The distribution of *Liotryphon caudatus*, a parasitoid of codling moth (*Cydia pomonella*) in Hawke's Bay apple orchards

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Abstract The ichneumonid parasitoid *Liotryphon caudatus* was introduced into New Zealand in 1906 for biological control of codling moth, *Cydia pomonella*, a pest of pipfruit. Following release, it was found in the Auckland area, with only isolated recoveries in the 1970s in Waikato and Hawke's Bay. In 2010, 9.6% parasitism of codling moth by *L. caudatus* in larvae collected from a Hawke's Bay orchard was recorded. *Liotryphon caudatus* harvested from this collection were used to establish a laboratory colony for behavioural observations. In 2011, 15 sites across Hawke's Bay comprising abandoned, organic and Integrated Fruit Production apple orchards were surveyed for the presence of *L. caudatus*. Coooned codling moth larvae in corrugated cardboard bands were placed at each site for 3 weeks and assessed for parasitism. *Liotryphon caudatus* was recovered from four of five abandoned orchards with up to 13% parasitism, but was not found in either organic or IFP orchards.

Keywords *Liotryphon caudatus*, codling moth, *Cydia pomonella*, ichneumonidae, ectoparasitoid, biological control.

INTRODUCTION

Codling moth, *Cydia pomonella*, is a key pest of pipfruit throughout New Zealand. Most commercial apple growers follow the sector's Integrated Fruit Production (IFP) guidelines for control of this moth. Pest management in this programme is based on selective insecticides that have minimal activity against important natural enemies and increasingly, the use of codling moth pheromone mating disruption. While high levels of codling moth control are essential for growers to meet demanding phytosanitary requirements in Asian markets, there are also strong imperatives to produce crops with negligible pesticide residues for European markets. This conundrum,

together with the presence of unmanaged host plants (e.g. abandoned apple trees and walnuts) adjacent to commercial orchards, has increased the significance of codling moth for growers.

In 1906, W.A. Boucher from the New Zealand Department of Agriculture travelled to California and imported a consignment of codling moth cocoons parasitised by *L. caudatus* from a colony maintained by the Californian State Board of Horticulture (Kirk 1907). In 1907, parasitoids reared from this colony were supplied to 69 apple orchards throughout New Zealand. Over 20 years later *L. caudatus* was known to occur only in the Auckland region (Dumbleton 1936). In 1942,

the Cawthron Institute in Nelson imported a shipment of *L. caudatus* larvae from Canada. Their release of the first generation from this shipment into three abandoned orchards in Nelson did not establish. Synonyms under which the parasitoids were imported between 1906 and 1944 were: *Calliephialtes messor* (Gravenhorst), *Ephialtes messor* Gravenhorst, *Ephialtes caudatus* Ratzeburg and *Apistephialtes caudatus* (Ratzeburg). In 1971, a mated female was collected in Hamilton and used to begin a colony at the Department of Scientific and Industrial Research (DSIR) in Nelson. Forty adults were released at the Appleby Research Orchard in Nelson, but no subsequent recoveries were made (Wearing & Charles 1989). In 1975, a single codling moth larva parasitised by *L. caudatus* was collected at the DSIR Research Orchard in Hawke's Bay (C.H. Wearing, unpublished data).

Liotryphon caudatus (Ratzeburg) (Hymenoptera: Ichneumonidae) is a solitary ectoparasitoid that attacks pre-pupal codling moth larvae when they have descended from the fruit to find protected pupation sites in the bark of trees. The wasp paralyses its host and then deposits an egg on cocooned codling moth larvae (Mills et al. 1996). Following an incubation period of 1–7 days, the parasitoid larva emerges and feeds on the host's body contents, moulting once before spinning a tan coloured cocoon within the host's cocoon. Depending on temperature, development from egg to the emerging adult is completed in 3–4 weeks. The parasitoid overwinters as a mature larva or cocooned pupa (Clausen 1978). Records show other hosts of *L. caudatus* in New Zealand include oriental fruit moth (*Grapholita molesta*) and *Stathmopoda* spp. Oriental fruit moth was recorded as a host when larvae were exposed to *L. caudatus* in cardboard bands attached to peach trees at Kumeu, Auckland (Russell 1989).

The objective of this study was to establish the abundance and potential significance of *L. caudatus* for biological control of codling moth in Hawke's Bay.

