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Redescription of *Austrosimulium bancrofti* (Taylor) (Diptera: Simuliidae): Australia's second-worst problem black fly

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Abstract

Though the taxonomic establishment of *Austrosimulium bancrofti* (Taylor) was muddled, the species, because of its pest status, has been the most highly researched black fly in Australia. The literature is, however, widely spread. This current work consolidates much of that and provides redescription of all stages.

Key words: Australia, Diptera, Simuliidae, *Austrosimulium, bancrofti*, redescription, biology, literature

Introduction

Austrosimulium bancrofti (Taylor) was described by Lee *et al*. (1962) as "*Second in importance to* A. pestilens *as a pest as it does not occur in such enormous swarms. However, its wider distribution and independence of flood conditions, coupled with its range of attacks on stock, would suggest it to be the most important species for epidemiological consideration*". They also noted that this black fly occurred in all Australian States except South Australia and Northern Territories, and was known to attack humans, horses, dogs, rabbits, kangaroos, wombats and eagles. Because of its notoriety, *A. bancrofti* has been subject to considerable examination over the years, albeit with the resultant information spread widely through the literature. Herein, information is consolidated and the species fully redescribed to recent standards (*e.g*., Moulton *et al*., 2018).

The early taxonomic history of *A. bancrofti* was closely intertwined with that of *A. pestilens* Mackerras & Mackerras and the two were initially confused with one other. It was antennal characteristics of females of the two species that was the source of that confusion and this is discussed here.

Earlier descriptions of insect antennae tended to interchange the terms 'joint' and 'segment' (the first term being particularly confusing!) and the distinction between a true segment (containing muscles as in the scape and pedicel) and an article (that comprising a division of the flagellum and lacking muscles) rarely employed. Here, definitions by Cumming and Wood (2017) are followed—as they put succinctly: "*Each antenna is made up of three basic parts (or* ***antennomeres****), the basal segment, or* ***scape****, the second segment, or* ***pedicel*** *and the third segment referred to as the* ***flagellum****, which contains varying numbers of* ***flagellomeres*** *.....*". Fig. 3a–f shows earlier illustrations of *A. bancrofti* female antennae and more recent examples, using these terms.

Taylor (1918: 168) described the antenna of *Simulium bancrofti* as "nine-jointed", with the first two, that is, the scape and pedicel brownish, the remainder black. The "*third joint*" (aka flagellomere I), broadest and about twice the length of the next. The image supplied (his Fig. 1), an early photomicrograph, is not clear enough to see full details. Tonnoir (1925: 241; his Fig. 1B), in his major taxonomic revision of Australasian simuliids, separated *Austrosimulium* as a new genus with a key character of ten-segmented antennae (*i.e*. eight flagellomeres**)** as against *Simulium* with 11 segments (*i.e.* nine flagellomeres). Another key character of the new genus was "*interarm struts*" on the anal sclerite of the larvae (*e.g*., Fig. 41). In his preliminary overview of the state of knowledge of Australian simuliids, Tonnoir (*loc. cit*. : 215) commented that the Taylor (1918) paper had a curious title (see that in References). Tonnoir repeated Taylor's description of *bancrofti*, but with several modifications, using specimens from Dawson River and Bumberry, New South Wales (NSW). Of significance is that Tonnoir described the antennae as

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having ten 'joints' (Fig. 3b), with the apical one partly fused to that preceding, so that the antenna could appear comprised of nine 'joints'—thence giving rise to Taylor's 'error'! Although at the time, immatures were not known for *S. bancrofti*, Tonnoir assigned the species to his new genus, *Austrosimulium*.

Taylor (1927: 70) clearly was not pleased with Tonnoir and re-described *A. bancrofti*. He used the term "segments" for the nine comprising the antenna and these show clearly (Fig. 3a) in a new photomicrograph he produced (his Fig. 2). On the basis of this definitive number of "segments", he declared Tonnoir (1925) to be mistaken and transferred *bancrofti* back to *Simulium*. Immatures were still not known. Drummond (1931), then, in a work dealing with Western Australia simuliids, described the immatures of *A. bancrofti*, noting the discrepancy between Taylor's and Tonnoir's descriptions of the adult antenna and stated that his material was as described by Taylor —the antenna comprised of nine "segments". Similar to Taylor (1927), Drummond wondered, also, if *bancrofti* should remain in *Austrosimulium*, but left it so. While describing the larvae for the first time he made no mention of the interarm struts on the anal sclerite—as noted previously, a key character for *Austrosimulium*.

Given the murky early taxonomy of *Austrosimulium bancrofti* and *A. pestilens*, the comments by Mackerras and Mackerras (1948: 258) follow here—"***Taxonomic Notes***

There has been much confusion about the identity of A. bancrofti*, Taylor maintaining that it had nine-segmented antennae, and Tonnoir that it normally had ten. The type series consists of nine females, all bearing a printed label "Eidsvold, Queensland, Dr. T. L. Bancroft" evidently affixed by Taylor. The type specimen is labeled "Allotype," and has nine-segmented antennae, with a large, broad third segment as illustrated by Taylor (1927) in his Figure 2. A specimen labeled "Paratype" has ten-segmented antennae of the form shown in Taylor's Figure 1. Of the others, one has nine-segmented antennae, and six have ten-segmented antennae. Thus, the type series comprised two* A. bancrofti *and seven* A. pestilens*! Tonnoir also had both forms before him in 1925, but later (MS) correctly placed this species and prepared notes on its life-history. Drummond (1931) also recognized it correctly, and, incidentally designated an allotype male, which he lodged in the collection of the Division of Economic Entomology, C.S.I.R., Canberra.*

Adults of A. bancrofti *can be immediately distinguished from all other species of the genus, except* A. pestilens*, by the abdominal markings in both sexes. From* A. pestilens*, it is only separable by the antennal characteristics, although the larvae and pupae are quite distinct."*

In their redescription of *A. bancrofti*, Mackerras & Mackerras (1948*:* 257) showed nine 'segments', but that the apical unit often had a notch or groove near the middle and they illustrated that (their Fig. 10d: 251) (here Fig. 3c). Dumbleton (1973: 557) made no comment regarding antenna, merely bringing information regarding Australian *Austrosimulium* up-to-date.

Material and methods

Manipulation of material, terms and photography follow those of Craig *et al*. (2019) with Cumming & Wood (2017) and de Moor (2017) regarding homologies of wing veins. All material illustrated here was either in ethyl alcohol (EtOH) and tended to be bleached, or was slide mounted.

When reporting data on labels, square brackets "[ ]" are used to indicate a label, with a slash "/" for the end of a line. Male and female symbols are given as {M} and {F} respectively. In the text, the States of Australia are abbreviated as in Fig. 42. A large amount of material, of all stages, collected by Heide & Peter Zwick was available to the author, as was material in the Australian National Insect Collection (ANIC), Canberra, ACT. The Zwick material is deposited in ANIC [ANIC Database No./29 026851-29 026872] and the Strickland Museum, University of Alberta [UASM#/370908-370920; 370930-37100; 386501-386516; 386527-386530].

Taxonomy

While Dumbleton (1973) considered the South American monotypic *Paraustrosimulium* Wygodzinsky and Coscarón to be a subgenus of *Austrosimulium,* other simuliid specialists (*e.g*., Crosskey, 1969; Wygodzinsky & Coscarón, 1973; Adler, 2019; amongst others) dealt with it at genus level. Rather than amend the diagnosis of *Paraustrosimulium* to include the Australian *Austrosimulium bancrofti* and *furiosum* species-groups, all of which show

affinities, he (Dumbleton, *loc. cit*.: 489) erected subgenus *Novaustrosimulium* for the latter two groups and that taxon is generally accepted (*e.g*. Adler, 2019). Craig *et al*. (2017) placed '*Austrosimulium*' *colboi* Davies & Györkös and a new species, *obcidens* Craig, Moulton & Currie into a revised *Paraustrosimulium* as Australian representatives of that genus.

Redescription

Austrosimulium (*Novaustrosimulium*) *bancrofti* (Taylor 1918).

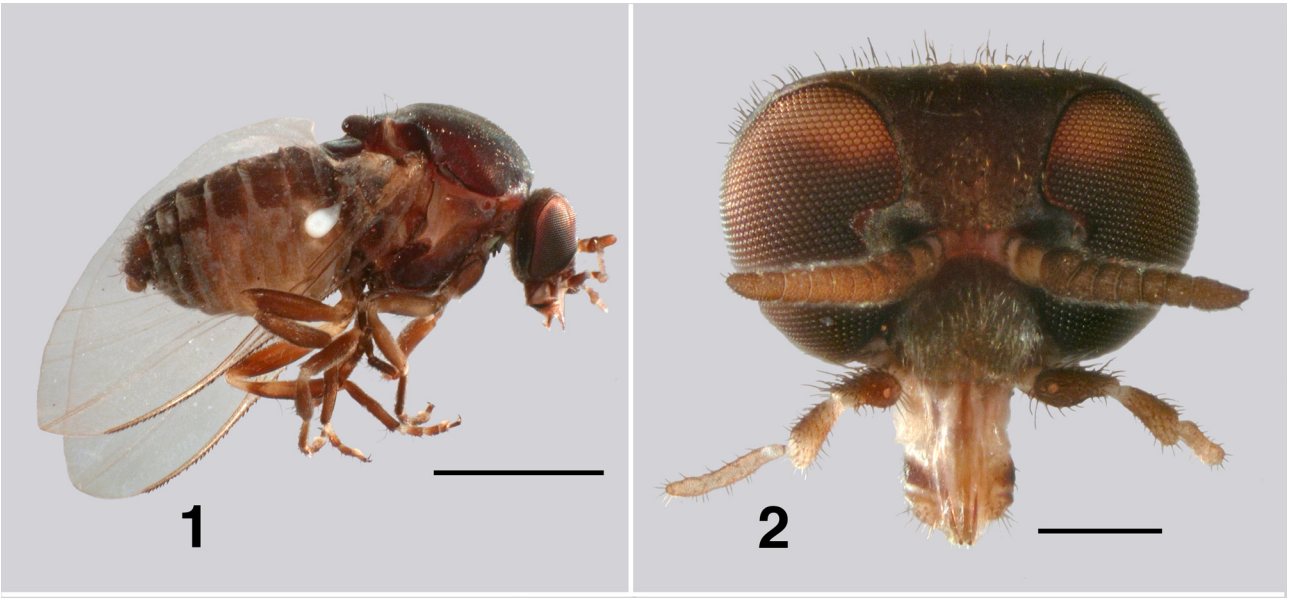
(Figs. 1–42)

Simulium bancrofti Taylor 1918: 168 (in part with *Austrosimulium pestilens*).
Austrosimulium bancrofti (Taylor). Tonnoir, 1925: 241 (in part with *A. pestilens*).
Simulium bancrofti Taylor. Taylor, 1927:70 (redescription, reassignment).
Austrosimulium bancrofti (Taylor). Drummond, 1931: 8 (male, immatures).
Austrosimulium bancrofti (Taylor). Smart, 1945: 499 (taxonomy).
Austrosimulium bancrofti (Taylor). Mackerras & Makerras, 1948: 256 (systematics, biology).
Austrosimulium (*Novaustrosimuli*um) *bancrofti* (Taylor). Dumbleton, 1973: 484 (subgenus)
Austrosimulium (*Novaustrosimuli*um) *bancrofti* (Taylor). Colbo, 1974 (biology).
Austrosimulium (*Novaustrosimuli*um) *bancrofti* (Taylor). Bugledich, 1999: 231 (listing of citations).
Austrosimulium (*Novaustrosimuli*um) *bancrofti* (Taylor). Ballard and Bedo, 1991: 338 (species complex).
Austrosimulium (*Novaustrosimuli*um) *bancrofti* (Taylor). Ballard, 1994: 131 (RNA, adult antennae).
Austrosimulium (*Novaustrosimuli*um) *bancrofti* (Taylor). Adler, 2019: 23.

Diagnosis. A small to medium grayish species, adults normally with seven antennal flagellomeres. *Female*: abdomen with wide, discontinuous, ashy dorsal stripe, distinguishing the species from all others, albeit not *A*. (*N*.) *pestilens*. *Male*: antenna black, traces of yellow on scape and pedicel; hind basitarsus lacking ventral row of stout setae; abdomen with conspicuous patch of ashy pollinosity laterally on V, VI segments. *Pupa*: gill horn flat, spatulate, spinous, numerous fine filaments concertinaed basally; sternite IX with simple grapnel hooks. *Cocoon*: shoe-shaped with well-developed anterior collar. *Larva*: head pigmentation usually distinct; lacking ventral papillae; semicircular sclerite absent. (Note, Dumbleton 1973, in his diagnosis of the subgenus, states that antennomeres of larva are subequal—however, for *bancrofti* and *pestilens*, the basal one is shorter, for *magnum* the apical one is longer).

