by habitat availability, climatic conditions, and water quality. Despite their ecological importance, limited studies have been conducted on the biodiversity of Anisoptera in Dir Lower, Khyber Pakhtunkhwa. This study aims to document the species richness, evenness, and abundance of dragonflies in the region, providing essential baseline data for future ecological and conservation research.

Objective: To assess the species richness, relative abundance, and ecological distribution of Anisoptera in Dir Lower during the summer season of 2022.

Methods: Field surveys were conducted from June to August 2022 across diverse freshwater habitats, including streams, riverbanks, rice paddies, marshes, irrigation channels, and stagnant water bodies. Specimens were collected weekly and bi-weekly between 9:00 am and 4:00 pm using aerial nets with a standardized 1.5 mm mesh size. Identification was performed using stereomicroscopes and taxonomic keys. Data analysis included species richness, evenness, and relative abundance calculations.

Results: A total of 169 specimens were collected, comprising 146 males (86.39%) and 23 females (13.61%), with a male-to-female ratio of 6.35:1. The specimens were classified into 15 species under 10 genera and 3 families. The family **Libellulidae** was the most dominant, contributing **96.57%** of the total specimens, followed by Aeshnidae (2.05%) and Gomphidae (1.36%). *Orthetrum pruinosum neglectum* was the most abundant species (**20.54%**), followed by *Orthetrum triangulare triangulare* (**19.17%**), while *Anax immaculifrons* and *Onychogomphus bistrigatus* were the least abundant (**1.36%** each).

Conclusion: The findings highlight the ecological significance of dragonflies in Dir Lower, emphasizing the need for habitat conservation. The dominance of Libellulidae suggests its adaptability to diverse freshwater environments. Future studies focusing on seasonal variations, larval stages, and environmental factors are recommended for a comprehensive understanding of Odonata biodiversity.

Keywords: Anisoptera, biodiversity, damselflies, dragonflies, Odonata, Pakistan, species richness.

INTRODUCTION

The study of biodiversity and ecological distribution of Odonata, comprising dragonflies (Anisoptera) and damselflies (Zygoptera), is fundamental to understanding freshwater ecosystems. These insects, characterized by their slender abdomens, large compound eyes, and membranous wings, are among the oldest flying organisms, with origins tracing back to the Carboniferous period approximately 300 million years ago (1). Their ecological significance stems from their dual aquatic and terrestrial life cycle, making them vital components of both habitats (2). Despite their global distribution, with approximately 6,000 species identified across 630 genera and 28 families, the Odonata fauna of Pakistan remains insufficiently documented, with only 121 recorded species, signifying a gap in research (3). Odonates exhibit hemimetabolous development, undergoing incomplete metamorphosis with three distinct stages: egg, naiad (larval), and adult. The larvae, also known as naiads, are aquatic predators that play an essential role in controlling populations of mosquito larvae, small crustaceans, and other aquatic organisms, thereby contributing to biological pest control (4). Upon metamorphosis, the adults emerge as terrestrial predators, preying on various flying insects, including agricultural pests. Their presence in diverse freshwater habitats, ranging from lotic (flowing) to lentic (still) water bodies, underscores their adaptability, yet they remain highly sensitive to environmental changes, making them excellent bioindicators of ecosystem health (5).

The classification of Odonata is traditionally divided into three suborders: Anisoptera (dragonflies), Zygoptera (damselflies), and Anisozygoptera (6). Anisoptera species are generally larger, more robust, and strong fliers, with broad hindwings and eyes that often meet dorsally. In contrast, Zygoptera are typically smaller, with slender bodies, weaker flight capabilities, and widely separated eyes (7). The third suborder, Anisozygoptera, contains a single extant genus, *Epiophlebia*, exhibiting characteristics intermediate between dragonflies and damselflies (8). Beyond their ecological role, Odonates hold agricultural, medical, and cultural significance. By naturally regulating mosquito populations, they indirectly aid in controlling vector-borne diseases such as malaria, dengue, and filariasis (9). In agricultural settings, they help mitigate pest infestations in crops like cotton and rice. In certain cultures, Odonates are consumed as food, while in traditional medicine, their extracts have been used to treat fever and other ailments (10). Their sensitivity to habitat destruction, climate change, and pollution underscores their utility as bioindicators, aiding in environmental monitoring and conservation strategies.

