A study on millipede (Myriapoda: Diplopoda) populations in relation to temperature and humidity at Mhaismal Hill Station, Maharashtra, India

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Received: 6 August 2024. Accepted: 9 October 2024

Abstract. A study, with the aim of investigating the impact of key abiotic factors, temperature and humidity, on the dynamics of millipede populations, was conducted at Mhaismal Hill Station, Chhatrapati Sambhajinagar (formerly Aurangabad) district, Maharashtra, India, for a period of one year (September 2021 to August 2022). The locality was found to be populated by two diplopod species, *Trigoniulus corallinus* (Eydoux & Souleyet, 1842) and *Anoplodesmus saussurii* (Humbert, 1865). The millipede populations showed a correlation with the specified factors, exhibiting a preference for the rainy season marked by relatively lower temperatures and high humidity.

Keywords. Arthropods, taxonomy, distribution, biodiversity, ecology

1 Introduction

Biodiversity provides a wide range of economic benefits both directly and indirectly (EHRLICH & EHRLICH 1992). In recent years, there has been a growing emphasis on understanding the influence of diversity on ecosystems and ecological processes (TILMAN 1999). Research consistently shows that a substantial majority of experimental studies, which manipulate species diversity to assess changes in ecosystem processes like productivity, stability, and resilience, demonstrate a positive correlation between diversity and ecosystem functioning (MCCANN 2000, PURVIS & HECTOR 2000). Among the essential contributors to soil fertility and the overall health of forest ecosystems are the soil macrofauna including, termites, ants, earthworms, and millipedes. Their pivotal role in promoting stability and productivity stems from their significant impact on crucial soil processes such as litter decomposition and nutrient dynamics (IRMLER 2000). Additionally, other components of the ecosystem—plants, fungi, and microorganisms—interact with these macrofauna to create a complex web of relationships that supports ecosystem resilience (HOPKIN & READ 1992). Therefore, it becomes essential not only to identify and understand the various components of the ecosystem but also to recognize the crucial role they play in sustaining biodiversity and ecosystem services.

The class Diplopoda (millipedes) stands as one of the most diverse groups of terrestrial arthropods with over 12,000 described species and an estimated 80,000 yet to be described species (SIERWALD & BOND 2007). These animals play an important role as effective decomposers, nutrient recyclers, and biogeographic indicators that contribute to the overall ecological balance (HOPKIN & READ 1992).

Notwithstanding the remarkable diversity of millipedes and their vital ecological contributions in the ecosystem, significant challenges still exist within the group such as the substantial gap between the number of described species and current diversity estimates (SIERWALD & BOND 2007).

India, situated in South Asia, distinguishes itself as the most populous nation and the seventh-largest country by land area. The present diplopod fauna of the country consists roughly of 280 described species, belonging to 12 orders, 26 families, and almost 90 genera (RANNAVRE et al. 2024). Although the initiation of studies on Indian millipedes dates back to as early as the 18th century (FABRICIUS 1775, LINNAEUS 1758), our understanding of the Indian fauna remains inadequate and confused due to various factors including insufficient sampling across different regions as well as the misidentification of non-Indian species as Indian (GOLOVATCH & WESENER 2016).

Given this context, an investigation was undertaken with the objective of exploring the millipede fauna at Mhaismal Hill Station, Maharashtra, India, and examining the effects of temperature and humidity on their population.

2 Material and methods

2.1 Study site

Mhaismal (20.0923°N 75.1803°E), a popular hill station in the Chhatrapati Sambhajinagar district (previously Aurangabad) of Maharashtra, India, sits at an altitude of 1,067 MASL. Spanning approximately 10,000 m^2, it is known for its tropical-deciduous forest.

2.2 Study period

The study was carried out over one year, from September 2021 to August 2022.

Figure 1: Mhaismal Hill Station, Maharashtra, India.

