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ERETMOCERUS DEBACHI N. SP. (HYMENOPTERA: APHELINIDAE), AN EFFECTIVE PARASITE OF *PARABEMISIA MYRICAE* (HOMOPTERA: ALEYRODIDAE)

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ABSTRACT

Eretmocerus debachi n. sp. is described, and the closely-related *E. longipes* Compere is redescribed and a lectotype is designated. Seasonal gynandromorphy and the importance of *E. debachi* in biological control are discussed.

KEY WORDS: biological control, whitefly, parasitic Hymenoptera, *Eretmocerus*.

The species of *Eretmocerus* Haldeman, 1850 (Hymenoptera : Aphelinidae) are only known to develop as primary ecto-endoparasites of whitefly (Homoptera : Aleyrodidae). Clausen (1932, 1958) first purposefully utilized *Eretmocerus* when he introduced *E. serius* Silvestri from Malaya into the West Indies, with spectacular results, against the citrus blackfly, *Aleurocanthus woglumi* Ashby, a severe pest of citrus. Today, this great success is considered one of the most outstanding cases in the more than 100-year history of applied biological control by natural enemies. Based on the effectiveness of *E. serius* and on Clausen's later statement that he had never seen a species of *Eretmocerus* that was not an effective parasite, Compere (1936), who revised the genus, concluded that the species of *Eretmocerus* are of economic interest.

The bayberry whitefly, *Parabemisia myricae* (Kuwana) (Homoptera : Aleyrodidae), an Asian species, invaded southern California, where it was discovered in 1979. An account of the biological control project that followed is presented by Rose and DeBach (1992). In summary, *P. myricae* proved to be a very damaging pest of California citrus, and its presence precipitated the use of various insecticides in groves where populations of many other pests had been satisfactorily regulated by natural enemies. Destruction of natural enemies led to pest population upsets, which compounded the damage levels. Several species of *Encarsia* Foerster and an undescribed *Eretmocerus* were discovered in Japan. These had been imported, cultured, colonized and established in California when an adventitious species of *Eretmocerus* was discovered attacking *P. myricae* in San Diego County, California in April 1982. Following both aided and natural dispersal, this *Eretmocerus* sp. proved to be the most effective parasite of *P. myricae* in southern California and later in Israel and Turkey. It is described below as a new species.

This species is named for our friend, colleague and mentor Paul DeBach, who has inspired many biological control researchers and practitioners throughout the world. We dedicate this paper to our friend and colleague, Eliyahu Swirski, who introduced *E. debachi* from California into Israel.

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Measurements in the following description were obtained from 11 female paratype specimens mounted in Hoyer's medium, utilizing a digitizing tablet and measurement programs provided by Marilyn Houck and Richard Strauss, University of Arizona at Tucson, and analyzed with PC-SAS; those presented in the text are derived from means. In all cases, except for the single male specimen of *Eretmocerus longipes* Compere, the values are approximate; qualifying terms such as "about" or "near" are not used in the text.

Abbreviations: USNM = United States National Museum of Natural History, Washington, DC; BMNH = Natural History Museum, London, UK; TAMU = Department of Entomology, Texas A & M University, College Station; HUAR = Department of Entomology, The Hebrew University, Faculty of Agriculture, Rehovot, Israel.

Eretmocerus debachi n. sp.

(Figs. 1–11)

Female (Fig. 1)

Light chrome yellow in life; eyes pale green, ocelli red; legs pale. Cleared, slide-mounted specimens colorless, except for head and eyes. Length: 0.86–0.90 mm (mean: 0.89). Eyes (Figs. 1, 2) finely setose. Mandibles small relative to large head, but well developed, with 2 denticles; maxillary palpi 1-segmented, labial palpi 1-segmented. Antennae (Figs. 2, 3) composed of radicle, scape, pedicel, 2 funicular segments and an unsegmented club. Radicle 4 times as long as wide; scape 4+ times as long as wide, twice as long as radicle, 0.6 length of club; pedicel 2.25 times as long as wide, 0.9 length of radicle, 0.4+ length of scape; funicle I right-triangular, nearly as long as wide; funicle II subquadrate, 1.4 times as wide as long; club clavate, apically rostrate (beaked), much narrower at base than apex, 4.3 (range 4.1–4.5) times as long as greatest width, 3.2 times as long as radicle, 1.6 times as long as scape, 3.5 times as long as pedicel, 1.5 times as long as middle tibia, bears 12–13 longitudinal sensilla.

