Zootaxa 2158: 33–49 (2009)
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

Review of the mite genus *Gaeolaelaps* Evans & Till (Acari: Laelapidae), and description of a new species from North America, *G. gillespiei* n. sp.

FRÉDÉRIC BEAULIEU
Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, 960 Carling Avenue, Ottawa, ON K1A 0C6, Canada. E-mail: frederic.beaulieu@agr.gc.ca

Abstract

The concept of the genus *Gaeolaelaps* of the mite family Laelapidae is reviewed, based on species descriptions in the literature and the examination of specimens of selected described and undescribed species. A short diagnosis and a description of the genus is presented, showing the range of morphological character states and indicating species that depart from the typical character states. *Gaeolaelaps* is restored from subgeneric to generic rank. A new species, *G. gillespiei* **n. sp.**, is described from adult female and male specimens. This species shows promise in the control of fungus gnats and thrips on greenhouse cucumbers in British Columbia, Canada. It is a relative of the well known biocontrol agent *Gaeolaelaps* (or *Hypoaspis*) *aculeifer*, but presents a set of morphological traits that distinguish it from *G. aculeifer* and other related species. The diversity of soil-dwelling mesostigmatic mites remains poorly explored, and so is their potential for biological control.

Key words: *Hypoaspis*, Hypoaspidinae, Mesostigmata, predatory mite, biocontrol

Introduction

The mesostigmatic mite family Laelapidae is ecologically diverse, and comprises obligate and facultative parasites of vertebrates, insect paraphages, and free-living predators that inhabit soil-litter habitats, as well as the nests of vertebrates and arthropods (Strong & Halliday 1994; Krantz & Walter 2009). The family, including the genus *Gaeolaelaps* Evans & Till 1966, is in need of taxonomic revision (Evans & Till 1966; Gilyarov & Bregetova 1977; Tenorio 1982; Casanueva 1993). The taxonomic rank and the boundaries of *Gaeolaelaps* are unclear and subject to disagreement between authors. Evans & Till (1966) defined *Gaeolaelaps* for the first time (Halliday & Lindquist 2007) as a subgenus of *Hypoaspis* Canestrini *sensu lato*. They later (1979) gave provisionally generic status to most of the subgenera of *Hypoaspis*, but kept *Gaeolaelaps* (along with *Alloparasitus* and *Hypoaspisella*) under the genus *Hypoaspis*. Most subsequent authors of taxonomic studies (e.g. Costa 1968; Hunter & Yeh 1969; Gilyarov & Bregetova 1977; Karg 1979; Tenorio 1982; Ruf & Koehler 1993; Ma & Yin 1998) and biological studies (e.g. Lesna *et al*. 2000; Vänninen & Koskula 2004) regarded *Gaeolaelaps*-like species as *Hypoaspis* species, sometimes giving *Gaeolaelaps* as a subgenus, or even as a species group (Van Aswegen & Loots 1970). Other authors have used *Gaeolaelaps* at the genus level (Ryke 1963; Hyatt 1964; Rosario 1981; Walter & Oliver 1989; Gillespie & Quiring 1990; Krantz & Ainscough 1990; Farrier & Hennessey 1993). In this paper, I revise the concept of *Gaeolaelaps* by describing the range of morphological character states based on species descriptions in the literature and on the examination of specimens of selected described and undescribed species.

Predatory laelapids tend to be voracious, polyphagous predators that reproduce quickly and can be reared easily (Walter & Oliver 1989; Gillespie & Quiring 1990; Lesna *et al*. 1995). This makes them good candidates for biological control of pests that spend time in the soil or in other plant growing media. Two soil-dwelling

Accepted by B. Halliday: 1 Jun. 2009; published: 15 Jul. 2009

laelapids, *Stratiolaelaps scimitus* (Womersley) (or *S. miles* (Berlese); see discussion) and *Gaeolaelaps aculeifer* (Canestrini), are increasingly used as biocontrol agents on greenhouse crops or in mushroom cultures against fungus gnats (Sciaridae: *Bradysia* and *Lycoriella* spp.), shore flies (Ephydridae: *Scatella* spp.), and bulb and mould mites (Acaridae: *Rhizoglyphus* and *Tyrophagus* spp.) (Enkegaard *et al*. 1997; Lesna *et al*. 2000; Vänninen & Koskula 2004). An undescribed species related to *G. aculeifer* was observed in large numbers in 1984 in potted gerbera that was damaged by fungus gnats near Sidney, British Columbia, Canada (Gillespie & Quiring 1990). The predatory mite was collected and successfully cultured, first on fungus gnats and then on *Tyrophagus putrescentiae* (Schrank), with the aim of testing it in biological control. In greenhouse experiments, the mite caused substantial reduction in numbers of fungus gnats (*Bradysia* spp.) and western flower thrips (Thripidae: *Frankliniella occidentalis* (Pergande)) on hydroponically grown cucumbers in British Columbia (Gillespie & Quiring 1990). It reaches high populations in greenhouses and further observations suggest it may help control fungus gnats (Brian Spencer & Don Elliott, pers. comm.). I here describe the adult female and male of this new *Gaeolaelaps* species to provide a formal name for its identification and reference in support of its use in biocontrol programs and future ecological studies.

Materials and methods

Review of the genus *Gaeolaelaps*

A total of 33 characters, as well as the leg and dorsal shield chaetotaxy when possible, was studied from descriptions (or redescriptions) in the literature, for about 75 species of *Gaeolaelaps*. Three species were also studied by the examination of specimens at hand: *G. aculeifer*, *G. marksi* (Strandtmann & Crossley) (female paratype)**,** and *G. queenslandicus* (Womersley) (female, Puerto Rico). In addition, characters were studied for the new species described herein, as well as for at least 15 undescribed species, mostly from the Nearctic and Neotropical regions. Type specimens of *G. aculeifer* were not examined, as the only type specimen seemingly available for this species can be found (and examined on site only) at the Berlese Acaroteca in Firenze, Italy (Castagnoli & Pegazzano 1985; Marisa Castagnoli, pers. comm.). Some characters (e.g. the number of deutosternal denticles, the leg chaetotaxy) were not studied for all species because they were not described in the species description. Morphometric ratios of the dorsal, sternal and epigynal shields were generally calculated using my own measurements from the illustrations of species in the literature, or, when available, on specimens at hand. When measurements of dorsal shields were indicated in the text, these were used. Lengths of shields were measured along their midlines, and widths were measured between setae *r3* and *s6* (at widest point) for the dorsal shield, and between coxae II (at narrowest point) for the sternal shield.

Description of the new species

Most specimens of the new species were obtained from cultures reared on *Tyrophagus* sp. in sawdust substrate, by Applied Bionomics Ltd., Victoria, British Columbia. The culture originated from mites collected in 1984 from a soil mix of potted gerbera plants. The soil potting mix was prepared at the Centre for Plant Health (Canadian Food Inspection Agency), Sidney, British Columbia. Mites were mounted directly in Hoyer's medium on microscope slides, or after clearing in lactic acid (Krantz & Walter 2009). Measurements (in µm; mean, minimum-maximum) were made from at least five females and five males mounted on slides using a stage-calibrated ocular micrometer or interactive measurement software connected to a digital camera and a compound microscope. Lengths of shields were measured along their midlines, and widths were measured at level of setae *s6* for the dorsal shield, between coxae II (narrowest point) for the sternal shield, and at level of setae *ZV1* for the male holoventral shield. Lengths of leg segments were measured dorso-medially, and setae from the bases of their insertions to their tips. Tarsi were measured without the ambulacra. Notation for the setae of legs and idiosoma follows Evans (1963), Evans & Till (1965, 1966), and Lindquist (1994). Notation of pore-like structures on the idiosoma mostly follows the system of Johnston & Moraza (1991) and Lindquist & Moraza (2008). I use the term 'spine-like' to describe setae that are strongly

thickened, and tapered apically, and 'spur-like' for strongly thickened setae that are blunter apically, and consequently often shorter. Holotype and paratypes are deposited at the CNCI (Canadian National Collection of Insects, Arachnids and Nematodes, at Agriculture and Agri-Food Canada) in Ottawa. The new species was compared to the descriptions of species in the literature, including the most reliable descriptions of *G. aculeifer* (Strandtmann 1963; Evans & Till 1966) as well as specimens (9♀, 4♂) from England, The Netherlands, Sweden, Spain, and Canada (deposited at the CNCI, and at the Ohio State University Acarology Collection) that conform to the descriptions of *G. aculeifer.*

Systematics

Genus *Gaeolaelaps* Evans & Till

Geolaelaps Berlese, 1923: 254, *nomen nudum* (see Halliday & Lindquist 2007)
Gaeolaelaps Trägårdh, 1952: 66, *nomen nudum*.
Gaeolaelaps Evans & Till, 1966: 159, correct original spelling as clarified by Halliday & Lindquist (2007).

