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Morphological ontogeny of *Amblydromalus limonicus* (Acari: Phytoseiidae)

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Abstract

The morphological ontogeny of *Amblydromalus limonicus* is described in this paper based on laboratory-reared specimens originated from Auckland, New Zealand. Comparisons between *A. limonicus* and *A. lailae* from Australia showed that the protonymphs, deutonymphs and adults of these two species are not distinguishable, but unusual differences are present in larvae. The larvae of "*A. lailae*" by Schicha of Australia were incorrectly associated with other stages of *A. lailae* and belong to the genus *Euseius*. The results of this study highlight a neglected area of research in phytoseiid taxonomy: the careful descriptions of immature stages based on reared specimens.

Key words: Mesostigmata, immature stages, life cycle, predatory mites

Introduction

Phytoseiid mites received much attention due to their important roles in controlling phytophagous mites and other small arthropods such as thrips, whitefly and psyllids (Hoogerbrugge *et al.* 2011; Knapp *et al.* 2013; McMurtry *et al*. 2013; Xu & Zhang 2015; Azevedo *et al*. 2016; Reichert *et al.* 2016; Silva *et al*. 2016; Fathipour *et al.* 2017; Liu & Zhang 2017; Patel & Zhang 2017a,b; Shakarami & Bazgir 2017; Song *et al.* 2017; Ullah & Lim 2017; Zheng *et al.* 2017). More than 2700 species have been recorded worldwide (Chant & McMurtry 2007; Ma *et al.* 2016; Demite *et al.* 2017).

Most descriptions of Phytoseiidae are based on adults, although immature stages can also provide useful characters for species delimitation (Cargnus & Zandigiacomo 2014) and are important for homology assessment of setae and other characters (Yoshida-Shaul & Chant 1983). Relatively few authors include descriptions of the immature stages (Yoshida-Shaul & Chant 1983; Aponte & McMurtry 1987). Evans (1953) was perhaps the first who made an extensive study on the immature stages of *Scapulaseius newsami* (Evans, 1953) based on laboratory-reared specimens. Collyer (1957) described the immature stages of *Neoseiulus scoticus* (Collyer, 1957) on fruit trees. Chant (1958) recorded immature and adult stages of 18 species of British Phytoseiidae in the first comprehensive study of this nature and suggested that it is insufficient to study adults only. Athias-Henriot (1960) reported three new species, including immature stages of *Eharius chergui* (Athias-Henroit, 1960). Karg (1965) recorded dorsal shield characters of *Neoseiulus reticulatus* (Oudemans, 1930), *Proprioseiopsis sororculus* (Wainstein, 1960) and *Amblyseius stramenti* Karg, 1965 from protonymphs to deutonymphs. Schuster (1966) described immature stages of *Metaseiulus* (*Metaseiulus*) *smithi* (Schuster, 1957), *M.* (*M.*) *mcgregori* (Chant, 1959) and *Galendromus* (*Galendromus*) *occidentalis* (Nesbitt, 1951), whereas Van der Merwe (1968) added those for *Euseius tutsi* (Pritchard & Baker, 1962) and *Phytoseiulus longipes* Evans, 1958. Karg (1971) recorded the immature stages of *Neoseiulus agrestis* (Karg, 1960) and *Amblyseius obtusus* (Koch, 1839). Swirski *et al.* (1973) described immature stages of *Euseius rubini* (Swirski & Amitai, 1961), *Neoseiulus barkeri* Hughes, 1948 and *Amblyseius swirskii* Athias-Henriot, 1962. Prasad (1974) described all the life stages of *Phytoseiulus macropilis* (Banks, 1904). Chaudhri *et al*. (1974) described all developmental stages of *Typhlodromus* (*Anthoseius*) *recki* Waistein, 1958. Schicha (1977a, b) added five species: *Amblyseius* (*A.*) *lentiginosus* Denmark & Schicha, 1974, *Euseius victoriensis* (Womersley, 1954), *Euseius elinae* (Schicha, 1977a), *Typhlodromus* (*Typhlodromus*) *baccettii* Lombardini, 1960 and *Phytoseius fotheringhamiae* Denmark & Schicha, 1975. Schicha (1979a) described all developmental stages of *Typhlodromus dossei* Schicha, 1978 collected from *Ficus carica* (Caricaceae) and Schicha (1979b) described the same for *Amblydromalus lailae* (Schicha, 1979b) from pawpaw (*Carica papaya* L.). Rowell and Chant (1979) described the ontogenetic development for four species and discussed the ontogenetic development of setae in the determination of setal homology in the family. Xin *et al.* (1981) described all life stages of *Neoseiulus pseudolongispinosus* (Xin, Liang & Ke, 1981). Yoshida-Shaul and Chant (1983) reported the ontogenetic development of setae in two species groups in the genus *Typhlodromus* Scheuten. Aponote and McMurtry (1987) described ontogenetic development of *Amblyseius colimensis* Aponote & McMurtry, 1987. Abou-Setta *et al.* (1991) reported all life stages of *Iphiseiodes quadripilis* (Banks, 1904). Fouly and El-Laithy (1992) described the immature stages of *N. barkeri* Hughes, 1948, whereas Fouly *et al*. (1994) described the same for *Proprioseiopsis rotundus* (Muma, 1961) and *P. asetus* (Chant, 1959). Papadoulis and Emmanouel (1993) reported the immature stage of *Typhloseiulus erymanthii* (Papadoulis & Emmanouel, 1988). Beard (1999a) described immatures of *Australiseiulus australicus* (Womersley, 1954) and *A. goondi* Beard, 1999b, but without reporting their larvae. Godim *et al*. (2000) reported characters of immatures stages of *Cocoseius palmarum* Gondim Jr., Moraes & McMurtry, 2000 from Brazil. Denmark and Welboum (2002) described ontogenetic development of three species of genus *Typhlodromus*: *T.* (*Anthoseius*) *bagdasarjani* Wainstein & Arutunjan, 1967, *T.* (*A.*) *hebetis* (De Leon, 1959) and *T.* (*A.*) *rhenanus* (Oudemans, 1905). Moraes *et al*. (2003) reported new genus and species *Macrocaudus multisetatus* Moraes, McMurtry & Mineiro, 2003 and described the morphology of immature stages. Wu *et al*. (2009) recorded characters of immature stages of *Typhlodromus* (*Typhlodromus*) *baccettii* Lombardini, 1960. Asali Fayaz *et al.* (2011) described the protonymphs and deutonymphs of *Neoseiulus bicaudus* (Wainstein, 1962a) from western Iran. Zhang (2012) studied morphological ontogeny of *Euseius utilis* (Liang & Ke, 1983). Cargnus and Zandigiacomo (2014) reported the morphometric characters in immature stages of four species of *Kampimodromus* Nesbitt from Italy and Croatia. Asali Fayaz *et al*. (2017a, b) studied the morphological characteristics of immatures of *Typhlodromus* (*A.*) *bagdasarjani* Wainstein & Arutunjan, 1967 and *Paraseiulus amacroporus* Faraji, Jalaeian & McMurtry, 2008. Ahmad-Hosseini *et al.* (2017) reported the immature stages of *Kuzinellus kuzini* (Wainstein, 1962b). Stathakis (2017) recorded immature stages of *Typhlodromus* (*A.*) *recki* Wainstein, 1958. In this study, we present the morphological ontogeny of *A. limonicus* (Garman & McGregor, 1956) based on specimens reared in the laboratory and compare it with that of *A. lailae* (Schicha 1979b).

Amblydromalus limonicus has been the focus of renewed interests in the last decade because it was commercialized as an efficient biological control agent of whiteflies and thrips in protected crops (Messelink *et al*. 2006; Hoogerbrugge *et al*. 2011; Knapp *et al*. 2013) and explored for its potential as a biocontrol agent against invasive insects such as whiteflies (Lee & Zhang 2018) and psyllids (Xu & Zhang 2015; Patel & Zhang 2017a,b). *Amblydromalus limonicus* was first described in the genus *Amblyseius* by Garman and McGregor (1956), and then Garman (1958) described it again. Collyer (1964, 1982) recorded this species in New Zealand. *Amblydromalus lailae* from Australia was considered a junior synonym of *A. limonicus* by Goodwin and Steiner (2004) based on DNA sequences. This synonymy has been accepted by applied literature (e.g. Knapp *et al*. 2013) but

A. lailae was considered a distinct species in revisions by Chant and McMurtry (2005, 2007) and a checklist by Demite *et al*. (2018). In this study, we describe the immature stages of *A. limonicus*, and compare it with those of *A. lailae* described by Schicha (1979b). We demonstrate the need for more studies on the immature stages of the Phytoseiidae, especially based on reared specimens and also the importance for comparisons between taxa. We also provide additional host and distribution records of *A. limonicus* based on examinations of new specimens from New Zealand and USA.

Material and methods

The morphological ontogeny of *A. limonicus* was based on laboratory-reared specimens originated in South Auckland and reared by the same methods in Liu and Zhang (2017) in a heated room at 25± 1 °C, 85 ± 5% RH and a photoperiod of 16:8 h light: dark (L:D) in the laboratory of Manaaki Whenua – Landcare Research, Auckland, New Zealand. Individually reared larvae, protonymphs, deutonymphs, and adults were collected with a fine hair brush and directly mounted in Hoyer's medium on microscope slides under a dissecting microscope (Leica). Mounted specimens were dried in an oven at 45 °C for at least one week. We also examined some other slides deposited in the New Zealand Arthropod Collection (NZAC), Manaaki Whenua, Auckland. All specimens were examined, measured, and photographed with a Nikon eclipse Ni 90 microscope. All measurements are provided in micrometers. Illustrations were made using a drawing tube (Nikon Y-IDT) attached to the microscope. Images and illustrations were edited with Photoshop CS6. The measuring method follows Ma *et al.* (2016), except in the larval stage, the dorsal length was measured from *j1* to the middle point of *Z4* to *Z4* (due to the fact that the larva does not have a single shield covering the whole idiosoma). Each measurement shows the average (minimum–maximum). All these specimens are deposited in NZAC.

The pedipalps consist of five movable segments, namely trochanter, femur, genu, tibia, and tarsus. In this paper, we only discussed the chaetotaxy of trochanter, femur and genu. In the immature stages, the nomenclature used for the idiosomal setae follows Rowell and Chant (1979). The nomenclature used for the idiosomal setae and legs follows Chant and McMurtry (2007), the terminology of dorsal pore-like structures follows Beard (2001) and the notations of lyrifissures (*iv1–iv5*) for the ventral idiosoma follow Athias-Henriot (1971).