Adult female (based on types and extensive material in ANIC). *Body* (Fig. 1): dark brown, with white patches on abdomen; total length 2.0–2.5 mm. *Head* (Fig. 2): overall dark brown, mouthparts paler, width 0.56–0.78 mm, depth 0.48–0.50 mm; postocciput not markedly hirsute, frons markedly broad, frons/ head ratio 1.0:3.4, under some lighting appears pollinose, cervical sclerites distinct. *Eyes*: interocular distance 0.2 mm; ommatidia diameter 0.027 mm; *ca.* 28 rows across and 40 down at mid-eye. *Clypeus*: width *ca*. 022mm; densely covered with fine gray hairs. *Antenna* (Fig. 3a–d): variable; not markedly extended beyond head margin; total length 0.3–04 mm; normally with seven flagellomeres (but numbers various); scape and pedicel brownish-yellow, remainder dark brown, flagellomere I *ca*. twice as long as cup-shaped scape and markedly expanded apically (*e.g*., Fig. 3a), occasionally smaller (Fig. 3f) even on same specimen; apical (VII) flagellomere commonly with groove at mid length (incomplete or complete division giving eight flagellomeres), markedly cone -shaped; (*e.g*. Fig. 3c, d, f), some specimens differ between sides. *Mouthparts*: well expressed; *ca.* 0.5× length of head depth; maxillary palpus (Fig. 4), total length 0.45 mm, palpomere III darker brown than remainder, proportional lengths of palpomeres III–V 1.0:0.7:1.3; sensory vesicle ovoid, large, 0.6× width palpomere III, opening 0.3× vesicle width; mandible (Fig. 5) substantial basally, finely tapered apically with *ca*. 30–45 inner markedly fine teeth, slightly increasing in size towards apex, outer teeth absent; lacinia with 16 inner teeth and 11 outer teeth; cibarial cornuae (for WA, thin basally, flared apically,) elongated, thin, strongly pigmented, central depression flat (Fig. 6). *Thorax*: length 1.1–1.2 mm; width 0.5 mm; scutum dark brown with dark pollinosity and moderately dense short hairs, showing dull golden dorsally, but silvery more laterally; scutellar depression with longer creamy hairs; scutellum black with similar hairs, but darker along apex; postnotum concolourous with scutellum, vestiture absent; pleuron and plural membrane with ashy pollinose. *Wing* (Fig. 8): clear, length 2.0–2.5 mm; width 1.0 mm; veins yellowish; anterior veins well expressed, except subcosta, others poorly so; CuA markedly sinuous; basal cell absent; a:b ratio 1.0: 3.4; slightly dusky on anal lobe. *Haltere*: knob creamy-yellow to dense white, stem grayish. *Legs* (Fig. 7): evenly medium brown; hind basitarsus *ca*. 8× longer than width, calcipala small, 0.5× width of basitarsus, not extended as far as pedisulcus; hind basitarsus mark-

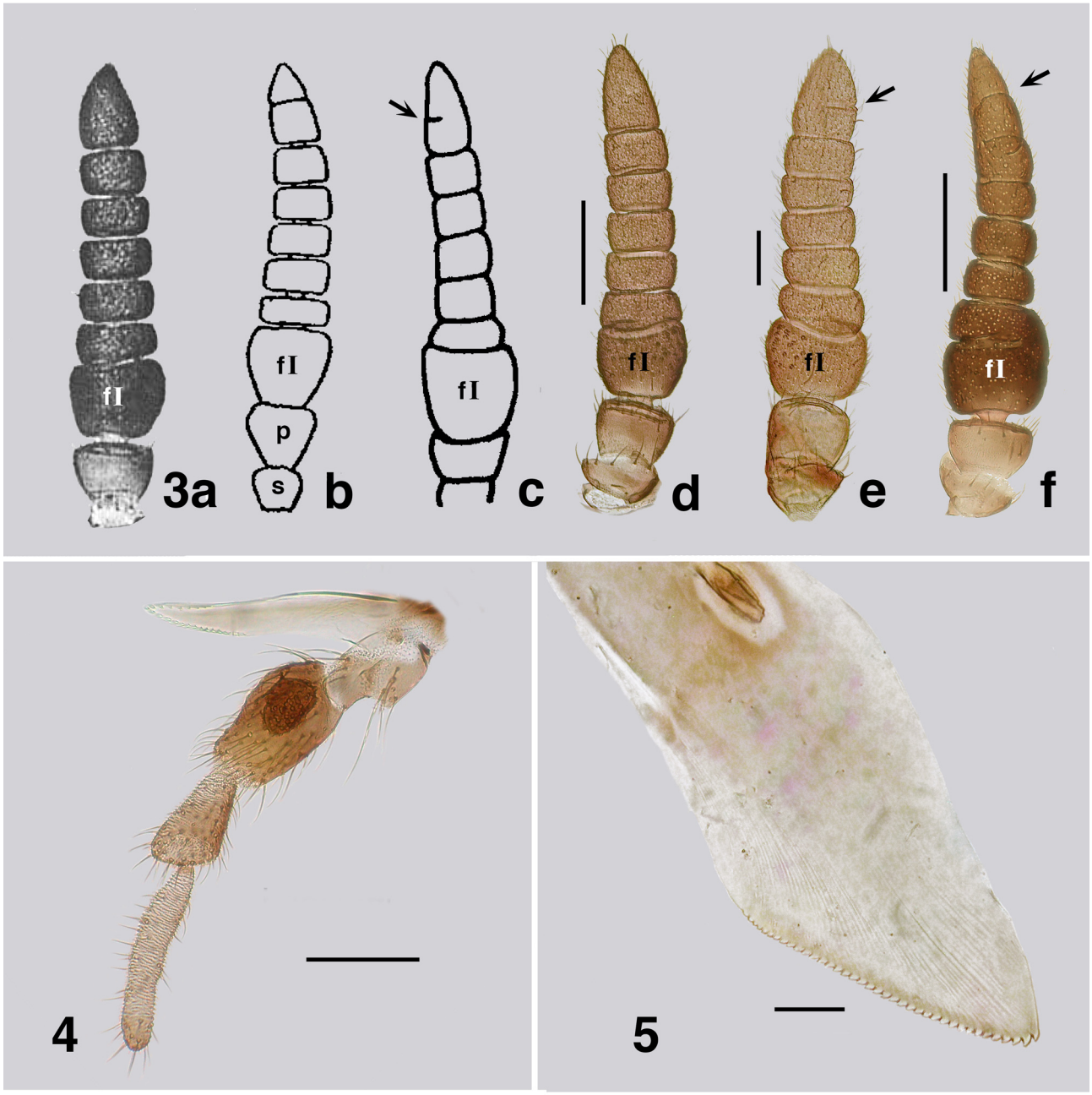
edly hirsute on proximal half, ventral row of stout spines poorly expressed, even less so on distal region; basitarsus II 2.5× as long as apical width; claws (Fig. 9) lacking basal tooth, with small heel. *Abdomen* (Fig. 10): abdominal scale dark brown with pale hairs; tergite II rich brown with small central patch of white scales, 4×, as wide as long, tergites III–V quadratic with pale patch increasing in size posteriorly, tergites VI, VII wider than long, pale posteriorly. *Genitalia*: (for WA, Fig. 14) sternite VIII heavily pigmented, hypogynial valves broadly cone-shaped, lightly pigmented, basally with dense microtrichia, apically bare and clear, medial gap straight, narrow; (for NSW, Fig. 15) sternite VIII light brown, hypogynial valves broadly cone-shaped, lightly pigmented, particularly at valve apices with a clear band of unpigmented cuticle (also seen in *A. pestilens*); genital fork, (ACT, Fig. 12) anterior arm well defined, slightly expanded apically, lateral membranous areas very lightly expressed, posterolateral arms with small knee bend; apodeme small, with sharp apex; (WA, Fig. 11) anterior arm short, broad, lateral membranous areas moderately expressed, apodeme small and rounded apically; spermatheca (Fig. 13) spherical, smooth, small scattered acanthae internally, junction with duct large with sculpted edge; cercus (VIC, Fig. 16) ovoid, anal lobe poorly expressed, (WA, Fig. 17) cercus broadly rounded, slightly ovoid, evenly spaced hairs, dense microtrichia, anal lobe larger, albeit not protrusive.



FIGURES 1, **2**. *Austrosimulium bancrofti* female. (1) Habitus of female (WA). Scale bar = 1.0 mm. (2) Frontal view of head (WA). Scale bar = 0.2 mm.

Adult male (based on 'allotype', WA; plus NSW material). *Body* (Fig. 18): head and thorax dark, abdomen lighter; total length *ca.* 1.6 mm. *Head* (Fig. 19): width 0.9 mm, depth 0.62 mm. *Eyes*: upper ommatidia yellowish orange, diameter 0.035 mm, *ca*. 23 across 26 down; lower ommatidia blackish red, diameter 0.011 mm, *ca.* 26 across and 30 down. *Clypeus*: pollinose. *Antenna* (Fig. 20): total length 0.5 mm; evenly dark brown, pedicel spherical and broader than remainder of antenna; flagellomere I elongated, 2× as long as wide, II rounded, III–IV angulate, distal (VII) markedly cone-shaped, often not completely separated from flagellomere VI. *Mouthparts*: poorly developed; length 0.3× head depth; mandibles and lacinia with terminal hairs; maxillary palpus (Fig. 21, 22) length *ca*. 0.5 mm, palpomere III dark, narrowed, sensory vesicle irregular in shape, 0.3× palpomere width, opening 0.2× vesicle width, palpomere IV moderately pigmented, expanded apically, palpomere V pale, proportional lengths of palpomeres III–V 1.0:0.7:1.3; there are minor differences between palpi from ACT (Fig. 21) and NSW (Fig. 22)—shape of palpomere III, and length and shape of palpomere V. *Thorax*: length 0.9 mm; width 0.8 mm; scutum evenly velvety brown, vestiture of sparse silvery scales; scutellum and postnotum concolourous with scutum. *Wing*: length 2.0 mm, width 1.1 mm; anterior veins yellowish. *Haltere*: stem gray, knob white. *Legs*: evenly dark brown; hind basitarsus, 5.5× longer than width, markedly hirsute on proximal half, ventral row of stout spines present, but spaced irregularly. *Abdomen*: dark brown, pollinosity absent. *Genitalia*: (Fig. 23). gonocoxa as long as basal width, poorly sclerotized anteromedially; gonostylus *ca.* 4× as long as basal width, angulate in lateral view, slightly curved, 3–5 terminal spines, various even on same specimen; ventral plate markedly cone-shaped laterally, 1.7× as wide as long, very broadly V-shaped posteriorly, anterior arms not markedly developed, medial keel mark-

edly broad, directed ventrally, with broad apex anteriorly, vestiture of dense fine hairs; median sclerite not markedly expressed, bifurcated apically; paramere as distinct curved rod with fine apical spinules; adeagal membrane with sparse microtrichia.



FIGURES 3–5. *Austrosimulium bancrofti* female. (3) Antennae, a—Eidsvold. Adapted from Taylor (1927). No scale bar. b—VIC. Adapted from Tonnoir (1925). s = scape, p = pedicel, f I = flagellomere I. No scale bar. c—VIC. Adapted from Mackerras & Mackerras (1948). No scale bar. d—WA. Scale bar = 0.05 mm. e—VIC. Scale bar = 0.05 mm. f—ACT. Scale bar = 0.1 mm. Arrows indicates partial division of apical flagellomere. (4) Palpus, lacinia (ACT). Scale bar = 0.1 mm. (5) Mandible apex (WA). Scale bar = 0.02 mm.

Pupa (numerous specimens, NSW, VIC) (Fig. 24). *Body*: female, length 2.3–3.0 mm, male 2.5–2.9 mm. *Head*: cephalic apotome lightly tuberculated with distinct tubercles arrayed along ecdysial sutures; male frons (Fig. 27) rounded apically, ratio of basal width to vertex width 1.0:2.2, basal width to length 1.0:2.6; frontal and facial setae present, but small; epicranial setae small, not obscured by antennal sheath; cuticle essentially smooth apically, tuberculate basally; female frons (Fig. 28) short broad with flat apex, ratio of basal width to vertex width 1.0:2.0, ratio of basal width to length 1.0:1.5, cuticle and setae as for female. *Thorax* (Fig. 29): cuticle with tubercles in rosettes, concentrated along medial ecdysial suture, more densely around gill base, no pattern; dorsocentral sensilla as small

fine hairs. *Gill* (Fig. 25): broad flat spatulate horn, 0.65 mm in length, with short sharp spinules distally; *ca*. 60 fine filaments, 0.005 mm in diameter, subequal to horn length, absent from distal quarter of horn; filament surface annulated, annulations 2×longer than wide, slightly bead-shaped, concertinaed (ringed) at attachment to horn (Fig. 26). *Abdomen* (Figs. 30, 31): cuticle thin, colourless; armature markedly reduced; sternite armature absent; tergite I slightly sclerotized, tergite II with fine hairs, III–VII with anteriorly directed hooks, spine combs absent, but with minute scales, tergite VIII with grapnel hooks and posterocentral region of scales, tergite IX terminal spines small, directed posteriorly, sternite IX with sparse grapnel hooks.

