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INTRODUCTION

Special Issue: 7th International Entomophagous Insects Conference

Entomophagous insects: Predators and parasitoids that shape insect communities and offer valuable tools for insect pest management

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Abstract

This special issue comprises papers presented at the 7th International Entomophagous Insects Conference (IEIC7), in Buenos Aires, Argentina, in 2023. Entomophagous insects, which prey on or parasitize other insects, play a pivotal role in ecosystems and are widely utilized as biocontrol agents. This special issue includes two review articles and nine research papers covering diverse subjects such as ecology, physiology, behavior, genetics, chemical ecology, and biological control, which reflects the diversity of topics presented and discussed during the conference.

KEYWORDS

behavior, biocontrol agents, biological control, chemical ecology, functional morphology, integrated pest management, intra-guild predation, mass rearing, proceedings, trophic networks

Entomophagous insects are predators or parasitoids that voraciously consume other insects and therefore play a pivotal role in shaping ecosystems and maintaining ecological balance (Hardy & Wajnberg, 2023). This special issue delves into the intricate world of these fascinating organisms, which were the focus of the 7th International Entomophagous Insect Conference (IEIC7), held in Buenos Aires, Argentina, in April 2023. The articles compiled in this issue gather valuable information on insect predators and parasitoids from a wide range of disciplines, such as physiology, behavior, ecology, genetics, and taxonomy. Distributed across diverse habitats worldwide, entomophagous insects exhibit a remarkable array of adaptations and behaviors that contribute to their effectiveness in biological control programs (Wajnberg et al., 2008). By synthesizing existing information and presenting new research, papers presented here aim to contribute to the basic knowledge about these insects and their use in insect pest management.

The global distribution of insect predators and parasitoids spans a diversity of ecosystems, each shaped by distinct environmental factors. Similarly, from a taxonomical perspective, these organisms showcase remarkable diversity, representing various orders and families. Insect predators are prevalent across diverse orders, encompassing Coleoptera, Diptera, Hemiptera, Heteroptera, Mantodea, Neuroptera, Odonata, and Thysanoptera. In contrast, parasitoids exhibit a more taxonomically

confined distribution, primarily belonging to wasps—the Parasitica subgroup of Hymenoptera—and certain families of Diptera, particularly Tachinidae. This underscores the taxonomic specificity associated with parasitoidism, highlighting wasps and specific fly families as key groups with this specialized ecological role. The taxonomy of entomophagous insects provides a foundational understanding of their evolutionary adaptations, offering insights into their morphological, physiological, and behavioral traits that contribute to their efficacy in attacking their hosts or prey (Quicke, 2015).

Entomophagous insects, as integral components of ecosystems, contribute significantly to the regulation of prey and host populations and overall ecological stability (Godfray, 1994; Quicke, 1997). The ecological roles of both predators and parasitoids, examined through the lens of multi-trophic interactions, offer a nuanced perspective on the fine-tuned balance maintained within natural systems. Disruptions of this balance may lead to cascading effects, highlighting the need for a comprehensive understanding of the ecological relationships at play (Coll & Wajnberg, 2017), and thus for studying behavioral, genetic, and physiological aspects of entomophagy (Smith et al., 2020). The significant role of entomophagous insects as natural enemies controlling insect populations has been exploited in pest control strategies and garnered considerable interest within the scientific community. By acting as natural enemies to numerous insect pests, these organisms offer a sustainable and highly effective alternative to chemical pesticides (Heimpel & Mills, 2017). This special journal issue aimed to explore the factors that condition the predatory and parasitic capabilities of entomophagous insects, emphasizing the practical implications for integrated pest management (IPM) programs in various agricultural and ecological contexts (Gurr et al., 2016).

The IEIC originated after the merger of two international meetings (the International Entomophagous Insects Workshop and the European Parasitoid Workshop) to strengthen international collaboration among scientists working on insects that prey on or parasitize other insects. After meetings in the USA (2009), France (2011), Canada (2013), Spain (2015), Japan (2017), and Italy (2019), the most recent IEIC arrived in Argentina in 2023, where it gathered 55 researchers from 18 countries in South and North America, Asia, and Europe.

