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NOTES ON GEOGRAPHIC DISTRIBUTION

New distribution records of *Gomphrena fuscipellita* T. Ortuño & T. Borsch (Amaranthaceae): a rare endemic from Bolivia

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Abstract. We report on *Gomphrena fuscipellita* T. Ortuño & T. Borsch, a species endemic to Bolivia's dry valleys. This species was initially described from a type specimen collected in 2005 in Cochabamba (Mizque Province) and an additional sample from Potosí (Charcas Province). However, after two decades, the species has been documented further across southern Bolivia. This study provides an updated geographical distribution, micro-morphological trichome descriptions, and ecological insights that refine habitat characterization and advance the understanding of its ecological and geographical features.

Key words. Conservation, dry valleys, El Palmar, protected areas, Toro Toro

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INTRODUCTION

The genus *Gomphrena* L. belongs to the family Amaranthaceae and has been circumscribed within the subfamily Gomphrenoideae (Müller and Borsch 2005; Sánchez del Pino et al. 2009). Over the past 20 years, significant morphological and molecular advances in this genus have been made (Ortuño and Borsch 2020). In these studies, major phylogenetic analyses of the family Amaranthaceae agree on the monophyly of Gomphrenoideae, a subfamily characterized by the presence of unilocular anthers (Müller and Borsch 2005; Sánchez del Pino et al. 2009). Additionally, the core of Gomphrenoideae (excluding *Iresine* P.Browne; Müller and Borsch 2005) is also supported by the presence of metareticulate pollen (Borsch 1998), which is recognized as a synapomorphy among its taxa. Kadereit et al. (2003), Müller and Borsch (2005), and Sánchez del Pino et al. (2009) also supported this classification.

The genus *Gomphrena* is polyphyletic (Sánchez del Pino et al. 2009), from which only a subclade called "core *Gomphrena*" (Ortuño and Borsch 2020) is monophyletic, including the type of the genus *G. globosa* L. (Sánchez del Pino et al. 2009). Ortuño and Borsch (2020) showed that the "core *Gomphrena*" subclade includes many species from the Inter-Andean dry valleys and Puna of Bolivia. These species have heteromorphic sepals, meaning that the two inner sepals are smaller than the three outer ones and are strongly compressed around the fruit (utricle). This trait is considered a synapomorphy of the core *Gomphrena*. Additionally, core *Gomphrena* species exhibit the highest diversity of C4 photosynthesis, which allows them to adapt to dry environments (Kadereit et al. 2012; Bena 2017; Ortuño and Borsch 2020). Currently, 22 species of core *Gomphrena* are included in the most recent checklist of vascular plants of Bolivia (Jorgensen et al. 2014), including three newly reported from the country. Of these, *G. fuscipellita* T. Ortuño & T. Borsch and *G. stellata* T. Ortuño & T. Borsch were categorized as Endangered in the Red Book of threatened species for the Andean zone of Bolivia (Ortuño et al. 2012).

In this study, we focus on *G. fuscipellita*, a species that diverged within the last 1.2 million years (Myr) (Ortuño 2020; Ortuño and Borsch 2020). *Gomphrena fuscipellita* was described in 2005 by Ortuño and Borsch

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(2005), based on a type specimen collected in Bolivia, Cochabamba. At the time, its known distribution was thought to be restricted to the southern part of the Cochabamba department, specifically in the Mizque province (see Appendix). Here, we provide an updated distribution record for *G. fuscipellita* in Bolivia based on recent findings and revision of Herbarium specimens. This endemic and endangered species faces increasing threats due to agricultural expansion, intensified livestock farming, competition with invasive species, and fires in its habitat (Vos et al. 2020). These factors not only highlight the importance for conservation and potential species categorization but also underline the urgency of monitoring its distribution and implementing measures to preserve its populations in the face of escalating environmental pressures.

METHODS

Specimens and study sites. Fieldwork was conducted in conjunction with various conservation projects across multiple regions in Bolivia. For instance, in the Potosí department, provinces Charcas, Chayanta and Rafael Bustillos, fieldwork was part of the project "Inventario de la biodiversidad en los ecosistemas verticales andinos (EVAs), en los Ayllus del Norte de Potosí y Sudeste de Oruro." Likewise, independent expeditions also took place in the Toro Toro Protected Area (Chuquisaca department, Zudañes province) as part of the Darwin Initiative Project 162/11/010, the project "Conservación y Uso Sostenible de la Agrobiodiversidad para mejorar la Nutrición Humana en Cinco Macro regiones", and the project "Sistemática y diversidad de las Amarantáceas de Bolivia". This fieldwork included visits to El Palmar Protected Area (the sole habitat of *Parajubaea torallyi* (Mart.)Burret). Aside from fieldwork, an exhaustive review of specimens of *Gomphrena fuscipellita* was conducted at the National Herbarium of Bolivia (LPB), and the Herbarium of Southern Bolivia (HSB).

