PAKISTAN JOURNAL OF ZOOLOGICAL SCIENCES

IJSMART PUBLISHING COMPANY

RESEARCH ARTICLE

Assessing The Role of Bioclimatic Variables in Shaping Diptera Biodiversity and Distribution in District Faisalabad, Punjab

Ujala Hanif[1,2], Maryam Riasat[2], Zubda Ashfaq[2], Muhammad Shahid[2], Rida Younas[2], Iqra[2], Naureen Rana[2], Tehreem Shakoor[2], Nawaz Haider Bashir[1], Muhammad Naeem[1], Huanhuan Chen[1,*]

[1] College of Biological Resource and Food Engineering, Qujing Normal University, Qujing 655011, China.
[2] Department of Zoology, Faculty of Engineering and Applied Sciences, Riphah International University, Faisalabad Campus, Faisalabad, 38000, Pakistan.
*Correspondence: chhuanhuan@163.com

Article Info

Academic Editor: Saba Malik

Received: 25, May, 2025
Accepted: 31, May, 2025
Published: 1 July, 2025

Citation: Hanif U, Riasat M, Ashfaq Z, Shahid M, Younas R, Iqra, Rana N, Shakoor T, Bashir NH, Naeem M, Chen H. Assessing the role of bioclimatic variables in shaping Diptera biodiversity and distribution in District Faisalabad, Punjab. *Pak J Zool Sci.* 2025;1(1):1–7.

Abstract

Agricultural and climatic changes are reshaping insect communities globally, yet the role of bioclimatic factors in determining Diptera diversity remains underexplored. This study examined the effects of temperature, precipitation, humidity, and seasonality on Diptera occurrence across 14 sites in District Faisalabad, Pakistan. Field observations of 11 ecologically and medically relevant species were analyzed alongside 19 WorldClim bioclimatic variables. Principal Component Analysis (PCA) revealed that temperature (PC1) and moisture (PC2) accounted for 61% of the environmental variation. Sites were grouped into four clusters warm, humid, cool, wet, cool and dry, and hot, dry each supporting distinct Diptera assemblages. K-means clustering validated these ecological groupings, highlighting microclimatic gradients as key drivers of species composition. Warm–humid sites harbored the highest richness, while arid and cooler areas supported more specialized or generalist taxa. Correlation analysis showed strong positive associations between Diptera abundance and both Bio5 (maximum temperature) and Bio12 (annual precipitation), suggesting these as primary predictors of species richness. Overall, the findings underscore the importance of temperature and moisture thresholds in shaping Diptera communities and offer a framework for forecasting climate-induced distribution shifts and managing key fly species.

Keywords: diptera diversity, bioclimatic variables, species distribution modeling, principal component analysis (PCA), microclimate gradients

Introduction

True flies (Order: Diptera) display remarkable biodiversity, with their distribution closely linked to bioclimatic factors such as temperature, humidity, precipitation, and seasonal variability. As ectothermic organisms, their development, reproduction, and survival are directly affected by these environmental variables. Species Distribution Models (SDMs) like MaxEnt are widely used to predict their ranges based on such climatic inputs. Temperature and humidity are among the most influential factors. Studies from Pakistan's Malakand and Dir Lower districts showed mosquito populations peaking at summer temperatures of 21.6°C to 34.6°C, with relative humidity from 21% to 94%. Similarly, a metabarcoding study in Eastern China found that Diptera diversity

#Both authors contributed equally

varied significantly with elevation, slope direction, and especially seasonal changes, which had the strongest effect on species composition.

