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Geo-climatic effects on the dragonfly diversity in Sikar region, Rajasthan (India)

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Abstract
Dragonflies (Order: Odonata) are sensitive to geoclimatic changes. This study investigates the influence of altitude, latitude and seasonal climate changes on dragonfly diversity across Sikar region. The sampling of dragonflies was performed from July 2023 to June 2025. By integrating field observations, seasonal species count and species distribution across geographic regions with reference to altitude, longitude and latitude, we could identify clear geoclimatic effects on dragonfly diversity. Higher altitude ranges from 397 to 714 meters tended to anchorage greater species diversity during the winter and monsoon climatic conditions. Although, during the summer, species were more concentrated in lower altitude range (308 to 701 meters). Findings revealed the significant shifts in range boundaries and seasonal activity correlated with dragonfly diversity and abundance. Even slight changes in geoclimatic range can significantly influence dragonfly diversity structure. These geoclimatic shifts not only affect local biodiversity but also have broader implications for ecosystem. As climate change accelerates, understanding the geoclimatic sensitivities of dragonflies is vital for predicting ecological responses and informing conservation strategies aimed at preserving both species and their habitats.

Keywords: Dragonfly, diversity, geoclimatic, altitude, longitude and latitude

Introduction

Dragonflies are known as important species for conservation and act as indicators of climate change (Clausnitzer *et al*., 2017; Bush *et al*., 2013; Simaika *et al*., 2013; Simaika & Samways, 2011 and 2015) [4, 6, 21, 22, 23]. Different latitudes, altitudes and longitudes make climatic conditions. Both latitudinal and altitudinal gradients are essential for understanding how insects adapt to different climatic zones. As altitude upturns, temperature becomes lower and relative humidity, wind, vegetation and oxygen level are changed, which can affect the diversity and abundance of insect species. Dragonflies are ectothermic organisms, so their biological processes, activity, and scattering are directly influenced by climatic factors such as temperature, humidity, and the availability of suitable breeding habitats (Harabiš & Dolný, 2010; Johansson & Suhling, (2004) [14, 16]). These climatic factors combined with geographic coordinates, altitude and latitude, decide the presence or absence of species during the year (Hassall, 2015) [15]. Dragonfly adults have stronger flying proficiency, therefore, capable to scatter over longer distances (Angelibert & Giani, 2003; Júnior *et al*., 2015; Mähn *et al*., 2023; Wootton, 2020) [2, 26, 27].

Due to high relative humidity, moderate temperature and abundant rainfall, monsoon climate is the most favorable time for dragonfly populations which relate to optimal conditions for reproduction, growth, and feeding (Corbet, 1999; Suhling *et al*., 2015) [7, 26]. Several species of dragonflies were absent during the winter and summer climate but were recorded fully in the monsoon climate. Dragonflies are more diverse and abundant in tropical regions near to the equator line, where temperature in high and more stable throughout the year. In contrast, in regions further from the equator, dragonfly diversity and abundance are often more seasonal and dependent on seasonal temperature changes. Equally, altitude can also influence dragonfly populations, with many species being restricted to specific elevations.

Geographical topographies such as mountains, oceans and human made unsuitable habitats like rural and urban areas or agricultural lands, which can prevent movement, isolate populations (Cordoba-Aguilar *et al*., 2023) [8]. Sikar region has such different geo-topographies like Aravali hill area, plain or human made urban and rural structures. So, expected species may be wide-ranged/narrow-ranged with different abundance. Broad-spread species territories are general whereas, narrow-ranged species territories are specialized (Grant & Samways, 2007) [13], although factors like species interactions may explain why some common species may be rare.

The geo-climatic conditions in the term longitude, latitude and altitude are varied which affect the diversity and abundance of dragonflies in Sikar region due to their adaptation to different environmental conditions. Understanding the geoclimatic diversity of dragonfly in this region includes how both latitudinal (north-south) and altitudinal gradients influence species diversity and abundance. Geoclimatic factors affect temperature, humidity, air pressure, availability of food, competition of life with other organisms, and their life maintaining other factors. The outcomes of this study strengthen the knowledge that dragonfly diversity and abundance are affected by geoclimatic conditions. Analysing the effects of latitude and altitude on dragonfly diversity and abundance will provide important insights into how geoclimatic changes may affect dragonfly diversity and play important roles in ecosystem stability and biodiversity conservation.

