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Species and abundance of ladybirds (Coleoptera: Coccinellidae) on citrus orchards in Northland, New Zealand, and a comparison of visual and manual methods of assessment

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Abstract

Ladybird populations were assessed on citrus orchards in Northland, New Zealand, from January 1991 to February 1994. Ten-minute visual counts were made during all months and compared with manual searches of trees on three occasions. *Halmus chalybeus* (steelblue ladybird) comprised 97-99% of the ladybirds found by both types of assessment and was present throughout the year. Over 95% of the ladybirds recorded in visual counts were adults, whose numbers peaked in February-March. The most larvae and pupae were recorded in December-January. A manual search for ladybirds at an orchard near Kerikeri, Northland, in November 1991 recorded 153 ladybirds / tree with 91% comprising egg batches, larvae and pupae. Searches at a nearby orchard in December 1992 found 22 ladybirds / tree (71% immature) and 59 / tree in February 1993 (5% immature). Visual counts of ladybirds recorded approximately 4–5% of the number of adult ladybirds found by manual searches, but only 0–3% of egg batches, larvae and pupae. Visual counting was a suitable method for estimating numbers of adult ladybirds on citrus orchards, but not immature stages.

Keywords: Coccinellidae, *Halmus chalybeus*, population sampling, Coccidae, citrus.

Introduction

The New Zealand citrus industry is developing an Integrated Pest Management (IPM) programme and a key priority is to enhance the biological control of pests while aiming to minimise the use of pesticides. Two important pests of citrus in Northland, New Zealand, are *Ceroplastes destructor* Newstead (soft wax scale) and *C. sinensis* Del Guercio (Chinese wax scale) (Homoptera: Coccidae). Predation by ladybirds of the immature stages has a major influence on the population dynamics of both scale species (Lo 1994).

Ladybirds (Coleoptera: Coccinellidae) have been successfully used for biological control of scale insects around the world for over a century. Several species were imported to New Zealand as predators of scales, mealybugs and aphids (Cameron *et al*. 1987), but not specifically to control wax scales. Three exotic species established in New Zealand, *Halmus chalybeus* (Boisduval) (steelblue ladybird), *Cryptolaemus montrouzieri* Mulsant (mealybug ladybird) and *Rhyzobius forestieri* (Mulsant), have been recorded preying on *Ceroplastes destructor* in Australia (Smith 1970, Snowball 1972, Beattie pers. comm.).

This paper reports on the species and seasonal abundance of ladybirds found on citrus orchards in Northland, New Zealand. A comparison was made between non-contact visual counts and manual searches where trees were examined closely by hand for ladybirds.

Methods

Four sampling methods, visual counts, beating, sweep-netting and suction sampling, were initially tested, but only the former proved to be practical. Beating was ineffective because unlike *Cryptolaemus montrouzieri*, *R. forestieri* and many other ladybirds, the main species present, *H. chalybeus*, did not drop readily when disturbed. Sweep-netting and suction sampling were difficult within the three-dimensional environment and woody vegetation of citrus trees. These techniques are more suited to the simpler habitat of field crops. Michels & Behle (1992) found visual counts were more precise than either sweep-netting or beating for sampling coccinellids in a grain crop.

Visual counts

One to three citrus orchards around Kerikeri and Whangarei were visited regularly from January 1991 to February 1994 to assess seasonal changes in ladybird populations. Intervals between visits varied from approximately two-weekly between December and April when ladybirds were most abundant, to 1-2 monthly at other times. Occasional counts of ladybirds were made on another 11 orchards during 1991 and 1992. The main varieties of citrus were tangelo, mandarin and orange.

All stages and species of ladybirds seen in 10 minutes were recorded while walking slowly through a block without disturbing the foliage. Trees were searched at a constant walking speed so that approximately 20–30 trees were examined per block depending on their size. Trees in different orchards varied from 1.2m to about 3.5m high. All counts were made on fine days between 1000–2000 hours (New Zealand standard time).

Additional data were obtained from a tangelo orchard near Whangarei where an experiment was conducted on the effect of fungicide applications on numbers of ladybirds. The same assessment method was used except that each plot of three trees was searched for three minutes. Counts were made every 1–2 weeks from 18 February–12 May 1991. This information was included in the data on species composition, but not in data on stages or estimates of ladybird abundance because of differential treatment effects.

