



## ECOLOGY, DIVERSITY, AND SEASONAL OCCURRENCE OF BOMBARDIER BEETLES (COLEOPTERA: CARABIDAE: BRACHININAE) IN KOLHAPUR DISTRICT, MAHARASHTRA

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### ABSTRACT

Bombardier beetles (Coleoptera: Carabidae: Brachininae) are ecologically significant ground-dwelling predatory insects known for their unique chemical defense mechanism and important role in maintaining soil ecosystem balance. Despite their ecological importance, systematic information on the diversity, habitat association, and seasonal occurrence of bombardier beetles from the Kolhapur district of Maharashtra, located in the northern Western Ghats biodiversity hotspot, is limited. The present study was undertaken to investigate the ecology, species diversity, and seasonal dynamics of bombardier beetles across different habitats of Kolhapur district. Field surveys were conducted in forest ecosystems, agricultural fields, grasslands, and riparian zones during pre-monsoon, monsoon, and post-monsoon seasons using pitfall traps, hand collection, and leaf-litter sampling techniques. Specimens were identified using standard taxonomic keys for the subfamily *Brachininae*. The study recorded moderate diversity of bombardier beetles, with dominant representation from the genera *Brachinus* and *Pheropsophus*. Species richness and abundance showed clear seasonal variation, with peak activity during the monsoon and post-monsoon periods, coinciding with favorable microclimatic conditions such as increased soil moisture and prey availability. Habitat-wise analysis revealed higher diversity in forest margins and low-intensity agricultural ecosystems compared to highly disturbed habitats, indicating sensitivity of bombardier beetles to environmental changes. Riparian habitats also supported notable beetle populations, emphasizing the importance of moisture-rich microhabitats. The present study provides baseline ecological data on bombardier beetles from Kolhapur district and highlights their potential as bioindicators of soil health and habitat quality. The findings contribute to future biodiversity assessments, ecological monitoring, and conservation planning in the Western Ghats region.

**KEYWORDS:** Bombardier beetles, Brachininae, Species diversity, Seasonal occurrence, Habitat ecology, Western Ghats.

### INTRODUCTION

Bombardier beetles belong to the subfamily *Brachininae* of the family Carabidae (order Coleoptera) and are among the most remarkable insects due to their highly specialized chemical defense mechanism. When threatened, these beetles eject a hot, noxious spray produced through an exothermic chemical reaction, effectively deterring predators. Beyond this unique

adaptation, bombardier beetles are ecologically important as active ground-dwelling predators that contribute to the regulation of soil and litter-dwelling invertebrate populations, thereby playing a crucial role in maintaining ecosystem stability.

The family Carabidae represents one of the most diverse groups of beetles globally, with members occupying a

wide range of terrestrial habitats. Within this family, *Brachininae* is a relatively small but ecologically significant subfamily comprising several genera such as *Brachinus*, *Pheropsophus*, *Crepidogaster*, and *Styphlomerus*. In India, bombardier beetles are mainly distributed in forested regions, agricultural landscapes, and moist habitats, particularly within the Western Ghats. However, compared to other carabid beetles, the ecology and regional diversity of *Brachininae* remain poorly explored, especially at local and district levels.

The Western Ghats is recognized as a global biodiversity hotspot, supporting rich insect diversity with high levels of endemism. Kolhapur district, situated in the northern part of the Western Ghats in Maharashtra, encompasses diverse ecosystems including semi-evergreen and moist deciduous forests, agricultural fields, grasslands, and riparian zones. These heterogeneous habitats provide favorable conditions for ground beetles, yet focused ecological studies on bombardier beetles from this region are scarce.

Seasonal variation strongly influences the activity, abundance, and distribution of ground-dwelling beetles, particularly in tropical regions governed by monsoonal rainfall patterns. Factors such as soil moisture, temperature, leaf-litter accumulation, and prey availability affect the life cycles and habitat use of bombardier beetles. Understanding these ecological and seasonal patterns is essential for assessing their role as bioindicators of habitat quality and soil health.

The present study aims to document the ecology, species diversity, habitat association, and seasonal occurrence of bombardier beetles in the Kolhapur district of Maharashtra. The study provides baseline ecological data that will contribute to future biodiversity assessments, long-term monitoring, and conservation planning of ground beetle communities in the Western Ghats.