In temperate regions like Moscow, drosophilid fly populations rose during hot, dry summers, confirming that temperature and precipitation drive abundance. Sandflies exhibit clear climatic preferences: *Phlebotomus* species dominate subtropical areas, while *Lutzomyia* and *Brumptomyia* prefer tropical climates. Seasonal activity patterns also reflect this dependence. For instance, in southern Punjab, Diptera remained active year-round, unlike other pollinators that ceased activity below 20°C. In Egypt, MaxEnt modeling of the gall midge *Schizomyia buboniae* identified temperature seasonality and altitude as critical distribution predictors. In Faisalabad, studies show fluctuations in Diptera biodiversity correspond with changing temperature and moisture. Vector studies reveal that *Phlebotomus major* and *P. hindustanicus* prefer cooler, moist highlands, while *P. papatasi* and *P. sergenti* are more prevalent in dry lowlands. In Sri Lanka, SARIMA modeling showed that *Bactrocera dorsalis* populations peak in wet and intermediate climate zones. In Iran and the U.S., similar models demonstrated that precipitation and temperature changes directly impact mosquito distribution. Climate change is predicted to expand the geographic range of species like *Sarcophaga dux* and *S. haemorrhoidalis*, affecting their forensic utility. In Europe, *Drosophila suzukii* has adapted to new conditions, influenced by factors like annual precipitation and temperature seasonality.

North American studies of frugivorous *Drosophila* and their parasitoids show increasing diversity with latitude, largely driven by temperature and rainfall variations. In Australia, temperature and elevation help explain the coastal confinement of *Anopheles farauti*. Land use and vegetation also impact Dipteran distributions. For instance, Austrian research showed mosquito composition differed between forested and agricultural zones. In Thailand's Doi Pha Hom Pok National Park, black fly diversity responded to stream velocity, canopy height, and vegetation cover, with stream width and conductivity being significant at 500–700 meters altitude. Malaysian studies found altitude, water speed, and dissolved oxygen to influence aquatic Diptera diversity. In Jordan, necrophagous flies increased in humid conditions but declined under temperature stress.

A Mexican study reported slightly higher genus-level Psychodidae diversity in protected forests versus unprotected ones, indicating that anthropogenic land use may reduce biodiversity. In Brazil's Pampa biome, *Drosophila melanogaster* and *Zygothrica vittimaculosa* showed negative correlations with temperature. Pakistani research on *Phlebotomus* species confirms that elevation and humidity are major determinants of distribution. Predictive models like MaxEnt remain essential. The distribution of *Spogostylum royale*, for instance, was strongly tied to maximum temperature and annual temperature range. In Iran, *Anopheles maculipennis s.l.* and *Culex theileri* distributions were linked to temperature seasonality, precipitation, and NDVI. In tropical streams, black flies and other Diptera were strongly affected by temperature, precipitation, and elevation. Climate projections suggest that pests like *Bactrocera dorsalis* will become more widespread under warming scenarios, especially by 2070. Such changes call for climate-informed strategies in pest control and vector management. Overall,bioclimatic factors—particularly temperature, rainfall, and seasonal dynamics—are crucial to understanding Diptera's distribution and ecological roles as pollinators, decomposers, and disease vectors. Ongoing modeling and field research continue to reveal how climate shapes Diptera biodiversity and distribution patterns globally.

Materials and Methods

Data Collection

This study on Diptera biodiversity and distribution, with emphasis on bioclimatic factors, is conducted in Faisalabad, located in central Punjab, Pakistan. Covering 5,856 square kilometers at 31°24′N and 73°04′E, Faisalabad comprises urban, rural, and agricultural landscapes. The district's semi-arid climate features hot summers with temperatures reaching 40°C and mild winters with nighttime lows near 10°C. Rainfall is concentrated during the monsoon season from July to September, contributing 300–400 mm annually as shown in Fig 1. These climate variations make Faisalabad a suitable site for studying insect biodiversity responses to environmental conditions such as temperature, humidity, and precipitation.

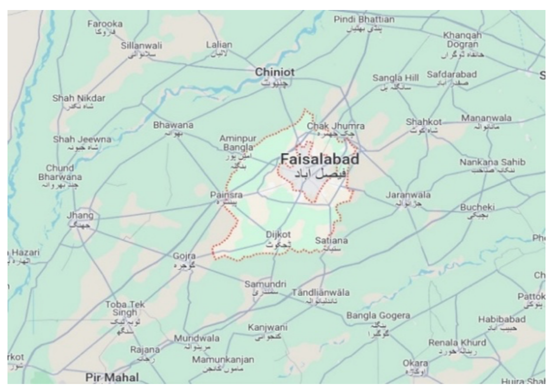

Figure 1. *Collection sites were within and around the Faisalabad region of Punjab, Pakistan.*