MATERIALS AND METHODS

Establishment of the colony

In 2010, 301 codling moth larvae were collected from corrugated cardboard bands in the Plant

& Food Research orchard, Havelock North, Hawke's Bay. Of these larvae, 29 (9.6%) were parasitised by what was identified as *L. caudatus*. Five voucher specimens were deposited in the New Zealand Arthropod Collection (NZACO 4033131, 4033621, 4034199, 4035203, 4036240). The remaining eggs and larvae were then used to establish a laboratory colony.

Fifth instar codling moth larvae were supplied by Plant & Food Research insect rearing laboratory in Auckland on a regular basis. They were programmed for diapause and were used both to maintain the parasitoids as well as for a survey of *L. caudatus* distribution in Hawke's Bay orchards.

The codling moth larvae were placed into rolls of corrugated cardboard (2.5 × 20 cm) and left for one week at 20–25°C for the larvae to spin cocoons. The rolls were then held at 4°C until they were required.

Observations and behaviour

Liotryphon caudatus adults were maintained in two wooden cages (30 × 28 × 32 cm), each with a glass front to allow observations and photography. A cotton sleeve attached to the side of each cage allowed easy access for feeding and retrieving the corrugated rolls. The parasitoids were provided with dishes containing moistened cotton wool, and honey was smeared on the glass and ceiling of the cage each day. Occasionally a small container of a honey and water mixture was added to the cages, which the males appeared to prefer. The cages were maintained at 20–25°C with a 16 h day length. Up to five rolls, each containing 10–20 cocooned codling moth larvae, were offered to the parasitoids and each roll was replaced daily. Initially, codling moth larvae that had been parasitised were removed from the rolls and placed in small vials inside Petri dishes for easy observation of developing parasitoids. The dishes were then sealed to prevent desiccation of the eggs and larvae, and held in an incubator at 20°C. Later, the entire corrugated rolls containing parasitised codling moth were placed at 20°C in plastic containers, and the adult parasitoids collected and added to the colony once they emerged. Observations of

L. caudatus development were made each day until adult emergence.

Superparasitism and alternative hosts

Superparasitism was found to be common because of the high number of wasps per cage. In September 2010, the fates of 28 wasp eggs oviposited on a single codling moth larva were observed. In addition, an assessment was made of the parasitoid survival and sex ratio from 10 single and 10 superparasitised codling moth larvae.

Other potential host species were investigated using a *L. caudatus* female observed to be actively ovipositing. One roll containing five native brownheaded leafroller (*Ctenopseustis obliquana*) late instars and one roll containing five native greenheaded leafroller (*Planotortrix excessana*) late instars were introduced at separate times to a cage containing one female and six male adult *L. caudatus*. These rolls remained in the cage for 7 days; there were no rolls containing codling moth present during this study.

Survey of incidence in Hawke's Bay

A survey of 15 orchards within 10 km of Hastings, Hawke's Bay, was conducted from February to March 2011. The sites comprised five abandoned, five organic and five IFP apple orchards. Ten corrugated cardboard bands each containing five cocooned codling moth larvae were deployed into each orchard. Each band was wrapped around and stapled to separate apple tree trunks directly underneath the first fruiting tier using a sleeve of plastic or wire netting to protect larvae from vertebrate predation. These bands remained in the orchard for approximately 3 weeks before being removed and assessed for parasitism. Any larvae that had died from undetermined causes were excluded when calculating the percentage parasitism.

RESULTS

Observations and behaviour

After mating, the females searched for and located codling moth larvae by moving their antennae and beating their wings. During oviposition the host was stung and paralysed and an egg

deposited on the codling moth larva. Usually one egg was deposited but superparasitism occurred in the artificial environment of the cages. When this occurred only one parasitoid developed from each codling moth larva. Depending on temperature, incubation took 1–7 days. The larvae fed for approximately 6 days, changing form after moulting. When fully grown they spun a tan coloured, slightly transparent cocoon. The life cycle from egg to adult was completed in 20–30 days and adults lived for up to 2 months under laboratory conditions.

