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A new subspecies of *Neolucia hobartensis* (Miskin, 1890) (Lepidoptera: Lycaenidae) from Mainland Southeastern Australia, with a Review of Butterfly Endemism in Montane Areas in this Region

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ABSTRACT. *Neolucia hobartensis albolineata* ssp. nov. is illustrated, diagnosed, described and compared with the nominate subspecies *N. hobartensis hobartensis* (Miskin, 1890) from Tasmania and *N. hobartensis monticola* Waterhouse & Lyell, 1914 from northern New South Wales, Australia. The new subspecies is restricted to montane areas (mainly >1000 m) in subalpine and alpine habitats on the mainland in southeastern Australia (southern NSW, ACT, VIC) where its larvae specialize on *Epacris* spp. (Ericaceae). It thus belongs to a distinct set of 22 butterfly taxa that are endemic and narrowly restricted to montane areas (>600 m, but mainly >900 m) on the tablelands and plateaus of mainland southeastern Australia. Monitoring of these taxa, including *N. hobartensis* ssp., is urgently required to assess the extent to which global climate change, particularly temperature rise and large-scale fire regimes, are key threatening processes.

KEYWORDS. Butterfly conservation; climate change; key threatening processes; Polyommatinae; taxonomy

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The lycaenid genus *Neolucia* Waterhouse & R.E. Turner, 1905 comprises three species all endemic to southern Australia (Braby, 2000). It is currently placed in the subfamily Polyommatinae, a large polyphyletic assemblage nested within the Theclinae (Espeland *et al.*, 2018). Within this group, *Neolucia* is morphologically distinct with no close relatives (Hirowatari, 1992): the dorsal surface of

the wings are uniformly dark bronze-brown, the egg is truncate dorsally with three prominent horizontal series of projections, and the larvae feed mainly on Ericaceae (with one species on Fabaceae) and are usually not attended by ants. *Neolucia hobartensis* (Miskin, 1890), commonly known as the ‘Montane Heath-blue’, is a polytypic species endemic to southeastern mainland Australia and Tasmania

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(Couchman & Couchman, 1977; Virtue & McQuillan, 1994; Braby, 2000; Field, 2013; Bond, 2016). All species of *Neolucia* occur in montane areas, but *N. hobartensis* is the only species restricted to high altitudes. Indeed, it is one of very few species of butterflies in Australia endemic to subalpine and alpine habitats (i.e. above the tree-line).

Two subspecies of *N. hobartensis* have been recognized: the nominate subspecies *N. hobartensis hobartensis* (Miskin, 1890) from Tasmania, and *N. hobartensis monticola* Waterhouse & Lyell, 1914 from montane areas in northern New South Wales (Braby, 2000, 2016). *Neolucia hobartensis monticola* was differentiated by several characters, namely larger size, darker underside ground colour, and darker upperside ground colour (Waterhouse & Lyell, 1914). Common & Waterhouse (1981) added that in the male the long hairs (androconia) on the upperside of the fore wing are more extensive. Material between the geographical ranges of these two subspecies (i.e. southern New South Wales, the Australian Capital Territory and Victoria) has been provisionally placed with *N. hobartensis hobartensis*, although Braby (2000, p. 820) noted that “The extent of the whitish patch on the underside of the hind wing varies considerably between populations from southern NSW, VIC and TAS.” Closer examination of a large series of specimens from this region, and comparison with the types of both *N. hobartensis hobartensis* and *N. hobartensis monticola*, has revealed that this geographically isolated population(s) is indeed distinct. The purpose of this paper is to describe the population(s) from this intervening region taxonomically. We also review the occurrence of butterflies endemic to the mountains and highlands of southeastern Australia, and comment on the subspecies’ restricted occurrence in montane areas and the potential risk of global climate change as a key threatening process.

The following abbreviations refer to repositories where material has been examined:

AMS	Australian Museum, Sydney
ANIC	Australian National Insect Collection, Canberra
NMV	Museum Victoria, Melbourne
QM	Queensland Museum, Brisbane
GEWC	Private collection of G. E. Wurtz, Albury

Taxonomy

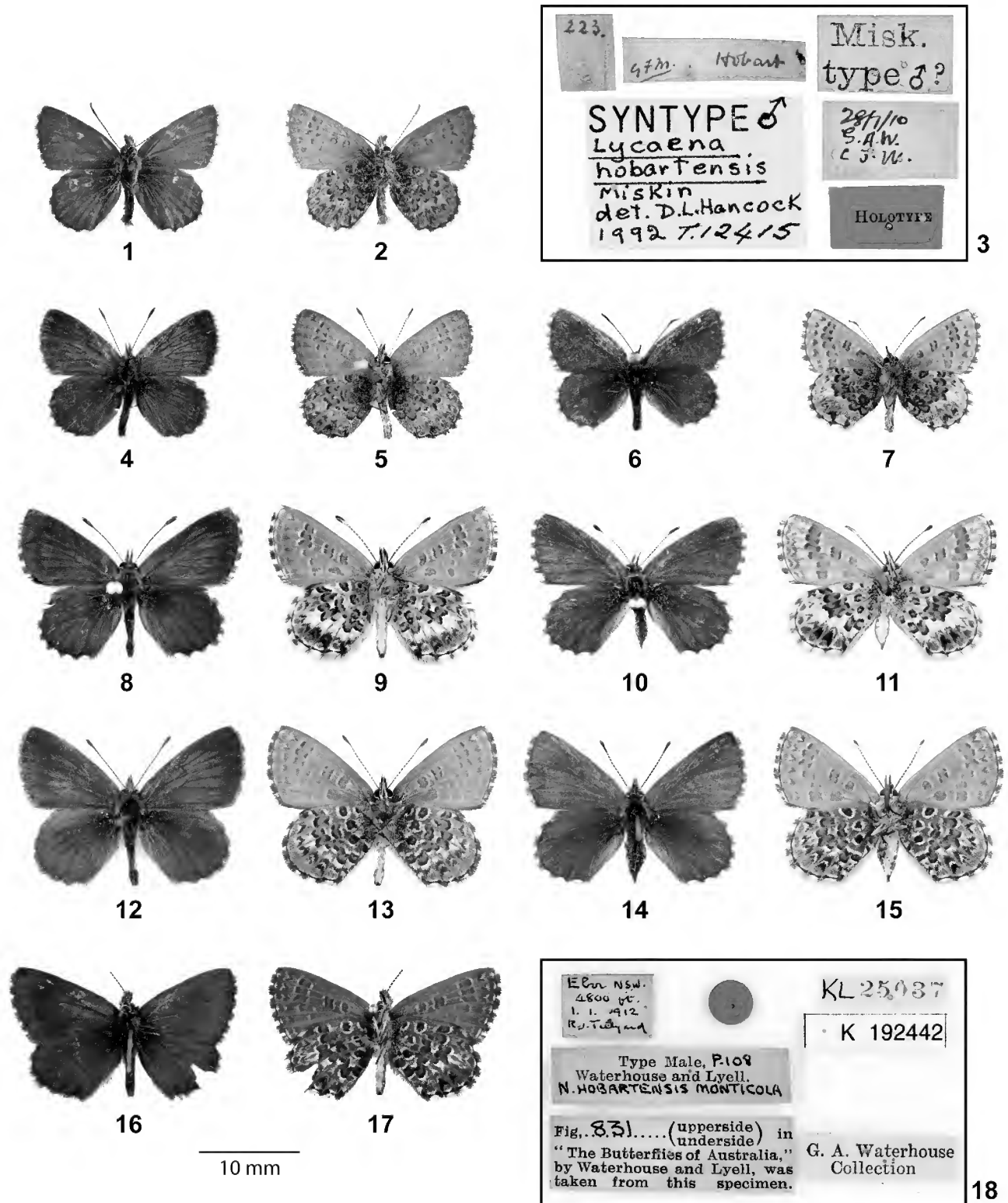
Neolucia hobartensis albolineata ssp. nov.

Figs 8–11

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Holotype ♂, “Smokers Gap, ACT, 25 DEC. 1998, M.F. Braby” (ANIC). **Paratypes** 55♂♂, 27♀♀. **Australian Capital Territory:** ♂ “SMOKER GAP, ACT, 1244 ALT, 6 JAN 1980, NB TINDALE” (ANIC); 4♀ “SMOKER’S GAP, CORIN DAM, ACT, 26th Jan 1987, GE Wurtz” (GEWC); ♂ “Smokers Gap, ACT, 12-Jan-1992, EGGLETON” (ANIC); 3♂, 2♀ “Smokers Gap, ACT, 5 FEB. 1995, M.F. Braby” (ANIC); 5♂, 3♀ “Smokers Gap, ACT, 25 DEC. 1998, M.F. Braby” (ANIC); 9♂, 2♀ “Smokers Gap, ACT, 16 JAN. 1999, M.F. Braby” (ANIC); ♀ “Smokers Gap, ACT, emg. 8 JAN. 1999, pupated 30 DEC. 98, M.F. Braby | reared from larva on EPACRIS BREVIFLORA flowers” (ANIC); ♀ “Smokers Gap, ACT, emg. 10 JAN. 1999, pupated 31 DEC. 98, M.F. Braby | reared from larva on *Epacris breviflora* flowers” (ANIC); ♀ “Smokers Gap, ACT, emg. 10 JAN. 1999, pupated 1 JAN. 99, M.F. Braby | reared from larva on EPACRIS BREVIFLORA flowers” (ANIC); ♂ “Mt. Gingera, A.C.T., 24 Jan. 1951, M.F. Day” (ANIC); ♂ “Mt. Gingera, A.C.T. 6000 ft., 25 Jan. 1956, I.F.B. Common” (ANIC); ♀ “Mt. Gingera, A.C.T. 5500 ft., 22-1-1956, I.F.B. Common” (ANIC); 3♂ “Mt. Gingera, A.C.T. 5500 ft., 6 Feb. 1962, I.F.B. Common” (ANIC); 6♂ “Mt. Gingera, ACT. 5500 ft., 5 Feb. 1969, I.F.B. Common & A.E. May” (ANIC); ♂, 2♀ “Mt. Gingera, A.C.T. 1670 m, Emg. 25 Jan. 1971, E.D. Edwards”, “6/71 Larva on flowers *Epacris petrophila*” (ANIC); ♀ same data but with date “Emg. 28 Jan. 1971” (ANIC); 4♂ “1 MI NE of Lee’s Springs, A.C.T. 4000 ft, 30 Jan. 1957, I.F.B. Common” (ANIC); ♂, 2♀ “Mt. Franklin, ACT. 4800 ft., 5 Feb. 1969, I.F.B. Common & A.E. May” (ANIC); 1♂ “[3.6 km S by road of] GIBRALTAR FALLS, TIDBINBILLA RGE, ACT, 4th Jan 1980, GE Wurtz” (GEWC); 1♂ “[3.6 km by road S of] GIBRALTAR FALLS, TIDBINBILLA RGE, ACT, 26th Jan 1987, GE Wurtz” (GEWC); 2♂ “HONEYSUCKLE CK, ACT, 29th NOV 1980, ANDREW ATKINS” (ANIC); 1♀ “Honey Suckle Crk, ACT, S 35.35.5, E 148.58, 2nd Feb 1984, GE Wurtz” (GEWC); 2♀ “Honeysuckle Ck, Namadgi NP, ACT, 1080 m, 35°35’S, 148°59’E, 15 JAN. 1995, M.F. Braby” (ANIC); 6♂, ♀ “Brindabella Ra., A.C.T., 21 Jan. 1981, J.F.R. Kerr” (ANIC); 8♂, 2♀ “2 STICKS ROAD, BRINDABELLA RANGE, W. CANBERRA, ACT, 14th Jan 1979, GE Wurtz” (GEWC); ♂ “2 km NTH of PICCADILLY CIRCUS, A.C.T., 21 JAN. 1984, K.L. DUNN, C.E. ASTON” (ANIC); ♀ “2.2 km N. Piccadilly Circus, ACT, 12 JAN. 1997, M.F. Braby” (ANIC). **New South Wales:** 6♂, ♀ “E.D. EDWARDS, 25.1.70, Boyd R, N.S.W., AUSTRALIA” (ANIC).