Spatial distribution and occurrence modeling. The spatial distribution of *Gomphrena fuscipellita* was determined from the field studies described above plus herbaria databases. The coordinates were collected and projected onto a GIS environment. Additionally, the distribution of *G. fuscipellita* was plotted against the geological map of the study area, which was extracted from the Geological Map of South America (2018) with a 1:1000000 scale (Gómez et al. 2019). Finally, to infer the potential distribution of *G. fuscipellita* and evaluate its possible occurrence in protected areas and other conservation units, we modeled its distribution using Maxent v. 3.4.4 (Phillips et al. 2017) using default settings. The environmental variables used here were derived from Phillips et al (2006) and included climatic (cloud cover, annual; diurnal temperature range, annual; frost frequency, annual; precipitation, annual; precipitation, January (average); precipitation, April (average); precipitation, July (average); precipitation, October (average); mean temperature, annual; minimum temperature, annual; maximum temperature, annual and vapor pressure, annual), elevation and potential vegetation (ecoregions, as categorical variables). The model's accuracy was assessed based on the area under the receiving operator curve (AUC), which yields a value of 0.89, indicating a moderate to good predictive capacity. Here, for reporting the results, grids with point-wise values higher than 75% were considered as areas with a high probability of species' presence. The delimitation of protected areas was obtained by SERNAP (2018).

Morphological description, dissection, and identification. Specimens were measured following structural features, as well as key characteristics described by Ortuño and Borsch (2020). Flowers were dissected under a stereomicroscope and digital microscope to analyze bracts, bracteoles, sepals, gynoecium, and the androecium in detail. To assess cell types, leaf trichomes were studied with a Leyca ICC50 optical microscope. To assess tissue ornamentation and its arrangement a digital microscope was used. The terminology was based on Payne (1978), Carolin (1983), and Vrijdaghs et al. (2014), with adjustments from Ortuño and Borsch (2020) to ensure accurate identification and characterization of the specimens.

RESULTS

***Gomphrena fuscipellita* T. Ortuño & T. Borsch**, Novon 15(1): 181–183. 2005.
Figures 1–6

New records. BOLIVIA — Chuquisaca • Jaime Zudañez, ANMI El Palmar, along road from Presto to El Rodeo; −64.8978, −018.7992; 2943 m a.s.l.; 1 Feb. 2007; Wood, J.R.I. leg., 22576; B • Jaime Zudañez, ANMI El Palmar, summit, at the entrance of protected area; −64.8947, −018.6185; 2429 m a.s.l.; 4 Feb. 2022; Ortuño T. leg., 1, 2700; 2, 2701; HSB — Potosí • Charcas, Manka Paqui hill, entering the Mula Wacana ravine; −65.8589, −018.1231; 3411 m a.s.l.; 27 Feb. 2003; Wood, J.R.I. leg., 19239; BOLV • Chayanta, Pocoata. Pacotanca ayllu Jilawi and Jila Quellana; −66.2037, −018.7803; 3674 m a.s.l.; 4 Feb. 2016; Lliully, A. and Ortuño,T. leg., 2470; LPB • Rafael Bustillo, Uncía, Kara kucho town, next to road between Uncía and Chayanta; −66.4955, −018.4402; 3891 m a.s.l.; 26 Jan. 2016; Jiménez, I. leg., 1, IJ-7205; 2, s/n; LPB • Rafael Bustillo, Kara kara ayllu Laime/Pucara;