The special issue starts with two review articles, each offering comprehensive insights into distinct facets of entomophagous insects. Complementary to a previous review that focused on exotic ladybirds (Rondoni et al., 2021), Grez and Zaviezo (2024) highlight the crucial role of native coccinellids (Coleoptera) as biocontrol agents in agroecosystems, particularly in Central Chile, a biodiversity hotspot. Despite their importance, native species face threats, like the invasion of the exotic coccinellid *Harmonia axyridis* (Pallas), agricultural landscape simplification, and climatic changes, resulting in declines in abundance and diversity. The loss of native coccinellid populations has led to decreased taxonomic and functional diversity, endangering biological control. The article advocates better management of alfalfa fields and surrounding habitats to conserve native coccinellids. In the second review article, Gokhman (2024) focuses on the cytogenetics of parasitoids within the hymenopteran families Pteromalidae and Spalangiidae, discussing the variation in haploid chromosome numbers among species. In this respect, the pteromalid *Nasonia vitripennis* (Walker) is highlighted as the most extensively studied species. The text also touches upon cryptic species within Pteromalidae, such as *Anisopteromalus quinarius* Gokhman & Baur and *Lariophagus distinguendus* (Förster), which can be differentiated based on their chromosome numbers. Additionally, it explores chromosomal evolution, including fusion events, and identifies shared telomeric motifs among certain species. The text concludes with a discussion on the prospects of chromosome studies in Pteromalidae and related taxa.

The highly invasive fruit pest *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) poses significant challenges to fruit-producing regions worldwide. Two articles, by Funes et al. (2024) and Buonocore Biancheri et al. (2024), shed light on the potential of native parasitoids as biocontrol agents against this pest. The first one focuses on the evaluation of the Neotropical native pupal endoparasitoid *Trichopria anastrephae* Costa Lima as a biocontrol agent against *D. suzukii* and *Zaprionus indianus* Gupta, another frugivorous drosophilid. The study revealed promising results, indicating that *T. anastrephae* has high potential, against both *D. suzukii* and *Z. indianus*. The second article explores the potential of the Neotropical native parasitoid *Ganaspis pelleranoi* (Brèthes) (Hymenoptera: Figitidae), particularly a population lineage from Tucumán (Argentina). Although *G. pelleranoi* successfully attacked *D. suzukii*, it did not develop in the host larvae, probably due to the host's immune system. These studies underscore the importance of native parasitoids in the management of *D. suzukii* infestations, offering potential eco-friendly control strategies in fruit-producing regions. Whereas Funes et al. (2024) provide insights into the potential of *T. anastrephae* as a biocontrol agent, Buonocore Biancheri et al. (2024) highlight the specific interactions between *G. pelleranoi* and *D. suzukii*, including other fruit fly species, such as *Ceratitis capitata* (Wiedemann) and *Anastrepha fraterculus* (Wiedemann) (both Diptera: Tephritidae), emphasizing the need for further research to optimize the efficacy of native parasitoids in IPM strategies.

Diachasmimorpha longicaudata (Ashmead) (Hymenoptera: Braconidae), the most widely used biocontrol agent against Tephritidae fruit fly pests (Dias et al., 2022), is central to the studies by Nussenbaum et al. (2024) and Devescovi et al. (2024), albeit from different perspectives. Nussenbaum et al. (2024) delve into the behavioral intricacies of *D. longicaudata* females, particularly their associative learning abilities regarding host habitat colors. The study highlights the adaptability of *D. longicaudata* in adjusting its behavior based on environmental cues, enhancing its efficacy in locating and parasitizing host

larvae. Devescovi et al. (2024) focus on the chemical basis of female parasitoids attraction, shedding light on the volatile organic compounds guiding *D. longicaudata* to its hosts. The research provides valuable insights into the development of novel tools to enhance biological control programs. By elucidating both the behavioral and chemical aspects of *D. longicaudata* foraging, these studies contribute to improve IPM strategies, facilitating the sustainable control of tephritid fruit flies and mitigating their detrimental impacts on fruit production and trade.

Hosts employ various mechanisms, both physiological and behavioral, to mitigate the impact of parasitism by parasitic wasps and other natural enemies. In this respect, Russo et al. (2024) explore the immuno-suppressive strategies employed by parasitic wasps, focusing on the host–parasitoid system involving the pea aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae), and the parasitoid *Aphidius ervi* Haliday (Hymenoptera: Braconidae). By functionally characterizing a serine protease homolog protein identified in *A. ervi* venom, the authors demonstrate its crucial role in inhibiting the melanization response of the host, thereby enhancing parasitism success. The study highlights the intricate biochemical mechanisms deployed by parasitic wasps to escape from the host immune defenses and regulate host populations. From a different perspective, Martel, Schlyter, et al. (2024) investigate the behavioral mechanisms of host choice and larval migration in the Egyptian leafworm, *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae), focusing on its preference for cotton and alfalfa as oviposition sites. Although cotton appears to be a superior host in terms of larval performance, females exhibit a preference for ovipositing on alfalfa, likely because eggs may escape from parasitism on this plant, achieving higher survival rates. In this respect, the study examines the impact of parasitism by the larval parasitoid *Microplitis rufiventris* Kokujev (Hymenoptera: Braconidae) on various host plants, indeed revealing higher parasitism rates on cotton and better parasitoid performance on cotton-fed larvae, indicating a possible enemy-free space on alternative hosts such as clover and alfalfa. Together, these studies emphasize the interplay between physiological and behavioral adaptations in both hosts and parasitoids through the complexity of host–parasitoid interactions and the evolutionary arms race between them, ultimately enriching our understanding of the co-evolutionary dynamics between hosts and their natural enemies in ecological communities.