Results

Amblydromalus limonicus **Garman & McGregor**

Amblyseius limonicus Garman & McGregor, 1956: 11.
Amblyseiopsis limonicus, Garman, 1958: 72.
Tyohlodromus (*Amblyseius*) *limonicus*, Chant, 1959: 96.
Typhlodromus (*Amblyseius*) *garmani* Chant, 1959: 81 (objective synonymy—Moraes *et al*. 1986).
Amblyseius (*Typhlodromalus*) *rapax* De Leon, 1965: 125 (synonymy—Moraes *et al*. 1982)
Amblyseius (*Typhlodromalus*) *limonicus*, Muma, 1961: 288.
Amblyseius (*Amblyseius*) *limonicus*, Wainstein (1962a): 15.
Tyohlodromalus limonicus, De Leon, 1967: 22.

Redescriptions of morphological ontogeny

LARVA (*n*=8, Figures 1–2, 10A. 11A)
Idiosoma (Figures 1A, 1B) 200 (182–208) long (*j1–Z4* level), 122 (112–126) wide at level of *s4*. DORSUM (Figure 1A): pronotal shield smooth, weakly sclerotized, bearing nine pairs of smooth

setae, *j1*, *j3*, *j4*, *j5*, *j6*, *z2*, *z4*, *z5* and *s4*. Opisthonotal region without discernible shields, bearing five pairs of smooth setae, *S2, S5, Z1*, *Z4* and *Z5*; *Z4* whip-like and apically blunt, *Z4*>*s4*>*j3*>*j1*. Stigmata and peritremes absent. Lengths of setae: *j1* 26 (23–33), *j3* 33 (31–39), *j4* 6 (4–8), *j5* 5 (4–6), *j6* 12 (10–14), *z2* 7 (6–7), *z4* 7 (7–9), *z5* 6 (6–7), *s4* 69 (55–78), *S2* 5 (3–7), *S5* 6 (4–8), *Z1* 7 (4–10), *Z4* 208 (181–245), *Z5* 9 (6–11). Lyrifissures and gland openings not observed. VENTER (Figure 1B): without discernible shields. Tritosternum with a stalk-like base and two flagella. Coxisternal area bearing three pairs of setae *st1*, *st2* and *st3* but without discernible lyrifissures. Four pairs of opisthogastric setae, *JV1*, *JV2*, *JV5* and *ZV2* present on membranous cuticles around anal valve, with *JV2* obviously longer than others; a pair of paranal setae (*pa*) and a postanal seta (*po*) present around anal valve; a pair of gland opening (*gv3*) present posterior to *JV2*; distance *gv3–gv3* 16 (11–20). Lengths of setae: *st1* 28 (24–31), *st2* 27 (25–29), *st3* 25 (22–29), *JV1* 7 (6–9), *JV2* 23 (17–27), *JV5* 8 (7–8), *ZV2* 8 (6–11).

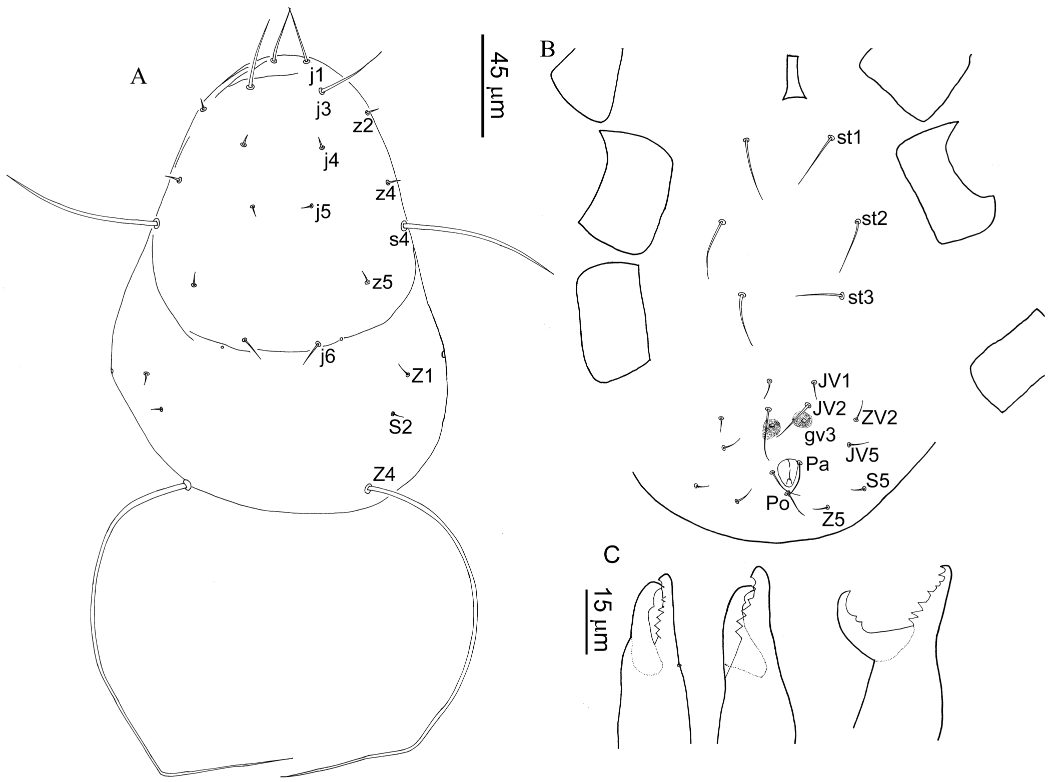

FIGURE 1. *Amblydromalus limonicus* (larva). A. Dorsal idiosoma; B. Ventral idiosoma; C. Chelicera.

Gnathosoma. CHELICERAE (Figure 1C): with movable digit 21 (20–24) long, bearing one to two teeth; fixed digit 25 (22–27) long, bearing five or seven teeth, *pilus dentilius* located between fourth and fifth teeth. PALP (Figure 10A) with trochanter devoid of setae; femur with a spatulate and four simple setae; genu bearing a spatulate and three simple setae; tarsus apotele two-tined. HYPOSTOME (Figure 11A): with only two pairs of hypostomal setae (*h1* and *h2*); deutosternal groove present but weakly developed, without rows of denticles; corniculi horn-like.

Legs (Figure 2). Leg I 308 (280–324) long, setal number (coxa to basitarsus): 2, 4, 10, 8 (including 1 macroseta), 8, 1. Macroseta on genu bluntly tipped, 41 (38–48). For chaetotactic formulae see table 1.

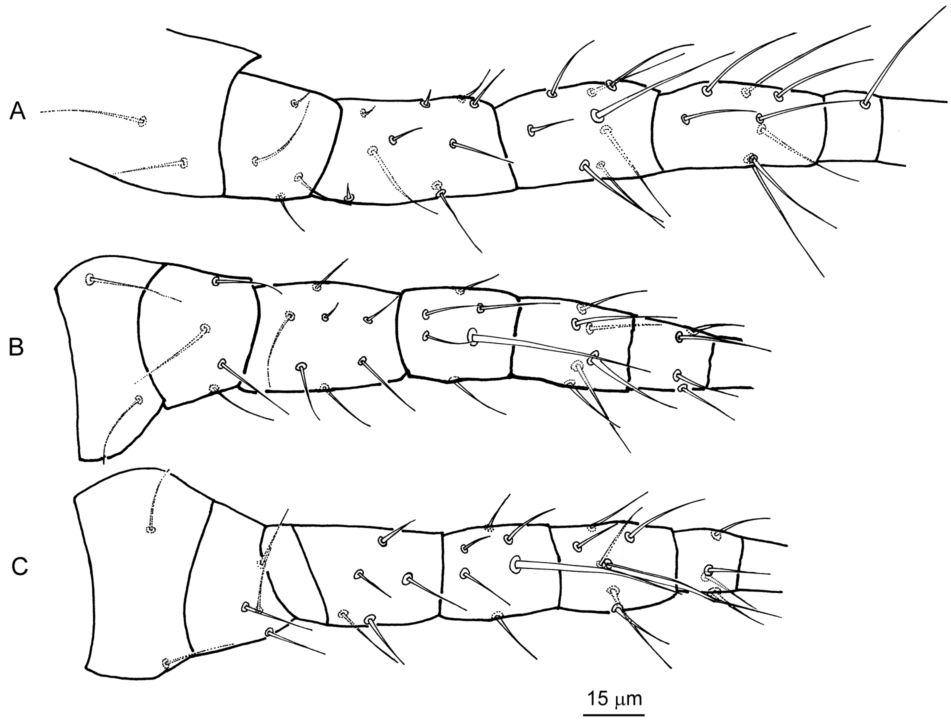

FIGURE 2. *Amblydromalus limonicus* (larva). A. Leg I; B. Leg II; C. Leg III.

TABLE 1. Comparison of leg chaetotaxy in *Amblydromalus limonicus* of different development stages.

Leg	Developmental stages	Leg segment					
		coxa	trochanter	femur	genu	tibia	basitarsus
Leg I	L	0-0/0-0/2-0	0-0/1-1/2-0	2-2/1-2/2-1	2-2/1-1/1-1	2-2/1-1/1-1	1-0/0-0/0-0
	PN	0-0/0-0/2-0	0-0/1-1/2-0	2-2/1-2/2-1	2-2/1-1/1-1	2-2/1-1/1-1	1-0/0-0/0-**1**
	DN	0-0/0-0/2-0	0-0/**2**-1/2-0	2-**3**/**2**-2/2-1	2-2/**2**-**2**/1-1	2-2/**2**-**2**/1-1	1-0/0-**1**/0-1
	A	0-0/0-0/2-0	0-0/2-1/2-0	2-3/2-2/2-1	2-2/2-2/1-1	2-2/2-2/1-1	1-**1**/0-1/0-1
Leg II	L	0-0/1-0/1-0	0-0/1-0/2-1	2-2/0-2/1-0	1-2/0-2/0-1	1-1/1-1/1-1	1-1/0-1/0-1
	PN	0-0/1-0/1-0	0-0/1-0/2-1	2-2/0-2/1-0	1-2/0-2/0-1	1-1/1-1/1-1	1-1/0-1/0-1
	DN	0-0/1-0/1-0	0-0/**2**-0/2-1	2-**3**/0-2/**2**-**1**	1-2/0-2/0-1	1-1/1-**2**/1-1	1-1/0-1/0-1
	A	0-0/1-0/1-0	0-0/2-0/2-1	2-3/0-2/2-1	1-2/**1**-2/0-1	1-1/1-2/1-1	1-1/0-1/0-1
Leg III	L	0-0/1-0/1-0	1-1/1-0/1-0	1-2/1-1/0-0	1-2/0-2/0-1	1-1/1-2/1-1	0-1/1-1/1-0
	PN	0-0/1-0/1-0	1-1/1-0/1-0	1-2/1-1/0-0	1-2/0-2/0-1	1-1/1-2/1-1	0-1/1-1/1-0
	DN	0-0/1-0/1-0	1-1/**2**-0/1-0	1-2/1-1/0-**1**	1-2/**1**-2/0-1	1-1/1-2/1-1	0-1/1-1/1-0
	A	0-0/1-0/1-**1**	1-1/2-0/1-0	1-2/1-1/0-1	1-2/1-2/0-1	1-1/1-2/1-1	0-1/1-1/1-0
Leg IV	L	–	–	–	–	–	–
	PN	0-0/1-0/0-0	0-1/1-1/1-0	0-1/0-2/1-0	1-2/0-2/0-0	1-1/0-2/1-1	1-1/1-1/0-0
	DN	0-0/1-0/0-0	**1**-1/1-1/1-0	0-**2**/**1**-2/1-0	1-2/**1**-2/**1**-0	1-1/0-2/1-1	1-1/1-1/0-0
	A	0-0/1-0/0-0	1-1/1-1/1-0	0-2/1-2/1-0	1-2/1-2/1-0	1-1/**1**-2/1-1	1-1/1-1/0-0

Note: L: Larva; PN: Protonymph; DN: Deutonymph; A: Adult.
Bold: Addition of setae on leg segments.

