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A new species of invasive gall wasp (Hymenoptera: Eulophidae: Tetrastichinae) on blue gum (*Eucalyptus globulus*) in California

JOHN LA SALLE[1], GEVORK ARAKELIAN[2], ROSSER W. GARRISON[3], & MICHAEL W. GATES[4]

[1]*CSIRO Entomology, GPO Box 1700, Canberra, ACT 2601, Australia. E-mail: john.lasalle@csiro.au*

[2]*Los Angeles County Department of Agricultural Commissioner/Weights & Measures, 11012 Garfield Ave., South Gate, CA 90280, USA. E-mail: GArakelian@acwm.lacounty.gov*

[3]*Plant Pest Diagnostics, California Department of Food & Agriculture, 3294 Meadowview Road, Sacramento, CA 95832-1448, USA. E-mail: rgarrison@cdfa.ca.gov*

[4]*Systematic Entomology Laboratory, USDA, ARS, PSI, c/o National Museum of Natural History, Washington, D. C. 20013-7012, USA. E-mail: michael.gates@ars.usda.gov*

Abstract

The blue gum gall wasp, *Selitrichodes globulus* La Salle & Gates, **n. sp.** (Hymenoptera: Eulophidae: Tetrastichinae), is described as an invasive gall inducer on blue gum, *Eucalyptus globulus* Labill. (Myrtaceae), in California.

Key words: Hymenoptera, Eulophidae, invasive species, *Selitrichodes*, *Eucalyptus*, Myrtaceae

Introduction

The blue gum (Tasmanian blue gum, southern blue gum), *Eucalyptus globulus* Labill., (Myrtaceae) is one of the most widely cultivated of Australia's native trees and one of the most extensively planted eucalyptus in the world (Doughy 2000, Eldridge *et al.* 1993). It can be found in parks and gardens in many parts of Australia, and is widely planted in California as an ornamental or for its value as a windbreak. Blue gum is widely planted commercially in many areas of the world (e.g. Bolivia, Chile, China, Colombia, Ethiopia, India, Peru, Spain) for its value in fuelwood, pulpwood and a primary source of medicinal eucalyptus oil (Eldridge *et al.* 1993, Doughy 2000).

In November 2008, a new species of insect, described here as *Selitrichodes globulus* La Salle & Gates, was discovered forming galls on blue gum in Los Angeles County, California. Based on the evidence at hand, this invasive species is almost certainly Australian in origin, although it is yet to be found in its native range. It joins a growing list of invasive species which have the potential to damage eucalyptus around the world.

The presence of *S. globulus* in California poses an interesting question in terms of biological control and conservation biology. Blue gum was introduced into California in the mid 1800's (Doughy 2000), where it is now naturalized and spreading into areas of native vegetation. For this reason, it has been placed on the California Exotic Pest Plant Council List as a potentially harmful invasive species (California Invasive Plant Council 2006). The question must be asked as to whether *S. globulus* is a potential biological control agent against *E. globulus* invasions (at least in California), or whether a search should be made for natural enemies of *S. globulus* in Australia to help protect the blue gum industry in other areas of the world if this invasive species spreads.

