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Battisti, Andrea

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Living on the edge: range limits of four short-winged endemic Orthoptera in the Northwestern Alps (Aosta Valley)

Andrea BATTISTI[1,*]

[1] *Mont Avic Natural Park, Loc. Covarey, 21 – 11020 Champdepraz (AO), Italy*

* *corresponding author, email: andre.battisti@gmail.com*

Keywords: *Anonconotus*, biogeography, endemism, *Epipodisma*, *Stenobothrus*.

SUMMARY

This study investigates the north-eastern distributional limits of four short-winged endemic Orthoptera from the north-western Alps: *Anonconotus ghilianii*, *A. pusillus*, *Epipodisma pedemontana*, and *Stenobothrus ursulae*. Their spatial and altitudinal distributions were addressed within the Special Protection Area (SPA) IT1202020 "Mont Avic and Mont Emilius", including the Mont Avic Natural Park, representing the north-eastern biogeographical margin for *A. pusillus*, *E. pedemontana*, and *S. ursulae*. In contrast, *A. ghilianii* occurs in the area as a small and isolated population of particular biogeographical interest. For comparison, two additional short-winged species with broader European ranges, *Bohemanella frigida* and *Podisma pedestris*, were also examined. A total of 258 records collected during 2020–2021 allowed the reconstruction of fine-scale distribution patterns within the study area. Most records (91.5%) were obtained above 1,950 m, highlighting the strong altitudinal affinity of these taxa. Higher upper altitudinal limits were documented for *E. pedemontana* (2,842 m a.s.l.) and *S. ursulae* (3,074 m), while the other two endemic species were confirmed at their upper elevational thresholds, with occurrences recorded in this study at 2,482 m for *A. ghilianii* and 2,827 m for *A. pusillus*. The spatial and altitudinal patterns observed are discussed in a broader Alpine context, and the distribution ranges of the four endemic species are interpreted in relation to adjacent mountainous sectors. The discussion of the genus *Anonconotus* also includes two additional species distributed adjacent to the study area, *A. alpinus* and *A. occidentalis*. These findings contribute to a better understanding of peripheral range dynamics, high-altitude biogeographical structuring, and the biogeographical history of endemic short-winged Orthoptera of the north-western Alps.

INTRODUCTION

The Alps host a wide and diverse environmental and geographical differentiation. This complexity, combined with the geographical isolation caused by Quaternary glaciations, has led to the presence of numerous endemic species (Schönswetter et al. 2005, Menchetti et al. 2021), often with very limited distribution ranges. Many of these taxa are characterized by low dispersal capacity, especially in short-winged or flightless insects (Heppner 1991) and Orthoptera are generally no exception (Kenyeres et al. 2009), although some exceptions have been reported under anthropogenic influence (Holuša et al. 2026). Within the Italian Alps, the order Orthoptera includes 32 endemic taxa (Massa and Fontana 2020), most montane taxa being concentrated in the extreme western and eastern sectors of the mountain chain. These two areas differ from the rest of the Alps both in the endemic taxa they host and in their overall biodiversity, a pattern attributable to the role played by interglacial Holocene refugia on high mountain summits (Berger et al. 2010).

The Pennine Alps, located between the Graian Alps in the Aosta Valley and the Lepontine Alps in the Ossola Valley, appear to constitute a biogeographical transition zone between a western context richer in endemic taxa and the Italian Central Alps, which host few endemic taxa and exhibit lower overall biodiversity, particularly regarding Orthoptera (Battisti et al. 2016). Within the Graian Alps, the Mont Emilius massif represents one of the westernmost sectors still rich in endemic fauna (Toso and Balletto 1976, Focarile and Casale 1978, Grehan and Knyazev 2019) and characterized by high taxonomic diversity, especially among insects (Allegro and Chiarabaglio 2007, Alma et al. 2009, Battisti et al. 2026).

Previous studies have investigated the Orthoptera community in parts of this sector, particularly within the Mont Avic Natural Park (Sindaco et al. 2007) and the Cogne Valley (Baroni 2015). These last works reported the presence of three species strictly endemic to the western Alps: *Anonconotus pusillus* Carron and Sardet, 2002; *Epipodisma pedemontana* (Brunner, 1882); and *Stenobothrus ursulae* Nadig, 1986; all characterized by short-winged states, and so poorly capable of long-range dispersal. Furthermore, all three species reach their westernmost distributional limit in the Graian Alps. In the adjacent sectors located slightly further west, another endemic species, *Anonconotus ghilianii* Camerano, 1878, reaches the peripheral margin of its distribution range.

In light of recent climate change (Pauli et al. 2001, Gonzales and Neilson 2010) and ongoing global biodiversity decline (Ceballos et al. 2015), both major threats to alpine ecosystems (Ernakovich et al. 2014), particularly in the Alps (Gobiet et al. 2014, Kuhn and Olefs 2020), we provide a detailed assessment of the current distribution of several low-vagility Orthoptera species in the Mont Avic – Mont Emilius massif. The study also contributes to understanding the biogeographical history and distribution of the genus *Anonconotus* Camerano, 1878, which remains of considerable biogeographic and taxonomic interest (Carron et al. 2002, Galvagni 2005, Galvagni and Fontana 2006). Finally, this work establishes a baseline for future local-scale research on climate-driven altitudinal shifts, an increasing threat to Orthoptera (Hochkirch et al. 2016).

MATERIALS AND METHODS

The study area corresponds to the Special Protection Area (SPA) “IT1202020-Mont Avic and Mont Emilius", part of the European Natura 2000 Network (Trochet and Schmeller 2013), entirely located in the Aosta Valley, in the north-western Alps. This SPA includes the Special Areas of Conservation “IT1202000-Mont Avic Natural Park".

This mountain area encompasses a vast territory of the North Western Alps, extending from the Cogne Valley in the west, along the entire orographic right-hand side of the Dora Baltea River, and reaching the border with the Piedmont region in the southeast. The SPA covers an area of 31,544 hectares, with an altitude range spanning from 900 to 3,559 meters (Mont Emilius summit).

This work originated with the launch of the Italy–France ALCOTRA cross-border cooperation project 2014/20 no. 3896 COBIODIV (see Acknowledgments for details), focused on protected, rare, or endemic species. Field data were collected by the author with the aim of answering the following question: Where exactly do the distributions of the target species terminate in this marginal sector of their range?

