

# Evolutionary history of the “short-winged type” of the alpine and subalpine scorpionfly *Panorpodes paradoxus* (Insecta, Mecoptera)

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The panorpid scorpionfly, *Panorpodes paradoxus* (Panorpididae), inhabits mountainous areas, mainly alpine and subalpine areas. Females of *P. paradoxus* living in the high altitude regions of the Central Japan and Mt. Hakkoda (Aomori Prefecture) have short wings and they are called “short-winged type”. Furthermore, the short-winged type has some morphological differences from the general “long-winged type”, as follows. (1) Male's antennae are longer than that of long-winged one. (2) Upper ridge of their hypandrium is rounder than that of long-winged one. (3) Body color of females is dark brown (long-winged type's body color is generally pale yellowish brown). (4) Wing spots' pattern of females is characteristic, and much differ from long-winged one (there are many long-winged females which have not any wing spots, but short-winged female always has wing spots). (5) Male of short-winged type has faint wing spots (appearance of wing spot is very rare in long-winged male). Therefore, it has been referred that “short-winged type” is an adaptation to high mountains. In addition, it has also been suggested that “short-winged type” is a different species from “long-winged type”. So, in this study, we performed molecular phylogenetic analyses based upon mitochondrial DNA COI, COII and 16S rRNA regions, and nuclear DNA EF1- $\alpha$  and 28S rRNA regions, in order to confirm whether there are genetic differences between *P. paradoxus* of long- and short-winged types, or not. As a result, the long- and short-winged types did not respectively compose monophyletic groups. This result suggests parallel evolution of “short-winged type”. Moreover, there was no clear regionality in the phylogenetic relationship at the intra-species level. Additionally, we also examined the degree of genetic differentiation and estimated the divergence date. As the result of this analysis, it was estimated that the “short-winged type” differentiation was a somewhat earlier age (about 5 Ma) than the time when the rapid mountain formation of the Japanese archipelago occurred. In the comprehensive discussion of these research results, it was suggested that the “short-winged type” evolved as adaptation to cold environment, when coldization due to past climate change occurred. In addition, as a result of the ecological niche modeling analysis, it was suggested that the distribution area of “long-winged type” was repeated northward and southward according to the past glacial cycles. On the other hand, such a tendency was not observed in “short-winged type” adapted to cold regions. This is also consistent with molecular phylogenetic analyses results that there is no distinct regionality in the phylogenetic relationship within the species. As described above, it was revealed that *P. paradoxus* have a very complicated evolutionary history. This research seems to be a typical example clearly showing that alpine insects have a deep relationship with the history of mountain formation and climate changes.

Keywords: Parallel evolution, Phylogeography, Speciation