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A new record of tropical land slug, a terrestrial gastropod, mollusk (*Laevicaulis alte* (Férussac, 1822): Pulmonata: Veronicellidae) in the southern plains of Yemen

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تسجيل جديد لنوع من أنواع الرخويات الأرضية الاستوائية (*Laevicaulis alte* ((Férussac, 1822): Pulmonata: Veronicellidae) في اليمن

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Abstract:
The tropical leatherleaf slug, *Laevicaulis alte* (Férussac, 1822) (Pulmonata: Veronicellidae), is a destructive terrestrial gastropod recognized as a high-risk invasive agricultural pest worldwide. Originally native to central and southern Africa, the species has expanded its range globally via international trade, establishing populations across tropical and subtropical regions, including parts of the Middle East and the Arabian Peninsula. This paper documents the first confirmed record of *L. alte* in the southern plains of Yemen, based on eighteen specimens collected from a single locality in the Al Mahfad district, Abyan Governorate at coordinates 14°33.101 N, 46°54.492 E, during the months of December 2025 and June 2026. Given the slug's high adaptability, its capacity to devastate crop yields, and its role as an intermediate host for parasitic nematodes of public health concern, documenting its presence in Yemen is a crucial first step toward establishing effective phytosanitary measures and integrated pest management (IPM) programs.

Keywords: Tropical land; Terrestrial slug; Gastropod; Mollusk; Invasive species.

الملخص
يُعدّ البزاق الجلدي الاستوائي، *Laevicaulis alte* (Férussac, 1822) (Pulmonata: Veronicellidae)، من الرخويات الأرضية المدمرة، ويُصنّف كآفة زراعية غازية عالية الخطورة على مستوى العالم. موطنه الأصلي وسط وجنوب أفريقيا، وقد توسّع نطاق انتشاره عالميًا عبر التجارة الدولية، مُؤسسًا تجمعات في المناطق الاستوائية وشبه الاستوائية، بما في ذلك أجزاء من الشرق الأوسط وشبه الجزيرة العربية. توثق هذه الورقة البحثية أول تسجيل مؤكد لوجود رخويات *L. alte* في السهل الساحلي الجنوبي لليمن على خليج عدن وبحر العرب، استنادًا إلى ثمانية عشر عينة جُمعت من موقع واحد في مديرية المحفد، محافظة أبين، عند الإحداثيات 14°33.101 شمالًا، 46°54.492 شرقًا، خلال الفترة من ديسمبر 2025 إلى يونيو 2026. ونظرًا لقدرة هذه الرخويات العالية على التكيف، وقدرتها

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على إتلاف المحاصيل الزراعية، ودورها كمضيف وسيط للديدان الخيطية الطفيلية التي تُشكل خطرًا على الصحة العامة، فإن توثيق وجودها في اليمن يُعد خطوة أولى حاسمة نحو وضع تدابير فعالة للوقاية النباتية وبرامج الإدارة المتكاملة للآفات.

الكلمات المفتاحية: المناطق الاستوائية، البزاقات الارضية، بطنية القدم، الرخويات، الأنواع الغازية.

1. Introduction

The Republic of Yemen is located at the southernmost tip of the Arabian Peninsula, covering an area of 531,000 square kilometers. It shares a 1,458-kilometer land border with the Kingdom of Saudi Arabia and a 288-kilometer border with the Sultanate of Oman (PERSGA, 2003; Hadden, 2012; Al-Hindi, 2019; Al-Hindi *et al.*, 2020). Yemen is a globally significant region, serving as a link and transit point between the continents of Asia and Africa. This unique location fosters rich biodiversity, contributing to a better understanding of the region's biodiversity and the exploration of its risks and opportunities (Busais & Al-Hindi, 2019; Busais *et al* 2023). Yemen is also considered an agricultural country due to the diversity of its terrain, environments and climate, and produces many agricultural crops, including various vegetables, fruits, and grains (Al-Khalidi, 2013; EPA, 2014), although it is located within arid and semi-arid climatic zones, where the average rainfall in the coastal strip and the interior desert ranges between 50-75 mm, while the average rainfall in some high mountain areas reaches more than 1000 mm, and in other high areas between 300-800 mm (Al-Hindi *et al*., 2022).

