

Alpine distribution of the disjunctly distributed arcto-boreal grasshopper *Aeropedellus variegatus* (Fischer von Waldheim, 1846) (Insecta: Orthoptera): new records for South Tyrol and an outlook on genetic studies targeting its biogeography.

The genus *Aeropedellus*

The genus *Aeropedellus* (HEBARD 1935) currently comprises 22 nominal species, whereas all of them are typical elements of the Holarctic (Orthoptera Species File, accession date 12th November 2020). The largest part of these 22 species is occurring in the Asian part of the Palearctic (20 species), while only two species are native to the Nearctic. The region harboring most *Aeropedellus* species worldwide is Northern China and Mongolia (15 species).

Only two species, *Aeropedellus variegatus* (Fischer von Waldheim, 1846) and *Ae. volgensis* (Predtechenskii, 1928) are occurring in Europe. While the latter is a xerophilic endemic of the steppe grasslands of the lower Volga basin (BEY-BIENKO & MISHCHENKO 1951), *Ae. variegatus* has the widest distribution of all palearctic *Aeropedellus* species. As such, *Ae. variegatus* occurs from Northeastern Russia to Western Europe (EBNER 1951). EBNER (1951) critically evaluated the distribution of *Ae. variegatus* and found that the species occupies a more diverse set of habitats in its Northern distribution than would be expected for a purely arcto-boreal species. Given this, he concluded that the attribute „arcto-boreal distribution“ largely oversimplifies the species' complex ecology and distribution in Asia, and he emphasized that *Ae. variegatus* has very strong ties to the xeric steppes of Asia. The species' European distribution, on the other hand, reflects a classic arctic-alpine disjunction pattern (SCHMITT et al. 2010).

European and Alpine distribution of *Aeropedellus variegatus*

Apart from its main distribution in Northern Eurasia, *Aeropedellus variegatus* is occurring in the treeless alpine zones of high mountain chains in Europe where it lives on wind-exposed sparsely vegetated mountain ridges, generally above 2200 m a.s.l. (Fig. 1). More specific, the species has been found in the European Alps, the Rila and Pirin Mountains, the Caucasus, and the Apennine.

The only record from the Apennine (Monte Cimone, Italy) reported by HEBARD (1925) could not be confirmed despite an intensive search effort on behalf of the authors of the present paper. Also, the search for the single female specimen collected by HEBARD (1925) in the Hebard collection at the Academy of Natural Sciences of Drexel University (Pennsylvania, USA) has not been successful. On our request, the curator confirmed that there is no specimen from Monte Cimone filed under *Ae. variegatus* or any synonym in Hebard's collection. We conclude that an occurrence of the species in the Apennine is unlikely, as other authors have emphasized before us (GALVAGNI 2001). A species misidentification on behalf of HEBARD (1925), who did not visit the site himself but received the specimen from an Italian entomologist, could be the cause for this doubtful record; a candidate for an identification error could be *Stenobothrus*

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apenninus – this species occurs in high densities in the alpine zone of Monte Cimone (Kirschner & Kranebitter, pers. obs.).

In the European Alps, the distribution of *Aeropedellus variegatus* can be divided into two disjunct distribution ranges, a Western range and an Eastern range (Fig. 2). The Western range comprises the Italian part of the Pennine Alps, the Graian Alps, the Dauphiné Alps, the Cottian Alps, and the Maritime Alps. The Eastern range includes mountain ranges of the Eastern and Western Rhaetian Alps, more specifically, the Livigno Alps, the Samnaun Alps, the Sesvenna Alps, and the Ötztal Alps. Two additional East Alpine occurrences that are separated from the species' main range have been recorded from the Julian Alps (Us 1971), and from the Dolomites (GALVAGNI 2001). While the latter record from the Dolomites was confirmed in 2020 by two of us (Kirschner & Kranebitter: individual rich population on Zanggen / Pala Santa, Province of Trento), an occurrence in the Julian Alps has not been confirmed since Us (1971). This biogeographically very interesting, easternmost Alpine population needs a critical reevaluation, especially as the collected specimens are not available anymore (GALVAGNI 2001).