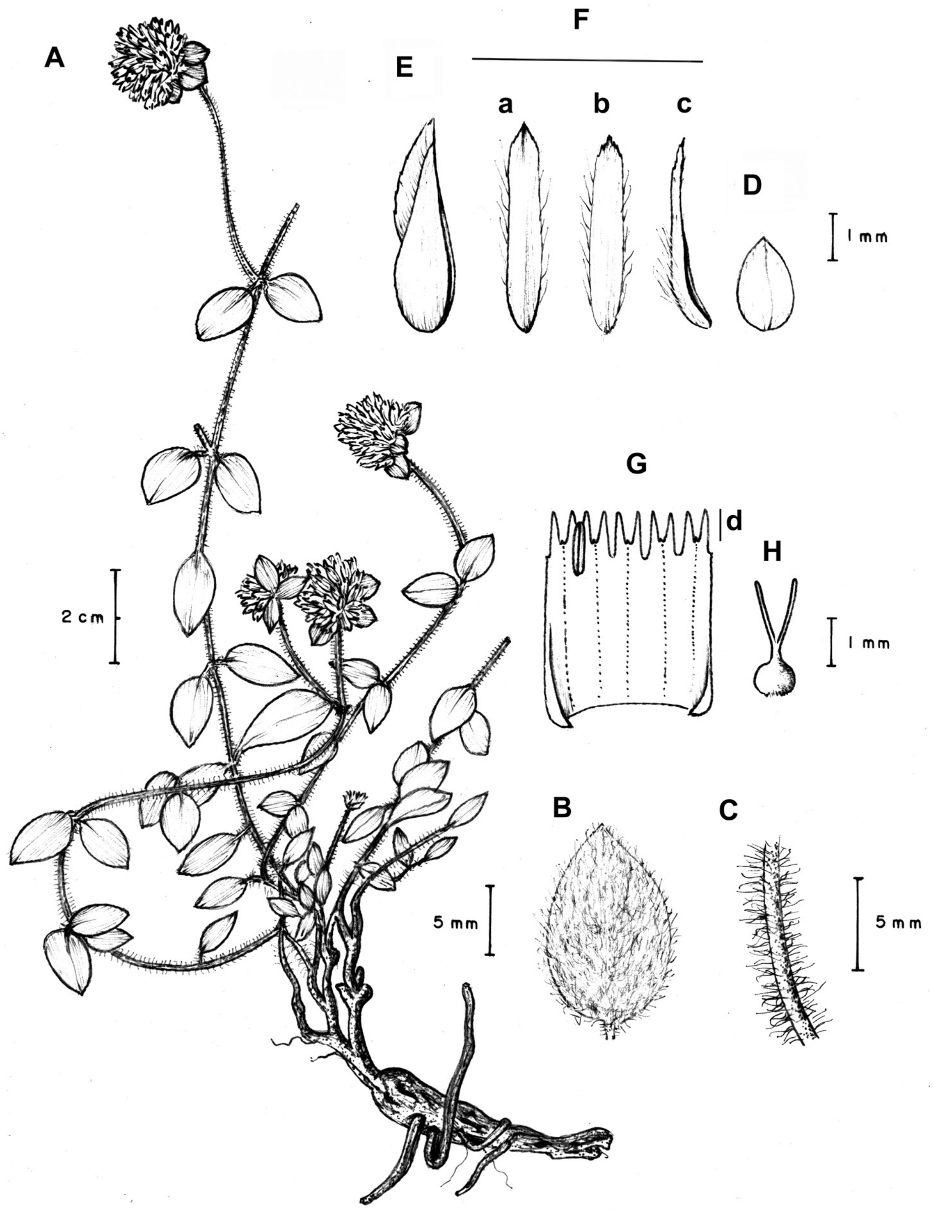

Figure 1. *Gomphrena fuscipellita*. **A.** Habit. **B.** Detail of hirsute indumentum of leaves. **C.** Hirsute indument of stems. **D.** Bract. **E.** Bracteole. **F.** Sepals (a: external, b: intermedian, c: inner). **G.** Detail of the androecium, with the anther inserted between two filament appendices. **H.** Gynoecium [voucher: Borsch and Ortuño 3594]. Drawing: Carlos Maldonado.

−66.4689, −018.5968; 3763 m a.s.l.; 25 Jan. 2016; Lliully, A. leg., 2275; LPB • Rafael Bustillo, Llallagua, Sencoma town, ayllu Laime/ Puraca; −66.5213, −018.7499; 4288 m a.s.l.; 26 Jan. 2016; Jiménez, I. leg., s/n; LPB • Charcas, Vila Kasa on road to San Pedro; −65.8414, −018.1314; 3625 m a.s.l; 29 Jan. 2012; Huaylla H. leg., 1, 3646; 2, 3647; LPB • Charcas, Torotoro ciudad de Itas; −65.5029, −18.0753; 3650 m a.s.l.; Ortuño, T. and Loza, N. leg., 1, 1664; 2, 1665; 3, 1666; 4, 1667; 5, 1668; 6, 1669; LPB — Tarija • Aniceto Arce, El Carmen, −64.8414, −022.0294; 2600 m a.s.l.; 12 Feb. 2006; Zenteno-R, F. leg., 3723; LPB.

The new and previously known records, including data from Ortuño and Borsch (2005), are shown in Figure 4.

Description. Perennial herb 15–30 cm length, 20–30 cm width. Root fleshy, woody taproot in adult plants. Stems decumbent; secondary and tertiary branches short, with dense, long, hirsute indumentum of 2–4 mm long trichomes, fusco, light brown to yellow (Figure 2E). Leaves ovate to elliptical, acute at apex, 1–2.8 × 0.5–1.8 cm, sessile, with margin entire, with densely appressed to villous indumentum on both sides and hirsute at margin, fusco and darkening in color close to the margin and nodes; middle veins prominent (Figure 2C). Involucral leaves all equally sized, ovate to elliptical, acute at apex, 0.5–1.3 × 0.3–1.0 cm, with densely appressed trichomes abaxially, hirsute adaxially and at margin (Figure 2D). Synflorescence terminal, globose, 1.4–2.5 cm in diameter, consisting of 3–5 partial inflorescences, white. Flowers 4–4.6 mm. Bracts ovate to lanceolate, 2.0–2.2 × 0.9–1 mm, membranous to hyaline, acute at apex; margin entire; middle nerve excurrent, white. Bracteoles lanceolate, acuminate at apex, 4–5 × 1.1 mm, equal or slightly smaller (~10%) than the sepals at maturity, membranous to hyaline, with prominent middle nerve, winged and toothed