Most previous studies and survey reports indicate that the coastal plains of Yemen, south of the Arabian Peninsula at the Gulf of Aden and the Arabian Sea, are rich in biodiversity. Unfortunately, many of the living communities have not been adequately studied, and most of the areas in this geographical range are uninhabited and their biodiversity has not been adequately studied. In addition, some classification errors occurred in previous research on the plants and animals of the region, which caused a large knowledge gap in this geographical range (Chapper *et al*., 1992; Saad, 1992; Apel & Spiridonov, 1998; Neumann & Spiridonov, 1999; Bawazir, 2003; Al-Hindi, 2010; Khvorov *et al*. 2012; Bawazir, 2017; Al-Hindi, 2019; Busais & Al-Hindi, 2019; Al-Hindi *et al*., 2023; Al-Hindi, 2024; Al-Hindi, 2025).

Among the living groups that have not been adequately studied in Yemen are land snails, about which we face a lack of information regarding their species, natural habitats, and distribution, especially in the southern regions of Yemen along the southern coast, starting from Bab al-Mandab in the west and reaching Hauf with the borders of the Sultanate of Oman in the east.

Land snails play an important role in the environment and ecological balance when they enter new environments. Some of their herbivorous species turn into serious agricultural pests, and they can push the native local snails to extinction (Barker, 2002; Hausdorf, 2023). One of these troublesome pests is the widespread ground snail *Allopeas gracile* (Hutton, 1834), and the leather leaf slug, *Laevicaulis alte* (Férussac, 1822), however, the tropical snail *Laevicaulis alte*, native to sub-Saharan Africa, is one of the most commonly classified agricultural pests among land snails, causing damage to crops. It can completely destroy small ornamental plant nurseries, and carries a dangerous roundworm that causes eosinophilic meningitis in humans (Gomes & Thomé, 2004; Hausdorf, 2023; Raut & Barker, 2002; Howard, 2024; Cowie *et al*., 2009; Guo & Zhang, 2022; Rollins *et al*., 2024).

There is still a significant knowledge gap in identifying and documenting the land snails in the southern coastal plain of Yemen, located on the Gulf of Aden and the Arabian Sea in particular, and Yemen in general, and in knowing their locations, distribution, and

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environments, and understanding their role as agricultural pests, invasive alien species, disease vectors, and impactors on public health.

2. Materials and Methods

2.1. Sample Collection and Study Site

Eighteen specimens of the tropical leatherleaf terrestrial slug (*Laevicaulis alte*) were collected from an agricultural region in the Al Mahfad District, Abyan governorate (14°33.101' N, 46°54.492' E), 270 km east of Aden city Fig (1). Field sampling was conducted during two distinct periods: December 2025 and June 2026. Specimens were primarily found in microhabitats with high ambient moisture, specifically within clay soils beneath the canopy of orange (*Citrus sinensis*), guava (*Psidium guajava*), and papaya (*Carica papaya*) trees, as well as along traditional irrigation canals. To maximize collection yield and avoid thermal stress on the specimens, sampling was restricted to the early morning hours prior to sunrise. Due to the medical significance of wild veronicellid slugs as intermediate hosts for the rat lungworm (*Angiostrongylus cantonensis*)- the causative agent of human eosinophilic meningitis- strict biosafety protocols were maintained. All specimens were collected manually using protective nitrile gloves.

2.2. Transportation and Laboratory Maintenance

Live specimens were transferred to well-ventilated plastic containers layered with damp clay soil and fresh leaves of *P. guajava* and *C. sinensis* to maintain humidity during transit. The samples were transported to the laboratories of the Department of Biology, Faculty of Education, University of Aden.