Concerning the above mentioned Western and Eastern distribution ranges, it is important to note that *Aeropedellus variegatus* is not occurring area-wide and in a continuous way within these ranges, but in an island-like manner. This within-range assembly of populations does not follow a distinct spatial pattern and is rather arbitrary. While *Ae. variegatus* can be found in high densities at some sites, it is absent from large parts of the range – even from potentially suitable habitats, and even if vital populations occur only a few kilometers apart.

While it can be assumed that the delimitation of the Eastern and Western Alpine range of *Aeropedellus variegatus* is accurate on the large scale, knowledge on its distribution on a smaller scale, that is within the respective ranges, is likely incomplete. This is largely connected to the fact that *Ae. variegatus* is hard to detect in the field due to its short period of occurrence (early August to mid-September), its habitat-specificity, the accessibility of the alpine zone, and the difficulty to detect specimens if the alpine weather conditions are unfavorable (wind, cold temperature). An increased search effort might thus lead to the discovery of previously overlooked populations (see the newly found populations listed below). Such effort could yield additional valuable insights into the Alpine biogeography of the species, especially if they are focused on areas that have previously not been searched for the species, such as the surroundings of the isolated Dolomite population at Zanggen / Pala Santa.

Outlook: A genetic approach to the Biogeography of an Alpine grasshopper species

Today's Alpine distribution of *Aeropedellus variegatus* hints at an intriguing biogeographic history. The species range in Europe has experienced multiple expansions and contractions throughout the Pleistocene glacial cycles. Considering the species' habitat preferences, the extent of suitable habitat during Pleistocene cold stages must have been very large compared to today's restricted alpine distribution (that reflects only the species' warm-stage refugia). Thus, some of the past range fluctuations must have been massive. A colonization of alpine warm-stage refugia was however only feasible postglacially, that is after the onset of deglaciation. This deglaciation must have co-occurred with increasingly unfavorable conditions for the species in the areas surrounding the Alps, suggesting a very dynamic spatiotemporal history - not only postglacially, but repeatedly throughout the Pleistocene climate oscillations. This dynamic spatiotemporal history is the subject of an ongoing research project at the Museum of Nature South Tyrol. Briefly, this project aims at clarifying the genealogic relationships of the Alpine populations of *Ae. variegatus*, at exploring its range wide Pleistocene demography, and also at resolving the phylogenetic status of the Alpine *Ae. variegatus* populations compared to non-Alpine populations of Europe. To address these points, high-throughput DNA sequencing techniques are utilized. In addition, these data will be used to assess the connectivity (i.e. gene flow) among the isolated refugial populations. In the light of global change that will lead to a loss of alpine habitats (DIRNBÖCK et al. 2011), our findings will also contribute to conservation of the species that has been listed as endangered by the latest IUCN report (HOCHKIRCH et al. 2016).