Material and Methods

Study area

Location

Sikar district is located in the northeastern part of Rajasthan (India) between geographical coordinates 27°21'-28°12' north latitudes and 74°44' - 75°25' east longitudes, covering an area of 7,726.9 km^2.

Climate and Geography:

Sikar is characterized by a semi-arid climate with hot summers and cold winters, and a general dryness of the air, except in the monsoon. The region covers plains, hill sides which are part of the oldest Aravali mountains as well as desert and vast crop areas. Systematic drainage system is lacking in western half of the district.

Temperature changes are varying, with difference in temperature of day and night. The western part represents typical desertic topography. The altitude of the highest peak is about 1052 metres AMSL (Above Mean Sea Level) and that of other hills generally ranges between 350 and 700 metres AMSL. The plain area generally lies at altitude between 380 and 530 metres AMSL.

Methodology

To examine the geoclimatic effects, a multi-site field survey was conducted across distinct ecological regions varying in altitude, longitude and latitude. The study spanned over two consecutive years to find climatic seasonal variability. Sites were selected across Sikar region and grouped for five different geoclimatic ranges. Range latitude and longitudes along with altitude were measured. The five ranges are as given in Table 1-

Table 1: Studied geo-range groups with latitudes, longitude and altitude

Geo-range group	**Latitude range**	**Longitude range**	**Altitude range**
A	27°25'32.6"N- 27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-714 m
B	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m
C	27°25'32.6"N-28°09'51"N	75°09'35.2"E-75°56'41.1"E	312- 701 m
D	27°14'21.6"N-28°11'34.8"N	74°45'12.7"E-75°56'41.1"E	308- 701 m
E	27°14'21.6"N-28°11'34.8"N	74°45'12.7"E-75°56'41.1"E	308-714 m

The data were analyzed in the respect of species and their findings in particular geo-range. At each range group, systematic surveys were carried out using line-transect and point count methods along freshwater habitats, including lakes, rivers, and wetlands.

Dragonfly Sampling and identification: The sampling of dragonflies was performed from July 2023[8] to June 2025. For documentation of dragonfly diversity with geo-climate range variations, data was gathered and grouped. Sampling was done at the time when the dragonfly species were more active (Corbet, 1999) [7].

Line transect techniques and Visual Encounter Survey method were applied to count dragonfly species diversity and abundance. For sampling, aerial net, camera and binoculars were used. Identification of sampled species was carried out using field guides or taxonomic keys (Andrew *et al*. 2008; Mitra 2002; Fraser 1933, 1934, 1936; Subramanian 2005, 2014) [1, 10, 11, 12, 20, 24, 25].

Geo-climate data collection: Climatic variables, including temperature, relative humidity and precipitation were obtained from local weather stations and the Indian Meteorological Department, Jaipur (IMD). Geographic coordinates were recorded using GPS devices.

Data analysis: Species abundance and diversity indices (Shannon-Wiener and Simpson's) were calculated for each geoclimatic group. Tables and pictures on the physical, environmental and morphometric factors of dragonflies were used for descriptive analysis, and evenness index (E) was used for quantitative analysis on dragonfly populations. Abundance was calculated by transect sampling count.

Results

From five geo-climate ranges, there were 31 dragonfly species recorded in 3 families namely Libellulidae, Cordulegastridae and Gomphidae. With 29 species, Libellulidae showed dominance in all the geo-climate range, but the Cordulegastridae and Gomphidae were represented by one family each only in geo-climate range A. Although highest percentage of specimen was observed in group B with 33.69% and lowest in group C with 10% (Figure-1) but geogroup range B, D and E were most abundant in monsoon, summer and winter, respectively. In winter season 4,12,2,3 and 2 species of dragonflies with two families namely Libellulidae and Gomphidae and in summer season 1,5,2,4 and 3 species of dragonflies which belonged to only one family, Libellulidae, were observed in geoclimatic group A, B, C, D and E respectively. For each species, its altitudinal findings are showed in Table 2.