2.3. Morphological Characterization and Preservation

Morphometric parameters, including total body length (mm), maximum width (mm), and total wet weight (g), were recorded for each individual. Following morphometric analysis, the slugs were humanely euthanized and fixed by immersion in a 70% ethanol solution. The preserved specimens were then stored in labeled plastic containers within the department's laboratory repository for subsequent analysis.

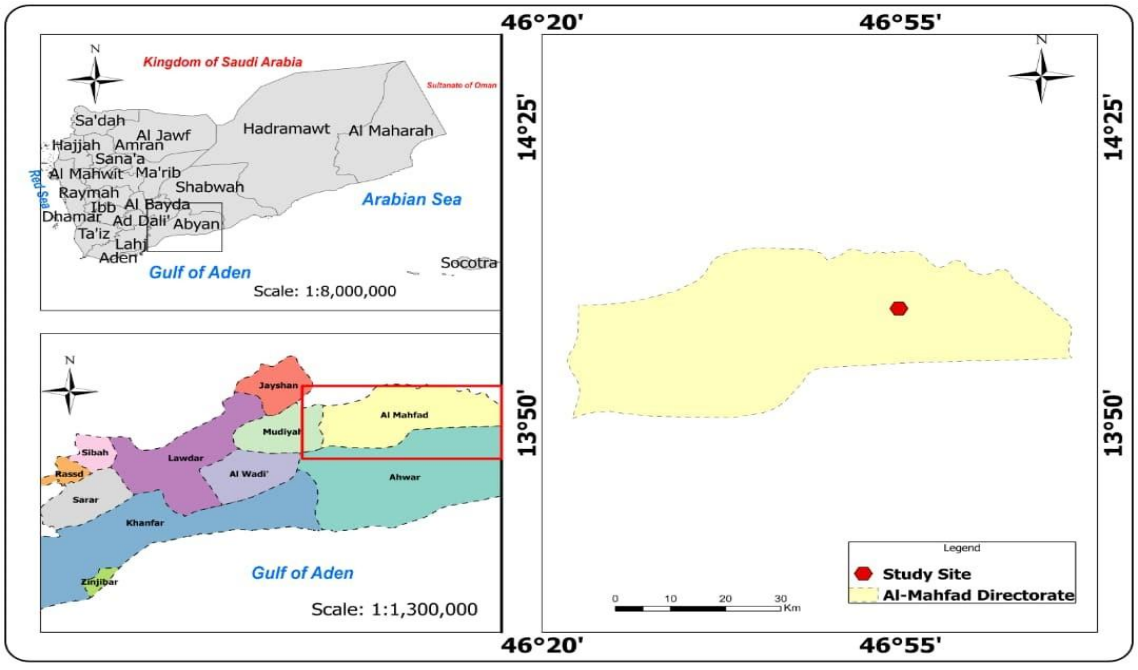

Fig. 1: Collecting site at Al-Mahfad Directorate (East Aden city- 270 Km), Yemen

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3. Results

The present study provides the first formal record of the tropical leatherback slug, *Laevicaulis alte* (Férussac, 1822) (Mollusca: Veronicellidae), in the southern plains of Yemen. Universally recognized as an invasive agricultural pest across tropical and subtropical regions, *L. alte* causes substantial economic damage to crops by feeding indiscriminately on foliage, fruits, apical buds, and ornamental plants.

Originating from its native range in Southern Africa, this terrestrial gastropod exhibits notable xerotolerance (drought resistance) compared to sympatric slug species. This high adaptability to arid environments is facilitated by its morphological specializations: a thick, cylindrical body and a significantly narrowed foot, both of which minimize total surface area and effectively reduce water loss via evaporation.