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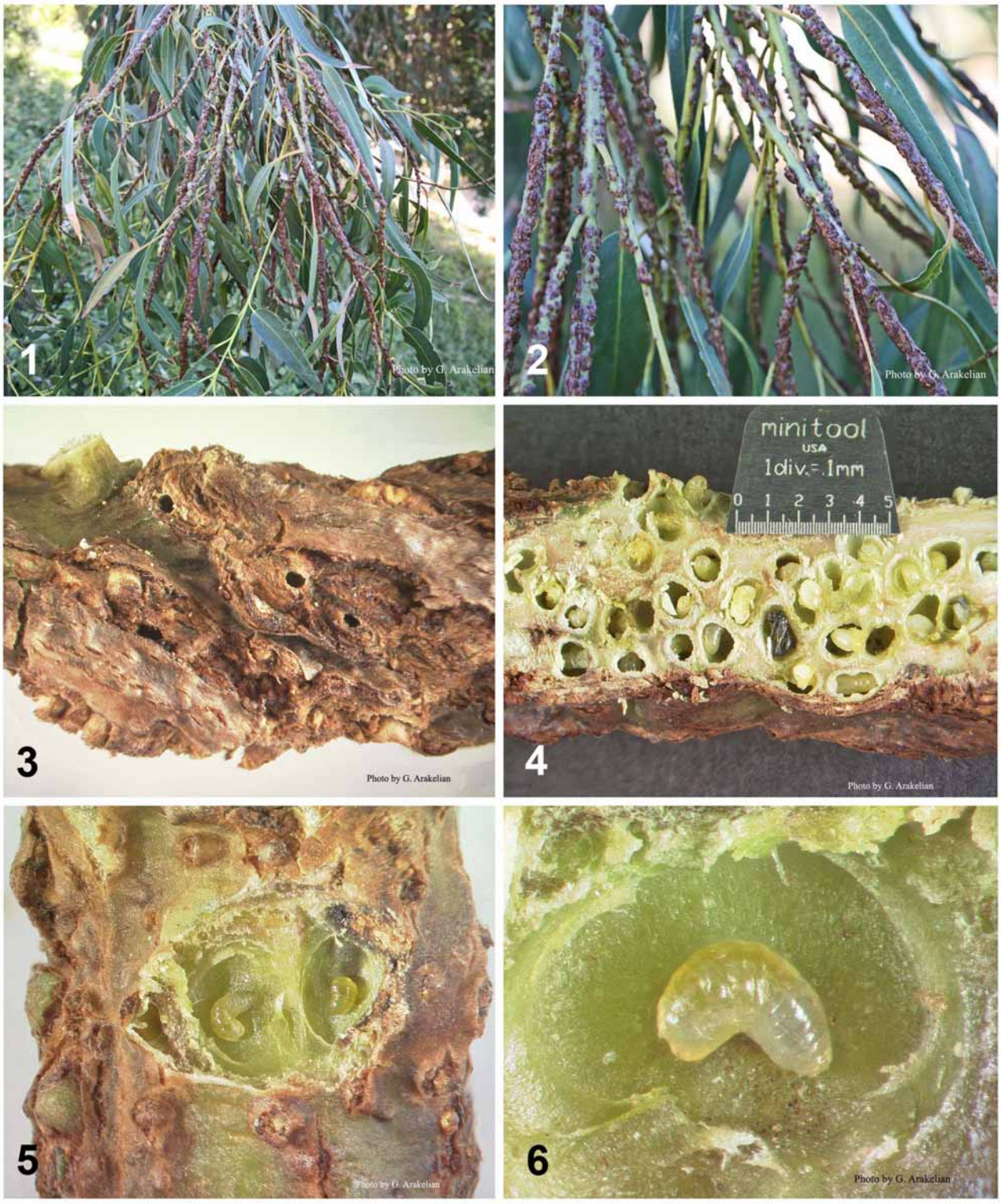


FIGURES 1–6. *Selitrichodes globulus*. 1–2, Gall damage on *Eucalyptus globulus*. 3, Galls showing adult emergence holes. 4, Dissected section of stem showing galls containing larvae and pupae. 5–6, Larvae within dissected galls.