Other material examined An additional 638 specimens from New South Wales and Victoria currently lodged in the ANIC (263♂, 106♀), NMV (106♂, 28♀), AMS (76♂, 28♀) and GEWC (18♂, 13♀) were examined (Table 1). Locations for these specimens are as follows. **New South Wales:** South Black Range, Tallaganda NP, 9 km E of Hoskinstown (4♂, 2♀); Cumberland Range, Talbingo (2♂); Tinderry Mountains (2♂, 1♀); 2 km SE of Tantangara Dam (1♂); 10 mls E of Kiandra, NSW (2♂); 1 km W of Three Mile



Figures 1–18. Adult specimens of *Neolucia hobartensis*: (1–3) *N. hobartensis hobartensis* lectotype male (QM) showing upperside, underside and labels; (4–7) *N. hobartensis hobartensis* from Tasmania: 4 and 5, male upperside and underside “Pine Tier Lake, TAS, S42.04.14, E146.28.74, 16th Jan. 2013, G.E. Wurtz” (GEWC), 6 and 7, female upperside and underside “Mt. Barrow, T. 4000 ft., 4 Mar. 1963, I.F.B. Common & M.S. Upton” (ANIC); (8–11) *N. hobartensis albolineata* ssp. nov. from ACT and southern NSW: 8 and 9, holotype male upperside and underside “Smokers Gap, ACT, 25 DEC. 1998, M.F. Braby” (ANIC), 10 and 11, paratype female upperside and underside “E.D. EDWARDS, 25.1.70, Boyd R, N.S.W., AUSTRALIA” (ANIC); (12–15) *N. hobartensis monticola* from northern NSW: 12 and 13, male upperside and underside “Barrington Tops, NSW, 23 Jan. 1987, J.F.R. Kerr” (ANIC), 14 and 15, female upperside and underside “Barrington Tops, NSW, 23 Jan. 1987, J.F.R. Kerr” (ANIC); (16–18) *N. hobartensis monticola* lectotype male (AMS) showing upperside, underside and labels.

Table 1. Spatial data for all specimens examined. Geocoordinates (lat/long) and altitudes were either extracted directly from the specimen label data (where given), from the private database of D. F. Crosby, or inferred from the *Location* using the Gazetteer of Australia Place Name Search (<http://www.ga.gov.au/placename>) and Google Earth Pro. All inferred geocoordinates and altitudes are highlighted in red, the number of decimal points indicates precision.

location	from label data				inferred data				♂	♀
	State	altitude	latitude	longitude	altitude (m)	latitude	longitude			
1 mi NE of Lees Springs	ACT	4000 ft	—	—	1220	-35.3	148.8	4	—	
Two Sticks Rd, 2 km N of Piccadilly Circus	ACT	—	—	—	1230	-35.3431	148.7964	9	3	
Mt Franklin	ACT	4800 ft	—	—	1460	-35.4856	148.7747	1	2	
[3.6 km by road S of] Gibraltar Falls, Tidbinbilla Rge	ACT	—	—	—	1190	-35.5083	148.9278	2	—	
Smokers Gap	ACT	1240 m	—	—	1240	-35.5180	148.9157	20	14	
Mt Gingera	ACT	5500–6000 ft	—	—	1670–1830	-35.5764	148.7797	12	3	
Honeysuckle Creek, Namadgi NP	ACT	1080 m	35°35'S	148°59'E	1080	-35.583	148.983	2	3	
Brindabella Range	ACT	—	—	—	—	—	—	6	1	
Boyd River	NSW	—	—	—	1220	-33.9667	150.0500	6	1	
South Black Range, [Tallaganda NP], 9 km E of Hoskinstown	NSW	—	—	—	1100	-35.4	149.5	4	2	
Cumberland Range, Talbingo	NSW	—	—	—	1140	-35.6167	148.3667	2	—	
Tinderry Mtns	NSW	4000 ft	—	—	1220	-35.7333	149.2667	2	—	
2 km SE of Tantangara Dam	NSW	—	35°48'S	148°41'E	1220	-35.8	148.7	1	—	
10 mi E of Kiandra	NSW	—	—	—	1340	-35.8667	148.6667	2	1	
1 km W of Three Mile Dam, Kosciuszko NP	NSW	—	35°53'38"S	148°26'34"E	1500	-35.894	148.443	18	3	
Ogilvies Creek	NSW	—	—	—	1400	-36.0483	148.3344	3	1	
Hotel Kosciuszko, Diggers Creek	NSW	5100 ft	—	—	1550	-36.2333	148.5167	16	—	
Mt Stilwell, Kosciuszko NP	NSW	1900 m	—	—	1900	-36.4167	148.3167	1	2	
Alpine Way, 7 mi NE of Thredbo	NSW	3800 ft	—	—	1160	-36.4	148.4	15	1	
Mt Kosciuszko ¹	NSW	4000–7000 ft	—	—	1220–2190	-36.45	148.25	80	27	
Brown Mountain [12 km SE of Nimmitabel]	NSW	—	—	—	1240	-36.5983	149.3844	3	1	
Mt Buffalo	VIC	4500 ft	—	—	1370	-36.7167	146.8167	3	3	
Glen Wills	VIC	—	36°50'30"S	147°30'30"E	1060	-36.8417	147.5083	3	7	
Tolmie [Toombullup]	VIC	—	—	—	820	-36.9167	146.2667	6	—	
Mt Cope	VIC	—	—	—	1820	-36.9270	147.2811	—	2	
Mt Hotham	VIC	—	—	—	1730	-36.98	147.13	18	4	
Brandy Creek, Hotham Heights	VIC	—	—	—	1370	-37.0	147.2	—	1	
4 km S[E] of Mt Hotham	VIC	—	37°00'30"S	147°10'30"E	1390	-37.008	147.175	—	1	
Mt St Bernard	VIC	—	37°00'30"S	147°02'30"E	1070	-37.008	147.042	—	—	
Cobbler Plateau	VIC	—	—	—	1580	-37.0436	146.5906	—	1	
Bindaree Hut	VIC	2750 ft	—	—	840	-37.1667	146.5333	1	2	
Howqua River	VIC	—	37°10'30"S	146°32'30"E	840	-37.175	146.542	2	—	
2 km E of Lost Plain	VIC	1370 m	—	—	1370	-37.33	146.67	—	1	

¹ Label data refers to altitudes or stations at 4000, 5000, 5400, 6000, and 7000 ft.

Table 1. Continued.

location	from label data				inferred data				
	State	altitude	latitude	longitude	altitude (m)	latitude	longitude	♂	♀
Lost Plain	VIC	1480 m	37°20'S	146°40'E	1480	-37.33	146.67	1	—
Mt Reynard	VIC	—	37°23'30"S	146°45'30"E	1500	-37.392	146.758	—	—
Shaws Creek, Bennison High Plains (near Licola)	VIC	—	37°28'30"S	146°42'30"E	1300	-37.475	146.708	—	1
Shaws Creek, Tamboritha Saddle	VIC	1200–1280 m	—	—	1200–1280	-37.4767	146.7069	1	5
Lake Mountain	VIC	—	—	—	1350	-37.5	145.9	3	—
5 km N[E] of Licola	VIC	—	—	—	1000	-37.537	146.644	—	1
Mt Erica	VIC	4500 ft	37°42'30"S	146°58'30"E	1370	-37.708	146.975	31	7
Mt St Gwinear	VIC	4950 ft	—	—	1510	-37.8	146.3	2	1
Mt Baw Baw village	VIC	1470 m	37°50'28"S	146°16'03"E	1470	-37.841	146.268	1	—
Mt Baw Baw	VIC	4700–5130ft	37°50'30"S	146°16'30"E	1430–1560	-37.842	146.275	223	99
subtotals (= total 720 specimens)								519	201

Dam, Kosciuszko NP (18♂, 3♀); Ogilvies Creek (3♂, 1♀); Hotel Kosciuszko, Diggers Creek (16♂, 2♀); Mt Stilwell, Kosciuszko NP (1♂, 1♀); Alpine Way, 7 mls NE of Thredbo (15♂); Mt Kosciuszko, NSW (80♂, 27♀); Brown Mountain [near Nimmitabel] (3♂, 1♀). **Victoria:** Mt Buffalo (3♂, 3♀); Glen Wills (3♂, 8♀); Toombullup via Tolmie (6♂); Mt Cope (2♀); Mt Hotham (18♂, 4♀); Brandy Creek, Hotham Heights (1♀); 4 km S[E] of Mt Hotham (1♀); Cobbler Plateau (1♀); Bindaree Hut / Howqua River (3♂, 2♀); Lost Plain (1♂); 2 km E of Lost Plain (1♀); Shaw's Creek, Tamboritha Saddle / Bennison High Plains (16♂, 6♀); 5 km N[E] of Licola (1♀); Lake Mountain (3♂); Mt Erica (29♂, 7♀); Mt St Gwinear (2♂, 1♀); Mt Baw Baw (223♂, 99♀). It has also been collected from Mt St Bernard (1♂) and Mt Reynard (1♂), VIC (D.F. Crosby, pers. comm.).

Diagnosis. *Neolucia hobartensis albolineata* is distinguished from *N. hobartensis hobartensis* (Figs 1, 2, 4–7) by the following four character states: (a) specimens of both sexes are substantially larger than those of *N. hobartensis hobartensis*; (b) the underside ground colour of the fore wing in males is greyish-brown, with the markings usually more distinct, particularly the postmedian band which is often more contrasted (darker) against the ground colour and conspicuously edged with dark brown and then white, whereas in *N. hobartensis hobartensis* the ground colour is grey, with the markings generally more obscure or less contrasting. This character, however, is not applicable in females. (c) The white postmedian band or patch on the underside of the hind wing in both sexes is broader and more conspicuous, whereas in *N. hobartensis hobartensis* the white band or patch is often absent; when present it is substantially smaller in extent and less clearly defined; (d) the markings on the underside of the hind wing in males, particularly the subbasal and median series of spots, are generally more distinct, being darker brown against a white ground colour, although this character is variable in both *N. hobartensis albolineata* and *N. hobartensis hobartensis* and is not applicable in females. In *N. hobartensis albolineata*, the ground colour of the basal area of the hind wing may be broadly white, a feature that is absent in both *N. hobartensis hobartensis* and *N. hobartensis monticola*.

Neolucia hobartensis monticola (Figs 12–17) is similar in size to *N. hobartensis albolineata*, but it differs in having the underside ground colour of the fore wing and basal area of the hind wing brown, and the white postmedian band or patch on the underside of the hind wing absent or smaller in extent and less clearly defined. The extensive brown underside ground colour is diagnostic of *N. hobartensis monticola* and this feature no doubt contributed to Waterhouse & Lyell's (1914, p. 108) conclusion that the subspecies is "much darker both above and beneath". Dissection and examination of the male genitalia of two specimens of each subspecies revealed no significant differences between *N. hobartensis hobartensis*, *N. hobartensis albolineata* and *N. hobartensis monticola*.

Description. The species *Neolucia hobartensis* has been adequately described and illustrated previously, by Waterhouse & Lyell (1914), Common & Waterhouse (1981) and Braby (2000); hence, only a brief description is provided here for *Neolucia hobartensis albolineata*.

Male. Fore wing length 12.0 mm (holotype). Upperside dark bronzy-brown, with scale-fringe chequered dark brown