Data were collected for four endemic species: *Anonconotus ghilianii*, *A. pusillus*, *Epipodisma pedemontana*, and *Stenobothrus ursulae*. These taxa were selected based on their

brachypterous condition and consequently reduced dispersal ability, which is associated with limited gene flow, high habitat specialization, and narrow geographic ranges, making them particularly suitable for analysing peripheral distributional limits in Alpine Orthoptera. As a comparative framework for assessing range limits of brachypterous Alpine Orthoptera more broadly, and to enrich the faunistic dataset of the area, two additional short-winged species were also included: *Bohemanella frigida* (Boheman, 1846) and *Podisma pedestris* (Linnaeus, 1758).

Orthoptera were primarily identified in the field based on external morphological traits, following Massa et al. (2012) and Sardet et al. (2015). For *Anonconotus*, some specimens were collected to examine male titillators under magnification (5–45×) to distinguish Western Alpine species (Carron et al. 2002, Galvagni 2005, Galvagni and Fontana 2006).

Visual Encounter Surveys (VES) were carried out at each locality within representative habitats for the target species, or at key topographic features (e.g. mountain passes, summits, and ridgelines). At each site, at least one sample area of 0.25 ha was surveyed. Each sample area was searched for at least 20 minutes targeting adult individuals. In extensive, homogeneous habitats, total survey effort was increased to at least 1 hour per site and included multiple sample areas. Where vegetation was present, it was gently brushed aside with a stick while walking through the sampling area to flush individuals and enable visual detection within approximately 1 m on either side (flushing technique; Gardiner & Hill 2006). Given the sparse alpine vegetation and low species richness, this method was considered adequate for presence/absence surveys.

Sampling localities were selected to provide representative coverage of the study area and the main geographic contexts relevant to the target species' distributions. A total of 78 localities (Fig. 1, Table 1) were surveyed with at least two visits per site across the 2020 and 2021 field seasons. Surveys were conducted during the peak adult period, within an altitudinally adjusted seasonal window from July to October. When target species were not detected during the first visit, a second survey was carried out later in the same season or in the following year, usually shifted toward late summer or early autumn to increase detectability under conditions of reduced vegetation cover and continued adult activity despite low temperatures. Sites where target species were detected during the first visit were not always revisited.

All field data were recorded in real time using a latest-generation Android smartphone equipped with the "NaturaList" application (Biolovision SARL, 2020) and an active GPS, with positional accuracy of ≤25 m. Presence records were defined as sampling events at the level of species by 0.25 ha sampling area by survey day. Occasional presence records collected while accessing or leaving sampling locations were treated as independent occurrences.

Following fieldwork, all data were exported to a spreadsheet and analysed and visualised using QGIS (QGIS Development Team, v.3.44). For the narrow-range endemic species *A. pusillus*, *S. ursulae*, and for the eastern nucleus of *A. ghilianii*, the Extent of Occurrence (EOO) was estimated following IUCN Red List guidelines (IUCN 2024) as a minimum convex polygon (MCP) derived from all available georeferenced occurrence records, including both original or published data. Only for the eastern nucleus of *A. ghilianii*, where records are scarce, the MCP was also derived from citizen-science observations from iNaturalist (2025). For all four target species, and restricted to the Italian sector of the Alps north of the Susa Valley (north of Moncenisio), an Altitudinally Constrained EOO (AC-EOO) was calculated using a conservative approach to reduce potential overestimation of the species' extent of occurrence. The suitable area was restricted to elevation bands defined by applying buffered limits to known occurrences, by rounding the minimum elevation downward and the maximum elevation upward to the nearest 100 m. These limits were based on the minimum and maximum altitudes reported in the literature and/or derived from original data. The procedure was applied separately to the Piedmont and Aosta Valley datasets, using all available presence records and associated habitat information to ensure consistency across regions. Only for the eastern nucleus of *A. ghilianii* the altitudinal limits were based exclusively on published data due to its more restricted distribution within the study area. The AC-EOO was implemented in QGIS, resulting in spatial polygons derived as follows: contour lines were extracted as vector layers from a Digital Surface Model (DSM) raster file. These were subsequently simplified using the Simplify tool, applying the Ramer–Douglas–

Peucker algorithm with a tolerance value set to 1,000 m. The area between the minimum and maximum contour lines (species-specific) was then smoothed using the Smooth tool, with parameters set to 20 iterations, a 25% offset, and a maximum node angle of 180°. The AC-EOO within the study area was refined through intensive field sampling, allowing the confirmation of species presence and absence. Altitudinally suitable areas without confirmed records were therefore excluded from the final AC-EOO estimates. This approach provides a geographically explicit representation of potential distribution limits under ecologically realistic altitudinal constraints.

For comparative purposes, Citizen Science (CS) observations from NW-Alps of *A. alpinus* (Yersin, 1858), *A. ghilianii*, *A. occidentalis* Carron & Wermeille, 2002, and *E. pedemontana* were included. Data were obtained from iNaturalist.org, updated to October 2025, and restricted to Research Grade observations (iNaturalist 2025). CS records of *A. pusillus* and *S. ursulae* were excluded because their exact locations are obscured on iNaturalist for conservation purposes.

Table 1. Local names and elevations of the 78 surveyed localities shown and numbered in Fig. 1. Topographic features are marked with an asterisk (*).

n°	Localities	Elevation (m s.l.m.)	n°	Localities	Elevation (m s.l.m.)	n°	Localities	Elevation (m s.l.m.)
1	Pila, Alpe Chalechemoz	2,000	27	Valle S.-Marcel, Loc. Layet (Lago)	2,300	53	*Cima Piana	2,512
2	Charvensod, Loc. le Pousses	1,580	28	Val Clavalité, Loc. Rovarey - Celey	1,550	54	*Col du Lac Blanc	2,309
3	Valle Comboè, Loc. Ponteilles	1,700	29	Val Clavalité, Borroz Bivouac	2,150	55	Valle Chalamy, Loc Prisonet	2,300
4	*Punta Replan	2,457	30	Val Clavalité, Loc. Comba Tersiva	2,500	56	Valle Chalamy, Gran Lac	2,500
5	Valle Comboè, Loc. Gran Plan	2,150	31	Val Clavalité, Lago Lavodilec	2,350	57	Valle Champorcher, Lac Muffé	2,100
6	Valle Comboè, Loc. Arbolle	2,500	32	*Col de Fénis	2,833	58	Valle Champ., Alpe Créton	1,900
7	Valle Comboè, Lac de l'Elmo	2,700	33	Val Clavalité (Savoney), Loc. Orgere	1,750	59	Valle Champ., Lac Giasset (Raty)	2,350
8	*Punta Tsa Setze	2,824	34	Val Clav. (Savoney), Loc. Savoney	2,100	60	Valle Champ., Rif. Dondena	2,200
9	Gimillan, Pian della Cretetta	1,980	35	Val Clav. (Savoney), Lago di Medzove	2,400	61	Valle Champ., Loc. Chila Damon	2,450
10	Vallone del Grauson, Cascate di Pila	2,100	36	Val Clavalité, Loc. Tramail de Cuneux	2,500	62	Valle Champ., Ayasse passing	2,350
11	Vall. del Grauson, Rifugio Grauson	2,500	37	*Colle di Medzove	2,613	63	Valle Champ., Lago del Miserin	2,580
12	Vall. del Grauson, Loc. Ervelleires	2,600	38	*Punta di Medzove	2,845	64	Valle Champ., Miserin - Colle d. Rosa	2,700
13	Alto Vallone del Grauson	2,800	39	*Punta Chermontane	2,680	65	*Colle della Rosa	2,959
14	*Passo dell'Invergneux	2,902	40	Pontey, Loc. Verthuy	1,100	66	Valle della Legna, Loc. Porte	1,350
15	Vallone dell'Urtier, Alpe Seutse	2,400	41	Pontey, Loc. Valmeriana	1,800	67	Valle della Legna, Loc. Ourty	1,550
16	Vall. dell'Urtier, Alpe Pianas - Mandaz	2,400	42	*Colle della Valmeriana	2,290	68	Valle d. Mandaz, Loc. Boset Dessus	1,600
17	Vall. dell'Urtier, Alpe Ponton (Lago)	2,600	43	*Monte Barbeston	2,482	69	Valle d. Mandaz, Loc. Champas	2,150