The *Selitrichodes globulus* outbreak in California

On November 5, 2008, the Entomology Lab of the Los Angeles County Department of Agricultural Commissioner/ Weights & Measures received a single blue gum eucalyptus branch from a homeowner

(Monrovia, Los Angeles County) with a note stating "infested tree in the backyard, cancerous growth on branches/twigs". Examination revealed multiple galls on branches containing live larvae of Eulophidae wasps. Since this was an unusual damage caused by an apparently new pest on eucalyptus for the US, an 'official' sample (per protocol) was collected at the property on November 6. The infested blue gum eucalyptus tree was in poor shape with heavy, hanging branches and twigs covered with galls (Figs 1–2). Galls consisted of multiple chambers containing larvae and pupae, and could occur almost continually along branches; there were up to as many as 20 specimens per 5 mm of branch. At the same time some leaves had isolated galls on them. Several smaller branches and twigs were entirely dry with 10–20 mm cracks along galls that could possibly promote fungal infection and decay spreading to larger branches.

Cut eucalyptus branches were stored in plastic bags punctured with #4 insect pins (to prevent adult escape and to keep material from fast drying). From November 8–10, these bags were placed in the lower (fruit/vegetable) section of a refrigerator to stop fungal growth and to possibly stimulate the emergence of adults. Adults started emerging on November 12 and were observed emerging until December 2. About 120–130 adults were reared along with two *Erythmelus gracilis* (Howard) (Mymaridae), which are egg parasitoids and were probably present as contaminants brought in on the twigs. There were high larval and pupal densities present in galls, with adults emerging at the same time.

A second infestation was subsequently found at the Los Angeles County Arboretum and Botanical Gardens located in Arcadia (by J.Turney, Los Angeles Co. Dept. of Agricultural Commissioner/Weights & Measures). As yet no adults have emerged from these samples; the larvae were submitted to CDFA to confirm the new location.

Subsequent rearings recovered additional species of wasps associated with these galls. The most interesting was the rearing of five males of an *Ophelimus* species (Eulophidae: Ophelimini). *Ophelimus* is an unusual Australian genus which contains over 50 described species and many more undescribed. Species have been assumed to always be gall inducers (Bouček 1988), and this is probably the largest group of gall inducing eulophids on *Eucalyptus*. However actual biology is known for relatively few species, and there is some indication that at least some species are not true gall inducers but are associated with galls in other ways, perhaps as inquilines or even parasitoids (La Salle 2005).

The presence of *Ophelimus* sp. questions the status of the two wasp species associated with blue gum galls in California. *Selitrichodes* species appear to be mainly parasitoids of gall inducing wasps (Kim *et al.* 2008), and *Ophelimus* are predominantly gall inducers. In this case, it appears that these roles are reversed. Further studies to clarify the exact roles of all the species associated with these galls will be of interest. However, it should be pointed out that when this paper was submitted, samples of gall infested *E. globulus* had produced almost 600 *S. globulus*, and less than 20 male *Ophelimus*. Under these circumstances, it is difficult to imagine *S. globulus* as being anything except the primary gall inducer.

Invasive eulophid gall inducers

Several species of Eulophidae are known to induce galls, and these have been reviewed by La Salle (2005). There is a growing list of eulophid gall inducers which have become invasive within the last two decades. Species which induce galls on eucalypts include: *Epichrysocharis burwelli* Schauff (in Schauff & Garrison 2000), *Ophelimus maskelli* (Ashmead) (Protasov *et al.* 2007b), *Leptocybe invasa* Fisher & La Salle (Mendel *et al.* 2004), as well as *Moona spermophaga* Kim & La Salle and *Leprosa milga* Kim & La Salle, both of which induce galls in eucalypt seed capsules (Kim *et al.* 2005, Kim & La Salle 2008). Several of these species have expanded their range substantially since first being noticed as invasives, and a range expansion for *S. globulus* would not be unexpected.

It has been recognized that eulophid gall inducers (and their associated parasitoids) represent a major radiation in Australia (Austin *et al.* 2004). Although the driving force is not exactly clear , several species of Australian gall inducing eulophids have become invasive within the last decade. With potentially hundreds of

species of eulophid gall inducers on eucalypts, one could expect more of these species to become invasive in the future.