Cocoon (Fig. 24): shoe-shaped, extended beyond pupa; fabric closely woven with distinct edge to anterodorsal opening, ventral collar well extended, with irregular edge.

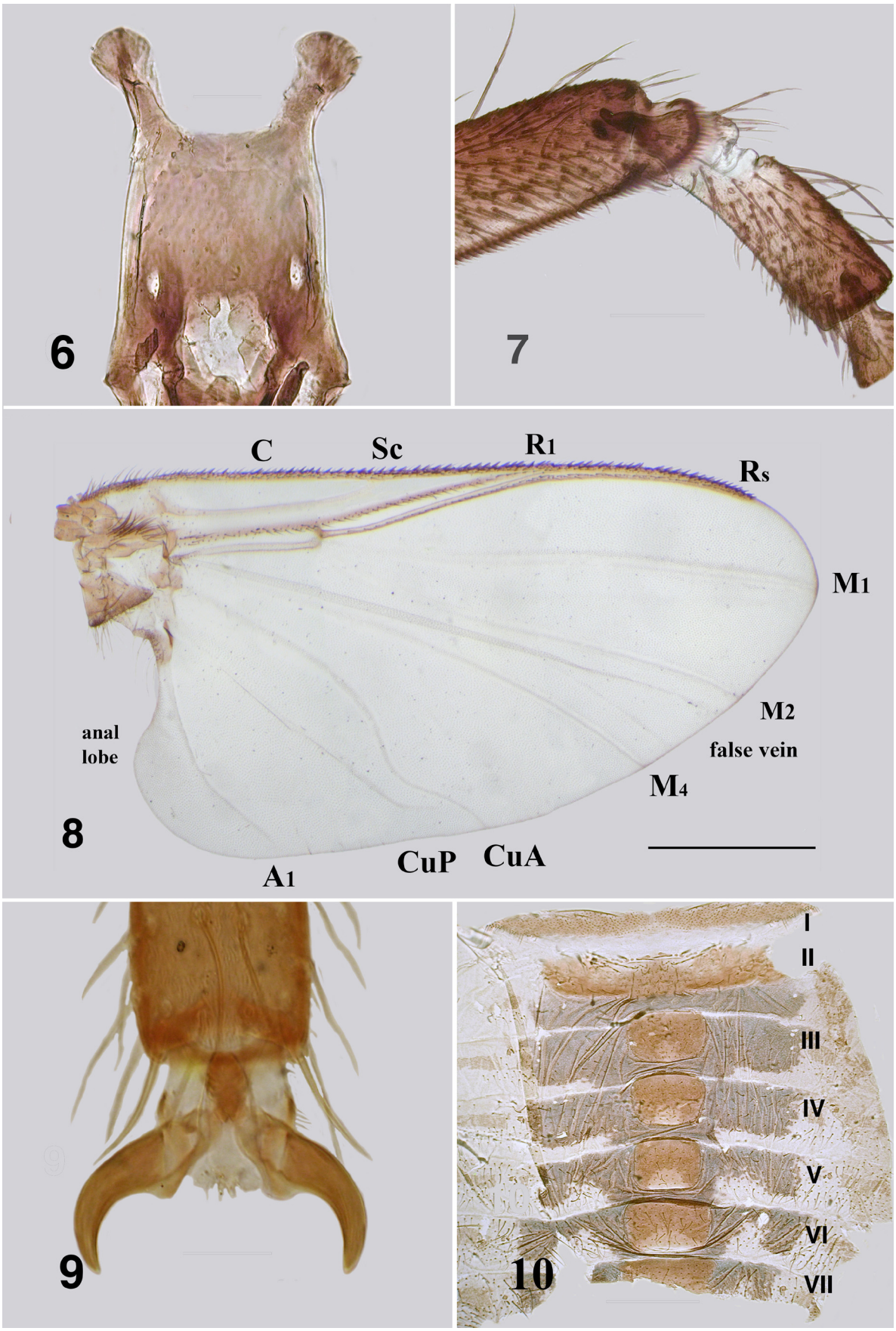
Larva (based on numerous last instar specimens). *Body* (Fig. 32): total length 5.0–6.7 mm, creamy ventrally, segments I–III with distinct dark brown bands and pale intersegmental regions, posteriorly merging into medium brown. *Head* (Fig. 33): slightly narrowed anteriorly, margins not markedly convex posteriorly; length 0.70 mm, width 0.53 mm; distance between antennal bases 0.38 mm; anterior apotome creamy, head spot pattern positive usually dark brown, pattern variable, but commonly as a diffuse cross, darker posteriorly across the apotome; laterally two spots each just ventral to stemmata; ecdysial sutures distinct posteriorly; postocciput markedly expressed, cervical sclerites small and fused to postocciput. *Antenna* (Fig. 34): total length 0.27 mm, extended slightly beyond labral fan stem; evenly light brown, basal antennomere short, medial and distal antennomeres subequal in length, proportional lengths of antennomeres I–III, 1.0:1.8:1.8. *Labral fan*: stem short and broad, slightly pigmented, *ca.* 40 fine rays, length 0.4 mm, width 0.005mm at mid-length; microtrichia all fine, long, subequal, *ca*. 0.023 mm long, regularly arrayed. *Postgenal cleft* (Fig. 35): broadly V-shaped with irregular apex; postgenal bridge mottled brown, concolourous with genae; ratio of hypostoma, postgenal bridge and cleft 1.0:1.6:1.6; posterior tentorial pits small, surrounding cuticle heavily sclerotized. *Hypostoma* (Fig. 36): teeth markedly variable, largely covered by ventral edge of hypostoma; tooth 0 (median) well expressed, but not protruded, tooth 1 (first sublateral) apparently absent, tooth 2 (second sublateral) small or non existent—variable even on same specimen, tooth 3 just protruding beyond ventral edge, tooth 4 (lateral) well developed and protrusive, teeth 5–7 apparently absent, replaced by points on hypostomal edge; four or five hypostomal setae per side. *Mandible* (Figs. 37, 38): short and broad, anterior covering brush exacerbated; outer, apical and subapical tooth on narrowed apex, with the apical brush short and protrusive; eight spinous teeth; sensillum and three to five serrations distinct, on raised base; blade region, smooth and slightly convex. *Maxilla* (Fig. 39): lobe short and broad, palp well separated from lobe, short, 2× longer than basal width, patch of short hairs basally. *Thorax* (Fig. 40): anterior proleg with small, poorly expressed lateral plates; mature pharate pupal gill elongated, directed 45º posteroventrally, filament aligned with horn posteriorly then recurved anterodorsally. *Ventral papillae*: absent. *Anal sclerite* (Fig. 41): anterodorsal arm short and not expanded, interarm struts distinct, posteroventral arms elongated and smoothly tapered; accessory and semicircular sclerites absent. *Rectal papillae*: three simple lobes. *Posterior circlet*: *ca.* 100 rows, 20–25 hooks per row (total *ca.* 2500).

Types. While the specific status of *Austrosimulium bancrofti* and *A. pestilens* was initially muddled, that of *bancrofti* types was equally so. Taylor (1918: 168) described *bancrofti* from females from Eidsvold. There is no mention specifically of types, except in the article's introduction that states "*The type specimens are contained in the Institute collection.*" There are no dates.

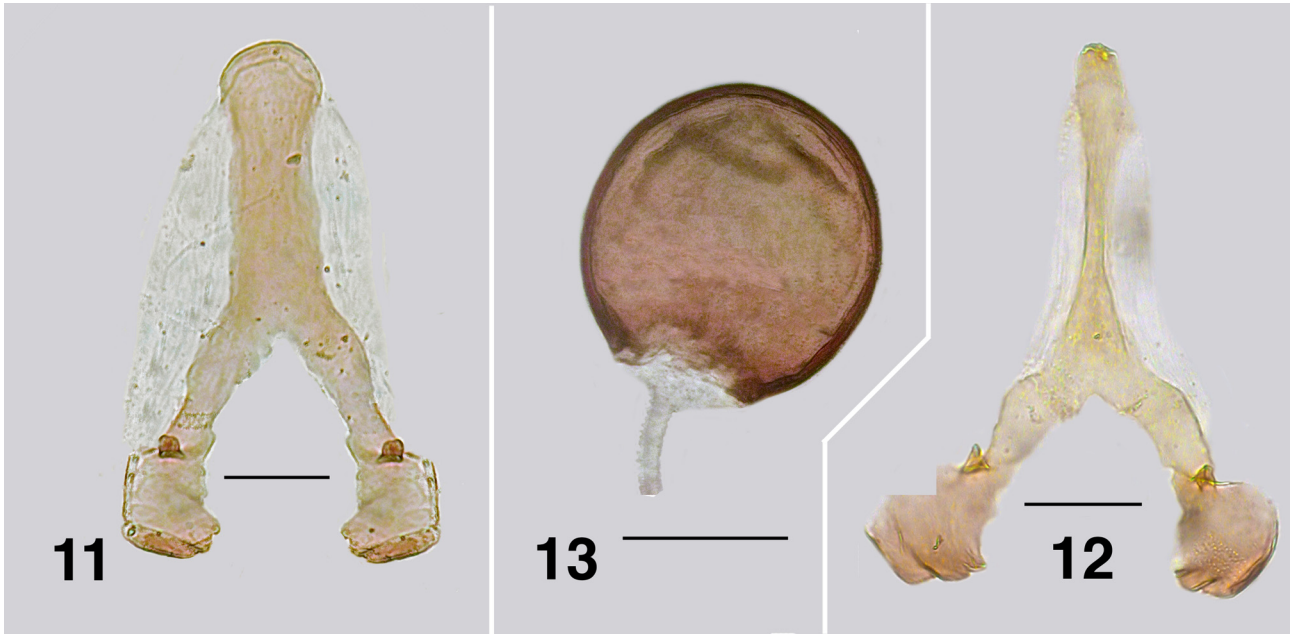
As given previously here, Mackerras and Mackerras (1948: 258) had access to Taylor's type series of *A. bancrofti*. There were nine specimens, all female. This material, originally housed in the Australian Institute of Tropical Medicine, Townsville, had been transferred to the collection of the Division of Economic Entomology, C.S.I.R., Canberra; now the Australian National Insect Collection (ANIC), C.S.I.R.O, Canberra. Only two of those specimens were of *A. bancrofti*, the other seven were *A. pestilens.* Of the two *bancrofti* specimens, one with "Allotype" on the label was accepted by the Mackerras' as the holotype. Another with "Paratype" appears to have been accepted as a paratype, but that is not fully clear. Dumbleton (1973: 557) and Bugledich (1999: 331), both accepted the "Allotype" specimen as the holotype and that is followed herein. Both these specimens are currently housed in ANIC and the "Paratype" specimen is accepted as a paratype.

Holotype. Pinned female on pith. Label data: [EIDSVOLD,/ QUEENSLAND/ Dr. T. L. Bancroft.] [Allotype/ Simulium/ bancrofti, Taylor]. No date. The type is in good condition, albeit missing maxillary palpi, and the minuten pin is badly corroded. ANIC. Examined DAC, 2011.

Paratype. One pinned adult. Label data: [EIDSVOLD,/ QUEENSLAND/ Dr. T. L. Bancroft.] [PARATYPE {F}/ Simulium/ bancrofti, Taylor]. No date. ANIC. Examined DAC, 2011. Oddly, Bugledich (1999) did not mention paratypes.



FIGURES 6–10. *Austrosimulium bancrofti* female. (6) Cibarium (WA). Scale bar = 0.05 mm. (7) Basitarsus (WA). Scale bar = 0.05 mm. (8) Wing (WA). Scale bar = 0.5 mm. (9) Claw. (ANIC). Scale bar = 0.02 mm. (10) Abdomen showing tergites I–VII (WA). Slide mounted. Scale bar = 0.5 mm.



FIGURES 11–13. *Austrosimulium bancrofti* female. **(**11**)** Genital fork (WA). Scale bar = 0.05 mm. (12) Genital fork (ACT). Scale bar = 0.05 mm. **(**13**)** Spermatheca (VIC). Scale bar = 0.05 mm.