Leg II 248 (229–261) long, setal formula: 2, 4, 7, 6 (including 1 macrosetae), 6, 4. Macroseta on genu bluntly tipped, 51 (46–56).

Leg III 257 (242–272) long, setal formula: 2, 4, 5, 6 (including 1 macroseta), 7 (including 1 macroseta), 4. Macroseta on genu and tibia bluntly tipped, 71 (63–86), 60 (53–76).

PROTONYMPH (*n*=8; Figures 3–4, 10B, 11B)

Idiosoma (Figure 3A) 252 (227–265) long (*j1*–*J5* level), 130 (122–131) wide at level of *s4*, podonotal and opisthonotal without discernible shields. DORSUM: pronotal shield weakly sclerotized, with seventeen pairs of setae, smooth except *Z5* barbed. *Z4* considerably shorter than those in larval stage. *J2*, *J5*, *S4* appeared in protonymph, *s4*>*j3*>*Z5*>*j1*. Interscutal membrance with setae *r3* and *R1*. Stigmata located ventrolaterally between coxae III and IV. Peritremes extending to *z5* level. Lengths of setae: *j1* 25 (24–27), *j3* 35 (32–38), *j4* 7 (5–10), *j5* 6 (4–8), *j6* 8 (7–8), *z2* 8 (6–10), *z4* 9 (8–10), *z5* 6 (5–7), *s4* 47 (43–51), *J2* 8 (7–9), *J5* 6 (4–7), *Z1* 8 (8–9), *Z4* 9 (8–11), *Z5* 42 (42–43), *S2* 10 (8–11), *S4* 10 (8–13), *S5* 7 (7–8), *r3* 13 (11–15), *R1* 8 (7–10). Lyrifissures and gland openings not observed. VENTER (Figure 3B): without discernible shield. Coxisternal with no setae, gland openings added. Four pairs of opisthogastric setae (*JV1*, *JV2*, *JV5*, *ZV2*) present on membranous around anal valve, *JV1* and *ZV2* obviously becoming longer, a pair of paranal setae (*pa*) and a postanal seta (*po*) of subequal length present around anal valve; a pair of gland openings *gv3* present posterior to *JV2*; distance *gv3*–*gv3* 24 (22–26). Lengths of setae: *st1* 28 (25–31), *st2* 26 (22–28), *st3* 24 (22–25), *JV1* 21 (19–22), *JV2* 19 (17–20), *JV5* 21 (20–24), *ZV2* 17 (14–17).

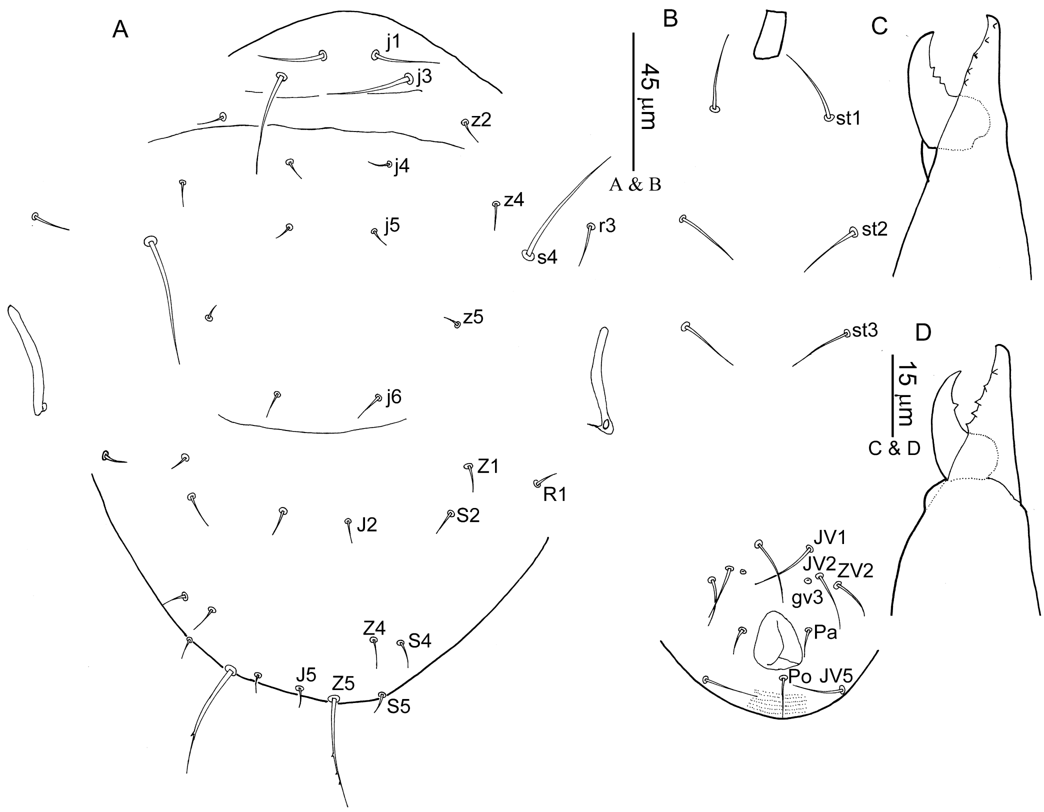

FIGURE 3. *Amblydromalus limonicus* (protonymph). A. Dorsal idiosoma; B. Ventral idiosoma; C & D. Chelicera.

Gnathosoma. CHELICERAE (Figures 3C, D): with movable digit 25 (22–30) long, bearing one or three teeth, fixed digit 25 (24–31) long, bearing five teeth. PALP (Figure 10B): with a seta presented on trochanter; femur with no setae added; genu chaetotaxy identical to that in larva. Tarsal apotele two-tined, constant in form and position throughout. HYPOSTOME (Figure 11B): with three pairs of hypostomal setae (*h1*, *h2* and *h3*) and one pair of palpcoxal setae (*pc*). deutosternal groove weak, bearing seven rows of denticles, corniculi horn-like.

Legs (Figure 4). Leg I 335 (328–341) long, setal formula (coxa to basitarsus): 2, 4, 10, 8 (including 1 macroseta), 8, 2. Segment with no seta added, except basitarsus with 1 seta added. Macroseta on genu bluntly tipped, 32 (29–35). For chaetotactic formulae see table 1.

Leg II 263 (256–277) long, setal formula: 2, 4, 7, 6 (including 1 macroseta), 6, 4. Segments with chaetotaxy identical to that in larva. Macroseta on genu bluntly tipped, 48 (46–50).

Leg III 264 (253–272) long, setal formula: 2, 4, 5, 6 (including 1 macroseta), 7 (including 1 macroseta), 4. Segments with no seta added. Macrosetae on genu III 45 (42–50) and tibia 39 (36–42), both bluntly tipped.

Leg IV 333 (318–349) long, setal formula: 1, 4, 4, 5 (including 1 macroseta), 6 (including 1 macroseta), 4 (including 1 macroseta). Macrosetae on genu 70 (64–76), tibia 73 (73–74), basitarsus 86 (81–91), all apically blunt.

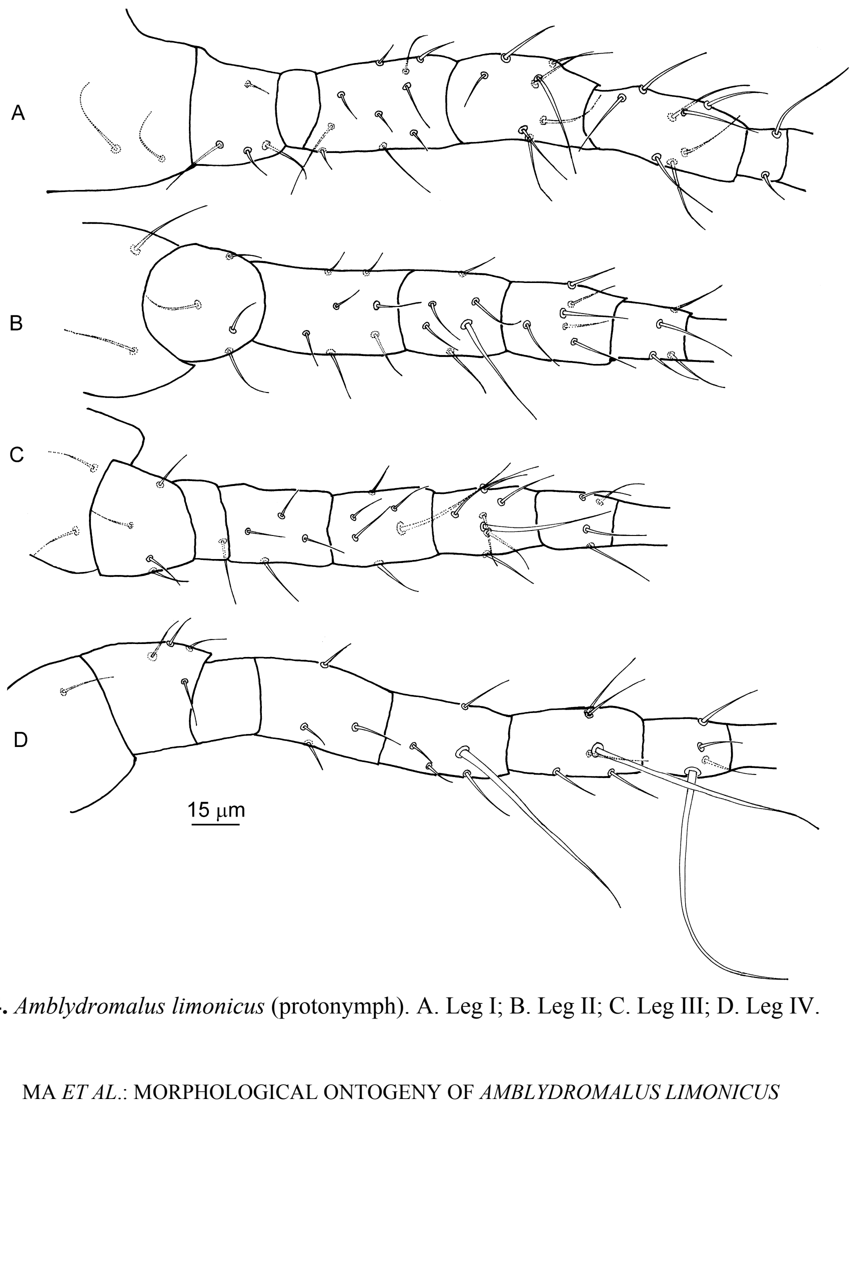

FIGURE 4. *Amblydromalus limonicus* (protonymph). A. Leg I; B. Leg II; C. Leg III; D. Leg IV.