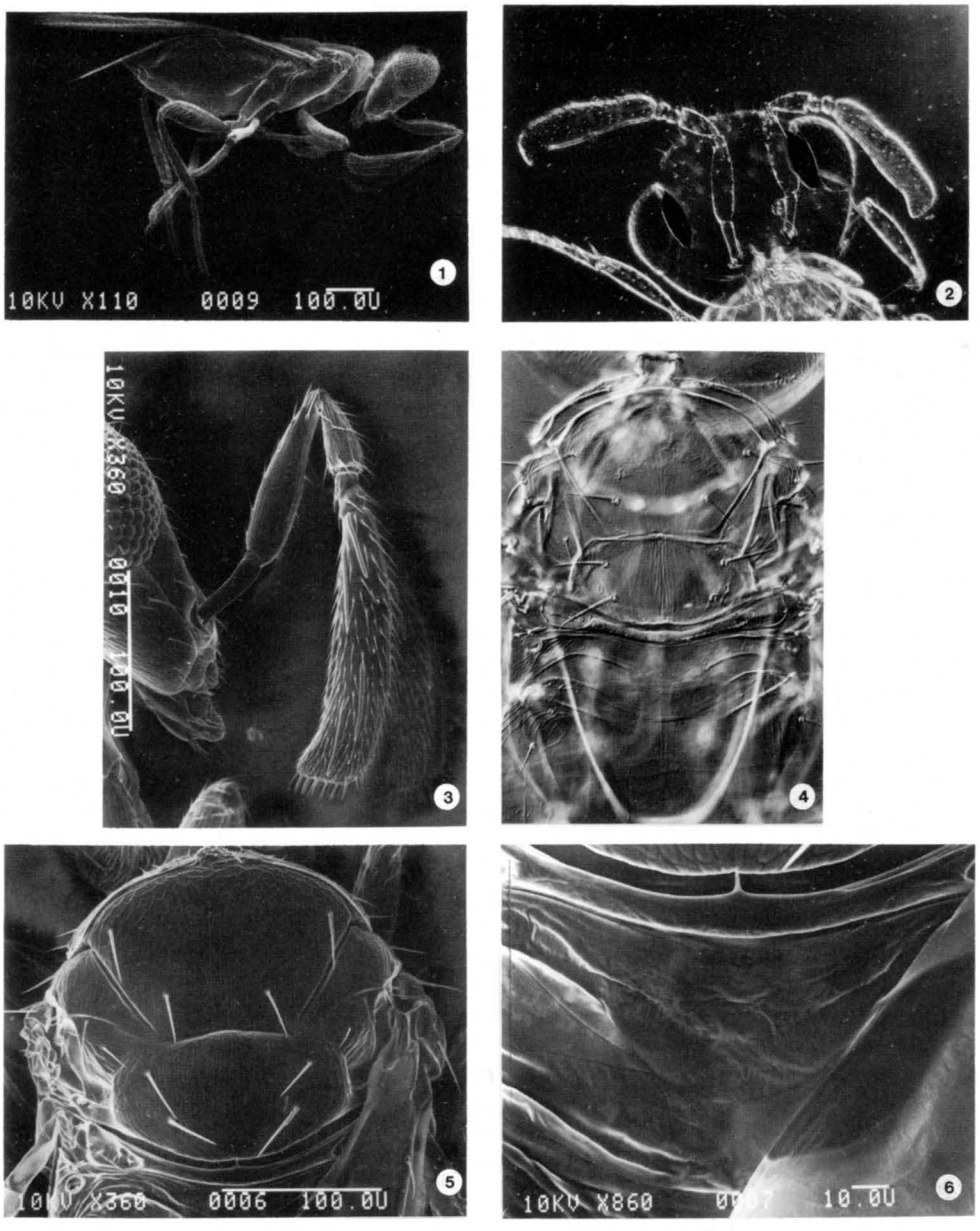
Setae on head, thorax and abdomen fine, pale, but readily visible under dissecting, phase contrast and Nomarski interference microscopy. Head substrigulate, vertex with 6 setae between eyes and 4–5 setae on margins of eyes; ocellar triangle nearly equilateral, with 9 setae; 8–9 setae at base of frons between antennal sockets. Pronotum with 2 setae on each distal corner. Mesoscutum (Figs. 4, 5) trapezoidal, 1.6 times as wide anteriorly as long, wider than scutellum anteriorly, narrower posteriorly, always with 4 setae, anteriorly reticulate, becoming longitudinally substrigulate medially, with fine reticulations continuing overall (except medium); each parapsis (Fig. 7) with 2 setae near antero-distal margin, alveolate/reticulate; each axilla with 1 median seta, faintly alveolate/reticulate; scutellum 1.9+ times as wide as long, with 4 setae, discoid sensilla laterad of and closer to posterior pair, alveolate/reticulate laterally, longitudinally substrigulate medially; propodeum (Figs. 4, 6) reticulate at lateral margins, 14+ times as wide as long at narrowest medial margins of central lobe, central lobe extends more than halfway over the second abdominal tergite; endophragma extends into fourth abdominal tergite.