18	*Col Fenêtre de Champorcher	2,827	44	*Mont Lyan	2,178	70	*Colle della Fricolla	2,540
19	Grand Brissogne, Loc. Gramonenche	1,200	45	Val Chalamy, Loc. L'Arp (Herin)	1,650	71	Vallone di Brenve, Loc. Barme - Breuil	2,000
20	Laghi delle Laures, Alpe Tramail	1,950	46	Val Chalamy, Loc. La Veulla	1,300	72	Vallone di Brenve, Loc. Lavassey	1,650
21	Laghi d. Laures, Lago inferiore	2,550	47	Val Chalamy, Loc. Pra Oursie	1,800	73	Valle del Fer, Loc. Mourate	1,050
22	Laghi d. Laures, Lago superiore	2,800	48	Val Chalamy, Loc. Serva Desot - Lac Gelé	2,200	74	Valle del Fer, Lago Liet	1,700
23	Laghi d. Laures, Lago Jacquin	2,980	49	Val Chalamy, Lac Gelé	2,600	75	Valle del Fer, Loc. Mouilla	1,800
24	*Col des Laures	3,035	50	Val Chalamy, Loc. Serva Damon - Coucy	2,050	76	Valle di Scalaro, Loc. Muanda	1,800
25	Valle Saint-Marcel, Loc. Praborna	1,900	51	Val Chalamy, Loc. Leser Desot - Damon	1,900	77	*Colle di Bonze	2,239
26	Valle S.-Marcel, Loc. Roullaz - Vauvire	2,250	52	Alpe di Panaz (Lago di Panaz)	1,900	78	*Cime Battaglia	2,298

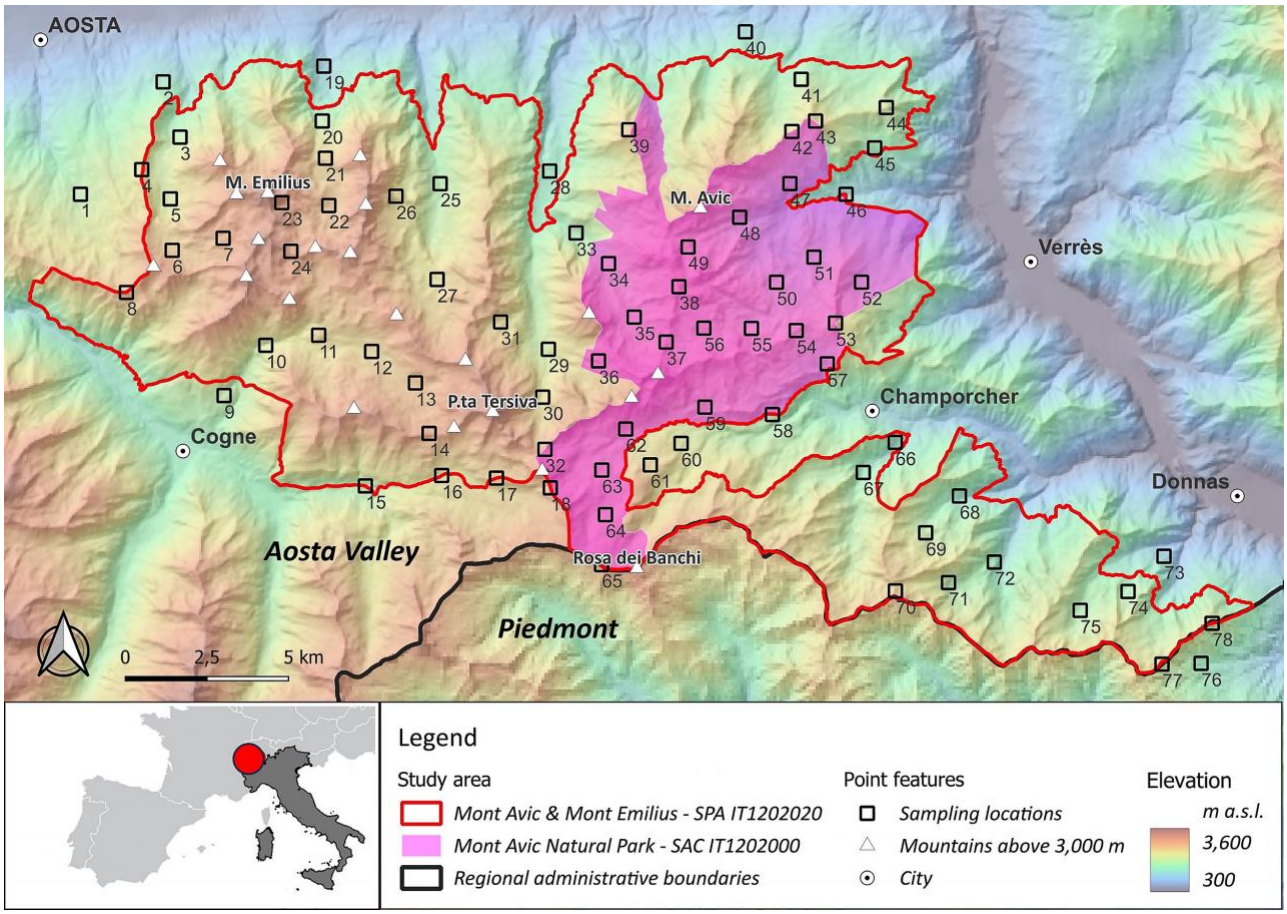


Figure 1. The Mont Avic and Mont Emilius massifs (study area), part of the Natura 2000 network. Names and elevations of the surveyed localities are listed in Table 1. The figure was produced in QGIS (version 3.44; QGIS Development Team); DTM data source: https://mappe.regione.vda.it/pub/geonavitg/geodownload.asp?carta=DTM0508; Natura2000 spatial data source: https://www.eea.europa.eu/data-and-maps/data/natura-14/natura-2000-spatial-data).