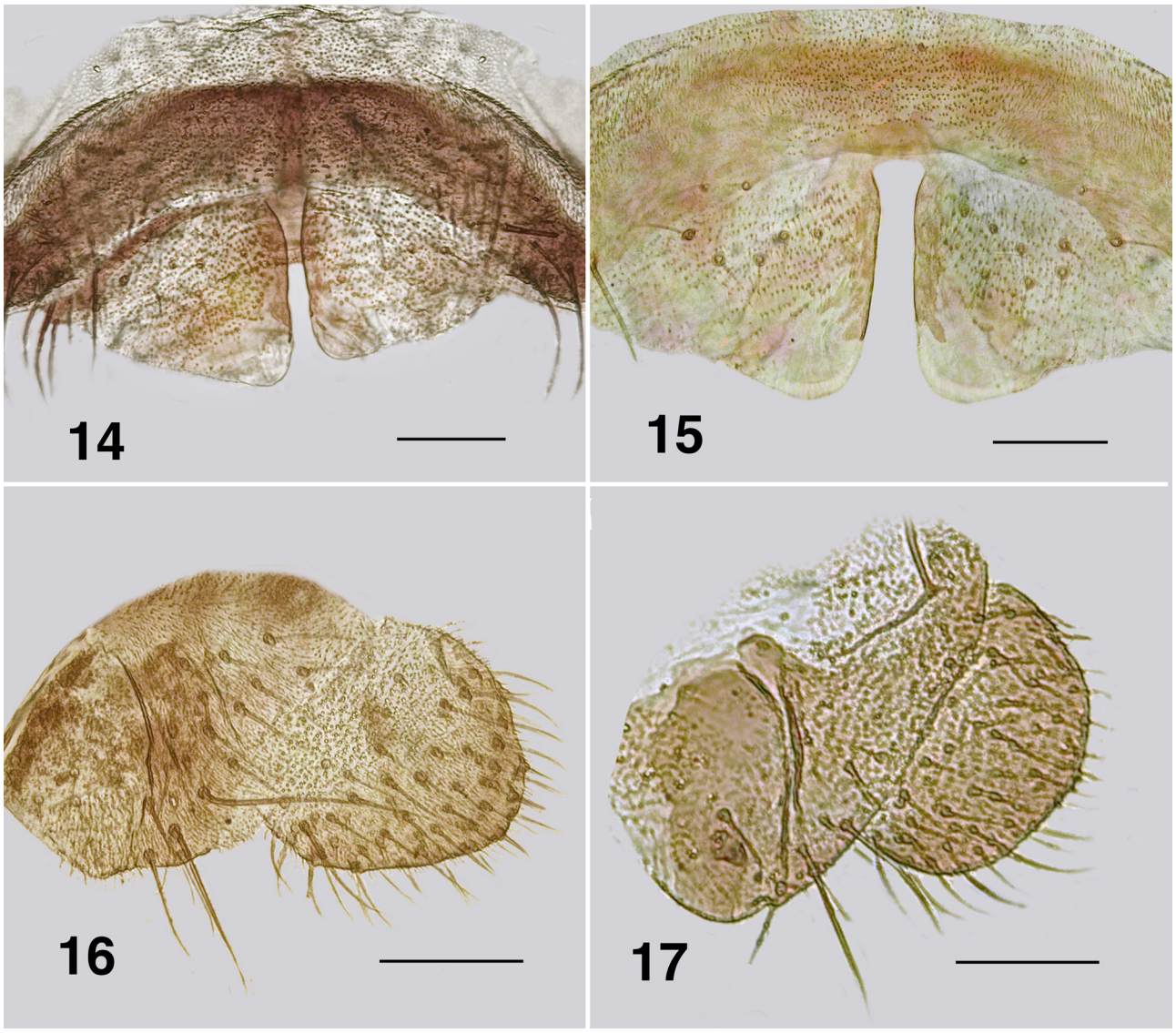
Date for the types from Eidsvold is unknown—T. L. Bancroft lived in Eidsvold for twenty years (1910–1930) and had many opportunities to collect simuliid material—as well as many other organisms, and he did (Marks, 1973; Mackerras & Marks, 1973).

Other material. There are some hundreds of pinned *A. bancrofti* adults in the ANIC. Of interest is that there are 12 pinned specimens from Eidsvold and seven have similar labeling as on the type specimens regarding locality and collector. The remainder of these specimens were clearly used by Tonnoir in a detailed examination, dated 1923, probably those to which he referred to as "*paratypotypes*"; with little doubt for his seminal 1925 study on Australasian simuliids. In the smaller ANIC collection of *A. pestilens*, there are no specimens from Eidsvold, raising the question as to whether the above seven specimens are the original 'type' series of Taylor and are not *A. bancrofti*, but of *A. pestilens*, never having been transferred or relabeled? These specimens were not examined for this work, apart from recording label data.

As well as the large holding of *A. bancrofti* in ANIC, a substantial alcohol collection, of mainly immatures, was provided to the author by Hiede and Peter Zwick. As already noted this material is now housed in ANIC and the Strickland Museum, University of Alberta (UASM).

Etymology. Named after Dr. Thomas Lane Bancroft (1869–1933), who collected the original material. T. L. Bancroft was the son of Joseph Bancroft, co-discoverer of the cause of filariasis. Thomas was himself of note (Mackerras & Marks, 1973) for his work on dengue, filariasis and the Queensland lungfish *Neoceratodus forsteri* (Krefft).

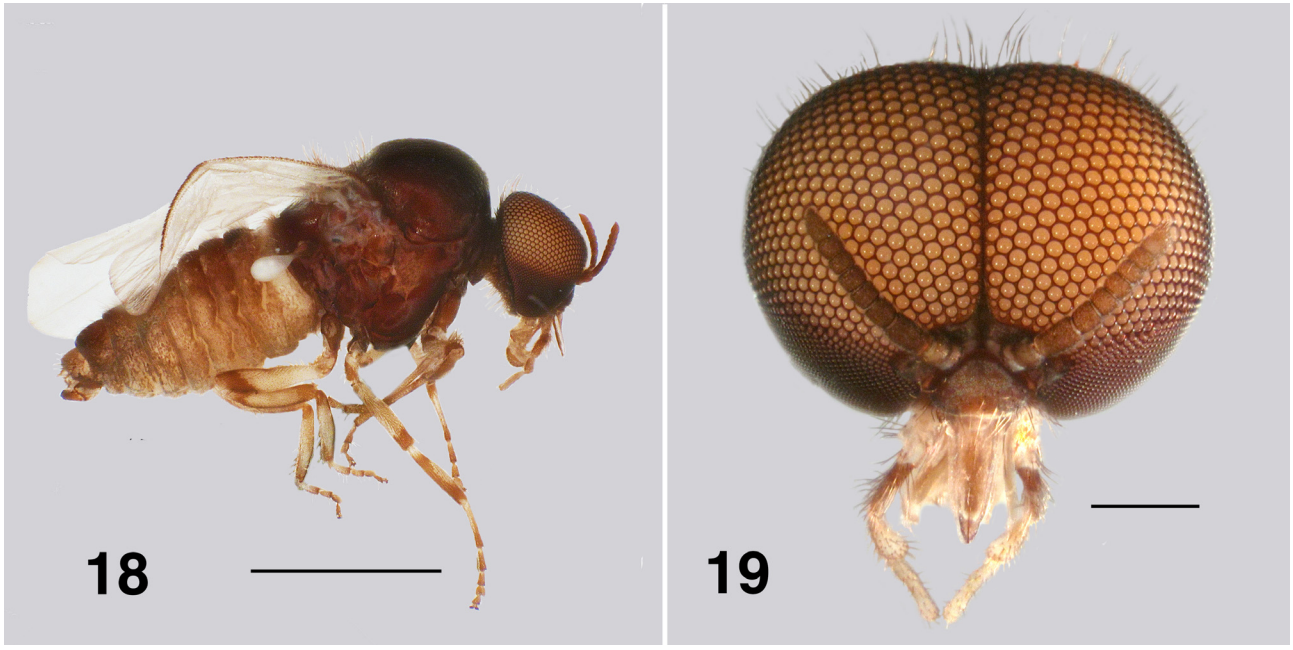
Distribution (Fig. 42). Tonnoir (1925: 219) noted that although *A. bancrofti* was originally known only from Queensland at Eidsvold, (S25.36700° E151.1300°) where T. L. Bancroft was located (Marks, 1979), Tonnoir had seen NSW material from Dawson River (S24.9700° E150.0500°) and Bumberry (S33.1600° E148.5100°), collected by Dr. E. W. Ferguson, 1-x-1916. Localities consolidated below are derived from literature citations, the large ANIC collection, from the Zwick material and the Atlas of Living Australia (ala.org.au); the list should, however, not be considered definitive. Dates are given in detail when known. For each State, localities are listed from north to south. Colbo (1974) showed a distribution map (his Fig. VIII) for *A. bancrofti*, as did Dumbleton (1973; his Fig. 10) and these are updated here (Fig. 42). Colbo (*loc. cit.*) commented that *A. bancrofti*, unlike *A. pestilens*, occurred in dryer western Queensland and he wondered how populations survived—either with a drought resistant stage such as is known for *A. pestilens*, or by reintroduction when conditions were suitable. The latter point is of general interest to biogeographers of Australian arid regions (Razeng, *et al.*, 2017; Majer *et a*l., 2018). Indeed, *Simulium ornatipes* Skuse is known from southwest of Alice Springs at the George Gill Range, Northern Territories (S24.2556° E131.5702°), one of the driest regions in Australia (Davis *et al.*,1993).



FIGURES 14–17. *Austrosimulium bancrofti* female. **(**14**)** Hypogynial valves (WA). Scale bar = 0.05 mm. **(**15**)** Hypogynial valves (VIC). Scale bar = 0.05 mm. **(**16**)** Cerci & anal lobe (VIC). Scale bar = 0.05 mm. **(**17**)** Cerci & anal lobe (WA). Scale bar = 0.05 mm.

Queensland. Annan Riv., Cooktown (S15.5400° E145.1900°), 20-vi-1971. Mt. Spec (S19.000° E146.2590°), 22-iv-1966. Don Riv. (S20.000° E148.1900°), 16-iv-1947. Cattle Crk., Eungella Valley (S21.1400° E148.2100°), 16-iii-1977. Lotus Crk. (S22.3528° E149.0961°). Mackenzie Riv. (S23.1600° E149.4900°), Apr., June. Fitzroy Riv., Rockhampton (S23.3400° E150.4900°), Jan., Feb., 19-i-1951. Don & Callide Riv., Calliungal, (S23.6400° E150.3800°), Apr., May. Rannes (S23.9500° E150.1900°), April. Burnett Riv. (S24.5600° E151.8900°), 5-v-1947. The Brook, Jacky Small's Crk. **(**S24.8500**°** E150.7100°), April, May. Theodore (S24.9400° E150.0600°), ?-ii-1939. Dawson Riv., near Theodore (S24.9500° E150.0700°), Apr. Gin Gin Crk. (S24.9723° E151.9454°). Ceratodus (S25.3008° E151.0891°). Burnett Riv., Eidsvold (S25.3781° E151.0836°), 1-v-1947. Lochaber Crk., Burnett Riv., Eidsvold (S25.3800° E151.1700°). Tin Can Bay Rd. (S25.9400° E152.9700°), 18-iv-1949. Boonara & Upper Barambah Crk., Goomeri (S25.9400° E151.8900°), Apr., May. Lower Barambah Crk., Gayndah (S25.6200° E151.6300°), Apr. May, 5-v-1947. Nambour (S26.2400° E152.5700°), Feb., Apr. Golden Beach, Noosa (S26.3100 E152.7400), 2-v-1949. Six Mile Crk, Cooroy (S26.4000° E152.7500°), 2-v-1949. Muckadilla Crk., Roma (S26.5700° E148.7900°), Mar.-Aug. Gympie (S26.6300° E152.9200°), Feb., Apr. Miles (S26.6500° E150.1800°). Brisbane, 15 km, W of Chinchilla (S26.6700° E150.3900°), 12-i-1997, 16-viii-1947. Charley Crk., Chinchilla (S26.7400° E150.6300°), Apr. Back Crk., Dalby (S27.2690° E151.2370°), Apr. Brisbane Riv., Wivenhoe (S27.4300° E152.6300°), Apr., May. Dunwich, Stradbroke Island (S27.5100° E153.4000°), 11-viii-1951. Blunder Crk., Oxley (S27.5932° E152.9970°), 14-v-1950.

