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Short Note

Shrews on top of high mountains: a new elevational record for *Sorex minutus* Linnaeus, 1766 (Eulipotyphla: Soricidae) in Europe

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Abstract

The Eurasian pygmy shrew, *Sorex minutus* Linnaeus, 1766 (Eulipotyphla: Soricidae), one of the smallest terrestrial mammals, is widely distributed from the British Isles and the Iberian Peninsula across continental Europe to Siberia. The species has been recorded at elevations from sea level to 2.500 m in the European Alps. This note reports two new elevational records that extend the known elevational range by 780 metres higher. Three individuals were collected as bycatch in pitfall traps for ground-dwelling invertebrates above 3.000 m elevation in the Eastern Alps in South Tyrol, Italy. Additionally, we provide data on the potential prey at these sparsely vegetated high alpine sites, where Coleoptera (mainly Carabidae) and Arachnida (Opiliones and Araneae) dominated in abundance and biomass, suggesting that they represent the main trophic resources.

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Introduction

The Eurasian pygmy shrew, *Sorex minutus* Linnaeus, 1766, is one of the smallest mammals in Europe and belongs to the family Soricidae (order Eulipotyphla). Adults measure between 4.0 and 6.4 cm in length, excluding the tail (3.3–4.5 cm; Wilson and Mittermeier, 2018). The distribution of *S. minutus* spans a wide geographical range across Europe and parts of northern Asia. Within Europe, it is commonly found in the western regions, such as the British Isles and the northern Iberian Peninsula, and extends eastward through central and eastern Europe into Russia and the Ural Mountains (Taylor, 2023).

The species has been recorded at elevations from sea level to 2.500 m a.s.l., with the highest elevations reported in Switzerland (2.496 m at the Alp Flix; Suter, 2023; Blant and Müller, 2021; Marchesi et al., 2014), Italy (2.480 m; Amori et al., 2008), Austria (2.260 m; Spitzenberger, 2001), Slovakia (2.250 m in the Slovak Tatras; Rosický and Kratochvíl, 1955), and Spain (2.000 m in the Pyrenees; Palomo et al., 2007).

Sorex minutus has an extremely high metabolic rate, requiring frequent feeding throughout the day. To meet its energy demands, individuals must consume a substantial amount of food relative to their body weight (Taylor, 2023; Churchfield, 1990). *Sorex minutus* feeds mainly on harvestmen (Opiliones), spiders (Araneae), and adult beetles (Coleoptera) (Churchfield and Rychlik, 2006; Churchfield, 1984).

In the summer of 2023, a first subadult female specimen was accidentally caught in South Tyrol, the northernmost province of Italy (Fig. 1), as bycatch in a pitfall trap used for collecting ground-dwelling invertebrates (Tab. 1; Fig.2). The site, at an elevation of 3.060 m, is near the border with Switzerland and the Piz Sesvenna peak (3.204 m, Sesvenna Alps); hereafter the site is mentioned as 'Piz Sesvenna' (Fig. 1–2). The pitfall traps were active from 17 July to 9 August 2023 (i.e., 23 days). This sampling site is part of 320 plots in the comprehensive 'Biodiversity Monitoring South Tyrol' project (Hilpold et al., 2023). In the summer of 2024, two additional subadult specimens were also accidentally caught as bycatch in pitfall traps that were active during 1–23 August 2024 (i.e., 22 days). This second site is 200 metres higher, at 3.280 m, and located near the Similaun peak (3.606 m, Ötztal Alps); hereafter this site is mentioned as 'Similaun' (Fig. 1–2). This sampling point is part of the international mountain biodiversity project 'Global Observation Research Initiative in Alpine Environments' (GLORIA, 2024), which assesses plants (Pauli et al., 2015) and, just recently, ground-dwelling invertebrates (Komposch et al., 2020) on remote mountain tops.

The 'Piz Sesvenna' site is characterised by a rocky high alpine environment (Fig. 1–3A), with scattered and fragmented alpine vegetation. Nineteen plant species within a 10 m^2 area were documented on the site (following the protocol of Hilpold et al., 2023). The 'Similaun' site (Fig. 1–3B) is a rocky high alpine area on a ridge within a periglacial zone, where a botanical survey revealed 13 plant species (Martin Mallaun, *pers. comm.*) in accordance with the 'GLORIA' protocol (Pauli et al., 2015). At both sites, the botanical surveys were conducted in the same summer in which each shrew was collected. Based on vegetation and habitat types, both areas can be classified within the alliance Androsacion alpinae Br.-Bl. in Br.-Bl. et Jenny 1926 – silicate screes of the alpine and nival levels and moraines (Habitat 8110, Habitat Directive - 92/43/EEC; Wilhalm et al., 2022; Delarze et al., 2015). The higher 'Similaun' site, at nearly 3.300 m, was further described as initial stage of the Androsacetum alpinae association Br.-Bl. in Br.-Bl.