DEUTONYMPH (n=6♀, 6♂; Figures 5–6, 10C)

Idiosoma (Figure 5A) 274 (259–307) long (*j1–J5* level), 136 (127–151) wide at level of setae *s4*. DORSUM: podonotal and opisthonotal shields undiscernible, with seventeen pairs of setae, smooth except *Z5* barbed. Four pairs of gland openings (*gd1*, *gd2*, *gd6* and *gd9*) present. Interscutal membrance with setae *r3* and *R1*. Peritremes extending to *z2* level. Lengths of setae: *j1* 28 (27–33), *j3* 43 (35–47), *j4* 7 (7–8), *j5* 7 (6–8), *j6* 8 (7–11), *z2* 9 (8–11), *z4* 11 (8–13), *z5* 7 (7–8), *s4* 56 (50–65), *J2* 9 (8–10), *J5* 7 (6–8), *Z1* 12 (10–14), *Z4* 11 (10–12), *Z5* 53 (46–60), *S2* 14 (14–16), *S4* 15 (13–17), *S5* 10 (10–11), *r3* 17 (13–18), *R1* 9 (8–11). VENTER (Figure 5B): smooth, without discernible shields. Tritosternum with a stalk-like base and two flagella. Coxisternal area bearing five pairs of setae, *st4* and *st5* added, but without discernible lyrifissures. Sexes distinguishable: male with four pairs of opisthogastric setae (*JV1*, *JV2*, *JV5*, *ZV2*) on the membranous cuticles around anal valve, whereas female with seven pairs of setae in opisthogaster region (*JV1*, *JV2*, *JV4*, *JV5*, *ZV1*, *ZV2*, *ZV3*); a pair of paranal setae (*pa*) and a postanal seta (*po*) of subequal length present around anal valve; a pair of gland openings (*gv3*) posterior to *JV2*, distance *gv3–gv3* 23 (20–26). Primary metapodal plates and secondary metapodal plates absent. Lengths of setae: *st1* 33 (29–34), *st2* 28 (25–31), *st3* 24 (17–31), *st4* 22 (15–22), *st5* 24 (22–26), *JV1* 25 (22–27), *JV2* 24 (20–29), *JV4* 14 (12–17), *JV5* 33 (30–38), *ZV1* 20 (18–25), *ZV2* 21 (18–23), *ZV3* 15 (12–17).

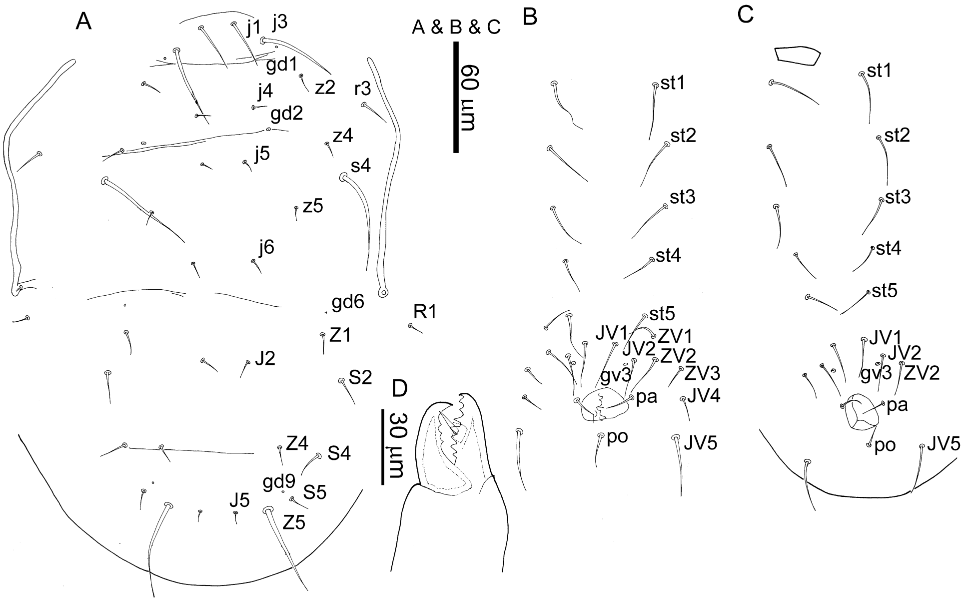

FIGURE 5. *Amblydromalus limonicus* (deutonymph). A. Dorsal idiosoma; B. Ventral idiosoma (female); C. Ventral idiosoma (male); D. Chelicera.

Gnathosoma. CHELICERAE (Figure 5C): with movable digit 24 (22–30) long, bearing three teeth in female and two to three teeth in male, fixed digit 29 (24–32) long, bearing seven to nine teeth in female and six to eight teeth in males, *pilus dentilis* 7 long, located between third and fourth teeth. PALP (Figure 10C): trochanter with two setae; femur with a spatulate and four simple setae; genu with two spatulate and three simple setae. Tarsal apotele two-tined. HYPOSTOME (Figure 5D): with three pairs of hypostomal setae (*h1*, *h2* and *h3*) and one pair of palpcoxal setae (*pc*). Deutosternal groove bearing seven rows of denticles; corniculi horn-like.

Legs (Figure 6). Leg I 358 (318–433) long, setal formula (coxa to basitarsus): 2, 5, 12, 10 (including 1 macroseta), 10, 3. Trochanter and basitarsus each with one seta added; femur, genu and tibia each with two setae added. Macroseta on genu bluntly tipped, 38 (32–42). For chaetotactic formulae see table 1.

Leg II 310 (279–341) long, setal formula: 2, 5, 10, 6, 7, 4. Femur with three setae added, trochanter and tibia each with one seta added. Macroseta on genu bluntly tipped, 37 (32–43).

Leg III 318 (288–351) long, setal formula: 2, 5, 6, 7 (including 1 macroseta), 7 (including 1 macroseta), 4. Trochanter, femur and genu each with one seta added. Macrosetae on genu 48 (42–57), tibia 38 (35–47), both bluntly tipped.

Leg IV 353 (337–424) long, setal formula: 1, 5, 6, 7 (including 1 macroseta), 6 (including 1 macroseta), 4 (including 1 macroseta). Trochanter with 1, femur with 2 and genu with 2 setae added, respectively. Macrosetae on genu, 62 (59–83), tibia 65 (57–75), and basal tarsus 86 (66–113), all bluntly tipped.

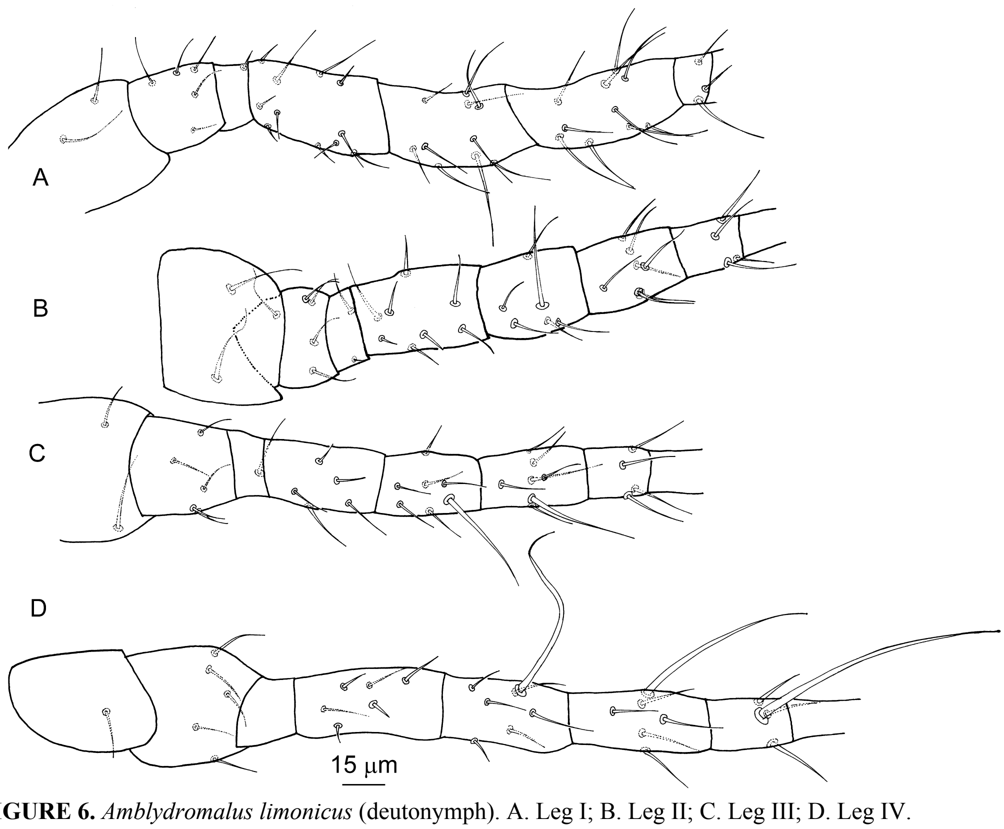

FIGURE 6. *Amblydromalus limonicus* (deutonymph). A. Leg I; B. Leg II; C. Leg III; D. Leg IV.