Despite their significance, the Odonata fauna of Pakistan remains underexplored, necessitating comprehensive studies to document their diversity and distribution. Neighboring countries such as India, Bangladesh, and Nepal have reported significantly higher species counts, indicating the potential for undiscovered species within Pakistan's freshwater ecosystems. The objective of this study is to bridge this knowledge gap by systematically assessing the biodiversity and ecological distribution of Anisoptera and Zygoptera in Dir Lower, providing insights into their habitat preferences and conservation status. The findings will contribute to the broader understanding of Odonata ecology, facilitating future research and conservation initiatives aimed at preserving these ecologically and medically important insects.

METHODS

The study was conducted in Dir Lower, Khyber Pakhtunkhwa, Pakistan, in 2022 to assess the biodiversity and ecological distribution of Anisoptera (dragonflies) and Zygoptera (damselflies). The district is located between 34°50'43.19" N latitude and 71°54'16.43" E longitude, with an altitude range of 1200 to 2800 meters above sea level. It has a continental climate with four distinct seasons, where the hottest months are June and July, with an average temperature of 32.5°C, while December through February experiences temperatures as low as 0°C. Annual rainfall in the region is 1468.8 mm, with peak precipitation occurring in December and January. The study area included various habitats such as riverbanks, ponds, streams, agricultural fields, and urban environments, providing an optimal range of ecological niches for Odonate species (1,4). A systematic field survey was conducted with weekly and bi-weekly specimen collection under clear, sunny conditions between 9:00 am and 4:00 pm. Specimens were captured using an aerial net with a standardized mesh size of 1.5 mm and a net diameter of 40 cm, ensuring efficiency in collecting dragonflies and damselflies while minimizing physical damage. Specimens were identified in the field based on morphological characteristics, and sex was determined. Male specimens were euthanized using ethyl acetate-soaked tissue paper inside a killing bottle, after which they were transferred to labeled triangular envelopes containing details such as location, date, and collector information. Pairs caught in tandem were initially documented in the field, but for preservation, individuals were separated into different envelopes to prevent damage during transportation and storage. Field data, including coordinates, elevation, habitat type, number of specimens, sex ratio, and meteorological conditions (temperature, humidity, and weather), were meticulously recorded in a field data book. Freshly collected specimens were photographed in their natural state for

documentation and later identification before being transported to the Department of Entomology, Abdul Wali Khan University, Mardan, for further analysis.

In the laboratory, dried specimens were rehydrated in a humid chamber and stretched on wooden setting boards for proper examination. Pinning was performed using stainless steel insect pins of appropriate sizes: size 0 for damselflies and size 2 for dragonflies. Damselflies were pinned through the midsection of the forewings, while dragonflies were pinned between the mesothorax and metathorax. After pinning, specimens were stored in insect boxes lined with naphthalene balls to prevent pest infestation, while ant powder was applied to the corners and center to deter crawling insects. Storage boxes were maintained under controlled conditions to ensure long-term preservation of specimens. Taxonomic identification was carried out under a stereomicroscope (LX 400 and Optica models) based on standard identification keys and literature, including "Biosystematics of Damselflies (Zygoptera: Odonata) and "Systematics of Dragonflies (Anisoptera: Odonata) of Pakistan (5,8). Specimens were labeled accordingly and arranged in storage boxes for future reference and verification. Recent taxonomic updates were consulted to ensure accuracy in species classification. Data analysis was conducted using Microsoft Excel and Microsoft Word 2016. Statistical parameters such as species richness, species evenness, and overall abundance were calculated to assess biodiversity patterns. The results were tabulated for further interpretation and comparison with previous studies. Ethical approval for this study was obtained from the Institutional Review Board (IRB) of Abdul Wali Khan University, Mardan, ensuring compliance with ethical standards for scientific research. No specimens were collected from protected or restricted areas, and all activities adhered to conservation guidelines. Informed consent was not applicable, as the study did not involve human participants.