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et Jenny 1926, as not all typical plant species of this association have yet been established (Nicklas et al., 2021).

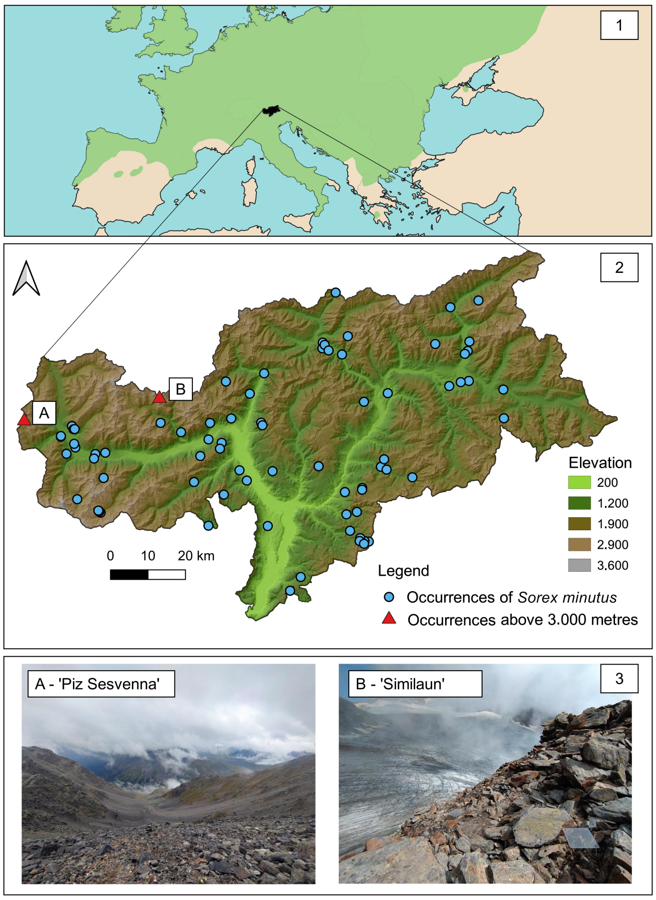

Figure 1 – 1) Central European distribution of *Sorex minutus* modified from Taylor (2023); in black the location of South Tyrol, Italy. 2) Occurrences of *Sorex minutus* in South Tyrol, Italy, based on 138 records; data were retrieved from the database of the Museum of Nature South Tyrol, Bozen/Bolzano. The new records are indicated as red triangles. 3) Photographs of the 'Piz Sesvenna' (A) and the 'Similaun' (B) sampling sites in South Tyrol.

During the three-week sampling period, when the pitfall traps were active, the following list of arthropod taxa was recorded. At the 'Piz Sesvenna' site, the most abundant group was Carabidae (Coleoptera) corresponding to 50.1 % of the total ground-dwelling fauna abundance (i.e., 2.4±0.6 individuals/day), followed by Phalangiidae (Opiliones, 12.6 %) and Craspedosomatidae (Diplopoda, 12.6 %). Two other abundant groups were Staphylinidae (Coleoptera) and Linyphiidae (Araneae) contributing 9.7 % and 9.4 % to the total abundance, respectively. On average, 4.8±1.7 ground-dwelling invertebrates were captured per pitfall trap per sampling day (Tab. 2). Looking at the total biomass of this arthropod community (measured as mg fresh weight per sampling day), the same three taxa were the most important; Carabidae dominated with 61.0 %, followed by Craspedosomatidae with 22.5 % and Phalangiidae with 10.8 % biomass.

A similar picture was found at the highest site 'Similaun', where the beetle families Carabidae and Staphylinidae accounted for 70.1 % and 11.7 % of the total abundance, respectively (i.e., on average 4.6±2.7 individuals/day), followed by Phalangiidae (5.2 %) and Lycosidae (Araneae, 3.2 %) (Table 2). Carabidae led in biomass, representing 83.7 % of the total ground-dwelling fauna biomass, followed by Phalangiidae (7.0 %) and the two Araneae families Gnaphosidae and Lycosidae (4.5 % and 4.3 %, respectively).

Notably, Staphylinidae and Linyphiidae were abundant at both sites, but due to their small body size, they represented only a small fraction of the total biomass (Tab. 2). Furthermore, Collembola and Acari (both soil mesofauna) were also abundant (i.e., >150 individuals/day), but due to their small size (<2 mm), their biomass could not be assessed.