Abdominal tergites smooth except tergite III which bears reticulations laterally; lateral margins of III–VII imbricate with stippling; tergites III–VII with paired setae as follows: 1, 1, 2, 2, 2, but this can vary; tergite VIII with 2 pairs of setae medially, syntergum with 4 dorsal setae. Cerci located laterally on anterior margin of syntergum, with 2 long and 1 short setae. Ventrally, mesosoma bears epicoxal pads beneath both fore and middle coxae, the fore pair are rounded, separate membranous pads bearing numerous minute spines, the pad under the middle coxae also bears minute spines but is narrow and can appear joined in the middle (Fig. 8). Ovipositor strong, slightly exerted, subequal in length to ovipositor sheaths, 2.6 times length of radicle, 1.3 times length of scape, 2.9 times length of pedicel, 0.8 length of both club and middle tibia.

Foreleg formula (length femur:tibia:tarsus) 1:0.8:1.1; tarsal formula (length tarsomeres 1:2:3:4) 1:0.6:0.5:0.5, fore-tibial spur 0.75 length of basitarsus; midleg formula 1:1.2:1.1–, tarsal formula

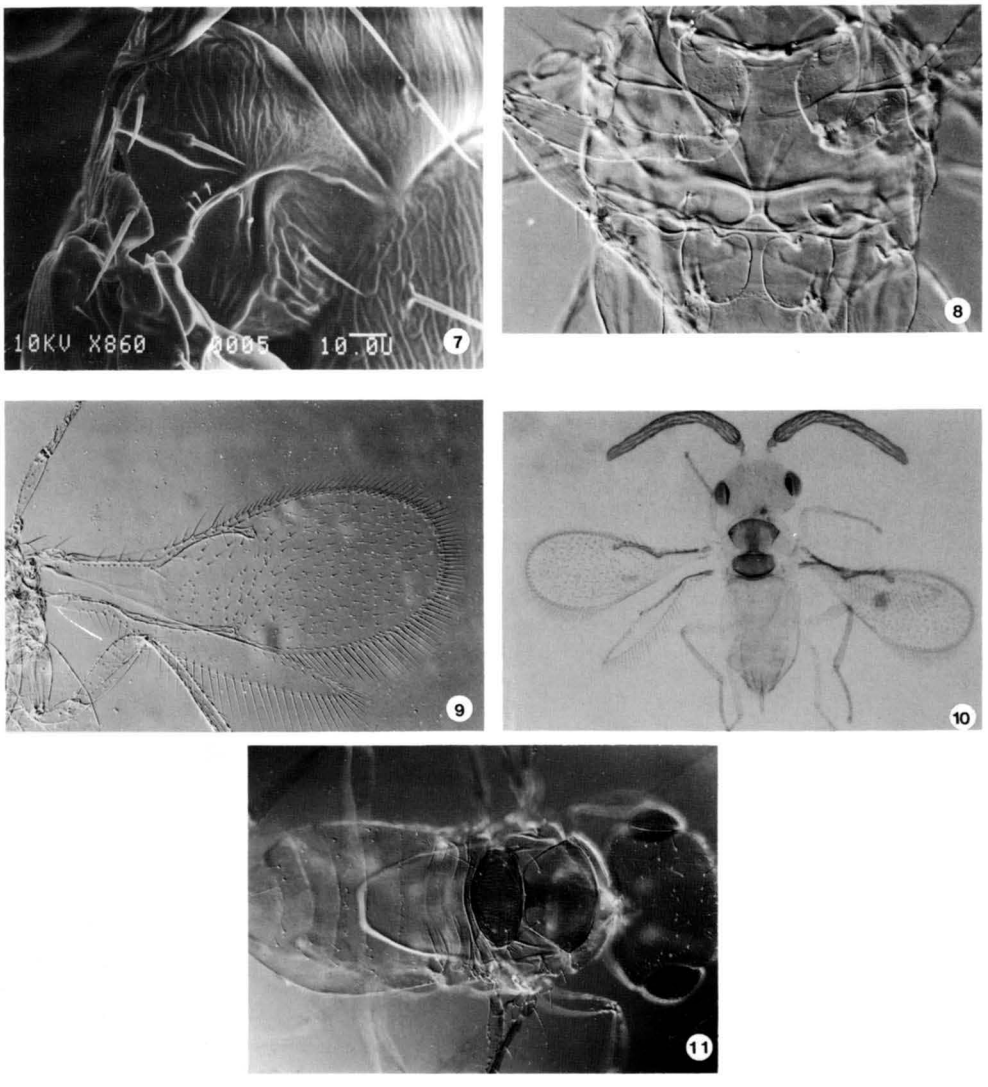
1:0.5+:0.5–:0.5–, mid-tibial spur 0.6 length of basitarsus; hindleg formula 1:1.3:1.1, tarsal formula 1:0.7:0.6:0.5, hind-tibial spur 0.5 length of basitarsus.

Forewing (Fig. 9) hyaline, almond-shaped, inflected at origin of marginal vein, 2.4 times as



Figs. 1–6. *Eretmocerus debachi*, ♀, n. sp. 1. Lateral view. SEM. 2. Head and antennae, ♀. 3. Antenna and mouthparts, ♀. SEM. 4. Mesosoma and metasoma, ♀. 5. Mesosoma, ♀. SEM. 6. Metanotum and central lobe of propodeum, ♀. SEM.

