



Research

First Record of Purcell's Hunter Slug (*Laevicaulis haroldi* Dundee, 1980) in Saharanpur District of Western Uttar Pradesh, India

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Abstract

Terrestrial gastropods of the family Veronicellidae represent ecologically significant components of soil invertebrate communities, yet their distributional dynamics across India remain incompletely documented. Here, we report the first confirmed occurrence of *Laevicaulis haroldi* Dundee, 1980 commonly designated Purcell's Hunter Slug in Kulheri village, Saharanpur district (29°52'54.5"N 77°16'18.3"E), western Uttar Pradesh. Field observations and systematic quadrat sampling were conducted across a two-month post-monsoon period (October–November 2025) in agricultural field margins. Population densities ranged from 0.75 to 2.25 individuals m⁻² across sampling events, with a progressive increase in mean density from 1.25 ± 0.38 ind. m⁻² (October) to 1.90 ± 0.30 ind. m⁻² (late November). Spatial distribution analysis revealed an aggregated pattern, evidenced by a variance-to-mean ratio of approximately 1.3. Specimens were observed foraging on *Amaranthus* sp. and *Ageratum* sp., demonstrating phytophagous activity consistent with this species' documented pest status. This record extends the verified range of *L. haroldi* within Uttar Pradesh and corroborates ecological niche model predictions of northwestward range expansion. Baseline population data presented herein are essential for regional invasive species monitoring and integrated pest management planning in Saharanpur's intensive agricultural landscape.

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Statement of Sustainability: The documentation of *L. haroldi* in western Uttar Pradesh provides critical baseline data for ecologically informed land management. Early detection and quantitative assessment of population density enable evidence-based monitoring of invasive or range-expanding gastropods within agroecosystems. Understanding its aggregated distribution and post-monsoon population increase supports targeted, site-specific control rather than indiscriminate chemical application, thereby reducing pesticide dependency, soil contamination, and non-target biodiversity loss. Integrating these findings into local surveillance frameworks strengthens adaptive pest management strategies and protects crop productivity. Sustainable agricultural planning in Saharanpur should incorporate periodic gastropod assessments to balance ecological integrity, food security, and long-term soil ecosystem resilience.

1. Introduction

Terrestrial gastropod molluscs constitute a functionally important component of soil and litter invertebrate communities across tropical and subtropical ecosystems (Barker, 2001). Among these, members of the family Veronicellidae commonly referred to as leatherleaf slugs or veronicellid slugs—are distinguished by the complete absence of an external shell, a smooth, mucus-covered integument, and a dorsoventrally flattened body form that facilitates movement through moist leaf litter and soil interstices (South, 1992; Gomes & Thomé, 2004). These morphological attributes, combined with broad dietary tolerance and tolerance for humid microclimates, predispose veronicellid species to ecological success as agricultural pests and invasive organisms in modified land-



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scapes (Kaur & Kaur, 2014).

The genus *Laevicaulis* Simroth, 1891 currently encompasses several species distributed across Africa, South Asia, and Southeast Asia, with multiple members achieving secondary distributions through inadvertent horticultural trade (Cowie et al., 2008). Among these, *Laevicaulis haroldi* Dundee, 1980, originally described from Natal, South Africa, has demonstrated notable invasive potential. The species was formally documented for the first time from India by Magare (2015), who reported specimens from Maharashtra, triggering scientific interest regarding its dispersion trajectory across the subcontinent. Subsequent ecological niche modelling by Mahapatra and Aravind (2021) predicted that extensive areas across peninsular and northern India present climatically suitable conditions for *L. haroldi*, forecasting progressive range expansion under both current and projected future climate scenarios.

India's terrestrial mollusc fauna is exceptionally diverse, comprising at least 1,129 documented species spanning a broad taxonomic and ecological spectrum (Ramakrishna et al., 2010). Despite this richness, systematic distributional surveys for many invertebrate taxa—including veronicellid slugs—remain geographically patchy, particularly across the densely cultivated plains of northern India. Uttar Pradesh, the most populous Indian state, supports an expansive and economically productive agricultural mosaic characterised by sugarcane, wheat, rice, and horticultural enterprises. The intensive cultivation practices, irrigation infrastructure, and organic matter inputs characteristic of this region create microhabitats highly conducive to slug colonisation (Raut & Panigrahi, 1990).