ADULT FEMALE (*n*=5, Figures 7–8, 10D, 11C, 12)

Idiosoma (Figure 7A) 381 (371–384) long, 215 (188–252) wide at level of *s4*. DORSUM: dorsal shield smooth, with waist at level of *R1*, muscles mark between *j4* and *Z4*, 17 pairs of setae, smooth except *Z5* slightly serrated. Dorsal shield with six pairs of gland openings (*gd1*, *gd2*, *gd4, gd5, gd8* and *gd9*) and seven pairs of lyrifissures (*id2*, *idl2*, *idl4*, *idm1*, *idm5, idm6* and *is1*). Marginal setae *r3* and *R1* smooth, on interscutal membrane. Peritremes extending to base of *j1*. Lengths of setae: *j1* 27 (25–31), *j3* 43 (35–61), *j4* 8 (7–10), *j5* 8 (6–10), *j6* 9 (7–13), *z2* 12 (8–15), *z4* 11 (8–14), *z5* 8(7–13), *s4* 53 (50–78), *J2* 12 (8–16), *J5* 7 (6–8), *Z1* 11 (10–12), *Z4* 11 (10–13), *Z5* 51 (48–68), *S2* 14 (12–16), *S4* 15 (13–17), *S5* 12 (10–15), *r3* 17 (13–20), *R1* 10 (8–13).VENTER (Figure 7B): tritosternum with a stalk-like base and two flagella. Sternal shield smooth, anterior edge convex, with three pairs of setae (*st1*, *st2* and *st3*) and two pairs of lyrifissures (*iv1* and *iv2*). Three pairs of lyrifissures and a slender transverse sclerite present between genital and ventrianal shields. Sternal shield longer than wide, 102 (86–112) long, 80 (78–90) wide, with a median posterior projection. Forth pair of sternal setae on small platelets, lyrifissures not observed. Lengths of setae: *st1* 42 (39–45), *st2* 35 (31–38), *st3* 38 (34–41), *st4* 33 (29–39), *st5* 36 (31–40). Genital shield smooth, 149 (129–159) long, 89 (83–98) wide at level of *st5*. Ventrianal shield vase-shaped, anterior edge lightly curve, smooth, with three pairs of preanal setae (*JV1*, *JV2* and *ZV2*) and a pair of elliptic gland openings (*gv3*), distance *gv3–gv3* 38 (35–40). *JV1* located on anterior margin of ventrianal shield, *ZV2* located at anterior corner, *JV2* posterior to *JV1*. A pair of marginal muscle marks situated on margins of ventrianal shield at level of *JV3*. *ZV1* and *ZV3* present on soft cuticle surrounding ventrianal shield, four pairs of setae (*JV3*, *JV4*, *JV5* and *ZV1*). Lengths of setae: *JV1* 31 (25–35), *JV2* 32 (30–37), *JV4* 21 (19–24), *JV5* 52 (47–61), *ZV1* 31 (24–35), *ZV2* 29 (25–35), *ZV3* 21 (18–24). Primary metapodal plate 16 (15–17) long, 2 (1–3) wide; secondary plate 30 (28–36) long, 3 (2–4) wide.

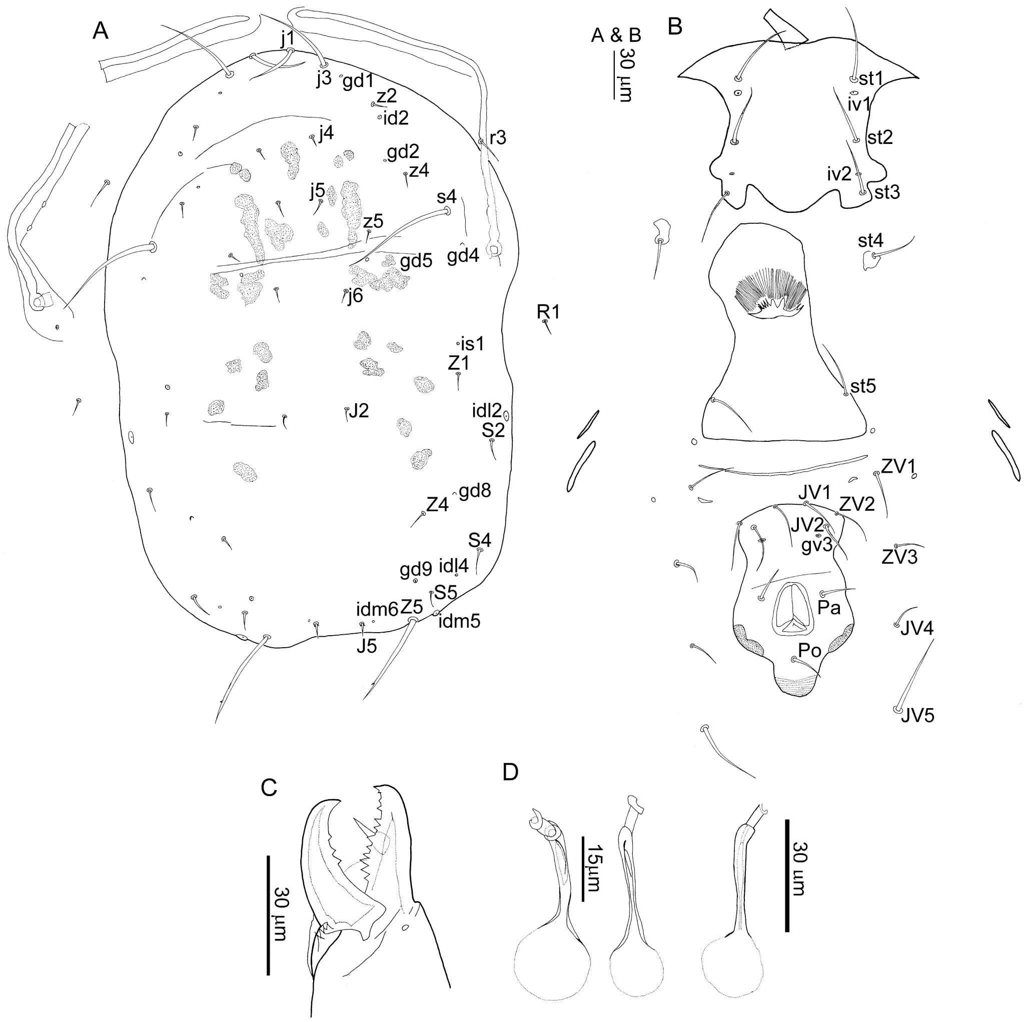

FIGURE 7. *Amblydromalus limonicus* (female). A. Dorsal idiosoma; B. Ventral idiosoma; C. Chelicera; D. Spermatheca.

Spermatheca (Figures 7D, 12). Cervix elongate, mostly tubular and flaring distally, 28 (28–29) long; minor duct thread-like at atrium; atrium slightly wider than basal cervix, major duct almost same width as calyx, very short, sometimes indiscernible.

Gnathosoma. CHELICERAE (Figure 7C): with movable digit 35 (34–36) long, bearing three teeth, fixed digit 37 (36–38) long, bearing nine to eleven visible teeth, *pilus dentilis* 9 (8–11) long. PALP (Figure 10D): trochanter with two setae; femur with one spatulate and four simple setae; genu bearing two spatulates and four simple setae; tarsal apotele two-tined. HYPOSTOME (Figure 11C): with three pairs of hypostomal setae (*h1*, *h2* and *h3*) and one pair of palpcoxal setae (*pc*), no seta added from protonymph.

Legs (Figure 8). Leg I 478 (447–503) long, setal formula (coxa to basitarsus): 2, 5, 12, 10 (including 1 macroseta), 10, 4. One seta added on basitarsus. Macrosetae on genu bluntly tipped, 38 (35–43). For chaetotactic formulae see table 1.

Leg II 407 (381–417) long, setal formula: 2, 5, 10, 7 (including 1 macroseta), 7, 4. Genu and basitarsus added one seta, respectively. Macroseta on genu bluntly tipped, 33 (32–39).

Leg III 400 (379–441) long, setal formula: 3, 5, 6, 7 (including 1 macroseta), 7 (including 1 macroseta), 4. No setae added except coxa (one seta added). Macrosetae on genu 45 (43–48), tibia 40 (38–41), both bluntly tipped.

Leg IV 561 (531–601) long, setal formula: 1, 5, 6, 7 (including 1 macroseta), 7 (including 1 macroseta), 4 (including 1 macroseta). One seta added on tibia. Macroseta on genu 83 (77–89), tibia 65 (58–71) and basitarsus 108 (104–112), all bluntly tipped.

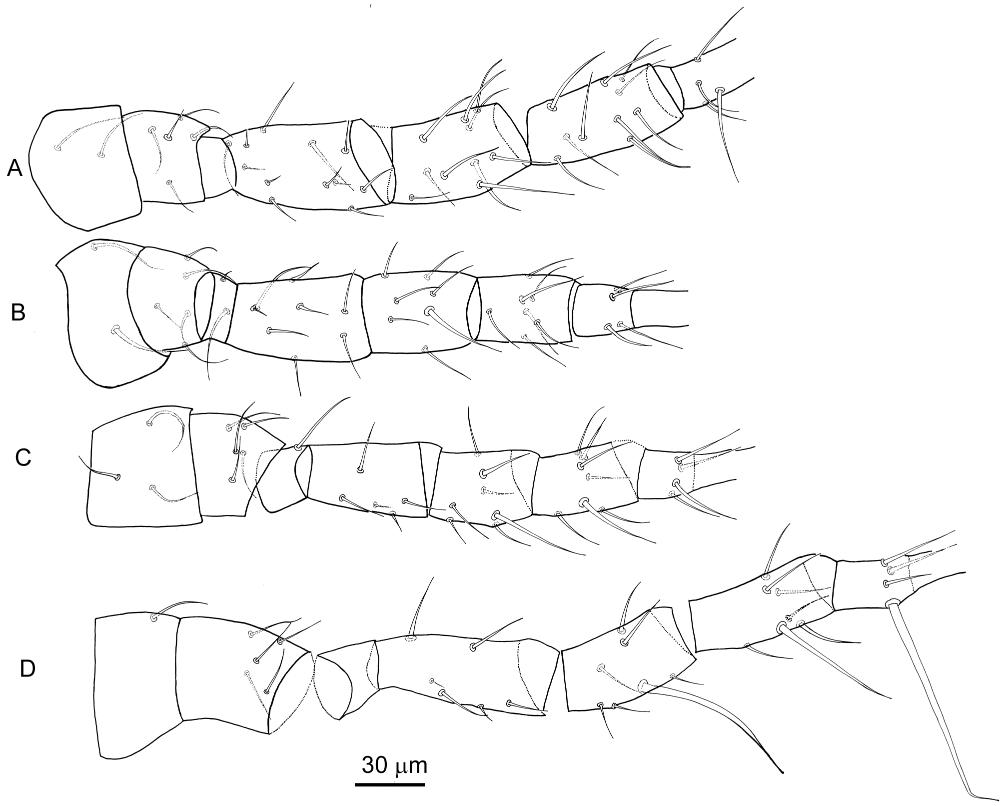

FIGURE 8. *Amblydromalus limonicus* (female). A. Leg I; B. Leg II; C. Leg III; D. Leg IV.

