ESTABLISHMENT OF A CHINESE STRAIN OF *COTESIA RUBECULA* (HYMENOPTERA: BRACONIDAE) IN THE NORTHEASTERN UNITED STATES

R. G. VAN DRIESCHE AND C. NUNN
Department of Entomology, University of Massachusetts, Amherst, MA, 01003

Cotesia rubecula (Marshall) is a braconid parasitoid of *Pieris* spp. larvae that is relatively specific to *Pieris rapae* (L.) (Lepidoptera: Pieridae), a pest of cabbage and related cole crops. The establishment of this parasitoid in the eastern United States to help suppress this garden pest has been long sought. Efforts to establish it in North America have a complex history. A self-introduced population of uncertain origin was discovered on Vancouver Island in British Columbia in 1963 (Wilkinson 1966), and the range of this population has extended as far south as Oregon (Biever 1992). This strain was later released in Missouri, New Jersey, South Carolina, and Ontario (near Ottawa) (Puttler et al. 1970; Williamson 1971, 1972). This strain appears not to have established in Missouri (Parker & Pinnell 1972), but may have established in Ontario (Corrigan 1982). Poor establishment of this strain was attributed to an improperly timed diapause induction response (Nealis 1985).

A second population, from the former Yugoslovia, was released in Missouri in the mid 1980s, and subsequently released in Virginia and Ontario. In 1988, the Yugoslavian strain was recovered in Virginia, but this population later appeared to have died out, perhaps due to high level of hyperparasitism (McDonald & Kok 1991). In 1993, *C. rubecula*, of uncertain origin, was found to be the dominant parasitoid in Quebec, in farming areas near Montreal (about 160 km east of Ottawa) (Godin & Boivin 1998).

In 1988, a population of *C. rubecula* was collected by David Reed of the USDA in Shenyang, China (42 north latitude, 123 east longitude), for release in the eastern United States. This location matched the intended release location in Massachusetts in latitude, and both locations have continental type climates. Parasitized host larvae (*P. rapae*) were shipped to the USDA quarantine laboratory in Newark, Delaware. Adult parasitoids were allowed to emerge and, following confirmation of species identity, 99 female and 49 male *C. rubecula* adults from this shipment were shipped to the senior author in Amherst, Massachusetts in July of 1988 and all were released in field cages in a pesticide-free, 0.1 ha collard plot in Deerfield, Massachusetts (42 n. l.). That *C. rubecula* was not present at this site before the release (through spread, perhaps from some distant source) is demonstrated by the absence of *C. rubecula* in large numbers of hosts collected at this location and dissected for parasitism rates in a population dynamics study I ran in 1985 and 1986 (Van Driesche 1988).

We subsequently reared this strain both in the laboratory and from field-collected larvae between 1988 and 1993 and made 12 other releases in Massachusetts, three in Connecticut, and one in Rhode Island, for 17 release locations in total (Fig. 1, two sets of MA sites overlap on map). Same-year recoveries of the parasitoid were made at seven of these sites, and recoveries were made after one or more years at seven other sites. Among the seven sites at which recoveries were made in subsequent years, we observed the parasitoid at three sites one year after release and at single sites 2, 3, 5, and 8 years after last release. Recovery efforts varied in different years and not all sites were visited yearly.

To assess spread away from release sites, we periodically collected groups of *P. rapae* larvae from non-release locations. We have recovered *C. rubecula* from 13 non-release sites, from just north of Hartford, Connecticut to Craftsbury, Vermont (north of St. Johnsbury) (Fig. 1). Recoveries have been made both along the Connecticut River Valley and in various locations in the Litchfield Hills in Connecticut, the Berkshire Hills in Massachusetts, and the Champlain Valley of Vermont. Towns in which recoveries have been made either at non-release sites or, if a release site, one or more years after the release include Winsor and Falls Village, Connecticut; Williamstown, Lanesboro, Westhampton, Northampton, Amherst, Hadley, Deerfield, Northfield, and Barre, Massachusetts; and Stamford, Rockingham, Hartland, South Royalton, Plainfield, Burlington, and Craftsbury, Vermont (Fig. 1), all of which indicate extensive range expansion in both agricultural valleys and adjacent forested hill country. Recoveries throughout Vermont bring the known range of *C. rubecula* near the Canadian border. Godin and Boivin (1998)'s report of recovery of *C. rubecula* of uncertain origin in southern Quebec, seen in the light of the data presented here, may be a further northward extension of the Chinese population, rather than an eastward extension of releases from near Ottawa. This is uncertain, as no molecular markers have been identified to separate these populations.