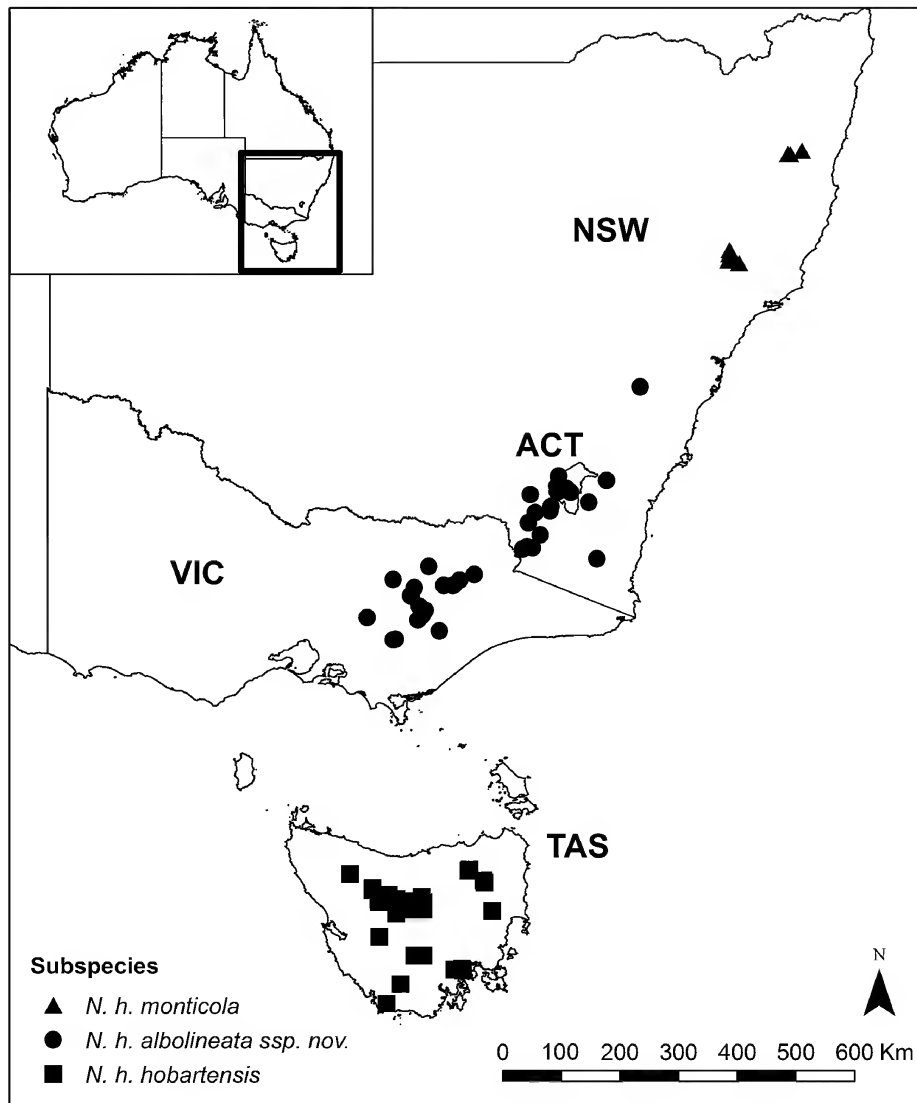


Figure 19. Map of southeastern Australia showing geographical distribution of *Neolucia hobartensis*. Records for *N. hobartensis albolineata ssp. nov.* are based on museum specimen material examined in this study, whereas those for *N. hobartensis hobartensis* and *N. hobartensis monticola* are from the Atlas of Living Australia (biocache.ala.org.au accessed 1 May 2018)

and white. Fore wings covered with long hairs (androconia) parallel to veins. Underside of fore wing ground colour grey-brown, with a series of slightly darker markings edged narrowly with dark brown and white, markings comprise a subbasal spot and a larger median spot in discal cell, an obscure median spot above vein 1A+2A and a conspicuous postmedian band from above vein M_1 to below vein CuA_2 , followed by one or two obscure dark subterminal bands, and a narrow brown-black terminal line; hind wing with a series of dark brown subbasal and median spots or markings which often coalesce, edged narrowly with black and usually broadly surrounded with white, followed by a prominent white postmedian band or patch, usually two indistinct black inverted V-shaped subterminal marks, and a narrow black terminal line.

Female. Fore wing length 9.6–11.4 mm (paratypes). Similar to male, but upperside without androconia; underside ground colour paler with markings more distinct, and termen of wings more rounded.

Variation. Specimens from the Kosciuszko Plateau, NSW,

particularly near the summit of Mt Kosciuszko (1900–2190 m), are unusual. They are smaller in size, paler brown, and the underside markings of the hind wing frequently lack the distinct contrasting pattern of spots and the conspicuous white postmedian band or patch is often absent or substantially reduced in extent. In many respects they resemble *N. hobartensis hobartensis* or *N. mathewi* (Miskin, 1890). Further investigation of this high altitude population is warranted to determine if the distinct phenotype has a genetic or environmental basis.

Remarks. *Neolucia hobartensis* was originally described by Miskin (1890) under the name *Lycaena hobartensis* Miskin, 1890 from Tasmania, with Mt Wellington near Hobart the type locality (Waterhouse, 1928). Miskin (1890, pp. 38–39) did not designate a type in the original description, which may have been based on a single specimen (but see Hancock, 1995). Waterhouse (1928) referred to a type, and Couchman (1956) referred to a holotype, though gave the sex as female, and referred to a second specimen. Hancock (1995) referred to a syntype male in the QM and gave label data. Edwards

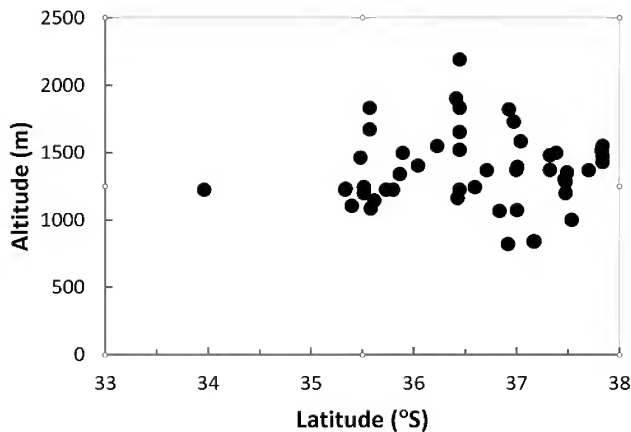


Figure 20. Scatter plot of altitude against latitude for each location of *Neolucia hobartensis albolineata* ssp. nov. based on specimen label data in the ANIC, NMV and GEWC.

et al. (2001) interpreted Waterhouse's reference to a type as a lectotype designation. The lectotype male is illustrated in Figs 1–3.

Twenty-four years after Miskin's description, Waterhouse & Lyell (1914) described the subspecies *Neolucia hobartensis monticola* Waterhouse & Lyell, 1914 based on a series of specimens from Ebor, NSW (9♂, 10♀). Waterhouse & Lyell (1914) illustrated a syntype male (figure 831), but they did not designate a type in the original description. Peters (1971) subsequently referred to a holotype in the AMS and provided a registration number (KL.25037). Edwards *et al.* (2001) interpreted Peter's incorrect reference to a holotype as a lectotype designation. We have examined the lectotype male (Figs 16–18) and the 18 paralectotypes in AMS and they agree with Waterhouse & Lyell's (1914) concept of *N. hobartensis monticola*.

It is perhaps surprising that the new geographically intermediate subspecies described herein was overlooked by G. A. Waterhouse, and has since remained unrecognized for more than 100 years since the revisionary work of Waterhouse & Lyell (1914) given the large number of specimens (721) available in public museums and the private collection of GEW from a relatively accessible and well-collected region of Australia. However, Waterhouse & Lyell's (1914) description of *N. hobartensis monticola* and examination of the G. A. Waterhouse collection in AMS revealed that in the early 1900's the diagnosis of *N. hobartensis monticola* was based chiefly on comparison of their material from Ebor with specimens from only four other locations: New South Wales (22♂, 5♀ Mt Kosciuszko), Victoria (3♂, 1♀ Mt Erica; 1♂, 1♀ Mt Hotham) and Tasmania (5♂ Mt Wellington). Thus, it is clear that of the material in AMS G. A. Waterhouse placed under *N. hobartensis hobartensis* the vast majority (71%) came from Mt Kosciuszko, most of which was collected by himself during an expedition in 27–29 January 1906 (Edwards, 2002). However, as noted above, material from the Kosciuszko Plateau is not typical of *N. hobartensis albolineata* elsewhere on the Australian mainland: although this population is variable, the specimens are generally smaller and paler and a large proportion (c. 60%) lack the diagnostic white patch on the underside of the hind

wing. Thus, comparison of this anomalous high altitude population with typical *N. hobartensis hobartensis* from Mt Wellington would explain lack of recognition of the southern mainland populations as being taxonomically distinct from the Tasmanian populations at that time.

Etymology. The name *albolineata* is derived from the Latin word *albus*, which means white, and the Latin word *lineatus*, which means lined, and refers to the broad white postmedian line or band on the underside of the hind wing. The species group name is thus a compound descriptive name comprising an adjective-adjective combination with the ending of the second name in feminine form to agree with the gender of the generic name (*Neolucia*) with which it is combined, according to Article 31.2 of the International Code of Zoological Nomenclature (1999).

Distribution. *Neolucia hobartensis albolineata* occurs in southeastern Australia where it has a patchy distribution in the southeastern highlands of the mainland along and adjacent to the Great Dividing Range. It extends from the South Black Range in Tallaganda National Park east of Hoskinstown, NSW (Braby, 2000) and the Brindabella Range (1.5 km NE of Lees Spring south of Mt Coree), ACT (Kitching *et al.*, 1978), southwest to Mt Baw Baw (Quick, 1973) and Lake Mountain (Quick, 1973), VIC (Fig. 19). The record further north from the Boyd River, NSW (1220 m) (E. D. Edwards), represents a disjunct population located approximately 170 km NNE of Hoskinstown. The subspecies is restricted to montane areas, mainly above 1000 m, although a plot of available specimen data indicates no clear relationship between altitude and latitude across the geographical range of *N. hobartensis albolineata* ($r = 0.072$, $P > 0.05$) (Fig. 20). Most specimens have been collected at altitudes between 1100–1800 m. The only records above 1900 m are from the Kosciuszko Plateau, NSW, which represents the highest altitude occurrences (up to 2190 m) within the geographic range of *N. hobartensis albolineata*. The only records below 1000 m that we are aware of are the series of specimens (3♂, 2♀) from Bindaree Hut / Howqua River, VIC (840 m), collected by the late W. N. B. Quick and D. F. Crosby on 3 Dec. 1972, and another series (6♂) from Toombullup near Tolmie, VIC (820 m), collected by M. F. Braby on 17 Dec. 1983.

The published record further east of the Boyd River from Medlow Barth near Kanangra Walls in the Blue Mountains, NSW (1060 m) by Edwards (1963) is erroneous—the specimens collected are actually *N. agricola* (Westwood, 1851) (E. D. Edwards, pers. comm). Material (2♂) in the ANIC from the low altitude town of “Valencia Creek, VIC” collected by D.F. Crosby on 15 NOV. 1961 is erroneous and refers to Mt Erica (D.F. Crosby, pers. comm. 2018). A female specimen in AMS labelled “Mylor, S. Australia, 30 Nov. 1902 | 023”, “G. A. Waterhouse Collection”, “KL24887”, and a male in AMS labelled “Woodside, S. Aust., M. W. Mules”, “Nov - 22nd 1933”, “G. A. Waterhouse Collection”, “KL24890” are considered to be erroneous. The species is not known to occur in the Mt Lofty Ranges near Adelaide, SA.

Biology. The biology of the subspecies, including descriptions or illustrations of the immature stages, life history and developmental times, has been well documented (Quick, 1973; Common & Waterhouse, 1981; Braby, 2000; Field, 2013; Bond, 2016). The larvae specialize on

the flowers and new foliage of *Epacris* spp. (Ericaceae), including *E. petrophila* Hook.f., *E. breviflora* Stapf and *E. paludosa* R.Br., growing in subalpine and alpine heathland or heathy open-woodland on acidic soils, especially along edges of swamps or along boggy creeks. The life cycle has an embryonic diapause that persists for about nine months of the year, mainly from autumn to spring.

The larval food plant of *N. hobartensis hobartensis* in Tasmania is *Epacris serpyllifolia* R.Br. (Virtue & McQuillan, 1994), whereas that of *N. hobartensis monticola* in northern New South Wales has not previously been identified. Waterhouse (1932, p. 170) reported the food plant for the latter subspecies in only general terms "... at Barrington Tops in January, this butterfly was very plentiful at the edges of the swamps, where two species of *Epacris* were growing. By beating these, I obtained a number of nearly full-grown larvae. These were all feeding on the *Epacris* with yellowish-green leaves and small white flowers." Since Waterhouse's observations, the species-level identity of the larval food plant of *N. hobartensis monticola* has remained undetermined. However, during a visit to Barrington Tops National Park, NSW the food plant was determined to be *Epacris rhombifolia* (L.R.Fraser & Vickery) Menadue—at Polblue Swamp (1450 m) adults flew in close proximity to this shrub growing along the edge of open swampland, and a female was observed on two occasions to lay eggs on the stems above the leaf axils on 27 January 2018 (M. F. Braby, unpublished data).

Discussion

The subspecies described herein fits the criteria proposed by Braby *et al.* (2012) for subspecies delineation of butterflies, namely the taxon is allopatric, phenotypically distinct (in colour pattern and morphology), and has at least one fixed diagnosable character state. We assume the taxon represents a partially isolated lineage from *N. hobartensis hobartensis* and *N. hobartensis monticola* and that the character state differences are correlated with evolutionary independence according to population genetic structure. The Bass Strait, which separates *N. hobartensis albolineata* and *N. hobartensis hobartensis*, is a well-known biogeographical barrier for many species distributed on the mainland and Tasmania; the two landmasses have been divided by an extensive water-body for the past 13,000 years (White, 1994), causing reproductive isolation for terrestrial species with limited dispersal capacity. Similarly, the Cassillis Gap, which separates *N. hobartensis albolineata* and *N. hobartensis monticola*, has been a biogeographical barrier for butterflies and other biota since the late Pleistocene, impeding gene flow between populations north of the Gap (Barrington Tops) and those south of the Gap (Blue Mountains) (Eastwood *et al.*, 2006).