Type species: *Laelaps aculeifer* Canestrini (1884), by original designation (Evans & Till 1966).

Diagnosis. Hypoaspidine Laelapidae with the following combination of characters: dorsal shield usually bearing 39 pairs of simple, short to moderately elongate setae; adult female sternal shield longer than broad (rarely broader than long), presternal area weakly sclerotized; epigynal shield tongue-shaped or flask-shaped, not markedly broadened posteriorly, and not touching the inversely subtriangular anal shield; peritrematal and exopodal plates narrow, not expanded posteriorly to coxae IV, and free from each other; without dorsal or ventral hypertrichy, except for 0–3 additional unpaired median setae on dorsal shield; anterior margin of tectum denticulate; deutosternum with six (rarely five or seven) rows of denticles, with at least five denticles each (rarely three or four); chelicerae chelate-dentate, well-developed; leg setation normal for Laelapidae.

Description. *Dorsal idiosoma*. Holodorsal shield covering part or all of dorsum, suboval or tapering posteriorly from setae *r3–4*; length 1.4–2.3 × width of shield (see *Note* **1** below); shield not extending ventrally, usually bearing 39 pairs of simple (**2**), short to moderately elongate setae (less than 0.2 × the length of dorsal shield), including setae *px2–3* between *J* and *Z* series, and sometimes with 1–3 additional unpaired *Jx* setae between *J* rows; sometimes one or more podonotal setae (e.g. *z3*) or one or both *px* setae are missing on the shield, resulting in 38 or 37 pairs of setae on the shield, exceptionally less; rarely other opisthonotal setae missing (**3**); rarely, setae *r2–3* off the dorsal shield, on soft cuticle (**4**); 1–8 marginal setae (*r–R*) and 0 to few *UR* setae on soft cuticle (**5**).

Ventral idiosoma. Tritosternum normal, with two pilose laciniae. Presternal area usually weakly sclerotized and lineate, exceptionally with a pair of separate, well-sclerotized platelets (**6**). Sternal shield of female fused with endopodals beside coxae II–III, with anterolateral corners acutely produced, sometimes extended into narrow (**7**) arms (endopodal extensions) flanking coxae II anteriorly (**8**); shield bearing three pairs of fine, simple setae, and two pairs of lyrifissures; seta *st1* sometimes off shield in presternal region (**9**); rarely, third pair of pore-like structures, *iv3* (=*pst3*), captured by sternal shield (**10**); length 1.1–1.9 × width of sternal shield, or sometimes less in arthropod associates (**11**); setae *st4* in soft cuticle, near *iv3*, or rarely *st4* on minute metasternal platelets (**12**) or endopodal platelets (**13**); posterior margin of sternal shield straight, slightly convex or slightly concave (**14**). Epigynal shield tongue-shaped or flask-shaped, always rounded and not markedly broadened posteriorly, with broadest width (in posterior portion) 1–1.9 × the width between coxae IV (narrowest point) (**15**) and 0.6–1.3 × the width of sternal shield (**16**), and distant from the anal shield by at least the length of the anal opening (**17**); epigynal shield bearing a single pair of setae (*st5*); endopodal platelet beside coxae III–IV free, narrow and angular. Peritremes narrow, usually reaching level of coxae I anteriorly, but sometimes shorter, ending near the middle of coxae II (**18**); peritrematal shield connected anteriorly to dorsal shield, free from exopodal platelets (**19**), and not extending posteriad coxae IV. Exopodals

not expanded posteriad coxae IV. Metapodal platelets small. Anal shield inversely pear-shaped, subtriangular or suboval bearing three circum-anal setae; para-anal setae slightly shorter than or as long as post-anal seta, rarely slightly longer. Soft opisthogastric cuticle with 7–9 pairs of setae (*JV*s + *ZV*s) and sometimes a few *UR*s and/or *R*s visible ventrally, never hypertrichous (**20**). Males with holoventral shield usually bearing 10 pairs of setae, sometimes eroded laterally, capturing fewer (3 pairs instead of 5) opisthogastric setae (**21**), rarely with separate anal shield (**22**).

Gnathosoma. Tectum with anterior margin rounded or subtriangular, sometimes almost straight, and occasionally with a few short, irregular projections (**23**), exceptionally with a narrow subtriangular projection (**24**), always with numerous denticles. Deutosternal groove with six rows of denticles, exceptionally five rows (**25**) or seven rows (**26**), usually preceded anteriorly and followed posteriorly by a smooth ridge; deutosternal rows with at least five denticles per row and usually some rows with over 10 denticles; exceptionally basal (6^{th}) row with fewer than five denticles (**27**), or all rows with fewer than five denticles (**28**); all rows of denticles of subequal width, or sometimes the posterior rows narrower (**29**); all rows limited on each side by the lateral margins of deutosternal gutter (**30**). Corniculi horn-like, relatively short, reaching at most 2/3 of the palpfemur. Palp tarsal claw two-tined, rarely three-tined (**31**). Both sexes with cheliceral digits chelate-dentate, well developed, female movable digit with two teeth, exceptionally with a row of 5–7 small teeth between these (**32**); female fixed digit with few to many teeth, sometimes with a row of small teeth past the pilus dentilis; male movable digit unidentate; spermatodactyl free distally, usually short, exceeding the tip of the movable digit by less than 0.5 × the length of the digit, sometimes longer, exceeding the digit by as much as 1–1.5 × (**33**); pilus dentilis short, setiform; arthrodial process a simple corona. Chaetotaxy of the subcapitulum and of the palps normal for Laelapidae (*sensu* Evans & Till 1965).

Legs. Chaetotaxy normal for Laelapidae (sensu Evans & Till 1965) (**34**); ventral setae of femora, genua, tibiae II–IV and many setae on tarsi II–IV usually at least thickened, sometimes spine-like or spur-like; setae of legs relatively short, except some setae on femur II (*pd1*), femur IV (*ad1*) and mostly on tarsus IV (*ad2*, *pd2–3*) can be elongate, sometimes as much as 0.6–0.7 × the length of tarsus IV (**35**). Pretarsi I–IV with well-developed paired claws, may be reduced on tarsi I (**36**).

