STATUS OF *COCCOBIUS* NR. *FULVUS* (HYMENOPTERA: APHELINIDAE), A PARASITOID OF EUONYMUS SCALE (HEMIPTERA: DIASPIDIDAE), 12-16 YEARS AFTER ITS RELEASE IN MASSACHUSETTS

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From 1990 to 1995, a classical biocontrol program was conducted in New England against an Asian scale, *Unaspis euonymi* (Comstock) (Hemiptera: Diaspididae), which attacks landscape *Euonymus* plants. Many *Euonymus* species are of Asian origin (Flint 1983) and widely planted as ornamentals (Gill et al. 1982). Collection of euonymus scale natural enemies for release in the USA began in Korea (Drea & Hendrickson 1988; Hendrickson et al. 1991), but from 1990-1995 our laboratory collected additional species near Beijing, China (Van Driesche et al. 1998a), including 2 predators (*Chilocorus kuwanae* Silvestri and *Cybocephalus* nr. *nipponicus* Endrody-Younga) and 3 parasitoids (*Coccobius* nr. *fulvus* (Compere et Annecke), *Encarsia* nr. *diaspidicola* (Silvestri) and *Aphytis* sp.). Impacts of the 2 predators have been documented (Van Driesche et al. 1998b; Van Driesche & Nunn 2003).

In 1991-1994, 3,862 adult *C.* nr. *fulvus* were released at 11 sites; 12,966 adult *E.* nr. *diaspidicola* at 27 sites; and 801 adult *Aphytis* sp. at 5 sites in New England (mostly Massachusetts) (Van Driesche et al. 1998a). By 1994, apparent establishment (recovery in 1 subsequent year following release) had occurred for *C.* nr. *fulvus* and *E.* nr. *diaspidicola*. No next-year recoveries were made for *Aphytis* sp., the species released last and in smallest numbers. No evidence of spread of any parasitoid was observed. In addition, a pre-existing cosmopolitan polyphagous aphelinid, *Encarsia citrina* (Crawford), was observed in samples from Massachusetts. In 1991, it was detected at 44% of 79 sites in southern New England. In 1994, parasitism of dissected adult female euonymus scales by *E. citrina*, pooled by generation across 18 locations in Massachusetts, averaged 13.4% (n = 2,174 scales) for the overwintered spring adults, 33.6% (n = 1,271 scales) for the summer generation, and 31.2% (n = 933 scales) for the fall generation.

Our objectives here were (1) to sample for exotic parasitoids of euonymus scale in western Massachusetts in 2006 and 2007 at their original release sites, (2) to sample non-release locations to detect parasitoid spread, and (3) to assess effects of exotic parasitoids on the pre-existing parasitoid *E. citrina*.

In 2006-2007, 5 *C.* nr. *fulvus,* 7 *E.* nr. *diaspidicola,* and 3 *Aphytis* sp. release sites were relocated and sampled. Sample sites were visited in Mar 2006 or Apr-Jun, 2007. From each site, 4-5 branches (10 cm long in 2006 and 15-20 cm long in 2007) of euonymus scale-infested foliage were collected. No other scales were present on this plant. Scale density on each shrub was estimated as none, light, medium, or heavy as per Van Driesche et al. (1998a). Scale-infested branches were placed in containers (10-cm dia paper cups in 2006 and larger paper bags in 2007) and held in the laboratory for 3 weeks to allow parasitoids present as pupae at the time of collection to emerge and die. Samples were then frozen until examined. The material in each container was shaken onto a piece of paper and examined under a dissecting microscope to detect micro-Hymenoptera. By comparing reared material with preserved voucher specimens, the numbers of *E. citrina*, *C.* nr. *fulvus*, *E.* nr. *diaspidicola*, and *Aphytis* sp. recovered were recorded. From these records we determined the proportion of release sites occupied by each of the released parasitoid species 12-16 years after release.

To determine if exotic parasitoids had spread to new locations, and if so, how far, we sampled non-release sites (as described above). Sample sites were selected at distances from 0.1 to 45 km from the nearest release site. In 2006, 51 sites ("site" = one shrub with scale, mostly at different physical locations, but not always) were visited, and in 2007 an additional 49 different sites were examined (see Fig. 1 for site locations), for a total of 100 surveyed sites.

