

Short Communication

Thermal Constraints on Morphological Plasticity in Butterflies: Wingspan Variation in Plain Tiger Across Temporal Gradients

Ishrat Aziz*, Rimsha Hassan, Samra Noreen and Saira Islam

Department of Biological Sciences, Virtual University, Kala Shah Kaku Campus, Lahore, Pakistan.

ABSTRACT

Understanding morphological responses to climate variation is crucial for predicting species resilience under global warming. This study evaluates the effects of regional temperature gradients on wingspan plasticity in *Danaus chrysippus* (Plain Tiger) across seven regions of the Punjab province of Pakistan. Between February and August 2024 morphometric measurements were obtained from 30 undamaged specimens. A striking inverse correlation was detected between ambient temperature and wingspan ($r = -0.910$, $p = 0.001$), and the random-effect model indicated that location explained 78.5% of wingspan variance. These findings support the hypothesis that lower temperature promotes larger wingspan, by linking temperature-driven morphological plasticity to ecological resilience. This study provides a conceptual basis for using butterfly morphology as an early indicator of climate-induced change in natural communities.

Article Information

Received 05 February 2026
Revised 20 May 2026
Accepted 29 May 2026
Available online 09 October 2026
(early access)
Published 12 October 2026

Authors' Contribution

RH, SN and SI: Participated in fieldwork and data collection, also contributed to the critical review and refinement of the manuscript. RH: Manuscript formatting and figure design. SN: Statistical analysis and interpretation. IA: Conceptualized and scientifically guided the study.

Key words

Danaus chrysippus, Temperature gradient, Wingspan variation, Phenotypic plasticity, Climate change, Bioindicators

Butterflies are sensitive to environmental variation and are widely used as bioindicators of ecological change (Bonebrake *et al.*, 2010). Morphological traits such as wingspan often reflect developmental responses to temperature, humidity, and resource availability (Kingsolver and Huey, 2008). The temperature size rule, observed in many ectotherms, predicts that cooler developmental environments promote larger adult body sizes due to prolonged growth periods (Nylin and Gotthard, 1998; Minter *et al.*, 2024). However, responses can vary across species and habitats, and recent work highlights both increases and decreases in size under warming, depending on species-specific adaptations (Ki *et al.*, 2024; Zografou *et al.*, 2025).

The *Danaus chrysippus* (plain tiger) butterfly is a widely distributed species with broad ecological tolerance

(Lushai *et al.*, 2003), making it an ideal model to investigate phenotypic plasticity along climatic gradients. Previous studies in South Asia have reported temperature-related differences in body size (Brakefield and Larsen 1984; Rao *et al.*, 2016), but region-specific morphometric data for Pakistan remain scarce.

Pakistan's diverse topography and climatic zones from coastal plains to montane regions provide a natural setting to test whether local temperature variation influences morphological traits in *D. chrysippus* (Rafi *et al.*, 2014).

This study tests the hypothesis that there is a relationship between temperature and plasticity of wingspan in *D. chrysippus*. This study provides a baseline regional data that can inform long-term climate impact assessments and butterfly conservation strategies in thermally variable environments.

Materials and methods

Field surveys were conducted across seven regions of Punjab province, Pakistan: Gujranwala, Warburton, Jhang, Bahawalpur, Rawalpindi, Gujar Khan, and Sheikhpura (Fig. 1). Sampling occurred from February to August 2024. Butterflies were collected using sweep nets and hand-picking during peak activity hours (0900-1400 h), and

* Corresponding author: ishrat.aziz@vu.edu.pk
0030-9923/2026/0006-2517 \$ 9.00/00



Copyright 2026 by the authors. Licensee Zoological Society of Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

observed under controlled conditions prior to euthanasia via thorax pinching.

Specimens were identified using Evans' guide to Indian butterflies (Evans, 1932). Morphological traits were measured using a magnifier and ruler, with special attention to wingspan. Morphometric measurements were obtained from 30 intact specimens representing different locations and temperature ranges.