Explanatory notes. Structures referred to above vary in the following species: (**1**) only arthropod associates have length / width ratios of 1.4–1.5: *G. barbarae* (Strong 1995), *blattae* (Strong & Halliday 1994), *glabrosimilis* (Hirschmann *et al*. 1969), *ruggi* (Strong & Halliday 1994), *passalus* Rosario (1981), *paraculeifer* Rosario (1981); (**2**) a few setae (e.g. *J4–5*, *Z5*) may be inconspicuously barbed, e.g. in some specimens of *G. aculeifer* and *G. gillespiei* **n. sp.**; (**3**) e.g. *G. disjuncta* (Hunter & Yeh 1969), *G. circularis* Hyatt (1964), and *G. ruggi* have 32, 33, and 34 pairs of setae on the shield, respectively; (**4**) e.g. *G. schusteri* (Hirschmann 1966) and *G. theodori* (Costa 1969); (**5**) about 18–19 *R* and *UR* setae on lateral soft cuticle in *G. millipedus* Rosario (1981); (**6**) e.g. *G. disjuncta*; (**7**) broad arms in *G. etiopicus* (Berlese) as illustrated by Van Aswegen & Loots (1971), and *G. wufengensis* (Liu & Ma 2003); (**8**) anterolateral corners apparently poorly (not acutely) produced in *G. blattae*, *millipedus*, *negevi* (Costa 1969; or *gracilis* Meledzhaeva 1963, see Gilyarov & Bregetova 1977), *mohrii* (Ishikawa 1982); (**9**) e.g. *G. minor* (Costa 1968), *franzi* (Van Aswegen & Loots 1970); (**10**) e.g. *G. schusteri*, *G. theodori*; (**11**) length 0.8–0.9 × width of sternal shield in *G. barbarae*, *paraculeifer*, *passalus*, *rarosae* Rosario (1981), *ruggi*, 1.0 × in *G. blattae*, and 0.6 × in *G. rosei* (Strong & Halliday 1994) partly because shield is strongly indented posteriorly; (**12**) e.g. *G. angustus* (Karg 1965), *ruggi*, *similisetae* (Karg 1965); (**13**) e.g. *G. minor*, *G. vanpletzeni* (Van Aswegen & Loots 1970); (**14**) posterior margin moderately indented in *G. barbarae*, deeply indented in *G. rosei*, and with a triangular process in *G. wufengensis*; (**15**) exceptionally broadest width 2.0 × width between coxae IV in *G. circularis*; (**16**) exceptionally 1.5 × in *G. etiopicus*; (**17**) epigynal shield separated from anal shield by about half the length of the anal opening in *G. tenuisetus* Rosario (1981); (**18**) e.g. *G. similisetae*, *G. nolli* (Karg 1962); (**19**) fused to exopodals beside coxae IV in *G. magkadikitus* Rosario (1981), and apparently abutting exopodals in *G. vanpletzeni*; (**20**) exceptionally, two unpaired median setae in *JV* area on soft cuticle in *G. angustiscutatus* (Willmann 1951); (**21**) e.g. *G. schusteri*, *theodori*, *millipedus*; (**22**) e.g. *G. negevi*, *G. schusteri*; (**23**) in *G. angustiscutatus*, *G. vertisimilis* (Karg 1994), and *G. praesternaloides* (Ma & Yin 1998); (**24**) in *G.*

magkadikitus; *G. wufengensis* has an acute median projection; (**25**) in *G. corpolongus* Rosario (1981), *G. etiopicus*, and *G. millipedus*; (**26**) e.g. *G. disjuncta*, *passalus*, *tarsalis* (Bhattacharyya 1968), *vanpletzeni*, *wufengensis*, in some individuals of *G. barbarae*, and in the male of *G. schusteri*; (**27**) 6th row with four denticles in *G. theodori*; (**28**) 3–4 denticles in *G. spiniseta* (Barilo 1991); (**29**) e.g. 6th row narrower in *G. theodori* and 4th to 6th rows narrower in *G. queenslandicus* (Womersley 1956); (**30**) exceptionally 6th row widened beyond lateral margins in *G. angustiscutatus* (Willmann) *sensu* Karg (1965); (**31**) e.g. *G. angustus*, *G. queenslandicus*; (**32**) in *G. angustiscutatus* (Willmann 1951); (**33**) e.g. *G. brevipilis* (Hirschmann *et al*. 1969), *G. disjuncta*, *G. ellipsoides* (Hirschmann *et al*. 1969), *G. postreticulatus* (Xu & Liang 1996); (**34**) *G. rosei* has 2 *pl* setae on genu IV; (**35**) e.g. *G. gillespiei* **n. sp.**, *kargi* (*Costa* 1968), *nolli*, *queenslandicus*; (**36**) e.g. *G. mohrii*.

Remarks. By restoring *Gaeolaelaps* to genus rank from previous usage at the subgeneric rank (Karg 1979, 2006), I follow Walter & Oliver (1989) and Farrier & Hennessey (1993) who used *Gaeolaelaps* as a genus. The concept of the genus used here is narrower than that of Evans & Till (1966) and Gilyarov & Bregetova (1977), mostly by limiting *Gaeolaelaps* to species with a denticulate tectum, which excludes many species such as *H. giffordi* Evans & Till (1966), *H. lubrica* Voigts & Oudemans (1904), and *H. heselhausi* Oudemans (1912), and a relatively narrow epigynal shield bearing a single pair of setae, which excludes *H. sardous* Berlese (1911) and most other species classified as *Alloparasitus* by Karg (1979) or *Euandrolaelaps* by Gilyarov & Bregetova (1977). This concept is broader than that of Walter & Oliver (1989), who characterized the genus by having spur-like or spine-like setae on the distal segments of legs II–IV, and a fixed digit with a row of small teeth flanked by larger teeth. However, it broadly agrees with the definition of *Hypoaspis* (*Gaeolaelaps*) used by Karg (1979, 1982) and of *Gaeolaelaps* used by Krantz & Ainscough (1990).

Most of the approximately 50 species classified by Karg as *H.* (*Gaeolaelaps*) (Karg 1982, 1987, 1989a, 1989b, 1994, 2000, 2003, 2006) probably belong to *Gaeolaelaps*. However, some of these species show disparate or exceptional character states and therefore may not belong to this group, and are, at least provisionally, excluded from *Gaeolaelaps* here. For instance, *H. kassaii* Van Aswegen & Loots (1970) and *H. pinnae* Karg (1987) have many barbed setae on the dorsal and opisthogastric regions. *Hypoaspis ciconia* Karg (1979) and *H. ardoris* Karg (1993) have hypertrichous dorsal shields. *Hypoaspis exquisita* Karg (1989a) has dorsal setae with spatulate tips and a dorsal shield extending ventrally. *Hypoaspis pugni* Karg (1979) has many podonotal setae inserted on tubercles, no claws on tarsi I, and an epigynal shield almost blunt posteriorly. *Hypoaspis loksai* Karg (2000) has an enlarged epigynal shield, 1.6 × as wide as the sternal shield, and almost touching the anal shield. *Hypoaspis passali* Hyatt (1964) has an epigynal shield almost axe-shaped, as many as 9–10 unpaired median opisthonotal setae, and about 20 marginal and submarginal setae on the lateral cuticle. *Hypoaspis spiculifer* Berlese *sensu* Van Aswegen & Loots (1970) has only two denticles on the otherwise smooth margin of the tectum. *Hypoaspis atomarius* Berlese as redescribed by Van Aswegen & Loots (1970) has two ventral setae on genu IV instead of one. *Hypoaspis guttaforma* Karg (1989b), *H. zachvatkini* Buyakova & Goncharova (1972), and *H. angustiscutatus* sensu Lapina (1976) have at least some dorsal setae inflated near their bases, as seen in some species of *Cosmolaelaps* (Evans & Till 1966).