The district's diverse habitats including urban parks, sidewalks, residential zones, agricultural fields, and riparian wetlands offer varied ecological conditions for Diptera species. Urban areas, despite human interference, sustain biodiversity in green spaces like parks and gardens. Agricultural regions produce wheat, rice, sugarcane, and cotton, offering suitable conditions for pollinators, decomposers, and pest-regulating flies. Wetlands and canals further enrich habitat diversity by supporting semi-aquatic species. Although urbanization has diminished natural forest cover, scattered forest patches and riverbank reserves continue to offer refuge for many Dipteran species. This environmental gradient, ranging from urban to wetland zones, allows for a detailed analysis of how temperature, moisture, and vegetation influence Diptera distribution. It also provides insight into the impacts of land use and climatic change on local biodiversity.

Diptera species exhibit marked sensitivity to bioclimatic variables. Many displays temperature-dependent seasonal life cycles, with some preferring moist conditions driven by precipitation levels. Relative humidity significantly influences survival and activity, especially in semi-arid zones. Solar radiation affects species behavior and reproduction. By assessing these factors, the study aims to explain Diptera distribution patterns across varied habitats in the Faisalabad district.

Data Processing

To determine Diptera richness and abundance, a comprehensive approach involving sampling, specimen handling, identification, and statistical analysis will be applied:

- Sampling Design
- Insect Pinning
- Identification of Insects
- Data Analysis
- Statistical Analysis

Sampling Design

A stratified random sampling approach will be used to ensure representative coverage of urban, rural, and agricultural habitats. Selected sites will vary by elevation, land use, and vegetation type to reflect different bioclimatic conditions. Collection tools will include pan traps for ground insects, yellow sticky traps for flying adults, Malaise traps for aerial species, and sweep nets for plant-dwelling Diptera. Light traps will be used to attract nocturnal species.

Sampling will occur every two weeks over 12 months to capture seasonal fluctuations in species diversity. Simultaneously, temperature, humidity, rainfall, and solar radiation data will be gathered using GIS-based tools and local meteorological records. This will enable correlation between environmental variables and Diptera distribution and diversity.

Pinning of Insects

Standard entomological techniques will be used to preserve collected Diptera specimens. Each insect will be pinned through the thorax, with careful positioning of wings and legs to maintain diagnostic features. Specimens will be stored in insect boxes and labeled with detailed collection information, including date, location, and local climate conditions at the time of capture. A controlled dry environment will ensure long-term preservation and prevent deterioration. These specimens will be maintained as a reference collection for future identification and taxonomic verification.

Identification of Insects

Insect identification will rely on both morphological and molecular approaches. Morphological classification will be based on established taxonomic keys that emphasize traits such as wing venation, antenna structure, and body segmentation (Mullen & Durden, 2002; Freidberg, 2008). When specimens lack distinguishable physical features or fall into cryptic groups, DNA barcoding will be employed. This involves analyzing the mitochondrial cytochrome c oxidase I (COI) gene to confirm species identity. The resulting sequences will be compared with global reference databases like the Barcode of Life Database (BOLD). All identified species will be cataloged, and relevant bioclimatic data will be used to assess species-environment relationships.

Statistical Analysis

Data analysis will include both univariate and multivariate techniques to explore the relationships between Diptera diversity and environmental factors. Diversity indices such as species richness, Shannon-Wiener, and Simpson's index will quantify the species composition in different habitats. Multivariate tools, including Principal Component Analysis (PCA) and Canonical Correspondence Analysis (CCA), will be used to examine how climate variables—temperature, precipitation, humidity, and solar radiation—influence community structure and species distribution. To forecast the potential distribution of Diptera under various climate scenarios, the MaxEnt (Maximum Entropy) species distribution modeling tool will be used. This model integrates presence-only data with environmental variables to predict suitable habitats. Statistical analysis will be conducted using R software (version 4.0) and SPSS (version 25), ensuring robust interpretation and reproducibility. These tools will help clarify how climatic and ecological factors interact to shape Diptera biodiversity across Faisalabad's heterogeneous landscape.