Manual searches

Manual searches for ladybirds were made on a total of three occasions at two orchards near Kerikeri. Search times differed between the three searches depending on the numbers of ladybirds present. In November 1991 at Orchard A, the leaves and all branches of 24, 2.5 m tall Harward late orange trees were examined closely with the aim of finding and removing all ladybird stages present. Each tree was re-checked three times to check for any ladybirds that had not been detected. The trees were covered with insect netting between searches to prevent re-invasion. Approximately 1.5 hours was spent searching each tree. This procedure was repeated on 24, 2.5 m high tangelo trees at Orchard B in December 1992. These trees were searched twice for a total of about 35 minutes each. In February 1993, one half of 9 trees in the same block was searched once for about 20 minutes each. Only one search was conducted on this occasion because the population consisted largely of adults, which were easier to find than immature stages, which predominated earlier in the year. A visual count was made at the same time as the three manual searches.

Results

Halmus chalybeus was the dominant species at all orchards throughout the year, comprising 97-99% of the total numbers in both visual and manual assessments (Table 1). *Rhyzobius forestieri* was the only other species found in both types of assessment. *Rodolia cardinalis* and *Cryptolaemus montrouzieri* occurred in low numbers, while three other species, *Adalia bipunctata L.*, *Harmonia conformis* (Boisduval) and *Illeis galbula* (Mulsant), were recorded a total of four times in the visual counts.

Halmus chalybeus were present throughout the year. Its numbers recorded by visual counts increased from spring until March before declining during mid-autumn and winter (Fig. 1). The mean for August and September was affected by unusually high counts from one orchard. The highest numbers of larvae and pupae were recorded during December and January. No egg batches were seen during visual searches.

Visual counts found predominantly adult ladybirds throughout the year, whereas in manual searches, the relative abundance of immature and adult ladybirds differed between spring and summer (Table 2). Between 96–100% of the ladybirds recorded in visual counts were adults in all months except December–January when 11% were larvae and pupae. In contrast, the manual search in

Table 1. Total ladybird fauna recorded on citrus orchards in Northland by visual counts and manual searches, January 1991 – February 1994.

Species	Visual %	Manual %
Halmus chalybeus	97.5	99.1
Rhyzobius forestieri	1.8	0.9
Rodolia cardinalis	0.4	0
Cryptolaemus montrouzieri	0.3	0
n	6902	3786

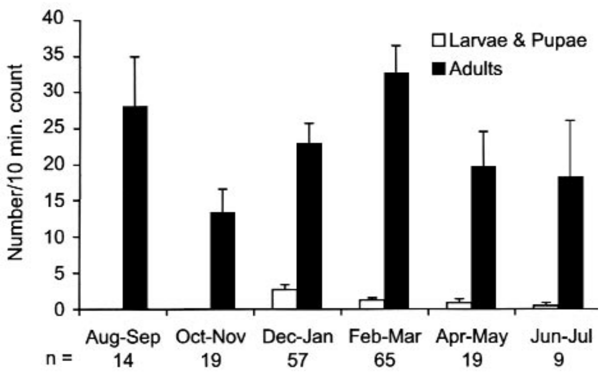

Fig. 1. Mean number (+SEM) of ladybirds recorded by visual counts on citrus orchards in Northland, January 1991 – February 1994. n = number of counts.

November found 91% of the population were immature stages compared with 71% in December and only 5% by February. In February, both assessment methods recorded similar proportions of immature and adult ladybirds.

Manual searches recorded 153 ladybirds/tree (Orchard A) in November, 22/tree (Orchard B) in December and 59/tree (Orchard B) in February (Table 3). These searches found much higher numbers of all ladybird stages compared with visual counts conducted at the same time. In the November, December and February searches, 183, 38 and 24 times more ladybirds were found than the respective visual counts. This variation was due to the declining proportion of larvae present.

Visual counts found an average of 4.4% (and at best 5%) of the number of adults recorded in manual searches. Even fewer immature stages were recorded, ranging from 0-3% of the numbers found in manual searches.

Discussion

Halmus chalybeus was clearly the most abundant coccinellid on citrus orchards in Northland. It is a generalist predator of insects and mites (Beattie & Gellately 1983). Its principal prey includes both soft (Coccidae) and armoured (Diaspididae) scales (Drea & Gordon 1990, Flynn 1995). *Rhyzobius forestieri* is also polyphagous and feeds readily on *Ceroplastes rubens* Maskell (Richards 1981). Both adults and larvae of this ladybird preyed on *C. destructor* and *C. sinensis* in laboratory and field trials (Lo 1994), but its numbers were too low to have much impact on scale populations. *Cryptolaemus montrouzieri* and *Rodolia cardinalis* are more specialised predators. *Cryptolaemus montrouzieri* is primarily a predator of mealybugs (Babu & Azam 1987), while the main prey of *R. cardinalis* is cottony-cushion scale, *Icerya purchasi* Maskell (Rosen 1990).