Superparasitism and alternative hosts

Five days after superparasitism all but three eggs had desiccated, and these remaining eggs were positioned on the body of the paralysed codling moth larva. The next day these eggs had hatched into three small healthy parasitoid larvae. The following day all three were still alive, but one was much larger than the other two and only it survived. During observations it was noted that 1st stage *L. caudatus* larvae cannibalised eggs and other larvae in superparasitism situations. There was no difference in the sex ratio of the emergent parasitoids from 10 single or 10 superparasitised codling moth larvae but superparasitism reduced parasitoid survival by about 50%.

A difference was observed in the ovipositional behaviour of female *L. caudatus* towards codling moth and two species of native leafrollers. Rolls containing brownheaded leafroller and greenheaded leafroller created some interest to the female *L. caudatus*, but on closer inspection neither oviposition nor parasitism of leafroller larvae occurred.

Survey of incidence in Hawke's Bay

During the 2011 survey, an additional 68 wild codling moth larvae in survey blocks moved down the trees during the survey and cocooned in the bands. Codling moth parasitised by *L. caudatus* were collected from four of the five abandoned orchards, but no *L. caudatus* were found in the organic and IFP orchards (Table 1).

While assessing the bands collected from the survey, a second species of hymenopteran

parasitoid was recovered from codling moth larvae from two of the five abandoned orchards. This was tentatively identified as *Dibrachys cavus* (Pteromalidae: Pteromalinae) and deposited at NZAC (NZAC04045415).

Table 1 Percentage of codling moth larval parasitism by *Liotryphon caudatus* in abandoned, organic and Integrated Fruit Production (IFP) apple orchards in Hawke’s Bay from February to March 2011. Sample size = 50 per orchard except where wild larvae also cocooned in rolls (n in brackets).

Orchard	Abandoned	Organic	IFP
1	13 (56)	0	0 (54)
2	10 (52)	0 (51)	0
3	9 (64)	0	0 (55)
4	3 (75)	0	0
5	0 (55)	0 (51)	0 (55)
Mean	7	0	0

DISCUSSION

This survey indicates that *L. caudatus* is present in abandoned Hawke’s Bay apple orchards, albeit at relatively modest levels of parasitism. It is likely that they are present in abandoned trees only because of the relatively high levels of codling moth at such sites. Although *L. caudatus* appeared to be widespread, its apparent absence from both organic and IFP orchards makes it difficult to estimate what real impact its activity might have on reducing the risk of codling moth damage in commercial apple production. Each of the managed blocks that was surveyed had a history of codling moth infestation and some damage was evident. Seven of the 10 managed blocks surveyed were in close proximity to walnut trees, which are a known host for codling moth (Wearing & Charles 1989). While these may support populations of *L. caudatus* they did not appear to influence its activity in the managed orchards with codling moth present. The presence of *L. caudatus* in adjacent trees may reduce the risk presented by immigrant moths.

In addition to codling moth, *L. caudatus* is known to attack some other members of the tortricid subfamily Olethreutinae (e.g. oriental fruit moth) and some members of the Family Stathmopodidae (e.g. *Stathmopoda* spp.); both families include cocoon-forming species. In this study *L. caudatus* detected the presence of both greenheaded and brownheaded leafroller larvae but exhibited no ovipositional behaviour on these non-cocooning native leafroller species. Furthermore *L. caudatus* has never been recovered from any leafroller larval parasitism surveys in Hawke’s Bay (P. Lo, Plant & Food Research, unpublished data).

Little is known about *D. cavus* as a parasitoid in New Zealand orchards. There are only four previous records catalogued with the NZAC, all from the South Island and of these just one was associated with codling moth. *Dibrachys cavus* was not mentioned by Wearing & Charles (1989) in their list of endemic and introduced natural enemies of codling moth in New Zealand. It is a gregarious ectoparasitoid in prepupae and pupae of many small-size Lepidoptera, but appears to have a wide host range (D. Ward, Landcare Research, pers. comm.).

Large numbers of codling moth present in abandoned blocks and walnut trees highlight the importance of biological control in unmanaged hosts. The lack of *L. caudatus* activity in commercial orchards in Hawke’s Bay and the apparent modest levels of parasitism at abandoned sites suggest that the potential introduction of other natural enemies is justified for improving codling moth control and risk management. In order to produce pipfruit with nil residue levels and reduced codling moth damage at harvest, the use of mating disruption coupled with biological control could be a successful method of management of codling moth in orchards and nearby hosts.

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