ADULT MALE (*n*=5, Figure 9)

Idiosoma (Figure 9A). 343 (308–407) long, 223 (185–265) wide between *s4* and *s4*. DORSUM: shield nearly oval, bearing nineteen pairs of setae, all smooth except *Z5* (barbed), *s4* longer than *Z5*. Lateral setae *r3* and *R1* smooth on dorsal shield, *r3* at *z4* level; bearing one pair of visible lyrifissures

(*idm1*) and seven pairs of gland opening (*gd1*, *gd2*, *gd4 gd5*, *gd6, gd8* and *gd9*). Peritremes extending forward to *j1*. Lengths of setae: *j1* 32 (29–34), *j3* 48 (46–56), *j4* 8 (7–8), *j5* 8 (7–10), *j6* 9 (7–11), *z2* 10 (7–13), *z4* 11 (10–12), *z5* 8 (7–9), *s4* 69 (62–78), *J2* 11 (10–14), *J5* 8 (7–8), *Z1* 10 (8–11), *Z4* 12 (10–14), *Z5* 60 (40–68), *S2* 14 (12–17), *S4* 15 (14–16), *S5* 10 (8–13), *r3* 22 (21–23), *R1* 11 (10–14).
VENTER (Figure 9B): sternogenital shield smooth, 169 (155–178) long from the middle of anterior margin to posterior margin, 77 (76–77) wide; posterior margin nearly straight, bearing five pairs of attenuate setae (*st1*, *st2, st3, st4* and *st5*) and two pair of lyrifissures *iv1* and *iv2.* Lengths of setae: *st1 39* (35–44), *st2* 32 (29–34), *st3* 31 (29–34), *st4* 29 (27–31), *st5* 32 (29–37). Ventrianal shield approximately subtriangular, middle of anterior margin convex, lightly reticulated, 134 (126–140) long, 193 (177–199) wide (at anterior corner), with three pairs of preanal setae (*JV1*, *JV2* and *ZV2*), arranged in triangular pattern, a pair of paranal setae (*pa*) and a postanal seta (*po*); gland openings (*gv3*) posteromedian to *JV2*, distance *gv3–gv3* 36 (35–37). Setae *JV5* on cuticle surrounding ventrianal shield. Lengths of setae: *JV1* 27 (25–30), *JV2* 28 (26–31), *JV5* 43 (41–46); *ZV2* 27 (24–30).

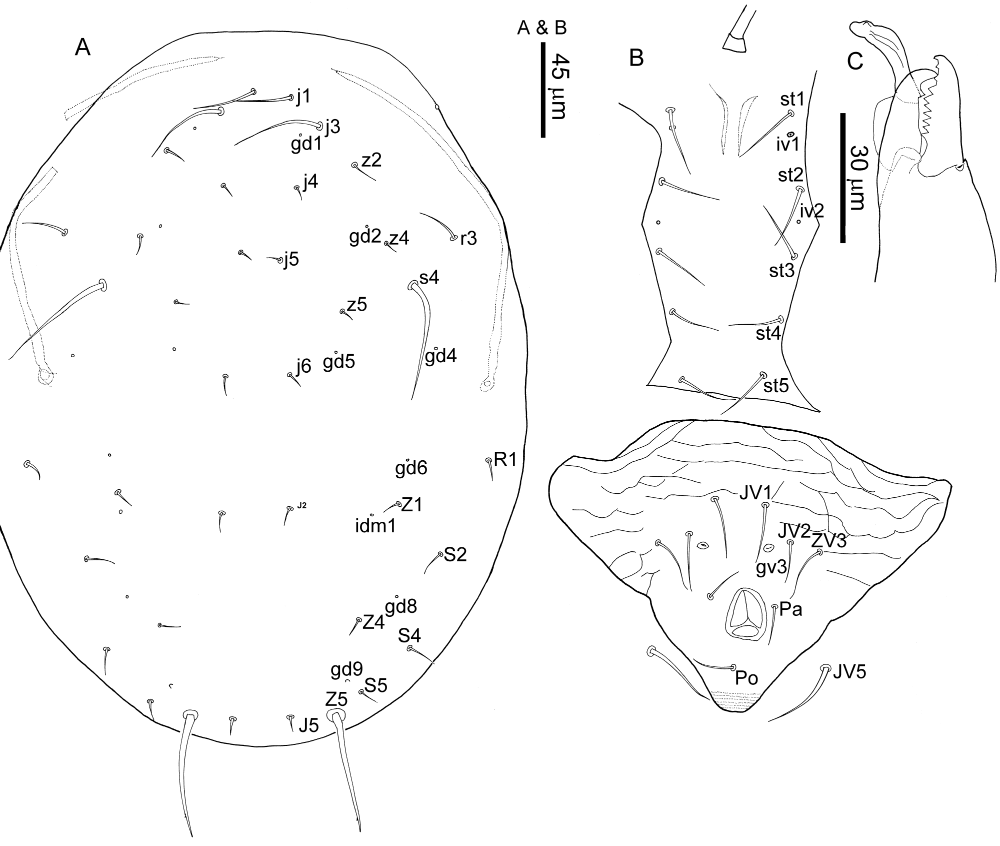

FIGURE 9. *Amblydromalus limonicus* (male). A. Dorsal idiosoma; B. Ventral idiosoma; C. Chelicera.

Gnathosoma. CHELICERAE (Figure 9C): with movable digit 30 (22–32) long, bearing one tooth, fixed digit 34 (24–36), bearing nine teeth; Spermatodactyl L-shaped, heel reduced. PALP and HYPOSTOME with same chaetotaxy as in female.

Legs. Leg chaetotaxy same as in adult female.

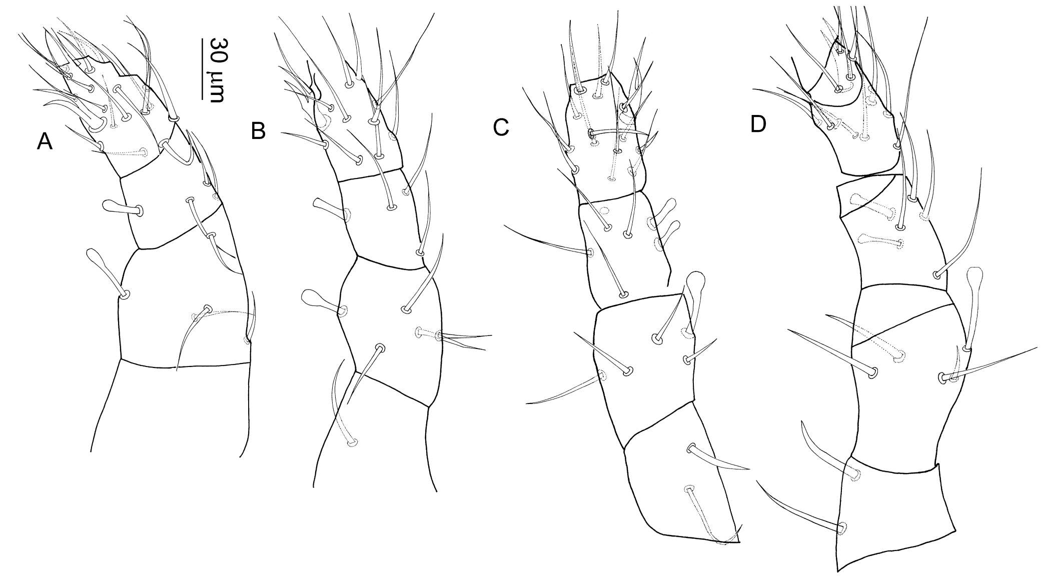

FIGURE 10. Palps of *Amblydromalus limonicus*. A. Larva; B. Protonymph; C. Deutonymph; D. Female.

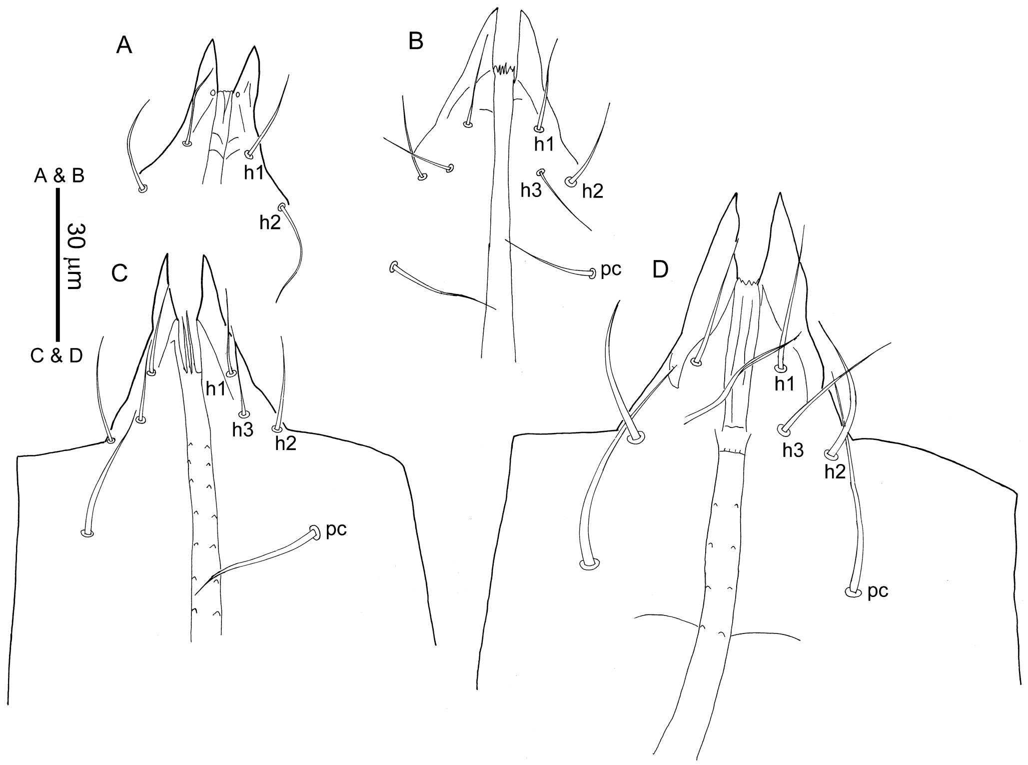

FIGURE 11. Gnathosoma of *Amblydromalus limonicus*. A. Larva; B. Protonymph; C. Deutonymph; D. Female.

Addition of setae on leg segments: Most setae added during the post-embryonic development of *A. limonicus* appeared in the deutonymph except a few that are added in the protonymph and adult (Table 1).