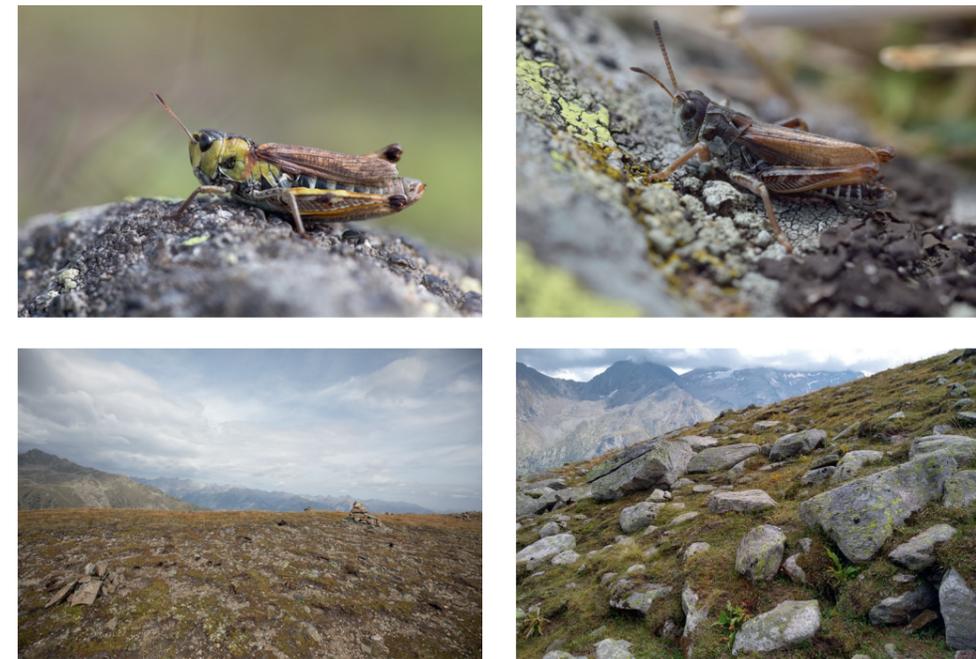


Fig. 1: *Aeropedellus variegatus*. Top left: female individual, Schönjoch, Tyrol, Austria (P. Kirschner); top right: male individual, near Rifugio V. Sella, Cogne, Aosta, Italy (T. Wilhalm); bottom left: habitat at Schönjoch 2300 m a.s.l., Tyrol, Austria (P. Kirschner); bottom right: habitat near Rifugio V. Sella 2550 m a.s.l., Cogne, Aosta, Italy (T. Wilhalm).

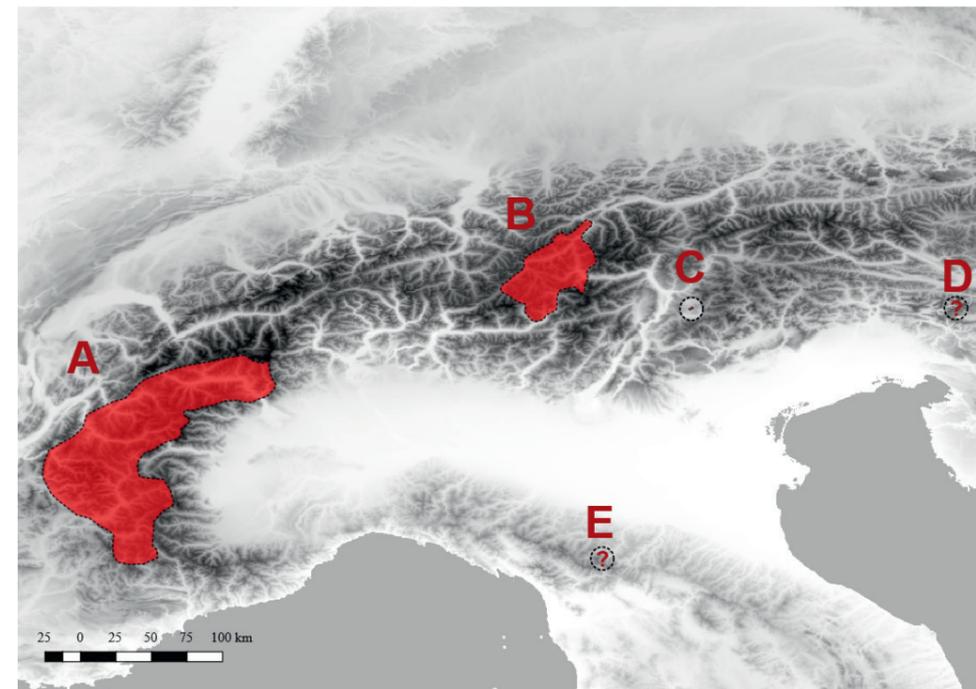


Fig. 2: Large-scale overview of the known distribution range of *Aeropedellus variegatus* in the Alps and in the Apennine. A: Western Alpine Range; B: Eastern Alpine Range; C: Zanggen / Pala Santa, Eastern Alpine outpost, single population; D: Julian Alps, this record needs to be re-evaluated (see text); E: Monte Cimone, this record is likely obsolete (see text). Polygons indicate the species range (occurrence points not shown). Range extent based on A: GALVAGNI 2001, additional records in the collection of the Museo Civico di Rovereto; B: NADIG 1986, GALVAGNI 2001, WILHALM 2004, DZIOCK 2011, WILHALM et al. 2018, new records listed in the present paper; C: GALVAGNI 2001; D: Us 1971; E: HEBARD 1925. Many sites reported in the above cited literature and the collection of the Museo Civico di Rovereto within the ranges A and B as well as site C could be reconfirmed by us in the years 2016-20. Topographic map is based on GTOPO30 Global Digital Elevation Model (United States Geological Service EROS Data Center, doi: 10.5066/F7DF6PQS)