RESULTS

The study documented the biodiversity, species richness, and relative abundance of Anisoptera (dragonflies) in Dir Lower, Khyber Pakhtunkhwa, during the summer of 2022. A total of 146 male and 23 female specimens were collected from various freshwater habitats, including streams, riverbanks, rice paddies, marshes, irrigation channels, storage water tanks, and stagnant water bodies across different locations. Specimens were identified under three families, ten genera, and fifteen species. Among these, the family Libellulidae emerged as the most dominant, represented by eight genera and thirteen species, whereas the families Gomphidae and Aeshnidae were each represented by a single genus and species. The most abundant genus was *Orthetrum*, with *Orthetrum pruinosum neglectum* being the most dominant species, represented by 30 individuals, contributing 20.54% of the total specimens. This was followed by *Orthetrum triangulare triangulare* with 28 individuals (19.17%), *Trithemis festiva* with 15 individuals (10.27%), and *Pantala flavescens* with 14 individuals (9.58%). Other species such as *Acisoma panorpoides panorpoides* (6.84%), *Orthetrum sabina* (5.47%), *Palpopleura sexmaculata sexmaculata* (5.47%), and *Rhyothemis variegata variegata* (4.10%) were less dominant. The rarest species recorded were *Onychogomphus bistrigatus* and *Crocothemis servilia*, each represented by only two specimens, contributing 1.36% to the total specimen count.Analysis of species richness and evenness confirmed that *Orthetrum pruinosum neglectum* and *Orthetrum triangulare triangulare* were the most widespread species, whereas *Anax immaculifrons* and *Onychogomphus bistrigatus* were the rarest. The family-wise distribution analysis revealed that Libellulidae was the most abundant family, constituting 96.57% of the total specimens collected, while Aeshnidae and Gomphidae accounted for 2.05% and 1.36%, respectively.

Among the genera, *Orthetrum* was the most widespread and dominant. The findings indicate that dragonfly diversity in Dir Lower is primarily influenced by habitat availability, climate conditions, and the presence of suitable breeding and feeding grounds. The predominance of *Libellulidae* suggests that this family is well-adapted to the local environmental conditions, particularly in standing and slow-moving water bodies. The data further emphasize the ecological significance of Anisoptera in maintaining freshwater ecosystem balance, as their presence is indicative of water quality and habitat stability. The sex ratio analysis of the collected specimens revealed a significant male dominance in the Anisoptera population, with males accounting for 86.39% (146 individuals) and females comprising only 13.61% (23 individuals). This results in a male-to-female ratio of approximately 6.35:1, indicating a substantial disparity in gender distribution. The skewed ratio may be attributed to behavioral and ecological factors, such as differential habitat preferences, variations in activity levels between sexes, or higher male detectability during sampling hours. Additionally, male dragonflies are known for their territorial behavior, actively patrolling breeding sites, which increases their likelihood of being captured. Conversely, females tend to exhibit more cryptic behavior, often staying hidden in vegetation away from open water bodies. This observed male-biased population structure suggests the need for further investigations into reproductive dynamics, habitat selection, and potential environmental influences affecting female abundance in the region.

Table 1 Sex Ratio Analysis of Collected Specimens

Category	Value
Total Specimens	169
Male Specimens	146
Female Specimens	23
Male Percentage	86.39%
Female Percentage	13.61%
Male-to-Female Ratio	6.35:1

Table 2 Summary of the Anisoptera fauna of the study area During Summer season 2022 Dir Lower Khayber Pakhtunkhwa Malakand Division.

Sub Order	Families	Genus	Species	No. of Specimens
Anisoptera	Libellulidae	Orthetrum	5	80
		Palpopleura	1	8
		Pantala	1	12
		Brachythemis	1	5
		Crocothemis	2	6
		Trithemis	1	14
		Rhyothemis	1	6
		Acisoma	1	10
	Aeshnidae	Anax	1	3
	Gomphidae	Onychogomphus	1	2
Summary	3	10	15	146

Table 3 Species richness, relative abundance and status Damselfly (Zygoptera)

Order	Sub Order	Family	Genus	Species	Number of Specimens	Relative Abundance	Status
Odonata	Zygoptera	Aeshnidae	Anax	Anax immaculifrons	3	2.05%	VR
		Gomphidae	Onychogomphus	Onychogomphus bistrigatus	2	1.36%	VR
		Libellulidae	Orthetrum	Orthetrum sabina	8	5.47%	LC
		Libellulidae	Orthetrum	Orthetrum anceps	5	3.42%	VR

VC= Very Common, VR= Very Rare, R= Rare, C= Common, LC= Less Common

Table 4 Species richness, relative abundance and status Dragonfly (Anisoptera)

Order	Sub Order	Family	Genus	Species	Number of Specimens	Relative Abundance
Odonata	Anisoptera	Libellulidae	Orthetrum	Orthetrum triangulare triangulare	28	19.17%
				Orthetrum pruinosum neglectum	30	20.54%
		Brachythemis		Brachythemis contaminate	5	3.42%
		Pantala		Pantala flavescens	14	9.58%
		Crocothemis		Crocothemis erythraea	4	2.73%
				Crocothemis servilia	2	1.36%
		Trithemis		Trithemis festiva	15	10.27%