long as greatest width, longest anterior alary fringe 0.2+ width of disc, longest posterior alary fringe 0.4+ width of disc, base of wing bare, 2–3 (usually 2) setae in costal cell, 1–2 (usually 2) setae on its anterior margin at origin of marginal vein; submarginal vein bearing 4 larger setae; marginal vein bearing 3–5 (usually 3) long setae along anterior edge; 1 long seta on neck of stigmal vein; a group of 8–12 (usually 9 or 10) setae below marginal and stigmal veins; linea calva rather broad and oval, incomplete due to a group of 10–16 (mean 12) tubercles and 0–1 (usually



Figs. 7–11. *Eretmocerus debachi*, ♀, n. sp. 7. Parapsis (left side) showing 2 setae on distal anterior corner, axilla with 1 seta and portions of the pronotum, mesoscutum and scutellum, ♀. SEM. 8. Ventral aspect of mesosoma showing epicoxal pads beneath fore and middle coxae, ♀. 9. Fore and hind wings, ♀. 10, 11. Paratype ♂, dorsal view.

0) small setae above proximal half of frenal fold; beneath and distad of linea calva a group of 28–32 (mean 29) setae point toward the front of the wing, the remaining 137–161 (mean 148) setae in the disc area point toward the wing apex; forewing vein formula (length submarginal:marginal:stigmal) 1.0:0.5+:0.3.

Hindwing (Fig. 9) hyaline, 6.9 times as long as wide, longest anterior alary fringe 0.5 width of disc, longest posterior alary fringe 1.6 width of disc, usually bears no setae in center, sometimes there is one small seta.