Gall inducing Eulophidae species are not restricted to eucalypts. *Oncastichus goughi* Headrick & La Salle induces galls on Geraldton wax, *Chamelaucium uncinatum* Schauer (Myrtaceae). This species was reported from California in the early 1990's (Headrick *et al.* 1995) and has subsequently spread to Israel and South America (Gates & Schauff 2005).

One extremely damaging gall-inducing eulophid is the Erythrina gall wasp, *Quadrastichus erythrinae* Kim (Kim *et al.* 2004). Originally from eastern Africa, this pest has spread extremely rapidly and is now recorded from Mauritius, La Réunion, Singapore, Hawaii, Taiwan, Hong Kong, China, India, Thailand, American Samoa, Guam, Okinawa, and Florida (USA). It induces galls on shoots, twigs, leaves and petioles of several species of *Erythrina*, and can cause extensive damage, defoliation, or even death of trees (Yang *et al.* 2004; Heu *et al*., 2006; Gates & Delvare 2008). Again, there seems to be a significant complex of *Quadrastichus* species inducing galls on *Erythrina* in Africa (Prinsloo & Kelly 2009), so additional species of invasive gall inducers on *Erythrina* would not be unexpected.

Biological control opportunities

Biological control attempts are currently underway for two species of invasive eulophid gall inducers on *Eucalyptus*. There is every indication that successful control of the eucalyptus gall wasp *Ophelimus maskelli* (Ashmead) (Eulophidae: Ophelimini) is underway in the Mediterranean Basin due largely to the introduction of *Closterocerus chamaeleon* (Girault) (Eulophidae: Entedoninae) (Rizzo *et al.* 2006; Mendel *et al.* 2007; Protasov *et al.* 2007a, b; De Marzo 2007). Two other parasitoids of *O. maskelli*, *Stethynium ophelimi* Huber and *S. breviovipositor* Huber (Mymaridae) were also released in Israel, where at least one of them may complement *C. chamaeleon* in controlling *O. maskelli* (Huber et al 2006; Z. Mendel pers. comm.). Additionally, two species of parasitoids have recently been released and established in Israel in an attempt at biological control of another invasive gall former, *Leptocybe invasa* Fisher & LaSalle (Kim et al. 2008). It is still too early to tell if this will result in successful control.

Biological control attempts have also begun against *Quadrastichus erythrinae* in Hawaii. Specimens of the recently described *Eurytoma erythrinae* Gates & Delvare (Gates & Delvare 2008) were released Oahu in November 2008. Wasps were observed probing and ovipositing in galls within 15 minutes of release (B. Kumashiro, pers.comm.)

Material and methods

Terminology follows Gibson (1997) and Graham (1987). OOL, ocellar–ocular distance; POL, post-ocellar distance; CC, costal cell; SMV, submarginal vein; MV, marginal vein; STV, stigmal vein; PMV, postmarginal vein; F1–3, funicular segments 1–3.

Acronyms used are as follows. ANIC, Australian National Insect Collection, CSIRO Entomology, Canberra, Australia; BMNH, Natural History Museum, London, UK; CDFA, California Department of Food and Agriculture, Sacramento, California, USA; LACM, Los Angeles County Museum of Natural History, Los Angeles, California, USA; QMB, Queensland Museum, Brisbane, Australia; USNM, National Museum of Natural History, Washington, D.C., USA.

Pictures of infested trees (Figs 1–2) were taken by GA using a Canon EOS 5D digital camera. Images using closeups/macro photography of galls and their occupants (Figs 3-6) and the *S. globulus* habitus shot (Fig. 7) were taken by GA using an Auto-Montage Pro digital imaging program connected to a JVC KY-F75U digital camera on a Zeiss Stemi SV 11 stereo microscope. SEM pictures (Figs 8-10) were taken by Nicole Fisher using Zeiss Evo Series Scanning Electron Microscope using a Carl Zeiss SmartSEM software. Wing

and antenna pictures (Figs 11-12) were taken by Nicole Fisher using Leica Application Suite version 3.3.0 digital imaging software, with a Leica DFC500 digital camera attached to a Leica M205C microscope.

