5.5 Establishment of *Mastrus ridens* (Hymenoptera: Ichneumonidae), an Ecto-parasitoid of Codling Moth, in New Zealand

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Mastrus ridens Horstmann (Hymenoptera: Ichneumonidae: Cryptinae), originally described as *Mastrus ridibundus* (Horstmann, 2009), is a synovigenic gregarious, idiobiont ectoparasitoid of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae). It was collected in Kazakhstan (as *M. ridibundus*) in the 1990s and released in California, Argentina and Chile to control codling moth (Hougardy and Mills, 2006). Following approval from New Zealand's regulatory agency, *M. ridens* was imported into New Zealand from Argentina in January 2009. After an extensive host testing programme (Charles *et al.*, 2013a,b) *M. ridens* was first released in Hawke's Bay in October 2012.

Laboratory cultures of both codling moth and *M. ridens* were maintained in Auckland. Diapausing codling moth larvae were reared on artificial diet (Singh and Ashby, 1986). Mature codling moth larvae were manually removed from rearing tubes and provided with cocooning sites within a 2- to 3-cm wide strip of corrugated cardboard rolled into a c. 8-cm diameter roll. Fifty codling moth larvae were allocated to each roll. Diapausing larvae produced in this way were stored at 4°C for rearing parasitoids.

A colony of *M. ridens* was maintained at 22±1°C, by exposing rolls of diapausing codling moth for parasitism (Sandanayaka *et al.*, 2011) to produce parasitoids for colony maintenance and field releases. We developed a system that efficiently produces a regular supply of parasitised, cocooned codling moth larvae, which are stored at 4-5°C. This allows us to increase *M. ridens* numbers rapidly to produce large numbers for releases.

Release of *Mastrus ridens*: Approximately 230,000 *M. ridens* were released at 40 sites in 7 regions in New Zealand (Hawke's Bay, Gisborne, Nelson, Central Otago, Waikato, Wairarapa and Auckland) from 2012-2017 (Table 5.5.1). Parasitoids were released into unsprayed sites of apple trees with large numbers of codling moths. The optimum time to release *M. ridens* adults is January to May, coinciding with maximum numbers of moth larvae.

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Table 5.5.1. Number of *Mastrus ridens* adults released into 7 regions in New Zealand. The numbers of release sites in each region are in parentheses.

Region	Oct. 2012 - Feb. 2013	January-May 2014	January-May 2015	January-May 2016	February-March 2017
Hawke's Bay	8500 (2)	36000 (4)	22500 (10)		
Gisborne	1600 (2)		14000 (7)		
Nelson/Motueka		34000 (6)	5240 (3)		
Central Otago		16000 (2)	28000 (5)		
Waikato			970 (4)		22800 (3)
Wairarapa			1500 (1)		
Auckland				39000 (17*)	
Total number released	10100	86000	72210	39000	22800

Seasonal activity and establishment of *Mastrus ridens* at the release sites: During 2014-15, seasonal activity of *M. ridens* at release sites was determined using 'sentinel bands' (five laboratory-reared diapausing codling moth larvae cocooned in corrugated cardboard strips of 2 cm wide, 30 cm long). Five bands were deployed monthly from June 2014 to June 2015 at each release site. The bands were stapled directly onto trees in the release zones, either around the trunk, or around medium-sized branches. The 'sentinel bands' were protected from bird and mammal predators by a 'collar' of either netting (wire or plastic) or shade cloth wrapped around the band.

Establishment of *M. ridens* was monitored in 2016 by using 'wide bands' (10-cm wide corrugated cardboard strips wrapped around the trunks of apple trees to catch wild codling moth larvae). A protective wire mesh collar was placed around the bands to prevent predation of host larvae. The wide bands were deployed in January 2016 at sites where *M. ridens* had been released between 2012 and 2015. Deployment was timed to catch larvae from the uni-voltine codling moth populations in Hawke's Bay, Gisborne, Nelson and Central Otago regions, and from the second generation of bi-voltine populations in the Waikato region. Fifty percent of the bands at each site were retrieved at the end of summer (early June) 2016. Predation and mortality over winter was determined by retrieving the remaining bands in spring (October 2016) prior to codling moth pupation and emergence. A total of 549 wide bands were retrieved from the five regions.

Retrieved sentinel and wide bands were returned to the laboratory where numbers of surviving and parasitized codling moth larvae were recorded. Retrieved sentinel codling moths were held at 20°C, and the numbers and species of emerging parasitoids recorded.

Mastrus ridens establishment was confirmed in four regions (Table 5.5.2). In those regions, the female parasitoids actively sought and attacked codling moth larvae from at least September to May. This seasonal activity indicates that they may complete several generations a year (compared with only one or two of its host codling moth). Such activity is a feature of effective parasitoid biocontrol agents. Monitoring in Waikato and Auckland is continuing in 2017 to confirm establishment.

Table 5.5.2. Establishment of *Mastrus ridens* in different regions of New Zealand recorded from 'sentinel bands' in 2014, 2015 and from 'wide bands' in 2016.

Region	***M. ridens* recovered from 'sentinel bands'**		***M. ridens* recovered from 'wide bands' in 2016**		
	# *M. ridens* in 2014 (# of sites)	# *M. ridens* in 2015 (# of sites)	# wild cm* recovered (# of sites)	# wild cm* parasitised by *M. ridens* (# of sites)	Average % parasitism
Hawke's Bay	32 (2)	26 (1)	601 (12)	176 (6)	37.9
Gisborne			62 (5)	3 (2)	20.1
Nelson/Motueka	209 (5)	112 (6)	2872 (8)	350 (6)	17.1
Central Otago			1194 (5)	13 (4)	10.4

*codling moth larvae

Existing parasitiod species: The presence of four other species of codling moth parasitoids was reported from sentinel and wide band data. *Liotryphon caudatus* (Ratzeburg) (Hymenoptera: Ichneumonidae), a long-established larval parasitoid from past biocontrol programmes, was commonly found in Hawke's Bay, Gisborne and Waikato. An introduced egg/larval parasitoid, *Ascogaster quadridentata* Wesmael (Hymenoptera: Braconidae), was found commonly in Nelson and Central Otago, and in low numbers in Hawke's Bay. Low parasitism by the introduced *Glabridorsum stokesii* (Cameron) (Hymenoptera: Ichneumonidae), a pupal parasitoid of many tortricids, was found in Hawke's Bay. *Dibrachys microgastri* (Bouché) (Hymenoptera: Pteromalidae) was recovered from Central Otago, Nelson, and Waikato, as a primary parasitoid from codling moth larvae and as a hyperparasitoid from *M. ridens* cocooned larvae. The very polyphagous *D. microgastri*, a recent accidental arrival would never be considered for introduction. How these parasitoids interact, and how they might affect the impact of *M. ridens*, have not been investigated. The ecological interactions of codling moth and its natural enemies in unmanaged apple blocks will become a focus for future research .

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