Parasitism levels for all sites were calculated by examining subsamples of scales from the branches held for parasitoid rearing. For each site, a random 1 cm section was cut from each branch (n = 3-20 branches/site). Scales were also examined from leaves on branch portions in subsamples. For each branch subsample and its associated leaves, we counted the number of adult female scales and each scale was classified as having or lacking a parasitoid emergence hole. No attempt was made to dissect scales to detect parasitoid immature stages, which would have died in rearing, or to determine to which generation scales might have belonged. We assumed that scale cadavers would fall off plants at similar rates regardless of parasitism. Our parasitism values represent a minimum estimate of the proportion of scales parasitized. To estimate parasitism rates for *C.* nr. *fulvus,* we used data from the sites where only this parasitoid was recovered (68 of 100). At 19 sites where both *E.* nr. *fulvus* and *E. citrinus* were reared, we could not separately estimate species-specific parasitism. At 4 sites, only *E. citrinus* was present.

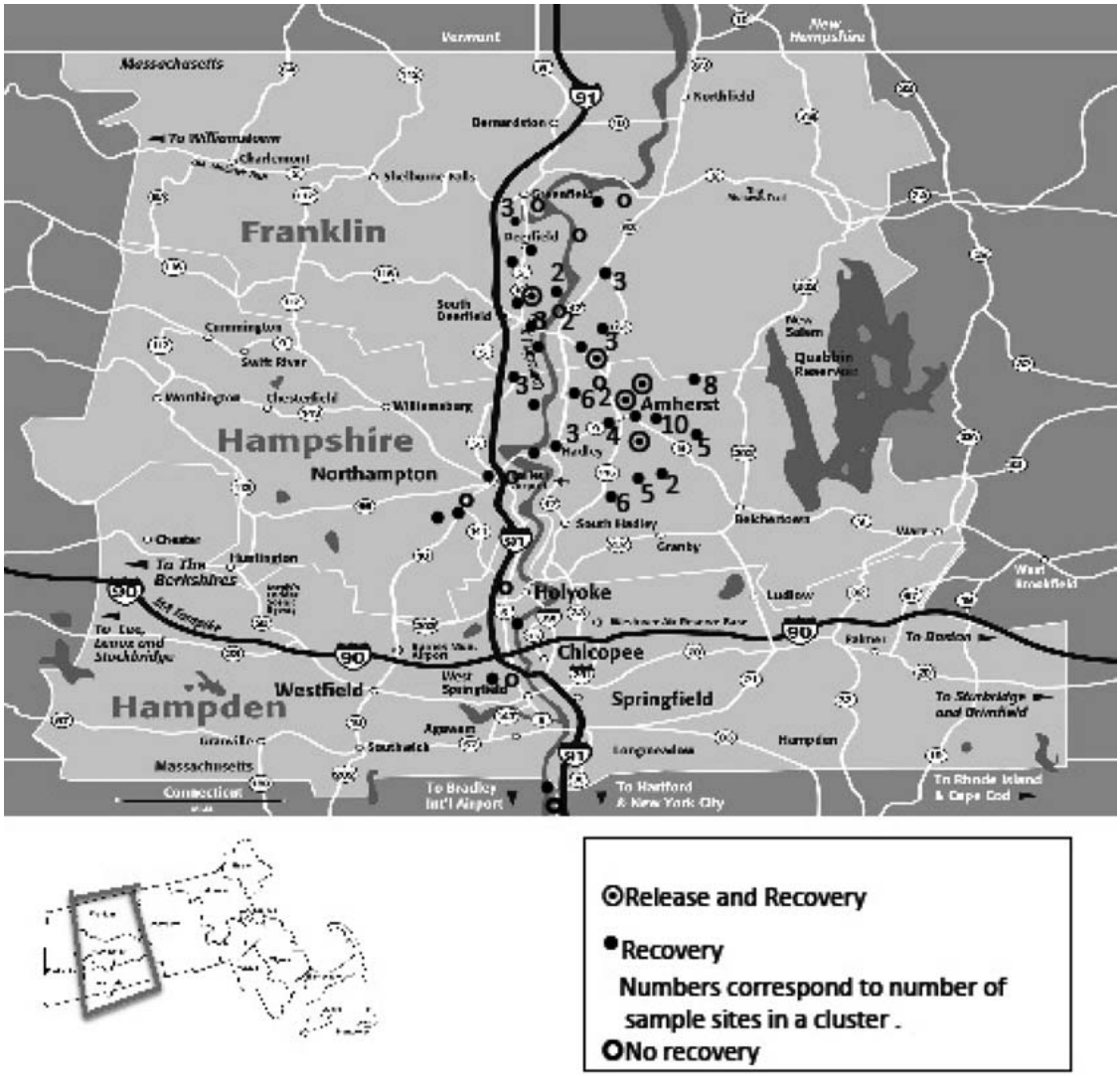

Fig. 1. Distribution of presence or absence of *Coccobius* sp. nr. *fulvus* at sites in western Massachusetts in 2006-2007.

To evaluate the effect of the new parasitoids on the previously present *E. citrina,* rates of parasitism by this species were compared between sites with and without exotic parasitoids. We estimated the rate of *E. citrina* parasitism as total percent parasitism (all species) multiplied by the proportion of *E. citrina* among all parasitoids reared at the site. We also compared the proportion of sites from which *E. citrina* was recovered to that found in a previous survey conducted in MA in 1991.

One parasitoid, *C.* nr. *fulvus*, was recovered at all 5 of its 1991-1994 release sites. Neither of the other 2 exotic parasitoids were recovered. *Encarsia* nr. *diaspidicola* was not recovered from any of seven 1993 release sites and *Aphytis* sp. was not recovered from any of three 1994 release sites. Nor were these latter 2 parasitoids recovered from any of the other sites sampled to measure parasitoid dispersal.