A total of 18 specimens were collected from the survey area, exhibiting the following morphometric variations: Total Length: 30–80 mm; Maximum Width**:** 10–20 mm; Total Weight: 5–10 g. Phenotypic observation revealed a dorsal coloration ranging from brown to light brown, bisected by a distinct median longitudinal cream-white line and interspersed with fine, irregular white maculations (spots). Conversely, the ventral surface, including the characteristic narrow foot, transitioned to a distinct pale yellow or yellowish-white hue (Fig. 2).

Fig. 2: **A**; A dorsal view of a tropical land slug in the study area, **B**; A group of land slug in agricultural soil, **C**; A frontal view of a slug showing the stalks eyes and narrow ventral foot, **D**; A female slug laying eggs in agricultural soil, **E**, A group of slugs gather near a plant stem.

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4. Discussion

According to previous studies and surveys conducted on land snails and in Yemen across its various environments and geographical ranges, we find that the Socotra archipelago has recorded 110 species of land snails in Yemen, some of which are considered endemic species such as *Achatinelloides socotorensis, Cinnabarica socotrana, Socotora naticoides, Passamaella polita, Lithidion lithidion, Riebeckia socotorana, Zootecus contiguous*. Following the Socotra archipelago in terms of land snail presence in Yemen, the northern and western highlands, such as Jabal An-Nabi Shu'ayb, Jabal Aiban, Hajjah, and the Sumara mountain ranges, with their rocky environments and high humidity, have recorded 21 species of these snails, such as *Zootecus insulari*, it is one of the most widespread land snails in Yemen and the Arabian Peninsula, and is found in agricultural areas, dry habitats, moist soil, and under rocks, and *Macroptychia sumarana*, it is a native endemic species whose presence is restricted to high-altitude humid environments, *Araboxychilus sabaeus, Macroptychia (Sabaeola) schweinfurthi, Euryptyxis fragosa, Zebrinops albata, , Revoilia bentianum*, and others (Al-Safadi, 1992; Neubert, 1998; García's *et al.,* 2015). While lower numbers of land snails were recorded in the western Yemeni region of the Tihama plains on the Red Sea, and the southern coastal plain of Yemen located on the Gulf of Aden and the Arabian Sea. Only 9 species of land snails were recorded in the Tihama plain, the most prominent of which was *Gastrocopta klunzingeri, Allopeas gracilis, Cecilioides tumulorum*, and others, and in the southern coastal plain of Yemen located on the Gulf of Aden and the Arabian Sea 11 species of land snails were recorded in this region (Fig. 3), although it is one of the largest geographical areas in Yemen, with a length of approximately 1400 km, the most prominent of which was *Biomphalaria arabica, Biomphalaria pfeifferi, Bulinus beccari* (These species are considered intermediate hosts for urinary and intestinal schistosomiasis), *Euryptyxis latireflexa, Euryptyxis labiosa, Cecilioides acicul*, and others (Neubert, 1998; Moqbil& Al-Hindi, 2011; García's *et al*., 2015; Haymad, 2023; Bayousuf *et al*., 2024).