RESULTS

During the 2020–2021 biennium, 47 field survey days were conducted (22 in 2020, 15 July–17 September; 25 in 2021, 5 August–17 October), yielding 258 georeferenced records: *Anonconotus ghilianii* (18; Fig. 2 and 3), *A. pusillus* (60; Fig. 2 and 3), *Epipodisma pedemontana* (29; Fig. 4), *Stenobothrus ursulae* (67; Fig. 4), *Podisma pedestris* (45; Fig. 5), and *Bohemanella frigida* (39; Fig. 5).

Within the study area, two species were recorded at their highest known elevations: *E. pedemontana* (2,842 m a.s.l.) and *S. ursulae* (3,074 m a.s.l.). All records, including two post-2018 original occurrences of *A. ghilianii* and two of *A. alpinus* outside the study area (Fig. 3), are available via GBIF (Battisti 2026).

For each species, Table 2 reports EOO (MCP) and AC-EOO, together with the minimum and maximum elevations used to calculate the AC-EOO.

Table 2. Values refer to the Minimum Convex Polygon (EOO), the altitudinally constrained extent of occurrence (AC-EOO) in the north-western Italian Alps, and the elevational range used to derive the AC-EOO. Elevation values were rounded to the nearest 100 m (minimum downward, maximum upward) based on published sources or original data. AC-EOO estimates for the north-western Alps are compared with those for the study area. Values are reported for *Anonconotus ghilianii* Camerano, 1878, *Anonconotus pusillus* Carron & Sardet, 2002, *Epipodisma pedemontana* (Brunner, 1882), and *Stenobothrus ursulae* Nadig, 1986. For *A. pusillus* and *S. ursulae* regional values correspond to the full known species distributions. Values for *A. ghilianii* refer only to its eastern distributional nucleus.

Species	EOO -MCP (km2)	Min. elev. Piedmont (m a.s.l.)	Min. elev. Aosta Valley (m a.s.l.)	Max. elevation (m a.s.l.)	NW Italian Alps AC-EOO (km²)	Study area AC-EOO (km²)
Anonconotus ghilianii	781	1,500	1,500	2,700	735	10
Anonconotus pusillus	1,551	1,400	2,000	2,900	1,187	84
Epipodisma pedemontana	-	1,600	2,200	2,900	1,208	54
Stenobothrus ursulae	960	1,300	2,000	3,100	1,077	173

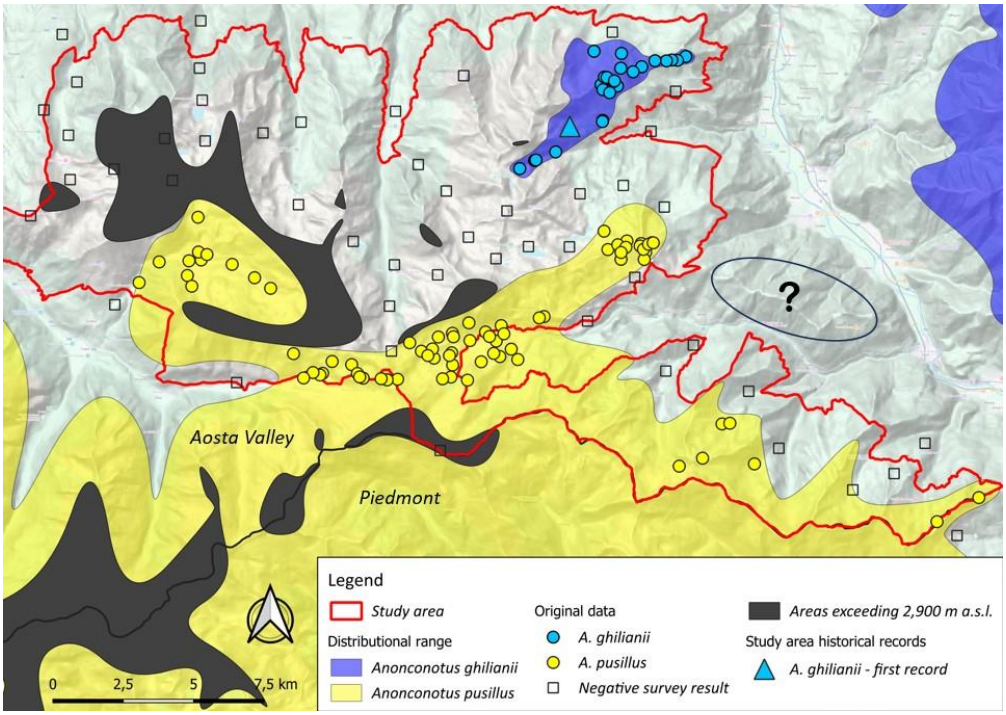


Figure 2. Distribution of original records of the genus *Anonconotus* within the study area (broader ranges and further details are shown in Fig. 3). The exclamation mark denotes a potentially restricted, unsurveyed area of species occurrence. Basemap: Google Terrain ©.