Table 2: Dragonfly species in different geo-climate range

Sr. no.	Species name	Latitude range	Longitude range	Altitude range	Winter count	Summer count	Monsoon count
1	*Acisoma variegatum*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	0	3	64
2	*Aethriamanta brevipennis*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	2	9	74
3	*Brachydiplax sobrina*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	3	15	88
4	*Crocothemis erythraea*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	18	18	128
5	*Crocothemis servilia*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	4	14	96
6	*Indothemis carnatica*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	5	0	59
7	*Libellula saturata*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	9	0	51
8	*Neurothemis intermedia*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	6	0	61
9	*Orthetrum glaucum*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	4	0	57
10	*Orthetrum pruinosum*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	7	0	56
11	*Rhodothemis rufa*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	3	0	113
12	*Sympetrum striolatum*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	5	0	59

13	*Tholymis tillarga*	27°25'32.6"N-27°49'58.5"N	75°06'31.0"E 75°56'41.1"E	397-614 m	5	0	70
14	*Trithemis annulata*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	0	0	52
15	*Trithemis aurora*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	0	0	51
16	*Urothemis signata*	27°25'32.6"N-27°49'58.5"N	75°09'35.2"E-75°56'41.1"E	397-614 m	0	0	61
17	*Brachythemis contaminata*	27°25'32.6"N -28°09'51"N	75°09'35.2"E-75°56'41.1"E	312- 701 m	21	15	211
18	*Diplacodes trivialis*	27°25'32.6"N -28°09'51"N	75°09'35.2"E-75°56'41.1"E	312- 701 m	9	6	115
19	*Bradinopyga cornuta*	27°14'21.6"N -28°11'34.8"N	74°45'12.7"E -75°56'41.1"E	308- 701 m	37	27	336
20	*Bradinopyga strachani*	27° 18'47.8"N- 28°11'39.4"N	74°47'47.3"E -75°56'41.1"E	308- 701 m	0	3	56
21	*Orthetrum sabina*	27°14'21.6"N -28°11'34.8"N	74°45'12.7"E -75°56'41.1"E	308- 701 m	8	23	103
22	*Trithemis kirbyi*	27°14'21.6"N -28°11'34.8"N	74°45'12.7"E -75°56'41.1"E	308- 701 m	3	37	115
23	*Bradinopyga geminata*	27°14'21.6"N -28°11'34.8"N	74°45'12.7"E -75°56'41.1"E	308-714 m	51	27	398
24	*Pantala flavescens*	27°14'21.6"N -28°11'34.8"N	74°45'12.7"E -75°56'41.1"E	308-714 m	45	17	330
25	*Cordulegaster boltonii*	27°25'32.6"N - 27°49'58.5"N	75°09'35.2"E -75°56'41.1"E	397-714	0	0	34
26	*Erythemis simplicicollis*	27°25'32.6"N - 27°49'58.5"N	75°09'35.2"E -75°56'41.1"E	397-714	3	0	39
27	*Ictinogomphus rapax*	27°25'32.6"N - 27°49'58.5"N	75°09'35.2"E -75°56'41.1"E	397-714	5	0	53
28	*Orthetrum taeniolatum*	27°25'32.6"N - 27°49'58.5"N	75°09'35.2"E -75°56'41.1"E	397-714	2	0	50
29	*Tramea basilaris*	27°25'32.6"N - 27°49'58.5"N	75°09'35.2"E -75°56'41.1"E	397-714	0	0	46
30	*Acisoma panorpoides*	27°25'32.6"N - 27°49'58.5"N	75°09'35.2"E -75°56'41.1"E	397-714 m	3	34	183
31	*Bradinopyga konkanensis*	27°18'47.8"N-28°11'39.4"N	74°47'47.3"E -75°56'41.1"E	308- 701 m	0	2	53

From the figure 1, it becomes clear that species were found in 11.98 %, 33.69%, 10%, 19.84%, 24.48% and 6,16,2,4,3 (no of species) for geo range group A, B, C, D and E respectively. Group A had highest 3 families and other have 1 in each group.