2.3 Collection and identification

The study employed a systematic search approach by dividing the site into four equally-sized quadrants using the "GPS Area Calculator" Android app. Monthly comprehensive surveys were then conducted throughout the day to find millipedes in every quadrant, covering the ground, leaf litter, soil, tree barks, and other accessible habitats. As sighted, millipedes (adults only) were carefully handpicked and their morphological characters—number of segments, body length, and others—were recorded except for individuals of the same species that had been studied during prior visits. For identification, the standard literature sources were consulted (ATTEMS 1936, SHELLEY & LEHTINEN 1998, 1999). Furthermore, images were taken with a Redmi-7 handset.

2.4 Environmental variables

To evaluate the effect of abiotic factors on millipede populations, the study focused on analyzing temperature and humidity. Data pertaining to both factors for Mhaismal was collected from the web-based service "AccuWeather" (https://www.accuweather.com/en/in/mhaismal/2762937/current-weather/2762937). Pearson correlations between these factors and millipede occurrences were calculated using the Pandas and Seaborn libraries of the Python programming language.

3 Results

A total of 565 millipede individuals, belonging to two species, *Trigoniulus corallinus* (Eydoux & Souleyet, 1842) (Spirobolida: Pachybolidae) and *Anoplodesmus saussurii* (Humbert, 1865) (Polydesmida: Paradoxosomatidae), were recorded at the locality. Among these, the majority belonged to *A. saussurii* (Fig. 2), with a count of 328 individuals, while *T. corallinus* (Fig. 3) accounted for the remaining 237 individuals. The former, with a mean of 27 individuals per month (Table 1), occurred more frequently than the latter (mean=20).

The presence of millipedes was expectedly significantly influenced by the ecological factors under investigation. They were more likely to be found in low-temperature periods (<20 °C) and less common during rising temperatures (>35 °C) (Fig. 4). On the other hand, an increase in humidity (>70%) due to rainfall positively affected millipede abundance despite a minor population decline at the onset of summer (March 2022) followed by an uptick in millipede numbers during the monsoon (after June 2022) (Fig. 5).

Figure 2: *Anoplodesmus saussurii* at Mhaismal Hill Station.

Figure 3: *Trigoniulus corallinus* at Mhaismal Hill Station.

As to their correlations, millipede abundance demonstrated a strong negative correlation with maximum temperature and a weaker negative correlation with minimum temperature (Fig. 6). In contrast, it exhibited a strong positive correlation with maximum humidity and a less pronounced positive correlation with minimum humidity.

Table 1. Statistics of the millipede abundance and ecological factors.

	Individuals		Temperature (°C)		Humidity (%)	
	Trigoniulus corallinus	*Anoplodesmus saussurii*	Min	Max	Min	Max
Mean	20	27	20	31.92	59.75	75.33
Median	20	29	19.50	30	59.50	73.50
Standard Deviation (±)	8.27	11.28	4.94	5.53	3.62	7.36
Minimum	6	7	12	26	53	65
Maximum	31	47	30	42	66	88