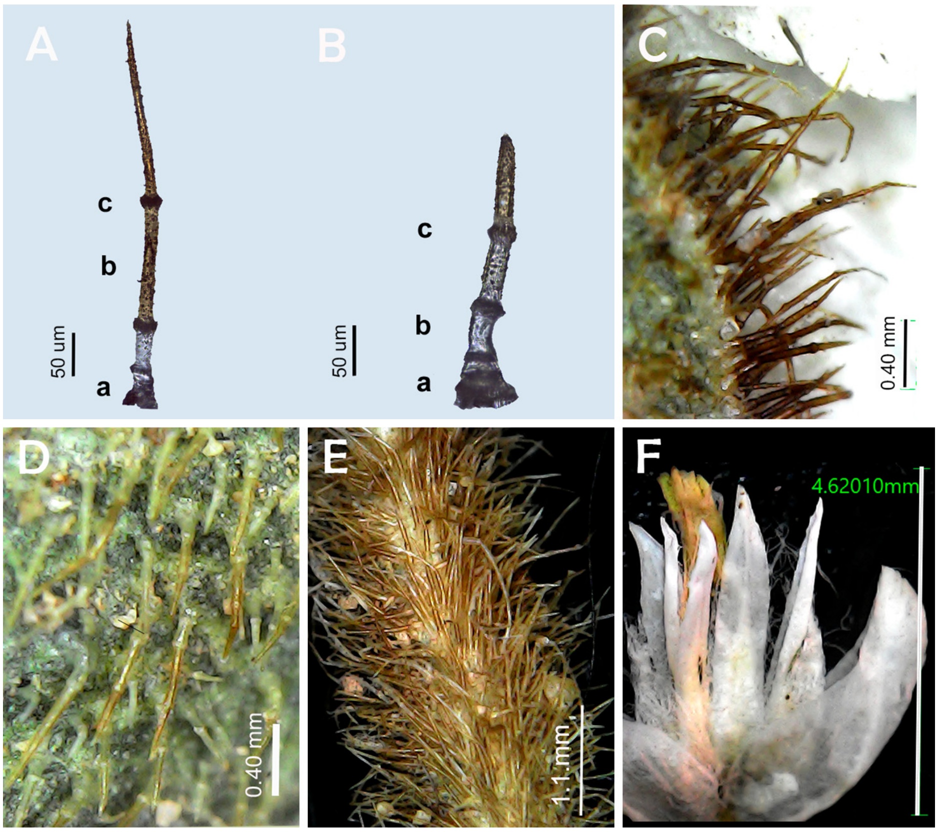

Figure 2. *Gomphrena fuscipellita*. **A.** Uniseriate trichomes of involucral leaves, abaxial side, a) basal cell, b) upper cells, c) interlocking junctions. **B.** Uniseriate trichomes of the involucral leaves, adaxial side, a) basal cell, b) upper cells, c) interlocking junctions. **C.** Trichomes at the margin of the involucral leaves. **D.** trichomes of the adaxial part of involucral leaves. **E.** trichomes of the stems. **F.** Single flower, with the bract removed, and part of the left bracteole. [voucher: T. Ortuño 2700].

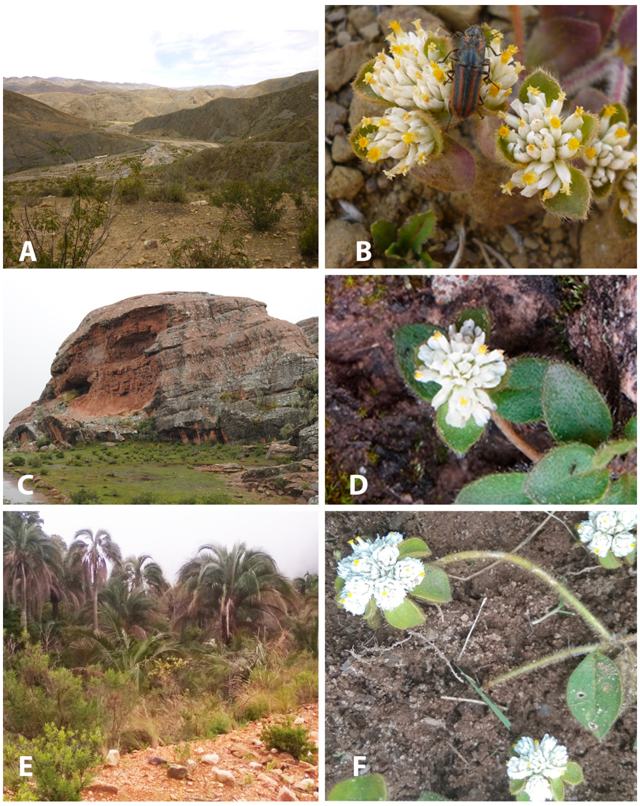

Figure 3. *Gomphrena fuscipellita* specimens (B, D, and F) in different regions. **A, B.** Locality of Kara Kara (Potosí). **C, D.** "ToroToro" Protected Area. **E, F.** "El Palmar" Protected Area. Photo credits: Freddy Zenteno (A, B), Guido Miranda (C), Teresa Ortuño Limarino (D–F).

crest extending for half of the upper dorsal part, white. **Sepals** lanceolate, membranous to hyaline, trichomes on the margin, toothed at apex, size unequal, external sepals 4–4.2(–4.6) mm, intermediate sepals 3.9–4.1(–4.5) mm, inner sepals 3.8–4.0(–4.4) mm, white. **Androecium** with filaments 3.1–5 mm long, largely fused into a tube, 2.1–4 mm long; free part of tube 1 mm long; appendages on filament conspicuous, 0.5 mm long; anthers oblong 1–1.4 mm long, positioned between free lobes of filament appendages. **Gynoecium**: ovary subglobose 0.5 mm; style 0.7 mm; stigmas two, filiform, 1.1 mm long [voucher Borsch, T. and Ortuño, T. 3594 (LPB, B, K, BOLV), type specimen] (Figure 1).

Micromorphology of the trichomes. Multicellular, uniseriate (Figure 2). **Stems and cauline leaves** with 1 or 2 flat basal cells, the first rounded, the second straight, the next 4–6 upper cells with firm consistency, granulated to scarcely spinous in ornamentation, cuticule walls striate; **interlocking junctions** conspicuous, linear scars or projections of extreme border cells, small spines, angle at 45°, overlapping. On **involucral leaves**, adaxial side with 2 or 3 thin, long cells, scarcely spinous or without ornamentation, with flat cuticle walls; on abaxial side of leaf, trichomes large, with 3–6 firm cells, like those on cauline leaves and stems. On **sepals**, trichomes large, with firm basal cells and collapsed upper cells; tissue of sepals composed by elongate, straight, cylindrical dermal cells, arranged in 1 row, with the extremes fitting perfectly [voucher: Borsch and Ortuño 3594].