Because establishment of *C. rubecula* has been associated with declines in density of the other introduced *P. rapae* parasitoid, *Cotesia glomerata* (L.), in Oregon and Washington (Biever 1992), we also counted numbers of *P. rapae* larvae and *Cotesia* parasitoid cocoons (as single cocoons for the solitary species *C. rubecula* and as cocoon groups for the gregarious species *C. glomerata*) on entire

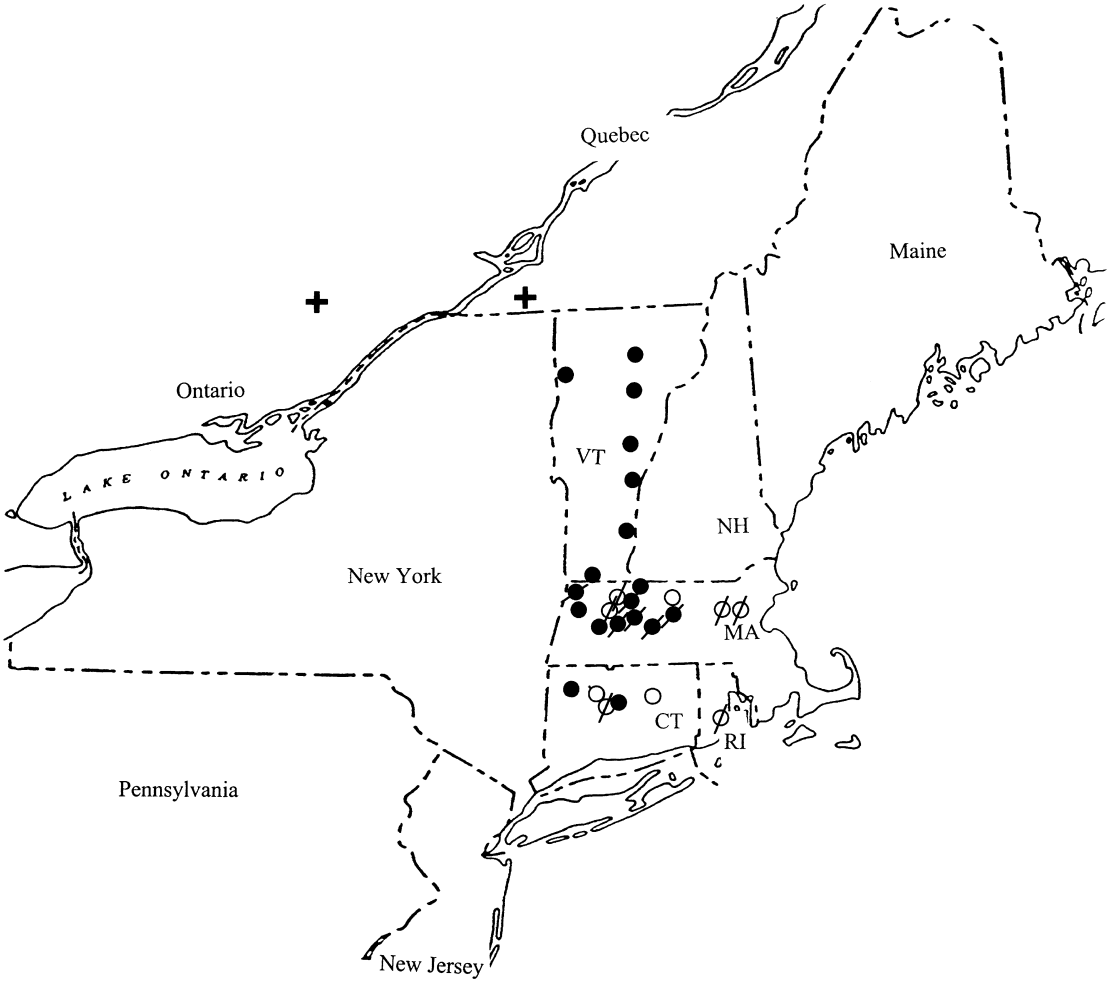

Fig. 1. Locations of release and recovery sites for *Cotesia rubecula* (Chinese strain) in the northeastern United States. Solid circles with cross hatches are release sites at which recoveries were made one or more years after release; solid circles without cross hatches are non-release sites where recoveries were made; hollow circles with cross hatches are release sites at which recoveries were made only in the year of release; hollow circles without cross hatches are release sites at which no recoveries were made; crosses (in Canada) indicate closest sites with known releases or recoveries of other strains of *C. rubecula*.

collard plant in two years (1985, 1986) before the release of *C. rubecula* (in 1988) in our Deerfield, Massachusetts plot and for three years (1990, 1991, 1992) after the parasitoid's establishment. The size and management of this 0.1 ha collard plot was maintained in a consistent manner from 1985 to 1992. For each week of the growing season (May through September) in these years, we examined 20-100 whole collard plants (187 sample occasions, with an average of 58 plants per date). Numbers of groups of *C. glomerata* cocoons were greatest in July, August and September. For all samples in these three months in five years, we classified each plant sampled into a 2×2 matrix. One factor was whether or not the plants had *C. glomerata* cocoons on them (+/-). The other factor was the time period (pre- or post-release of *C. rubecula*). Data from two pre-release years were available (1985 and 1986), as well as three post-release years (1990, 1991, and 1992). Data from the year of release (1988) and the following year (1989) were not included in order to allow for population interactions to reach a stable end point before analysis. We then