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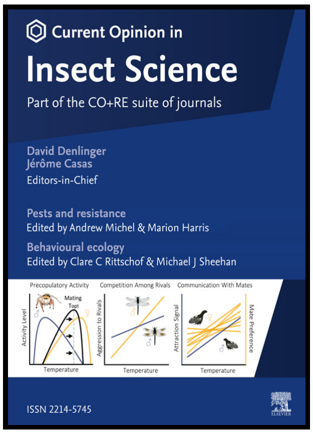

Editorial Overview – Insect Genomics (2026): enhancing public health, food security, and biodiversity through genetic biocontrol.Short title: Editorial overview

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Editorial Overview – Insect Genomics (2026): enhancing public health, food security, and biodiversity through genetic biocontrol.

Short title: Editorial overview

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Genetic biocontrol is a form of biological control in which genetic variants or genetically modified forms of the target species act to reduce or eliminate the target species [1]. In entomology, target species include agricultural pests and vector species that transmit pathogens to human, animal, or plant systems. Examples include the *Anopheles* mosquito gene drive system to reduce or replace malaria vectors in Africa [2–4], the use of *Wolbachia* symbiont induced cytoplasmic incompatibility in *Culex* mosquitoes to project Hawaiian native birds from avian malaria related deaths [5], and the use of CRISPR to generate sterile males at a scale useful for suppressing pests of fruit crops [6].

The widespread availability of robust transgenic technologies combined with new RNA-guided DNA endonuclease-based genome manipulation technologies and platforms and advances in synthetic biology are fueling the development of genetic biocontrol technologies and systems for combating arthropods that contribute to food insecurity, pathogen- and parasite-transmission, and invasive arthropods that threaten biodiversity. Heretofore a niche area of genetic biocontrol now commands great interest and an ever-growing number of applications.

The field of genetic biocontrol requires integrative scientific approaches. Laboratory research on genetics and microbiology advances the knowledge of potential targets for genetic engineering. In order to conduct field trials to evaluate its efficacy, ecology and population genetic knowledge have to come together to produce evidence-driven models for deployment and inform post-release monitoring [7–10]. Community engagement and regulatory science also play critical roles in determining the feasibility of field trials of genetic biocontrol products [11–14]. The scope of this special issue captures this integrative spirit of insect genetic biocontrol, including genetics, microbiology, ecology, population genetics, and modeling.

The population suppression strategy in genetic biocontrol is aimed at reducing target species population size. This strategy often uses techniques that skew the sex ratio of offspring through methods, including cytoplasmic incompatibility [15,16] or by the manipulation of sex-determination mechanisms [17,18], although alternative approaches, such as the sex-dependent flightless phenotype, can achieve a similar outcome [19,20]. Population suppression is most often employed for invasive and non-native species control. Articles in this issue provide updates on the latest developments in population suppression technology in *Anopheles gambiae* [21], *Aedes albopictus* [22], and various other insect species [23].

The population replacement strategy in genetic biocontrol is aimed at displacing a target species with a modified version that is unable to transmit pathogens, breaking the disease transmission cycle. This often involves manipulating effector genes involved in arthropod immune response [24,25]. This strategy is more appealing than population suppression for native species because removing them from the natural setting might open a niche for other disease-transmitting species. This issue provides a synthesis of current knowledge on the immune response at the salivary gland invasion stage, where the knowledge gap is most evident [26].

Gene drive systems are used for both population suppression and population replacement strategies of genetic biocontrol [27,28]. While most gene drive studies use CRISPR-Cas9 induced DNA repair mechanisms for engineering, insect endonuclease systems are emerging as an alternative strategy [29]. This special issue provides a synthesis of the increasing variety of DNA repair mechanisms that can be used for gene editing [30]. An overview is provided of the efforts to understand the temperature-dependent outcomes of gene editing systems in laboratory conditions to better predict the outcome in the field [31].

The expansion of insect genetic biocontrol applications to taxa beyond the *Anopheles* malaria vector and *Aedes* dengue vector systems presents some challenges. For example, injecting transgenic elements into tick eggs is complicated by their round shape, which makes it difficult to locate polar cells, and by the resistance of the external thick wax layer surrounding its eggs to injection needles [32,33]. Similarly, separating the eggs of *Culex quinquefasciatus* from their egg raft for injection can drastically reduce their viability [34]. This issue provides a summary of recent advances in transgenesis tools of *Culex* [35] and *Tephritidae* fruit flies [36]. In addition, the latest information on protecting honeybees by engineering their gut microbiomes is provided [37].

These genetic biocontrol tools developed in the laboratory need to be tested in controlled field trial settings before they can be approved for larger-scale deployment. The World Health Organization has developed frameworks for staged field trials of genetic biocontrol tools [38]. Mathematical models and baseline ecology and population genetic data play a central role in evaluating these genetic biocontrol interventions. Here we provide an overview of the latest effort to incorporate genome-wide markers for biocontrol models [39]. In addition, a summary of the current genetic biocontrol applications that were conducted or considered for deployment in the remote islands of the Pacific region is available in Vorsino *et al*. [40].

This Insect Genomics issue showcases the latest developments in research on the genetic biocontrol of arthropods. This comprehensive presentation of current scientific knowledge is intended to foster scientific progress toward the translation and adaptation of genetic biocontrol techniques to a wide variety of systems. We express our sincere thanks to the contributors for providing excellent reviews on these topics.

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Biographies

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Yoosook Lee, editor of the Insect Genomics 2026 section, studies natural populations of arthropod disease vectors such as mosquitoes. Dispersal has particular importance to innovative pest management strategies such as genetic biocontrol. She uses interdisciplinary approaches to understand mosquito population dynamics and try to translate her findings to improve mosquito surveillance and control strategies, with the ultimate goal of protecting humans and nonhuman animals from vector-borne disease.

Omar Akbari is the Tata Chancellor's Endowed Professor of Cell and Developmental Biology at UC San Diego and a leader in genetic systems engineering. He develops scalable CRISPR-based technologies for population-level control of disease vectors and agricultural pests, including the precision-guided sterile insect technique (pgSIT) and SEPARATOR. His innovations are being commercialized for global health and crop protection applications.