Surviving at sky islands?

Recent study questions ancient theories about the relict status of alpine grasshoppers in Europe (Acrididae, Gomphocerinae, Podismopsis)

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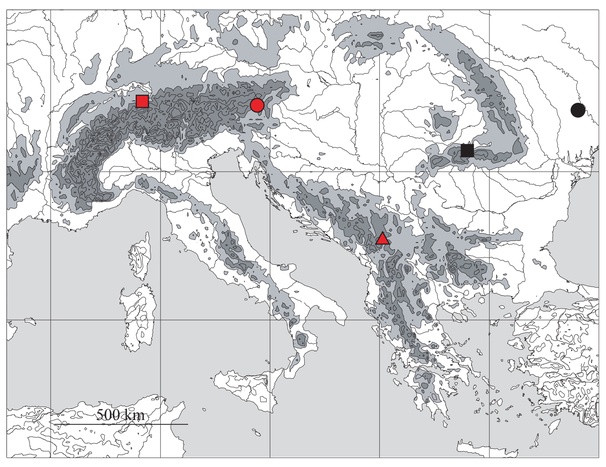
The five European species of *Podismopsis* occur vicariantly in the Swiss and Austrian Alps, Montenegro, the Carpathians, Moldova and northern Russia. All species are endemic to small montane and alpine areas at altitudes above 1800 m a.s.l. All other 30 species of the genus occur in northeastern Asia (Eades et al. 2011). Not much is known about these grasshoppers yet and the two species from the European Alps were described quite recently by Nadig (1989) and Koschuh (2008). It was supposed that the cold adapted *Podismopsis*-species survived glaciations in the cold Asian steppes of Siberia or in lower altitudes in Europe (Holdhaus 1912, Ander 1949).

Current disjunctive distribution of the genus *Podismopsis* in Europe



- *P. keisti* (Switzerland, Chäserrugg)
- *P. styriaca* (Austria, Zirbitzkogel)
- *P. relicta* (Montenegro, Hajla)
- *P. transsylvanica* (Romania, Fagaras)
- *P. poppiusi* (Moldova, National Reserve Codrii)

This disjunctive distribution pattern is typical for cold adapted boreo-alpine species, which are currently restricted to small mountain peaks, i.e. sitting in their Holocene refugia. The shortened wings in all species are an adaptation of alpine grasshopper species that prevent the migration to neighbouring mountains and thus cause their restriction to patchily distributed meadows. The populations shown with red symbols from Switzerland, Austria and Montenegro were already sampled in summer 2010.