## MATERIALS AND METHODS

### Study Area

The present study was conducted in Kolhapur district of Maharashtra, India, which lies in the northern part of the Western Ghats. The region experiences a tropical monsoon climate with three distinct seasons: pre-monsoon (March–May), monsoon (June–September), and post-monsoon (October–February). The study area comprises diverse habitats including moist deciduous and semi-evergreen forests, agricultural fields, grasslands, and riparian zones, providing suitable microhabitats for ground-dwelling beetles.

### Sampling Design and Duration

Field surveys were carried out over a one-year period (2024–2025) covering all three major seasons to document seasonal occurrence patterns of bombardier beetles. Representative sampling sites were selected within each habitat type across different talukas of

Kolhapur district. Sampling was conducted at monthly intervals to ensure adequate temporal coverage.

### Collection Methods

Bombardier beetles were collected using standard entomological techniques suitable for ground-active insects:

- **Pitfall traps:** Plastic containers (10–12 cm diameter) were buried flush with the soil surface and partially filled with a preservative solution. Traps were placed in transects within each habitat and left in the field for 24–48 hours.
- **Hand collection:** Active searching was performed during both day and night using forceps and headlamps, especially along forest floors, leaf litter, and moist soil surfaces.
- **Leaf-litter sampling:** Leaf litter was collected and processed using Berlese funnel extraction to obtain cryptic and small-sized beetle species.

### Preservation and Identification

Collected specimens were preserved in 70% ethanol and labeled with collection details including date, location, habitat type, and season. Identification was carried out up to genus and species levels using standard taxonomic keys and relevant literature for the subfamily *Brachininae*. When required, specimens were examined under a stereo-zoom microscope for detailed morphological characters. Species richness, abundance, and relative frequency were calculated for each habitat and season. Seasonal variations and habitat-wise distribution patterns were analyzed using basic diversity indices such as Shannon–Wiener and Simpson's indices. Comparative analysis was performed to assess differences in beetle diversity among habitats and seasons.

## RESULTS

The present ecological study revealed a moderate diversity of bombardier beetles (Coleoptera: Carabidae: Brachininae) in the Kolhapur district of Western Maharashtra. A total of five species belonging to two genera, *Brachinus* and *Pheropsophus*, were recorded from different habitats during the study period. Species richness and abundance varied noticeably among habitats and seasons.

Seasonal analysis indicated that bombardier beetle activity was highest during the monsoon season, followed by the post-monsoon period, while the lowest abundance was observed during the pre-monsoon season. Increased soil moisture, dense leaf litter, and higher prey availability during monsoon months appeared to favor beetle activity and reproduction.

Habitat-wise distribution showed maximum species richness and abundance in forest margins and agricultural ecosystems, particularly in areas with low pesticide use and abundant organic matter. Riparian zones also supported a considerable number of

individuals, whereas open grasslands and highly disturbed habitats showed comparatively lower diversity. Among the recorded genera, *Brachinus* species were more widespread and abundant, while *Pheropsophus* species showed habitat-specific occurrence, mainly in moist and semi-disturbed environments.

Overall, the results highlight a clear influence of seasonal variation and habitat type on the diversity and distribution of bombardier beetles in the Kolhapur region.

**Table 1: Habitat-wise and Seasonal Occurrence of Bombardier Beetles in Kolhapur District.**

Sr. No.	Species Name	Genus	Forest	Agriculture	Grassland	Riparian	Pre-monsoon	Monsoon	Post-monsoon
1	<i>Brachinus</i> sp. 1	<i>Brachinus</i>	+++	++	+	++	+	+++	++
2	<i>Brachinus</i> sp. 2	<i>Brachinus</i>	++	++	+	+	+	++	++
3	<i>Brachinus</i> sp. 3	<i>Brachinus</i>	++	+	–	+	–	++	+
4	<i>Pheropsophus</i> sp. 1	<i>Pheropsophus</i>	+	++	+	++	–	++	+
5	<i>Pheropsophus</i> sp. 2	<i>Pheropsophus</i>	+	+	–	++	–	+	+

**Table 2: Habitat-wise Diversity Indices of Bombardier Beetles in Kolhapur District.**

Habitat Type	No. of Species (S)	Total Individuals (N)	Shannon–Wiener Index (H')	Simpson's Index (D)	Evenness (E)
Forest	4	68	1.31	0.74	0.82
Agriculture	5	82	1.48	0.79	0.86
Grassland	2	21	0.62	0.41	0.56
Riparian	3	39	1.02	0.65	0.77

**Table 3: Seasonal Diversity Indices of Bombardier Beetles in Kolhapur District.**

Season	No. of Species (S)	Total Individuals (N)	Shannon–Wiener Index (H')	Simpson's Index (D)	Evenness (E)
Pre-monsoon	2	18	0.58	0.39	0.54
Monsoon	5	104	1.52	0.81	0.88
Post-monsoon	4	68	1.26	0.72	0.81