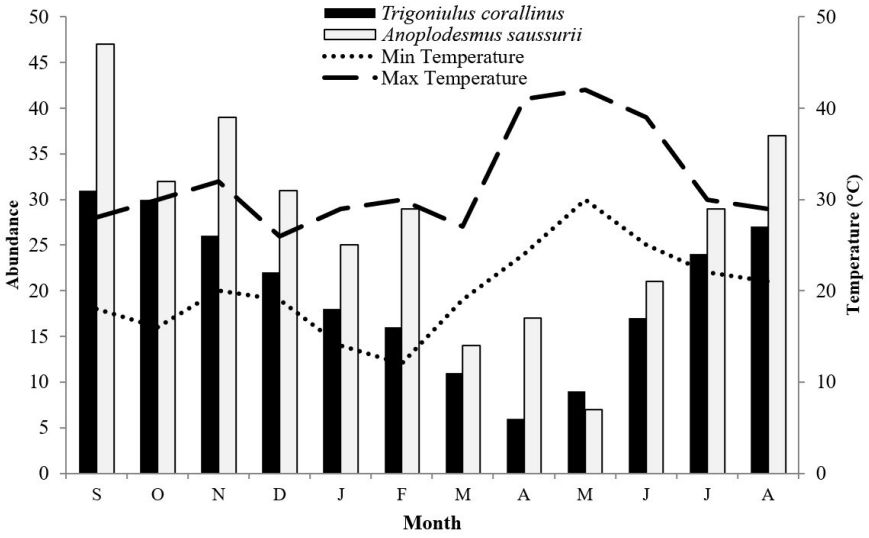

Figure 4. Relationship between the abundance of *Trigoniulus corallinus* and *Anoplodesmus saussurii* and temperature.

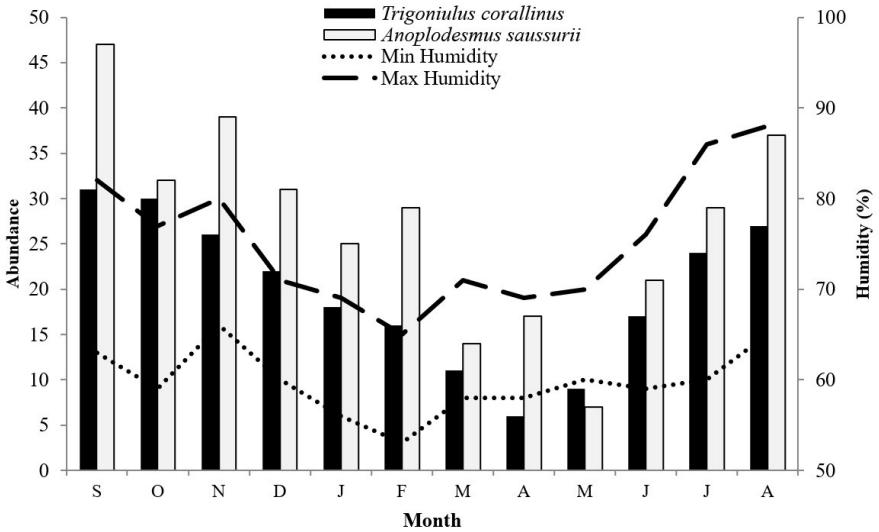

Figure 5. Relationship between the abundance of *Trigoniulus corallinus* and *Anoplodesmus saussurii* and humidity.