Results and Discussion

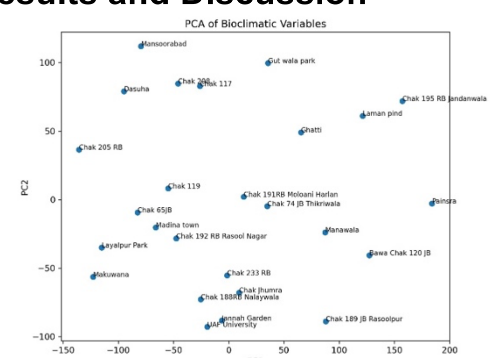

Figure 2. *PCA of Bioclimatic Variables.*

Fig 1. Principal Component Analysis (PCA) revealed key climatic factors influencing Diptera distribution across various sites in District Faisalabad. The first two principal components (PC1 and PC2) explained 61% of total variance. PC1 mainly reflected temperature-related variables (e.g., annual mean temperature, seasonality), while PC2 represented precipitation and moisture (e.g., rainfall in the wettest quarter).

Sites like Chak 195 RB Jandawala and Laman Pind—positioned in the upper-right PCA quadrant—exhibited high temperature and humidity, supporting moisture-dependent Dipteran species such as mosquitoes and crane flies. Meanwhile, areas like Mansoorabad and Gut Wala Park (top-left quadrant) showed cooler but moist conditions, ideal for species such as non-biting midges and fungus gnats. The lower-left quadrant, including UAF University and Jannah Garden, had both low temperature and precipitation, likely limiting Diptera diversity to generalist species like Muscidae. In contrast, the lower-right quadrant (Painsra, Chak 189 JB Rasoolpur) featured hot, arid conditions favoring thermophilic and xerophilic species, albeit with reduced overall diversity.

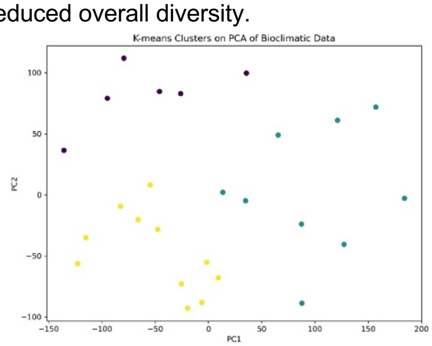

Figure 3. *K-means Cluster on PCA.*

K-means clustering Fig 3, helped group locations by climate similarity. Moderate environments like Chak 119 and Madina Town clustered near the PCA center, indicating balanced conditions that support greater Diptera diversity. More extreme sites such as Painsra and Makuwana, located at PCA margins, exhibited either heat stress or moisture extremes, supporting more specialized Dipteran communities. These groupings validated the importance of microclimatic gradients in determining insect distribution and biodiversity hotspots.

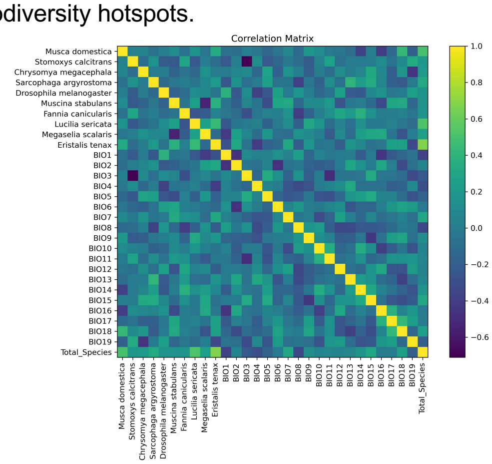

Figure 4. *Correlation Matrix.*

The correlation matrix displayed associations between Diptera abundance, total species richness, and 19 bioclimatic variables (BIO1–BIO19) as shown in Fig 4. Bright yellow tones indicated strong positive correlations, particularly between species richness and variables like Bio10 (mean temperature of the warmest quarter) and Bio18 (precipitation of the warmest quarter), suggesting these factors promote Diptera diversity. Negative correlations highlighted in dark blue indicated climatic stress, such as high maximum temperatures (Bio5) reducing species presence. This matrix provided valuable ecological thresholds and highlighted key drivers affecting Diptera communities, crucial for modeling climate impacts and informing biodiversity conservation in Faisalabad.