Figure 2 – Left: *Sorex minutus* specimen retrieved at 3.280 m elevation at the 'Similaun' site (Ötztal Alps) in South Tyrol, Italy. Right: Skulls and mandibles from the three specimens. HM = height of mandible; LM = maximum length of mandible; ZB = zygomatic breadth; CBL = condylobasal length. Voucher codes (MAM) for each specimen deposited in the Museum of Nature South Tyrol are given..

Herein we present new elevational records for the Eurasian pygmy shrew in Europe, which exceed the previously reported maximum elevational range by 780 metres and extend the known elevation limit above 3.000 m. There may be four main potential explanations for the previously unreported high alpine presence of this species. First, the species is often neglected because it is not listed as a target species under any European Habitat Directive, resulting in limited monitoring efforts (Bertolino et al., 2023; Lang et al., 2022). Second, studying this species poses significant challenges (Bertolino et al., 2015; Pocock and Jennings, 2006). Interestingly, while pitfall traps are primarily designed for ground-dwelling invertebrates such as spiders, beetles, and millipedes, they have been shown to be particularly effective in capturing *S. minutus* (Amori et al., 2008; Yalden, 1981). In contrast, live traps, a method for studying shrews, are severely limited in capturing *S. minutus* due to the animal's extremely light weight (3.0–4.5 g) which often fails to trigger the trap mechanism (Pocock and Bell, 2011).

Table 1 – Measurements (mean mm± standard deviation of three replicates) of three subadult (sub) specimens of *Sorex minutus* from two high alpine sites in South Tyrol, Italy. F = female; ND = sex not identified. Cranial measurements were taken with a Leica S APO stereoscope (Leica Microsystems GmbH, Wetzlar, Germany), while body measurements were obtained with a calliper (accuracy of 0.05 mm). Locality and voucher codes (MAM) from the Museum of Nature South Tyrol are given.

Variable	Piz Sesvenna (sub-F) MAM 2419	Similaun 1 (sub-F) MAM 2430	Similaun 2 (sub-ND) MAM 2431
Tail length	44.00 ± 0.10	41.50 ± 0.10	42.00 ± 0.10
Hind foot length	11.00 ± 0.10	10.25 ± 0.25	10.50 ± 0.50
Condylobasal length	16.30 ± 0.25	16.33 ± 0.02	16.10 ± 0.10
Height of mandible	3.25 ± 0.05	3.10 ± 0.10	3.25 ± 0.03
Maximum length of mandible	6.45 ± 0.50	6.30 ± 0.50	6.35 ± 0.50
Zygomatic breadth	4.10 ± 0.10	3.88 ± 0.01	4.00 ± 0.00

Table 2 – Abundance and fresh biomass (mean ± standard deviation) of the top five grounddwelling macroinvertebrate taxa captured using the pitfall trap method on high alpine mountains in western South Tyrol, Italy. The data are averaged over four pitfall traps at each sampling site. To standardise the data, the number of individuals and fresh biomass were divided by the number of sampling days (i.e., 23 days for the 'Piz Sesvenna' site and 22 days for the 'Similaun' site).

'Piz Sesvenna'

Top 5 Taxa	Order	Abundance [ind./day]		Biomass [mg/day]	
Carabidae	Coleoptera	2.424 ± 0.643	50.11%	67.346 ± 17.06	61.01%
Phalangiidae	Opiliones	0.609 ± 0.177	12.58%	11.874 ± 4.931	10.76%
Craspedosomatidae	Diplopoda	0.609 ± 0.198	12.58%	24.823 ± 35.15	22.49%
Staphylinidae	Coleoptera	0.467 ± 0.424	9.66%	0.229 ± 0.218	0.21%
Linyphiidae	Araneae	0.457 ± 0.135	9.44%	0.317 ± 0.124	0.29%
Rest		0.272 ± 0.358	5.62%	5.790 ± 8.256	5.25%
TOTAL (17 taxa)		4.837 ± 1.685		110.379 ± 64.55	

'Similaun'

Top 5 Taxa	Order	Abundance [ind./day]		Biomass [mg/day]	
Carabidae	Coleoptera	3.193 ± 2.264	70.07%	96.776 ± 70.28	83.71%
Staphylinidae	Coleoptera	0.534 ± 0.763	11.72%	0.181 ± 0.233	0.16%
Phalangiidae	Opiliones	0.239 ± 0.068	5.24%	8.045 ± 4.316	6.96%
Lycosidae	Araneae	0.148 ± 0.146	3.24%	4.973 ± 4.508	4.30%
Gnaphosidae	Araneae	0.125 ± 0.044	2.74%	5.141 ± 3.181	4.45%
Rest		0.318 ± 0.388	6.98%	0.491 ± 0.761	0.43%
TOTAL (13 taxa)		4.557 ± 2.728		115.607 ± 80.67	

Third, studies at high elevations are generally scarce (but see Praeg et al., 2025; Suter, 2023; Winkler et al., 2018; Marchesi et al., 2014), which further explains the lack of data on this elevational belt. Research on the alpine soil fauna and ground-dwelling animals, during which shrews might be detected as bycatch, is mainly conducted in Central Europe and Central Asia, but less in other regions of the world (Praeg et al., 2025).