The following additional species, mostly described as *Hypoaspis*, are regarded here as *Gaeolaelaps* species (see also those mentioned in *Explanatory notes* above): *G. aculeiferoides* (Teng 1982), *concinna* (Teng 1982), *dailingensis* (Ma & Yin 1998), *debilis* (Ma 1996), *deinos* (Zeman 1982), *ellipsoides* (Hirschmann *et al*. 1969), *fishtowni* (Ruf & Koehler 1993), *haiyuanensis* (Bai *et al*. 1994), *krantzi* (Arutunian 1993), *marksi* (Strandtmann & Crossley 1962), *matinikus* Rosario (1981), *paraculeifer* Rosario (1981), *neoaculeifer* (Hirschmann 1966), *oreithyiae* Walter & Oliver (1989), *postreticulatus* (Xu & Liang 1996), *singuloides* (Gu & Duan 1993; described as *Androlaelaps*), *subminor* (Gu & Bai 1991), *taitzujungi* (Samšiňák 1964), and *G. tengi* (Gu & Bai 1991). Additional '*Hypoaspis*' or '*Androlaelaps*' species may belong to *Gaeolaelaps* but are not listed here, either because I overlooked the reference or because their description in the literature did not provide sufficient information for placement in the genus.

Species of the genus *Hypoaspis* sensu stricto described by Costa (1971) are distinct from *Gaeolaelaps* species and can be differentiated from them by their elongate setae on the dorsal shield (particularly *j3*, *z4*, *s4–5*, and *Z4* which is 0.2–0.5 × the length of the dorsal shield), and on femur IV (seta *ad1*), tarsus IV (setae *ad2*, *pd2–3*, which are usually 0.6–1.0 × the length of tarsus IV), usually also on femora II and III (*pd1* and *ad1*, respectively), and sometimes on genu IV (*ad1*). Species of *Hypoaspis* also have a subtriangular median projection of the tectum, peritremes free from the dorsal shield anteriorly, and setae *z4* and *s4* tend to be inserted more laterally on the dorsal shield, resulting in exposed areas laterad *j4–5* and *z5*. They also have a maximum of 37 pairs of setae on the dorsal shield, *r2–3* being off the shield.

More distant taxa, such as *Androlaelaps* (Laelapidae) and some Leptolaelapidae may be confused with *Gaeolaelaps* on the basis of similarities in dorsal chaetotaxy and the shape of the epigynal shield. *Androlaelaps* species can be distinguished from *Gaeolaelaps* by their frequently enlarged pilus dentilis, the presence of seta *pl2* on genu IV, and the male chelicerae with the fixed digit reduced and edentate, and the movable digit partially or entirely fused with an elongate spermatodactyl (Till 1963; Krantz & Ainscough 1990). Leptolaelapids have the spermatodactyl directed posteriorly, often more than seven rows of deutosternal denticles, and sometimes also large metapodal plates (*Ayersacarus*), some setae pilose laterally (*Ayersacarus*) or apically (*Hunteracarus*), or a sternal shield that extends strongly anterior to coxa II (*Leptolaelaps*) (Evans 1957; Hunter 1964; Costa 1975).

***Gaeolaelaps gillespiei* sp. nov.**
(Figures 1–11)

Material examined. Holotype: Female. Canada, British Columbia, Sidney, ex. roots and soil of wilting gerbera plants, 15 April 1982, Dave Gillespie. Paratypes: 3 females, 2 males, same data as holotype; 3 females, Sidney, ex. sawdust growing media in greenhouse, 4 May 2005, Don Elliott; 21 females, 5 males, reared from culture originated from specimens collected from potted *Gerbera jamsonii* Hook. that were damaged by fungus gnats, Sidney, 1984, Dave Gillespie.

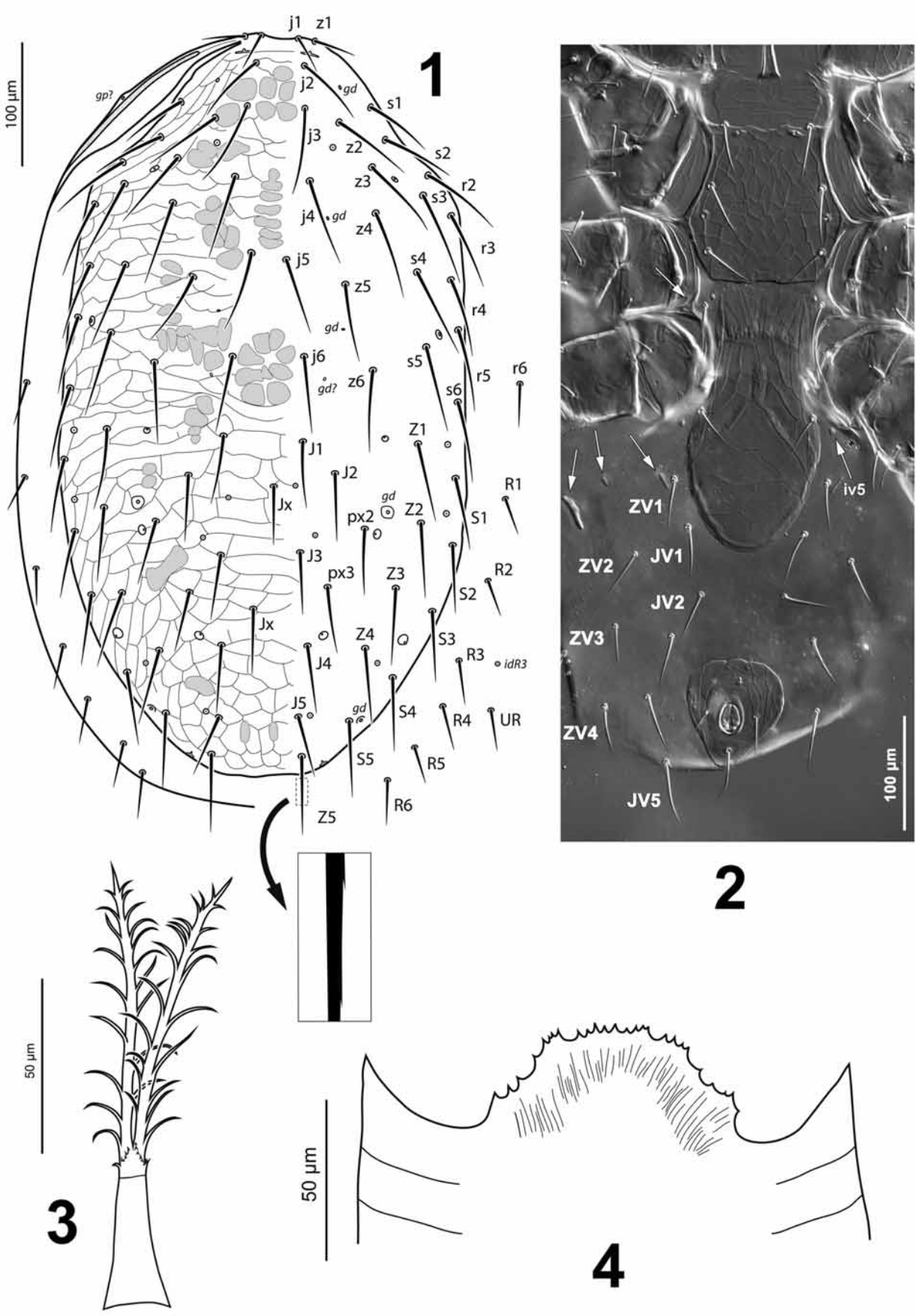
Diagnosis. Female dorsal shield suboval with 39 pairs of setae and 1–3 additional unpaired setae in the median area between *J2–3* and between *J3–4*; setae *px2–3* present between *J* and *Z* series; setae on shield long and slender. Seven pairs of marginal setae (*r6*, *R1–6*) in soft lateral cuticle. Peritremes extending to level of *j2* and past acetabulum I. Sternal shield reticulated throughout except smooth postero-medially. Presternal area weakly sclerotized, notched anteriorly. Epigynal shield flask-shaped, relatively small, separated from the anal shield by about the length of the anal shield; reticulated throughout with larger cells behind two diagonal lines forming an inverted-V. Tectum with anterior margin rounded and denticulate. Subcapitulum with six rows of 11–34 deutosternal denticles; hypostomal seta *h3* elongate and posterior to *h2*. Fixed digit of female chelicera with 7–10 teeth of irregular size, and male fixed digit with 11–15 small to minute teeth. Palp genua with tips of setae *al1* trifurcate. Setae on legs simple and slender except the following setae thickened and/or spine-like: seta *al* on trochanter II, dorsal seta on trochanter IV, *av2* on femur II, *pd* on femur III (slightly thickened), *pd* on femur IV, *av1* on genua III–IV, *pv1* on tibia II (slightly thickened), *av1* and *pv1* on tibia III–IV, most setae on telotarsi II–IV; *pd2* and *al2* on tarsus IV slender and elongate. Spermatodactyl relatively long, tip tapering sharply and bent ventrally.

