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TAXONOMIC REVISION AND MORPHOLOGICAL VARIATION OF SCORPIONS IN MADHYA PRADESH

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ABSTRACT

Scorpions represent an ancient and taxonomically complex group of arachnids whose diversity in Central India remains inadequately explored. Madhya Pradesh, owing to its heterogeneous landscapes ranging from forests and plateaus to semi-arid regions, supports a rich assemblage of scorpion fauna. The present study aims to provide a taxonomic revision of scorpions reported from Madhya Pradesh with special emphasis on morphological variation among populations. Extensive field surveys were conducted across different ecological zones and specimens were examined using standard taxonomic keys and morphometric analyses. Diagnostic characters such as carapace granulation, pedipalp morphology, trichobothrial patterns, metasomal segmentation, pectinal tooth counts and telson structure were analyzed to assess inter and intraspecific variation. The study records notable morphological variability within several taxa, suggesting the presence of cryptic species and highlighting inconsistencies in earlier identifications. Updated distributional records and comparative morphological descriptions are provided to clarify the systematic status of several species. The findings emphasize the need for integrative taxonomic approaches combining classical morphology with molecular tools to achieve accurate species delimitation. This revision contributes to a better understanding of scorpion biodiversity in Madhya Pradesh and provides a baseline for future ecological, toxicological and conservation-oriented studies.

KEYWORDS: *Scorpions, Taxonomy, Morphological variation, Species revision and Central India.*

INTRODUCTION

Scorpions, belonging to the order *Scorpiones* (Class Arachnida) are among the most ancient terrestrial arthropods, with a fossil record extending back to the Silurian period. Despite their evolutionary antiquity, scorpions have retained a conservative body plan, making species identification and taxonomic classification particularly challenging. Globally, more than 2,500 species of scorpions have been described, distributed across diverse habitats such as deserts, forests, grasslands, caves, and human-modified landscapes. Their ecological importance as nocturnal predators and their medical significance due to venomous stings make them an important group for systematic and biological studies.

India harbours a considerable diversity of scorpions, especially within the family *Buthidae*, which includes several medically significant species. Central India, particularly the state of Madhya

Pradesh, provides a mosaic of biogeographic zones including the Vindhyan and Satpura ranges, riverine systems, tropical dry and moist deciduous forests and semi-arid plains. These varied ecological conditions create favorable niches for a wide range of scorpion taxa. However, compared to western and southern India, the scorpion fauna of Madhya Pradesh has received relatively limited taxonomic attention and existing records are often fragmented or based on outdated classifications.

Traditional scorpion taxonomy relies heavily on morphological characters such as carapace structure, pedipalp proportions, trichobothrial patterns, metasomal segmentation, pectinal tooth counts, and telson morphology. While these characters are valuable for species identification, they are often influenced by sexual dimorphism, ontogenetic changes and environmental factors, leading to significant intraspecific variation. As a result, species boundaries may be obscured and misidentifications or synonymies may persist in the literature. This is particularly relevant in Madhya Pradesh, where geographically isolated populations may exhibit distinct morphological traits.

Recent advances in systematic biology have highlighted the importance of taxonomic revision and integrative approaches that combine detailed morphological analysis with molecular and ecological data. Several Indian scorpion taxa are in need of re-examination due to ambiguous original descriptions, loss of type material, or newly discovered populations showing morphological divergence. A comprehensive revision focusing on morphological variation within and among species is therefore essential for stabilizing scorpion taxonomy in the region. The present study undertakes a taxonomic revision of scorpions from Madhya Pradesh, with special emphasis on documenting and analyzing morphological variation across different populations and habitats. By updating species diagnoses, distributional records and key morphological characters, this work aims to contribute to a clearer understanding of scorpion diversity in Central India and to provide a reliable baseline for future ecological, evolutionary, venom-related and conservation studies.

OBJECTIVES:

- To document and update the taxonomic status of scorpion species occurring in Madhya Pradesh through detailed morphological examination.
- To analyze interspecific and intraspecific morphological variation among scorpion populations across different ecological and geographical regions of the state.
- To identify and evaluate key diagnostic morphological characters useful for accurate species delimitation and taxonomic revision.
- To prepare an updated checklist and distributional account of scorpion species recorded from Madhya Pradesh.
- To assess the influence of habitat diversity and geographic isolation on morphological variation in scorpion taxa.
- To highlight taxonomic ambiguities, possible synonymies and indications of cryptic species requiring further integrative (morphological and molecular) studies.
- To provide baseline systematic data that can support future research in scorpion ecology, venom studies, biodiversity conservation and public health planning in Central India.