Saharanpur district, located in the northwestern corner of Uttar Pradesh near the foothills of the Shivalik range, occupies a transitional ecotone between the Indo-Gangetic Plain and the sub-Himalayan tract. This geographic position, combined with a relatively humid regional climate and heterogeneous land use including agroforestry, sugarcane cultivation, and kitchen gardens, creates ecological conditions potentially favourable for veronicellid slug establishment. Khan (2019) previously recorded an exotic *Laevicaulis* sp. from northern India, and the ecological niche predictions of Mahapatra and Aravind (2021) explicitly identified the Saharanpur–Dehradun corridor as climatically suitable for *L. haroldi* presence, yet no confirmed specimen record had been established for the region.

Documenting first occurrence records for invasive or expanding species carries substantial scientific value. Such records provide empirical verification of biogeographic model predictions, establish temporal baselines for future population monitoring, and generate critical data for regional biodiversity assessments and invasive species management frameworks (Jayashankar et al., 2012; Sreeraj, 2021). The documentation of population density alongside distributional data further enhances the utility of such records by enabling comparison with populations from other regions and informing risk assessments of agricultural impact.

Agricultural pest management in Saharanpur district requires accurate knowledge of which species are present, their abundance, and their spatial distribution. Veronicellid slugs are documented consumers of seedlings, young leaf tissues, and root crops across various agricultural systems (South, 1992; Jayashankar et al., 2012), and their cryptic, crepuscular-to-nocturnal habits can result in crop damage that is misattributed to other organisms or simply overlooked until economically significant thresholds are exceeded (Raut & Panigrahi, 1990; Kaur & Kaur, 2014). Establishing the presence and initial abundance of *L. haroldi* in Saharanpur thus serves both scientific and applied agricultural objectives.

Population density estimation using standardised quadrat sampling protocols (Krebs, 1999; Elzinga et al., 1998) allows repeatable, quantitative assessment of abundance and enables detection of temporal and spatial trends that may signal further population establishment or range expansion. The variance-to-mean ratio (Taylor, 1961), a widely applied index in ecological studies of invertebrate aggregation, provides additional information on spatial distribution patterns that influence both pest risk and monitoring strategy design (Southwood & Henderson, 2000; Magurran, 2004).

The present study was motivated by direct field observations of an unfamiliar slug species during routine ecological surveys of agricultural margins in Kulheri village, Saharanpur district. Subsequent identification confirmed the presence of *L. haroldi*, establishing a first district-level record for Saharanpur. We report population density estimates across three biweekly sampling events spanning October–November 2025, document the spatial distribution pattern, identify observed host plants, and contextualise the findings within the broader literature on *L. haroldi* invasiveness and range dynamics in India. The data presented are intended to serve as a documented baseline for future monitoring and to facilitate further investigation of this species' ecology and potential economic impact in western Uttar Pradesh.

2. Materials and Methods

2.1. Study Area

The study was conducted in Kulheri village, Saharanpur district, Uttar Pradesh, India (29°52'54.5"N, 77°16'18.3"E; elevation approximately 270 m a.s.l.) (Figure 1). Saharanpur district occupies the northwestern extremity of Uttar Pradesh, bounded by Uttarakhand to the north and east, Himachal Pradesh to the northeast, and Haryana to the west. The district's physiography transitions from the flat alluvial terrain of the Upper Gangetic Plain to the gently undulating sub-Himalayan foothills in its northern sectors. The regional climate is classified as humid subtropical (Köppen Cwa), with mean annual rainfall of approximately 900–1,100 mm concentrated during the June–September monsoon. Post-monsoon October temperatures typically range between 18°C and

32°C, with relative humidity remaining above 60%, creating conditions conducive to slug activity. The sampling locality consisted of agricultural field margins adjacent to sugarcane and mixed vegetable plots, characterised by dense herbaceous ground cover including *Amaranthus* sp., *Ageratum* sp., and various grasses.