Albert Riv., (S27.7700° E153.1900°), June. Nerang (S27.9900° E153.3000°), 23-iii-1947. St. George (S28.0400° E148.5600°). Mudgeeraba Crk. (S28.0800° E153.3700°), Mar., May, 23-iii-1947. Duraki (S28.1873° E151.6243°). Cave Crk., nr Numinbah (S28.2218° E153.2406°), 16-iii-1992. Wilson's Peak (S28.2499° E152.4833°). Bransby, Nockatunga (S28.3700° E142.0200°), 9-xi-1949. McIntyre Riv., Goondiwindi (S28.5400° E150.2900°), Aug. Weir on McIntyre Riv., Goondiwindi (S28.5553° E150.3130°), ?-?-1947. Texas (S29.0582° E150.8438°). Gravesend (S29.6500° E150.2000°), 28-ix-1952. Upper Taylors Arm (S30.0700° E152.6333°).



FIGURES 18, 19. *Austrosimulium bancrofti* male. (18) Habitus (NSW). Scale bar = 1.0 mm. (19) Head (NSW). Scale bar = 0.2 mm.

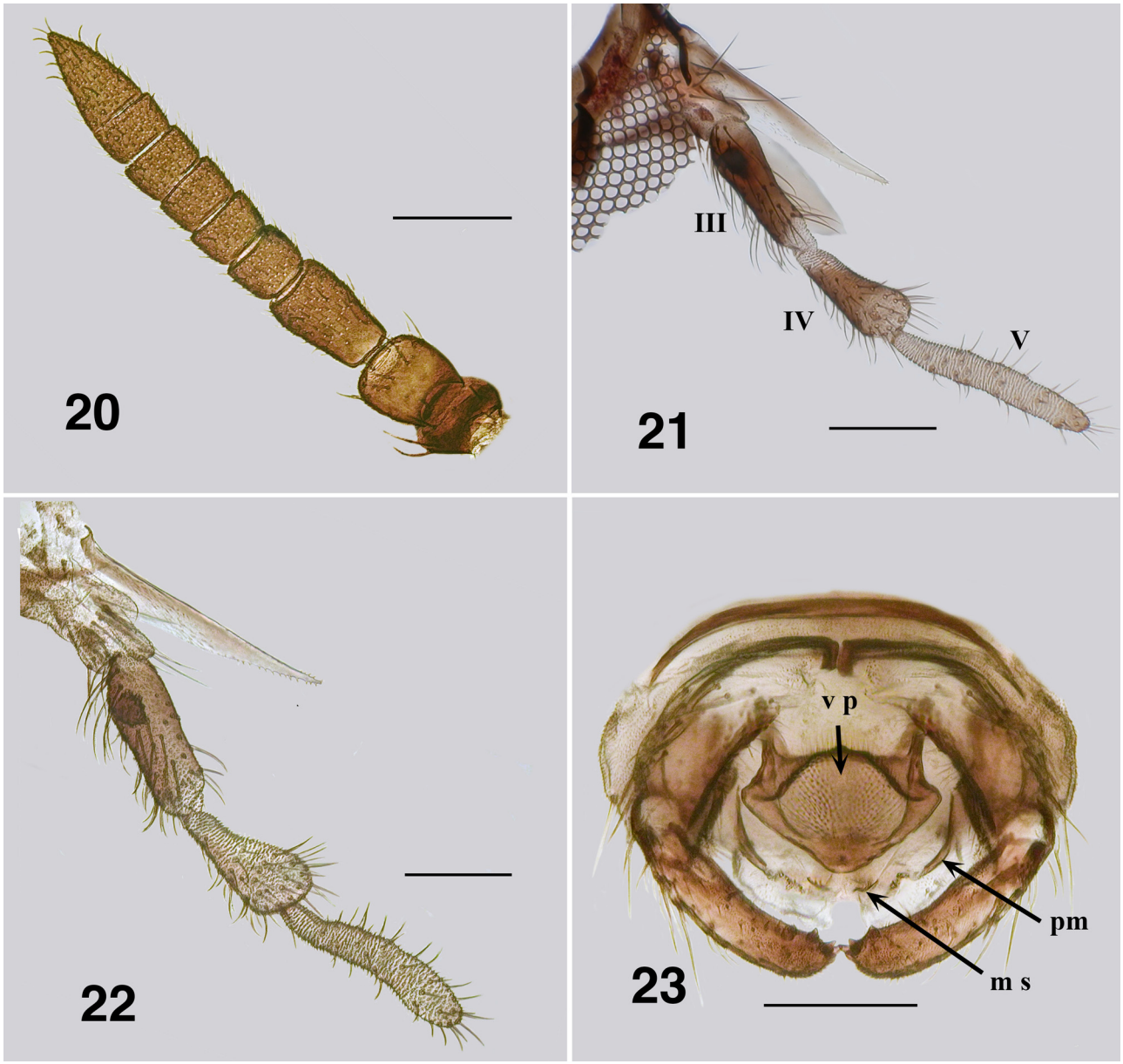
New South Wales. Moree (S29.3000° E149.4900°), 16-v-1951. Collarenebri (S29.4200° E148.2600°), 21-ix-1950. Yargobi Crossing (S29.5347° E150.2472°), 5-xi-1951. Bingara (S29.8300° E150.5000°), 24-ix-1952. Bourke (S30.1100° E145.9400°), May. Gooch's Water, Ebor (S30.4000° E152.3400°), 22-x-1950. McCleay Riv., Willawarrin (S30.9300° E152.6200°). Bumberry (S33.1600° E148.5100°), 1-x-1923. Nyngan (S31.5571° E147.1849°), ?-ix-1952, 3-iii-1956. Barrington Tops, Gummi (S31.9000° E151.4600°), 2-iii-1951. Lochaber Crk. (S33.1739° E149.9573°), 25-iv-1947. Molong Crk., Mt. Canoblas (S33.3378° E149.0181°), 8-x-1950. Forbes (S33.3900° E147.8600°), 14-xi-1964. Fish Riv., Bathurst (S33.5000° E149.6900°), April. River Lett, Hartley (S33.5277° E150.2006°) Dec. Hornsby (S33.6900° E151.0800°), 23-xii-1952. Colo Vale (S34.4050° E150.4600°), 25/26-ii-1958. Euston (S34.5901° E142.7532°). Minnamurra Falls, nr. Wollongong (S34.6310° E150.7420°), 22-ii-2001. Tallong (S34.7500° E150.0400°). Yass, (S34.8200° E148.9000°), Aug., Nov. Goodrabigbee Riv., Wee Jasper (S35.1631° E148.6868°), 18-iv-1964. Shoalhaven Riv., N. of Braidwood (S35.3428° E149.7375°), 22-x-1952, 1-xi-2007. Deniliquin (S35.5400° E144.6100°), ?-ix-1926. Logbridge Crk., 19 km w of Corryong (S36.2100° E147.7100°), 13-xi-2007. Biggara (S36.3401° E148.056°). Leatherbarrel Crk., Mt. Kosziusko Nat. Prk. (S36.5257° E148.1914°), 5-x-2002. Wullwye Crk., Dalgety (S36.4896° E148.8358°), 21-xii-1972.

Australian Capital Territory. Canberra (S35.2800° E149.1200°), 18-x-1929, 2-x-1931, 13-xii-1950. Molonglo Riv. (S35.2800° E149.0400°), Sept-April, 18-ix-1931. Black Mt. (S35.2800° E149.1100°), June, Nov., 22-x-1929, 16-x-31. Mt. Coree (S35.3000° E148.8000°), 22-iii-1955. Murrumbidgee Riv. (S35.3200° E148.9500°), ?-i-1934, 21-ix-1953, 25-ii-1955, 11-x-2014. Cotter Riv. (S35.3200° E148.9400°), Nov-April. Cotter Riv., Bridge (S35.3258° E148.9397°), 11-xi-1929, ?-viii-1972. Lee's Spring (S35.3500° E148.8000°), Oct., 21-iii-1951. Blundells (S35.3600° E148.8100°), Sept, Dec, Feb., 24-x-1930, 18-i-1931, 20-xi-1934, 22-x-1938. Brindabella (S35.3600° E148.5100°), Oct., 17-xi-1924, 20-iii-1930, 21-xi-1962. Pierces Crk. (S35.3600° E148.9000°), 12-ix-1950. Tidbinbilla (S35.4400° E148.9400°), 11-xi-1953. Mt. Gingera, Brindabella (S35.5700° E148.7700°), 31-i-1951.

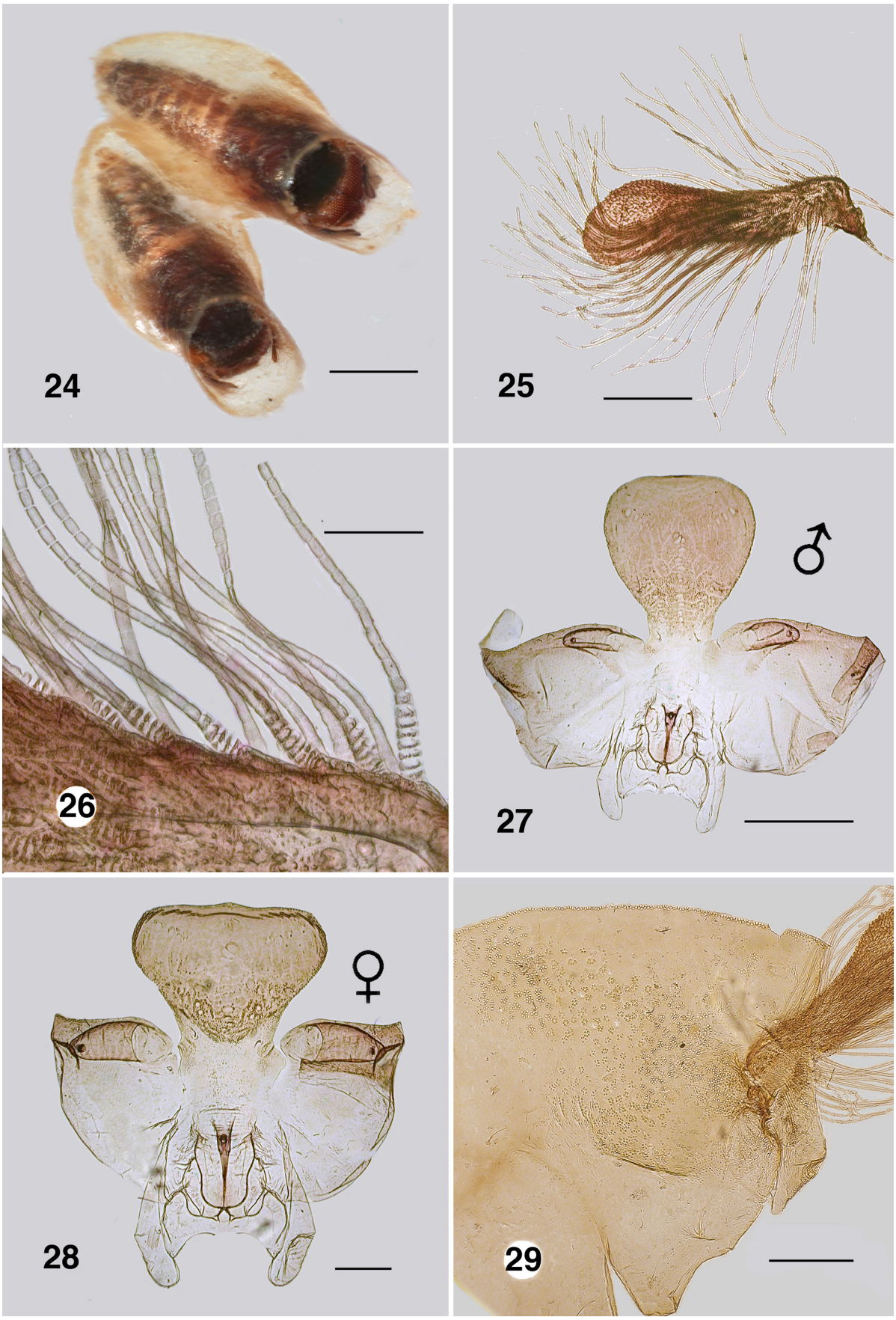
Victoria. Murray Riv., west of Merbein, (S34.1600° E142.0500°), Dec. Jingellic (S35.9625° E147.5086°). Barmah (S36.0192° E144.9549°). Tallandoon, Mitta Mitta (S36.4393° E147.2033°). Callaghans Creek Rd (S36.5078° E147.4175°). Mitta Mitta (S36.5202° E147.3703°), (S36.5624° E147.4106°), (S36.5153° E147.4349°).