P. keisti male | *P. keisti* female | *P. styriaca* male | *P. styriaca* female | *P. relicta* male

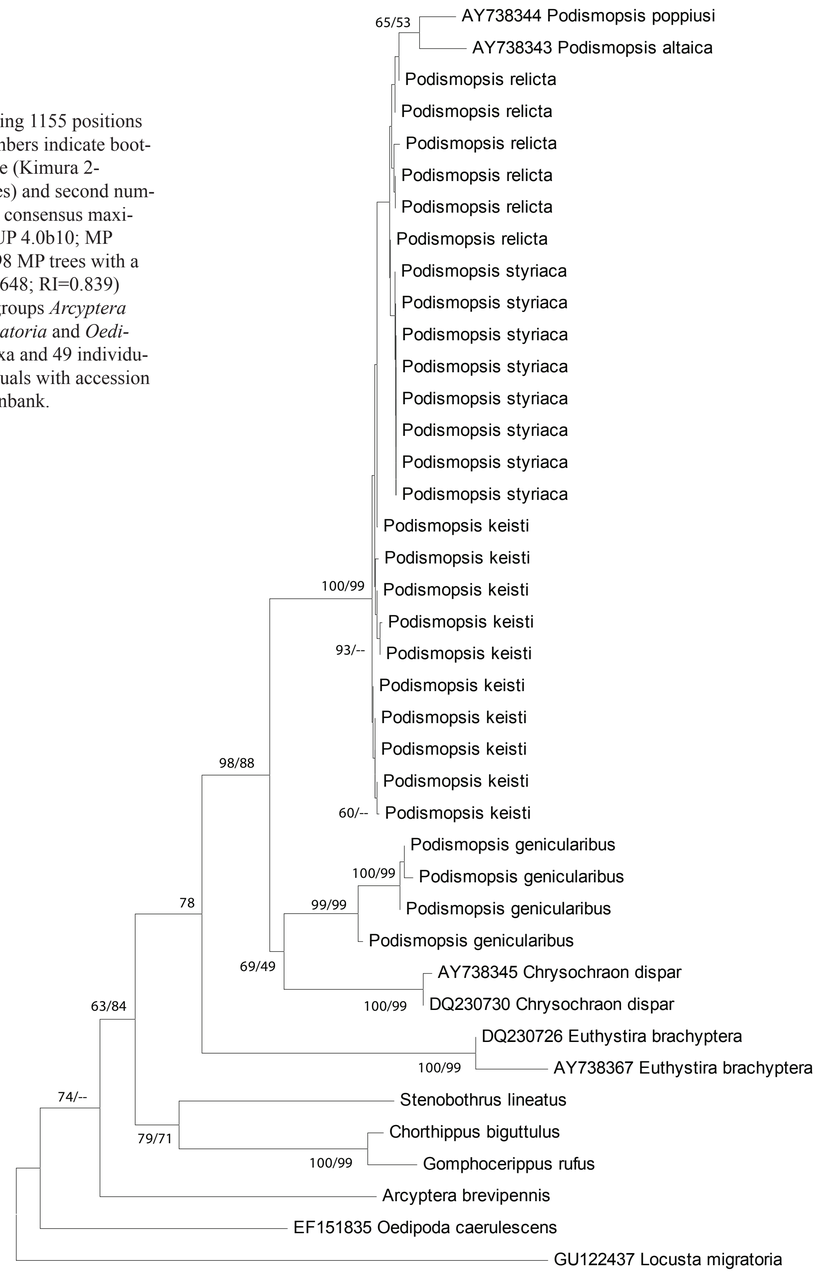
Low levels of morphological differentiation between distinctive European populations

All studied populations are morphologically very similar. No inter-population differences in body size or in distinct morphological characters were found so far in both sexes. In females varying colour morphs occur frequently in all studied populations. Own morphological studies – morphometric measurements of 40 morphological characters as well as analyses of the genitalia and the sound producing apparatus of an adequate number of specimens – are in progress.

Low species number in Europe and the immobility of the alpine *Podismopsis* species indicate that they could be old relict species occurring at sky islands. To evaluate inter-population divergence we did molecular and behavioral analyses.