Discussion

Study's findings demonstrate how bioclimatic factors particularly temperature and precipitation have great influence on the distribution and abundance of Diptera species in Faisalabad. This is in line with earlier studies that emphasize how climate influences the makeup of insect communities (e.g., Zhang et al., 2020; Hammami et al., 2021). Spatial differences between study sites were well-represented by the PCA plot, which demonstrated that areas with moderate to high humidity and temperature, as Chak 195 RB Jandawala and Laman Pind, support a higher diversity of Diptera. This lends credence to the ecological theory that warm, humid climates promote insect reproduction and survival by providing adequate food supplies and larval homes (Rogers and Randolph, 2006).

Conversely, localities such as UAF University and Chak 188RB Nalyawala, with lower temperatures and limited rainfall, were associated with reduced species richness. Such environments impose physiological stress on insects, restricting survival to only a few generalists or xerophilic taxa like Muscidae or Calliphoridae. These finding parallels previous observations where Diptera biodiversity was reduced in arid or thermally extreme zones (Basset et al., 2012).

The correlation matrix enhances understanding through its capability to detect individual species reactions to different climate variables. The house fly (Musca domestica) exhibited maximal population distribution in urban and semi-urban areas due to its positive connection with Bio10 (mean temperature of the warmest quarter) and Bio12 (annual precipitation) (Grzywacz et al., 2017). The occurrence of Megaselia scalaris together with Eristalis tenax declined because these species need moist and organic-rich areas yet they can't tolerate dry climatic conditions as shown by research from diverse temperature and tropical zones (Brown et al., 2005).

Faisalabad's climate microzones according to the PCA site grouping determine the distribution patterns of Diptera insects in this region. Stomoxys calcitrans along with Chrysomya megacephala showed higher incidence levels in wet and waste-containing locations near agricultural and water resources. Another example of how microhabitats influence species distribution is the presence of Drosophila melanogaster close to ripening and fermenting regions (Markow & O'Grady et al., 2005).

Furthermore, during the wettest times (Bio16 and Bio18), species richness and precipitation showed a positive correlation, indicating that rainfall affects adult emergence rates and dispersal in addition to providing breeding substrates. This supports results from research on tropical entomology, which showed that temporal population surges in Dipteran flies were directly governed by rainfall patterns (Carvalho et al., 2004). The study offers strong proof that the biodiversity of Diptera in District Faisalabad is largely influenced by bioclimatic factors, particularly temperature and moisture availability. PCA and correlation matrix analysis work well together to show that some areas support great species diversity because of their climatic circumstances, making them ecological hotspots. Harder microclimates, on the other hand, restrict variety to a small number of hardy or specialist taxa.

These discoveries have applications in public health, pest control, and conservation in addition to advancing our ecological knowledge of Diptera distribution in Pakistan. Keeping an eye on Diptera population variations can be a sensitive bioindicator of ecological change as climate patterns alter as a result of global warming. The study emphasizes the necessity of adaptive biodiversity initiatives and targeted climate monitoring, particularly in areas like Faisalabad that are quickly urbanizing.

Conclusions

This study clearly demonstrates that bioclimatic factors, especially temperature and precipitation, play a crucial role in shaping the distribution and diversity of Diptera species in Faisalabad. Areas with warm and humid conditions supported higher species richness, while cooler and drier zones showed reduced diversity, reflecting the physiological constraints these environments impose on insects. The combination of PCA and correlation matrix analyses highlighted how specific climatic variables influence not only overall species abundance but also the presence of particular Diptera taxa with distinct ecological preferences. These findings align with broader ecological theories and previous research, confirming that suitable temperature and moisture levels are essential for the survival, reproduction, and dispersal of many Diptera species.