Male (Fig. 10)

Similar to female in habitus, differing conspicuously in coloration and in antennal structure. Orange-yellow (gamboge) in life, with antennae and dorsum of thorax dusky. Cleared, slide-mounted specimens in Hoyer's medium retain some orange color and the fuscous pigmentation (Figs. 10, 11). Length: 0.75–0.85 mm (mean: 0.81). Antennal club, particularly the longitudinal sensilla, and pedicel fuscous; pronotum unpigmented; fuscous pigmentation on mesoscutum darkest anteriorly, particularly at antero-lateral margins, and medially, where the pigment nearly encompasses the posterior margin, forming a broad "T" shape; scutellum completely fuscous, with anterior and posterior margins darkest; central two-thirds of metanotum fuscous; tegula and forewing venation fuscous, as is proximal 2/3 of costal cell; remainder of forewing hyaline. Venation of hindwing fuscous, remainder hyaline. Tarsus of foreleg and midleg faintly fuscous; tibia and tarsus of hindleg faintly dusky.

Antennae (Fig. 10) composed of radicle, scape, pedicel, and an enormous, unsegmented club. Radicle 4.7 times as long as wide; scape 4+ times as long as wide, 1.7 times as long as radicle and 0.25 length of club; pedicel 1.35 times as long as wide, 0.6 length of radicle, 0.3 length of scape; club long, curving, 8.6+ times as long as its greatest width and 11.8 times as long as narrowest width, 7 times as long as radicle, 4.1 times as long as scape, 12 times as long as pedicel and 3.5+ times as long as middle tibia, bearing numerous longitudinal sensilla.

Genitalia with aedeagus exserted; length of aedeagus (from proximal margin of digital sclerites to apex) 2.9 times length of digital sclerites.

MATERIAL EXAMINED. Holotype ♀, USA, California, Orange County, Rancho Mission Viejo, 15.vii.1982, ex. *Parabemisia myricae* on Valencia orange and lemon, M. Rose, in balsam (USNM). Allotype ♂, same data as holotype (USNM). Paratypes, 5 ♀♀, 1 ♂, same data as holotype (1 ♀, 1 ♂ BMNH, 1 ♀ TAMU, 1 ♀ HUAR; remainder in M. Rose's collection); 15 ♀♀, 11 ♂♂, San Diego County, Pauma Valley, Beemer Lemons, same host on lemon, M. Rose and G. Ferrentino, 20.iv.82, 4 slides in Hoyer's medium; 3 ♀♀, 1 ♂, same data, 25.v.1982, 2 slides in Hoyer's; 3 ♀♀, same data as holotype, 2.xi.1982, 1 slide in Hoyer's; 3 ♀♀, same data, M. Rose and G. Ferrentino, 3.vi.1982, 1 slide in Hoyer's; 11 ♀♀, 2 ♂♂, same data as holotype, 4.vi.1982, 4 slides in Hoyer's; 1 ♀, same locality and host, on *Salix* sp., J.B. Woolley, 22.vi.1982, 4 slides in Hoyer's; 12 ♀♀, Orange County, Irvine Ranch, same host on lemon, M. Rose and G. Ferrentino, 4.xi.1982, 2 slides in Hoyer's; 1 ♀, same data, G. Ferrentino and S. Key, 28.vi.1983, in Hoyer's; 1 ♀, same data, W. Gregory and J. Huber, 30.vi.1983, in Hoyer's; 1 ♀, Riverside County, Riverside, University of California Biological Control Grove, same host on lemon, G. Ferrentino and J.B. Woolley, 1.ii.1983, in Hoyer's; 6 ♀♀, Orange County, South Coast Field Station, same host on lemon in glasshouse, M. Rose, 1.v.1983, 1 slide in Hoyer's; 2 ♀♀, same data, 22.iii.1983, 1 slide in Hoyer's; 13 ♀♀, same data, S. Key, 2.v.1983, 1 slide in Hoyer's.