Lake Buffalo, (S36.7383° E146.6616°), 12-iv-1972. King Riv., Whitfield (S36.7529° E146.4247°), 12-iv-1972. Lower Tablelands Rd. (S36.7968¡ E147.6741°). Omeo Valley (S36.9638° E147.6044°). Howqua Riv., Lake Eildon (S37.2366° E146.2291°), 12-vi-1972. Lee's Spring, Mt. Franklin (S37.2600° E144.1490°), 1-i-1952. Jamieson Riv. (S37.3100° E146.1100°), 16-ii-2001. Taggerty Riv. (S37.3218° E145.7080°), 11-x-2002. Acheron Riv., Buxton (S37.4168° E145.6984°), 13-x-1951. Steavenson Riv., Buxton (S37.4257° E145.7076°), 3-ii-1973. Buchan Riv. (S37.5008 E148.1734), 1-v-2012. Branxholme (S37.8400° E141.65000°), 12-viii-1958. Stratford/Avon. Gippsland (S37.9800° E147.0960°), 20-xi-1972.

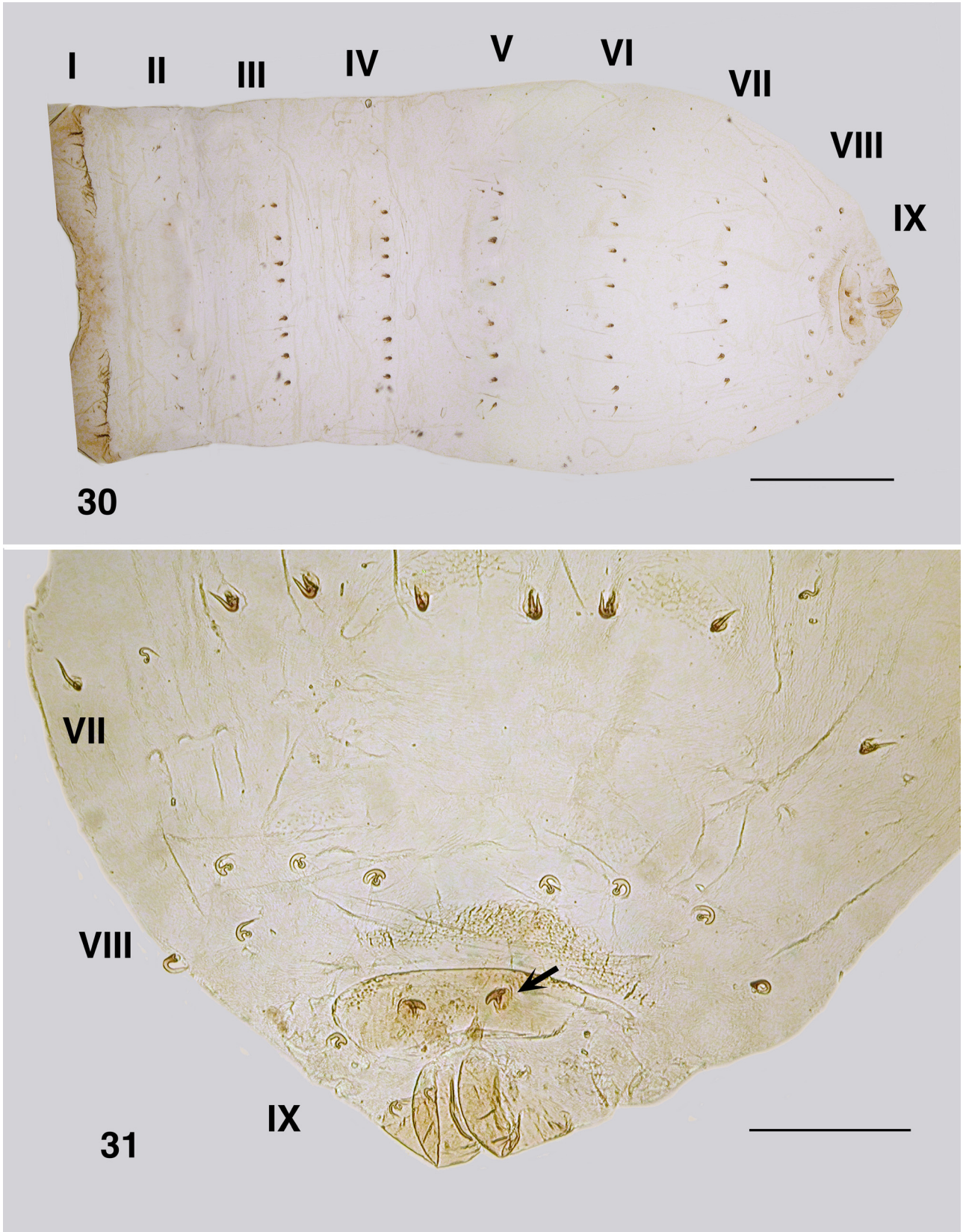
Western Australia. Bullsbrook (S31.6700° E115.9900°), 3-viii-1953. Hovea (S31.8700° E116.0800°), 29-ix-1935. Mundaring (S31.9100° E116.1600°), 23-viii-1926. Perth (S31.9500° E115.8300°), ?-vii-1930. Serpentine Falls, S of Perth. (S32.3679° E116.0111°), 26-x-2005. Serpentine Riv. (S32.3684° E116.0103°), ?-iv-1972. Serpentine Riv. (S32.3700° E115.9900°), Apr. Groper, Harvey (S33.0800° E115.8900°), ?-iii-1972. Kirup (S33.7100° E115.8500°), 29-viii-1926. S. Bridgetown (S33.9500° E116.1300°), 29-viii-1926, 27-x-2005. Bridgetown (S33.9700° E116.1300°). Donnely Riv. NW Pemberton (S34.0800° E115.9400°). Channeybearup (S34.4000° E115.9000°), 5-x-1970. Beedelup Falls, NW Pemberton (S34.4189° E115.8674°), March 1972. Carey Brook, Beedelup Nat. Pk. (S34.4345° E115.7986°), ?-iii-1972. Pemberton (S34.4400° E116.0300°), 15-iii-1956, 6-x-1970.



FIGURES 20–23. *Austrosimulium bancrofti* male. (20) Antenna (NSW). Scale bar = 0.1 mm. (21) Maxillary palpus (ACT), showing palpomeres III–V. Scale bar = 0.1 mm. (22) Maxillary palpus (NSW). Scale bar = 0.1 mm. (23) Genitalia (NSW). m s—median sclerite; pm—paramere; v p—ventral plate. Scale bar = 0.1 mm.



FIGURES 24–29. *Austrosimulium bancrofti* pupa. (24) Dorsal view of pupae & cocoons (NSW). Scale bar = 1.0 mm. (25) Gill (NSW). Scale bar = 0.2 mm. (26) Gill filament bases (NSW). Scale bar = 0.05 mm. (27) Head capsule, male (NSW). Scale bar = 0.5 mm. (28) Head capsule, female (NSW). Scale bar = 0.2 mm. (29) Thoracic cuticle (ACT). Scale bar = 0.2 mm.



FIGURES 30–31. *Austrosimulium bancrofti* pupa. (30) Abdominal cuticle & armature, dorsoventrally flattened (ACT). Scale bar = 0.5 mm. (31) Terminal abdomen (ACT). Arrow indicates terminal spines. Scale bar = 0.02 mm.

Tasmania. Brisbane River, Wivenhoe (S41.0800° E145.9200°), 5-v-1947. Devonport (S41.1700° E146.3200°), 18-x-1933. Great Forester River (S41.2673° E147.5070°). Launceston (S41.4400° E147.1200°), Apr. Launceston Gorge (S41.4510° E147.1144°), 23-iv-1946, 8-xii-1972. Meander River, Birralee Road (S41.4947° E146.8172°).

Ben Lomond, S Perth (S41.5600° E147.5200°), 8-xii-1972. Evendale (S41.5700° E147.2400°), 1-iii-1964. St. Pauls River, upstream of Royal George (S41.8248° E147.9757°). Jordan River, Mauriceton (S42.5273° E147.1244°). Clyde River, below Hamilton (S42.5623° E146.8267°). Muntain Riv., Ranelagh (S42.9378° E147.1348°).

In general, *A. bancrofti* distribution (Fig. 42) is markedly similar to that of other Australian Gondwanan Simuliidae—eastern and western, absent from the arid center, some present in Tasmania. Similar to those taxa, the WA form of *A. bancrofti* is likely a separate sister species, as well maybe that in Tasmania; this latter alluded to by Dumbleton (1973) for Tasmanian *Austrosimulium* spp. These situations warrant further investigation. Of possible interest with regard to eastern *A. bancrofti* as a species complex, is the apparent gap in distribution north of the ACT and the northern edge of NSW. For Tasmania, the distribution of *A. bancrofti* appears to follow Tyler's Line (Shiel *et al*., 1989; discussed by Craig *et al.*, 2019) where there is a sharp diagonal cutoff to the west, reminescent of that for *Austrocnephia orientalis* (Mackerras and Mackerras) (Craig *et al*., 2019). These distributions may represent, however, an artifact of collection.

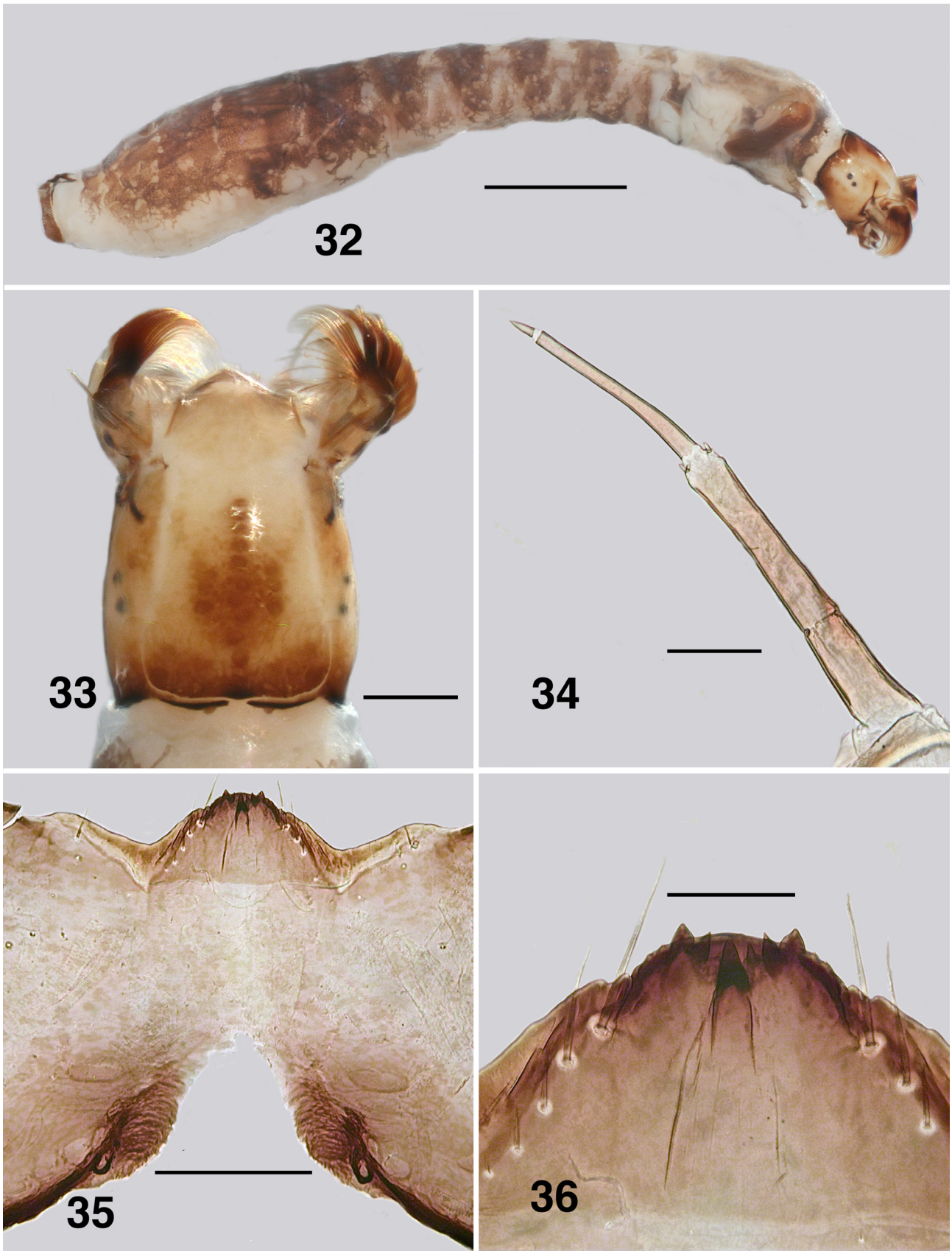
Remarks. Given the dates, a Western Australia specimen of *A. bancrofti* in the ANIC, reared by Drummond and labeled as follows [From pupa/ serpintine(sic)/16.4.20/ coll. F.H.D.] [Type {M}/Austrosimulium/ bancrofti] [Serpintine(sic)/ 10.4.20/ coll. F.H.D.] [Simulium/ bancrofti {M}/ Drawn) Tay/ ALLOTYPE], is considered to have no status as a Type. This peculiar usage of 'type' raises the question as to why the specimen accepted generally as the holotype, has the word "Allotype" on the label when all the specimens that Taylor had were female?