Female. *Dorsal idiosoma* (Fig. 1). Dorsal shield (600–672 long × 328–368 wide) suboval, reticulate throughout, bearing 39 pairs of setae and 1–3 unpaired setae: 22 pairs (*j1–6*, *z1–6*, *s1–6*, *r2–r5*) in podonotal region and 17 pairs (*J1–5*, *Z1–5*, *px2–3*, *S1–5*) in opisthonotal region and usually 2 (rarely 1 or 3) additional unpaired setae (*Jx*) in the median area between *J2–3* and between *J3–4*; all setae simple (although *J4–5* and *Z5* are sometimes inconspicuously barbed, Fig. 1 inset), slender and long (49–83), except *j1* (30–36) and *z1* (35–43) shorter; setae *s1*, *J1–5*, *Jx*, and *px2–3* tend to be slightly shorter (55, 49–63) than other setae, and *j3–4*, *z3–4*, *s3–5* tend to be the longest (73, 66–83). Marginal setae *r6* and *R1–R6* relatively short (37, 30–53), in soft lateral cuticle. Peritrematal shield smooth, limited to a narrow band of varying width (3–16) bordering

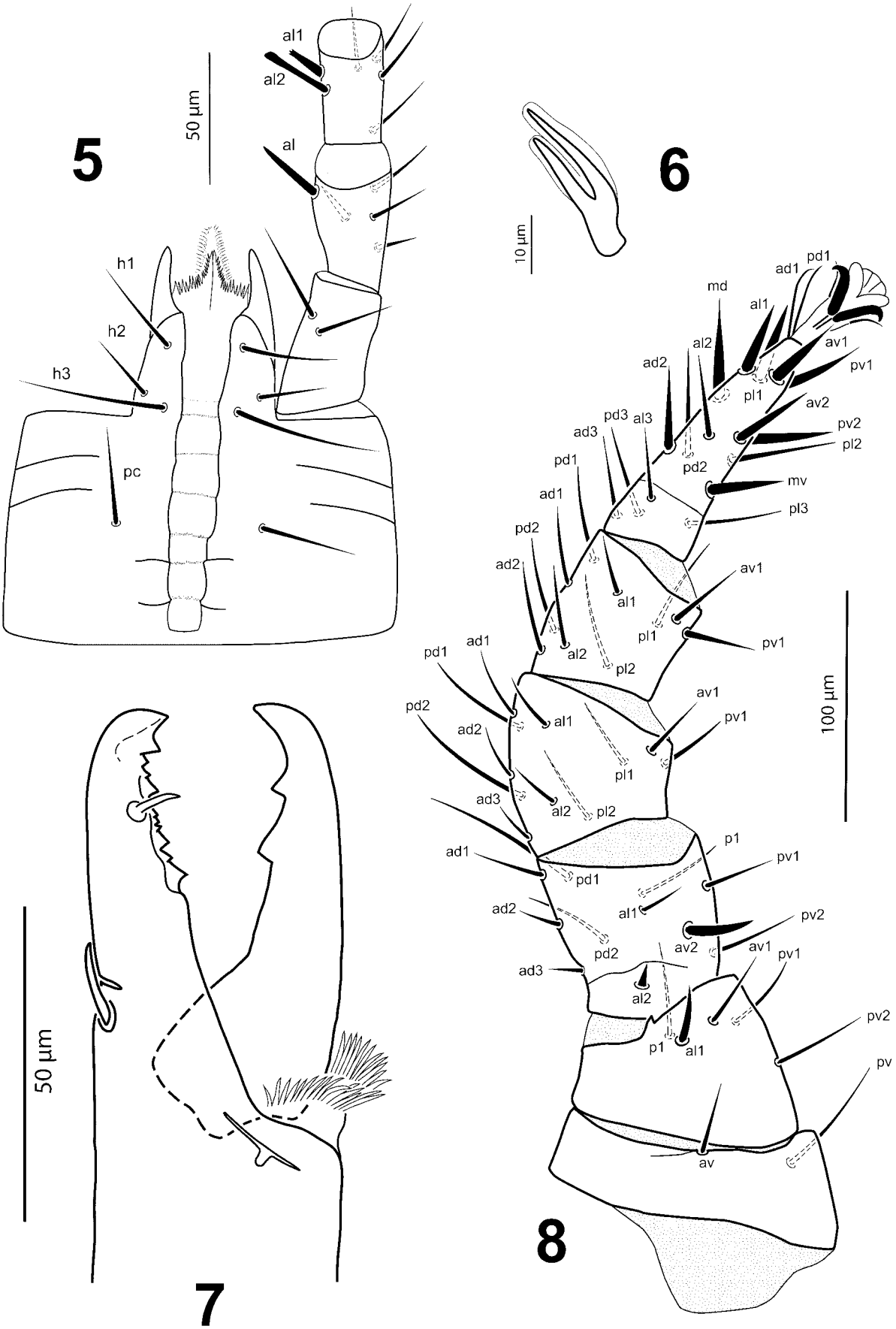
the peritreme on the side neighbouring the dorsal shield, free posteriorly, narrowly fused to dorsal shield near *z1*, bearing six pairs of discernible pore-like structures (apparently at least three lyrifissures '*ip'*, and two or three gland pores '*gp'*; see also male in Fig. 10); peritreme extending to level of *j2*. Dorsal shield with 21 pairs of discernible pore-like structures, of which five or six (three or four podonotal, two opisthonotal) appear secretory (gland pores '*gd'*, Fig. 1) and at least 15 non-secretory (lyrifissures); the gland pore anterolaterad seta *px2* is conspicuous and surrounded by a lacuna (cell-like border); the other opisthonotal pore, laterad seta *S5*, is similar although appears less conspicuous because the shield surface is more oblique near the edge; other gland pores minute. Gland pores on the dorsal shield can usually be distinguished from lyrifissures by their deeper structures and their sac-like invaginations and diverticula at high magnification.