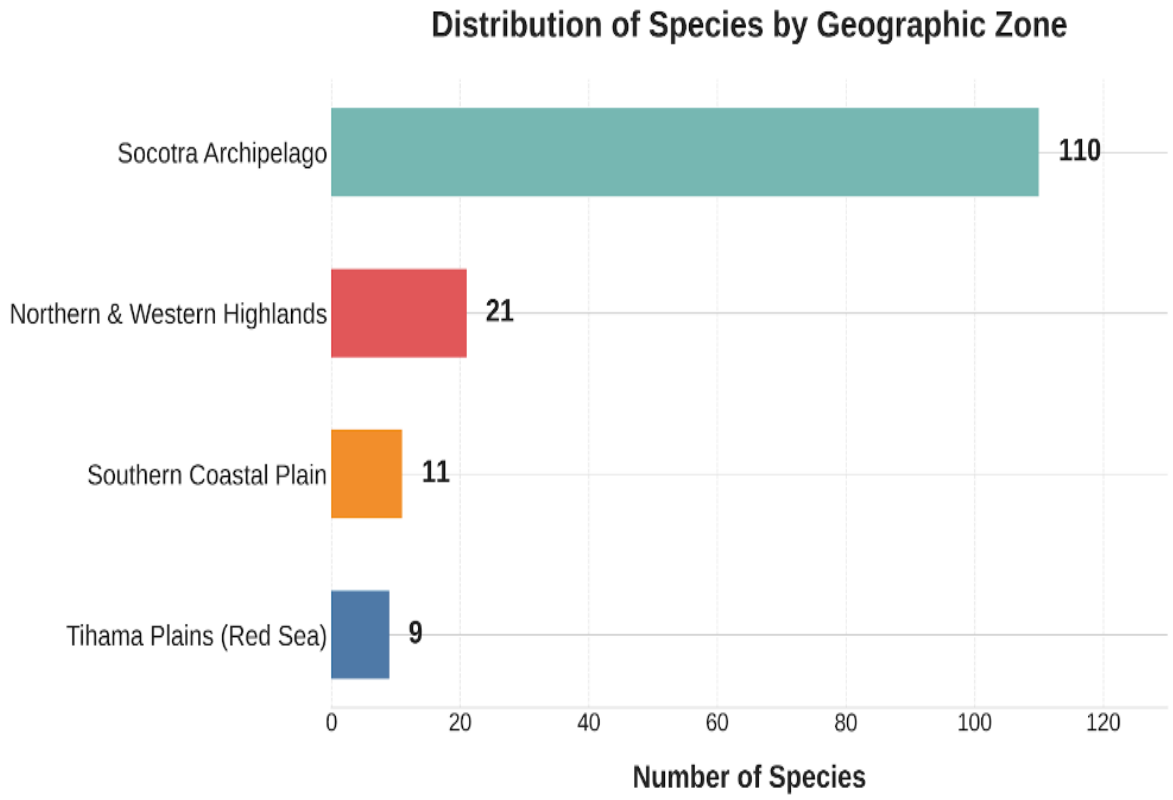

Fig. 3: Number of species of land snails according to different geographical zones in Yemen.

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There are land snails that are considered agricultural pests and invasive alien species, and their impact on crops, especially ornamental plants, is significant and destructive, and they are dangerous if their numbers increase greatly. One such species is the *Allopeas gracile* (Hutton, 1834), it is widely in tropical and subtropical areas of Asia, Australia, and Polynesia, as well as Central and South America, and also it is omnivorous, feeding on green plants (vegetables, weeds, and flowers), fungi, and animal matter (dead cockroaches and earthworms), but not decaying vegetation (tree leaves) (Capinera, 2017). This species was recorded on the western coast of Yemen in the Tihama plains by Neubert (1998), and no damage to agricultural crops was reported, nor was it recorded among the agricultural pests in this geographical region of Yemen.

The other species is the tropical leatherleaf slug, *Laevicaulis alte* (Férussac, 1822), native to East Africa, and it is has established invasive populations globally (Rowson et al., 2017). This species was recorded in the Arabian Peninsula in Jubail, Jeddah, Dammam and Riyadh in Saudi Arabia during the period 1983-1990, and was also recorded in Oman in 1986 Neubert, (1998).

Al-Safadi (1992) recorded *L. alte* in northern Yemen while collecting samples of land snails from the northern and western highlands and the western plain of Tihama before the Yemeni unity in the period time 1986-1990, while working at Sana'a University, as the first record of northern Yemen in the Tihama plain on the Red Sea. He did not refer to this species as an agricultural pest or an invasive alien species. There are no studies after this study that documented the recording and presence of this species in Yemen.

This current study is considered the first record of the tropical leather slug (*L. alte*) in the southern coastal plain of Yemen on the Gulf of Aden and the Arabian Sea, and also as an invasive species and agricultural pest that infects crops, and it officially documents its presence within the biodiversity of Yemen. Furthermore, informal or loosely regulated movement of planting materials through local ports often bypasses rigorous phytosanitary screening, creating ideal conditions for the undetected entry of soil-borne pests.