Geographic distribution. From the 14 variables analyzed, eight variables were the most significant: elevation (47.2%), ecoregions (22.3%), and average precipitation in January (9.9%). Other environmental variables with a lower contribution were annual frequency of frost, annual cloudiness, annual diurnal thermal amplitude, precipitation in October, and maximum annual temperature. The model generated areas with a maximum probability of presence of 99.8%. The Maxent model yielded a total potential distribution area of approximately 27200 km^2, including a >75% probability of presence. Of this surface, only 6.9% (~1900 km^2) is located within protected areas, including Carrasco, Tunari, Toro Toro, Cordillera de Sama and Tunari (Table 1, Figure 6). Besides the currently known occurrence points of *G. fuscipellita*, considerable adjacent areas in the departments of Tarija, Toro Toro, and Cochabamba are estimated to have a high probability of occurrence (>75%, Figure 6), but still need to be evaluated with fieldwork.

Ecology. *Gomphrena fuscipellita* thrives on east-facing slopes with gradients ranging from 25° to 35° (Figure 3). It lives in well-drained, sandy, rocky soils or on rocky outcrops. This species was initially recorded in the

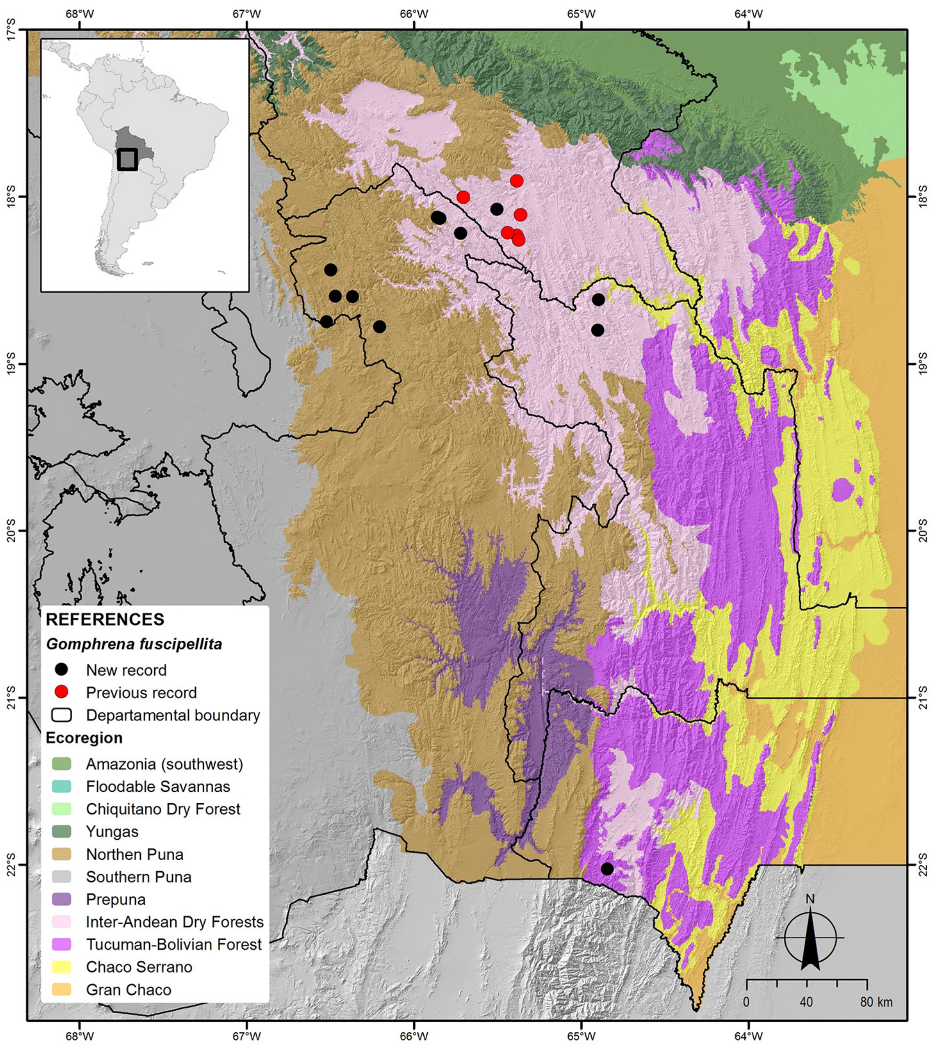

Figure 4. Distribution of *Gomphrena fuscipellita* with ecoregions (according to Ibisch et al. 2003) shown. Previous records (see Appendix) and new records are shown in red and black, respectively.

Table 1. Protected areas with high probability of presence of *Gomphrena fuscipellita*, as estimated by Maxent. Measured here: total surface (TS) of the protected area, intersection surface (IS) between high-probability-presence area and the protected area, and relative percentage IS/TS. TS and IS are given in km^2.