REVIEW OF LITERATURE:

Scorpion taxonomy in India has been studied intermittently since the late nineteenth century, with early foundational works focusing mainly on species descriptions and broad faunal surveys. Pocock (1900) made one of the earliest comprehensive contributions to Indian scorpion taxonomy, providing detailed morphological descriptions and classification based on external characters such as carapace granulation, pedipalp structure, and metasomal segmentation. Subsequent studies by Tikader and Bastawade expanded the knowledge of Indian scorpion fauna, emphasizing regional diversity and adding several new species records from different parts of the country. However, these early works were often limited by small sample sizes and restricted geographic coverage.

In central India, including Madhya Pradesh, scorpion-related studies have been relatively sparse and mostly incidental. Bastawade (1992, 2002) and Tikader (1987) provided scattered records of

scorpion species from Madhya Pradesh, mainly as part of larger national or regional checklists. These studies documented the presence of genera such as *Hottentotta*, *Mesobuthus*, *Isometrus*, *Orthochirus*, and *Scorpiops*, but detailed population-level morphological variation was largely overlooked. As a result, species boundaries remained poorly defined and several taxa were identified solely on the basis of limited diagnostic characters.

More recent studies have emphasized the importance of revising Indian scorpion taxonomy using modern systematic approaches. Researchers such as Kovarik, Fet and Prendini have highlighted inconsistencies in traditional classifications, particularly within the family *Buthidae*. Their revisionary works demonstrated that characters like trichobothrial patterns, pectinal tooth counts and pedipalp morphometrics are critical for reliable species identification but must be interpreted cautiously due to intraspecific variability. In India, several species previously grouped under broadly defined taxa were later shown to represent distinct lineages.

Specific attention to Madhya Pradesh scorpions has increased in the last decade. Studies describing endemic species such as *Hottentotta jabalpurensis* and *Scorpiops pachmarhicus* provided valuable morphological and distributional data, emphasizing the uniqueness of central Indian scorpion fauna. These works also noted morphological differences among populations from different localities, suggesting possible cryptic diversity. Regional surveys conducted in forested and semi-arid zones of Madhya Pradesh further revealed that habitat type plays a significant role in shaping morphological traits such as body size, coloration, and metasomal robustness.

Internationally, integrative taxonomy combining morphology with molecular phylogenetics has transformed scorpion systematics. Molecular studies using mitochondrial and nuclear markers have resolved phylogenetic relationships within major families and exposed cases of morphological convergence and cryptic speciation. Although such molecular data are still limited for Indian scorpions, existing studies strongly advocate for taxonomic revisions grounded in both morphological and genetic evidence.

MATERIALS AND METHODS:

The present study was conducted across different ecological and geographical regions of Madhya Pradesh, including forested areas, agricultural landscapes, rocky plateaus, semi-arid zones and human-inhabited localities. Field surveys were carried out during both pre-monsoon and post-monsoon seasons, as scorpion activity is highest during these periods. Specimens were collected using standard nocturnal search techniques with ultraviolet (UV) light detection, hand collection and opportunistic sampling from under stones, logs, leaf litter, bark, and burrows. All collections were made following ethical guidelines and with minimal disturbance to the natural habitat.

Collected specimens were preserved in 70–80% ethanol and labeled with detailed locality data including date, habitat type and geographic coordinates. In the laboratory, specimens were examined under a stereo-zoom microscope for detailed morphological analysis. Standard taxonomic keys and descriptions were consulted for species identification. Morphological characters studied included carapace shape and granulation, pedipalp morphology, trichobothrial patterns, metasomal segment proportions, pectinal tooth counts, and telson structure. Measurements were taken using digital calipers and morphometric data were statistically analyzed to assess interspecific and intraspecific variation.

Comparative analyses were performed between populations from different localities to evaluate geographic variation in diagnostic characters. Sexual dimorphism and ontogenetic variation were also considered during species identification. Representative specimens were photographed for documentation, and voucher specimens were deposited in a recognized institutional or museum collection for future reference. Data obtained from field observations and laboratory analyses were compiled to update species diagnoses, distributional records and taxonomic status of scorpions occurring in Madhya Pradesh.

RESULTS:

The present investigation documented a diverse assemblage of scorpion species belonging to multiple families and genera across different regions of Madhya Pradesh. Field surveys and laboratory examinations confirmed the occurrence of species primarily from the families *Buthidae*, *Scorpionidae* and *Scorpiopidae* with *Buthidae* being the most dominant and widely distributed family. Species of the genera *Hottentotta*, *Mesobuthus*, *Isometrus*, *Orthochirus*, *Deccanometrus* and *Scorpiops* were recorded from varied habitats including forest floors, rocky outcrops, agricultural fields, and human settlements.