Australia is a relatively flat country and is not renowned for its mountains (Australia's highest Mountain, Mt Kosciuszko, is 2,228 m), which are eroded and low in elevation (White, 1994) in comparison with other continents. The greatest topographic relief occurs in the southeast of the continent where butterfly endemism at the species and subspecies level is more pronounced, particularly among the Trapezitinae (Hesperiidae) and Coenonymphina (Nymphalidae: Satyrinae) and to a

lesser extent the Theclinae-Polyommatae assemblage (Lycaenidae) (New, 1999; Braby, 2000), highlighting the importance of the southern Great Dividing Range in the evolution of the Australian butterfly fauna. Thus, *Neolucia hobartensis albolineata* is one of a set of 22 butterfly taxa that are endemic and narrowly restricted to montane areas (>600 m, but mainly >900 m) in the tablelands and plateaus of mainland southeastern Australia (Table 2). Interestingly, the larvae of many of these montane endemic taxa (all Trapezitinae and Satyrinae) specialize on monocots, particularly Poaceae and Cyperaceae.

Further work is needed to assess the conservation status of all of these narrow-range montane endemics because their restricted high altitudinal distribution, with frequently disjunct occurrences on isolated mountain ranges and plateaus of and near the Great Dividing Range, implies that they may be susceptible to global climate change, particularly changes in temperature (Parmesan *et al.*, 1999; New, 2011). During the past century the global average surface temperature has increased by 0.6°C (Australia has warmed c. 0.8°C over this period), with much of this increase occurring during the last three decades, and further substantial rises in temperature are projected over the next 50 years (IPCC, 2001, 2007). Australian butterflies are expected to respond to these temperature changes because, being ectotherms, their metabolic and developmental rates are temperature-dependent. These responses include changes in spatial distribution (altitude or latitude), phenology (e.g., adult emergence time, flight period) and adaptation, all of which may affect levels of abundance and ecological interactions with other species, and may lead to extinction of local populations (Hughes, 2000, 2003; Beaumont & Hughes, 2002; Beaumont *et al.*, 2005). For example, a 1°C rise in mean annual temperature corresponds to a shift in isotherms of approximately 160 m in elevation or 100–130 km in latitude in the temperate zone (Hughes, 2000). Therefore, species are expected to move upwards in elevation or polewards in latitude in response to shifting climate zones. Indeed, global meta-analyses of 99 species have revealed significant upward shifts in altitudinal range, averaging 6.1 m per decade (Parmesan & Yohe, 2003).

Although the altitudinal range *N. hobartensis albolineata* is quite large (1370 m over 4° latitude), the taxon has limited capacity to expand upward and/or poleward (southward) because it already occurs near the summit of Mt Kosciuszko and at the southern limit of the Australian Alps (Mt Erica and Mt Baw Baw). Thus, the lower altitude limit of the range (820–840 m, as of 1972–1983) is more likely to be severely impacted and retract upward by global climate change, if it hasn't already. Any contraction in altitudinal range, however, will lead to substantial population isolation and fragmentation because of the discontinuous nature and comparatively low altitude of the montane country in southeastern Australia. Some populations, such as the Boyd River (1220 m), occur at their altitudinal maxima and essentially have no capacity to move upwards. Long-term monitoring of all populations of all subspecies of *N. hobartensis* is therefore required to assess how the species responds to global climate change and whether mitigating actions are needed to safeguard its future survival. Indeed, two decades ago Crosby (1998) recommended that monitoring populations of *N. hobartensis* and other alpine butterflies restricted to the Mount Buffalo

Table 2. Butterfly taxa endemic to montane areas (> c. 600 m altitude) on the mainland in southeastern Australia; compiled from data in Common & Waterhouse (1981), Braby (2000, 2016), Johnson & Wilson (2005), Sands & Sands (2017) and M. F. Braby and J. J. Armstrong (unpublished data).

species	altitude (m)	distribution	larval food plants
HESPERIIDAE: TRAPEZITINAE			
<i>Anisynta tillyardi</i>	900–1500	Bunya Mtns, QLD to Barrington Tops, NSW	<i>Poa labillardieri</i> , <i>P. queenslandica</i> , <i>P. sieberiana</i> , <i>P. tenera</i> (Poaceae)
<i>Anisynta cynone anomala</i>	1080–1210	New England Tableland, NSW	<i>Poa</i> sp. (Poaceae)
^a <i>Anisynta monticolae</i>	600–1500	Blue Mountains, NSW to Black Range, VIC	<i>Poa tenera</i> (Poaceae)
<i>Anisynta dominula dominula</i>	600–1670	New England Tableland, NSW to Mt Donna Buang, VIC	<i>Poa</i> sp. (Poaceae)
<i>Oreisplanus munionga munionga</i>	1060–1600	Barrington Tops, NSW to Mt Buller, VIC	<i>Carex appressa</i> , <i>C. longibrachiata</i> , <i>Scirpus polystachyus</i> (Cyperaceae)
<i>Hesperilla crypsargyra binna</i>	840	Lamington Plateau, QLD	<i>Gahnia insignis</i> (Cyperaceae)
<i>Hesperilla hopsoni</i>	1280–1500	Near Stanthorpe, QLD to Barrington Tops, NSW	<i>Gahnia sieberiana</i> , <i>G. grandis</i> (Cyperaceae)
<i>Mesodina aeluropis</i>	820–1270	New England Tableland to Kosciuszko NP, NSW	<i>Patersonia</i> sp. aff. <i>sericea</i> (Iridaceae)
NYMPHALIDAE: SATYRINAE			
<i>Tisiphone abeona regalis</i>	900–1370	Near Stanthorpe, QLD to Barrington Tops, NSW	<i>Gahnia</i> spp. (Cyperaceae)
<i>Oreixenica orichora orichora</i>	1200–2100	Brindabella Range, ACT to Mt Tamboritha, VIC	<i>Poa fawcettiae</i> , <i>P. hiemata</i> (Poaceae)
<i>Oreixenica correae</i>	1200–1800	Brindabella Range, ACT to Mt Donna Buang, VIC	<i>Poa ensiformis</i> , <i>P. hiemata</i> (Poaceae)
<i>Oreixenica kershawi ella</i>	900–1450	Barrington Tops, NSW	Poaceae
<i>Oreixenica latialis latialis</i>	1200–1800	Boyd River, NSW to Mt Tamboritha, VIC	<i>Poa hiemata</i> (Poaceae)
<i>Oreixenica latialis theddora</i>	1230–1370	Mt Buffalo plateau, VIC	<i>Poa</i> sp. (Poaceae)
^b <i>Heteronympha solandri</i>	840–1600	Boyd River, NSW to Grampians, VIC	<i>Poa labillardieri</i> , <i>Tetrarrhena juncea</i> (Poaceae)
<i>Heteronympha banksii mariposa</i>	600–900	Bunya Mnts to Macpherson Range and nr Stanthorpe, QLD	<i>Poa labillardieri</i> , <i>P. queenslandica</i> , <i>P. sieberiana</i> , <i>P. tenera</i> (Poaceae)
LYCAENIDAE			
<i>Acrodipsas aurata</i>	580–1060	Blue Mountains, NSW to Pine Mountain, VIC	<i>Crematogaster</i> ants
<i>Pseudalmenus chlorinda barringtonensis</i>	1200–1580	Mt McKenzie to Barrington Tops, NSW	<i>Acacia dealbata</i> , <i>A. melanoxylon</i> , <i>A. irrorata</i> (Fabaceae)
<i>Candalides heathi doddi</i>	1300–1340	New England Tableland to Barrington Tops, NSW	<i>Veronica perfoliata</i> (Plantaginaceae)
<i>Candalides heathi alpinus</i>	700–1820	South Black Range, NSW to Dellicknora, VIC	<i>Veronica derwentiana</i> , <i>V. perfoliata</i> (Plantaginaceae)
<i>Neolucia hobartensis monticola</i>	1200–1450	Dorrigo Plateau to Barrington Tops, NSW	<i>Epacris rhombifolia</i> (Ericaceae)
<i>Neolucia hobartensis albolineata</i> ssp. nov.	820–2190	Boyd River, NSW to Mt Baw Baw, VIC	<i>Epacris petrophila</i> , <i>E. breviflora</i> , <i>E. paludosa</i> (Ericaceae)

^a The population of *Anisynta monticolae* in western Victoria in the Black Range State Park near the Grampians occurs at lower altitudes (>400 m).^b Disjunct populations of *Heteronympha solandri* in western and southwestern Victoria occur at lower altitudes (320–640 m, but generally >500 m), with those from the Otway Range representing an undescribed taxon (Braby, 2000).

plateau, VIC, was required to assess the impact of global climate change, especially rising temperatures. Laboratory studies investigating the degree of physiological tolerance and adaption to temperature variation are also required, including the cues inducing, maintaining and terminating egg diapause.

Related to global climate change, another potential threat facing *N. hobartensis albolineata* that needs further investigation is the increasing scale and frequency of mega fire events in southeastern Australia, such as the Canberra bushfires (18–22 January 2003) that destroyed most of the montane forests of the Australian Capital Territory and adjacent mountains in New South Wales (e.g., Kosciuszko National Park), and the Black Saturday bushfires (7 February 2009) that devastated large areas of mountainous habitat of the butterfly in Victoria. These events, and subsequent prescribed burning practices, are likely to have a detrimental effect on insects (New *et al.*, 2010). It is not known how butterflies such as *N. hobartensis albolineata* recover from such catastrophic events or what time interval is required for habitats to reach a state of ecological succession suitable for breeding post-fire. Presumably the butterfly recolonizes regrowth areas, but this clearly depends on: (a) the extent of refuges (spatial mosaics of unburnt patches) within the landscape, and (b) the dispersal capability of adults. Given the patchy and discontinuous nature of much of the species' habitat over the mountains of southeastern Australia, long-distance dispersal events between mountain peaks/plateaus are probably rare. Species of *Epacris* show a range of adaptive responses to disturbance such as high intensity fire, including resprouting from woody rootstock or basal lignotuber and regenerating from soil-stored seed after death of the parent plant with seedlings requiring at least three years to flower and set fruit (Benson & McDougall, 1995). Among the known larval food plants of *N. hobartensis albolineata*, *E. paludosa* and *E. breviflora* resprout after fire (Benson & McDougall, 1995; K. McDougall, pers. comm.), whereas *E. petrophila* is killed and recruitment may be poor following high intensity fire (K. McDougall, pers. comm.). Thus, *N. hobartensis albolineata* may be at further risk because of its ecological dependency on *Epacris* spp. growing in subalpine and alpine swampland habitats—obligate seeders such as *E. petrophila* may be diminished or possibly eliminated if the fire frequency is too high, and adult dispersal may be limited for recolonization if the spatial distance between unburnt patches is large following large-scale catastrophic fire events.

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A Review of the Morphology, Biology, Distribution and Conservation Status of the New Caledonian Scincid Lizard *Simiscincus aurantiacus* (Reptilia: Scincidae)

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ABSTRACT. *Simiscincus aurantiacus* was described in 1997 from a single specimen collected in humid forest habitat on Mt Koghis in southern New Caledonia. The recent acquisition of a number of additional specimens from surveys conducted in the south of the island has provided new information on the species' morphology, biology and distribution. The results of field studies indicate it has a scattered distribution across the region that includes both humid forest and tall, canopied maquis forest habitats, and that it can persist in even extremely small remnants of these forest types and appears to have a primarily subterranean mode of existence. The additional material collected has also allowed an assessment of variation in the species' morphology, including an unusually long tail the basal half of which is uniformly rounded. Morphological studies suggest a close relationship between *Simiscincus aurantiacus* and the regionally sympatric fossorial species *Graciliscincus shonae*, and genetic studies undertaken since its description place these taxa within a larger group that also includes the surface active species of the genera *Caledoniscincus* and *Phaeoscincus*, the latter only recently established. The information on the species' distribution and biology presented here supports its recent IUCN Red List assessment as Vulnerable.

KEYWORDS. Scincidae; *Simiscincus*; New Caledonia; morphology; forest; fragmentation; vulnerable.

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The southern ultramafic region of New Caledonia has a rich and diverse lizard fauna that includes a number of regionally endemic species and genera (Bauer & Sadlier, 2000; Sadlier, 2010). The landscape of the region is dominated by steep, high ranges dissected by deep river valleys, but with an extensive low-mid elevation ultramafic plateau in the far south in the area known as the Grand Sud.

