Biotic and abiotic drivers of global body size distributions and macroevolutionary diversification in an old insect order

John T. Waller and Erik I. Svensson

## Abstract

Global body size distributions in ectotherms are shaped by multiple ecological and evolutionary processes, including abiotic factors like temperature, natural and sexual selection on adults and biotic factors like natural enemies such as predators and parasites. However, little is known how these factors interact and shape global interspecific body size distributions, and latitudinal gradients in body size, such as “Bergmann’s Rule” (larger body sizes at higher latitudes). Here, we investigated the macroecological and evolutionary factors shaping latitudinal gradients and global body size distributions in an old insect order (Odonata; dragonflies and damselflies), using a global database of odonate phenotypic traits, fossils and phylogenetic comparative methods. Controlling for phylogeny, we find that extant species of both odonate suborders are larger in the temperate region than in the tropics. Next, using fossil data, we show that the relationship between body size and latitude in has shifted over macroevolutionary time scales from having negative slopes in both suborders to become more shallow or even positive following the evolutionary emergence of birds 150 MYA. As birds are important predators on extant species of these insects, we argue that these macroevolutionary changing temporal pattern in the geographic body size-latitude trend is likely to be driven by avian predation in combination with high dispersal ability of large dragonflies. In further support of this, we show that interspecific body size variation of extant odonate taxa is negatively influenced by both regional avian diversity and temperature with a surprisingly large effect of the former. Finally, evolutionary shifts to larger body size were more likely to occur in the tropics, followed by dispersal of large clades in to the temperature region. Once lineages invaded the temperate region, temperature had a limited direct effect on body size, but indirectly influences body size via prolonged larval development time. Ambient temperatures are therefore not the primary force shaping latitudinal body size variation in odonates, and instead predator diversity and dispersal ability might play more important roles in shaping interspecific geographic body size patterns. Thus, latitudinal body size gradients are shaped by both evolutionary processes leading to the emergence of large taxa in the tropics, followed by ecological processes such as increased dispersal ability of large clades.