Drummond (1931) when describing the pupa remarked on the "ringed" nature of gill filaments adjacent to their insertion on the gill stem. Close inspection (Fig. 26) indicates it is actually concertinaed and of unknown function—perhaps flexibility? As far as known, such a character state is unique within Simuliidae. An expectation here, is that it would occur in the 'sister' species of the *bancrofti* species-group, namely *A. pestilens* and *A. magnum*—indeed, distinctly in the latter, less so in the former (DAC, pers. obs.). This character is possibly definitive for the species-group.

Bionomics. Because of serious biting by female adults of *A. bancrofti*, the species has been well investigated. Tonnoir (1925), oddly, made no comment, but Mackerras & Mackerras (1948: 258) gave considerable details. In short, at the Eidsvold type locality, few adults were netted even though a large population of immatures was present, that suggested to them rapid dispersal; albeit this might have been a timing issue. Immature stages were found in moderately clear, swift water (velocity 1.2 m/s), attached to clean substrates, either stones or larger vegetation. Larvae formed clumps with pupae in crevices out of the full force of water. The larvae could occur to a depth of 38 cm and were commonly associated with *A. pestilens* and *S. nicholsoni* Mackerras & Mackerras. Pupae took some three days to develop before the adults emerged. Mackerras & Mackerras (1949: 396) noted that *A. bancrofti* occurred after the peak emergence of *A. pestilens*; both associated with prior flooding. A drought-resistant stage was suggested. Mackerras & Mackerras (1952: 110) recorded that *A. bancrofti* females bit humans, dogs and rabbits.

Colbo (1974) made extensive investigation into the biology of Queensland simuliids, including climatic and geographic aspects. While eggs of *A. pestilens* had been discovered in vast numbers in substrate deposits, oviposition behaviour for *A. bancrofti* was not known. Determination of number of larval instars indicated that *A. bancrofti* had seven larval instars, of which the first instar possessed distinct labral fans—similarly known for other *Austrosimulium* spp. (*e.g*., Crosby, 1974; Craig *et al*., 2012). Early instar larvae drifted into faster water, which suggested oviposition might be upstream of such areas (Colbo & Moorhouse, 1979). Velocities in larval habitats ranged from 1.2 to 1.3 m/sec., in close agreement with Mackerras & Mackerras (1948). The larval period ranged from 18–25 days under the conditions of Colbo's observation. Of note, similar to Mackerras & Mackerras (*loc. cit*.), was that *A. bancrofti* larvae tended to clump together, even attaching to one another—given the high velocity of the water, a now well-known ploy to produce skimming flow and ameliorate drag (*e.g*., Moulton *et al*., 2018). This phenomenon is probably similar for *A. bancrofti* pupae, that formed groups numbering 8–85, all which were at the same stage of development. With regard to the sequence of species associated with flooding, *A. pestilens* occurred when discharge was high and water muddy, with *A. bancrofti* later at more moderate flows and clearer water; *S. ornatipes* occurred when flow was at base levels. Maximum breeding period was from June to September, less so during October–December when water flow was low and substrates covered with algae. Water temperatures of 20–28°C were recorded.

Colbo (1974: 189) recorded parasites from larvae of *A. bancrofti*. These appeared to the Blastocladiales *Coelomycidium* (?)*simulii* (Debais). The description is similar to that given by Craig *et al*. (2012) for examples from larvae of New Zealand *Austrosimulium*. Colbo also recorded the microsporidians *Thelohania* Henneguy and

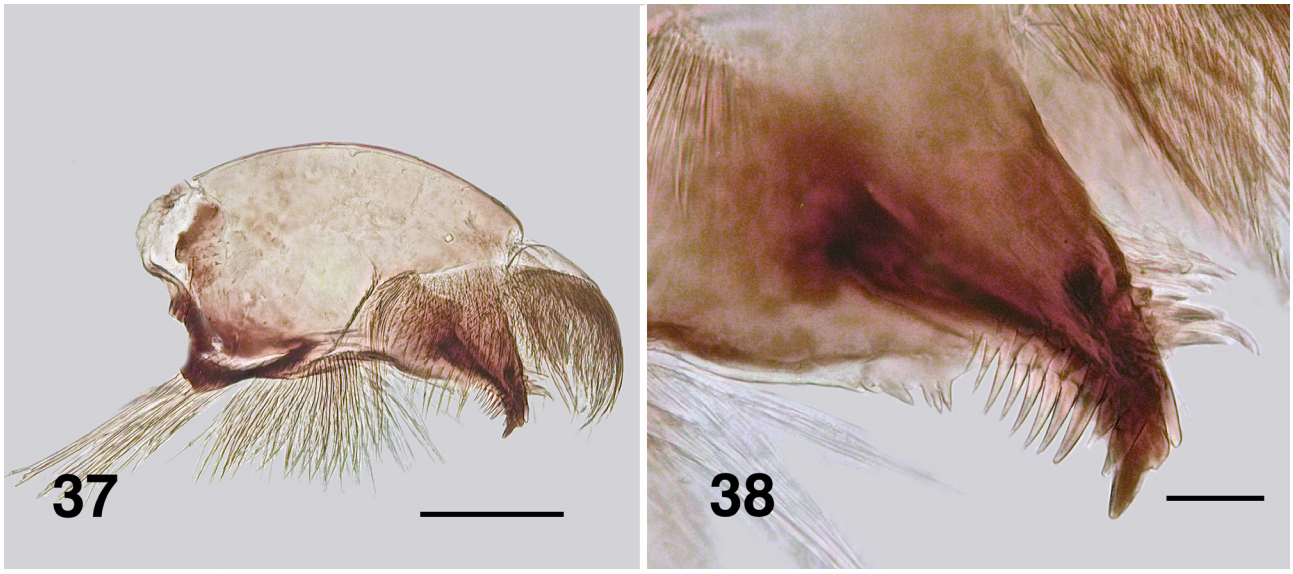


FIGURES 32–36. *Austrosimulium bancrofti* last instar larvae. (32) Habitus (NSW). Scale bar = 1.0 mm. (33) Head (NSW). Scale bar = 0.2 mm. (34) Antenna (NSW). Scale bar = 0.05 mm. (35) Postgenal cleft (NSW). Scale bar = 0.2 mm. (36) Hypostoma (NSW). Scale bar = 0.05 mm.

Pl(e)istophora (*sic*) Gurley. Also noted were unidentified mermithids in adults, albeit at markedly low levels and other nematodes, although apparently not of *Onchocerca*. No nematodes were recovered from *A. bancrofti* larvae, although such were moderately common in associated species, so Colbo (*loc. cit.*: 321) concluded that even though a nematode was known from *A. bancrofti*, transmission or any disease significance remained unlikely. Hunter & Moorhouse (1976a) described a gynandromorph and intersexes of *A. bancrofti* females that were infected with, again, unidentified mermithids.

Tang *et al*. (1996) in a phylogenetic analysis of simuliid vectors of human and bovine onchocerciasis, used *A. bancrofti* as the out-group taxon. They state that no Australian simuliids transmit the causative organism.

Armaments, such as teeth on the cibaria of biting flies, are generally considered as a first line defense against filarial pathogens. Colbo *et al*. (1979), examined cibaria of a suite of Simuliidae female adults, including *A. bancrofti*. Of the five species of *Austrosimulium* dealt with, all were similar with only fine spine combs on the cibarial cornua at the junction with the pharynx. Reid (1994) also examined the cibaria of *A. bancrofti* and other simuliids. In agreement with Colbo *et al*. (*loc. cit.*) the cibarium of *A. bancrofti* lacks teeth, albeit possess 'small spicules', classified as 'Type 2 cibarial armature'. These are not visible in Fig. 6 here. Reid (*loc. cit.*) lists *A. bancrofti* as a non-vector of filarial pathogens, not at variance to Colbo's (1974) conclusions, or later, Tang's (1996). On the other hand, earlier work by Lee *et al.* (1957), Lee *et al.* (1962: 374), plus Fenner & Radcliffe (1965: 198) suggested that *A. bancrofti* females are probably involved in transmission of livestock diseases including the causative virus of myxomatosis in rabbits.



FIGURES 37, 38. *Austrosimulium bancrofti* last instar larvae. (37) Mandible (NSW). Scale bar = 0.1 mm. (38) Mandible apex (NSW). Scale bar = 0.02 mm.

Lichtward & Williams (1990) recorded the trichomycetes *Harpella melusina* Leger & Duboscq, *Smittium simulii* Lichtward and *Paramoebidium* spp. from larvae of *A. bancrofti* from widely disparate localities.

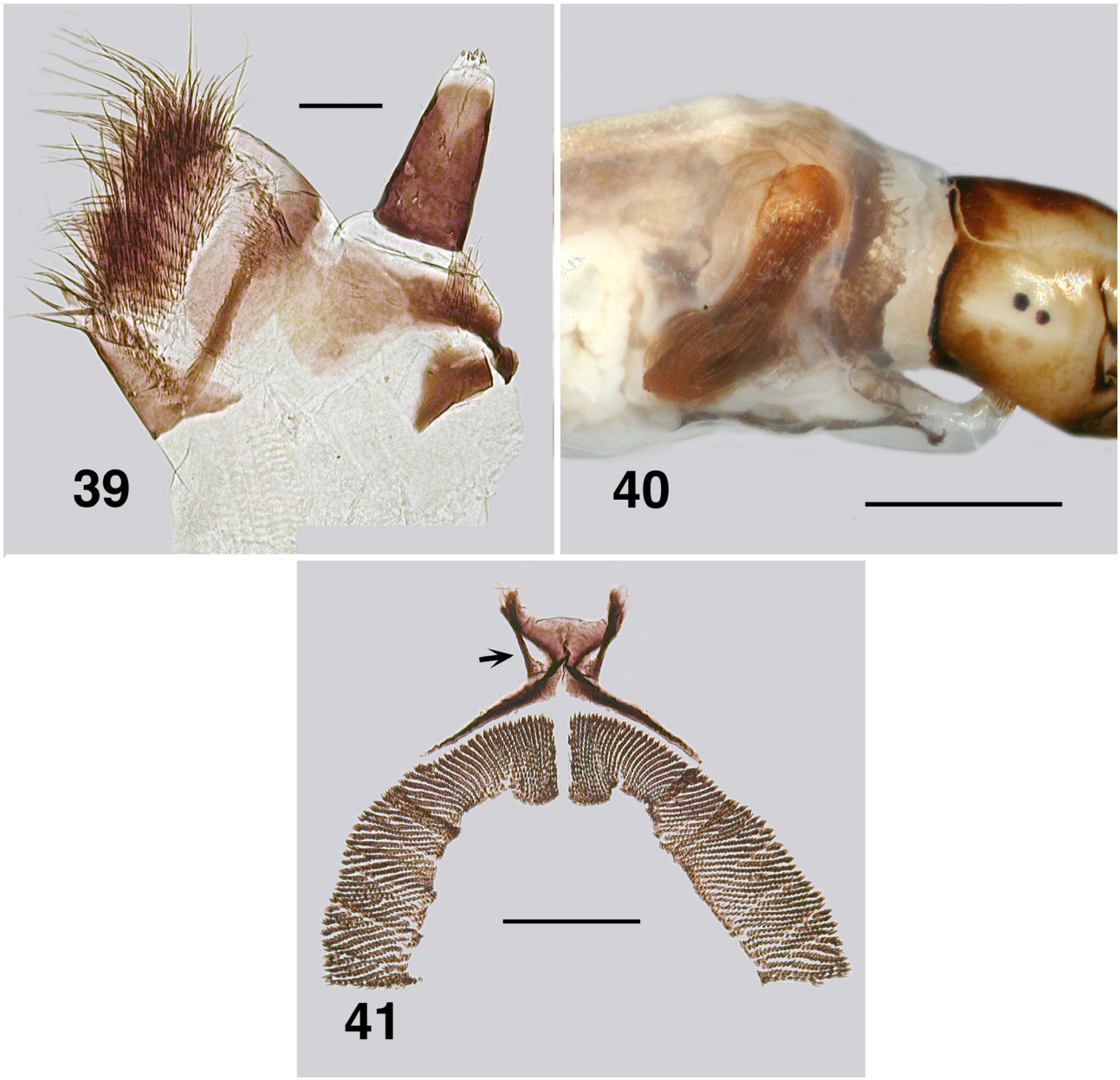
Sex ratio from a large sample of reared pupae was 46.4% males and 53.6% females (Colbo, 1974: 240). The major peak of adult emergence was 18:00 hrs (Colbo, 1977) and fly activity appeared to be related to temperature, females not being very active below 14°C. Oviposition behaviour of *A. bancrofti* is still unknown, albeit that for *A. pestilens* is well established (Moorhouse & Colbo, 1973; Hunter, 1979), the latter females deposit eggs on the water. A general assumption is that *A. bancrofti* females do the same. Females of *bancrofti* appear to be non-autogenous (requiring a blood meal for egg production). Average number of eggs recovered from gravid truck-trapped females was 123 (range 52–198)—considerably lower than for other species.