The results emphasize the importance of microclimatic variability in determining local Diptera communities, with wetter and moderate temperature regions acting as biodiversity hotspots and harsher environments favoring more specialized, tolerant species. This knowledge has practical implications for public health, pest management, and biodiversity conservation in rapidly urbanizing regions like Faisalabad. Monitoring Diptera populations can serve as an effective bioindicator of environmental change amid climate variability and urban expansion. Therefore, ongoing ecological surveillance and adaptive conservation strategies are vital to maintaining insect diversity and ecosystem health in the face of future climate challenges.

Author Contributions

Qi Xue: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. Qian Tang: Writing – review & editing, Visualization, Formal analysis, Conceptualization. Lin Deng: Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition. Wei Luo: Writing – review & editing, Conceptualization. Mingle Xia: Writing – review & editing, Conceptualization. Shuang Fu: Writing – review & editing, Conceptualization. Chaoqun Tan: Writing – review & editing, Conceptualization. Jun Hu: Writing – review & editing, Conceptualization. Rajendra Prasad Singh: Writing – review & editing.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Acknowledgment

This work is part of a research project, FRGS19-090-0699, supported by the Ministry of Higher Education, Malaysia, and the International Islamic University Malaysia.

Data Availability

Data will be made available on request

References

[1] ABDO, A. S. S., Md Rawi, C. S., Ahmad, A. H., & Rosmahanie Madrus, M. (2013). Biodiversity of stream insects in the M alaysian P eninsula: spatial patterns and environmental constraints. *Ecological Entomology*, *38*(3), 238-249.

[2] Ačanski, J., Miličić, M., Likov, L., Milić, D., Radenković, S., & Vujić, A. (2017). Environmental niche divergence of species from Merodon ruficornis group (Diptera: Syrphidae). *Archives of Biological Sciences*, *69*(2), 247-259.

[3] Adler, P. H., Cheke, R. A., & Post, R. J. (2010). Evolution, epidemiology, and population genetics of black flies (Diptera: Simuliidae). *Infection, Genetics and Evolution*, *10*(7), 846-865.

[4] Ahmed, K. S., Volpato, A., Day, M. F., Mulkeen, C. J., O'Hanlon, A., Carey, J., ... & Gormally, M. J. (2021). Linear habitats across a range of farming intensities contribute differently to dipteran abundance and diversity. Insect

Conservation and Diversity, 14(3), 335-347.

[5] Al-Khalaf, A. A., Nasser, M. G., & Hosni, E. M. (2023). Global Potential Distribution of Sarcophaga dux and Sarcophaga haemorrhoidalis under Climate Change. *Diversity*, *15*(8), 903.

[6] Arya, M. K., Omanakuttan, K., & Pandey, T. (2025). Flower visiting insects of the invasive Mexican daisy (Erigeron karvinskianus, DC) and its proximity effect on native flora in the Western Himalaya. *Oriental Insects*, 1-31.

[7] Bana, J. K., Sharma, H., Kumar, S., & Singh, P. (2017). Impact of weather parameters on population dynamics of oriental fruit fly, Bactrocera dorsalis (Hendel)(Diptera: Tephritidae) under south Gujarat mango ecosystem. *Journal of Agrometeorology*, *19*(1), 78-80.

[8] Bashir, M. A., Saeed, S., Sajjad, A., & Ali, M. (2021). 19. Seasonal variations in abundance and diversity of insect pollinator in forest ecosystems of Southern Punjab Pakistan. *Pure and Applied Biology (PAB)*, *4*(3), 441-452.

[9] Basset, Y., Miller, S. E., Gripenberg, S., Ctvrtecka, R., Dahl, C., Leather, S. R., & Didham, R. K. (2019). An entomocentric view of the Janzen-Connell hypothesis. *Insect Conservation and Diversity*, *12*(1), 1-8.

[10] Bedoya-Rodríguez, F. J., Guevara-Fletcher, C. E., & Pelegrin-Ramírez, J. S. (2025). Diversity analysis, distribution and abundance of mosquito (Diptera: Culicidae) assemblages at urban sector from southwestern Colombia. *Biologia*, 1-12.