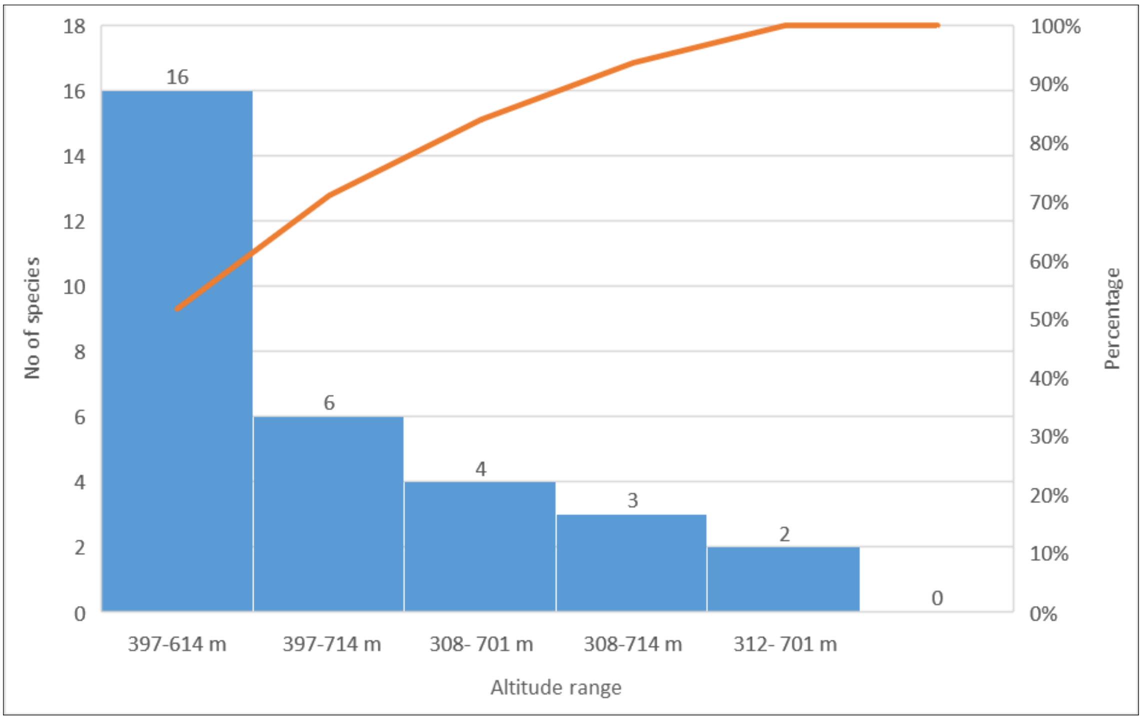

Fig 1: Species, family and total percentage share in different georange

Diversity of dragonflies was affected by geoclimatic ranges. All species were not present on particular points of geoclimatic measures. On the measure of geo-range group, A, species *Acisoma panorpoides, Cordulegaster boltonii, Erythemis simplicicolis, Ictinogomphus rapax, Orthetrum taeniolatum,* and *Tramea basilaris* were observed but climatic presence differed with monsoon value of H'= 1.56, winter value of H'=1.33 and summer value of H'=0. Evenness values were 0.80 in monsoon and 0.95 in winter.