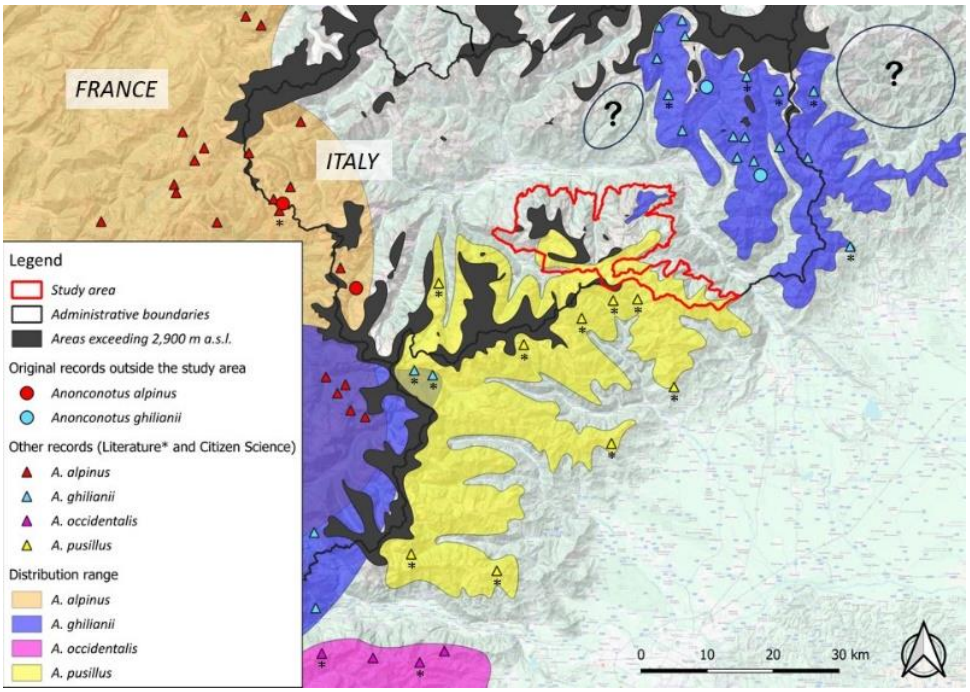


Figure 3. Distribution of the genus *Anonconotus* Camerano, 1878, in the surroundings of the study area. Species ranges of *Anonconotus alpinus* (Yersin, 1858) and the French populations of *A. ghilianii* are based on Sardet et al. (2015) and Galvagni and Fontana (2006) respectively, while the range of *Anonconotus occidentalis* Carron & Wermeille, 2002 follows Belenguier et al. (2023). Outside the study area, two post-2018 records of *A. alpinus* and two of *A. ghilianii* collected by the author are shown, together with Citizen Science observations from iNaturalist (2025) for these two species and for *A. occidentalis*. The exclamation mark denotes marginal areas of cautiously hypothesised species occurrence, whereas literature-based records are highlighted with an asterisk (*) below the symbol. Basemap: Google Terrain ©.

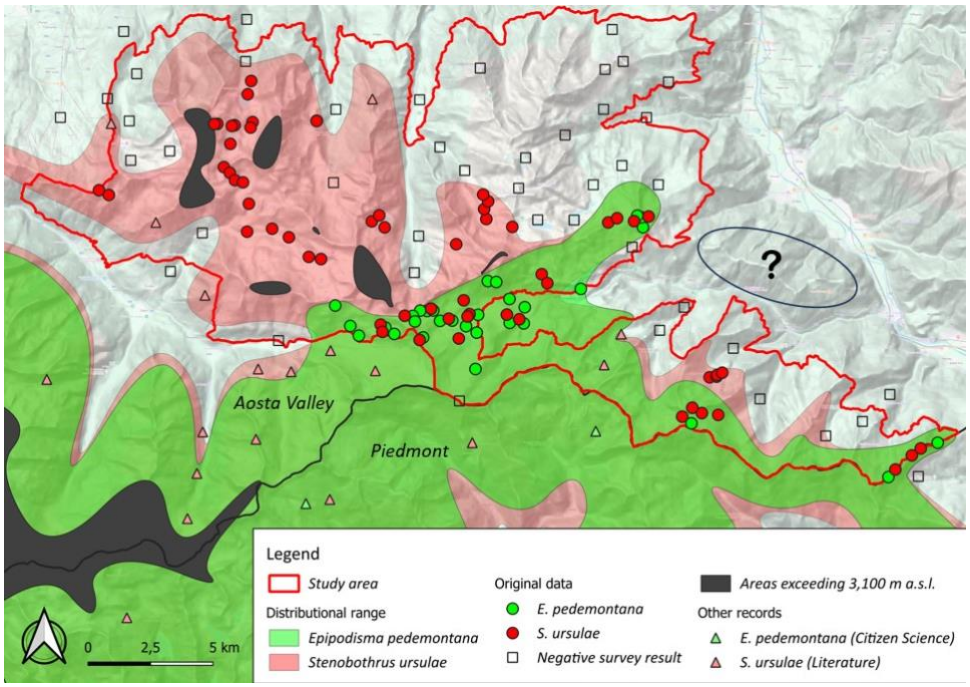


Figure 4. Distribution of original records of *Epipodisma pedemontana* and *Stenobothrus ursulae* within the study area (broader ranges and further details are shown in Fig. 5). Historical records of *S. ursulae* from Massa (2010) and Baroni and Masoero (2018); Citizen Science observations of *E. pedemotnana* from iNaturalist (2025). The exclamation mark indicates a potentially restricted, unsurveyed area of species occurrence. Basemap: Google Terrain ©.

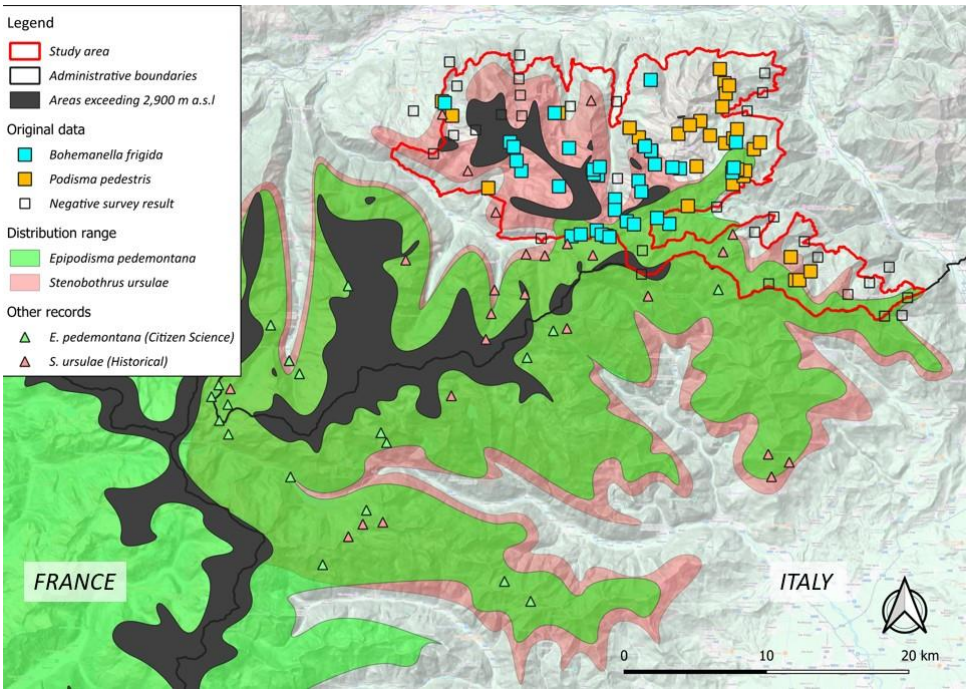


Figure 5. Occurrences of *Bohemanella frigida* (Boheman, 1846) and *Podisma pedestris* (Linnaeus, 1758), and their relative negative survey results within the study area. The map extent includes the full range of *S. ursulae* and includes literature-based records from Massa (2010) and Baroni & Masoero (2018). The range of *E. pedemontana* includes Citizen Science observations from iNaturalist (2025). Basemap: Google Terrain©.