This region is home to 17 endemic species of skink including taxa in four primarily endemic genera, and six endemic species of gecko (Table 1), the majority of which have only been recognized in the past 20 years, while new species are still being described. Included are six species of skink restricted to high elevation habitats (Sadlier & Bauer, 2000; Sadlier *et al.*, 2006, 2014a,b), primarily in forest habitat. The uniqueness and diversity of the region's lizard fauna support its recognition as a distinct and significant bioregion (Sadlier, 2010). Unfortunately, the landscape has undergone extensive human-mediated habitat modification (McCoy *et al.*, 1999; Perry & Enright, 2002) both pre- and post European settlement, a scenario complicated by past, current and future potential exploitation of parts of the region for nickel mining (Pascal *et al.*, 2008).

Field research conducted over the past 10 years on the ultramafic surfaces of the Grand Sud, including the Plaine des Lacs, Goro Plateau and adjacent ranges, has greatly enhanced our understanding of the distribution and habitat preferences of many lizard species. As a consequence our perceptions as to their perceived "rareness", particularly with respect to those species thought to be primarily reliant on forest habitats which are now highly fragmented, has changed. The pattern emerging indicates that some of the species of skink regarded as forest dependent are influenced as much by certain attributes of microhabitat, such as moisture, as they are by the structural characteristics of habitat type. As a consequence, the distribution of a number

of species can extend across a range of forest habitats (both humid forest and tall maquis forest), and even into adjacent areas of maquis scrub when the preferred microhabitat attributes are present. By contrast, the majority of truly "narrow range" species in southern New Caledonia appear to be those restricted to high elevation habitats, usually forest, with both deep and relatively recent historical contraction of forest, probably spanning from the Miocene through to Pleistocene, as the likely factor driving isolation and speciation, as exemplified by the radiation of three species in the genus *Sigaloseps* endemic to the high elevation ranges associated with the Kouakoué and Humboldt massifs (Sadlier *et al.*, 2014a).

Simiscincus aurantiacus was described in 1997 from a single specimen collected in mid-elevation humid forest habitat on Mt Koghis in the ranges of the southern ultramafic region adjacent to the Grande Sud. It is an elongate skink with a particularly broad snout (Fig. 1), and has a number of unusual, and in some cases unique, morphological traits, features which contributed to the erection of a monotypic genus to accommodate it. At the time of discovery the specimen was detected under a rock and retreated into the complex of crevices and holes in the forest floor. This behavior in combination with certain morphological traits suggested that it likely led a primarily subterranean existence (Sadlier & Bauer, 1997). Since then a further 16 individual records have been made from a number of locations scattered across the region, and from a range of forest types that includes both humid forest and tall canopied maquis scrub. Most records are from captures made on strategically placed glue traps, and despite extensive diurnal survey time within forest habitat the species has not been trapped during daylight hours, nor has it been observed active during the course of field studies.

Table 1. Skinks and geckos endemic to the southern ultramafic bioregion—species in genera primarily endemic to the region are highlighted with asterisk.

Diplodactylidae	<i>Bavayia geitiana</i>	Wright, Bauer & Sadlier, 2000
Diplodactylidae	<i>Bavayia goroensis</i>	Bauer, Jackman, Sadlier, Shea & Whitaker, 2008
Diplodactylidae	<i>Bavayia nubila</i>	Bauer, Jackman, Sadlier & Shea, 2008
Diplodactylidae	<i>Bavayia septuiclavis</i>	Sadlier, 1989
Diplodactylidae	<i>Eurydactylodes symmetricus</i>	(Andersson, 1908)
Diplodactylidae	<i>Correlophus sarasinorum</i>	Roux, 1913
Scincidae	<i>Caledoniscincus notialis</i>	Sadlier, Bauer, Wood, Smith & Jackman, 2013
Scincidae	* <i>Graciliscincus shonae</i>	Sadlier, 1986
Scincidae	* <i>Lacertoides pardalis</i>	Sadlier, Shea & Bauer, 1997
Scincidae	<i>Marmorosphax montana</i>	Sadlier & Bauer, 2000
Scincidae	<i>Nannoscincus fuscus</i>	Günther, 1872
Scincidae	<i>Nannoscincus garrulus</i>	Sadlier, Bauer & Smith, 2006
Scincidae	<i>Nannoscincus mariei</i>	(Bavay, 1869)
Scincidae	<i>Phaeoscincus ouinensis</i>	Sadlier, Shea & Bauer, 2014
Scincidae	<i>Phasmasaurus tillieri</i>	(Ineich & Sadlier, 1991)
Scincidae	* <i>Sigaloseps deplanchei</i>	(Bavay, 1869)
Scincidae	* <i>Sigaloseps ruficauda</i>	Sadlier & Bauer, 1999
Scincidae	* <i>Sigaloseps balios</i>	Sadlier, Bauer & Wood, 2014
Scincidae	* <i>Sigaloseps ferrugicauda</i>	Sadlier, Smith, Shea & Bauer, 2014
Scincidae	* <i>Sigaloseps pissimus</i>	Sadlier, Shea, Whitaker, Bauer & Wood, 2014
Scincidae	* <i>Sigaloseps conditus</i>	Sadlier, Bauer & Wood, 2014
Scincidae	* <i>Simiscincus aurantiacus</i>	Sadlier & Bauer, 1997
Scincidae	<i>Tropidoscincus variabilis</i>	(Bavay, 1869)

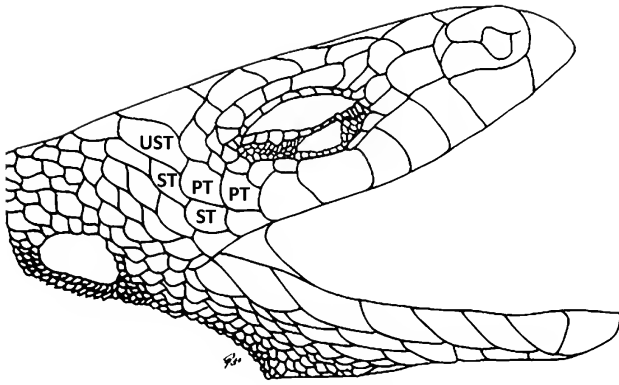


Figure 1. Lateral head scalation of *Simiscincus aurantiacus* (holotype AM R.148050) showing the position of the two large scales bordering the posterior edge of the eye between the last supraciliary and penultimate upper labial, re-interpreted as two primary temporal scales (PT), bordered along the posterior edge by two secondary temporal scales (ST) and a single upper secondary temporal scale (UST) uppermost.

Morphological similarities between *Simiscincus aurantiacus* and *Graciliscincus shonae* have previously been documented (Sadlier & Bauer, 1997), the traits shared by both species likely being associated with a particular mode of subsurface biology. The suite of morphological apomorphies shared by *Simiscincus aurantiacus* and *Graciliscincus shonae* would indicate that they are sister taxa (Sadlier, 2010), but there is little support for this relationship from genetic studies (Smith *et al.*, 2007), other than that both reside within the broader group that also includes *Caledoniscincus* and the recently described *Phaeoscincus* (Sadlier *et al.*, 2014b).

It is the purpose of this paper to provide an account of the morphological variation in *Simiscincus aurantiacus* based on the additional material obtained since the species description 20 years ago, to document the expanded distribution and range of habitats from which the species has now been recorded, and to provide a reassessment of its conservation status.

Systematics

The original description of *Simiscincus aurantiacus* was limited to the holotype, the only known specimen at that time. With an abundance of distinctive character states to diagnose the species there was no hesitation in recognising it as a highly distinctive evolutionary entity. However, the lack of comparative material did not allow for an understanding of variation within the species, not just for the standard meristic and mensural characters typically used to describe the species, but also for an assessment of the extent of variation in some of the more unusual character states associated with body form and osteology, or of sexual dimorphism in body form and colouration. The additional material collected in the intervening 20 years since its discovery offers the opportunity to present here a description of variation in the species, and is based on five adult males (one of which is the holotype) and nine adult females. Measurements are presented as a percentage of body length as expressed by the distance from the tip of the snout to the vent (SVL) and terminology for scalation follows that used by Sadlier & Bauer (1997) in the original description, unless where specifically noted.

A revised account of the morphology of *Simiscincus aurantiacus*: A particularly unexpected aspect of body form apparent in the specimen collections made has been the length and morphology of the tail. The tail of the holotype of *Simiscincus aurantiacus* had been lost, and the specimen had only a healed-over basal part of the tail when captured. The tail length of individuals with nearly complete tails collected subsequently are long, almost twice the body length, and even more surprising more or less evenly cylindrical over the anterior half of the length of the tail.

The body size of adult males ($n = 5$) ranges from 68–85 mm SVL and adult females ($n = 9$) 74–87 mm SVL; distance from axilla to groin 54.2–60.0% SVL (mean = 57.9, $n = 14$); distance from forelimb to snout 34.8–41.7% SVL (mean = 37.2, $n = 14$); hind-limb length 29.1–36.1% SVL (mean = 30.9, $n = 14$); tail length of the individual with the longest most complete tail (as determined by x-rays) 181.3% of SVL (last c. 10 mm regenerated).

The description of the holotype of *Simiscincus aurantiacus* identified a number of unusual apomorphies in the configuration of the head scales that included: a frontonasal scale more than twice as broad as long; widely separated prefrontal scales; a single well developed loreal scale with a small semilunar scale positioned anterodorsally on the right loreal largely separating contact between that scale and the nasal scale; an oblique division of last upper labial; fragmentation of the temporal scales; and two (rather than three) pairs of enlarged chinshields.

Examination of the holotype and the additional 13 specimens confirms the presence of widely (80%) to very widely separated prefrontal scales and the presence of a small semilunar scale positioned on the anterodorsal margin of the large loreal scale in all individuals that is best interpreted as the anterior loreal which has undergone significant reduction in size, a trait seen in several other New Caledonian skink genera (*Marmorosphax*, *Graciliscincus* and some *Nannoscincus*). The extent of fragmentation of scales at the rear of the jaw makes the homology of the posterior upper labial and adjacent temporal scales difficult to determine. The original description interpreted the anterior-most of two large scales bordering the posterior edge of the eye between the last supraciliary and penultimate upper labial as being a division of the last upper labial scale, with the posterior-most of these two large scales as the (single) primary temporal scale. Examination of the additional material indicates the homology of these particular scales may best be interpreted as two primary temporal scales (Fig. 1), a condition which occurs in 61% of cases but with fusion of these scales in the remainder, and with the last upper labial reduced in size such that it is smaller (rather than larger—the typical condition in skinks) than the preceding penultimate upper labial scale. Frequent fusion of these two large scales bordering the posterior edge of the eye (40%) is taken as evidence of a reversal to the pleisiomorphic condition of a single primary temporal. Further, no case of fusion between the anterior-most of these large scales with the adjoining last upper labial (to give a larger and taller scale), and which could be interpreted as a reversal to the pleisiomorphic condition, has been observed. Following this interpretation the homology of the remaining temporal scales would be that the posterior edges of the primary temporal scales are bordered by the last upper labial scales, two lower secondary temporal scales, and the upper secondary temporal scale,



Figure 2. Colouration of a typically boldly marked adult (sex unknown) *Simiscincus aurantiacus* from the Kwé River west.

with the secondary temporals in turn bordered posteriorly by three (occasionally four) tertiary temporal scales. The configuration of the chinshields also shows variation, with two pairs of enlarged scales posterior to the postmental scale as the modal condition, but with the shield posterior to these varying considerably, typically where the third pair of enlarged shields would be positioned. In some individuals the scales could be interpreted as representing a (third) pair of enlarged chinshields divided medially (as seen in *Marmorosphax* and *Kanakysaurus*), or were compressed and resembled the genial shields bordering the posterior lower labial scales. The number of upper labials scales was consistently seven. Variation was observed in the number of lower labials which were modally six (85%), rarely five or seven, and in the number of supraciliary scales which was modally seven (89.3%), occasionally six.

There was no discernable sexual dimorphism in scalation for the body and limbs, and minimal variation in these characters for all specimens examined as follows: midbody scale rows 36–40 (mean = 37.0, sd = 1.30, n = 14); dorsal scale rows 91–102 (mean = 98.0, sd = 2.93, n = 14); scales on top of the fourth finger 8–10 (mean = 9.25, sd = 0.47, n = 14); lamellae under the fourth finger 12–18 (mean = 15.4, sd = 1.47, n = 14); scales on top of the fourth toe 12–16 (mean = 14.1, sd = 0.84, n = 14); lamellae under the fourth toe 25–29 (mean = 27.25, sd = 1.41, n = 14).