Regional trade in agricultural commodities and plant seedlings is the main factor facilitating the spread of the tropical leather slug (*L. alte*) in Yemen. Because of the small size of their eggs and larvae, these slugs can easily evade visual inspections of plant health by hiding in moist soil, plant roots, or among fallen leaves, as confirmed by previous studies such as those conducted by Kumar& Vishwakarma (2020),and Ali& Robinson (2021).

Despite Yemen's arid climate, the tropical leather slug (*L. alte*) survives by exploiting specific environments that meet its physiological needs. It thrives in the dense, consistently shaded papaya fields of the study area, which block direct sunlight, and also under the thick, deciduous leaves of guava and orange trees, which reduces water evaporation and helps retain soil moisture. Additionally, the irrigated coastal agricultural lands, valleys, and hillsides of southern Yemen are characterized by high relative humidity and warm temperatures year-round. These ecological niches closely resemble the environmental conditions supporting established populations in Salalah, Oman, and Giza, Egypt (Neubert, 1998; Ali & Robinson, 2021), thereby facilitating the acclimatization and survival of the species in local agro-ecosystems.

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Unregulated agricultural trade, particularly the importation of planting materials such as banana suckers and Mango from East Africa (The native range of *L. alte*), is widely recognized as a major introduction pathway, and It is highly probable that L. alte entered Yemen via Aden through these trade shipments before expanding inland toward agricultural areas in Abyan Governorate.

Field observations in Al-Mahfad District (Abyan Governorate) in this study revealed a high population density of *L. alte* within papaya and guava orchards, with no apparent physical damage to mature crop trees. This indicates that this species feeds mainly on decaying organic matter or weeds in these environments, consuming fallen leaves, decaying organic matter, low weeds and small ornamental plants rather than attacking mature perennial crops. However, periodic monitoring of the numbers of these slugs remains necessary, and this is consistent with the result that Pinnamaneni& Potineni (2022) found in their study. It should be noted that recent results by Datta Modi *et al* (2025) demonstrated *L. alte* ability to decompose cellulose-rich waste, such as paper and cardboard. Nevertheless, as the researchers emphasized, using this invasive pest for organic waste management poses significant environmental risks, as any accidental release could destabilize local agricultural ecosystems.

The continued spread of *L. alte* poses significant agricultural and epidemiological risks. Although mature trees in Abyan showed resilience, the species is known to cause severe damage to leafy vegetables, nursery stock, and young seedlings in other invaded regions (Sreeraj, 2021). Furthermore, *L. alte* is a recognized intermediate host for parasitic nematodes of public health and veterinary significance. The lack of historical baseline data in Yemen raises concerns that other cryptic invasive species may be spreading undetected. To mitigate these risks, strict phytosanitary enforcement and thorough soil/plant inspections are urgently recommended at all Yemeni ports of entry handling East African shipments. Additionally, nationwide field surveys across adjacent governorates are required to map the full extent of its distribution and prevent further encroachment into primary agricultural zones.

Conclusion

The current study has proven that the tropical slug *Laevicaulis alte* has been officially recorded in Yemen as a species that adds to the biodiversity, as an invasive species, and as an agricultural pest that affects agricultural crops. The possibility of its entry into Yemen came through the importation of banana, mango and papaya seedlings from East Africa, its original home. This species causes severe damage to leafy crops, ornamental plants and small seedlings. It is also an intermediate host for parasitic nematodes that are important in the field of public health and veterinary medicine, and customs officials should tighten inspection procedures for seedling shipments entering Yemen, and examine the soil for the possible presence of slug eggs and larvae. Survey studies should also be expanded in agricultural areas adjacent to Abyan Governorate, due to the possibility of tropical slugs transition to these areas.

Future studies should incorporate molecular techniques, such as DNA barcoding, to confirm the precise geographic origins of the populations and map their genetic relationship to those in neighboring regions.

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