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FOREWORD

From biological control to invasion: the ladybird *Harmonia axyridis* as a model species

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> The one process now going on, that will take millions of years to correct, is the loss of genetic and species diversity. This is the folly our descendants are least likely to forgive us.
> E.O. Wilson (1994)

Biotic homogenisation is considered among the greatest threats to global biodiversity. The rapid increase in introduced exotic species worldwide and the potential of these species to become invasive have now been widely recognised to have ecological and evolutionary consequences (Olden and Poff 2004; Olden et al. 2006). However, many accidentally or intentionally introduced species fail to establish in their new range. Of those alien species that do manage to establish many have negligible effects and some species, often those introduced with agriculture and forestry, are even considered beneficial and desirable (Williamson 1999). The impact of some invaders is unquestionably negative and as such they are designated as invasive alien species (IAS). *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae), "the most invasive ladybird on Earth", is undoubtedly one such species (Roy et al. 2006).

Ladybirds have a long history of use as biological control agents against pest insects (Majerus 1994). Indeed, the Australian vedalia ladybird, *Rodolia cardinalis*, was released in 1888 to control cushiony scale insects, *Icerya purchasi*, which were having devastating impacts on the Californian citrus industry (Majerus 1994). This ladybird, introduced as a classical biological control agent, established and drastically reduced the scale insect population. This marked the advent of modern biological control. Ladybirds are considered "flagships" of biological control and their predatory habits have no doubt contributed to their popularity, particularly with gardeners. Ladybirds are one of the most loved insects worldwide but *H. axyridis* is extremely unpopular outside of its native range for a number

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of reasons. First and foremost, *H. axyridis* threatens the diversity of native aphidophagous species through direct competition and as a voracious, polyphagous predator (Majerus et al. 2006). Second, *H. axyridis* is now considered in the USA as a pest species because it consumes soft fruit and is adversely affecting the wine and fruit growing industries (Koch et al. 2004; Kovach 2004). Third, *H. axyridis* occurs at high densities in buildings (thousands being reported in a single household) during overwintering and is thus regarded as a human nuisance (Kovach 2004). Everyone loves ladybirds but, seemingly, not this one!

This book, which is a special issue of BioControl, is a synthesis of current research on *H. axyridis* providing current perspectives and future directions. *Harmonia axyridis* was first used as a classical biological control agent in 1916 (in the USA) but it was not until the 1980s that it became established there and regarded as an IAS (Koch et al. 2003). In Europe, the time between release and establishment was not marked by such a long lag. Through the 1980 and 1990s, *H. axyridis* was released in various European countries and just a decade later reports of establishment throughout Europe were widespread. We hope that lessons learnt from the *H. axyridis* invasion will prove useful in preventing other unwanted insect invaders arriving and becoming permanent residents in new environments.

In this special edition, authors have contributed the latest research on this species from a European perspective, although a contribution by Koch and Galvan (2007) provides an invaluable overview of *H. axyridis* in North America. The first papers within this special edition focus on the distribution of *H. axyridis*. Peter Brown and co-workers comprehensively describe the history of release, spread and distribution of *H. axyridis* Europe-wide. They reflect on the possible origins of *H. axyridis* and provide fascinating insights into the reasons behind the lag between introduction, establishment and major expansion. The following few papers provide more information on specific European countries where high resolution monitoring has enabled detailed analysis on spread, distribution, phenology and phenotypic variation (Adriaens et al. 2007; Brown et al. 2007a, b; Lombaert et al. 2007; Poutsma et al. 2007; Soares et al. 2007). In all these papers it is predicted that the advance of *H. axyridis* across Europe is set to continue, particularly to the north and east.

Risk assessment is an essential component in the development of any biological control strategy (Babendreier 2007). Joop van Lenteren and co-workers provide an overview of the international situation with respect to environmental risk assessment for biological control agents. The authors conclude that *H. axyridis* is an excellent aphid predator but the risks of its release are manifold and it should not have been used as a biological control agent in Northwest Europe. However, this is based on our current understanding and such comprehensive information was not widely available during the early releases. It is imperative that further unnecessary and risky releases of exotic organisms are prevented and van Lenteren et al. (2007) reassuringly report that concerns have been triggered by "the case of *Harmonia axyridis*". We can only hope that it is not too late to mitigate against other historical releases and that in the future, stringent, harmonized, Europe-wide regulation of biological control agents will limit the already rapid, biotic homogenisation.

One of the most significant threats posed by *H. axyridis* is to native biodiversity predominantly through intra-guild predation (when one of two species (or both) competing for the same host or prey also consumes its competitor). Judith Pell and co-workers review the current knowledge on intraguild predation involving *H. axyridis* and consider the implications to ecosystem services. These authors conclude that *H. axyridis* remains in equilibrium with its co-evolved native guild of predators through niche complimentarity, but in its exotic range the native guild of predators are co-evolved with each other but not with *H. axyridis* (Pell et al. 2007). This has serious consequences for predator diversity

and ecosystem services and there is a need for rigorous research data to fill the gaps in knowledge. In this special edition there are a number of experimental papers that provide robust data on this subject, including: contributions on intra-guild predation and other feeding interactions; defence strategies that protect *H. axyridis* from becoming intra-guild prey and a fascinating study on phenotypic variation between naturalized populations from around Europe compared to those from biological control rearing facilities (Berkvens et al. 2007a, b; Jansen et al. 2007; Ware and Majerus 2007; Ware et al. 2007).

It is somewhat ironic that *H. axyridis*, being first released as a biocontrol agent, is now widely regarded as an unwanted IAS which itself requires control (Koch et al. 2003; Roy et al. 2006). In this special edition Marc Kenis and coworker comprehensively review the literature on current and potential management strategies against *H. axyridis*. They describe tested protocols, mostly mechanical and conventional chemical techniques, but also consider the possibility of novel strategies involving semiochemicals coupled with natural enemies (Kenis et al. 2007). Experimental research papers included within this edition provide new perspectives on the possibilities for controlling *H. axyridis* (Burgio et al. 2007; Koyama and Majerus 2007; Roy et al. 2007).

In conclusion, there is no doubt that *H. axyridis*, as an IAS, contributes to biotic homogenization and that, in particular, its threat to biodiversity is unacceptable. We hope that this special edition "From biological control to invasion: the ladybird *Harmonia axyridis* as a model species" will ensure this species can be used as a model to prevent, or mitigate against, subsequent releases of high risk organisms, by contributing to our understanding of the mechanisms involved in biological invasions. Biological control is an essential component of sustainable agriculture but the distinction between a successful biological control agent and an invasive species can be narrow. There are many lessons that can be learnt from *H. axyridis* as a model IAS.

Invasive species, and consequent biotic homogenisation, are a global threat to biodiversity and such major drivers of environmental change require global collaboration. This special edition on *H. axyridis* is the result of rich and fruitful collaborations between scientists across Europe and beyond. It has been an enormous pleasure to work with the many scientists, technicians and others who have made this special edition possible. The enthusiasm and passion of all involved has been inspiring and hugely encouraging. The story has just begun and we do not yet know how it will unfold and eventually conclude. However, the contributions in this book demonstrate the commitment to work cooperatively and to increase understanding within this extremely important field of research.

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