Eretmocerus debachi is very closely related to *E. longipes* Compere (1936: 320). Distinguishing characters are given in the Discussion. Compere distinguished *E. longipes* by "The comparatively short club is a distinctive character of the antenna. Unlike *portoricensis*, the club widens from the base to near the apex, and it is not shaped like a parrot's beak," and by the "apical tarsal joints, which are lengthened and appear almost divided. This species may actually have five-

instead of four-jointed tarsi." The apical tarsal segment of *E. debachi* is also lengthened and the tarsus can appear to be 5-jointed. Compere (1936) noted in his description of *E. longipes* that the specimens — collected in 1918 — were then poorly preserved.

Eretmocerus longipes (Compere, 1936)
(Figs. 12–15)

Eretmocerus longipes Compere, 1936:320 (description); Hayat, 1972:105 (Key)

Female

Length: 0.66–0.77 mm (mean: 0.72). Antennae (Fig. 12) with radicle 3.9+ times as long as wide; scape 4 times as long as wide, twice as long as radicle, 0.6 length of club; pedicel twice as long as wide, subequal to radicle, 0.5 length of scape; funicle I right-triangular, as long as wide; funicle II subquadrate, 1.5 times as wide as long; club clavate, semi-rostrate, 3.8 (range 3.6–4.1) times as long as greatest width, 3.3 times as long as radicle, 1.6 times as long as scape and 3.3 times as long as pedicel, 1.5 times as long as middle tibia.

Mesoscutum (Fig. 13) trapezoidal, 1.6 times as wide anteriorly as long, wider than scutellum anteriorly, narrower posteriorly, bearing 6 setae (in 8 cotype specimens, but this feature cannot always be seen due to poor condition of specimens at hand, sometimes only 4 setae visible); each parapsis with 3 setae, 1 in the center and 2 on distal anterior margin; each axilla with 1 seta; scutellum 1.8 times as wide as long, with 4 setae, the discoid sensilla invisible; metanotum narrow; propodeum 10+ times as wide as long at most narrow medial margins of central lobe, central lobe extends to posterior margin of second tergite; endophragma long, extending well into fifth tergite.

Ovipositor strongly exserted (but the specimens were not cleared and thus were not relaxed), subequal in length to sheaths, 2.5 times as long as radicle, 1.3 times as long as scape, 2.6 times as long as pedicel, 0.8– length of club, 0.8 length of middle tibia.

Foreleg formula 1:0.8:1.1, tarsal formula 1:0.5+:0.5–:0.5–, fore-tibial spur 0.7 length of basitarsus, midleg formula 1:1.2:1.2, tarsal formula 1:0.4+:0.4–:0.4–, mid-tibial spur 0.8– length of basitarsus; hindleg formula 1:1.6–:1.4–, tarsal formula 1:0.6+:0.5:0.5–, hind-tibial spur 0.45 length of basitarsus.

Forewing hyaline, almond-shaped, 2.5 times as long as greatest width, longest anterior alary fringe 0.3 width of disc, longest posterior alary fringe 0.5 width of disc, base of wing bare; 2–3 setae in costal cell, 1–4 (usually 2) setae on its anterior margin at origin of marginal vein; submarginal vein bearing 4 longer setae, marginal vein bearing 3–4 (usually 3) longer setae along anterior edge; 1 long seta on neck of stigmal vein; a group of 7–11 (usually 8–10) setae below marginal and stigmal veins; linea calva rather broad and oval, incomplete due to a group of 10–12 (mean 11) tubercles and 3–4 (mean 3+) small setae above proximal half of frenal fold; beneath and distad of linea calva a group of 37–47 (mean 42+) setae point toward the front of the wing, the remaining 130–168 (mean 149) setae in the disc area point toward the wing apex; forewing vein formula 1.0:0.6:0.3– (see ♂ forewing, Fig. 14).

Hindwing hyaline, 7.5 times as long as wide, longest anterior alary fringe 0.5– width of disc, longest posterior alary fringe 1.7 width of disc, bears 2–4 tiny setae in center.