On the second geo-range group B, species found were *Acisoma variegatum, Aethriamanta brevipennis, Brachydiplax sobrina, Crocothemis erythraea, Crocothemis servilia, Indothemis carnatica, Libellula saturata, Neurothemis intermedia, Orthetrum glaucum, Orthetrum pruinosum, Rhodothemis rufa, Sympetrum striolatum, Tholymis tillarga, Trithemis annulata, Trithemis aurora,* and *Urothemis signata,* but climatic presence also differed with monsoon value of H'= 2.73, winter value of H'=2.3 and summer value of H'=1.49. Evenness values were 0.96, 0.89 and 0.83 in monsoon, summer and winter respectively (Figure 2).

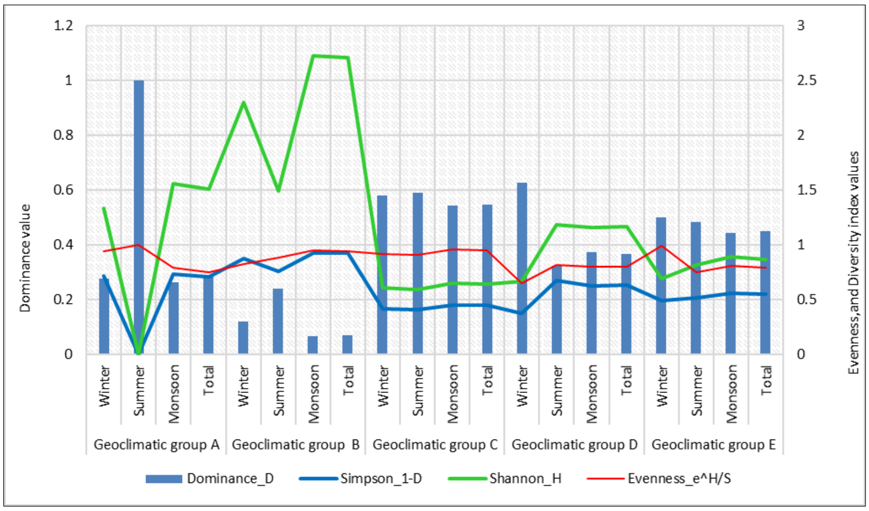

Fig 2: Diversity index for different geoclimatic range

Brachythemis contaminata, and *Diplacodes trivialis* species were found in geo range group C but climatic presence also differed with monsoon value of H'=0.65, winter value of H'=0.61 and summer value of H'=0.60. Evenness values were 0.96, 0.91 and 0.92 in monsoon, summer and winter respectively. Geo range group D included *Bradinopyga cornuta, Bradinopyga strachani, Orthetrum sabina,* and *Trithemis kirbyi* species. For this group, monsoon value of H'=1.16, winter value of H'=0.67 and summer value of H'=1.19 were observed.

Evenness values are 0.8, 0.82 and 0.65 in monsoon, summer and winter respectively.

Bradinopyga geminata, Bradinopyga konkanensis, and *Pantala flavescens* species were found in the last one - fifth geo range E with monsoon value of H'=0.89, winter value of H'=0.69 and summer value of H'=0.82. Evenness values were 0.81, 0.75 and 0.998 in monsoon, summer and winter respectively.

Overall group diversity index value of H'=1.51, 2.71, 0.64,1.17 and 0.83 and evenness value of 0.75, 0.94, 0.96, 0.80 and 0.80 were recorded for geo range group A, B, C, D and E respectively.

Discussion

Dragonfly diversity and abundance was observed to be highly sensitive to geoclimatic range change which includes latitude, longitude and altitude influence, affecting species activity, reproduction and distribution. This study's data analysis revealed that dragonfly species exhibit distinct seasonal responses demonstrating how geoclimatic variables govern their distribution. Similar studies showed that dragonflies' life cycles were closely related to climate conditions, as noted by Corbet (1999) [7] and reaffirmed in studies such as Harabiš & Dolný (2010) and Hassall (2015) [14, 15]. Dragonflies geoclimatic presence differed with monsoon, winter and summer values of H' and evenness values in different geoclimatic ranges.