Halmus chalybeus has several attributes that enable

Table 2. Number of ladybirds (n) and percentage of each stage recorded by visual counts and manual searches on citrus orchards in Northland, January 1991–February 1994. (– = no data for these periods)

Period	n	Egg batches	Larvae	Pupae	Adults	n	Egg batches	Larvae	Pupae	Adults
Aug-Sep	362	0	0	0	100.0	–				
Oct-Nov	225	0	0.9	0.9	98.2	3668	4.0	77.7	9.2	9.1
Dec-Jan	1395	0	7.3	3.6	89.1	537	1.3	48.8	20.6	29.2
Feb-Mar	2100	0	2.4	1.3	96.2	266	0	4.5	0.4	95.1
Apr-May	386	0	2.6	1.8	95.6	–				
Jun-July	126	0	0.8	0.8	98.4	–				

Table 3. Comparison between the mean number of ladybirds per tree (+SEM) recorded by visual counts and manual searches conducted at the same time. The visual counts are also expressed as a percentage of the number found in the respective manual search.

Sampling date		Egg batches	Larvae	Pupae	Adults	Total
November 1991 (Orchard A)						
	Visual	0	0.06	0.06	0.72	0.83
	Manual	6.17 (0.7)	118.79 (7.2)	14.0 (2.2)	13.88 (0.8)	152.83 (8.4)
	Visual/Manual (%)	0	0	0.4	5.2	0.5
December 1992 (Orchard B)						
	Visual	0	0.29	0.06	0.24	0.59
	Manual	0.29 (0.1)	10.92 (0.9)	4.63 (0.6)	6.54 (1.0)	22.38 (1.9)
	Visual/Manual (%)	0	2.7	1.3	3.6	2.6
February 1993 (Orchard B)						
	Visual	0	0.03	0	2.45	2.48
	Manual	0	2.67 (1.1)	0.22 (0.2)	56.22 (6.8)	59.11 (7.1)
	Visual/Manual (%)	0	0.9	0	4.4	4.2

it to be an effective natural enemy of wax scales. Firstly, both larvae and adults can greatly reduce populations of *C. destructor* and *C. sinensis* by feeding on crawlers and settled first and second instars (Lo 1994). Secondly, its phenology is well synchronised with that of its prey. The emergence and settlement of first instar *C. destructor* occurs in early summer (Lo *et al*. 1996), which coincided with the presence of large numbers of *H. chalybeus* larvae. Thirdly, the year-round presence of *H. chalybeus* means that it does not need to become re-established on orchards each year. In contrast, the majority of coccinellid species of economic importance in orchards migrate and hibernate elsewhere (Hodek 1973). This makes them vulnerable to adverse conditions in other habitats and means that their life cycle may not always be closely synchronised with that of their prey.

The abundance of *H. chalybeus* on citrus orchards could potentially be used, in conjunction with scale counts, to develop spray thresholds for *C. destructor* and *C. sinensis*. Lo (1994) found an inverse correlation between the density of first and second instar *C. destructor* in January (around the time of peak crawler settlement), and the numbers of ladybirds recorded in 10-minute visual counts. Few scales survived on orchards with more than 30 ladybirds/count at this time of year. Given the importance of *H. chalybeus*, it is crucial that an IPM programme uses pesticides that are compatible with this ladybird. Predation of wax scales by *H. chalybeus* was disrupted by commonly used copper-based fungicides and by several insecticides in both laboratory and field experiments (Lo 1994, Lo & Blank 1992).

Visual counts provided good relative estimates of ladybird numbers, while data from manual searches enabled counts to be calibrated with absolute densities of adults. The proportion of adults recorded by visual searches compared to manual searches was about 4-5%, so actual populations can be estimated by multiplying visual counts by 25. Successive weekly counts from the same orchard usually gave similar numbers of ladybirds (unpubl. data), indicating that this method gave repeatable results. However, daily temperatures can affect counts because adult ladybirds were less active in cold weather. On cold days they tended to remain stationary and somewhere sheltered, such as between two leaves, which made them less likely to be seen. Over 80% of *H. chalybeus* studied by Flynn (1995) were sheltering in clusters during July. Therefore populations on orchards may not actually vary between summer and winter as much as is suggested in Fig. 1.