Genus *Selitrichodes* Girault

Selitrichodes was treated by Kim et al. (2008), who removed it from synonymy with *Aprostocetus* Westwood, provided a generic diagnosis, recognized 12 valid species, and pointed out that this genus would probably contain many more species. Although exact biology and host plants are unknown for most species, most of them appear to be associated with galls in some manner. Detailed biology is known only for *S. kryceri*, which was recently described as a parasitoid of the gall inducing *Leptocybe invasa* (Kim et al. 2008). Another species of *Selitrichodes* has recently been found in Florida, where it is a parasitoid of *Leptocybe invasa*. It is not clear how it arrived in Florida. It is interesting that this group now contains species that are both gall inducers and parasitoids of gall inducers. La Salle (2005) pointed out that, at least within the Chalcidoidea, several groups that display a general relationship with galls can contain species that are parasitoids of gall inducers, inquilines, or gall inducers.

Diagnosis. A key to North American Tetrastichinae genera was provided by La Salle (1994), and keys to all North American Eulophidae genera were supplied by Schauff *et al*. (1997). In these keys *Selitrichodes* would key to *Baryscapus* or *Aprostocetus*, but can be distinguished by the diagnostic characters given in Kim *et al.* (2008), and which are repeated below.

SMV usually with 2 or 1 dorsal setae. PMV distinct, usually about 0.4–0.5 the length of STV. Propodeum without a raised lobe of callus which partially overhangs outer rim of spiracle. Cercal setae short and subequal in length. Mesosternum anterior to trochantinal lobe convex and without a precoxal suture. Malar sulcus generally curved, and gena may be somewhat swollen. All funicular segments subquadrate or slightly transverse. Postmarginal vein distinctly developed, although shorter than stigmal vein. Non-metallic (mainly yellow with black markings). Males (of at least some species) with 3 funicular segments.

Selitrichodes species can be distinguished from *Baryscapus* in that *Baryscapus* species are all predominantly metallic in coloration, and *Selitrichodes* species are non-metallic. *Selitrichodes* can be separated from *Aprostocetus* in that *Selitrichodes* species have 1 or 2 setae on the SMV, and the bulk of *Aprostocetus* species have 3 or more setae on the SMV; the few *Aprostocetus* species with only 2 setae on the SMV have metallic coloration.

The following characters in combination serve to distinguish *S. globulus* from other described species of *Selitrichodes*: Color uniformly dark brown, without extensive areas of yellow markings; POL about 3 times as long as OOL; speculum small and open posteriorly; cubital setal line approaching but not reaching basal line; speculum may have a few small setae on underside of wing; antenna with F1 longer than wide; F3 subquadrate to wider than long.

Selitrichodes globulus La Salle & Gates, sp. nov.

(Figs 7–12)

