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Impacts of Open-Cast Coal Mining on Orthopteran and Coleopteran Diversity and Ecosystem Functions in Jharia Coalfields, Jharkhand

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Abstract:
This study evaluates how open-cast coal mining alters the diversity, composition, and functional roles of Orthopteran and Coleopteran assemblages in mining (Anna and Kusunda) versus non-mining (Karmatand and Dhangi Basti) habitats of the Jharia coalfields, Jharkhand. Species richness and abundance of most herbivorous Orthopterans (e.g., grasshoppers, katydids, crickets) and functionally important Coleopterans (e.g., dung beetles, ground beetles, decomposers) were markedly reduced at mining sites, where severe vegetation loss, soil compaction, and habitat fragmentation prevail. In contrast, disturbance-tolerant taxa such as Sphingonotus spp. and some pestiferous leaf beetles persisted or increased, indicating community homogenisation and a shift towards stress-tolerant guilds. These changes weaken key ecosystem services, including nutrient cycling, decomposition, natural pest regulation, and food provision for higher trophic levels, thereby compromising ecological resilience and recovery potential of mined landscapes. The findings underscore the value of Orthopteran and Coleopteran groups as bioindicators of environmental integrity and highlight the urgent need for habitat restoration, revegetation, and conservation-focused mine reclamation in coal mining regions of eastern India

Keywords: *Coleopteran, Orthopteran, mining areas, Jharia coalfields*

Introduction

Orthopteran and Coleopteran insects are among the most functionally diverse and ecologically significant components of terrestrial ecosystems, contributing to herbivory, predation, decomposition, nutrient cycling, and the maintenance of food webs (Losey & Vaughan, 2006; New, 2019). Grasshoppers, crickets, katydids, dung beetles, ground beetles, and other beetle groups jointly influence primary production, soil structure, and the regulation of agricultural pests, thereby supporting both natural ecosystems and agroecosystems (Ingrisch & Köhler, 1998; Nichols et al., 2008). Because many of these taxa respond sensitively to habitat alteration, pollution, and microclimatic shifts, their community structure provides a powerful lens through which to evaluate human impacts on the environment (Niemelä, 2000; Rainio & Niemelä, 2003). In particular, changes in the richness, abundance, and functional composition of Orthopteran and Coleopteran assemblages can signal the degradation or recovery of

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ecosystem processes long before such changes become evident at higher trophic levels or in vegetation (Cardoso et al., 2011).

Open-cast coal mining is one of the most environmentally disruptive forms of resource extraction, causing large-scale removal of topsoil and vegetation, severe landscape fragmentation, and long-term alteration of soil physicochemical properties (Didham et al., 1996; Fahrig, 2003). The Jharia coalfields of Dhanbad, Jharkhand, represent one of India's oldest and most intensively exploited coal mining regions, where open-cast operations have created a mosaic of degraded mine pits, overburden dumps, and remnant non-mining patches embedded within human-dominated landscapes. In such systems, the direct impacts of excavation and overburden dumping combine with indirect effects such as dust deposition, altered hydrology, and increased fire risk to transform habitats that formerly supported complex insect communities into structurally simplified and stressful environments (Balian et al., 2008; Frouz et al., 2008). These changes are particularly critical in a densely populated region where surrounding agricultural land, forest fragments, and village common lands depend on healthy soil biota and insect-mediated ecosystem services for productivity and resilience (Losey & Vaughan, 2006).

Evidence from Jharia and similar coal mining regions indicates that non-mining sites typically host a richer and more functionally diverse assemblage of Orthopteran and Coleopteran species than adjacent mining-impacted areas (Balian et al., 2008; New, 2019). In intact or less disturbed habitats, a broad spectrum of herbivores, predators, detritivores, and decomposers co-occur, supporting robust nutrient cycling, natural pest regulation, and multi-layered food webs (Losey & Vaughan, 2006; Nichols et al., 2008). In contrast, mining sites often show reduced species richness and lower total abundance, with communities dominated by a narrower subset of disturbance-tolerant taxa that perform fewer ecological roles (McKinney & Lockwood, 1999; Cardoso et al., 2011). This shift leads to the homogenisation of insect communities, where functionally redundant or resilient species persist while more specialised or sensitive taxa vanish, thereby eroding ecological resilience and the capacity of ecosystems to absorb and recover from further disturbances (Didham et al., 1996; Cardoso et al., 2011). The depletion of dung beetles and ground beetles, in particular, can have cascading effects on soil productivity, pest pressure, and vegetation recovery, forcing greater reliance on chemical inputs and intensifying environmental trade-offs in surrounding agricultural landscapes (Nichols et al., 2008; Rainio & Niemelä, 2003).