Department	Protected Area	Jurisdiction	TS (km²)	IS (km²)	Rel. %
Cochabamba	Carrasco	National	6864.3	434.2	6.3
Cochabamba	Tunari	National	3260.6	283.0	8.7
Potosi	Toro Toro	National	166.9	166.9	100.0
Tarija	Cordillera de Sama	National	1068.2	117.8	11.0
Cochabamba	Tunari	National	3260.6	343.4	10.5
Santa Cruz	Amboró	National	1587.5	24.2	1.5
Tarija	Tariquía	National	2477.6	33.7	1.4
Tarija	Las Barrancas	Departmental	2.2	2.2	100.0
Cochabamba	Lagarpampa	Municipal	301.3	74.6	24.8
Cochabamba	Cotapachi	Municipal	73.8	73.8	100.0
Tarija	San Agustin	Municipal	72.5	71.9	99.1
Cochabamba	Colcapirhua	Municipal	73.8	69.3	93.9
Cochabamba	Pasorapa	Municipal	1784.8	50.5	2.8
Cochabamba	Norte de Tiquipaya	Municipal	73.8	46.6	63.1
Tarija	Pino del Cerro	Municipal	47.1	47.1	100.0
Tarija	Entre Ríos	Municipal	1602.2	20.9	1.3
Cochabamba	Parque Ecólogico Incachaca	Municipal	4.3	4.3	100.0
Cochabamba	Laguna Alalay	Municipal	2.1	2.1	100.0
Cochabamba	Las Serranias de Pokotaika	Municipal	1.4	1.4	100.0
Cochabamba	Arocagua	Municipal	0.8	0.8	100.0
Cochabamba	Bosque de algarrobos de Tiataco	Municipal	0.2	0.2	100.0

Inter-Andean dry forest ecoregion, but recent discoveries have expanded its range to the semi-humid Puna, at altitudes between 2280 and 4200 m (Figure 4). These regions are generally characterized by low rainfall, with annual precipitation of 400–600 mm.

Geology. *Gomphrena fuscipellita* grows mostly in places with rocky outcrops, sandy soils, and reddish clays. Even though the types of geological soils where this species grows are varied, there is an over-representation in old formations composed of Paleozoic soils (Figure 5) mostly from the Ordovician, Silurian, Devonian, and Carboniferous periods. The Ordovician and Silurian formations (Mizque province in Cochabamba and Chayanta province in Potosí) are made up of sandstones and lutites, which were originated from sediments deposited in marine and coastal environments (Arispe and Diaz-Martinez 1996; Soruco 1996), while the Devonian formation (in Torotoro National Park and El Palmar) has soils composed of fine quartz sands and gray shales. The Carboniferous formation (El Palmar) has quartzites with thin levels of black shales and siltstones with plant fragments (Chacaltana et al. 2011).

DISCUSSION

Geographic distribution. The new records of *Gomphrena fuscipellita* have significantly expanded its original area of distribution, revealing that its area is not only limited to Inter-Andean dry valleys. Our recent findings show that the species seems to be adapted to a variety of ecosystems, including the semi-humid Puna in Potosí and high montane regions. The common factor across these regions appears to be rocky, well-drained soils, often found in open areas near forests or rocky outcrops (Figures 4–6). These new records suggest that *G. fuscipellita* might thrive in a broader range of habitats, possibly due to its morphological adaptations, such as specialized root structures, enabling survival in dry conditions. The plant typically loses its above-ground vegetative parts during dry seasons, while its roots remain dormant, allowing it to endure extreme climate fluctuations. This resilience, combined with changes in the surrounding environment, might support the species' ability to colonize new areas, indicating a response to climatic variability and local ecosystem disturbances.

Despite the fact that most of the current known records of *G. fuscipellita* are centered around Potosí and Cochabamba departments, where the Maxent model projected expanded areas with high probability