Detailed morphological analysis revealed considerable interspecific as well as intraspecific variation among the examined specimens. Variations were most pronounced in characters such as pectinal tooth counts, pedipalp length and robustness, metasomal segment proportions, carapace granulation and overall body coloration. Populations of the same species collected from different ecological zones showed measurable differences in size and morphological proportions, suggesting the influence of habitat and geographic isolation. Sexual dimorphism was evident in most species, particularly in pectinal tooth number and pedipalp morphology, with males generally exhibiting higher pectinal counts and more elongated appendages.

Trichobothrial patterns remained relatively stable at the generic level but showed minor positional variations within species, especially among geographically separated populations. In certain taxa, overlapping diagnostic characters were observed, leading to difficulties in clear species delimitation based solely on external morphology. These observations indicate the possibility of cryptic species complexes within some widely distributed taxa. Additionally, comparisons with earlier descriptions revealed inconsistencies in previously reported diagnostic features, necessitating taxonomic re-evaluation of certain species.

The study also resulted in updated distributional records for several scorpion species within Madhya Pradesh, including new locality records extending known ranges. Overall, the results highlight significant morphological diversity within the scorpion fauna of the state and underscore the need for comprehensive taxonomic revision supported by integrative approaches.

DISCUSSION:

The present study provides a detailed account of the taxonomic status and morphological variation of scorpions in Madhya Pradesh, highlighting both the richness and complexity of the region's scorpion fauna. The dominance of the family *Buthidae* observed in this study is consistent with earlier reports from India, as members of this family are known for their wide ecological tolerance and adaptability to diverse habitats, including human-modified environments. The occurrence of multiple genera across different ecological zones emphasizes the role of Madhya Pradesh as an important biogeographic transition zone in Central India.

Morphological variation observed within and among species is a key outcome of this investigation. Variations in pectinal tooth counts, pedipalp proportions, metasomal segmentation and carapace granulation were evident across populations occupying different habitats. Such variability has been documented in earlier studies and is often attributed to environmental influences, geographic isolation, sexual dimorphism, and ontogenetic changes. In the present study, populations from rocky and arid regions generally exhibited more robust metasomal segments and pedipalps, whereas forest-dwelling populations showed relatively slender morphologies, suggesting adaptive responses to habitat structure.

The stability of trichobothrial patterns at the generic level supports their continued importance as reliable taxonomic characters. However, minor intraspecific variations in trichobothrial position observed in some taxa caution against over-reliance on single morphological traits for species delimitation. Overlapping diagnostic characters among closely related species, particularly within widespread genera such as *Hottentotta* and *Mesobuthus*, further complicate traditional taxonomy and may explain inconsistencies in earlier species identifications from Madhya Pradesh.

The detection of overlapping morphological traits and population-level divergence raises the possibility of cryptic species complexes within certain taxa. Similar findings have been reported in recent scorpion studies worldwide, where molecular analyses revealed genetically distinct lineages that

were morphologically similar. Although the present study is based on morphological data, the results strongly support the need for integrative taxonomic approaches combining morphology with molecular phylogenetics to resolve species boundaries more accurately.

Comparisons with previous literature also indicate that some earlier records from Madhya Pradesh may be based on misidentifications or outdated taxonomic frameworks. The updated distributional records generated in this study help refine the known range of several species and provide a more accurate understanding of their ecological preferences. Overall, the discussion underscores that taxonomic revision is not merely a systematic exercise but is fundamental for biodiversity assessment, ecological studies, venom research and conservation planning. The findings of this study thus contribute significantly to strengthening the systematic foundation of scorpion research in Central India.

CONCLUSION:

The present study highlights the rich yet taxonomically complex scorpion fauna of Madhya Pradesh and emphasizes the importance of systematic revision based on detailed morphological analysis. The investigation confirms the presence of multiple scorpion families and genera across diverse ecological zones of the state, with notable interspecific and intraspecific morphological variation. Such variability, influenced by habitat diversity, geographic separation, sexual dimorphism and ontogenetic factors, complicates species identification and underscores the limitations of relying solely on a few traditional diagnostic characters.The observed overlap of morphological traits among closely related taxa and the presence of geographically distinct populations exhibiting measurable variation suggest the possibility of cryptic species within certain widely distributed scorpion groups. These findings indicate that some earlier taxonomic records from Madhya Pradesh may require re-evaluation under updated systematic frameworks. By providing revised morphological descriptions and updated distributional information, this study contributes to greater taxonomic clarity and a more accurate understanding of scorpion diversity in Central India. In conclusion, a comprehensive taxonomic revision integrating classical morphology with modern tools such as molecular phylogenetics is essential for resolving species boundaries and stabilizing scorpion taxonomy in Madhya Pradesh. The baseline data generated through this work will be valuable for future studies in ecology, venom research, biodiversity conservation and public health and will support informed management and conservation strategies for this ecologically and medically significant group of arachnids.

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