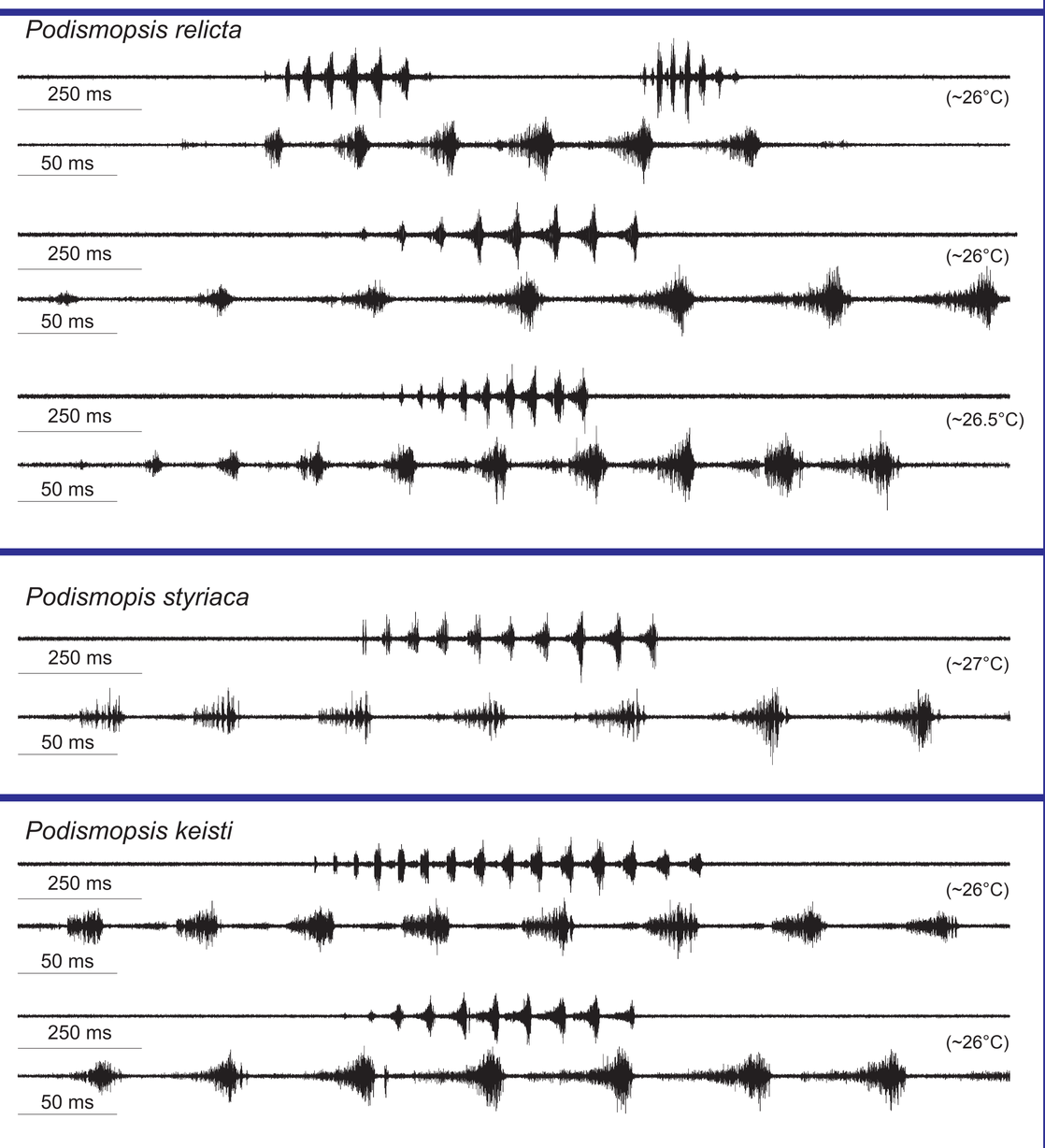
RESULT 1: No genetic differentiation between the three European species

Neighbour-Joining tree using 1155 positions of the *COI* gene. First numbers indicate bootstrap support of the NJ tree (Kimura 2-parameters; 1000 replicates) and second numbers are support of a strict consensus maximum parsimony tree (PAUP 4.0b10; MP analyses resulted in 320298 MP trees with a length of 648 steps; CI=0.648; RI=0.839) Trees are rooted with outgroups *Arcyptera brevipennis*, *Locusta migratoria* and *Oedipoda caeruslescens*. 21 taxa and 49 individuals were analysed. Individuals with accession number are taken from genbank.



We did not detect any genetic differentiation between *P. keisti*, *P. relicta* and *P. styriaca*. Additionally, *P. poppiusi* and *P. altaica* fell into a cluster with these three species, although a small differentiation, but without high bootstrap support, was existent. Only *P. genicularibus* differentiated clearly from the other *Podismopsis* species analysed so far. The European taxa fall into a clade with western Asiatic species, but are well differentiated from the species from eastern Asia. This absence of significant genetic differentiation was quite unexpected for us and indicates that these taxa are no glacial relicts that survived Pleistocene glaciations on nunataks in the central part of the Alps.

RESULT 2: No differentiation between the male calling songs of three European species



Oscillograms showing the calling songs of six *Podismopsis* males from the three European populations. Each set comprises an overview over the song phrases (upper trace) and detailed sections of the syllable structure (thereunder; recording temperatures are given in brackets). The songs of the three analysed *Podismopsis* species from Montenegro, Austria and Switzerland are phrases containing simple structured syllables, which are lacking a distinct syllable substructure. Phrases are produced single wise or in series. The sound intensity increases during the phrase. The number of syllables per phrase varies from few up to more than ten per phrase even in one singing male. Also temporal patterns as syllable periods vary between and within the different *Podismopsis*-populations in a wide range.

The lack of genetic and phenotypic differentiation between alpine and arctic *Podismopsis* populations indicates that they probably were widespread throughout the glacial steppes between the northern ice shield and the glaciers in the mountains in the south. The large scale gene flow was only interrupted by the postglacial disjunction into different high mountain systems and the arctic.

We conclude that the European *Podismopsis* spp. can not be regarded as old relict species!

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