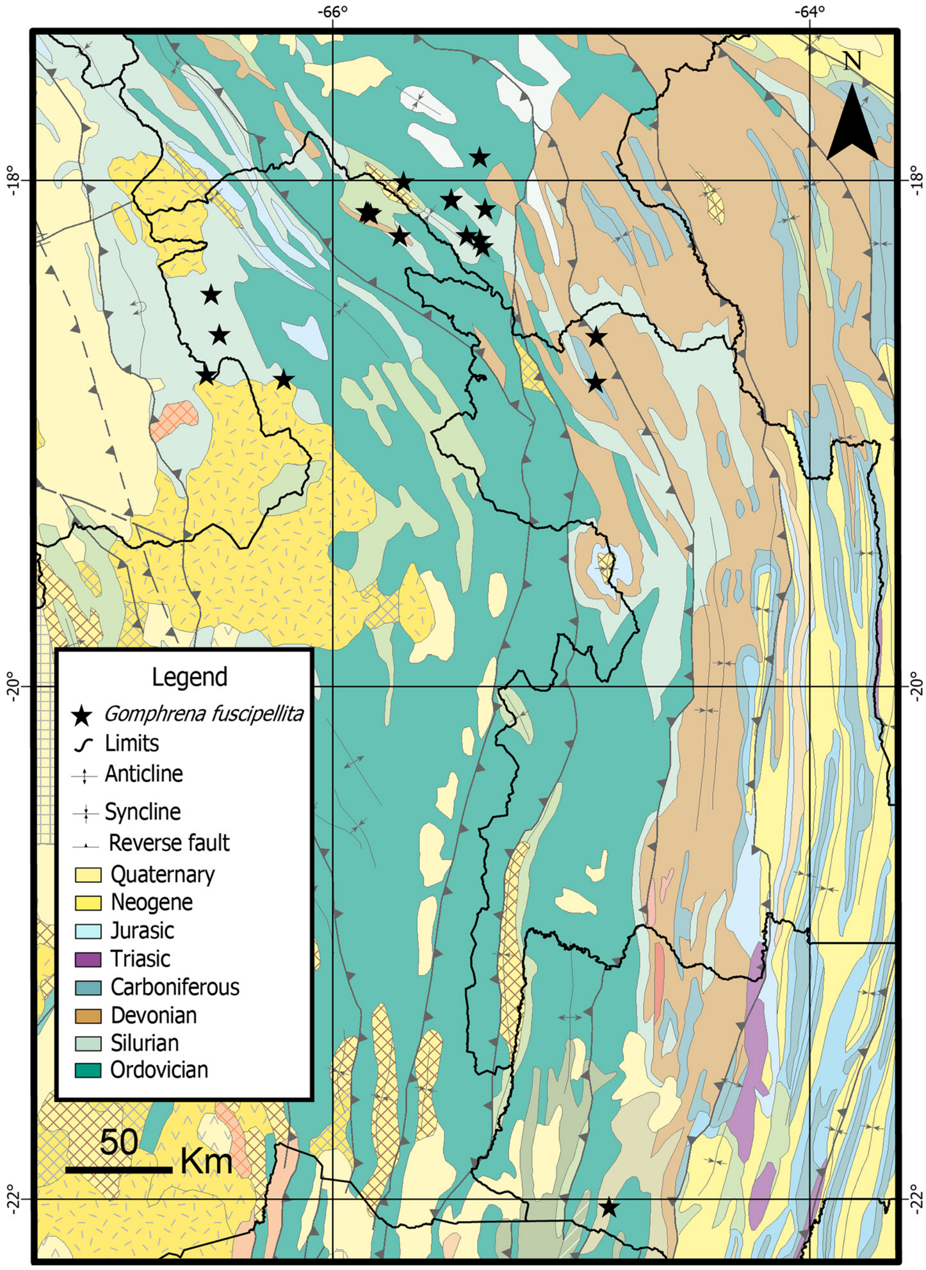

Figure 5. Distribution of *Gomphrena fuscipellita* overlaid on a geological map (Gómez et al. 2019).

of occurrence, the additional record confirmed in Tarija (Zenteno 3723, LPB) revealed an apparent disjunction of ca. 400 km, and the area between these two extremes was mainly projected with low to medium probability of presence (25–75%, Figure 6). However, it should be noted that some areas where the species is known to occur also had low probability of occurrence estimated by Maxent. For example, two-thirds of the El Palmar protected area are in the low probability zone (25–50%, Figure 6), while the remaining third is in the medium-high probability zone (50–75%). This could be because the resolution of environmental variables (e.g. temperature and precipitation) may be too coarse to detect specific microhabitats. On the other hand, the variables used in the model may not represent all the conditions necessary for the presence of the species. Some specific local conditions, such as soil type, may not be captured by the large-scale environmental variables.

Geology. As shown above, the distribution of *G. fuscipellita* is over-represented by Paleozoic formations, which have a marine origin. This marine origin results in saline soils because of mineralization. According to Ortuño and Borsch (2020), the Australian species of *Gomphrena* originate from South American species with coastal habits that are resistant to high salt concentrations. It is hypothesized that this origin occurred through a marine migration of species of *Philoxerus* R.Br. or *Lithophila* Selbmann & Isola, which are now included within *Gomphrena* (Ortuño and Borsch 2020). An open question is whether Andean species of *Gomphrena*, such as *G. fuscipellita*, show a preference for soils of marine origin due to a pre-adaptation to coastal