Ventral idiosoma (Figs 2–3). Tritosternum with plumose laciniae (85–92), apparently fused proximally for 5–7 from base apex (transversal line) to a fringe of 12–14 denticles, columnar base (32–37 long) (Fig. 3). Sternal shield (length 127–141), narrowest width between coxae II (95–100) (Fig. 2), broadest between coxae II–III (144–170), ratio length / width 1.27–1.42, with narrow, extended arms flanking coxae II anteriorly, often obscure; reticulated throughout except smooth in postero-median region where overlapped by hyaline anterior margin of epigynal shield, cells elongate and compressed in median anterior area; shield bearing long, slender setae *st1–3* (47–50, 52–59, 47–53, respectively), and lyrifissures *iv1–2*; posterior margin more or less straight, with a pair of minute pits near the median line (sometimes not discernible). Presternal area weakly sclerotized, lineate and lightly granulate, notched medially (Fig. 2, see also male, Fig. 10). Setae *st4* (51–56) and lyrifissure *iv3* in soft cuticle; endopodals mediad coxae III–IV, angular, separate from sternal shield. Epigynal shield (full length 210–230; 95–110 from level of *st5* to posterior tip) with hyaline anterior margin broadly rounded, reticulate throughout, with 6–8 larger cells in the posterior area delimited by two lines forming an inverted-V (only four cells if longitudinal divisions are not discernible), narrowest width between coxae IV (73–82), and oval posteriorly (maximum width 106–115), bearing setae *st5* on margins, and flanked by pair of lyrifissures *iv5* (=*pst5*) on soft cuticle near *st5*. Narrow endopodal platelet present mediad coxae III–IV. Narrow exopodal plate surrounding coxae IV, and small exopodal plate between coxae II and III. External, primary (27–30 × 5–8) and inner (9–20 × 3–4) metapodal platelets narrow; paragenital platelet narrow, beside seta *ZV1* (Fig. 2). Anal shield (85–103 × 78–94 wide) inversely subtriangular, lineate, with post-anal seta (44–49) longer than para-anal setae (33–36); cribrum with dense field of spicules. Soft cuticle with long (most 38–53), slender ventral setae *JV1–5*, *ZV1–4*, with *JV5* longest (52–64), *ZV3* shortest (31–39), and one pair of submarginal setae (*UR*) laterad *ZV3–4* (or laterad *R3–4* if seen dorsally) (Figs 1–2).

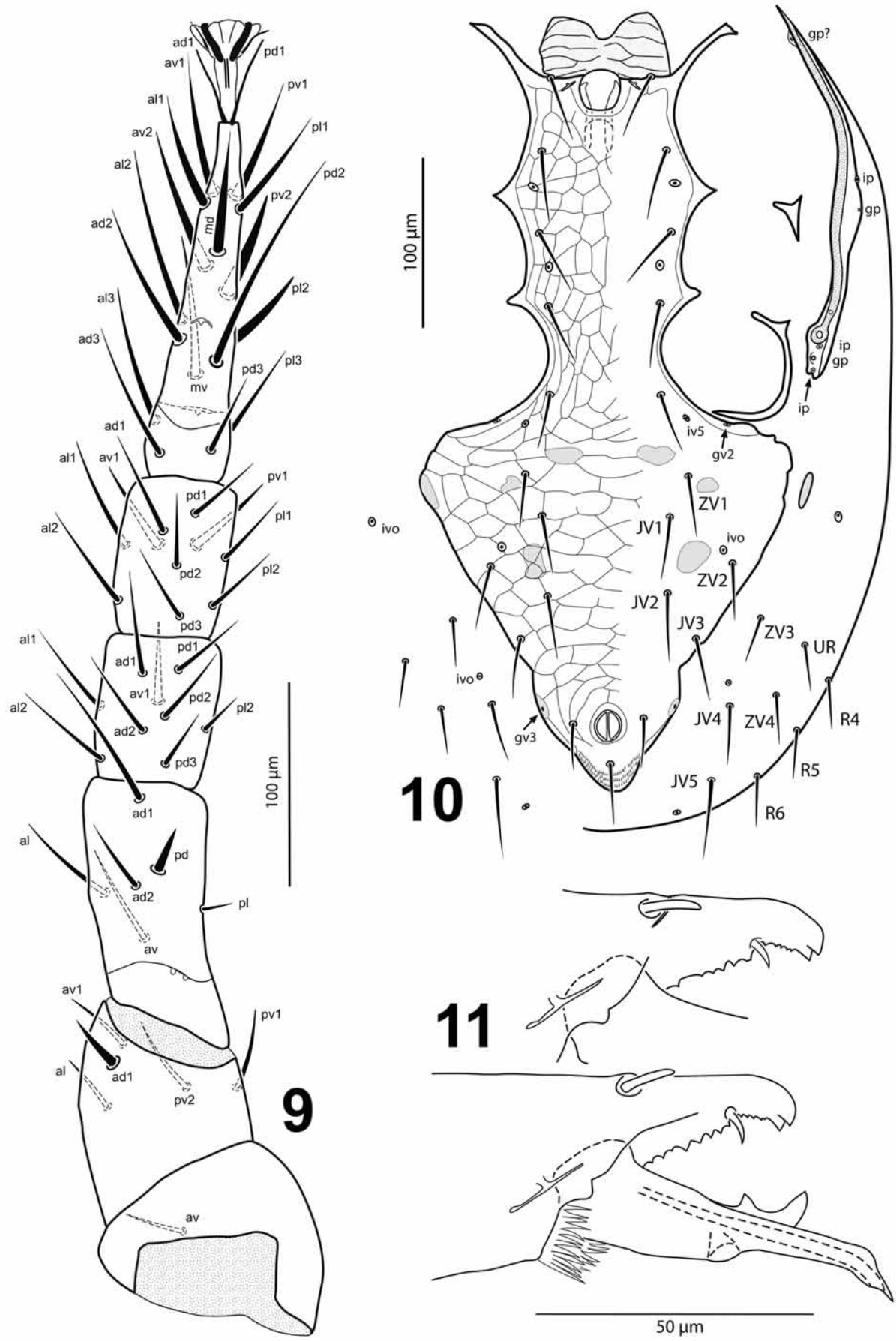
Gnathosoma (Figs 4–7). Tectum (Fig. 4) with anterior medial margin somewhat rounded and denticulate. Subcapitulum (Fig. 5) with six rows of deutosternal denticles, preceded anteriorly and followed posteriorly by a smooth ridge devoid of teeth; rows 2–3 with most denticles (23–34) and row 6 (basal row) with fewest (11–16); rows 4–6 usually with slightly larger denticles, and ridges of rows 5–6 extending onto genae; corniculi horn-like (51–55), extending slightly beyond palptrochanter; internal malae abutting and projecting medially, coarsely fringed laterally, more finely fringed along median projection, almost reaching tip of corniculi; labrum extending slightly beyond corniculi for 6–12 (Fig. 5); hypostomal setae long and fine, inner posterior *h3* longer (60–63) than anterior *h1* (39–43), outer posterior setae *h2* (26–29), and palpcoxal setae *pc* (41–43); setae *h2* 42–46 apart, and *pc* 52–58 apart. First cheliceral segment 68–88; second cheliceral segment (170–187) ending in fixed digit, bearing an offset large tooth and 1–2 small teeth subapically, followed by a large tooth at the level of a short, setiform pilus dentilis, and a row of 2–6 teeth of irregular size (the most proximal ones tend to be larger) flanked proximally by a larger tooth; dorsal seta posteriad dorsal lyrifissure; movable digit (64–67) bidentate, with fringed arthrodial corona (Fig. 7). Palps (195–211) (Figs 5–6) with simple setae except *al* on femur thickened, spine-like, *al1* and *al2* of genu thickened, and apically trifurcate and subspatulate respectively; setation of palp segments from trochanter to tarsus: 2-5-6-14-15, including two dorso-distal setae on tibia apparently hollow and with narrowly rounded tip, and nine similar setae on tarsus; palp tarsal claw 2-tined, with tines tapered and flanked by a hyaline flap (not always discernible), ventral tine shorter (12–15 from the fork) than dorsal tine (18–20 from fork, 26–29 from base) (Fig. 6).



FIGURES 1–4. *Gaeolaelaps gillespiei* **n. sp.**, female. 1, Dorsal shield; 2, Ventral idiosoma. Arrows showing endopodal platelet, (2) metapodal platelets, (1) paragenital platelet, and lyrifissure *iv5*; 3, Tritosternum; 4, Tectum.