Coccobius nr. *fulvus* was detected at 49 of 51 sites in 2006 and 38 of 49 in 2007, for an overall site occupancy rate of 87%. The recovery furthest from any release site was in Enfield, CT, approximately 35 km south of the nearest release point in Amherst, MA (Fig. 1). Further spread is likely to have occurred since the survey occurred in a restricted area and did not detect the edge of the parasitoid's distribution.

Over both years, for sites where *C.* nr *fulvus* was the only parasitoid recovered, parasitism averaged 21.0%, based on detection of emergence

holes in 1,546 of 7,349 adult female scales. Parasitism did not differ significantly with regard to scale density at the plant level, with parasitism for light, medium and heavily infestations being 21% (n = 857), 22.8% (n = 1,278) and 20.6% (n = 5,214) (χ^2 = 2.91, df =1, P > 0.05).

In 2006-2007, *E. citrina* was present at only 22% of 100 sites and was the only parasitoid at just 4 sites. In 1991, this parasitoid was present at 44% of surveyed sites (35 of 79) (Van Driesche et al. 1998a). In 1994, parasitism of adult female scales by *E. citrina*, measured by scale dissection at 18 sites, ranged from 13.4 to 33.6% parasitism, depending on scale generation (Van Driesche et al. 1998a). At 4 sites where *E. citrina* occurred alone in 2006-2007, parasitism averaged 39.2%. In contrast, parasitism by *E. citrina* at 17 sites where *C.* sp. nr. *fulvus* was also present, was only 5.6%. Of 5025 parasitoids reared in this survey, 91.5% were *C.* sp. nr. *fulvus* and only 9.5% were *E. citrina*.

Summary

Of 3 aphelinids (*Coccobius* nr. *fulvus*, *Encarsia* nr. *diaspidicola,* and *Aphytis* sp.) released against euonymus scale (*Unaspis euonymi*) in Massachusetts in 1991-1994, *Coccobius* nr *fulvus* is now established and widespread in urban areas in the Connecticut River Valley. In 2006-2007, it was found at 87% of all sampled sites and average parasitism of adult females was 21%. *Encarsia* nr *diaspidicola,* seemingly established in 1991-1994, was not detected in this survey. The formerly dominant *E. citrina* now parasitizes only 5.6% of scales, down by 58-83% from the 1994 estimates. Estimating the impact of *C.* nr. *fulvus* on scale density will require further work.

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