Specimens examined: *Laboratory-reared*: 37 larvae, 21 protonymphs, 18 deutonymphs, 20 adult females and 7 adult males were derived from a laboratory culture initiated by Liu & Zhang (2017), Manaaki Whenua, Auckland, **New Zealand**, 30.X.2017, 17.VII.2018, 20.VII.2018, coll. M. Ma.

Other specimens examined: **NEW ZEALAND**: 6♀♀, Auckland, Clevedon, ex. tomato, 9.III.2007, coll. P.J. Workman (#07-783Z); 4♀♀, Auckland, Clevedon, Ness Valley, ex. runner beans, 30.IV.2007, coll. P.J. Workman (#07-784Z); 1♀, [+ *Neoseiulus womersleyi* 1♀], Auckland, Glenfield, ex. on bean leaves, 6.II.1991, coll. D. Steven; 2♀♀, [+ *Neoseiulus cucumeris* (labelled on slide as *Neoseiulus bellinus*) 1♀; *Amblyseius herbicolus* (labelled on slide as *Amblyseius deleoni*) 1♀], Auckland, Mangere Bridge, Blackbridge Nursery, ex. cucumber leaf, 12.II.1991, coll. P. Workman; 1♀, Auckland, Mt Albert Research Centre, ex. *Lonicera japonica*, 26.I.1994, coll. N.A. Martin; 1♀, Auckland, Mt Albert Research Centre, ex. *Lonicera japonica*, 24.I.1994, coll. N.A. Martin; 2♀♀, [+ *Neoseiulus cucumeris* 9♀♀, 1♂], Auckland, Mt. Albert, P.D.D, ex. under apple tree, 15.II.1961, coll. E. Collyer; 2♀♀, Auckland, Mangere, NZ Gourmet, ex. capsicum fruit, 25.II.2005, coll. R. Martinez; 4♀♀, location same as above, ex. Capsicum fruit, 26.II.2005, coll. R. Martinez; 3♀♀, location same as above all, ex. capsicum fruit, 1.III.2005, coll. R. Martinez; 6♀♀, Auckland, Pukekohe, glasshouse, ex. capsicum, 7.V.1994, by P. Workman; 2♀♀, 1♂, Auckland, Waimauku, Taha Rd, greenhouse, ex. tomatoes, 9.IV.1997, coll. T. Marais; 8♀♀, 3♂♂, [+ *Neoseiulus longispinosus* 11♀♀, 1♂; *Tetranychus lambi* 1♀], Auckland, West Auckland, Ranui, ex. strawberry, 20.XII.1960, coll. E. Collyer; 1♀, Auckland, Warkworth, Southern Paprika Ltd, ex. capsicum fruit, 9.III.2005, coll. P. Gibbens; 4♀♀, Waikato, Te Kauwhata, Pty Wheeler. ex. tomato, 9.III.2007, coll. P.J. Workman (#07-785Z); 6♀♀, 1 protonymph, Waikato, Hamilton, ex. capsicum leaf, 11.IX.2001, coll. T. Marais; 3♀, Waikato, Te Kauwhata, ex. outdoor tomato, 18.III.2007, coll. P.J. Workman (#07-738Z); 1♀, Bay of Plenty, Tauranga, Steele, ex. unsprayed kiwifruit leaves, 7.III.1978, coll. M.K. York; 1♀, 1♂, [+ *Neoseiulus cucumeris* 1♂], Hawke's Bay, Havelock North, ex. apple tree, 3.XI.1959, coll. E. Collyer; 4♀♀, Hawke's Bay, Hastings, ex. culture of *Neoseiulus cucumeris* (ZONDA), 17.X.2001, coll. N. Pomeroy; 1♀, [+ *Neoseiulus cucumeris* 2♀♀, 1 larva, 1 protonymph], Dunedin, Warrington, unknown host but with thrips, 18.III.1993, Coll. Unknown. **USA**: 6♀♀, California, San Mateo Co., Nr. Atherton, ex. lemon, date unknown, coll. P.D. Schuster (LD14).

Distribution From southern parts of North America to South America (USA, Mexico Guatemala, Honduras, Puerto Rico, Trinidad, Costa Rica, Venezuela, Colombia, Bolivia, Ecuador, Brazil, Cuba, French Guiana, Guyana, Jamaica); New Zealand and Australia; Spain (Goodwin & Steiner 2004; Demite *et al.* 2018).

Comparison of *Amblydromalus limonicus* from New Zealand and USA, and *Amblydromalus lailae* from Australia

We reexamined specimens (adult females) of *A. limonicus* from California (USA) and some old specimens (adults) identified by E. Collyer in New Zealand. Adult females of *A. limonicus* from New Zealand are not distinguishable from those of California, nor from those of *A. lailae* (Schicha, 1979b) (Table 2).

TABLE 2. Lengths (μm) of body setae in adult females of *Amblydromalus limonicus* and *Amblydromalus lailae.*

	A. limonicus		*A. lailae**
setae	California (*n*=3)	New Zealand (*n*=8)	Australia
j1	28–34	25–34	30–32
j3	45–50	35–61	45–48
j4	7	7–10	6–8
j5	7–8	6–10	6–8
j6	8–11	7–13	8–9
J2	7–10	8–16	9–10
J5	6–10	6–8	7–8
Z1	8–11	10–14	8–10
z2	10	8–15	8–10
z4	10–11	8–14	8–9
z5	7–8	7–13	6–8
Z4	10–11	10–13	9
Z5	57–64	48–68	57–59
s4	67–70	50–78	63–71
S2	14	12–16	11–12
S4	13–15	13–17	10–14
S5	11–13	10–15	7–10
r3	17–20	13–21	16–17
R1	10–13	8–13	9–11
st1	38–39	39–45	---
st2	34–39	31–39	---
st3	29–36	34–41	---
st4	32–35	29–39	---
st5	31–39	31–40	---
JV1	28–29	25–35	---
JV2	27–28	27–37	---
JV4	17–21	17–24	---
JV5	43–45	47–61	---
ZV1	29–36	24–35	---
ZV2	24–28	25–35	---
ZV3	17–22	18–24	---
gv3–gv3	34–48	32–40	34–37
Sge IV	77–83	77–89	73–77
Sti IV	50–76	58–71	61–62
St IV	99–111	104–115	106–111

*: All data from original description: *Amblydromalus lailae* (Schicha, 1979b).

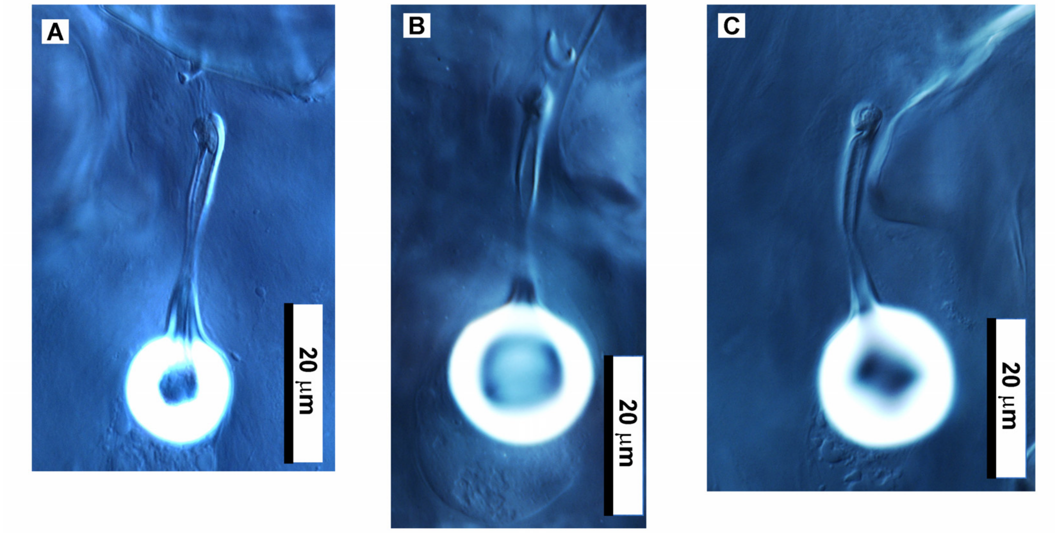

FIGURE 12. Spermatheca of *Amblydromalus limonicus* (female).

We also compared ontogenetic data (mainly chaetotaxy) of *A. limonicus* from this study with those of *A. lailae* described by Schicha (1979b). Although the protonymphs and deutonymphs of these two species are not distinguishable (Table 3), the larva of *A. limonicus* differs obviously from that of *A. lailae* in that the former has setae *Z1*, *S2*, *S5* and *Z5* which are absent in *A. lailae*; also, the chelicerae of larvae have 5–7 teeth on fixed digits in *A. limonicus* but only three teeth in *A. lailae.* Schicha (1979b) described immatures of *A. lailae* based on mites collected on leaves in the field (not based on laboratory rearing)—this is not usual as nearly half of 50 described larvae are based on collected specimens. There is a possibility the larvae described as *A. lailae* by Schicha (1979b) may be from another species that contaminated the same host. Schicha was an experienced phytoseiid specialist and typically we would not expect him to make such an error. However, Schicha (1979b)'s description itself provides evidence that suggests this may be the case because the ontogenetic changes from larvae to adults of *A. lailae* provide internal inconsistences within the species. These can be reflected both in the presence/absence and the relatively length of setae. For example, setae *j3* are much longer than *j4* in all stages of *A. limonicus* in our results, whereas the same level of consistence is only found in protonymphs, deutonymphs and adults in *A. lailae* in Schicha (1979b), which suggests that the larvae described therein may be from another species. Our comparisons of 50 species of larval Phytoseiidae known to us so far suggest that the absence of several idiosomal setae more likely represents generic rather specific differences. In a later paper, Schicha (1983) reported *Proprioseiopsis ovatus* (Garman, 1958) with the same collection data (location, host plant, date and collector) as *A. lailae* in Schicha (1979b). The larvae of two species of this genus, *P. rotundus* (Muma, 1961) and *P. mexicanus* (Garman, 1958) were described before (Table 4). Although the number of dorsal setae in these two species is similar to that in "*A. lailae*" (larvae), the relative lengths of setae are obviously different (Table 4). For example, setae *j1* is more than 3 times as long as *j3* in "*A. lailae*" but shorter than or as long as *j3* in *P. rotundus* and *P. mexicanus.* The number of setae in the ventrianal region is also different between *A. lailae* and the genus *Proprioseiopsis*, which has only three pairs of setae *JV1*, *JV2* and *ZV2*, lacking *JV5*). We compared all larval characters of published data and found the larval characters of "*A. lailae*" of Schicha (1979b) match those of the genus *Euseius* (Table 4). Thus, the larvae of "*A. lailae*" described by Schicha (1979b) are from a species of *Euseius* different from *E. victoriensis* (Womersley, 1954)

(Schicha, 1977a) and *E. elinae* (Schicha, 1977a) (Table 4): their true identity will require a future study to collect specimens from habitats/hosts previously reported in Schicha (1979b) and rear them in the laboratory.