Manual searches showed that visual counts were unsuitable for estimating the abundance of eggs and immature ladybirds. In spring and early summer when these stages predominated, visual searches will seriously underestimate ladybird populations. Egg batches were not detected by visual searches because they were usually laid on the underside of leaves inside the tree canopy. Larvae and pupae were more difficult to observe than adults because larvae are smaller and more cryptically coloured, while pupae are dull coloured, stationary and generally in the interior of tree canopies. Although manual searches estimated actual population levels much more accurately than did visual counts, they were very time consuming, especially in spring. On large trees, and when the population was largely immature stages, one manual search was insufficient to find all the ladybirds present. A practical solution to reduce the time involved would be to use a quadrat, such as a 50cm sided cube to sample portions of trees.

In conclusion, the predominance of *H. chalybeus* meant it was the predator with the greatest potential to control wax scales. Visual counts provided a simple, consistent and quick technique for assessing adult ladybirds that could be readily incorporated into an IPM programme. As long as the method is described well, it should be robust enough to give comparable results between different observers. Visual counts, however, were poorly suited for estimating the abundance of immature ladybirds, although the peak of larvae in early summer was recorded. In contrast, manual searches produced good estimates of the actual numbers of all ladybird stages, but searches of whole trees were too labour intensive to be a practical monitoring tool. Searching a portion of trees, however, may be useful especially in spring, to determine the abundance of immature ladybirds. There is potential for developing a spray threshold for wax scales based on visual counts of ladybirds. However, further research is needed to determine the relative importance of larval and adult ladybirds in reducing populations of these pests. This will help to determine the need to conduct both visual counts and manual searches.

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References

Babu TR, Azam KM. 1987. Biology of *Cryptolaemus montrouzieri* Mulsant (Coccinellidae: Coleoptera) in relation with temperature. *Entomophaga 32*: 381-386.

Beattie GAC, Gellatley JG. 1983. Mite pests of citrus. Agfact H2.AE.3 6pp. Department of Agriculture, New South Wales.

Cameron PJ, Hill RL, Valentine EW, Thomas WP. 1987. *Invertebrates Imported into New Zealand for Biological Control of Invertebrate Pests and Weeds, for Pollination, and for Dung Dispersal, from 1874 to 1985*. DSIR Bulletin 242, 51 pp.

Drea JJ, Gordon RD. 1990. Coccinellidae. In: *Armored Scale Insects their Biology, Natural Enemies and Control. Volume 4B.* (ed D Rosen) pp 19-40. Elsevier, Amsterdam.

Flynn AR. 1995. Aspects of the biology of the steel blue ladybird *Halmus chalybeus* (Boisduval) (Coleoptera: Coccinellidae). MSc thesis, University of Auckland, New Zealand.

Hodek I. 1973. *Biology of Coccinellidae*. Academia Press, Prague.

Lo PL. 1994. Population ecology and integrated management of soft wax scale (*Ceroplastes destructor*) and Chinese wax scale (*C. sinensis*) (Hemiptera: Coccidae) on citrus. Ph.D thesis, Lincoln University, New Zealand.

Lo PL, Blank RH. 1992. Effect of pesticides on predation of soft wax scale by the steel-blue ladybird. *Proceedings of the 45th New Zealand Plant Protection Conference:* 99-102.

Lo PL, Blank RH, Penman DR. 1996. Phenology and relative abundance of *Ceroplastes destructor* and *C. sinensis* (Hemiptera: Coccidae) on citrus in Northland, New Zealand. *New Zealand Journal of Crop and Horticultural Science 24*: 315-321.

Michels GJ, Behle RW. 1992. Evaluation of sampling methods for lady beetles (Coleoptera: Coccinellidae) in grain sorghum. *Journal of Economic Entomology 85*: 2251-2257.

Richards AM. 1981. *Rhyzobius ventralis* (Erichson) and *R. forestieri* (Mulsant) (Coleoptera: Coccinellidae), their biology and value for scale insect control. *Bulletin of Entomological Research 71*: 33-46.

Rosen D. 1990. Biological control. In: *Armored Scale Insects their Biology, Natural Enemies and Control. Volume 4B*. (ed D Rosen) pp 413-415. Elsevier, Amsterdam.

Smith D. 1970. White wax scale and its control. *Queensland Agricultural Journal 96*: 704-708.

Snowball GJ. 1972. Status of natural enemies of white wax scale, *Gascardia destructor* (Newst.) (Homoptera: Coccidae), in eastern Australia. *Proceedings of the XIV International Congress of Entomology*: p. 212.