The present study, addresses these knowledge gaps by systematically comparing the diversity, abundance, and functional composition of Orthopteran and Coleopteran assemblages in selected mining and non-mining sites. By integrating field surveys of insect communities with assessments of habitat quality and soil condition, the research seeks to clarify how open-cast coal mining reshapes insect assemblages and the ecosystem services they deliver (Balian et al., 2008; Nichols et al., 2008). Specifically, the study aims to quantify differences in species richness and functional guild representation, identify sensitive and disturbance-tolerant indicator taxa, and interpret the ecological consequences of observed changes for nutrient cycling, pest regulation, and food-web stability (Cardoso et al., 2011; New, 2019).

Methodology

This study employed a comparative field-based design to assess the impact of open-cast coal mining on Orthopteran and Coleopteran diversity and associated ecosystem functions in the Jharia coalfields, Dhanbad, Jharkhand. Two mining sites (Anna and Kusunda) and two non-mining sites (Karmatand and Dhangi Basti along the Sindri–Baliapur road) were selected to represent a gradient of disturbance, from heavily degraded mine-affected landscapes to relatively less disturbed agro-forest mosaics. Site selection was based on land-use history, intensity of mining activity, vegetation structure, and accessibility, ensuring that all sites were comparable in terms of regional climate but differed in disturbance regime and habitat quality (Didham et al., 1996; Fahrig, 2003).

Insect sampling

Orthopteran and Coleopteran assemblages were sampled using a combination of standard entomological techniques to capture both ground-dwelling and vegetation-associated taxa. At each site, parallel belt transects were established, and along each transect, pitfall traps were installed at fixed intervals to sample ground-active beetles and orthopterans, following widely used bioindicator protocols for Carabidae and other soil-surface arthropods (Lövei & Sunderland, 1996; Rainio & Niemelä, 2003). Traps consisted of plastic cups partially filled with a preservative solution and were operated for multiple consecutive days during peak activity periods to reduce short-term temporal bias. Sweep-netting and hand collection were conducted along the same transects to sample foliage-dwelling grasshoppers, katydids, crickets, and leaf beetles, with effort standardised by sampling time and distance.

For each taxon, ecological function was assigned (e.g., herbivore, predator, detritivore, dung feeder, wood-borer) based on published information on diet, habitat, and life history (Losey & Vaughan, 2006; Nichols et al., 2008). This allowed subsequent grouping of species into functional guilds for functional diversity analysis.

Habitat and soil measurements

To relate insect patterns to environmental drivers, vegetation and soil parameters were measured concurrently at each site. Vegetation structure was quantified within quadrats placed along the insect sampling transects, recording variables such as percentage ground cover, shrub and tree density, and canopy height. Soil samples were collected from the upper 0–15 cm layer at multiple points per site, composited, and analysed for key physicochemical properties, including pH, electrical conductivity (EC), organic carbon (OC), and macro- and micronutrient concentrations, following standard soil analysis protocols already applied in the broader Jharia study (Binkley & Vitousek, 2000; Ryu & Spuller, 2021). These parameters were chosen because they strongly influence insect habitat suitability, plant productivity, and nutrient cycling (Nichols et al., 2008; Holomb et al., 2024).

Data analysis

For each site, insect species richness, abundance, and diversity indices (e.g., Shannon–Wiener index) were calculated separately for Orthoptera and Coleoptera and then for pooled functional guilds. Functional composition was compared by examining the relative representation of herbivores, predators, detritivores, and dung beetles across sites, similar to previous functional-guild approaches in invertebrate conservation (Cardoso et al., 2011; Nichols et al., 2008). All statistical analyses were conducted using standard statistical software, and significance levels were set at $\alpha = 0.05$.

Results and Discussion

This study revealed clear and consistent differences in Orthopteran and Coleopteran assemblages between mining and non-mining sites in the Jharia coalfields, confirming that open-cast coal mining substantially alters insect diversity and functional structure. Non-mining sites (Karmatand and Dhangi Basti) supported markedly higher species richness and abundance of both Orthoptera and Coleoptera, with a broad representation of herbivores, predators, detritivores, dung beetles, and wood-borers, indicating relatively intact, multidimensional communities (Losey & Vaughan, 2006; Nichols et al., 2008). In contrast, mining sites (Anna and Kusunda) were characterised by reduced richness and abundance and were dominated by a narrower suite of disturbance-tolerant taxa, consistent with patterns of biotic homogenisation reported from other disturbed landscapes (McKinney & Lockwood, 1999; Didham et al., 1996).

Table 1.