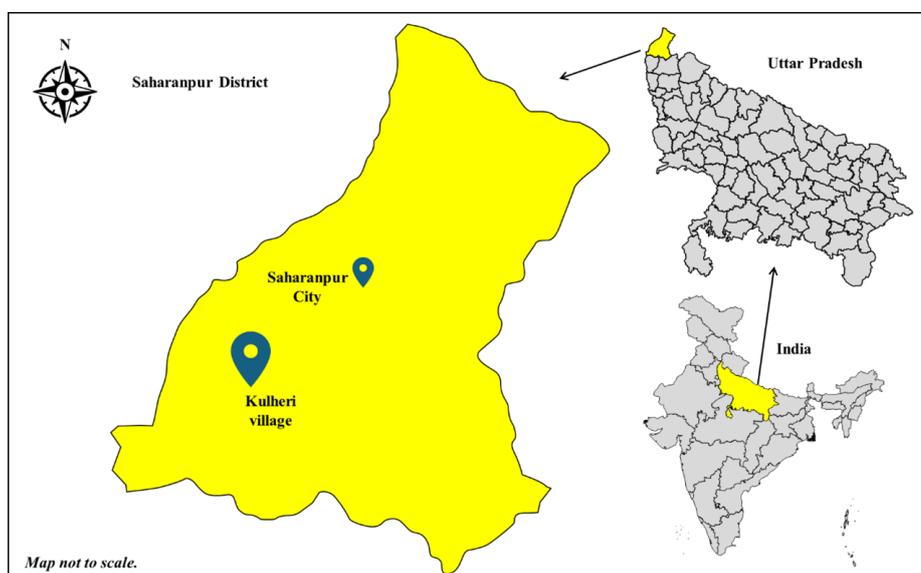


Figure 1. Map of the study area.

2.2. Survey Period and Duration

Field observations and systematic sampling were conducted over a two-month period, commencing on 21 October 2025 and concluding on 22 November 2025. Three discrete sampling events were undertaken at approximately biweekly intervals: 21 October, 04 November, and 18 November 2025. This temporal window was selected to coincide with the post-monsoon season, when soil moisture levels remain elevated, ambient temperatures favour gastropod activity, and herbaceous vegetation along field margins is at peak biomass. Surveys were carried out during early morning hours (07:00–10:00 h), corresponding to peak slug surface activity in tropical and subtropical systems (Raut & Panigrahi, 1990).

2.3. Population Density Estimation

Population density was estimated using the quadrat sampling method, a standardised technique recommended for quantifying the abundance of slow-moving or sessile soil invertebrates (Krebs, 1999; Elzinga et al., 1998). At each sampling event, five quadrats of 2×2 m (4 m^2) were systematically established along agricultural field margins at pre-selected, randomly positioned transect points. All *L. haroldi* individuals observed on the ground surface, on herbaceous vegetation, and under debris within each quadrat were counted and recorded. Density per quadrat was calculated as the number of individuals divided by quadrat area (4 m^2), expressed as individuals per square metre (ind. m^{-2}).

2.4. Specimen Identification

Slug specimens encountered during sampling were identified to species level based on external morphological characters, including overall body shape, coloration, integumental texture, and the characteristic dorsal tuberculation pattern. Identification followed the original description and diagnostic keys provided by Dundee (1980) and supplementary taxonomic references for veronicellid gastropods (Gomes & Thomé, 2004). Reference was also made to the descriptions and photographs provided by Magare (2015) and Sreeraj (2021) for Indian records of the same species. No specimens were collected; observations and photographic documentation were used exclusively for identification and record purposes.

2.5. Statistical Analysis

Population density was calculated per quadrat and expressed as mean \pm standard deviation (SD) for each sampling date and calendar month. Temporal trends in mean density were assessed by comparing values across the three sampling events. Spatial distribution pattern was evaluated using the variance-to-mean ratio (VMR), also termed the index of dispersion (Taylor, 1961; Southwood & Henderson, 2000). A VMR of 1.0 indicates random (Poisson) distribution; values exceeding 1.0 indicate aggregated (clumped) distribution; values below 1.0 indicate uniform distribution. Variance and mean were calculated from the five quadrat counts pooled across all sampling events. All statistical computations were performed using basic descriptive statistics. No statistical hypothesis testing requiring parametric assumptions was applied given the preliminary, observational nature of the dataset.

3. Results and Discussion

3.1. Population Density and Temporal Variation

Quadrat sampling across three biweekly events confirmed the presence of established *L. haroldi* populations in agricultural field margins at Kulheri village (Figure 2 and 3). Individual counts per quadrat ranged from 3 to 9 individuals across all sampling dates (Table 1). Mean population density increased progressively from 1.25 ± 0.38 ind. m^{-2} during Week 1 (21 October 2025) to 1.60 ± 0.29 ind. m^{-2} in Week 2 (04 November 2025) and 1.90 ± 0.30 ind. m^{-2} in Week 3 (18 November 2025) (Table 2). Monthly aggregated means were 1.25 ± 0.38 ind. m^{-2} for October and 1.75 ± 0.32 ind. m^{-2} for the combined November sampling events.



Figure 2. Adult specimen of *L. haroldi* observed on amaranth (*Amaranthus* sp.) in agricultural field margin, Kulheri village, Saharanpur district, Uttar Pradesh.