DISCUSSION

The spatial and altitudinal distributions of the six species across the Alps are discussed in comparison with observations from the study area, and sixty-four Citizen Science observations (iNaturalist 2025) were added to Figures 2 to 5 for comparative purposes, with records of *Anonconotus alpinus* (20 observations), *A. ghilianii* (15 obs.), *A. occidentalis* (2 obs.) and *E. pedemontana* (25 obs.). Similarly, thirty-seven literature-based records were added: *A. ghilianii*, 3 records (Galvagni 2003, 2005); *A. pusillus*, 9 rec. (Galvagni 2005); and *S. ursulae*, 25 rec. (Massa 2010, and Baroni and Masoero 2018).

For the six target species the European conservation status, according to the European Red List of Orthoptera (Hochkirch et al. 2016), is also provided. Species are presented in alphabetical order following the nomenclature of Massa et al. (2021), with the four endemic target species listed first, followed by the two comparison species.

1. *Anonconotus ghilianii* Camerano, 1878

Conservation status: Least Concern.

Anonconotus ghilianii is endemic to the Western Alps and is known to have a disjunct distribution in two main areas: a southern sector between the south-westernmost Alps (France) and the Susa Valley (Italy), and a north-eastern Italian sector between the left-hand side of the Dora Baltea River in Aosta Valley and the Sesia Valley (Galvagni and Fontana 2006). Its altitudinal range spans 1,000–2,700 m on the French side (Sardet et al. 2015) and 1,500–2,545 m on the Italian side (Sindaco et al. 2012).

Within the study area, the species occurs between 1,800 m at Pra Oursie and 2,482 m at the summit of Monte Barbeston (Fig. 2). In the Chalamy Valley, *A. ghilianii* occupies open habitats above the tree-line on the left-hand side of the stream, with confirmed presence from the small valley of Lac Gelé (west) to Mont Lyan (east) and on north-facing slopes beyond Colle di Valmeriana (2,290 m). No individuals were recorded below 1,837 m, including Alpe Valmeriana (1,790 m), likely reflecting dispersal limitations imposed by forested habitats. Similar absences were observed in inner alpine pastures of Val Chalamy, including Treby Desot (1,700 m) and Costà (1,600 m).

The local population appears isolated from previously known distributional nuclei (Fig. 3), representing the only occurrence on the right-hand side of the Dora Baltea River in Aosta Valley,

covering 10 km^2 of distribution. The species was first observed on 22 September 2012 (M. Bocca unpublished data) and initially identified by D. Baroni (personal communication via M. Bocca, former director of MANP), with the most recent morphological confirmation from the examination of the male titillators from this study. Until genetic studies are conducted, the population observed in the study area should be considered part of the easternmost nucleus of *A. ghilianii*, for which an AC-EOO of 735 km² was estimated, and whose hypothetical distribution is confirmed by historical data and recent CS data (iNaturalist 2025) (Fig. 3). However, given the taxonomic complexity of this genus, new taxa or alternative interpretations cannot be excluded.

Only two published records are known from the north-western Italian Alps north of the Susa Valley and outside the eastern distribution nucleus. These records refer to two specimens collected at Ceresole Reale, in the Orco Valley, originally attributed to *A. alpinus* (Carron et al., 2002) and subsequently reassigned to *A. ghilianii* by Galvagni (2005) on the basis of the female genital plate of one historical specimen. Galvagni (2005) further supported this reassignment by referring to the high alpine ridges bordering France. Considering the elevation of the alpine passes in this sector, dispersal of *Anonconotus* species other than *A. pusillus* into the Italian slope would have required crossing the Col de la Lose / Colle della Vacca (2,957 m) or the nearby Col de la Galise (2,987 m). Although the genus has never been recorded above 2,900 m, the limited altitudinal gap from the highest known occurrences makes occasional dispersal across the French–Italian watershed plausible. Similar alpine passes, likely acting as obligatory dispersal routes, have already been crossed by *A. alpinus* from France into Italy, including Col de la Seigne (Val Veny, 2,516 m) and Little St Bernard Pass (La Thuile, 2,188 m). Col du Mont (Valgrisenche, 2,637 m) may also be included among these dispersal routes, based on a recent original record obtained on 20 August 2023 from Valgrisenche at 1,950 m, along the road to Rifugio Bezzi. This last hypothesis is further supported by an additional CS observation at ~2,200 m along the footpath to Col du Mont (Bosio G., 22 August 2020; https://www.inaturalist.org/observations/57252387). In light of these considerations, the two specimens referred to *A. ghilianii* from the upper Orco Valley should be treated with caution, especially if the 'Research Grade' citizen-science observations of *A. alpinus* available for the French side west of the Orco Valley were to be confirmed as reliable (Fig. 3). The approximate distribution of the western nucleus of *A. ghilianii* along the French border, as shown in Fig. 3, is currently based on the available recent literature and will require further refinement through future investigations.

2. *Anonconotus pusillus* Carron and Sardet, 2002

Conservation status: Near Threatened.

Anonconotus pusillus is endemic to the Italian Graian Alps, ranging from the Susa Valley (Piedmont) (Galvagni 2005) to the north-eastern portion of the study area. Its altitudinal range extends from 1,400 m (Sindaco et al. 2012) to 2,834 m (Baroni 2015).

Within the study area, the upper-altitude records confirm presence at Col Fenêtre de Champorcher (2,827 m), while the lower limit is represented by a single female at 1,800 m in the Vallone di Brenve, along the trail to Colle della Fricolla (2,540 m). The lower site, dominated by boulders, shrubs, and young broadleaf vegetation, provides limited suitable microhabitats, with the trail itself likely representing the only suitable niche at this elevation. The northernmost record occurs in Vallone del Grauson (Cogne Valley), with absence in the adjacent north-eastern Clavalité valley and at Col Pontonnet (2,898 m), whereas the species is regularly present at Col Fenêtre de Champorcher. This alpine pass likely enabled the species to expand eastwards into the Champorcher Valley, while Col du Lac Blanc (2,309 m) subsequently allowed dispersal into the Chalamy Valley, where the species has been recently recorded in alpine meadows near Lac Blanc and Rifugio Barbustel (2,132 m). Within this sector, the species is absent at Col Fénis (2,833 m) but well represented further east above the treeline, including Col de la Croix (2,379 m) and Cima Piana (2,512 m). Despite targeted surveys, no additional high-altitude records were obtained in Upper Val Chalamy, including the Gran Lac area (2,539 m) in presence of suitable habitat conditions. This apparent north-eastern limit may reflect spatial segregation from *A. ghilianii* (Fig. 2), possibly due to an environmental belt unsuitable for colonization (woods and rocky slopes). The easternmost record is confirmed at Cime Battaglia (2,298 m), along the Piedmont border.