Mean daily ambient temperature for each collection and location was obtained from Google Weather historical records on the day of collection (Google Weather, 2024). These values were directly matched to each measured individual rather than using site-wide averages.

The relationship between ambient temperature and wingspan was analyzed in Python using a random-effect model that combined Pearson's correlation with location-based variance estimation based on measurements from 30 specimens ($p < 0.05$).

Results and discussion

Thirty specimens of *Danaus chrysippus* were collected across seven regions of Punjab (province), Pakistan. Morphometric data for 30 intact specimens (Table I) showed clear variation in wingspan along the temperature gradient. Mean adult wingspan ($\pm$ SD) varied

among sites, with the largest wingspan recorded from lower temperature and smaller ones from higher.

Table I. Sample size (n), temperature range, and mean adult wingspan ($\pm$ SD) of *Danaus chrysippus* across seven regions of Punjab, Pakistan during February–August 2024.

Site	n	Temperature range (°C)	Mean wingspan $\pm$ SD (mm)
Gujranwala	6	14-21°C	81.25 $\pm$ 0.99
Sheikhupura	3	25-34°C	72.83 $\pm$ 2.57
Gujar Khan	5	24-34°C	72.90 $\pm$ 2.13
Jhang	2	23-30.5°C	77.50 $\pm$ 3.54
Bahawalpur	6	17-32°C	76.17 $\pm$ 3.86
Warburton	4	29-41°C	72.00 $\pm$ 4.76
Rawalpindi	4	35-44°C	58.75 $\pm$ 7.50

Butterflies from lower temperature exhibited larger wingspans, up to 82 mm (temperature 14°C), while those from higher temperature had smaller wingspans, as low as 50 mm (44 °C).