Order	Sub Order	Family	Genus	Species	Number of Specimens	Relative Abundance
		Rhyothemis		Rhyothemis variegata variegata	6	4.10%
		Acisoma		Acisoma panorpoides panorpoides	10	6.84%

Table 5 Family-Wise Distribution of Genera, Species, and Specimens of Anisoptera in Dir Lower

Family	Number of Genus	Number of Species	Number of Specimens
Libellulidae	8 (80%)	13 (86.66%)	141 (96.57%)
Aeshnidae	1 (10%)	01 (6.66%)	03 (2.05%)
Gomphidae	1 (10%)	01 (6.66%)	02 (1.36%)

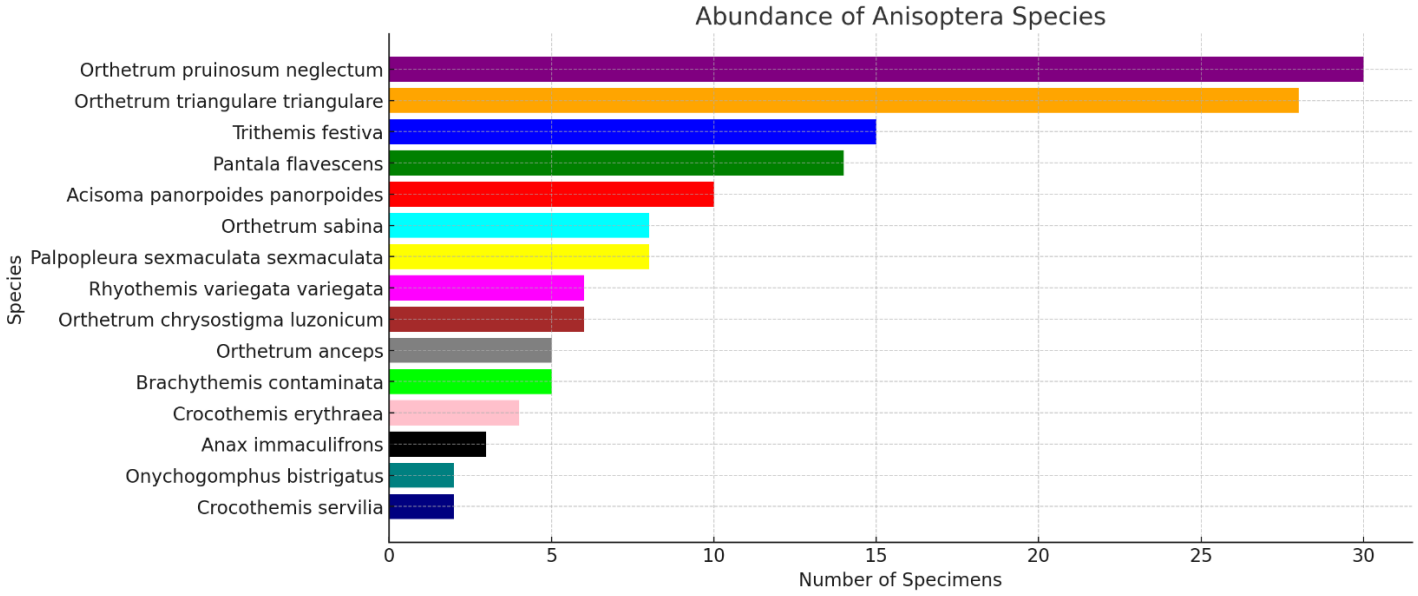


Figure 1 Abundance of Anisoptera Species

