3.1 Introduction and Non-target Effects of Insect Biological Control: Concepts, Examples, and Trends

R.G. Van Driesche[1] and M.S. Hoddle[2]

[1]Department of Environmental Conservation, University of Massachusetts, Amherst, Massachusetts, USA, vandries@cns.umass.edu, [2]Department of Entomology, University of California, Riverside, California, USA, mark.hoddle@ucr.edu

Whether, when, and how frequently introductions of biological control agents have important population-level effects on non-target species is a question of continuing importance to both biological control scientists and conservation biologists. Howarth (1991) first outlined an argument for significant non-target impacts of biological control agents, but this article was, in our opinion, flawed. While it opened a conversation, it did not provide a definitive answer and further discussion ensued (Follett and Duan, 2000; Follett *et al.*, 2000; van Lenteren and Loomans, 2000; Louda *et al.*, 2003; Hoddle 2004a,b,c; Stewart and New, 2007; Parry, 2009; Barratt *et al.*, 2010; Suckling and Sforza, 2014).

The impacts of these biological control agents for arthropods are less understood than those of herbivorous insects and plant pathogens released against invasive weeds. For parasitoids and predators, whose actions are generally invisible to any but specialists, we have less information on population-level impacts on non-target species. This has led to speculation that non-target impacts are high, based largely on extrapolation from several cases of likely or presumed high-level impact, especially the coccinellid beetles *Harmonia axyridis* (Pallas) and *Coccinella septempunctata* (L.) (Coleoptera: Coccinellidae) (Harmon *et al.*, 2007; Losey *et al.*, 2007) and the tachinid flies *Compsilura concinnata* (Meigen) (Boettner *et al.*, 2000) and *Bessa remota* (Aldrich) (Diptera: Tachinidae) (Kuris, 2003; Hoddle, 2006).

Past summaries of impacts of parasitoids and predators on non-target insects and mites include a mini-review for the island of Guam (Nafus, 1993); global literature reviews (Lynch and Thomas, 2000; van Lenteren *et al.*, 2006), and a detailed analysis of releases of both weed and insect biocontrol agents in Florida (Frank and McCoy, 2007). Lynch and Thomas (2000) state that nontarget effects are recorded for 1.7% of the ca 5000 recorded cases of parasitoid or predator introductions (species x country releases of about 2000 natural enemy species), as detailed in the database "BioCat" (van Lenteren *et al.*, 2006).

Non-target impacts of parasitoids and predators include (1) direct attacks on native insects, (2) negative foodweb effects, such as competition for prey, apparent competition, or displacement of native species, (3) positive foodweb effects, (4) hybridization, and (5) attacks on introduced weed biocontrol agents.

Trends (Fig. 3.1.1) showed a recent shift (2005-2015) toward a preponderance of agents with an index of genus-level (60%) or species-level (8%) specificity (with only 12% having a family-level or above index of specificity) compared to both 1985-1994 and 1995-2004, when 50% and 40% of introductions had family level or above specificity and only 21-27 (1985-1994, and 1995-2004, respectively) with genus, or 1-11% (1985-1994 and 1995-2004, respectively) with species level specificity. In all three decades, 11-12% of introductions could not be classified in this manner due to lack of information on natural enemy host specificity.

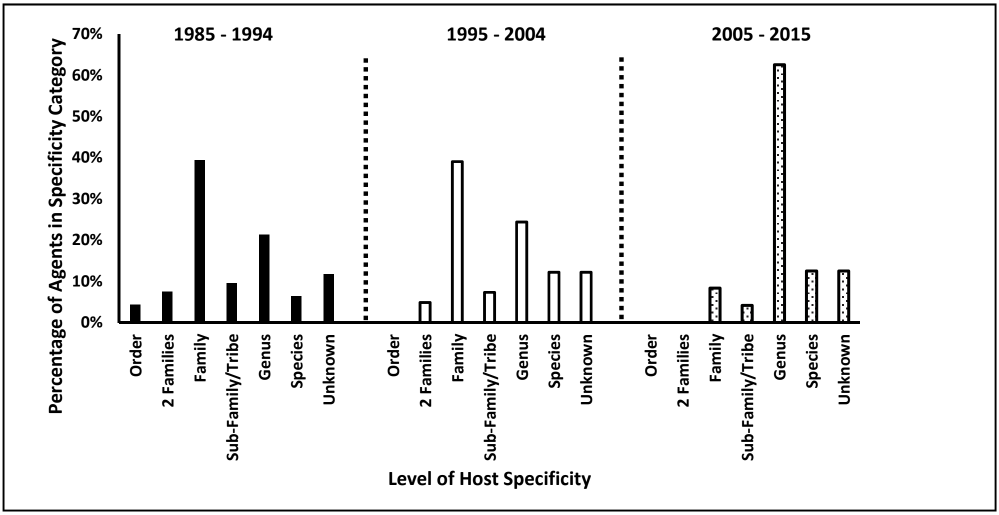

Fig. 3.1.1. Trends in levels of host specificity of parasitoids released for insect biocontrol over three decades, indicating a shift toward genus-level specificity and a reduction in use of agents with family - level specificity.

Future reductions in non-target risk from release of parasitoids and predaceous arthropods will depend on continuing to improve the forecasting of potential host ranges of agents before release. Conversely, our understanding of what impacts actually happen later under field conditions (host use that doesn't affect population densities vs. population-level impacts) will require careful study of non-target populations, with the use of lifetables, models, and experimental methods to separate impacts of co-acting sources of mortality.

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