Finally, global warming, which is particularly pronounced in the European Alps, has led to a temperature increase twice the global average, making Europe the fastest warming continent (Copernicus Climate Change Service (C3S), 2024). Temperature changes may directly and indirectly affect the elevational distribution of *S. minutus* and its prey, as warming may create more favourable conditions and cause an upward shift in the range of different organisms, but there are only few studies to date (e.g., Gilgado et al., 2022; Hågvar et al., 2024), and more research is needed (Dainese et al., 2024).

Nonetheless, we suggest that this species either has always been present at high elevations or recently expanded its range, supported by its high adaptability and broad ecological potential (Taylor, 2023). The discovery of three subadults may indicate reproductive activity and suggest a stable population of the species at these high alpine sites. On the other hand, some studies suggest that subadult males could undertake remarkably long dispersal movements (Mukhacheva and Tolkachev, 2022; Shchipanov et al., 2005), potentially as an adaptation to the small and scattered nature of populations. While this option cannot be entirely excluded, we must consider the fact that an alpine scree is a challenging habitat for wide-ranging movements of such a small mammal. These considerations lead to two possible scenarios. The first assumes continuous reproduction sustained by the availability of food and life beneath the snow cover. The second suggests the possibility of vertical movement, as documented by some studies. However, it is important to acknowledge substantial gaps in global research on this phenomenon (Mukhacheva and Tolkachev, 2022).

In general, *S. minutus* inhabits predominantly moist ecosystems such as forests, grasslands, and shrublands, where dense ground cover provides essential shelter and food resources (Taylor, 2023). At our high alpine sites, with almost no vegetation, rocks and boulders may provide the necessary shelter, corridors, and gap systems for these animals, ensuring also sufficient protection (e.g., insulating snow cover) against low temperatures and storms during environmental extremes (Shi et al., 2014).

Furthermore, based on the literature, the diet of *S. minutus* consists mainly of invertebrates that are available as prey in the surrounding environment (Churchfield, 1990; Pernetta, 1976), with a preference for small prey sizes (1–5 mm) in forest habitats (Churchfield and Rychlik, 2006). As food is generally scarce in the high alpine environments, more opportunistic feeding strategies by some species have been observed compared to their lower-elevation counterparts (Hågvar et al., 2020; Steinwandter et al., 2018). In our high alpine study sites, the potential prey caught via pitfall traps was mainly larger than 10 mm but also included larger specimens of the soil mesofauna (up to 2 mm body size). This suggests two possibilities: either pitfall trap catches may not entirely capture the potential prey of the Eurasian pygmy shrew in this environment, or the shrew's diet consists of the larger body parts instead of entire specimens of the prey. To resolve this, further investigation of gut contents or direct observations of their feeding behaviour in the field is necessary.

Furthermore, *S. minutus* may exhibit a different dietary preference in the absence of larger competitors, consistent with the competitive release phenomenon. Dickman (1988) demonstrated that, in environments where the larger *Sorex araneus* Linnaeus, 1758 is experimentally removed, *S. minutus* increases its consumption of larger prey. At higher elevations, where *S. araneus* and other large competitors, such as *Sorex alpinus* Schinz, 1837, are presumably less abundant, *S. minutus* might similarly shift its diet toward larger prey. However, it is important to note that *S. araneus* may still be present at these elevations, as reproductive populations have been recorded at elevations up to 2.500 m in Switzerland (Müller and Maddalena, 2021; Marchesi et al., 2014).

In conclusion, our new findings represent a valuable addition to understanding how specimens live at the edge of alpine ecosystems and set new elevational limits to the distribution of the Eurasian pigmy shrew in Europe, which was previously never recorded above 2.500 m.

Further research is needed to determine whether populations of *S. minutus* have long existed at these high elevations, or they have recently colonised higher areas. Investigating gut contents, genetic markers, and morphology could reveal whether these species are specifically adapted to the alpine environment, or they represent locally adapted variants. Genetic and morphological comparisons could help to clarify whether alpine populations differ from those at lower elevations, enhancing our understanding of how organisms adapt to such extreme environments. We also encourage the exchange of incidental bycatch data or samples among experts to further enrich the scientific knowledge of *Sorex* species and alpine ecosystems at large, which require special conservation attention due to their inherent vulnerability to global change.

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