The holotype, and a number of specimens of *Simiscincus aurantiacus* collected subsequently, were x-rayed (n = 8) and consistently had 29 presacral vertebrae, the number regarded as the plesiomorphic state for the endemic New Caledonian skink radiation. The individual with the most complete tail had 52 postsacral vertebrae. The extent of tail missing in this individual was small, and even a modest increase in the number of vertebrae by three to a possible total of 55 would only place it at the very upper limits of the plesiomorphic

state (50±5), and an increase by five to a possible total of 57 just within the range for the apomorphic state (>55) for the endemic New Caledonian skink radiation (Sadlier, 2010). One of the most unusual morphological traits of the holotype of *Simiscincus aurantiacus* was its highly elevated number of premaxillary teeth, 19. Examination of a further seven individuals on which this trait could be assessed showed this to be the modal state, with one individual having a reduced number of 17 and one at 18.

The 14 specimens examined are remarkably uniform in coloration and pattern, and show little differentiation from the original description of the holotype, all having the black upper lateral color to the side of the head and body, and bright orange color to the lower lateral surface of the body and the venter (Figs 2, 3). The only obvious variation observed was in the extent of dark markings on the scales on the throat back to the level of the forelimbs. In most (n = 7) adult females each scale of the throat was heavily marked with dark coloration (Fig. 3), but in two individuals (R.172096 and R.171364) the dark markings were only moderately (or less) present. By comparison the dark markings to the throat of adult males were not as uniformly distributed, and where present these markings were boldest anteriorly around the margins of the chin, and more diffuse posteriorly, except for the smallest male (68 mm SVL) which had the boldly marked throat color typical of the adult females, indicating that the intensity of dark coloration may be progressively lost with maturity in males (as seen in the skink genera *Marmorosphax* and *Kanakysaurus*). The tail (which was not present on the holotype at the time of description) differs in coloration to the body. The top and sides of the tail are dark in color overall compared to the body, predominately a mix of dark grey with brown and black markings, and lighter grey below, but with dorsal, lateral and ventral colors of the body extending onto the basal part of the tail.



Figure 3. Ventral coloration of adult female *Simiscincus aurantiacus* (AM R.179770) showing bright orange color to the underside of the body typical of both sexes and bold dark coloration to the throat typical of females.

Specimens examined (all Australian Museum specimens): R.144356 Mt Koghis (22°10'43"S 166°30'20"E), Aug. 1994 (holotype); R.164368 Forêt Nord (22°19'28"S 166°54'51"E), 19 Dec. 2004; R.168159 Pic du Pin (22°14'50"S 166°52'58"E), 26 Oct. 2007; R.171364 Goro Plateau, Kwé Nord (22°17'43"S 166°58'38"E), 5 Nov. 2008; R.172096 Goro Plateau, Kwé Nord (22°16'47"S 166°56'46"E), 14 May 2009; R.172910 Goro Plateau, Kwé Nord (22°16'38"S 166°58'39"E), Nov. 2009; R.174503 Rivière Bleue, Parc Provincial de la Rivière Bleue, Lieu dit des Bucherons (22°6'32"S 166°41'25"E), 5 June 2010; R.174506 Goro Plateau, Kwé Nord Range (22°16'33"S 166°57'26"E), 21 June 2010; R.174507 Goro Plateau, Plaine des Lacs (22°15'35"S 166°56'52"E), 1 Sep. 2010; R.175547 Goro Plateau, Plaine des Lacs (22°13'8"S 166°57'12"E) May 2011; R.179762 Touango River near Plaine des Champ de Bataille (22°16'14"S 166°45'7"E), 11 Oct. 2013; R.179770 Riviere des Pirogues—upper reaches near Col des Deux Tétons (22°12'0"S 166°42'2"E), 23 June 2014; R.179779 Kwé River west, KO4 basin (22°17'19"S 166°55'55"E), 29 July 2014; R.179780 Kwé River west, KO4 basin (22°17'45"S 166°56'4"E), 29 July 2014; Kwé River west, KO4 basin (22°17'56"S 166°54'57"E) 6–10 Jan. 2015 (observation—Sadlier *et al.*, 2015); Lake Yaté near the confluence of the Rivière des Lacs (22°9'22"S 166°50'2"E), 1 Dec. 2012 (observation—Sadlier *et al.*, 2014c).

Intergeneric relationships: The placement of *Simiscincus aurantiacus* in a monotypic genus at the time of its description was not problematic given it could not be accommodated in any existing genus (within or outside the *Eugongylus* group of skinks) without compromising the diagnosis of existing genera as monophyletic groups. At the time of its description similarities in morphology and biology between *Simiscincus aurantiacus* and *Graciliscincus shonae* were identified, and by inference a sister relationship was assumed.

The first substantial inference of relationships between *Simiscincus aurantiacus* and other *Eugongylus* group taxa comes from the genetic phylogeny of Smith *et al.* (2007). This study produced the first broad-scale phylogeny for the New Caledonian skink fauna based on combined DNA sequence data for the mitochondrial ND2 gene and nuclear *c-mos* and *Rag-1* genes, identifying a number of discrete genetic groupings of genera, each of which represented an independent lineage within a largely monophyletic New Caledonian radiation. Notably it identified a subgroup of genera that included *Caledoniscincus* + *Simiscincus* + *Graciliscincus* + “New Genus Mt Taom” (now = *Phaeoscincus taomensis*). However, while monophyly of this subgroup of genera received high support from Bayesian posterior probability values (BPP 1.00) it received only low support from maximum parsimony (MP) bootstrap values (<50%), and relationships between the included genera were typically low (BPP around 50% and MP <50%). Regardless, a relationship of *Caledoniscincus* to either *Simiscincus* or *Graciliscincus*, as inferred by their inclusion in the same genetic group (the “*Caledoniscincus* subgroup”—Sadlier, 2010) was unexpected and had not previously been considered. A similar grouping of *Caledoniscincus* + *Simiscincus* + *Graciliscincus* was retrieved in a subsequent re-analysis of the mitochondrial ND2 nuclear *Rag-1* sequence data combined (Ineich *et al.*, 2014), with similarly high support from Bayesian posterior probability values (BPP 1.00) but low support from maximum parsimony (MP) bootstrap values (<50%). This analysis now included the giant skink *Phoboscincus bocourti* (missing in the earlier analysis) but omitted the taxon now recognized as *Phaeoscincus taomensis* (included in the earlier analysis). It identified *Simiscincus* and *Graciliscincus* as sister taxa (high support BPP of 1.00 but low MP of <50%), but in the absence of *Phaeoscincus taomensis* from the analysis

the robustness of this relationship is open to question. Note the genus *Phaeoscincus* includes two taxa, *Phaeoscincus taomensis* the type species which was included in the genetic study of Smith *et al.* (2007), and *Phaeoscincus ouinensis* known only from a single specimen nominally placed in the genus on morphological criteria, and for which genetic data are not available.

The monophyly of the “*Caledoniscincus* subgroup” identified in the genetic studies receives support from a suite of diagnostic morphological apomorphies that include reduction in the size of the prefrontal scales and a degree of fusion of elements of the first cervical vertebra, the atlas (the state for this character is unknown for *Phaeoscincus*). Among the endemic New Caledonian skink radiation reduction in size of the prefrontal scales is only otherwise seen in the *Nannoscincus* group. However, in *Nannoscincus* the degree of diminution is extreme and the scale can be variably lost in some species, and as such the modes of reduction of the prefrontal scales seen in the “*Caledoniscincus* subgroup” and in the *Nannoscincus* group are considered to be most likely independently derived. Fusion of the elements of the atlantal vertebra also occurs in *Nannoscincus*, *Sigaloseps* and *Celatisincincus* (the latter two members of the *Lioscincus* group as defined by Sadlier, 2010) and its presence in each group is at this point best interpreted as an independent derivation.

Although the internal relationships between the genera within “*Caledoniscincus* subgroup” were not well resolved in the genetic studies, a putative sister relationship for *Simiscincus* and *Graciliscincus* does receive support from a suite of morphological apomorphies. Both have undergone an elongation of the body and reduction in the size of the limbs, character states typical of subterranean skinks. Interestingly, both species also share apomorphies that typify their particular mode of fossorial existence, including: a relatively stout tail over much of the basal half of its length; an extremely broad snout as typified by a frontonasal scale being nearly or more than twice as broad as long, and in having an elevated number of premaxillary teeth (13 in *Graciliscincus* and a mode of 19 in *Simiscincus*); and a shortening of the snout as expressed via an extreme reduction in the anterior loreal such that it is a semilunar scale positioned on the anterodorsal margin of the nasal. These are physical traits that would be expected to have evolved in a species that exploits the use of existing passageways beneath the forest floor, rather than pushing through and displacing substrate at the subsurface level, such as the species of *Nannoscincus*. By contrast the species of *Caledoniscincus* are all day active heliothermic species that are usually conspicuous and abundant, and have the body form more typical of a surface-active species of skink.

Graciliscincus and *Simiscincus* each also have an independent suite of unique apomorphies that identify the two genera as each being on independent evolutionary trajectories. *Graciliscincus* has undergone a significant elongation of the body as evidenced by the relationship of axilla-groin length to total snout-vent length (62–66%) and in having a significantly elevated number of presacral vertebrae (34+ vs mode 29 for most endemic New Caledonian skink genera). It has also undergone: a reduction in the number of upper labial scales to six by what appears to be fusion of the anterior labial scales to produce an extended and elongate anterior-most scale; extreme diminution of the prefrontal scales; and further fusion in the elements of the first cervical

vertebrae (atlas) such that the atlantal arches are fused to the intercentrum dorsally and to each other to form a complete ring. The extent of development in these character states in *Graciliscincus* would appear to be associated with evolution towards a progressively more extreme sub-surface existence mode than that inferred for *Simiscincus*. By contrast, *Simiscincus* has a number of more plesiomorphic traits (character state polarities from Sadlier, 2010) that include: a less elongate body with an axilla-groin length relative to total snout-vent length of 58%; larger prefrontal scales than *Graciliscincus shonae*; seven supraciliaries; the anterior upper labial scales even-sized; only 29 presacral vertebrae; and the atlantal arches of first cervical vertebrae fused to the intercentrum but not fused dorsally to each other as they are in *Graciliscincus*. However, *Simiscincus* does have several apomorphies not found in *Graciliscincus* that includes a division of the primary and lower secondary temporals, and an exceptionally high number of premaxillary teeth, the latter a highly derived osteological trait unique within the *Eugongylus* group of skinks.

Distribution, biology and conservation

Distribution: Extensive survey work across the Grand Sud of southern New Caledonia over the past eight years has greatly enhanced our knowledge of the extent and distribution of many lizard species in the region, and of the range of habitats they occupy. *Simiscincus aurantiacus* has now been recorded from a number of sites scattered across the Grand Sud (Fig. 4), including areas of humid forest within the reserves Forêt Nord, Pic du Grand Kaori, Pic du Pin and Parc de la Rivière Bleue, and smaller areas of humid forest often in close proximity to these reserves (Fig. 5). The majority of these sites are on the extensive low elevation ultramafic plateau (100–200 m) that comprises much of the far south of the island. The plateau is transected by chains of mid elevation ranges (c. 450 m) in its interior, and dissected by steep valleys in the east associated with river systems. The best known natural features of the region are the large natural freshwater lakes from which the place name of Plaine des Lacs is derived, and the Chutes des Madeleine, a broad waterfall in the river draining the elevated plateau on which the Plaine des Lacs is located.

It has also been recorded from a number of sites within tall, sometimes canopied, maquis forest habitat (paraforest and preforest) a forest-like vegetation association (Fig. 6), but usually only where these habitats occur on a broken ferralitic iron cap (cuirasse) or on areas of outcropping and broken peridotite. In the Grande Sud both humid forest and tall maquis forest habitats occur singularly as isolated patches of varying size, or in combination as a continuous grade, but ultimately surrounded by extensive areas of dense-open maquis scrub. As a consequence the distribution of *Simiscincus aurantiacus* in the region is highly fragmented. The combination of paraforest and preforest habitat on a broken cuirasse surface is most prevalent in the southeast in the region on the Goro Plateau and the Plaine des Lacs. Here the species’ occurrence in tall canopied maquis forest habitats appears to be highly correlated with the presence of the extensive matrix of subsurface sheltering and foraging sites provided by the underlying, broken, cuirasse cap.