New findings of *Aeropedellus variegatus* in the Eastern Alps Province of Bolzano/Bozen (Fig. 3)

Upper Venosta Valley, Curon, Ötztal Alps, Langtaufers Valley: 0,7-1 km ENE-(E)NE Lake Pedrosssee, alpine grassland, partially gappy, crystalline bedrock, 2630-2660 m a.s.l., ca. 100 individuals (males and females), together with *Melanoplus frigidus* and *Podisma pedestris*, 11th August 2020, leg. Thomas Wilhelm.

Upper Venosta Valley, Malles, Ötztal Alps, crest between the lateral valleys Matsch (Mazia) and Planeil (Planol): on the whole length of the mountain ridge between Mt. Niederjoch and 1.5 km SE Mt. Jafaut, 2460-2680 m a.s.l., open to block-rich alpine grassland (Elynetum, fragments of *Caricetum curvulae*), crystalline bedrock, several hundred individuals (males and females), together with *Gomphocerus sibiricus*, *Melanoplus frigidus* and *Podisma pedestris*, at lower ranges also with *Omocestus viridulus* and *Stenobothrus nigromaculatus*, 18th August 2020, leg. Thomas Wilhelm.

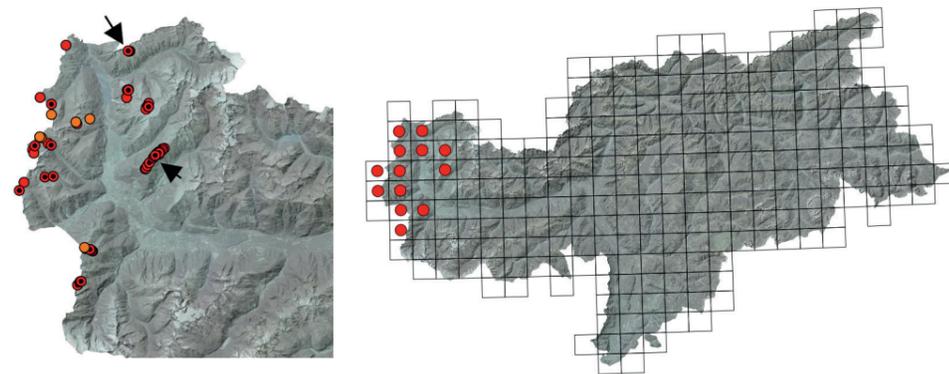


Fig. 3: Distribution of *Aeropedellus variegatus* in South Tyrol (Province of Bolzano): occurrence in grid cells (left) and location of known populations (right). Data sources: NADIG 1986, Galvagni & Wilhelm in GALVAGNI 2001, WILHALM 2004, WILHALM et al. 2018. The newly discovered partial areas are marked with arrows. Red dots mean finds after, orange before 2000. Dots with black centers refer to an exact location.

Confirmation and specification of the occurrence of *Aeropedellus variegatus* in the Eastern Alps, Passo Foscagno, Province of Sondrio (record from Museo Civico di Rovereto; leg. La Greca, 1971)

Passo Foscagno, Livigno, Livigno Alps, NNE of Strada Statale 301: on the broad ridge connecting Le Piazze and Monte Rocca and on the west facing slopes underneath this ridge, 2450-2650 m a.s.l. Vegetation: open and block-rich alpine grassland above crystalline bedrock (fragments of *Caricetum curvulae*), partly sparse vegetation cover, especially above the old moraines and on the wind-exposed edges; these sparsely covered parts were at the same time the most individual rich areas. Presence of females and singing males; generally, the whole site was found to be not very individual rich (which might be an artifact - the site was visited after 16:00 and generally rather late concerning the species' phenology). 15th September 2020, leg. Philipp Kirschner.

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