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Digest

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Digest: Winter is coming: overwintering selection and the cost of insecticide resistance in fruit flies

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This article corresponds to Prileson, E. G., Campagnari, B., Clare, C. I., Gabidulin, A. R., Shahmohamadloo, R. S., & Rudman, S. M. (2025). Overwintering drives rapid adaptation in *Drosophila* with potential costs to insecticide resistance. *Evolution*, qpaf205, https://doi.org/10.1093/evolut/qpaf205

Abstract

Do winter conditions drive rapid adaptation in insects, and does prior selection for insecticide resistance constrain it? To test these questions, Prileson et al. (2025) exposed replicate *Drosophila* populations to an outdoor overwintering period and tracked traits before and after in common gardens. Control populations that had not been previously exposed to insecticides showed consistent shifts in body size and fecundity, indicating rapid adaptation. Resistant populations suffered higher winter mortality, and both control and resistant populations were more susceptible to insecticides after overwintering, indicating a trade-off between resistance and overwintering performance.

Main text

For ectotherms such as insects, the temperature of the environment determines patterns of life history, physiology, and survival. Climate change research often focuses on whether and how insects adapt to rising temperatures, but less attention has been paid to effects of winter conditions. In addition, despite a wealth of knowledge on the low-temperature physiology of insects, very little is known about whether winter itself can be a driver of rapid adaptation. To address this gap, Prileson et al. (2025) use large, replicated *Drosophila melanogaster* populations in a field experiment to test whether selection across winter drives rapid parallel adaptive shifts in phenotypes such as fecundity, body size, or starvation tolerance. The authors also examine whether prior selection for resistance against insecticides—a major anthropogenic selective pressure—results in trade-offs with overwintering performance.

Specifically, Prileson et al. (2025) use replicated *D. melanogaster* populations derived from two treatments: control populations that were not exposed to insecticides, and populations that were exposed to spinosad, a commonly used organic insecticide targeting the nervous system. Flies originating from these experimental populations were reared in common garden conditions both before and after an overwintering period. At both timepoints, they were assayed for fitness-related and stress tolerance traits (fecundity, body mass, and starvation tolerance) as well as for resistance against spinosad. This design allowed the authors to assess whether control populations showed parallel adaptive shifts in phenotypes across the overwintering period, and whether prior selection for spinosad resistance limited adaptive responses to overwintering.

Control populations showed parallel, putatively adaptive phenotypic shifts, though not always in the directions initially predicted from insect physiology and field data. After the overwintering period, flies had decreased body mass and increased fecundity, while starvation tolerance remained unchanged. The overwintering period imposed strong selection on all populations (>98% mortality), but resistant populations tended to perform worse, with three resistant populations going extinct during overwintering compared to only one control population. Consistent with selection against resistant genotypes, all populations (both control and resistant) saw reduced levels of resistance, and the difference in spinosad resistance between resistant and control populations narrowed after overwintering. The authors conclude that overwintering can drive rapid adaptation in insects, but prior evolution to insecticides may limit these adaptive responses.

This study highlights two particularly interesting aspects of rapid adaptation and resistance evolution. First, the use of large, replicated outdoor *D. melanogaster* populations demonstrates an experimental approach that bridges the gap between laboratory and nature. These so-called "mesocosm" populations experience natural environmental fluctuations but provide the experimental replication necessary to disentangle consistent adaptive shifts from stochastic events (Barghi et al., 2025). Second, the suggested trade-off between resistance and overwintering performance may reflect the hidden costs of resistance evolution (Pu et al., 2020). Many conventional insecticides target the insect nervous system, and resistance mutations at target sites can reduce enzymatic turnover or protein stability (Shu et al., 2004). In insects, where low ambient temperature can challenge neuronal signaling homeostasis, such fitness costs may be amplified during cold overwintering periods (Langmüller et al., 2020). However, the exact nature of this trade-off likely depends on the specific molecular mechanisms and their underlying

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genetic signatures segregating in these *Drosophila* populations (Pu & Chung, 2024).

Conflict of interest

The author declares no conflict of interest.

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