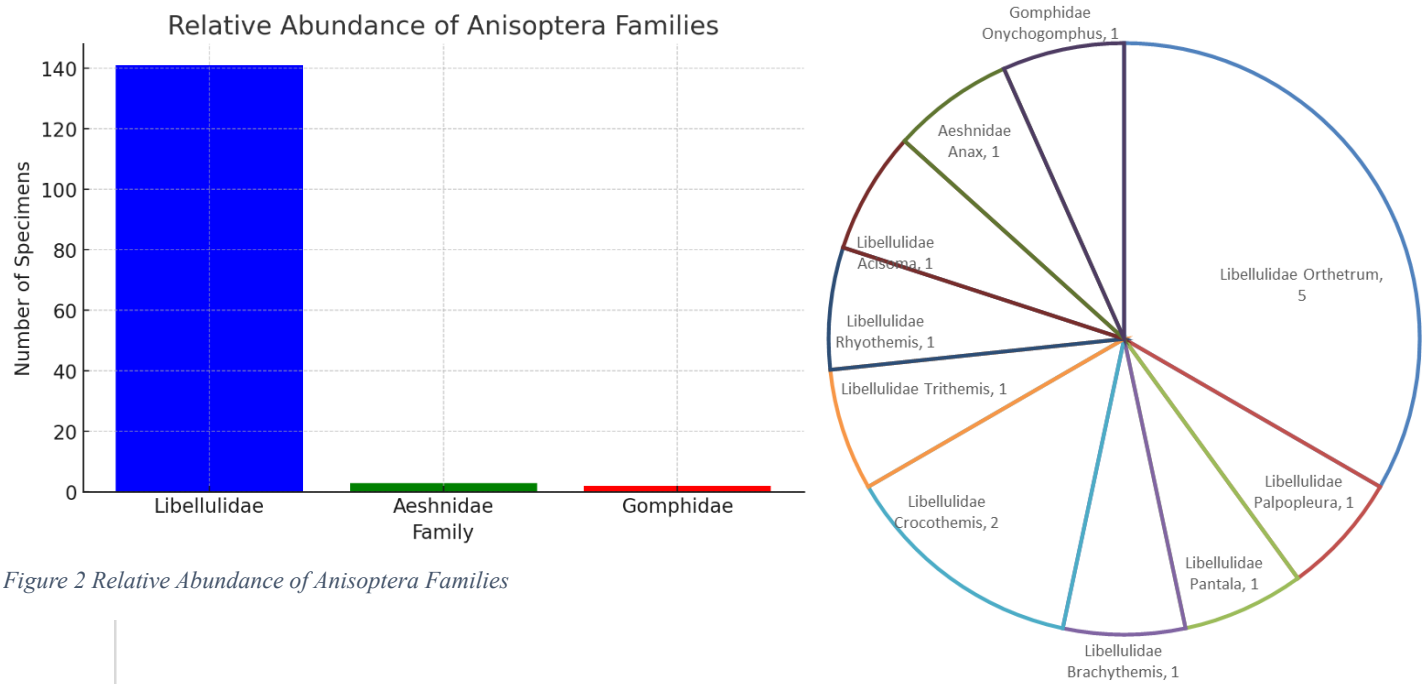
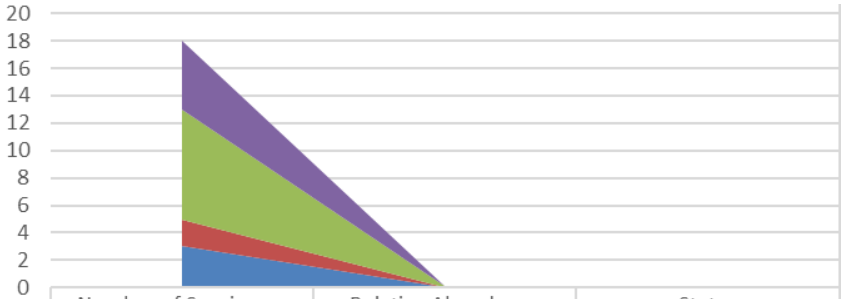


Figure 2 Relative Abundance of Anisoptera Families



	Number of Specimens	Relative Abundance	Status
VC= Very Common, VR= Very Rare, R= Rare, C= Common, LC= Less Common			
Odonata Zygoptera Libellulidae Orthetrum Orthetrum anceps	5	3.42%	0
Odonata Zygoptera Libellulidae Orthetrum Orthetrum sabina	8	5.47%	0
Odonata Zygoptera Gomphidae Onychogomphus Onychogomphus bistrigatus	2	1.36%	0
Odonata Zygoptera Aeshnidae Anax Anax immaculifrons	3	2.05%	0