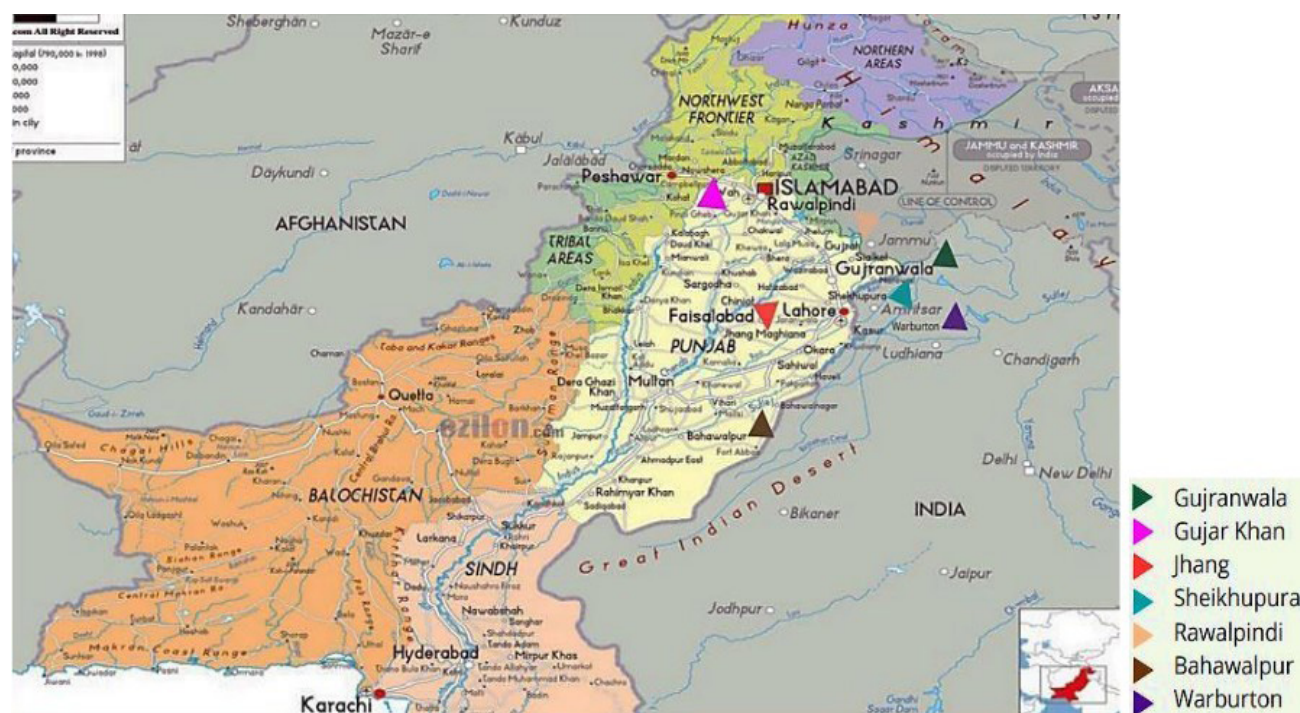


Fig. 1. Selected regions where the butterfly specimens were observed and collected throughout the research are highlighted with different colored triangles.

Pearson's correlation analysis revealed a strong inverse relationship between temperature and wingspan ($r = -0.910$, $p = 0.001$; Fig. 2) supporting the hypothesis that lower temperature facilitates greater wingspan in *D. chrysippus*. The random-effect model further showed that location explained 78.5% of wingspan variance, indicating substantial site-level influence on morphological response.

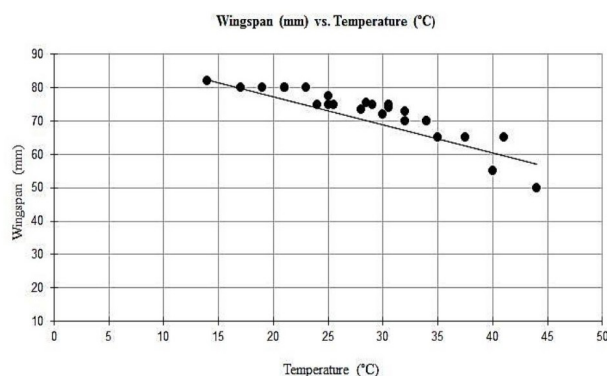


Fig. 2. Relationship between ambient temperature and wingspan of *Danaus chrysippus* across sampling sites in Punjab, Pakistan ($n=30$).

This significant negative correlation ($r = -0.910$, $p = 0.001$) indicates that individuals developing under lower temperature attain larger wingspans, whereas those in higher temperature exhibit reduced size. Similar temperature-size patterns have been documented in other butterfly species, supporting the temperature-size rule for ectotherms (Nylin and Gotthard, 1998; Kingsolver and Huey, 2008; Minter *et al.*, 2024). Within Pakistan, Khan and Hanif (2016) and Perveen and Fazal (2013) reported larger wingspan of *Danaus chrysippus* in cooler northern sites, while comparable trends were observed in India (Rao *et al.*, 2016) and parts of Sindh (Mangi *et al.*, 2023). Globally, cooler climates have been linked to increased adult size in temperature and montane butterfly species (Berwaerts *et al.*, 2002; Ki *et al.*, 2024).

From an ecological perspective, larger wingspans in cooler environments may enhance thermoregulation, flight efficiency, and dispersal, while smaller wingspans in hotter regions may reduce desiccation risk and metabolic demands. Given projected increases in average temperatures, such phenotypic shifts could influence population persistence, mating success and pollination services.

While the observed pattern is robust, the relatively small morphometric sample size and absence of other environmental covariates (e.g., host plant availability, humidity) suggest caution in generalizing results. Future

work should integrate controlled rearing experiments and multi-site long-term monitoring to confirm causal mechanisms and assess potential evolutionary responses to observe the sustainability and resilience of the concerned phenomenon. These findings contribute a baseline dataset for South Asia and highlight the value of butterfly morphology as a cost-effective bioindicator for detecting climate-driven ecological change.