Figure 3 shows an AC-EOO of 1,187 km², consistent with Sindaco et al. (2012) and updating Galvagni and Fontana (2006), currently apparently

constrained by areas above 2,900 m, which likely facilitated its speciation and further restricts its distribution by an additional 120 km², corresponding to high-elevation areas.

3. *Epipodisma pedemontana* (Brunner, 1882)

Conservation status: Least Concern.

Epipodisma pedemontana is endemic to the Western Alps, ranging from the south-western French Alps to the present study area. Its altitudinal range spans 1,700–2,800 m in France (Sardet et al. 2015) and 1,550–2,834 m in Italy (Sindaco et al. 2012, Baroni 2015).

Data from the study area (Fig. 4) confirm an upper limit of 2,842 m above Col Fenêtre de Champorcher (2,826 m). As for *A. pusillus*, the species does not extend beyond Col Fénis (2,833 m), whereas the lower limit within the study area is higher than other species and confirmed at 2,211 m. Distributional margins largely mirror *A. pusillus*, with exceptions including absence from Vallone del Grauson and no confirmed presence north of Col du Lac Blanc (2,309 m), in Upper Val Chalamy.

Figure 5 shows a distributional range consistent with Sindaco et al. (2012) and Sardet et al. (2015), corresponding to a preliminary estimate of the potential maximum northern distribution in Italy (north of Moncenisio, Susa Valley) of 1,208 km². This estimated area is consistent with all CS observations (iNaturalist 2025) (Fig. 5), with the exception of the locality of Pont (Valsavarenche), which represents the only currently known site on the Aosta Valley slope where the species seems to occurs at 1,950 m (Sabbatini M., https://www.inaturalist.org/observations/15221884).

As for *A. pusillus*, areas above 2,900 m further restrict its distribution by an additional 120 km². A complete AC-EOO is not provided due to environmental heterogeneity across the broader range. as well as the MCP due to the lack of presence records from the French side.

4. *Stenobothrus ursulae* Nadig, 1986

Conservation status: Vulnerable.

Stenobothrus ursulae is endemic to the Italian Graian Alps, occurring between the Orco Valley (Piedmont) and the present study area, with a previously estimated MCP of 826 km² (Baroni and Masoero 2018). Its altitudinal range is known from 1,300 m (Massa, 2010) to 2,994 m at Punta della Valletta (Baroni 2015), in the study area.

Records from this study (Fig. 4) extend the upper limit to 3,074 m on grassy slopes above Lac Jaquin (also known as Lago Gelato; Vallone delle Laures, Brissogne) along Mont Emilius' south-eastern slopes. The lower limit is confirmed at 1,900 m at Lago Champas (Vallone della Mandaz, Pont Boset), where the species occurs at low densities in elevated grassy microhabitats within conifer and shrub matrices. Similar microhabitats elsewhere suggest constraints related to vegetation structure.

Within the study area, *S. ursulae* has the widest distribution among the four taxa, occurring throughout except in inner Val Chalamy, bounded by Punta Medzove (2,845 m), Mont Glacier (3,185 m), and Gran Rossa (2,865 m). It occurs at Cima Piana (2,512 m) and the pass below (2,369 m), similarly to *E. pedemontana*. Marginal records, such as those from Lago Champas (1,900 m) likely represent suboptimal habitats. In relation to this broader distribution, it should be noted that this species is the smaller and the only one among the four endemics to exhibit a brachypterous wing condition, unlike the genus *Anonconotus* and *E. pedemontana*, which are clearly micropterous.

Original records expand the known distribution by 16%, resulting in an MCP of 960 km². Records from Cime Battaglia confirm the easternmost limit of the species and, together with most newly detected localities, is broadly consistent with the environmental suitability model proposed by Baroni and Masoero (2018). Outside the surveyed area, the distribution includes mountain areas between 1,300 m in Piedmont (lowest recorded elevation) and 3,100 m, or above 2,000 m in the Aosta Valley. This approach incorporates topographically continuous areas with suitable environmental conditions beyond currently documented occurrences. Accordingly, the AC-EOO of 1,077 km² slightly exceeds the MCP estimate, reflecting the inclusion of suitable but unsampled areas. Areas above 3,100 m further restrict its distribution by an additional 65 km².

5. *Bohemanella frigida frigida* (Boheman, 1846)

Conservation status: Least Concern.

Bohemanella frigida is a brachypterous, primarily montane species with a broad, disjunct distribution. In Europe, southern ranges are fragmented by

Quaternary glacial retreat (Lemonnier-Darcemont and Darcemont 2021), and the species occurs throughout the Alps, occasionally above 3,000 m (Massa et al., 2012). It is also present in the mountains of boreal Asia (Sergeev 2011) and North America (Vickery 1967).

Within the study area, the species was recorded from 1,906 m (Dondenaz, Champorcher) to 2,997 m (Punta Arpisson, Cogne), with higher abundance and frequency above 2,400 m (Fig. 5). This pattern reflects a preference for high-altitude alpine habitats, although lower sub-alpine sites are occasionally occupied when micro-habitat conditions are suitable.

6. *Podisma pedestris pedestris* (Linnaeus, 1758)

Conservation status: Least Concern.

Podisma pedestris is a micropterous species with a broad Eurasian distribution, probably due to the occasional occurrence of macropterous individuals (Lemonnier-Darcemont 2014), which likely allow greater dispersal. It is not strictly a montane species.

Within the study area, it occurs along most of the altitudinal gradient, from 1,697 m (Fer Valley, Champorcher) to 2,624 m (Gran Lac, Chalamy Valley), but below the maximum elevation of 2,800 m reported in the French Alps (Sardet et al. 2015). The species shows a preference for thermophilous mid-elevation slopes (<2,000 m), indicating broader ecological tolerance compared to strictly alpine endemics. Observations also suggest apparent spatial segregation from *Bohemanella frigida*, with each species occupying distinct climatic niches within the study area: *P. pedestris* favoring warmer, thermophilous habitats, and *B. frigida* restricted to colder, high-altitude microclimates (Fig. 5).