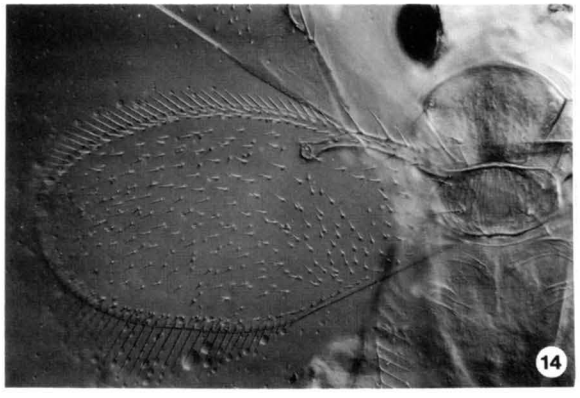
Male (Fig. 15)

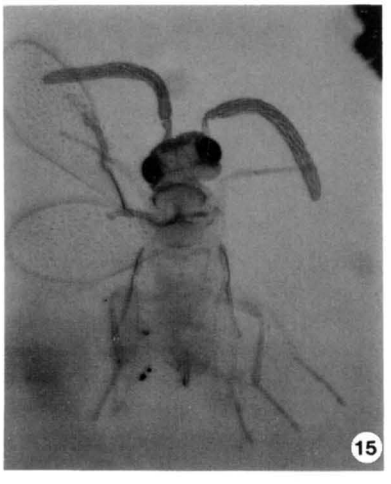
Length: 0.73 mm. Male pigmentation now appears to be a good diagnostic character for species of *Eretmocerus*. Pigmentation of the single ♂ specimen of *E. longipes* is redescribed here. Antennal club with fuscous longitudinal sensilla; pedicel faintly fuscous; pronotum faintly fuscous; mesoscutum fuscous along entire anterior margin and center; scutellum fuscous along anterior margin, very faintly fuscous overall; metanotum unpigmented; tegula, venation and costal cell of

forewing fuscous, remainder hyaline. Venation of hindwing fuscous, remainder hyaline. The basitarsus of the foreleg is fuscous, as is the apical one-fourth of the basitarsus of the hindleg.

Antennal radicle 4.1+ times as long as wide; scape 3.3+ times as long as wide, 1.35 times as long as radicle and 0.16 length of club; pedicel 1.2– times as long as wide, 0.6 length of radicle, 0.4 length of scape; club 10 times as long as its greatest width, 8.3 times as long as radicle, 6.1 times as long as scape, 14 times as long as pedicel and 3.9 times as long as middle tibia, bearing numerous longitudinal sensilla.

Genitalia without aedeagus exserted; length of aedeagus (from proximal margin of digital sclerites to apex) 1.9– times length of digital sclerites.





Figs. 12–15. *Eretmocerus longipes* Compere. 12. Lectotype ♀: head, antennae. 13. Lectotype ♀: mesosoma, metasoma. 14. Paralectotype ♂: forewing. 15. Paralectotype ♂: dorsal view.

MATERIAL EXAMINED. Cotypes: 15 ♀♀, 1 ♂, Hawaii, Hilo, ex. aleyrodid on *Hibiscus*, P.H. Timberlake, i.1918 (USNM Type slide no. 51934). Pigmentation, chaetotaxis and sculpture difficult to distinguish. One of the ♀ specimens, partially circumscribed in black ink (apparently by Compere), is hereby designated as lectotype. The lectotype ♀ is located to the right and above the single ♂ specimen; there are 2 ♀ specimens nearly immediately below the lectotype ♀. A label has been attached to the back of the USNM slide designating the location of the lectotype.

DISCUSSION

Species of *Eretmocerus* are very similar in most respects. Other than outstanding characteristics such as female pigmentation (*E. mundus* Mercet, 1931; *E. illinoisensis* Dozier, 1932; *E. pallidus* Dozier, 1932, *E. nairobii* Gerling, 1970), the form and relative size of antennal segments have been primarily used by various authors to construct keys and to distinguish species (Mercet, 1931; Compere, 1936; Hayat, 1972). To a lesser degree, wing shape, wing vein characteristics and chaetotaxis of wing and mesosoma have been included in species descriptions and figured by various authors. As is in other groups, as more collections are undertaken and specimens are studied more closely, separation of species using often cursory descriptions and comparison with few, and often poor, type specimens is increasingly difficult.

We have stressed characterization of antennae, wings, legs, and chaetotaxis of the mesosoma because these features appear to be most consistent and reliable. We have utilized digital measuring systems as a means to develop consistent, non-biased measurement programs. Male pigmentation now appears to be a further means to characterize species and these data are therefore included.