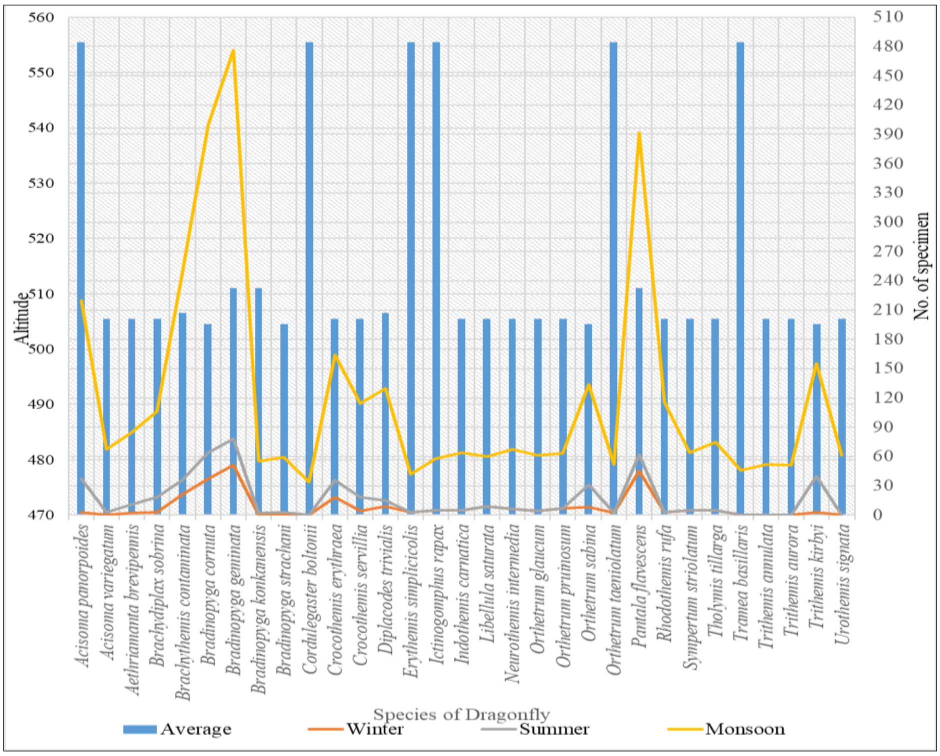

Fig 3: Dragonfly species diversity and abundance in different seasons at different georange

During winter, number of dragonfly species presence was 4, 12, 2, 3 and 2 in group A, B, C, D and E respectively out of 23 (Figure 3). Notable species included *B. geminata* and *P. flavescens* which were species thriving across 308–714-meter altitudes, showcasing adaptations to cooler temperatures. The migratory nature of *P. flavescens* highlights its flexibility in adjusting to seasonal conditions (Corbet, 1999) [7].

In summer climate, dragonfly species presence was 1, 5, 2, 4 and 3 in group A, B, C, D and E respectively out of 23. The summer season brought extreme heat and low humidity, leading to significant low count in dragonfly abundance and composition reflecting the stress of harsh conditions. However, species *T. kirbyi* was most abundant with 37 specimens, suggesting physiological adaptations to arid conditions, as discussed in previous studies (Suhling *et al*., 2015) [26].

Species like *B. konkanensis* were present in minimal numbers, indicating limited tolerance to extreme heat and a preference for cooler or more humid environments, aligning with studies on species-specific temperature tolerances.

In monsoon climate, dragonfly species presence was 6, 16, 2, 4 and 3 in group A, B, C, D and E respectively. So, the monsoon climate emerged as the most favourable season, with 31 species recorded but *B. geminata*, *P. flavescens*, and *B. cornuta* were particularly abundant. Species absent in other seasons, such as *C. boltonii* and *T. aurora*, reappeared, thriving in the optimal conditions of increased humidity, rainfall, and water body availability.

The importance of monsoon rainfall in providing breeding habitats and improving food availability for dragonflies is also supported by Bried and Samways (2015) [3], who emphasized the role of hydrological conditions in shaping Odonate populations.

The study altitudinal range (308–714 meters) provided diverse microhabitats, supporting species with varying climatic tolerances. Higher altitudes offered cooler temperatures, while lower altitudes provided warmer and more stable conditions.