[11] Blakeman, E., Wilson, A. B., Romer, S., Olin, E., Scott, C., Popescu, V., & Brodie, B. (2023). Passively crowdsourcing images online for measuring broad-scale fly (Diptera) floral interactions and biodiversity. *Journal of Pollination Ecology*, *35*, 180-193.

[12] Bong, L. J., Neoh, K. B., Jaal, Z., & Lee, C. Y. (2013). Influence of temperature on survival and water relations of Paederus fuscipes (Coleoptera: Staphylinidae). *Journal of Medical Entomology*, *50*(5), 1003-1013.

[13] Brown, M. E., Treviño, L. K., & Harrison, D. A. (2005). Ethical leadership: A social learning perspective for construct development and testing. *Organizational behavior and human decision processes*, *97*(2), 117-134.

[14] Burgio, G., Sommaggio, D., Marini, M., Puppi, G., Chiarucci, A., Landi, S., ... & Masetti, A. (2015). The influence of vegetation and landscape structural connectivity on butterflies (Lepidoptera: Papilionoidea and Hesperiidae), carabids (Coleoptera: Carabidae), syrphids (Diptera: Syrphidae), and sawflies (Hymenoptera: Symphyta) in Northern Italy farmland. *Environmental entomology*, *44*(5), 1299-1307.

[15] Carvalho, L. M., Jones, C., & Liebmann, B. (2004). The South Atlantic convergence zone: Intensity, form, persistence, and relationships with intraseasonal to interannual activity and extreme rainfall. *Journal of climate*, *17*(1), 88-108.

[16] Cerasoli, F., Iannella, M., D'Alessandro, P., & Biondi, M. (2017). Comparing pseudo-absences generation techniques in Boosted Regression Trees models for conservation purposes: A case study on amphibians in a protected area. *PLoS One*, *12*(11), e0187589.

[17] Changbunjong, T., Chaiphongpachara, T., & Weluwanarak, T. (2023). Species discrimination of Stomoxys flies S. bengalensis, S. calcitrans, and S. sitiens (Diptera: Muscidae) using wing geometric morphometrics. *Animals*, *13*(4), 647.

[18] Chen, Q., Duan, Y., Wang, X., Zheng, X., & Lu, W. (2024). Insights into pupal development of Bactrocera dorsalis: factors influencing eclosion. *Scientific Reports*, *14*(1), 27981.

[19] Colzani, E., Siqueira, T., Suriano, M. T., & Roque, F. O. (2013). Responses of aquatic insect functional diversity to landscape changes in Atlantic forest. *Biotropica*, *45*(3), 343-350.

[20] Couret, J., & Benedict, M. Q. (2014). A meta-analysis of the factors influencing development rate variation in Aedes aegypti (Diptera: Culicidae). *BMC ecology*, *14*, 1-15.

[21] D'Agostino, E. R., Vivero, R., Romero, L., Bejarano, E., Hurlbert, A. H., Comeault, A. A., & Matute, D. R. (2022). Phylogenetic climatic niche conservatism in sandflies (Diptera: Phlebotominae) and their relatives. *Evolution*, *76*(10), 2361-2374.

[22] de Oca-Aguilar, A. C. M., de Luna, E., Ibáñez-Bernal, S., & Rebollar-Téllez, E. A. (2024). Head shape variations between populations of the sand fly Lutzomyia cruciata (Diptera: Phlebotominae) from two Neotropical biogeographic provinces. *Zoologischer Anzeiger*.

[23] Françoso, E., Zuntini, A. R., Carnaval, A. C., & Arias, M. C. (2016). Comparative phylogeography in the Atlantic Forest and Brazilian savannas: Pleistocene fluctuations and dispersal shape spatial patterns in two bumblebees. *BMC Evolutionary Biology*, *16*, 1-16.

[24] Frelich, L. E., Peterson, R. O., Dovčiak, M., Reich, P. B., Vucetich, J. A., & Eisenhauer, N. (2012). Trophic cascades, invasive species and body-size hierarchies interactively modulate climate change responses of ecotonal temperate–boreal forest. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1605), 2955-2961.