FIGURES 5–8. *Gaeolaelaps gillespiei* **n. sp.**, female. 5, Subcapitulum and trochanter, femur and genu of palp; 6, Palp tarsal claw; 7, Chelicera, antiaxial view; 8, Left leg II, antero-lateral view.



FIGURES 9–11. *Gaeolaelaps gillespiei* **n. sp.** 9, Female, right leg IV, dorsal view; 10, Male, holoventral and peritrematal shields; 11, Male, chelicera, spermatodactyl, and variation in teeth on fixed digit, antiaxial view.

Legs (Figs 8–9). Excluding ambulacra, lengths of leg I 543–619, leg II 413–465, leg III 398–443, leg IV 570–628. Tarsus I with ambulacrum (28–38, including claws and pulvillus, excluding stalk) on short stalk (8–12); ambulacra II–III (41–51), IV (46–54); claws I–IV well developed. Lengths of femora I 113–128, II 66–85, III 74–91, IV 112–142; genua I 81–87, II 71–84, III 44–54, IV 68–74; tibiae I 94–103, II 65–70, III 47–50, IV 73–80; tarsi I 137–150, II–III 109–123, IV 162–182. Setation of leg segments I–IV normal for Laelapidae: coxae 2-2-2-1; trochanters 6-5-5-5, seta *al* on trochanter II and dorsal seta on trochanter IV thickened; femora 13-11-6-6, or I (2–2/1, 3/3–2) (as *al–ad*/*av, pd*/*pv–pl*), II (2–3/1, 2/2–1), III (1–2/1, 1/0–1), IV (1–2/1, 1/0–1), seta *av2* on femur II spine-like, seta *al2* tiny, thickened, seta *pd* on femur III slightly thickened, and seta *pd* on femur IV spine-like; genua 13-11-9-9, or I (2–3/2, 3/1–2), II (2–3/1, 2/1–2), III (2–2/1, 2/1–1), IV (2–2/1, 3/0–1), *pv1* and *pl1* absent on genu IV, ventral setae on genua III–IV slightly thickened; tibiae 13-10-8-10, or I (2–3/2, 3/1–2), II (2–2/1, 2/1–2), III (2–1/1, 2/1–1), IV (2–1/1, 3/1–2), ventral setae on tibiae II–IV thickened, especially on tibia IV; tarsi II–IV 18-18-18, with *ad1–pd1* as very fine, apical processes, 0.7–0.9 × the length of the pretarsi, all setae on telotarsi II–III thick and/or spine-like, some with fine, tapering tip, except setae *pd2*, *al2*, and *pl2* on tarsus II slender, and setae *al2* and *pl2* on tarsus III only slightly thickened; many setae on telotarsus IV spine-like, especially *pl2* and *pv2* which have blunter tips, setae *pd2* (98–117) and *al2* (77–88) slender and elongate (Figs 8–9). Other leg setae simple and slender. Tarsus I with numerous poorly tapered and apparently hollow (sensory) setae dorsodistally of various lengths (13–55).

Male. *Dorsal idiosoma*. Dorsal shield (519–555 long × 271–305 wide), similar in ornamentation and setation to female except setae 71–91% length of same setae in female. Peritrematal shield fused to dorsal shield at the level of setae *s1–2*.

Ventral idiosoma (Fig. 10). Holoventral shield (414–453 long × 209–235 wide) reticulated throughout, bearing long, slender setae *st1–5* (33–47), *JV1–3, ZV1–2* (31–44), para-anal (25–31) and post-anal (33–37) setae. Weakly sclerotized area anterior to ventral shield as in female. Metapodal platelet free (Fig. 10, right) or fused to ventral shield (Fig. 10, left). Soft cuticle with *JV4* (28–36), *JV5* (39–44) and *ZV3–4* (23–32) and one pair of submarginal setae.

Gnathosoma. As in female except setae about 20% shorter with *h1* (32–37), *h2* (22–25), *h3* (41–46), *pc* (31–34), palps (120–128), corniculi (40–44); chelicerae (Fig. 11) with fixed digit (26–29) bearing an offset large tooth near apex with a row of (also offset) 2–3 minute teeth, followed by 3–6 minute teeth distal to setiform pilus dentilis, and 5–8 teeth of irregular size proximal to pilus dentilis; movable digit (43–47) with one tooth; spermatodactyl relatively long (from base of digit: 61–66; from articulation with digit, at around level of the tooth: 28–33), bending downward from the digit near apex with a ~45° angle, to a tapered tip.

Legs. As in female, except leg segments approximately 12–20% and ambulacra 11–26% shorter than in female.

Remarks. Because of the unpaired median opisthonotal setae between the *J* series, this species could be placed in the *schusteri* species group of Karg (1979). However, it appears more closely related to *G. aculeifer* and relatives (e.g. *G. neoaculeifer*, *G. oreithyiae*) because of the spine-like setae on the legs, fixed digit with serrations posterior to pilus dentilus, and numerous deutosternal denticles per row. Unpaired median setae between *J* setae occur sporadically in several laelapid genera and vary among individuals of some species; hence, they may have little taxonomic value beyond the species level among hypoaspidines (Faraji & Halliday 2009).

The new species can be readily distinguished from *G. aculeifer* by its longer dorsal setae, mostly in the opisthonotal region (*G. aculeifer* has short opisthonotal setae), and by the two unpaired median setae between *J2–4*. It also differs from *G. aculeifer* by the following characters: dorsal setae smoothly tapering (some setae in *G. aculeifer* are sword-shaped, i.e. they have nearly parallel sides and taper mostly near tip, making them look thicker), dorsal shield parallel-sided from setae *r3* to *S2* (slowly tapering from *r3–4* in *G. aculeifer*), distance between *j6* setae about 2 × distance between *j5* setae (about equal in *G. aculeifer*), seta *Z4* anteromediad *S4* (*Z4* is posterior to *S4* in *G. aculeifer*); sternal shield with a smaller ratio length/width (1.3–1.4) (1.5–1.9 in *G. aculeifer*); seta *al1* on palpgenu with trifurcate tip (bluntly rounded in *G. aculeifer*);

hypostomal seta *h3* posterior to *h2* (*h3* level with or slightly anterior to *h2* in *G. aculeifer*); anteriormost (first) deutosternal row is nearly straight and is as broad or narrower than the two following rows (first row is the broadest, and is rounded or angled medially in *G. aculeifer*); corniculi shorter, extending slightly beyond palptrochanter (reaching middle of palpfemur in *G. aculeifer*); internal malae forming a single, median projection (2–3 additional lateral, fimbriate projections in *G. aculeifer*); movable digit shorter (64–67 in female) (83–98 in *G. aculeifer*), despite body size (dorsal shield length 600–672) subequal with *G. aculeifer* (620–740); spermatodactyl longer relative to the tip of movable digit, bending downward from digit near apex at a ~45° angle, and tapering to an acute tip (smoothly curved towards digit in *G. aculeifer*, and tip more blunt); thickened setae on legs II–IV in *G. aculeifer* are generally thinner and more acuminate in *G. gillespiei*, and consistent differences are as follows: genu and tibia II with *av1* simple (spine-like in *G. aculeifer*), tibia II with *pv1* barely thickened (spur-like in *G. aculeifer*), tarsus II with *ad2*, *al1*, *pl1*, *av1–2* and *pv1–2* spine-like (spur-like in *G. aculeifer*), genu III with *pv1* barely thickened (spine-like in *G. aculeifer*), tarsus III with *al3* and *pl3* slightly thickened (spine-like and spur-like in *G. aculeifer*, respectively), femur IV with *ad2* simple (spine-like in *G. aculeifer*), tibia IV with *pl1* simple (spine-like in *G. aculeifer*), tarsus IV with *pd2* relatively thin, elongate (98–117) (shorter 80–96 and spine-like in *G. aculeifer*); leg setae of *G. gillespiei* that are not modified are smoothly tapering to a fine tip, whereas many leg setae of *G. aculeifer*, especially on femora, genua, tibiae and basitarsi III–IV, are sword-shaped; legs of *G. aculeifer* tend to be thicker and longer relative to body size, especially leg IV, which is 1.08–1.22 × the length of the dorsal shield (0.91–0.97 × in *G. gillespiei*). Also, *G. aculeifer* has an extra pair of gland pores postero-mediad setae *z6* (absent in *G. gillespiei*).