The north and west area of the Grand Sud, an area largely

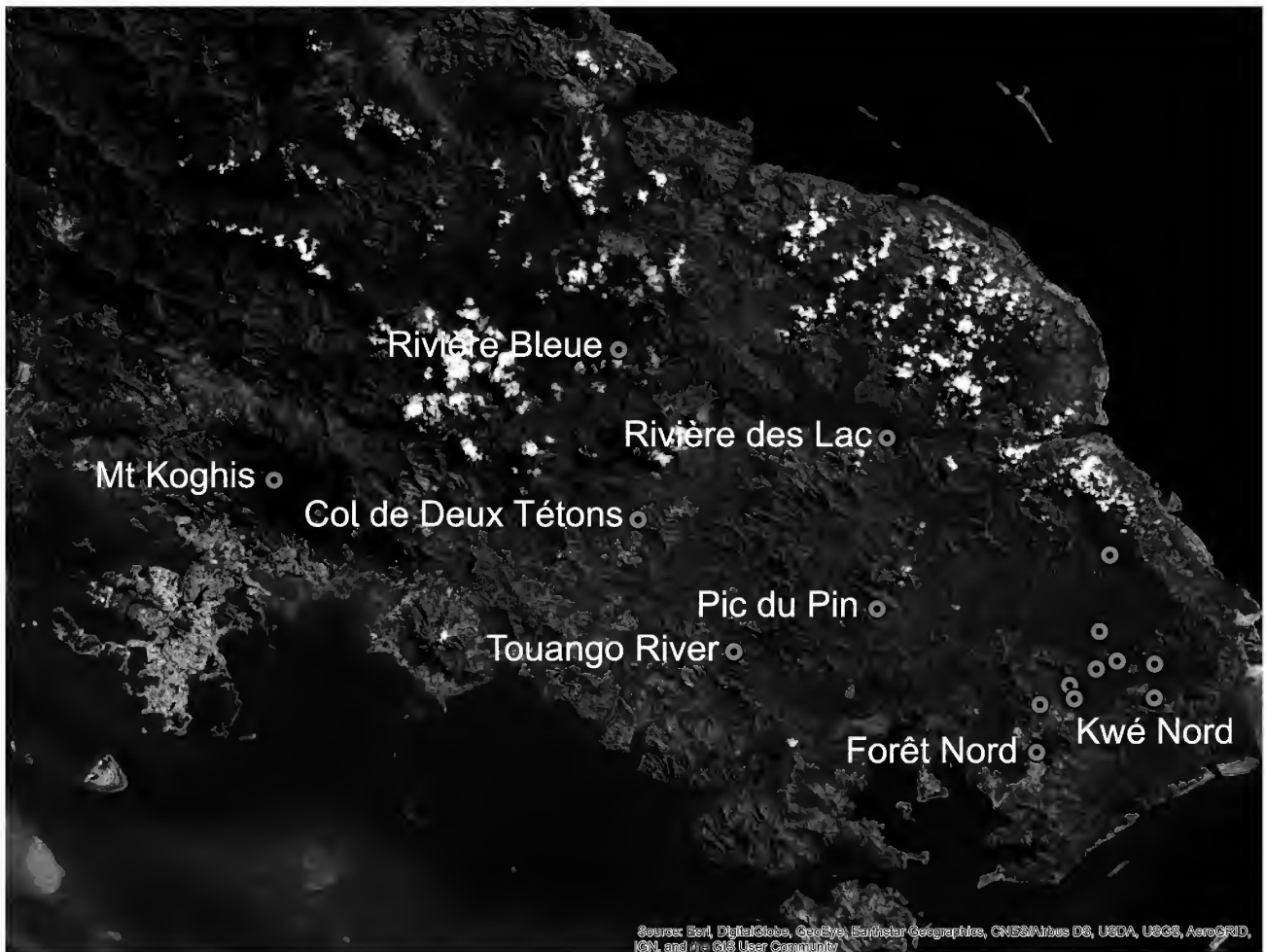


Figure 4. Locations from which *Simiscincus aurantiacus* has been recorded in southern New Caledonia (green dots), with key locations mentioned in the text against sites.

encompassed by the ranges and drainage of the Rivière des Pirogues, is dominated by maquis shrubland, with humid forest usually present as isolated patches in gullies at the base of the ranges and canopied maquis habitat as small isolated patches in gullies or as narrow transitional zones around the perimeter of forest patches. In this area these forest types are usually on a lateritic soil surface. The distribution of *Simiscincus aurantiacus* here is represented by only a few scattered records: one from humid forest at the Touango River near the Plaine des Champ de Baille, one from a small area of humid forest in a gully at Col des Deux Tétons, and one from a very small area of paraforest in a gully near the confluence of Rivière des Lac and Lac Yaté. The record from humid forest at the Touango River was not surprising given the forest was located in a gully with extensive outcropping peridotite rock present in its interior, ideal habitat for the species. Conversely, its presence in the patch of humid forest at Col des Deux Tétons was not expected, given the forest here was on a lateritic soil surface that lacked outcropping rock or a broken cuirasse cap, and had few fallen logs on the forest floor—in effect providing very few suitable sheltering sites. The most surprising record was the species' presence in a small patch of paraforest habitat (Fig. 7) near the confluence of Rivière des Lac and Lac Yaté, a site surrounded by extensive areas of maquis shrubland and distant from larger areas at forest habitat (7 km from Forêt Cachée and 10 km

from Pic du Pin). However, the interior of the gully had an area of broken outcropping peridotite, apparently sufficient in itself to provide the necessary microhabitat for the species to persist in this isolated forest remnant.

The area adjacent to, and to the north of the Grand Sud, is dominated by steep-sided, high elevation ranges (c. 1000 m asl) which lie at the southern end of the Chaîne Centrale, the elevated ranges that dominate the landscape of much of New Caledonia. The ranges adjacent to the Grand Sud have not been subject to the systematic survey work undertaken in that region. The occurrence of *Simiscincus aurantiacus* in the ranges is limited to the record of the holotype from mid-elevation humid forest on Mt Koghis and a single individual recorded from low-elevation humid forest in the Parc Provincial de la Rivière Bleue. The lower-mid slopes of the ranges are dominated maquis shrubland, with humid forest persisting mostly as isolated patches, but with more extensive areas of forest habitat at the base of the ranges adjacent to rivers, and at higher elevations. The distribution and extent of canopied maquis forest habitat (paraforest and preforest) in these ranges is difficult to comment on, but is also likely to be present as small isolated patches or as narrow transitional zones around the perimeter of humid forest. The fossorial species *Graciliscincus shonae* is similar in ecology and distribution to *Simiscincus aurantiacus* and has been recorded in these ranges as far north as Mt Dzumac



Figure 5. Typical humid forest remnant in the Grand Sud (A) surrounded by lingo-herbaceous maquis shrubland, and interior of forest (B); note large logs on forest floor that provide sheltering sites for *Simiscincus aurantiacus*.



Figure 6. Typical patch of tall maquis paraforest on cuirasse (A) in the Grand Sud, and interior of paraforest (B); note extensive broken cuirasse cap that provide sheltering sites for *Simiscincus aurantiacus*.



Figure 7. Isolated area of maquis paraforest in gully on low range near Lac Yaté (A), and the interior of the paraforest showing extensive outcropping peridotite (B) from which *Simiscincus aurantiacus* was recorded.

in humid forest at 900 m elevation. Given the similarities shared by these two species in terms of their evolutionary history, biology and morphology, and that they occur in sympatry over most of their known range, it is conceivable that the distribution of *Simiscincus aurantiacus* could likewise extend further north into these ranges, and into forest habitat at higher elevations than previously recorded.

Population differentiation. The genetic relationships of the various populations of *Simiscincus aurantiacus* were investigated as part of a study initiated by Valé Nouvelle-Calédonie (see Sadlier & Bauer, 2014) to provide information reflecting the evolutionary histories of the lizard faunas across the Grand Sud, which in turn would provide a framework for the identification of specific management units within the species investigated, and for which management actions could then be developed i.e. the Evolutionary Significant Units (ESU's) of Moritz (1994).

To assess the relatedness between populations of *Simiscincus aurantiacus* sequence data were generated for the mitochondrial ND2 gene to retrieve fine scale patterns, and from the more conservative nuclear RAG1 gene to retrieve broader and historically deeper patterns of relatedness within the species. The sampling for *Simiscincus aurantiacus* included all known populations in the Grand Sud for which genetic samples were available. Sampling for the mitochondrial ND2 gene comprised eight individuals representing seven different sites, and sampling for the nuclear RAG1 gene included 8 individuals with multiple sampling ($n = 3$) from Kwé Nord. Genetic differentiation between samples for the mitochondrial ND2 gene (Table 2) was minimal, typically less than 1%, and there was no regional sub-structuring. The population from Forêt Nord was exceptional in being approximately 2% different from all other populations sampled. Somewhat paradoxically, the nuclear RAG1 gene showed greater genetic diversity than observed for the mitochondrial DNA, but still with no geographic structure to this diversity, a pattern of genetic variation consistent with a single widespread population with continuity of gene flow between populations historically, but with a recent reduction in variation of the mitochondrial DNA in association with strong selection for a particular mutation that also affects linked sites (a selective sweep; Maricic *et al.*, 2013).

The distribution of humid forest in the southern ultramafic region is highly fragmented, with extensive areas of low, open maquis shrubland between the areas of forest, and the distribution of canopied maquis forest habitat is similarly fragmented. The extent to which the mosaic of forest and shrubland seen today is human induced or natural has been a point of conjecture. Maquis vegetation is diverse and highly specialized in its adaption to "toxic" nickel bearing soils (Lowry, 1998; Lowry *et al.*, 2004), traits which could be interpreted as reflecting a long evolutionary history for this vegetation type. The inference of a long-term persistence of maquis habitat in the region has implications with regard to the extent of historical connectivity of forest habitat, which in turn would also have implications with regard to the extent of historical connectivity in distribution of forest dependent species.

The results of genetic studies showed the various populations in the region maintained sufficient connectivity to enable gene flow, and by inference forest habitat suitable for *Simiscincus aurantiacus* was historically

Table 2. Uncorrected pairwise distances between individuals of *Simiscincus aurantiacus* for the mitochondrial ND2 gene, with the New Caledonian skink *Phoboscincus garnieri* included for outgroup comparison (AM specimen numbers with R prefix).

			1	2	3	4	5	6	7	8	9	
1	<i>S. aurantiacus</i>	R.164368	Forêt Nord	—								
2	<i>S. aurantiacus</i>	R.171364	Kwé Nord	0.0193	—							
3	<i>S. aurantiacus</i>	R.172096	Kwé Nord Range	0.0210	0.0018	—						
4	<i>S. aurantiacus</i>	R.172910	Kwé Nord	0.0193	0.0000	0.0018	—					
5	<i>S. aurantiacus</i>	R.174503	Rivière Bleue	0.0263	0.0070	0.0088	0.0070	—				
6	<i>S. aurantiacus</i>	R.174507	Plaine des Lacs	0.0245	0.0053	0.0070	0.0053	0.0018	—			
7	<i>S. aurantiacus</i>	R.175547	Plaine des Lacs	0.0210	0.0018	0.0035	0.0018	0.0088	0.0070	—		
8	<i>S. aurantiacus</i>	R.180396	Rivière des Lacs	0.0228	0.0035	0.0053	0.0035	0.0105	0.0088	0.0053	—	
9	<i>P. garnieri</i>	R.151965	Mt Koghis	0.2294	0.2189	0.2172	0.2189	0.2172	0.2189	0.2207	0.2224	—

widespread across the Grand Sud. This is very different from the landscape seen today which is one dominated by expanses of maquis shrubland with forest habitat present as isolated patches, a scenario clearly attributed to the presence of humans on Grande Terre. Whether the extent of past connectivity between populations of *Simiscincus aurantiacus* was achieved through a historically continuous unit of forest or as a shifting mosaic of forest and maquis progressing through successional stages from shrubland to forest is not known. Fluctuations in the presence of forest vegetation in the region in recent times (over a period of approximately the past 130,000 years) have been reported from studies of the distribution of pollen in core samples from perched still-water lakes on the Goro Plateau (Hope & Pask, 1998; Stevenson & Hope, 2004), with its periodic absence attributed primarily to fire (McCoy *et al.*, 1999). While the time frame of these results is too recent to be directly referable to the phylogenetic structure retrieved in the genetic study, it does provide evidence for cycles of presence/loss/reappearance of forest habitat in the region, and by inference support for the scenario of a shifting mosaic of forest and maquis vegetation through time.