Discussion

The importance of studying ontogeny of Phytoseiidae

In this study, we described for the first time the complete ontogenetic sequence of *A. limonicus* based on reared specimens and compared with that described for *A. lailae* by Schicha (1979b): all stages except the larvae of two species are not distinguishable. Our morphological data thus support the synonymy of the two species based on DNA data (Goodwin & Steiner 2004). We further observed internal consistence in the number and relatively lengths of setae from larvae to adults of our *A. limonicus*, but only those from protonymphs to adults of *A. lailae* by Schicha (1979b). The descriptions of immatures are still limited for the Phytoseiidae, but the available data show that they are useful. Based on our new data as well as published data of other phytoseiid larvae, we were able to place the incorrectly identified larvae of "*A. lailae*" by Schicha (1979b) in the genus *Euseius*. The results of this study are therefore important for phytoseiid systematics and highlight a neglected area of research: the careful descriptions of immature stages based on reared specimens.

In the larvae of Phytoseiidae, ten pairs of dorsal setae (*j1*, *j3*, *j4*, *j5*, *j6*, *z2*, *z4*, *z5*, *s4*, *Z4)* are stable and are present on almost all species. But within the genus, different species can be distinguished by their unstable setae or the relative length. Cargnus *et al.* (2014) reported immature stages of four species of *Kampimodromus*; during the larval stage, the numbers of dorsal setae are the same in the four species, but the relative lengths of the posterior dorsal setae *Z4* allow the larvae of *K. aberrans* (Oudemans) to be easily separated from those of the other three species. *Amblyseius colimensis* and *A. aberrans* have the same number of dorsal setae during the larval stage. Aponte and McMurtry (1987) described seven pairs of lyrifissures and one pair of gland openings on the dorsal shield, but Chant (1958) did not describe lyrifissures and gland openings; we need to confirm if the lyrifissures and gland openings exist in this species. Schicha (1979a) reported *Typhlodromus* (*A.*) *dossei*, whereas Chant (1958) described *Typhlodromus* (*A.*) *rhenanus*; they have the same number of dorsal setae in larvae, but the morphology of dorsal setae is different—*T. dossei* with *s4* and *Z4* knobbed, *z4* blunt, whereas *T. rhenanus* with *s4*, *z4* and *Z4* smooth. *Neoseiulus reticulatus* and *N. cucumeris* were thought to be synonymous and yet their larvae differ considerably (Chant 1958).

Evans and other authors observed that the larvae of phytoseiid mites have two dorsal shields (Chant 1958). We agree that the larvae of *A. limonicus* also have two dorsal shields, because the posterior shield is too faint to observe. Bernhart (1955) stated that phytoseiid protonymphs also have two dorsal shields but this was not corroborated. However, we did not find two dorsal shields in *A. limonicus* protonymphs—perhaps the posterior dorsal shield is weakly sclerotized.

Remarks on distribution of Amblydromalus limonicus *in New Zealand*

In New Zealand, *A. limonicus* was common in North Island and the Nelson area of the South Island (Collyer 1964). Later it was reported from Motueka in the northern part of South Island and Tauranga in North Island (Collyer 1982). In this paper, we added numerous additional collections of this species from various localities in North Island. One interesting sample of this species is from Warrington on the coast of Otago, in South Island—the southernmost record of this species in New Zealand. Despite its location further south, Warrington (high/low 9/2–3 °C during June–August) is only slightly colder than Nelson (high/low 19/5–6 °C during June–August) in terms of lower winter temperature.

TABLE 3. Comparison of characters of all stages of *Amblydromalus limonicus and A. lailae* (Schicha, 1979b).

Ch./Stage	*A. limonicus*					*A. lailae**				
setae	L	PN	DN	F	M	L	PN	DN	F	M
j1	+	+	+	+	+	+	+	+	+	+
j3	+	+	+	+	+	+	+	+	+	+
j4	+	+	+	+	+	+	+	+	+	+
j5	+	+	+	+	+	+	+	+	+	+
j6	+	+	+	+	+	+	+	+	+	+
J2	---	+	+	+	+	---	+	+	+	+
J5	---	+	+	+	+	---	+	+	+	+
Z1	+	+	+	+	+	-	+	+	+	+
z2	+	+	+	+	+	+	+	+	+	+
z4	+	+	+	+	+	+	+	+	+	+
z5	+	+	+	+	+	+	+	+	+	+
Z4	---	+	+	+	+	-	+	+	+	+
Z5	+	+	+	+	+	+	+	+	+	+
s4	+	+	+	+	+	+	+	+	+	+
S2	+	+	+	+	+	---	+	+	+	+
S4	---	+	+	+	+	---	+	+	+	+
S5	---	+	+	+	+	---	+	+	+	+
r3	---	+	+	+	+	---	+	+	+	+
R1	---	+	+	+	+	---	+	+	+	+
st1	+	+	+	+	+	▲	▲	▲	+	+
st2	+	+	+	+	+	▲	▲	▲	+	+
st3	+	+	+	+	+	▲	▲	▲	+	+
st4	---	---	+	+	+	▲	▲	▲	+	+
st5	---	---	+	+	+	▲	▲	▲	+	+
JV1	+	+	+	+	+	+	+	+	+	+
JV2	+	+	+	+	+	+	+	+	+	+
JV4	+	---	+ (---)	+	---	---	---	+	+	---
JV5	+	+	+	+	+	---	+	+	+	+
ZV1	---	---	+ (---)	+	---	---	---	+	+	---
ZV2	+	+	+	+	+	+	+	+	+	+
ZV3	+	---	+ (---)	+	---	+	---	+	+	---
Fixed digit-no.	**5–7**	**5**	**7–9 (6–8）**	9–11	9	**3**	**6**	7	9	9
Movable digit-no.	1–2	1–3	**3 (2–3)**	3	1	1	3	**4**	3	1
Sge I	1	1	1	1	1	1	1	1	1	1
Sti I	---	---	---	---	---	---	---	---	---	---
St I	---	---	---	---	---	---	---	---	---	---
Sge II	1	1	1	1	1	1	1	1	1	1
Sti II	---	---	---	---	---	---	---	---	---	---
St II	---	---	---	---	---	---	---	---	---	---
Sge III	1	1	1	1	1	1	1	1	1	1
Sti III	1	1	1	1	1	1	1	1	1	1
St III	---	---	---	---	---	---	---	---	---	---
Sge IV	---	1	1	1	1	-	1	1	1	1
Sti IV	---	1	1	1	1	-	1	1	1	1
St IV	---	1	1	1	1	-	1	1	1	1

L: larva; PN: protonymph; DN: deutonymph; F: female; M: male; ▲: without measurement and description in the original description (Schicha, 1979b); +: the seta present; ---: the seta absent; *: All data from original description: *Amblydromalus lailae* (Schicha, 1979b); for deutonymphs, conditions in ( ) are for males.

TABLE 4. Comparison of characters of larval stages of seven phytoseiid species.

setae	*A. limonicus*	*A. lailae**	*E. finlandicus**	*E. victoriensis**	*E. elinae**	*P. rotundus**	*P. mexicanus**
j1	28 (23–33)	24	+	16–24	22–26	17–19	19–21
j3	**34 (31–39)**	**7**	+	**7–9**	**7–9**	**22–24**	**19–21**
j4	4 (4–8)	3	+	**5–6**	**5–6**	**8–10**	**6–9**
j5	6 (4–6)	3	+	6–7	4–5	**8–10**	**7–9**
j6	10 (10–14)	7	+	10–12	9–10	14–16	11–13
J2	---	---	---	---	---	---	---
J5	---	---	---	---	---	---	---
Z1	**7 (4–10)**	---	---	---	---	---	---
z2	6 (6–7)	7	+	7–9	7–8	**8–10**	**11–12**
z4	8 (7–9)	8	+	6–9	9–11	**11–13**	**11–12**
z5	6 (6–7)	5	+	6–8	4–6	**8–10**	**7–9**
Z4	204 (181–245)	171	+	174–222	203–232	131–135	143–146
Z5	**10 (6–11)**	---	---	---	---	---	---
s4	73 (55–78)	47	+	51–59	49–52	59–62	40–43
S2	**7 (3–7)**	---	---	---	---	---	---
S4	---	---	---	---	---	---	---
S5	**8 (4–8)**	---	---	---	---	---	---
r3	---	---	---	---	---	---	---
R1	---	---	---	---	---	---	---
st1	31 (24–31)	▲	+	+	+	+	+
st2	24 (25–29)	▲	+	+	+	+	+
st3	25 (22–29)	▲	+	+	+	+	+
st4	---	▲	---	---	---	---	---
st5	---	▲	---	---	---	---	---
JV1	**7 (6–9)**	+	+	**7–8**	**6–9**	+	+
JV2	25 (17–27)	3 times as long as *JV1*	+	28–30	19–26	+	+
JV4	---	---	---	---	---	---	---
JV5	8 (7–8)	**as long as *JV1***	+	**shorter than *JV1***	**shorter than *JV1***	---	---
ZV1	---	---	---	---	---	---	---
ZV2	**10 (6–11)**	**as long as *JV1***	+	**shorter than *JV1***	**shorter than *JV1***	+	+
ZV3	---	---	---	---	---	---	---

▲: without measurement and description in the original description; +: the seta existed but without measurement; ---: without the seta.
*: All data from original descriptions: *Amblydromalus lailae* (Schicha, 1979b), *Euseius finlandicus* (Oudenmans) (Chant, 1958), *Euseius victoriensis* (Womersley) (Schicha, 1977a), *Euseius elinae* (Schicha, 1977a), *Proprioseiopsis rotundus* (Muma) (Fouly *et al.* 1994) and *Proprioseiopsis mexicanus* (Garman) (Fouly *et al.*1994).

Remarks on host plants (tomato) of Amblydromalus limonicus

Amblydromalus limonicus recently established in northern Spain and was common on tomato plants (Choraźy *et al.* 2016). In this study, we also examined several records of this species on tomato (both greenhouse and field crops) in New Zealand. As this species is currently explored as a potential biocontrol agent against tomato/potato psyllid (*B. cockerrelli*) in New Zealand (Xu & Zhang 2015; Liu & Zhang 2017, Patel & Zhang 2017a,b) and the capsicum-collected strain does not perform well on tomato due to the interference of mite searching by glandular trichomes (Van Houten *et al.* 2013), the availability of a strain adapted to tomato will be very important. Further collection and study of New Zealand populations of *A. limonicus* on tomato are therefore highly recommended.

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