The same or additional characters distinguish *G. gillespiei* from other species of *Gaeolaelaps* or '*Hypoaspis*' (s. lat.). Species with long dorsal setae and unpaired median setae (*Jx*) such as *G. singuloides* (Gu & Duan 1993), *H. spiculifer* Berlese (*sensu* Ryke 1963), and *G. mohrii* (Ishikawa 1982) appear similar to the new species but differ from it at least by their fewer teeth on the cheliceral fixed digit, the shape of sternal and epigynal shields (*mohrii*), different spines on leg II (*singuloides*), and by seta *st1* on the presternal area (*spiculifer*). It could also be initially confused with *H. lubrica* Voigts & Oudemans (1904) and *H. giffordi* Evans & Till (1966), but clearly differs from them by its serrated tectum (smooth in *H. lubrica* and *H. giffordi*), deutosternal groove with 11–34 denticles per row (7–10 in *H. lubrica* and 3–10 in *H. giffordi*), one ventral seta (*av*) on genu IV (*pv* also present in *H. lubrica*), fixed digit with 7–10 teeth (three teeth in *H. lubrica* and *H. giffordi*), a smaller epigynal shield (more extensive in *H. lubrica* and *H. giffordi*, almost reaching anal shield), and fewer *Jx* setae on the dorsal shield (at least four *Jx* in *H. lubrica* and *H. giffordi*) (Evans & Till 1966).

This species is named in honour of David Gillespie (Agriculture & Agri-Food Canada) who collected the species and encouraged its use as a predator against fungus gnats and thrips (Gillespie & Quiring 1990). Because *G. gillespiei* was collected from a substrate with components that may have several sources, it is unclear whether the mite is native to North American soil or originates from overseas.

Discussion

Defining *Gaeolaelaps* and other hypoaspidine groups is made difficult by the apparent lack of apomorphies and a high level of potential homoplasy. For instance, Karg (1979) based his division of *Hypoaspis* into subgenera on few characters, primarily the form of the tectum margin (mainly serrate vs. smooth), the number of denticles on deutosternal rows, the size of the epigynal shield and the number of setae captured by it. Unfortunately, the phylogenetic importance of these characters is often unclear beyond very closely related species. Otherwise, Karg seems to largely ignore the leg chaetotaxy despite its apparent usefulness in defining some taxa (Evans & Till 1966; Hunter & Husband 1973; Krantz 1998). Convergent evolution of morphological characters due to ecological adaptations may also complicate hypoaspidine taxonomy. For instance, most putative *Gaeolaelaps* species described to date were collected from soil-litter habitats, whereas several were collected from the nests of vertebrates, and others from arthropods or their nests, including ants,

cerambycid and passalid beetles, cockroaches, millipedes, crickets, mygalomorph spiders, and termites (Hyatt 1964; Samšiňák 1964; Hirschmann *et al*. 1969; Hunter & Yeh 1969; Rosario 1981; Arutunian 1993; Gu & Duan 1993; Strong & Halliday 1994; Strong 1995; Faraji & Halliday 2009). Among those arthropod associates, some depart morphologically from the usual type of *Gaeolaelaps* — and therefore may or may not belong to this group, but are provisionally included here — in having broader dorsal shields (see *Note* 1 in description of the genus *Gaeolaelaps*), reduced dorsal setation (*Note* 3), sternal shields broader than long (*Note* 11), a pair of sclerotized presternal platelets (*Note* 6) and different leg chaetotaxy (*Note* 34). Some of these character states occur in other arthropod-associated laelapids (Costa 1971; Hunter & Husband 1973; Ishikawa 1986) and may reflect convergent adaptations to a symbiotic life-style. Also, some podonotal setae (e.g. *s4*) are inserted more laterally on the shield in some of these species (e.g. *G. circularis*, *disjuncta*, *ruggi*) as in members of *Hypoaspis* sensu stricto, which are associated mostly with dynastine scarabs (Hyatt 1964; Hunter & Yeh 1969; Costa 1971; Rosario 1981; Strong & Halliday 1994). Other unusual character states for *Gaeolaelaps* (characterizing species collected from either litter, vertebrate nests, or arthropods) include a sternal shield with broad anterolateral arms (endopodal extensions, *Note* 7), exopodals connected to peritrematal shields (*Note* 19), a tectum with an acute median projection (*Note* 24), and an epigynal shield more inflated posteriorly (*Notes* 15–16). Before these species are firmly placed into *Gaeolaelaps*, the genus will have to be properly revised, following the examination of the type specimens of most of the ~75 species and the study of more *Gaeolaelaps* species from outside the Palaearctic region in concert with other related hypoaspidine groups. This was outside the scope of the present study, but the data provided here may encourage such an undertaking.

Another impediment to hypoaspidine taxonomy and in assessing the placement of species is the doubtful reliability and incompleteness of many previous species descriptions and illustrations. For example, several potentially diagnostic characters are often ignored in descriptions, notably the setation of legs, the deutosternal denticles, internal malae, details of the peritrematal shield, details of the spermathecal system (although not often visible), the pilus dentilis of the chelicerae, and the number and shape of pore-like structures on the dorsum and venter of the idiosoma. Characters of the palps are also often neglected, including the palp lengths, the anterolateral setae of the femur and genu, and the number and shape of the tines of the palp tarsal claw. Even dorsal setation and ornamentation are sometimes not carefully described. These characters vary among genera and species, and better inclusions of them in species descriptions will facilitate identifications and provide data for more robust classifications.

Reliable taxonomic information is also a pre-requisite for safe and successful biological control (Huber *et al*. 2001). Inaccurate identifications during research on the species biology, or before releases in the field, can lead to poor pest control due to the use of the wrong species, which may have different host, prey, and habitat preferences or requirements, as well as lower voracity or lower reproductive capacity. It could also disastrously result in the introduction of a predator or parasitoïd that could spread geographically and damage non-target, native species. Detailed morphological species descriptions, including diagnostic characters, are therefore imperative, especially because many species are distinguished by a mere few, minor morphological differences. Such almost cryptic species occur in economically important groups such as phytoseiids (e.g. *Neoseiulus*, Beard 1999) and laelapids. For example, *Stratiolaelaps scimitus* and *S. miles* differ by a few, easily overlooked characters (Walter & Campbell 2003). Although *S. miles* has been reported from North America for decades, recent routine identifications suggest that *S. scimitus* is the only species used as biocontrol agent in North America (Beaulieu personal observations; Walter & Campbell 2003).

Acknowledgements

I thank Brian Spencer and Don Elliott (Applied Bionomics Ltd.) for providing specimens of *Gaeolaelaps gillespiei* **n. sp.**, Matthew Shaw (Queensland Museum, Australia) and Evert Lindquist (Agriculture & Agri-Food Canada) for valuable comments on a previous version of this manuscript, Gabriel Gregorich and Ashley

Robertson for their help in illustrating the new mite, and Valerie Behan-Pelletier, Scott Brooks, Marisa Castagnoli, Dave Gillespie, Vasily Grebennikov, Bruce Halliday, Alessandro Minelli, Aleš Smetana, Ian Smith, Neville Winchester and King Wan Wu for their helpful advice and assistance.

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