CONCLUSIONS

Overall, these data refine our understanding of species distributions in a biogeographically significant sector of the Alps, particularly for endemic taxa. The dataset reveals a previously unknown and geographically isolated population of *A. ghilianii* and, together with the refined AC-EOO distribution, indicates greater fragmentation in the species' north-eastern distribution nucleus. For *S. ursulae*, new records extend its distribution eastwards and to higher elevations. For all target species, the available data do not allow inference of recent upward shifts, as no historical absence records are available and many earlier records are geographically non-overlapping, possibly reflecting previous sampling gaps. Nonetheless, the high-resolution dataset presented here (updated to 2021) provides a robust baseline for detecting future range dynamics under climatic or anthropogenic environmental change (Gonzalez and Neilson 2010), including potential climate-driven contractions at lower elevations and colonisation of newly suitable habitats at higher elevations.

Species occurrence was more strongly associated with vegetation structure and habitat conditions than with elevation per se, with local microclimatic conditions likely representing the main driver, largely confirming the pattern previously reported by König et al. (2024). Small patches of unsuitable habitat (e.g. ridges, rocky peaks, and coarse scree) appear to act as effective dispersal barriers, supporting the limited dispersal ability typically associated with short-winged species.

The AC-EOO presented here provides a useful approximation of distributional extent for narrow-range species in topographically complex systems such as the Alps. However, the Area of Occupancy (AOO) would likely provide a more informative framework for conservation assessments under ongoing climate change. Across all studied species (Fig. 6), AOO is expected to be highly fragmented and substantially smaller than the estimated AC-EOO because to habitat discontinuity, species-specific ecological requirements, and incomplete sampling across their ranges. This limitation highlights the need for further refinement, as a more detailed assessment of AOO would be necessary for robust evaluations of conservation status. In addition, increasing herbaceous cover and shrub encroachment, potentially linked to environmental change and land-use abandonment in the southern Alps (Hinojosa et al. 2016), may further constrain species persistence at lower elevations. These considerations highlight the importance of fine-scale distributional data for improving Red List assessments and better assessing the vulnerability of alpine endemic species to environmental change, particularly at lower elevations and in marginal areas.

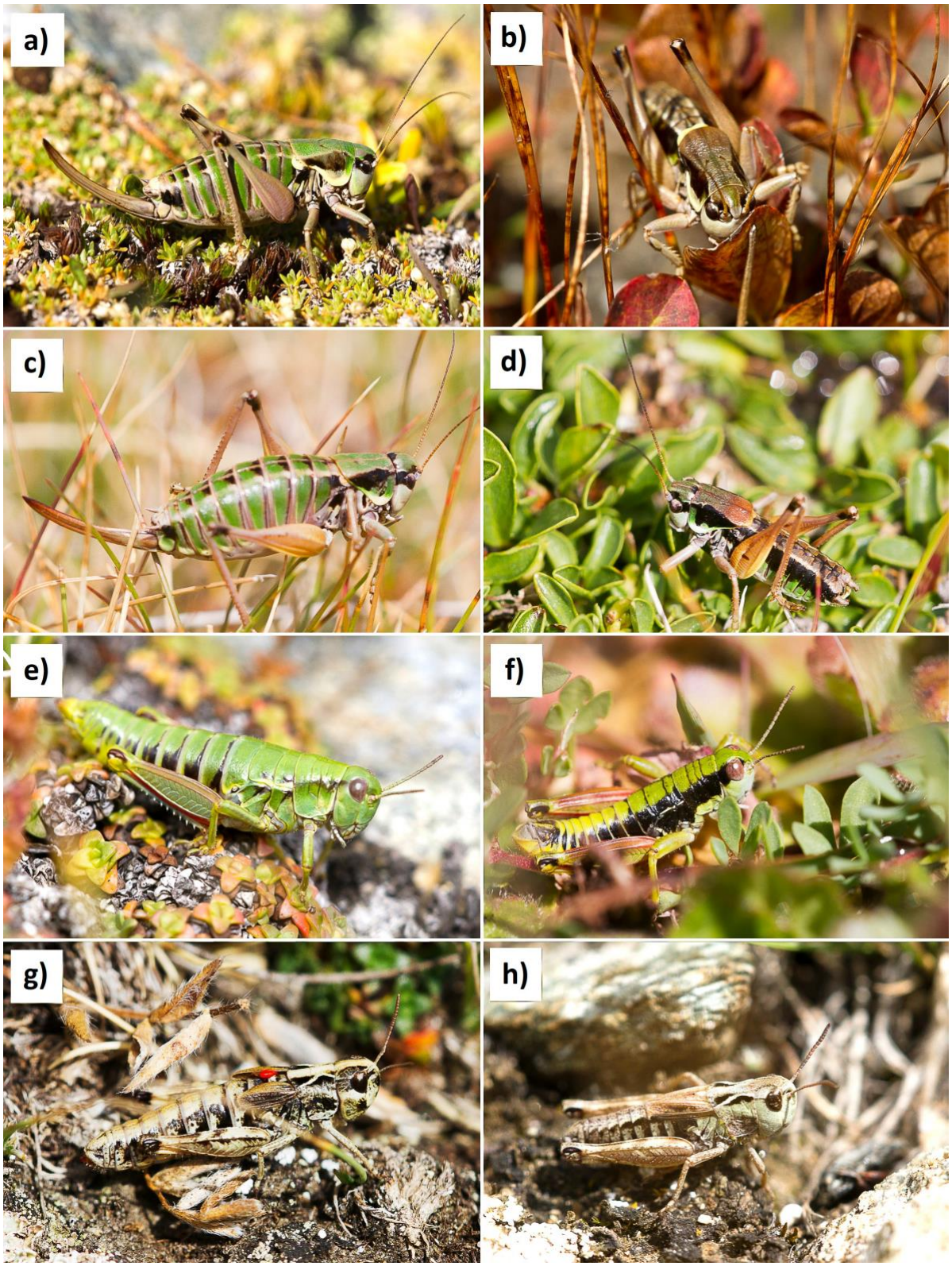


Figure 6. The four endemic species: a) *Anonconotus ghilianii* female, (Locality n° 42, Colle della Valmeriana, 09/09/2020), and b) male (Loc. n° 47, Pra Oursi, 09/09/2020); c) *A. pusillus* female and d) male (Loc. n°61, Chila Damon, 24/08/2021); e) *Epipodisma pedemontana* female (Loc. n°63, Lago Miserin, 24/08/2021) and f) male (Loc. n° 53, Cima Piana, 01/09/2021); g) *Stenobothrus ursulae* female and h) male (Loc. n°53, Cima Piana, 01/09/2021). © Andrea Battisti (all pictures).

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