DISCUSSION

The present study documented the species richness, evenness, and abundance of Anisoptera fauna in Dir Lower, Khyber Pakhtunkhwa, Pakistan, identifying 146 male and 23 female specimens. These specimens were classified into 15 species, distributed across 10 genera and three families, with the family Libellulidae emerging as the most dominant, comprising 13 species, while Aeshnidae and Gomphidae were each represented by a single species. The genus *Orthetrum* was found to be the most widespread, encompassing five species, whereas *Anax* and *Onychogomphus* were the least represented. The findings align with previous research from various regions of Pakistan, where Anisoptera was consistently found to be the more diverse suborder compared to Zygoptera, and the dominance of Libellulidae was a recurring trend (11). This similarity in findings across multiple studies is likely attributed to comparable physiographic, ecological, and meteorological conditions. Comparative analysis with previous research conducted in various districts of Pakistan, including Swat, Swabi, and Kuram, revealed strong similarities in species composition and distribution patterns (12). Studies from different geographical regions have consistently reported Libellulidae as the most dominant family, with *Orthetrum*, *Trithemis*, and *Pantala* being among the most frequently encountered genera (13). The repeated documentation of *Orthetrum pruinosum neglectum* and *Orthetrum triangulare triangulare* as dominant species suggests that these species have a high ecological adaptability to diverse habitats. However, certain discrepancies in species abundance were observed, particularly in areas where environmental degradation has altered natural ecosystems. For example, *Orthetrum triangulare triangulare*, classified as a moderately abundant species in some regions, emerged as the most widespread species in the present study, which may be attributed to variations in habitat conditions, pollution levels, and anthropogenic disturbances (14).

Studies conducted in the Potohar Plateau and the Himalayan foothills reported a greater diversity of Odonata naiads, emphasizing the importance of aquatic habitat diversity in supporting species richness (15). The relatively lower species count in the present study suggests that additional surveys across varied seasonal and altitudinal gradients are required to capture the full diversity of the region. Moreover, species richness and distribution have been found to be influenced by local environmental conditions, with factors such as water quality, temperature, and vegetation cover playing a crucial role in shaping Odonata communities (16). The findings indicate that Dir Lower provides suitable breeding and feeding grounds for Anisoptera, but further assessment of habitat quality and water parameters is necessary to understand the ecological drivers of species distribution. One of the notable observations in the present study was the significant male-biased sex ratio, with males outnumbering females by a ratio of approximately 6.35:1. This trend is consistent with previous research and can be attributed to multiple biological and behavioral factors (17). Male dragonflies are highly territorial, actively patrolling breeding sites, which increases their likelihood of being captured, whereas females exhibit more cryptic behavior, often remaining hidden in vegetation (18). Additionally, differences in dispersal patterns and predation risks may contribute to the observed skewed sex ratio. The implications of this male dominance warrant further investigation to assess whether habitat conditions, environmental stressors, or anthropogenic factors are affecting female survival rates or reproductive success (19).

The study has several strengths, including the systematic field survey conducted across multiple habitats and the detailed documentation of species abundance. The use of standardized identification keys and taxonomic references ensured the accuracy of species classification. However, certain limitations must be acknowledged. The study was restricted to a single season, limiting the ability to assess seasonal variations in species composition. Furthermore, while the study provides valuable insights into species diversity, the lack of molecular identification techniques presents a potential limitation in distinguishing cryptic species. Future research should incorporate genetic analysis and environmental assessments to provide a more comprehensive understanding of Odonata biodiversity. The findings highlight the ecological significance of Anisoptera as bioindicators of freshwater ecosystems. Given their sensitivity to environmental changes, long-term monitoring of Odonata populations could serve as an effective tool for assessing habitat quality and detecting early signs of ecological disturbances. Additionally, the role of dragonflies in mosquito population control underscores their importance in public health, particularly in regions where vector-borne diseases are prevalent (20). Expanding research efforts to include the study of Odonata naiads and their ecological interactions would provide further insights into their habitat preferences and conservation needs. Future studies should also explore the impacts of climate change, land use alterations, and water pollution on Odonata populations to develop conservation strategies aimed at preserving these ecologically valuable insects.

CONCLUSION

The study documented the diversity and ecological distribution of Anisoptera in Dir Lower, highlighting the dominance of the family Libellulidae and the prevalence of *Orthetrum* species. The findings emphasize the critical role of dragonflies in freshwater ecosystems, where their presence serves as an indicator of environmental health and biodiversity. The variation in species distribution across different

habitats underscores the importance of maintaining diverse and undisturbed aquatic environments to support their populations. By providing insights into species richness and abundance, this research contributes to a better understanding of Odonata ecology and its potential applications in ecological monitoring and biological control. The study reinforces the need for continued research and conservation efforts to protect these ecologically significant insects, ensuring the sustainability of their habitats and the vital ecosystem services they provide.

Author Contribution

Author	Contribution
Fawad Khan	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Kiran Fatima & Farman Ali	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Sabeeka Zaffar & Akhtar Badshah Khan	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Farkhanda Manzoor & Kamran Nawaz	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Samina Yasmin	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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