Figure 3. Adult specimen of *L. haroldi* observed on bakhumbhar grass (*Ageratum* sp.) in agricultural field margin, Kulheri village, Saharanpur district, Uttar Pradesh.

The observed density range of 0.75 – 2.25 ind. m^{-2} is broadly consistent with values reported for veronicellid slugs in comparable agricultural habitats elsewhere. Maceira-Filgueira (2002) documented population densities of *Veronicella cubensis* reaching up to 2.5 ind. m^{-2} in Cuban agricultural settings. The progressive increase in mean density across the two-month observation window is notable, given that seasonal temperature declines during October–November in the sub-Himalayan foothills might be expected to suppress invertebrate activity. This counterintuitive trend likely reflects residual high soil moisture following monsoon retreat, continued availability of senescent herbaceous biomass as food resources, and the possibility of immigrant slug recruitment from



adjacent habitats during the early post-monsoon period. Alternatively, improved detection efficiency as observer familiarity with slug micro-habitats increased cannot be entirely excluded, though standardised protocols were maintained throughout.

Table 1. Quadrat-wise counts and density estimates of *L. haroldi* in Kulheri village, Saharanpur district, Uttar Pradesh (October–November 2025). Quadrat size: 2 × 2 m (4 m²); sampling time: 07:00–10:00 h; n = 5 quadrats per event.

Sampling Date	Quadrat No.	Individuals Counted	Density (ind. m ⁻²)
21 Oct 2025	Q1	6	1.50
21 Oct 2025	Q2	4	1.00
21 Oct 2025	Q3	5	1.25
21 Oct 2025	Q4	3	0.75
21 Oct 2025	Q5	7	1.75
04 Nov 2025	Q1	8	2.00
04 Nov 2025	Q2	6	1.50
04 Nov 2025	Q3	5	1.25
04 Nov 2025	Q4	7	1.75
04 Nov 2025	Q5	6	1.50
18 Nov 2025	Q1	9	2.25
18 Nov 2025	Q2	8	2.00
18 Nov 2025	Q3	7	1.75
18 Nov 2025	Q4	6	1.50
18 Nov 2025	Q5	8	2.00

Table 2. Weekly and monthly mean population density (± SD) of *L. haroldi* in Kulheri village, Saharanpur district, Uttar Pradesh.

Period	No. of Quadrats	Total Individuals	Mean Density ± SD (ind. m ⁻²)
Week 1 (21 Oct 2025)	5	25	1.25 ± 0.38
Week 2 (04 Nov 2025)	5	32	1.60 ± 0.29
Week 3 (18 Nov 2025)	5	38	1.90 ± 0.30
October 2025	5	25	1.25 ± 0.38
November 2025	10	70	1.75 ± 0.32

3.2. Spatial Distribution Pattern

Analysis of quadrat count data revealed a variance-to-mean ratio (VMR) of approximately 1.3, calculated from the pooled dataset of 15 quadrat counts (total n = 95 individuals; mean = 6.33 ind. quadrat⁻¹; variance ≈ 8.24). This VMR value exceeding 1.0 indicates an aggregated spatial distribution pattern, consistent with a negative binomial rather than a random (Poisson) dispersion model (Taylor, 1961; Southwood & Henderson, 2000). Aggregated distributions are commonly observed in terrestrial gastropod populations and typically arise through the combined influence of resource patchiness, microhabitat heterogeneity, limited natal dispersal, and social or reproductive aggregation (Magurran, 2004).

In the present study, slug aggregations were consistently observed in association with dense stands of *Amaranthus* sp. and *Ageratum* sp. along field margins, suggesting that vegetational microhabitat structure strongly mediates local distribution. The presence of moist soil and abundant organic litter beneath these herbaceous stands likely provides both food resources and daytime refuge conditions. This association corroborates observations from other veronicellid studies in which resource patch quality strongly predicts local density (South, 1992; Kaur & Kaur, 2014).

3.3. Species Identification and Diagnostic Characters

Individuals of *L. haroldi* were identified based on the following combination of external morphological characters as described by Dundee (1980) and subsequently referenced in Indian records (Magare, 2015; Sreeraj, 2021): (i) elongated, dorsoventrally flattened body measuring 40–75 mm in extended length; (ii) uniform olive-brown to dark greyish dorsal colouration; (iii) smooth, non-granular integumental texture; (iv) distinct sole divided into three longitudinal zones; and (v) absence of any shell remnant or shell field. These characters collectively distinguish *L. haroldi* from the more commonly recorded Indian veronicellid *L. alte* (Ferussac),



which typically exhibits a more distinctly keeled dorsal surface and lighter colouration. All observed individuals were adults or sub-adults based on body size; juveniles were not detected during the sampling period, though their absence may reflect cryptic habits or temporal offset in cohort emergence.