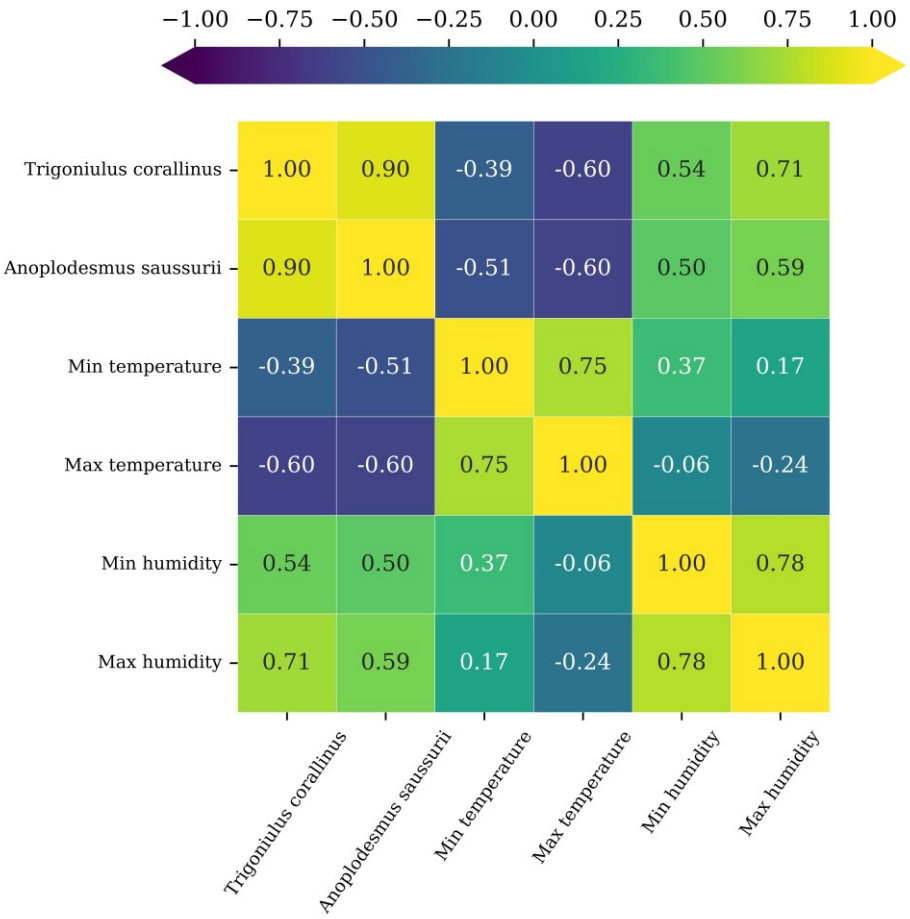

Figure 6. Pearson correlations among the millipede abundance and ecological factors.

4 Discussions and conclusions

This research, conducted at Mhaismal Hill Station, Maharashtra, India, brought to light the existence of two millipede species—*Trigoniulus corallinus* and *Anoplodesmus saussurii*—not only at the site but also within the district for the first time. Both species are essentially pantropical tramp species that have been introduced and established populations beyond their native habitats in numerous tropical and subtropical regions worldwide (DECKER 2013, HOFFMAN 1999, JEEKEL 2001, SHELLEY & LEHTINEN 1998, 1999). In India, the former, likely of southeast Asian origin (SHELLEY & LEHTINEN 1999), is supposedly common, while the latter, presumably native to India and/or Sri Lanka (SHELLEY & LEHTINEN 1998), has been found in West Bengal, Karnataka, Kerala, Gujarat, and Tamil Nadu (GOLOVATCH & WESENER 2016).

The consistent atmospheric observations made over the course of the study revealed an expected seasonal pattern in millipede surface activity. Activity levels notably increased with the onset of the monsoon season in June and gradually decreased as December approached. These findings underscore the significant influence of the abiotic seasonal variables, temperature and humidity, on millipede behavior and activity dynamics within this ecological context. A comparable seasonal trend was observed for *Arthrosphaera magna* Attems, 1936 in the Western Ghats where its abundance was positively correlated with rainfall (ASHWINI & SRIDHAR 2006).

Interestingly, our work revealed a remarkably low species diversity that, we suspect, could be due to two factors. First, the surveys were conducted during the day whereas most millipedes are typically

more active in the evening or at night (HOPKIN & READ 1992). Second, the site appears to be substantially affected by some anthropogenic influences. The gradual expansion of small residential areas, shops, hotels, and other developments along with continuous deforestation disrupts natural habitats of the area. In addition to that, the presence of two very famous temples that attract a large number of visitors throughout the year results in frequent disturbances to the local ecosystem. Also, being a hill station, the place experiences heavy footfalls especially in the rainy season which coincides with the peak activity period for millipedes (HOPKIN & READ 1992). These combined pressures from urbanization, tourism, and environmental degradation emphasize the challenges faced by millipedes in maintaining stable populations in this rapidly changing environment.

This endeavor not only allowed us to investigate the impact of abiotic factors on diplopods in this picturesque location but also made an initial step in understanding and documenting the region's rich yet poorly-known wildlife. We hope that our findings will inspire further research on the ecological importance and biodiversity of this area.

Acknowledgments

We express our sincere thanks to Dr. D. V. Pawar, the Principal, and the staff of the Department of Zoology at Kirti M. Doongursee College, Dadar (W), Mumbai, India, for their constant support and encouragement. We would also like to thank the reviewers of the manuscript.

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