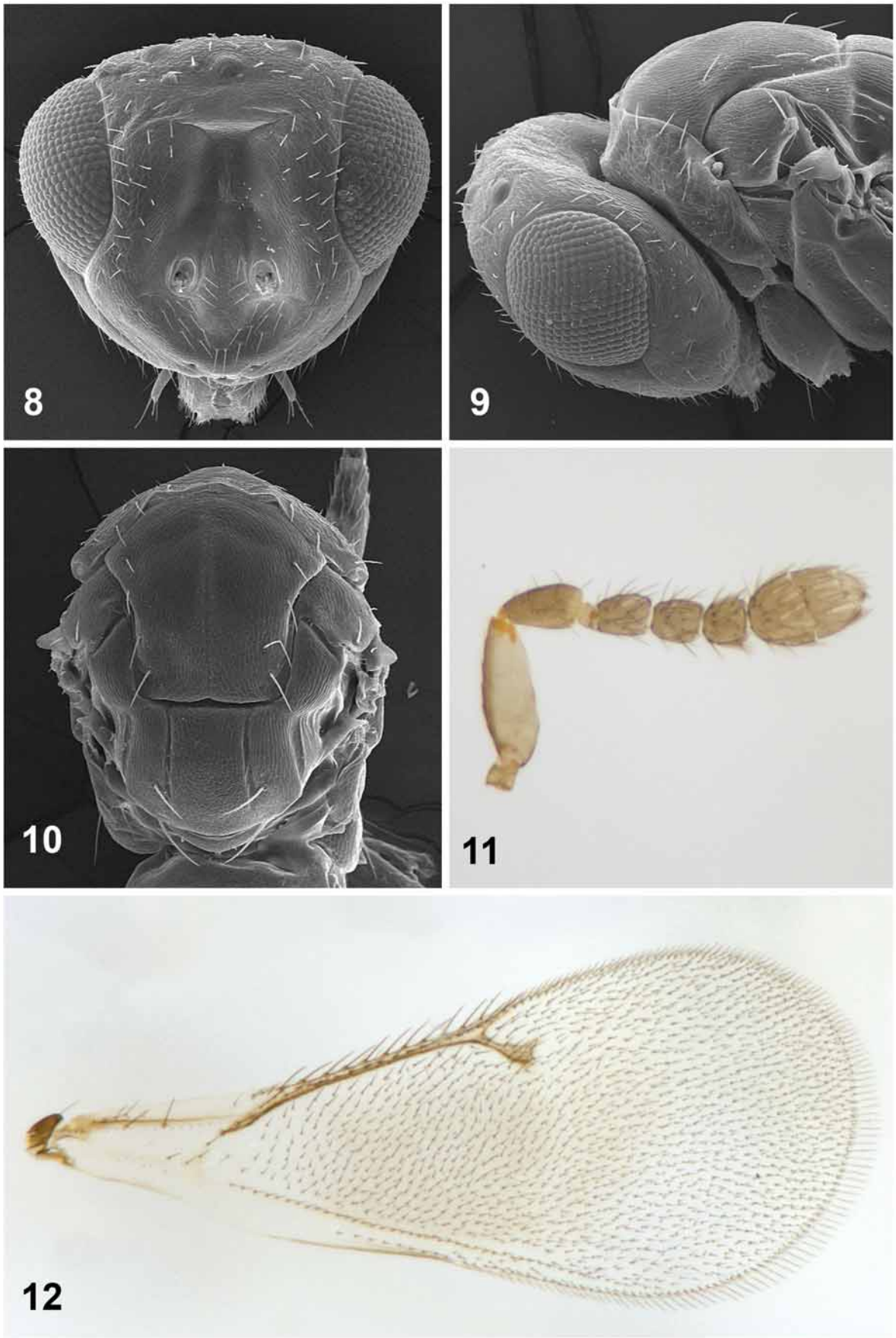
***Female* (Figs 7–12).** Length 0.95–1.5 mm. Head generally dark brown to black, with following areas light brown to yellow: bordering eye margin, both anteriorly and posteriorly, extending from just above ventral eye margin to vertex (although weaker on vertex); transverse stripe covering frontal suture; scrobal cavity, and sometimes longitudinal stripe bordering lateral margin of supraclypeal area. These color patterns variable, and may be very difficult to see in darker specimens. In teneral specimens, there can be more extensive lighter coloration, including entire vertex. Antenna with scape dark brown on dorsal margin; light brown to yellow ventrally; flagellum brown. Mesosoma dark brown to black; dorsellum light brown to yellow. Gaster brown. Coxae brown, may be lighter apically; trochanters light brown to yellow; femora dark brown, lighter apically; fore and middle tibiae light brown to yellow; hind tibia dark brown basally, light brown to yellow apically.

FIGURE 7. *Selitrichodes globulus* ♀. Habitus.