Both, biotic and abiotic factors conditioning the development of parasitoids play a crucial role in shaping their life-history traits and population dynamics. Martel, Régnière, et al. (2024) investigate the competitive interactions between two parasitoid species, *Tranosema rostrale* (Brishke) (Hymenoptera: Ichneumonidae) and *Elachertus cacoeciae* (Howard) (Hymenoptera: Eulophidae), targeting the spruce budworm, *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae). Through field experiments conducted over 35 years, the authors found that both parasitoids are most effective at very low host population density and that a strong, density-dependent, and negative correlation of frequencies exists between them, indicating adaptive strategies to minimize direct competition and maximize their respective performance. This study points out the significance of biotic factors, such as interspecific competition, in shaping parasitoid population dynamics and individual behavior. In contrast, Gagnon et al. (2024) explore the influence of abiotic factors, specifically temperature, on the developmental characteristics of *Trichogramma euproctidis* (Girault) (Hymenoptera: Trichogrammatidae), an idiobiont egg parasitoid of Lepidoptera. Developmental time, body size, fecundity, and gamete size of *T. euproctidis* are all affected by temperature, following a nonlinear reaction norm with an optimal temperature. This finding supports the resource acquisition hypothesis, suggesting that, for species with unlimited access to food resources, temperature influences resource allocation and subsequently life-history traits. This study contributes to our understanding of the temperature–size rule, a phenomenon that describes the growth response of ectotherms to temperature (Atkinson, 1994), and its implications in the context of climate change. Together, these studies highlight the complex interplay between biotic factors, such as competition, and abiotic factors such as temperature in shaping the life-history strategies and population dynamics of parasitoid insects.

Focusing on a predator of important insect pests, Maza et al. (2024) investigated the consumption and preference rates of the various larval stages of the hoverfly *Allograpta exotica* (Wiedemann) (Diptera: Syrphidae) as a biocontrol agent for two major insect pests, the aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) and the thrips *Frankliniella gemina* (Bagnall) (Thysanoptera: Thripidae). Through controlled laboratory conditions, the authors demonstrate that *A. exotica* larvae consume both aphids and thrips, with a preference for aphids. However, second-instar larvae exhibit a significantly higher consumption rate of thrips than aphids. This study sheds light on the potential of *A. exotica*, a common hoverfly species in fruit and vegetable crops, as an effective biocontrol agent against aphids and thrips, highlighting the importance of further research to explore its potential in both laboratory and field settings.

In conclusion, the articles published in this special issue offer a comprehensive glimpse into the diverse and dynamic world of entomophagous insects, encompassing both parasitoids and predators. They reflect the breadth and depth of the various sessions of the 7th International Entomophagous Insects Conference that focused on behavior, systematics and biodiversity, chemical ecology, population dynamics, community interactions, biological control, as well as evolutionary genetic, and physiological aspects. These contributions highlight the complex interactions between entomophagous insects and their environments, paving the way for future progress in sustainable pest management strategies, conservation efforts, and fundamental understanding of insect ecology and evolution.

AUTHOR CONTRIBUTIONS

Diego F. Segura: Conceptualization (equal); data curation (lead); formal analysis (lead); funding acquisition (equal); investigation (lead); project administration (lead); resources (lead); supervision (lead); validation (lead); visualization (equal); writing – original draft (lead); writing – review and editing (lead). **María Fernanda Cingolani:** Conceptualization (supporting); data curation (supporting); formal analysis (supporting); funding acquisition (equal); investigation (supporting); visualization (equal); writing – original draft (supporting); writing – review and editing (supporting). **Eric Wajnberg:** Conceptualization (supporting); data curation (supporting); investigation (supporting); resources (supporting); visualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Leo W. Beukeboom:** Conceptualization (equal); data curation (equal); funding acquisition (supporting); investigation (supporting); resources (supporting); visualization (supporting); writing – original draft (supporting); writing – review and editing (supporting).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable—no new data generated, or the article describes entirely theoretical research.

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