



DECOUPLING BETWEEN CLIMATE CHANGE AND BIOLOGICAL INVASION RESHAPES ALLOMETRY ACROSS AQUATIC INSECT ONTOGENY

Tauany Rodrigues^{1,2,3,4}, Joseph Ferro^{3,4}, Aliny P. F. Pires^{1,2}, Vinicius F. Farjalla^{3,4}

¹ Universidade do Estado do Rio de Janeiro, Departamento de Ecologia, Rio de Janeiro, RJ, Brasil

² Laboratório de Ecologia e Conservação de Ecossistemas, Departamento de Ecologia, Rio de Janeiro, RJ, Brasil

³ Universidade Federal do Rio de Janeiro, Departamento de Ecologia, Rio de Janeiro, RJ, Brasil

⁴ Laboratório de Limnologia, Departamento de Ecologia, Rio de Janeiro, RJ, Brasil

E-mail: tauanyrodrigues27@gmail.com

Aquatic insects play a fundamental role in freshwater ecosystems by mediating energy transference between basal and higher trophic levels, with their developmental trajectories regulating the amount and timing of energy transferred through food webs. Climate change and biological invasions are among the most pervasive threats to freshwater ecosystems, with the potential to interactively affect the development of aquatic insects. However, it remains unclear whether the effects of these threats are consistent across ontogenetic stages of aquatic insects and how their interactions shape energy acquisition and allocation during development. Here, we investigate how climate change scenarios and biological invasion interactively affect the allometric growth of *Chironomus* larvae and pupae. We conducted a field mesocosm experiment manipulating temperature and precipitation across three climate scenarios (Baseline, Mitigation, and Business-as-Usual) combined with the presence of the invasive macrophyte *Hydrilla verticillata*. Our results indicate that climate change influenced growth trajectories across *Chironomus* ontogenetic stages, whereas the combined effects of climate change and biological invasion emerged only during the larval stage. In particular, the Business-as-Usual scenario increased larval growth efficiency, but this effect was partially offset in the invaded treatments, resulting in reduced biomass accumulation per unit body length. This antagonistic interaction suggests that biological invasion can modulate climate-driven energy acquisition during early ontogeny, likely by altering habitat structural complexity and nutrient availability that affect larval foraging efficiency and movement-related energetic costs. In contrast, *Chironomus* pupal allometry was primarily affected by climate change, in which pupae exhibited a steeper biomass-length relationship under the Mitigation scenario, indicating a more efficient biomass



allocation during metamorphosis and greater retention of larval energy reserves. These results suggest that climate change strongly affects aquatic insect energy acquisition and allocation across ontogeny, while biological invasion antagonistically modifies climate-driven responses during early development with potential consequences for aquatic food webs and ecosystem functioning.

Palavras-chave: *Aquatic insect ontogeny; climatic mitigation; multiple stressors*