Parameter / Group	Mining sites (Anna, Kusunda)	Non-mining sites (Karmatand, Dhangi Basti)
Total Orthopteran species richness	25 species	39 species
Total Orthopteran abundance (individuals)	1189	1876
Total Coleopteran species richness	31 species	46 species
Total Coleopteran abundance (individuals)	1456	2104
Herbivorous Orthopterans (e.g. Oxya, Acrida) dominant?	Low richness and abundance; many absent	High richness and abundance; common in agricultural/grassland patches
Sensitive katydids (e.g. Phaneroptera falcata)	Absent	Present, restricted to shrubland mosaics
Disturbance-tolerant Orthopterans (e.g. Sphingonotus spp.)	Present at low densities	Rare or absent

Dung beetles (Scarabaeinae)	Low richness and density; dung and tunnelling constrained	High richness and density; active tunnellers in organic-rich soils
Ground beetles (Carabidae)	Nearly absent	Abundant and diverse; strong bioindicator signal
Leaf beetles (Chrysomelidae)	Fewer species; Aulacophora spp. more frequent on regenerating vegetation	More species overall; Coptocycla spp. common on crops
Longhorn beetles (Cerambycidae, e.g. Batocera rufomaculata)	More frequent on stressed trees in disturbed patches	Present mainly on relatively healthy trees

Within Orthoptera, species such as *Oxya chinensis* and *Acrida exaltata*, which prefer vegetated agricultural and grassland habitats, were abundant in non-mining plots but strongly depressed or absent in mined landscapes where vegetation cover and soil quality were severely degraded (Katiyar & Katti, 2010; Ingrisch & Köhler, 1998). Sensitive taxa like *Phaneroptera falcata* occurred exclusively in structurally complex, undisturbed shrubland mosaics, underlining their dependence on microclimatic stability and continuous vegetation (Rentz, 1996). Disturbance-tolerant forms such as *Sphingonotus* spp., adapted to dry, sparsely vegetated conditions, were more frequent in mining areas but at low densities, suggesting that even tolerant Orthopterans experience stress under extreme disturbance (Uvarov, 1977; McKinney & Lockwood, 1999). These patterns align with broader evidence that habitat simplification and soil degradation reduce Orthopteran diversity and alter trophic pathways (Ingrisch & Köhler, 1998; Cardoso et al., 2011).

The observed compositional differences between mining and non-mining assemblages corresponded closely to gradients in vegetation structure and soil properties documented for the same sites. Non-mining areas exhibited higher organic carbon, more favourable pH, and greater macronutrient availability, conditions known to support dense vegetation, richer litter layers, and diverse microhabitats for arthropods (Binkley & Vitousek, 2000; Ryu & Spuller, 2021). Mining soils, in contrast, showed depleted organic carbon, altered pH, and elevated electrical conductivity, reflecting salinisation and chemical disturbance that constrain plant productivity and reduce habitat quality for soil- and vegetation-associated fauna (Holomb et al., 2024; Prach & Tolvanen, 2016). Correlative patterns—positive associations between insect richness (especially dung beetles, ground beetles, and herbivorous Orthopterans) and soil organic carbon, nitrogen, and vegetation cover, and negative relationships with extreme pH or high electrical conductivity—mirror the strong linkages between organic carbon, nitrogen, and micronutrients in the wider soil dataset and emphasise the central role of organic matter in sustaining biological activity (Nichols et al., 2008; Balian et al., 2008).

Conclusion

The decline of herbivorous Orthopterans and detritivorous or dung-feeding beetles in mining sites implies reduced herbivory pressure, diminished nutrient recycling, and a contracted prey base for higher trophic levels, potentially disrupting food webs and weakening ecosystem resilience (Losey & Vaughan, 2006; Cardoso et al., 2011). The depletion of predatory Carabidae further undermines natural pest control, increasing the likelihood of pest outbreaks and reliance on chemical pesticides in adjacent agroecosystems (Lövei & Sunderland, 1996; Rainio & Niemelä, 2003). At the same time, the persistence and sometimes proliferation of disturbance-tolerant and pest species (e.g., *Sphingonotus* spp., *Aulacophora* spp., *Locusta migratoria*) signal a shift towards homogenised, stress-adapted communities that provide fewer ecosystem services and may exacerbate agricultural risks (McKinney & Lockwood, 1999; Didham et al., 1996). Overall, these results corroborate the view that open-cast coal mining in the Jharia coalfields not only reduces Orthopteran and Coleopteran diversity but also simplifies functional guild structure and erodes the ecosystem services these insects provide, while also demonstrating that targeted restoration—revegetation, organic matter enrichment, and decompaction—could gradually re-establish more diverse and functionally robust communities (Prach & Tolvanen, 2016; Nichols et al., 2008).

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