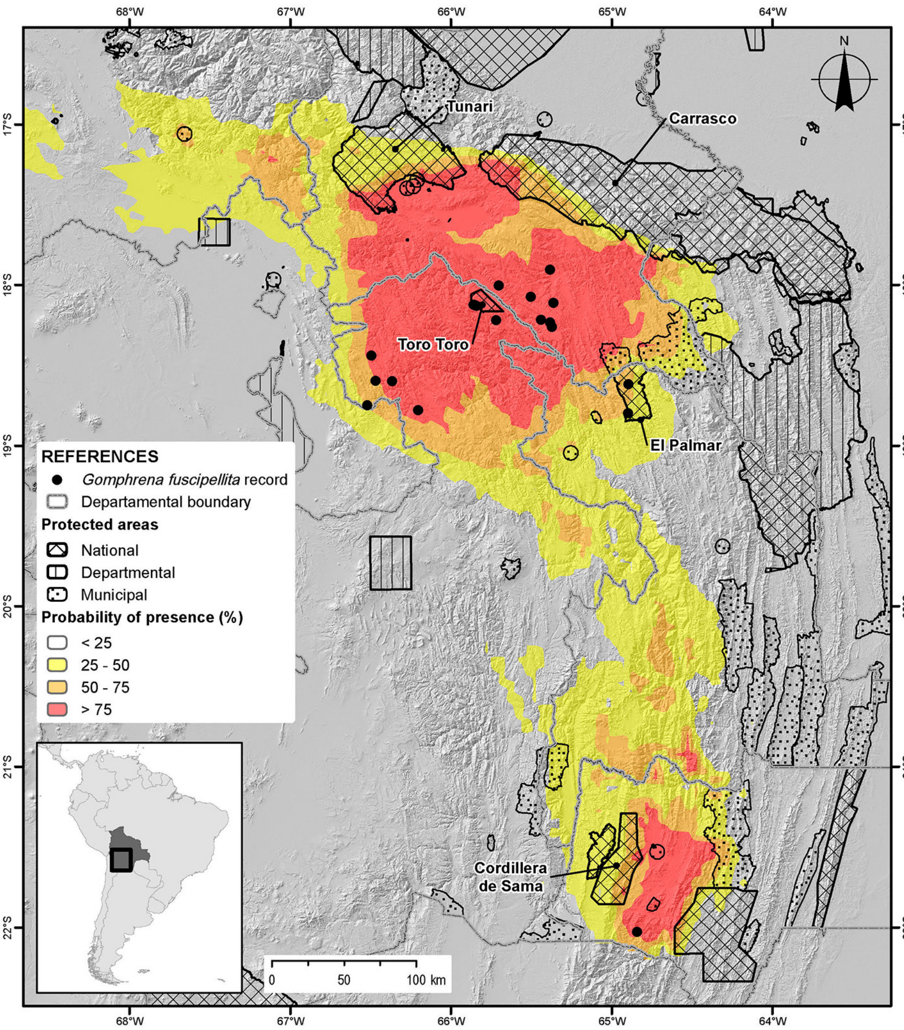

Figure 6. Potential geographic distribution of *Gomphrena fuscipellita* calculated using Maxent software (Phillips et al. 2017).

habits, or if it is a more recent form of acclimation. As stated above, a large part of the distribution area of *G. fuscipellita* consists of ephemeral soils and rocky outcrops, made up of shales (lutites) and psamites (sandstones). These rocks tend to have low porosity, which restricts water retention and limits the availability of water resources during the rainy season (Sempéré et al. 1988). Thus, we hypothesize that this species' ability to survive over long periods of drought could be linked to its adaptation to saline environments, together with the C4 adaptation (Kadereit et al. 2012; Bena 2017; Ortuño and Borsch 2020). Another such adaptation to drought (achieved through root modification) has been documented in *G. meyeniana* Walp. (Ortuño and Bosch 2020). In fact, *Gomphrena* is called "Dormilona" (meaning "sleepy" in Spanish) by the locals because it survives through dormancy during the dry season.

Conservation. *Gomphrena fuscipellita* was categorized as Endangered in the Red Book of the Andean Region of Bolivia, using the International Union for Conservation of Nature (IUCN) methodology. The justification for its endangered status is based on the threats posed by farming and agriculture, as well as its restricted habitat (IUCN 2024). This study reports new findings regarding both the spatial and altitudinal distribution of *G. fuscipellita*. According to the IUCN, 28% of evaluated species are Endangered (Cheek et al. 2020; IUCN 2024). Notably, many specimens were collected in protected areas, such as the protected areas of Toro Toro and El Palmar, which are essential in safeguarding biodiversity and cultural resources. These protected areas play a critical role in preserving ecosystems and mitigating the impact of climate change and urbanization, which affect both natural environments and human communities (Gaston et al. 2008; Dosso et al. 2012; Watson et al. 2014).

Families such as Amaranthaceae highlight the unique flora of the Inte-Andean dry valleys, with extraordinary adaptations to diverse ecological niches, including high-altitude, arid, and saline environments. As Gascon et al. (2015) emphasized, documenting and conserving species is critical to safeguarding ecological resilience, as each species plays a role in ecosystem functionality and human well-being. Similarly, Löbl et al. (2023) highlighted the urgent need to address the decline in taxonomic expertise and its implications for biodiversity conservation, underscoring the necessity of legal and scientific support to accelerate taxonomic work and mitigate species extinctions. In remote Andean areas, such discoveries emphasize the urgent need for conservation strategies that balance ecological preservation with sustainable development. By integrating taxonomy, ecology, and conservation, the study of unexplored Andean regions provides critical insights into global biodiversity patterns and reinforces the importance of preserving these ecosystems for future generations.

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ADDITIONAL INFORMATION

Conflict of interest

The authors declare that no competing interests exist.

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Author contributions

Herbarium work and fieldwork: TO. Analysis: TO, EC, DBMT, SL, PD. Writing original draft: TO, EC, DBMT, SL, and PD. Writing review and editing: PD.

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Data availability

All data that support the findings of this study are available in the main text.

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APPENDIX

The following are older records, already published in Ortuño and Borsch (2005), that form part of the distribution map of Figure 4.

Paratypes. BOLIVIA — Cochabamba • Mizque, road between Mizque and Raykampampa, going up from Tintin to Raykampampa; −65.3609, −018.1113; 2870 m a.s.l.; 3 Apr. 2003; Borsch, T. leg., 3594; LPB, B (this is the type specimen) — Cochabamba • Mizque, road from Raykapampa to Molinero along the old road; −65.3833, −018.2333; 2935 m a.s.l.; 4 Apr. 2003; Borsch, T. leg., 3608; LPB, B — Cochabamba • Mizque, Raqaypampa, Kollpana town; −65.7027, −018.0043; 2860 m a.s.l.; 10 Apr. 1992; Gutiérrez, E. leg., 57; BOLV, LPB — Cochabamba • Mizque, Ramadero town; −65.3839, −017.9059; 2280 m a.s.l.; 14 Mar. 1994; Lopez, A. leg., 381; BOLV, LPB — Cochabamba • Mizque, Equestrian trail from Molineros to Botijas; −65.4389, −018.2183; 2700 m a.s.l.; 24 Jan. 1994; Lopez, A. leg., 151; BOLV, LPB — Cochabamba • Mizque, Cantón Molinero, Rakaypampa; −65.3716, −018.2621; 2792 m a.s.l.; 11 Jan. 1987; Sigle, M. leg., 237; LPB.