Seasonal changes significantly impacted dragonfly populations. The monsoon, with its high humidity and rainfall, created ideal breeding conditions, leading to peak abundance and diversity. Conversely, summer's extreme heat and winter's cooler temperatures constrained species activity and distribution.

Comparatively low temperatures were found at higher altitudes and more stable conditions during extreme seasons, making them suitable for some species, while at lower altitudes high temperature was found which provide warmer conditions that are better suited for others (Corbet, 1999) [7].

Latitudinal variation also plays an important role in species distribution, with higher latitudes being associated with species adapted to cooler climates (Harabiš & Dolný, 2010) [14].

High temperature and low humidity in summer significantly affects the diversity and abundance of dragonfly species, with many species absent during this period. In contrast, the monsoon season provided ideal environment, with high humidity, suitable temperatures, and abundant water, leading to an increase in dragonfly populations (Kumar and Saxena, 2025) [18]. Climatic factors play a central role in structuring dragonfly communities (Hassall, 2015) [15]. For instance, some species have adapted to fluctuations in temperature and humidity, such as the ability to migrate to more favourable habitats (Suhling *et al*., 2015) [26]. The availability of suitable breeding sites is another key factor influencing dragonfly populations. The monsoon season, with its abundance of temporary water bodies, offers ideal conditions for dragonfly larvae development, while the lack of rainfall in summer limits breeding opportunities for many species (Dijkstra & Kalkman, 2012) [9]. The presence of ephemeral wetlands during the rainy season significantly contributes to dragonfly reproductive success (Bried & Samways, 2015) [3].

Conclusion

The studied area of Sikar district, including altitudes of 308 to 714 meters and latitudes from 27°14'21.6"N to 28°11'39.4"N, offers a range of microclimates that support different species at varying geoclimates. The results of this study highlight the significant influence of geoclimatic factors on the distribution and abundance of dragonfly species. Climatic variations, particularly in temperature, humidity, and precipitation, play a critical role in determining species richness and activity patterns within the studied latitude (27°14'21.6"N to 28°11'39.4"N) and altitude range (308 to 714 meters). During the winter, dragonfly activity was relatively low, with only 258 individuals of 23 species recorded and highest H' value was 2.3 in geoclimatic group B and lowest in group C with H'=0.61. This low activity may be attributed to lower temperatures, which limit the mobility and metabolic rates of ectothermic organisms like dragonflies (Suhling *et al*., 2015) [26]. During the summer, dragonfly activity was relatively low, with only 250 individuals of 15 species recorded and highest H' value was 1.49 in geoclimatic group B and lowest in group A with H'=0. 11 species out of the 23 species observed in winter climate were not observed during the summer climate and 3 species namely *A. variegatum*, *B. konkanensis*, and *B. strachani* were absent in winter reflecting the impact of unfavorable geoclimatic conditions.

This study underlines the importance of altitude and latitude in shaping the distribution patterns of dragonfly species. Higher altitude range 397 to 714 meter tended to anchorage greater species diversity with species during the winter and monsoon climatic conditions, likely due to the availability of suitable microhabitats and reduced temperature extremes compared to lower altitudes (Bried & Samways, 2015) [3]. Although, during the summer climate, species were more concentrated in lower altitudes range 308 to 701 meter suggesting that these areas may provide critical refuges from extreme heat (Hassall, 2015) [15].

Overall, the conclusion highlights the complex interplay between geoclimatic factors and dragonfly diversity.

The distinct seasonal variations in species diversity and abundance highlight the need for targeted conservation efforts. Future studies should focus on exploring the microhabitat preferences, reproductive strategies, and migratory behaviors of these species to better understand their ecological requirements.

Understanding the dynamics is critical in the context of climate change, as it provides insights into the resilience and adaptability of dragonfly populations in diverse geoclimatic zones. This research contributes to the predictive modeling of ecological outcomes under future climate scenarios and supports the development of targeted conservation and management strategies.

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