[25] Gerecke, R., Cantonati, M., Spitale, D., Stur, E., & Wiedenbrug, S. (2011). The challenges of long-term ecological research in springs in the northern and southern Alps: indicator groups, habitat diversity, and medium-term change.

[26] Ghosh-Harihar, M. (2013). Distribution and abundance of foliage-arthropods across elevational gradients in the east and west Himalayas. *Ecological research*, *28*, 125-130.

[27] Gornostaev, N. G., Lyupina, Y. V., Lazebny, O. E., & Kulikov, A. M. (2024). Seasonal Dynamics of Fruit Flies (Diptera: Drosophilidae) in Natural Parks of Moscow City, Russia. *Insects*, *15*(6),

398.
[28] Grzywacz, A., Ogiela, J., & Tofilski, A. (2017). Identification of Muscidae (Diptera) of medico-legal importance by means of wing measurements. *Parasitology Research*, *116*, 1495-1504.
[29] Gull-e-Fareen, A., Bodlah, I., Bodlah, M. A., Rasheed, M. T., Ali, H., & Asif, M. (2021). Colour and Distributional Pattern of Callaspidia notata (Boyer de Fonscolombe, 1832)(Hymenoptera: Figitidae: Aspicerinae) from Pakistan.
[30] Hanafi-Bojd, A. A., Khoobdel, M., Soleimani-Ahmadi, M., Azizi, K., Aghaei Afshar, A., Jaberhashemi, S. A., ... & Safari, R. (2018). Species composition of sand flies (Diptera: Psychodidae) and modeling the spatial distribution of main vectors of cutaneous leishmaniasis in Hormozgan Province, Southern Iran. *Journal of medical entomology*, *55*(2), 292-299.
[31] Hernández-Ortiz, V., Dzul-Cauich, J. F., Madora, M., & Coates, R. (2022). Local climate conditions shape the seasonal patterns of the Diptera community in a tropical rainforest of the Americas. *Neotropical entomology*, *51*(4), 499-513.
[32] Hesami, N., Abai, M. R., Vatandoost, H., Alizadeh, M., Fatemi, M., Ramazanpour, J., & Hanafi-Bojd, A. A. (2019). Using ecological niche modeling to predict the spatial distribution of Anopheles maculipennis sl and Culex theileri (Diptera: Culicidae) in Central Iran. *Journal of Arthropod-Borne Diseases*, *13*(2), 165.
[33] Hill, M. P., & Terblanche, J. S. (2014). Niche overlap of congeneric invaders supports a single-species hypothesis and provides insight into future invasion risk: implications for global management of the Bactrocera dorsalis complex. *PloS one*, *9*(2), e90121
[34] Himawan, T., & Rizali, A. (2021). Diversity and species composition of fruit flies (Diptera: Tephritidae) in Lombok Island, Indonesia. *Biodiversitas Journal of Biological Diversity*, *22*(10).
[35] Hosseini, S. H., Allah-Kalteh, E., & Sofizadeh, A. (2021). The effect of geographical and climatic factors on the distribution of Phlebotomus papatasi (diptera: psychodidae) in Golestan Province, an endemic focus of zoonotic cutaneous leishmaniasis in Iran, 2014. *Journal of Arthropod-Borne Diseases*, *15*(2), 225.
[36] Hoxha, I., Trájer, A. J., Dvorak, V., Halada, P., Šupić, J., Obwaller, A. G., ... & Kniha, E. (2024). Phlebotomine sand flies (Diptera: Psychodidae) of Bosnia and Herzegovina: distribution, ecology and environmental preferences. *Acta Tropica*, *260*, 107393.

Disclaimer / Publisher's Note

The statements, opinions, and data contained in all publications of the *PAKISTAN JOURNAL OF ZOOLOGICAL SCIENCES (PJZS)* are solely those of the individual author(s) and contributor(s) and do not necessarily reflect those of IJSMART Publishing and/or the editor(s). IJSMART Publishing and/or the editor(s) disclaim any responsibility for any injury to persons or property resulting from any ideas, methods, instructions, or products mentioned in the content.