Head (Figs 8–9). Ocellar triangle without grooves; sometimes grooves can be seen only on a shrunken specimen. POL about 3 times as long as OOL. Frontal suture transverse, short, not connected medially and curving ventrally, well separated from eye margin, placed ventral to median ocellus, separated from median ocellus by 1.5–2.0 times its diameter. Scrobal area without distinct median carina; with a small transverse cracklike suture present about halfway between frontal suture and torulus. Torulus level with ventral margin of eye. A broad depression (supraclypeal area) below torulus extending to clypeus and with some pilosity. Gena swollen and with malar sulcus somewhat curved near mouth margin. Clypeal margin bidentate.

Antenna (Fig. 11) with 3 funicular segments and 2 anelli; first anellus longer than second and seemingly composed of two fused segments. First and second funicular segments slightly longer than wide, third slightly wider than long to subquadrate: length/width ratio of F1 1.4–1.7; F2 1.25–1.35; F3 0.95–1.0. Relative length of funicular segments to pedicel as follows: PDL: F1: F2: F3 = 1: 0.55–0.8: 0.55–0.8: 0.5–0.7. Clava 1.5–2.0 times longer than wide, wider than funicle, without distinct terminal spine; C3 very short and its end broad, not tapering apically. Scape slightly flattened.

Mesosoma (Fig. 10). Pronotum very short medially in dorsal view. Mid lobe of mesoscutum with very weak median line and with one row of 4–5 adnotaular setae on each side; some setae may form a partial second row. Mesosternum convex just in front of the trochantinal lobes and without precoxal suture. Scutellum with anterior pair of setae located behind middle. Dorsellum rounded posteriorly and slightly



FIGURES 8–12. *Selitrichodes globulus* ♀. 8, Head, frontal view. 9, Head, lateral view. 10, Mesosoma, dorsal. 11, Antenna. 12, Fore wing.

overhanging propodeum. Propodeum medially shorter than dorsellum in dorsal view; with median carina. Propodeal spiracle with entire rim exposed and separated from anterior margin of propodeum by less than its longest diameter. Paraspiracular carina absent. Callus with 2–3 setae.

Fore wing (Fig. 12) hyaline, with very faint infumated cloud posterior to venation. Submarginal vein usually with 2 dorsal setae. Costal cell asetose except for a line of ventral setae near apex. Relative length of wing veins to stigmal vein as follows: CC: MV: STV: PMV = 1.0–1.2: 1: 0.25–0.35: 0.1–0.15. PMV one-third to one-half length of stigmal vein. Speculum small and open posteriorly, cubital line of setae not extending to basal line; speculum may have one to a few small setae on underside of wing. Wing disk beyond speculum densely pilose.

Metasoma. Gaster distinctly longer (1.4–1.6 times) than mesosoma. Hypopygium reaching less than half length of gaster. Cercus with 3 longest setae subequal in length and slightly curved. Ovipositor sheath slightly protruding, very short in dorsal view.

Male. Length 0.85 mm. Body color pattern similar with female (although difficult to determine from a single, teneral specimen). Antenna with 3 anelli and only 3 funicular segments; F1 and F2 quadrate to slightly longer than wide; F3 wider than long. Each successive segment increasingly broader. Funicle and clava without compact subbasal whorls of long setae. Ventral plaque less than one-quarter length of scape, situated near apex of scape.

Type material. Holotype ♀: USA: California, Monrovia, 12.xi.2008, coll. G. Arakelian, ex galls on *Eucalyptus globulus*, emerged 20.xi.2008 (CDFA).

Paratypes. 50♀, 1♂ Same data as holotype (30♀,1♂ ANIC; 4♀ each: USNM, CDFA, QMB, LACM, BMNH)

Distribution. USA: California. Although this species has not yet been found in Australia, it is certainly Australian in origin.

Etymology. Named for the specific epithet of the host plant with which this wasp is associated.

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