used a χ^2 test on these data to determine if the percentage of plants with *C. glomerata* cocoons on them varied between the pre and post release periods. Of 4098 plants examined in these months in 1985 or 1986, 16% (661) bore live *C. glomerata* cocoons, compared to only 3% (82) of 2708 plants examined in July-September of 1990, 1991 or 1992, a significant difference ($\chi^2 = 288.7$, df = 1, $P < 0.005$). Total

numbers of larvae on sampled plants in the prerelease period (9980) were either the same or lower (2.45 larvae per plant) than in the post release period (8683 larvae on 2708 plants, or 3.21 per plant) and therefore the decline in the proportion of plants bearing *C. glomerata* cocoons in the post release period cannot be explained as being due to a decrease in the number of larvae per plant available for parasitization. Furthermore, in the 1990-1992 period, *C. rubecula* accounted for over half of all *Cotesia* parasitism of *P. rapae* larvae in the Deerfield, MA, release plot (74% [n = 175], 91% [n = 87], and 49% [n = 76], in 1990, 1991, and 1992 respectively, with percentage being based cocoons of each parasitoid species seen on sampled plants). These data suggest that *C. glomerata* declined in density in the study area following establishment of *C. rubecula*. However, regionally *C. glomerata* remains common in New England and we cannot say if it has declined at that larger spatial scale.

We conclude that *C. rubecula* has become an important parasitoid of *P. rapae* in parts of New England since its establishment in 1988 and we suspect that its range is still increasing and should be examined in other states in the region. Potential effects of this new parastioid on related native *Pieris* butterflies have been examined (Benson et al. unpubl.).

Summary

A population of *Cotesia rubecula*, collected from near Beijing, China and released in Massachusetts in 1988, has established and spread throughout much of New England. It has become a common parasitoid of *Pieris rapae* in agriculture fields and is also found in meadow habitats. *Cotesia glomerata* appears to have declined in abundance following establishment of *C. rubecula*.

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