Conclusion

This study demonstrates a strong negative relationship between temperature and plasticity of wingspan in *Danaus chrysippus* across Punjab, Pakistan, with low temperature producing larger wingspan and notable location-based differences reflecting environmental influence. These findings align with the temperature-size rule and emphasize the potential of butterfly morphology as a rapid, low-cost bioindicator of climate change impacts. Establishing such regions-specific baselines is essential for future monitoring and conservation planning in thermally stressed ecosystems.

DECLARATIONS

Acknowledgements

We thank the nursery owners and field volunteers across Pakistan who facilitated butterfly observations and collections. Special thanks to Dr. Ishrat Aziz for her mentorship throughout the research.

Funding

No external funding was received for this study.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

References

- Berwaerts, K., Van Dyck, H. and Aerts, P., 2002. *Funct. Ecol.*, **16**: 484–491. <https://doi.org/10.1046/j.1365-2435.2002.00650.x>
- Bonebrake, T.C., Ponisio, L.C., Boggs, C.L. and Ehrlich, P.R., 2010. *Biol. Conserv.*, **143**: 1831–1841. <https://doi.org/10.1016/j.biocon.2010.04.044>
- Brakefield, P.M. and Larsen, T.B., 1984. *Biol. J. Linn. Soc.*, **22**: 1–12. <https://doi.org/10.1111/j.1095-8312.1984.tb00795.x>
- Evans, W.H., 1932. *The identification of Indian*

- butterflies*. Bombay Natural History Society, India.
- Google Weather, 2024. Historical daily weather data. Available at: <https://www.google.com/search?q=weather> (accessed 1 February – 30 August, 2024).
- Khan, H.A. and Hanif, H., 2016. *Int. J. entomol. Res.*, **1**: 27–30.
- Ki, T.L., Beale, C.M., Huertas, B. and Hill, J.K., 2024. *Insect Conserv. Divers.*, **17**: 788–799. <https://doi.org/10.1111/icad.12744>
- Kingsolver, J.G. and Huey, R.B., 2008. Size, temperature, and fitness: Three rules. *Evol. Ecol. Res.*, **10**: 251–268.
- Lushai, G., Goulson, D. and Allen, J.A., 2003. *Biol. J. Linn. Soc.*, **79**: 233–238.
- Mangi, A., Panhwar, W.A., Shaikh, A.M., Sirohi, M.H., Soomro, S.R.S., Mirbhar, A.A. and Mustafa, S.B., 2023. *J. appl. Res. Pl. Sci.*, **4**: 385–389. <https://doi.org/10.38211/joarps.2023.04.01.46>
- Minter, M., Dasamahapatra, K.K., Morecroft, M.D., Thomas, C.D. and Hill, J.K., 2024. *Ecol. Ent.*, **49**: 983–988. <https://doi.org/10.1111/een.13369>
- Nylin, S. and Gotthard, K., 1998. *Annu. Rev. Ent.*, **43**: 63–83. <https://doi.org/10.1146/annurev.ento.43.1.63>
- Perveen, F. and Fazal, F., 2013. *Open J. Anim. Sci.*, **3**: 28–36. <https://doi.org/10.4236/ojas.2013.32A004>
- Rafi, M.A., Akbar, S.A. and Ghafoor, A., 2014. *Zool. Stud.*, **53**: 1–10.
- Rao, K.E., Chandar, G.S. and Atluri, J.B., 2016. *J. Pharma. Biol. Sci.*, **11**: 91–98.
- Zografou, K., Knop, E., Sewall, B.J., Schweiger, O., De Moraes, C.M., Whitaker, M. and Kati, V., 2025. *bioRxiv*, pp. 2025-02. <https://doi.org/10.1101/2025.02.06.636804>