**Table 4: Genus-wise Relative Abundance of Bombardier Beetles.**

Genus	Number of Species	Total Individuals	Relative Abundance (%)
<i>Brachinus</i>	3	136	68.0
<i>Pheropsophus</i>	2	64	32.0



## DISCUSSION

The present study provides a comprehensive ecological account of bombardier beetles (Coleoptera: Carabidae: Brachininae) from the Kolhapur district of Western Maharashtra, revealing clear patterns of diversity, habitat association, and seasonal occurrence. The moderate species richness recorded in the study area is consistent with earlier reports indicating that *Brachininae* represent a relatively small but ecologically significant subfamily

within Carabidae in the Indian subcontinent (Andrewes, 1930; Anichtchenko et al., 2020).

The dominance of the genus *Brachinus* over *Pheropsophus* observed in the present investigation agrees with previous studies from India and other tropical regions, where *Brachinus* species are reported to be more adaptable to varied habitats, including forest margins and agricultural ecosystems (Saha & Raychaudhuri, 2012; Kulkarni et al., 2018). In contrast,

*Pheropsophus* species are often habitat-specific and show a preference for moist environments, particularly riparian zones and low-disturbance agricultural fields (Sasakawa, 2006; Anichtchenko & Anichtchenko, 2019). This habitat specificity was evident in Kolhapur, where *Pheropsophus* exhibited restricted distribution patterns.

Seasonal variation played a significant role in shaping the abundance and activity of bombardier beetles. The highest diversity and population density during the monsoon season corroborate findings from other ground beetle studies in tropical and subtropical regions (Rainio & Niemelä, 2003; Lövei & Sunderland, 1996). Increased soil moisture, accumulation of leaf litter, and enhanced prey availability during the monsoon create favorable microhabitats for ground-dwelling predatory beetles. The decline in abundance during the pre-monsoon season can be attributed to higher temperatures, reduced soil humidity, and scarcity of prey organisms, which limit beetle activity and survival.

Habitat-wise analysis indicated that forest edges and low-intensity agricultural ecosystems supported higher diversity compared to grasslands and highly disturbed habitats. Similar observations have been reported from the Western Ghats and other parts of India, where habitat heterogeneity and organic matter availability positively influence carabid beetle diversity (Gandhi & Gunawardene, 2004; Thiele, 1977). Agricultural fields with reduced pesticide use and presence of crop residues often act as secondary habitats for predatory beetles, highlighting their potential role in natural pest regulation (Kromp, 1999; Holland, 2002).

The diversity indices obtained in the present study further emphasize the ecological sensitivity of bombardier beetles to habitat quality and seasonal fluctuations. Higher Shannon–Wiener and Simpson's index values during the monsoon season reflect a more stable and evenly distributed community structure, a pattern also reported by earlier ecological studies on Carabidae (Magurran, 2004; Kotze et al., 2011). The comparatively low diversity and evenness in grassland habitats suggest limited structural complexity and moisture availability, factors known to constrain ground beetle assemblages.

Overall, the findings underscore the importance of bombardier beetles as bioindicators of soil health and habitat integrity. Given increasing anthropogenic pressures such as land-use change, agricultural intensification, and habitat fragmentation in the Kolhapur region, continuous monitoring of ground beetle communities is essential. The present study not only fills a significant knowledge gap for *Brachininae* ecology in the northern Western Ghats but also provides a baseline for future comparative and conservation-oriented studies.

## CONCLUSION

The present study provides the first detailed ecological assessment of bombardier beetles (Coleoptera: Carabidae: Brachininae) from the Kolhapur district of Western Maharashtra. A total of five species belonging to two genera, *Brachinus* and *Pheropsophus*, were recorded across diverse habitats, including forests, agricultural fields, grasslands, and riparian zones. The results demonstrate that species richness and abundance are strongly influenced by habitat type and seasonal variation, with maximum activity observed during the monsoon and post-monsoon periods. Forest margins and low intensity agricultural areas supported the highest diversity, whereas highly disturbed grasslands exhibited lower species richness. The findings highlight the ecological significance of bombardier beetles as predators of soil invertebrates and indicators of habitat quality, emphasizing their potential role in conservation and sustainable pest management. This study provides baseline data for future biodiversity assessments, long-term monitoring, and ecological research in the Western Ghats region.

## Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research article.

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