Species of *Eretmocerus* described as having clavate antennal clubs in the female include only *E. longipes* and *E. nairobii* Gerling (1970). *Eretmocerus nairobii* is readily separated from *E. debachi* by the relative length/width of club (3.5–4.0 times as long as wide in *E. nairobii*, 4.1–4.5 times as long in *E. debachi*), the shape of the funicular segments (see Gerling 1970: 328) and the presence of brown pigmentation on the forewings and scutellum of *E. nairobii* which is lacking in *E. debachi* (see Gerling 1970: 327).

Female *E. debachi* are readily separated from *E. longipes* by the chaetotaxis of the mesoscutum and parapsis: *E. debachi* always bears 4 setae on the mesoscutum, whereas *E. longipes* bears 6; *E. debachi* bears 2 setae on each parapsis, *E. longipes* bears 3. Study of *Eretmocerus* spp. has shown that chaetotaxis of the mesoscutum, scutellum, parapsis and axilla are very stable in series. There are also differences in antennal configuration: in *E. debachi* the club is 4.3 times as long as wide and the pedicel is 2.25 times as long as wide, in *E. longipes* the club is 3.8 times as long as wide and the pedicel is 2 times as long as wide. Although there is a small overlap in the club ratio, this appears to be a reliable diagnostic character. The forewing of *E. debachi* bears a group of 28–32 setae beneath and distad of the linea calva that point toward the front of the wing, in *E. longipes* there are 37–47 setae in this group; the linea calva is proximally interrupted by 10–16 tubercles and 0–1 setae in *E. debachi*, in *E. longipes* there are 10–12 tubercles with 3–4 setae. The mid-tibial spur of *E. debachi* is 0.6 length of corresponding basitarsus, in *E. longipes* it is conspicuously long, 0.8– length of corresponding basitarsus. Male pigmentation is distinct; in *E. debachi* all of the scutellum and the central two-thirds of the metanotum are fuscous, whereas in *E. longipes* the scutellum is fuscous primarily on the margins and the metanotum is unpigmented. There appear to be differences in leg pigmentation. There are also significant differences in nearly all aspects of male antennal configuration and in the relative lengths of the aedeagus and digital sclerites between *E. debachi* and *E. longipes*. Unfortunately there is only one paralectotype ♂ of *E. longipes*.

Gynandromorphs of *E. debachi* were found in Orange, San Diego and Santa Barbara counties in California. Specimens exhibited such bizarre characteristics as partial (bilateral) male pigmen-

tation in combination with both female and male antennae and mismatched genitalia. Their appearance was seasonal; most specimens were found in spring/early summer and during fall. They were rare, perhaps one per thousand. *Eretmocerus debachi* reproduces parthenogenetically and males were generally rare in the field and in glasshouse culture, but became more common during the periods when gynandromorphs were found. Male *E. debachi* mated readily with virgin females, but it is unknown if sperm transfer occurred.

The role of *E. debachi* in biological control has been significant. Early during the *P. myricae* biological control program in California, in 1982, this whitefly also invaded Israel, where it rapidly became a severe pest of citrus and avocado (Swirski et al., 1988a). At that time M. Rose and P. DeBach were collaborating closely with E. Swirski, D. Blumberg, D. Rosen, and Y. Rössler in Israel in an effort to share natural enemy species. As a result, *E. debachi* was introduced by Swirski and Blumberg into Israel within only a few weeks of its discovery in California. As in California, the parasite has proved highly successful in Israel and has brought about complete biological control of *P. myricae* on both citrus and avocado (Swirski et al., 1988b).

Parabemisia myricae was discovered in Turkey in 1982, and there too it rapidly became a very serious pest (Uygun et al., 1990). *Eretmocerus debachi* was introduced into Turkey from California in 1986 and has recently brought about complete biological control of *P. myricae* (Uygun et al., 1990). *Parabemisia myricae* also invaded Italy. Swirski has recently (April 1991) provided specimens of *E. debachi* to Italy (Barbagallo, pers. comm., 1991) and additional specimens will be provided from California during summer 1991.

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