Hunter & Moorhouse (1976b) in a major comparison of bionomics of *A. pestilens* and *A. bancrofti,* noted that *A. bancrofti* larvae inhabited more permanent waterways and the adults dispersed soon after emergence, the latter observation in agreement with those earlier. Females congregated on hill tops some distance from the breeding site, presumably where mating took place. As noted by others, trapping of adults was influenced by temperature, as well as wind, light intensity and rain. Few adults were collected below 15°C, with no reduction in numbers at temperatures up to 30°C. Oddly, during that particular study, females did not bite any of the animals tested as hosts.

Mermithid-infected females were also recovered. Hunter (1977) investigated sugar feeding and survival of adults of *A. bancrofti*, *A. pestilens* and *Simulium ornatipes*—the former survived longer than the latter two. Considerably more information on immatures of *A. bancrofti* and associated simuliids can be garnered from Colbo & Moorhouse (1979).

Other aspects. Drummond (1931) when describing the pupa remarked on the "ringed" nature of gill filaments adjacent to their insertion on the gill stem. Close inspection (Fig. 26) indicates it is actually concertinaed and of unknown function—perhaps flexibility? As far as known, such a character state is unique within Simuliidae. An expectation here, is that it would occur in the 'sister' species of the *bancrofti* species-group, namely *A. pestilens* and *A. magnum*—indeed, well in the latter, less so in the former (DAC, pers. obs.). This character is possibly definitive for the species-group.

Lee *et al*. (1962) investigating the possibility of biting flies in Australia as vectors of disease in domesticated animals, obtained definitive precipitin tests for humans, horses and rabbits from field-caught blood-fed *A. bancrofti*. In summation (their Table 3), they list *A. bancrofti* as occurring in all States except South Australia and the Northern Territories and known, overall, to attack humans, horses, dogs, rabbits, kangaroos, wombats and eagles. As noted previously, they considered the species to be second in importance to *A. pestilens* as a pest.



FIGURES 39–41. *Austrosimulium bancrofti* last instar larvae. (39) Maxilla (NSW). Scale bar = 0.05 mm. (40) Thorax (NSW). Scale bar = 0.5 mm. (41 Anal sclerite & circlet of hooks (NSW). Arrow indicates 'interarm strut'. Scale bar = 0.2 mm.

The work by William J. Ballard and associates on *A. bancrofti* is considerable. Ballard (1988) described a method for sexing mature last larvae of *A. bancrofti*, using the shape of stained gonads. Ballard & Barnes (1988) in a preliminary examination of trap shape in regard to attraction for simuliid females, reasoned that a simulated shape of a host might reveal host preferences. Indeed, *A. bancrofti* females from Ipswich were attracted more to an elongated trap simulating a bovine host. The differences in behaviour between two populations (Ipswich and Taylors Arm) led to the suggestion that *A. bancrofti* was a species complex. Ballard (1989) further investigated the effect of silhouette shape of traps on capture of *A. bancrofti* adults. In general, higher numbers were captured under conditions of low wind speed and high cloud cover, with temperature and solar radiation also important, respectively 19°C and 620 watts/m^2 optimal, in agreement with earlier observation. Ballard & Morton (1990) examined the different trap-finding behaviour of two populations of *A. bancrofti* in Queensland. They found considerable differences between the two populations. Bovines were found to be the most attractive bait, with humans, bandicoots and chickens not attractive; the latter three non-attractive baits at major variance to other observations.

Of significance, Ballard & Bedo (1991) cytologically examined larvae of *Austrosimulium bancrofti* from four sites in eastern Australia. Eight cytoforms were recorded. Two cytoforms (A, B) were from Ipswich, another from Willawarin, plus one from Canberra and four (A, B, C, D) from Eidsvold, the type region. Some cytoforms were collected in sympatry, others not. The data suggested that *A. bancrofti* was a complex of at least eight cryptic species. This agreed with variation in behaviour of *A. bancrofti* adult females and larvae from near Ipswich, Willawarin and Canberra, previously known (Ballard 1989; Ballard 1990; Ballard and Barnes 1988; Ballard & Morton 1990; Ballard & Bedo, 1991), supporting the hypothesis that such populations of *A. bancrofti* were distinct sibling species. Ballard *et al*. (1992) used the above data as part of an examination of relationship between arthropods and onychophorans.

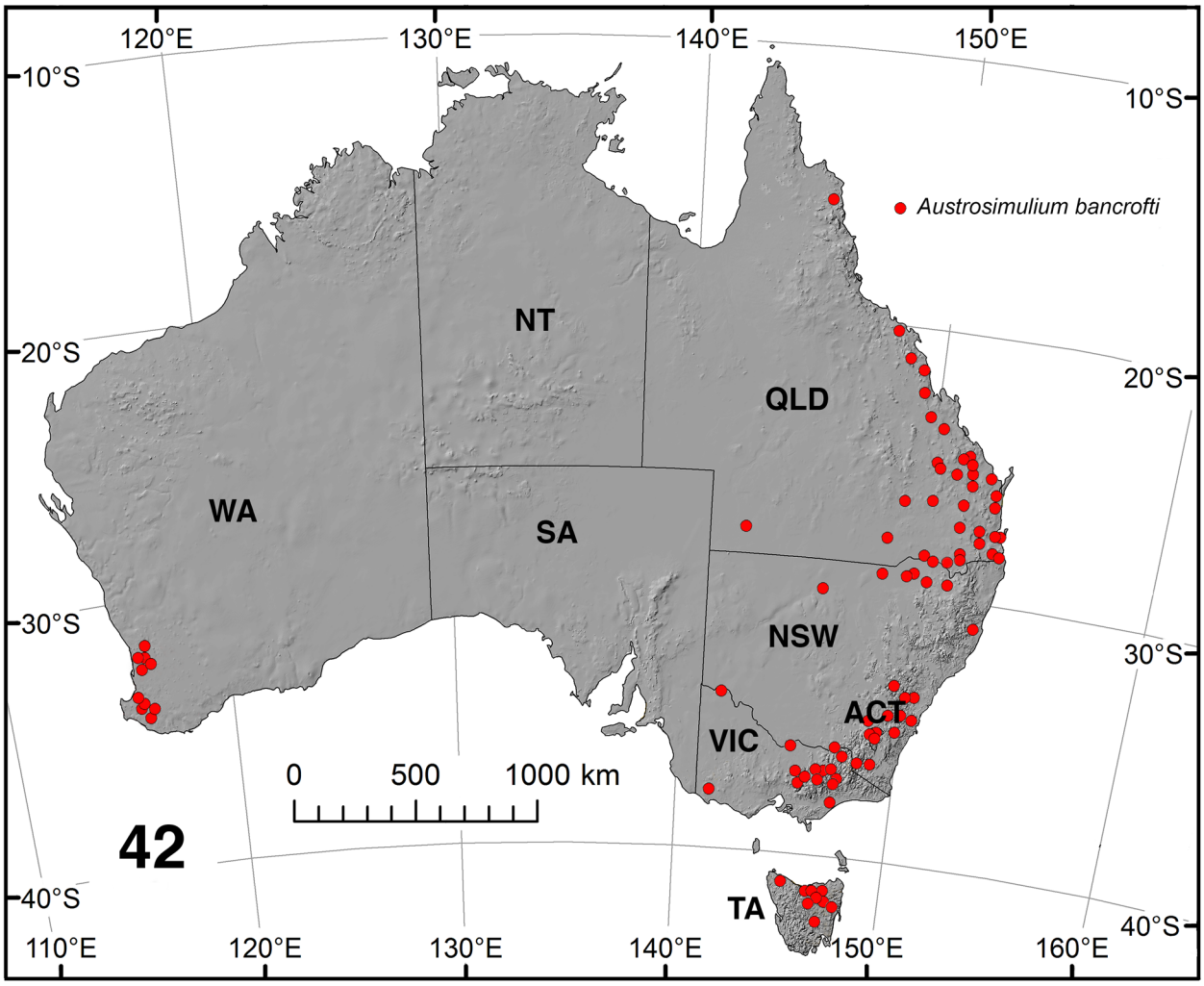


FIGURE 42. Map of Australia showing distribution of *Austrosimulium bancrofti*.

Bedo (1976) successfully prepared chromosomes from pupae and adults of a number of Australian simuliids, with those of *A. bancrofti* showing extensive asynapsis (*i.e.* failure of the pairing of homologous chromosomes during meiosis).

Ballard (1991) and Ballard *et al*. (1991) investigated colonization of artificial substrate by larvae of *A. bancrofti*. Larvae colonizing Perspex (aka Plexiglas) strips in the Brisbane River were collected during the Austral summer (January) and spring (October). Larvae of *S. ornatipes* and *S. nicolsoni* were taken in conjunction. For the latter study the majority of larvae were of the Ipswich cytoform. Determination of larval instars showed that there were six or seven instars in January and October respectively. Texture of the substrate was significant, with higher colonization on the rougher. Preferred velocity was high, 1.0–1.4 m/s, in agreement with the earlier work by Mackerras & Mackerras (1948) and Colbo (1974).

Ballard & Elder (1992), and Elder & Ballard (1993) used a major outbreak of *A. pestilens* and *A. bancrofti*, following flooding of the Fitzroy River, Rockhampton, QLD in 1991, to investigate trapping methods to quantify such outbreaks. They used two trap types with CO^2 plus a human-baited station, and used the biting rates to suggest thresholds for initiating control measures.

Ballard (1994) used 12S ribosomal RNA to investigate the problem of the variable antennae of *A. bancrofti* females, in relation to those of *A. pestilens*. Material available possessed variable numbers of flagellomeres, with some having the apical unit partially divided. Those with eight distinct flagellomeres were all shown to be definitively *A. pestilens*. Those with a variable number of five to seven flagellomeres and an incompletely divided apical flagellomere, were *A. bancrofti.* Analysis indicated that *A. bancrofti* from Rockhampton, Canberra and Ipswich were monophyletic (cytoform A). Further, a suggestion was made that there may well be an undescribed cytoform (Rockhampton) beyond the previously noted eight, recognized earlier by Ballard & Bedo (1991). Otsuka *et al*. (2007) used 16S rRNA for a phylogeny of Oriental *Simulium s.l*., with *A. bancrofti* as one of the out-group. Moulton (2000, 2003), similarly used *A. bancrofti* in a molecular analysis of simuliid basal relationships.

Indication that *A. bancrofti* is a complex of entities is also signaled by the morphological discrepancies between the eastern Australian forms and that from Western Australia. This includes the genital fork (*cf*. Figs. 11, 12) plus anal lobes and cerci of females (*cf*. Figs. 16, 17), and maxillary palpi of males (*cf*. Figs. 21, 22). Separate species would not be surprising given the situation of other Gondwanan simuliid genera in Australia (*e.g*., Currie *et al*., 2018; Moulton *et al*., 2018). With, however, the small amount of material available from Western Australia, new collections will be needed to resolve this state of affairs.

At a higher taxonomic level, *Austrosimulium bancrofti* was included by Gil-Azevedo & Maia-Herzog (2007) in a phylogenetic analysis of Southern Hemisphere Simuliidae, based on morphological characteristics. The relationship between *Austrosimulium* and *Paraustrosimulium* was well supported.

Austrosimulium bancrofti larvae were part of a study on the effect of salinity in stream ecosystems (Rutherford & Kefford, 2005) and similarly, part of a study on effect on aquatic ecosystems in Tasmania of insecticide drift from orchards (Brown & Walker, 2000).

Further work on *Austrosimulium bancrofti* should involve elucidating mating and oviposition behaviour of the adults. An effort also should be made to determine the specific status of Western Australia and Tasmania forms, to bring a similar level of understanding to that known for other Australian Gondwanan simuliids (*e.g*., Craig *et al*., 2017, 2019; Currie *et al*., 2018; Moulton *et al*., 2018). As well, distribution and relationships between the various cytoforms and their different biting behaviours (*e.g*., Ballard & Bedo 1991)—of considerable practical value in regards to control measures. There is still much to be done.

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