3.4. Host Plant Associations

Feeding and resting activity was documented on two herbaceous plant species: *Amaranthus* sp. (pigweed/amaranth) and *Ageratum* sp. (floss flower / bakhumbhar grass). Feeding traces, including characteristic rasp marks on leaf surfaces and mucous trails, were observed on *Amaranthus* leaves in particular. Both plant species are widespread weeds in north Indian agricultural margins and are not cultivated crops; however, their role as transient hosts may facilitate slug movement into adjacent crop rows. Veronicellid slugs have been documented consuming a broad range of monocots and dicots, and the host range of *L. haroldi* remains incompletely characterised (Herbert, 2013; Sreeraj, 2021). The observed association with common agro-ecological weeds underscores the species' potential to exploit disturbed agricultural habitats effectively.

3.5. Biogeographic Context and Range Expansion

The present record from Saharanpur district constitutes the first confirmed occurrence of *L. haroldi* in the western Uttar Pradesh region, extending the species' known distribution northwestward. Following its initial Indian record from Maharashtra (Magare, 2015), the species has been progressively documented from new localities, including Sreeraj's (2021) record from the Sundarbans Biosphere Reserve, West Bengal. These geographically dispersed records collectively suggest either multiple independent introduction events via horticultural trade (consistent with the mechanism described by Cowie et al. (2008) for Hawaii) or natural dispersal facilitated by connectivity of agricultural landscapes. The ecological niche models of Mahapatra and Aravind (2021) explicitly predicted climatically suitable conditions for *L. haroldi* in northwestern Uttar Pradesh and adjacent regions, and the present empirical record provides direct confirmation of this prediction.

3.6. Agricultural and Conservation Implications

Saharanpur district's agricultural economy is anchored by sugarcane, wheat, and extensive horticultural production. The establishment of *L. haroldi* populations in agricultural field margins represents an emerging concern, given the species' documented phytophagous behaviour and the precedent set by related veronicellid species as significant crop pests elsewhere (South, 1992; Kaur & Kaur, 2014). The aggregated spatial distribution documented in this study has practical implications for integrated pest management: clumped populations can be targeted with concentrated bait or barrier treatments, potentially improving the cost-effectiveness of control interventions compared to area-wide applications required for randomly distributed populations (Southwood & Henderson, 2000). Nevertheless, the population densities recorded (up to 2.25 ind. m⁻²) fall below those associated with economically significant crop damage thresholds in comparable systems, and the current threat level in Saharanpur appears low. Continued monitoring is essential to track whether populations expand in density and geographic extent. The role of the horticultural trade network operating through Saharanpur's large plant nursery sector as a potential dispersal vector for this species warrants investigation.

4. Conclusion

This study reports the first confirmed occurrence of Purcell's Hunter Slug, *L. haroldi* Dundee, 1980 (Gastropoda: Veronicellidae), in Saharanpur district, western Uttar Pradesh, India, based on systematic field observations and quadrat-based population surveys conducted during October–November 2025. Population densities ranged from 0.75 to 2.25 ind. m⁻², with a progressive temporal increase across the two-month post-monsoon sampling window (overall mean 1.58 ± 0.38 ind. m⁻²). Spatial analysis indicated an aggregated distribution pattern (VMR ≈ 1.3), attributed to microhabitat heterogeneity and resource patchiness along field margins. Observed foraging associations with *Amaranthus* sp. and *Ageratum* sp. confirm phytophagous activity in the study area.

This record extends the verified Indian range of *L. haroldi* into northwestern Uttar Pradesh and provides empirical corroboration for prior ecological niche model predictions. The data establish a documented baseline for future population monitoring efforts and underscore the necessity of continued faunal surveillance in Saharanpur's agriculturally modified landscapes. Future work should investigate seasonal population dynamics, quantify crop damage under field conditions, characterise host plant breadth, and assess potential dispersal routes to inform evidence-based invasive species management in the region.

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Author Contributions

Aaryan Kumar: Methodology, Investigation, Data Curation, Writing – Original Draft; Sandeep Kumar Barwal: Formal Analysis, Software, Validation, Visualization; Madhumita Goala: Resources, Supervision, Writing – Review & Editing; Pankaj Kumar: Conceptualization, Project Administration, Supervision, Funding Acquisition, Writing – Review & Editing. All authors read and approved the final manuscript.

Declarations

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