Biology: *Simiscincus aurantiacus* has not been observed active and only two have been found by searching under sheltering sites, both in the interior of humid forest habitat. One (the holotype) was located beneath a rock in an area of outcropping peridotite in forest on Mt Koghis, and immediately sought shelter in the underlying matrix of crevices in the rock and soil below. The other was located beneath a small log on soil on the forest floor at the base of Forêt Nord. The remaining records for the species are from individuals captured on glue traps set on forest floor or among rocks and logs in forest habitat, or, in or next to openings in the exposed and broken cuirasse cap in canopied maquis forest habitat. Only on two occasions have individuals been caught on traps on the open forest floor away from obvious sheltering sites. While these data support earlier inferences of a primarily subterranean mode of existence derived from morphology and (limited) field observations (Sadlier & Bauer, 1997), it appears the species is also active on the surface of humid forest habitat. Further, both were recorded in early morning checks of traps, indicating they were most likely active either late in the previous day and/or at night. Such on-surface activity late in the day and/or at night may account for the presence of scales of *Simiscincus aurantiacus* in rodent stomach contents studies (Jourdan *et al.*, 2015; Thibault *et al.*, 2016).

Maturity and reproduction: Three adult males collected in the austral mid-late winter months of June (R.174503—SVL 72.5 mm), July (R.179779—SVL 71.5 mm) and August (R.144356—SVL 85 mm) had enlarged testes (turgid with seminiferous tubules obvious), whereas two adult males collected in the austral mid-summer months of November (R.172910—SVL 74 mm) and December (R.164346—SVL 68 mm) had the testes reduced in size by comparison. It is equivocal as to whether the reduced testis size in the smallest individual which was collected in December indicates it is a subadult or a reproductively inactive mature individual. Adult females collected in the austral mid-late winter month of July and the spring months of September/October had enlarged yolked ovarian follicles in the ovaries. The individuals collected in July had two (R.179780—SVL 74 mm—1 left/1 right) and four (R.179770—SVL 82 mm—2 left/2 right), enlarged follicles, and the individuals collected in September (R.174507—SVL 85 mm—1 left/2 right) and October (R.168159—SVL 82 mm) each had three enlarged follicles. The number of enlarged follicles recorded during these months appears to closely reflect the potential clutch size when compared to the observed number of shelled eggs present in gravid individuals. Three large shelled eggs were recorded in an individual collected October (R.172096—SVL 80 mm) and four from an individual collected in early December (specimen from 1 Dec. 2012 listed in Specimens Examined). Two adult females collected in the austral winter months of May (R.172096—SVL 82 mm) and June (R.174506—SVL 75 mm) had enlarged oviducts but no indication of obvious enlargement of the ovarian follicles, indicating that these females had passed eggs and were now reproductively quiescent in the post summer period.

Conservation: The genetic data indicates the various (now) isolated populations of *Simiscincus aurantiacus* are part of a single discrete evolutionary unit, and that the preferred habitat for the species was likely once more widespread across the Grand Sud, although it is possible these populations could have undergone periods of natural disjunction associated with fluctuations in extent of forest habitat historically. However, since human occupation of the island the species distribution has become highly fragmented and undergone a significant reduction in area of occupancy and total population size as a consequence of the widespread loss of closed forest and canopied maquis forest habitat from recurrent wildfires. Some areas of habitat have also been lost to mining and logging, or degraded through disturbance associated with these activities. All post-human occupation

impacts are ongoing. *Simiscincus aurantiacus* is currently ranked as Vulnerable (B1ab (i, ii, iii, iv)) on IUCN Red List criteria (Whitaker & Sadlier, 2011), having an extent of occurrence (B1) estimated to be less than 100 km², being severely fragmented in distribution, with a continuing decline (observed, inferred or projected) in its extent of occurrence, area of occupancy, area, extent and/or quality of habitat, and number of locations or subpopulations. The data presented here support that ranking. There are no quantitative data on population size and trends for this species.

The species biology indicates it relies on forest habitats, and as such would clearly benefit from the preservation of areas of forest habitat. However, it is unlikely to be able to migrate between the now isolated forest patches. The designation of areas of forest and/or maquis habitats as potential corridors has recently been proposed as a conservation strategy for avifauna in the Grand Sud (Desmoulins & Barré, 2004), to enable animals to migrate across the landscape and thereby alleviate the possibility of genetic bottlenecks between populations of forest dependent species occupying isolated patches of habitat. For *Simiscincus aurantiacus* the relatively low level of genetic differentiation between populations would suggest that maintenance of genetic diversity through corridors (or translocation) is not at this time a high conservation priority for the species relative to other issues. Further, from a point of practicality, the effectiveness of corridors in facilitating migration between the scattered populations of *Simiscincus aurantiacus* would be entirely dependent upon these corridors reaching a level of development sufficient to maintain the desired microhabitat and resources required for this species.

The most immediate and serious conservation priorities for the long-term persistence of *Simiscincus aurantiacus* are in the prevention of further loss and fragmentation of the species' preferred habitat through the clearing of humid forest and canopied maquis forest habitat, and in the prevention of further degradation of the remaining areas of these forest habitats. The loss of forest habitats from activities associated with mining are in the main obvious, but tend to be localized, while the impacts of habitat degradation from wildfire and exotic species are widespread across the landscape of the Grand Sud. Throughout the region forest habitats are under threat from wildfires in maquis shrublands which threaten forest margins, a situation exacerbated in periods of drought (Ibanez *et al.*, 2012). More insidious and pervasive is the disturbance and loss of microhabitat from the activities of introduced species. Ungulates (deer and pigs) damage the litter layer and disturb ground sheltering sites (such as rocks and logs), and through browsing open the forest understory and lower humidity. The introduced ant *Wasmannia auropunctata* has invaded areas of humid forest habitat in the Grand Sud, and is expected to have a negative impact indirectly through a reduction in abundance or diversity of the invertebrate prey for lizards in forest habitats. Introduced mammals are also potential predators, and predation on lizards by feral cats and rats has been identified as a threatening process (Jourdan *et al.*, 2015) for the New Caledonian lizard fauna. The scales of *Simiscincus aurantiacus* have been recorded from the stomach contents of rats (Jourdan *et al.*, 2015; Thibault *et al.*, 2016), and although not reported from cat scat analysis studies (Jourdan *et al.*, 2015), predation by cats on individuals active on the forest floor at night could also be expected to occur.

The species occurs in several reserves in the Grand Sud, including the Réserve Naturelle de la Forêt Nord, Pic du Grand Kaori, Pic du Pin and Parc Provincial de la Rivière Bleue. The primary management actions for *Simiscincus aurantiacus* would be in identifying key populations for conservation management within the existing reserve system and in developing management strategies to moderate threats to these key populations.

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***Ozeoura*—a New Genus of Chioneinae (Insecta: Diptera: Tipuloidea: Limoniidae) from Australia**

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ABSTRACT. *Ozeoura* g. nov. (subfamily Chioneinae, family Limoniidae) is established for nine Australian species, four previously known species and five newly described here: *Ozeoura billeang* sp. nov., *O. bonelya* sp. nov., *O. lotheggi* sp. nov. and *O. narahdarn* sp. nov., all from tropical Queensland, and *O. dingo* sp. nov. from northeastern New South Wales. The taxonomy of *Ozeoura* is discussed, a key for separating males is presented and the larval and pupal stages are described and figured.

KEYWORDS. *Ozeoura*; new genus; Diptera; Tipuloidea; Limoniidae; freshwater ecosystem.

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This paper proposes a new genus, *Ozeoura* g. nov., to receive four species of Australian chioneine limoniid crane flies, previously included in *Baeoura* Alexander, 1924 along with an additional five species described as new. *Ozeoura* is endemic to Australia, primarily occurring in the east along the Great Dividing Range, with a single species present in Tasmania (Fig. 1). They are rather rarely encountered,

generally in close proximity to waterways in forested areas (Figs 2, 3) of alpine and temperate and tropical rainforest environments.

Ozeoura (Fig. 4) is morphologically similar to the New World genus *Cryptolabis* Osten Sacken, 1860 and to *Baeoura*, a genus virtually restricted to the Old World. Together the three genera likely constitute a closely related

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group, with *Baeoura* and *Cryptolabis* far more speciose than *Ozeoura*, containing 71 and 59 species respectively (Oosterbroek, 2018). Wing venation and male genital structure are useful morphological characters for separating the three genera in this group, and while the species included in *Baeoura* and *Ozeoura* are rather uniform in wing venational and male genital characters, *Cryptolabis*, even *Cryptolabis (Cryptolabis)*, in its present concept, is very variable in these features and may be polyphyletic.

Owing to the similarities within this group of genera and the apparent polyphyly of *Cryptolabis* the historic placement of the four described Australian species of *Ozeoura* has been tenuous. Alexander (1926, 1931) first assigned three species to *Cryptolabis* (*C. tonnoiri*, *C. tasmanica* and *C. convoluta*), he then later moved these three species to *Baeoura* (Alexander, 1978) along with a fourth species (*B. hemmingseni*) which was described as new. Theischinger (1996) followed Alexander (1978), illustrating as *Baeoura* what is here considered to be *Ozeoura*, citing the number of Australian *Baeoura* species as four and not including *Cryptolabis* in the key to the Limoniinae of Australia.

Through detailed examination of Australian material,

preliminarily identified as belonging in *Baeoura*, and by examining specimens of the type species of *Baeoura*, *Cryptolabis (Cryptolabis)* and *Cryptolabis (Procryptolabis)* (these being *Baeoura nigrolateralis* Alexander, 1920, *Cryptolabis (Cryptolabis) paradoxa* Osten Sacken, 1860 and *Cryptolabis (Procryptolabis) argentinensis* Alexander, 1923), the present study has determined that all Australian species examined represent, based on wing venation and male genital features, a homogeneous unit indicating a monophyly, suggesting that the previous assignment of Australian material to *Baeoura* or *Cryptolabis* was problematic and highlighting the need for a new genus to accommodate the Australian species.

This paper therefore establishes *Ozeoura* to receive not only the four species described by Alexander but also an additional five species identified and described as new. It also provides a key for the identification of male *Ozeoura* specimens and gives the first detailed illustrations of the male genitalia of *Baeoura nigrolateralis* and *Cryptolabis (Cryptolabis) paradoxa*. Adult and immature stages of the new genus are associated using morphology and molecular techniques and the larvae and pupae are described and figured.



Figures 1–3. (1) Occurrence records of Australian *Ozeoura* (then *Baeoura*), as of December 2017. (2, 3) Habitats of *Ozeoura* spp.; (2) *O. convoluta*, Big River, Glen Valley Victoria; (3) *O. tonnoiri*, Bakers Creek, Reefton Victoria.



Materials and methods

Pinned material and material in 70% ethanol from institutional and private collections were studied. More recently adult specimens were collected by sweeping a hand net through vegetation or by light trapping with an ultraviolet black light. Aquatic larval and pupal specimens were collected from waterway substrates in sections of moderate to high flow velocity using the rapid bioassessment sampling techniques recommended by the Environmental Protection Authority Victoria (EPA, 2003). Following collection all specimens were preserved in 100% ethanol. As a result of different methods of preservation, the coloration of specimens may have changed in different ways from the natural state. Geospatial coordinates are derived from a GPS using map datum WGS84 (precision ± 50 m). Coordinates for collections made earlier than 1997 are derived from maps, or are inferred, and have ± 1 km precision.

The type material of the new species is lodged in the Australian Museum (AM) in Sydney and in the Australian National Insect Collection (ANIC) in Canberra. Other material studied comes from the Natural History Museum (NHM) in London, the Alexander Collection in the Smithsonian Institution in Washington D.C. (USNM), the Canadian National Collection, Agriculture and Agri-Food Canada in Ottawa, from the Museum of Victoria (MV) and from the research collection of the second author (ZB).

Tissue for molecular analysis was dissected from the coxal and pleural segments in adults and the mid-abdominal segments in larvae. Tissues were sent to the Canadian Centre for DNA Barcoding (CCDB) at the University of Guelph for DNA extraction, amplification and sequencing using standard in-house protocols (available via *ibolproject.org*). Sequences were generated for the mitochondrial cytochrome c oxidase I (CO1) gene using universal forward and reverse primers (C_LepFolF and C_LepFolR respectively) developed by Folmer *et al.* (1994). CO1 sequence data was aligned using the Geneious algorithm in Geneious 9.0.5

(Kearse *et al.*, 2012). The Geneious platform was also used to construct a phylogenetic tree using the Tamura-Nei distance model with 1,000 bootstrap replicates and to produce p-distance values. Sequences generated from this study have been deposited on BOLD and GenBank, BINs and Accession Numbers are detailed in Table 1.

For previously described species in the Systematics section (p. 450), some possibly diagnostic venational and hypopygial characters, if available in the original descriptions and illustrations, are presented with an updated discussion. The new species are described, illustrated and discussed in detail. Differential diagnoses are given for all species. In order to most reliably, clearly and sometimes in slightly different aspects, show structural details, photos and line drawings (camera lucida) are used. Australian Aboriginal words for naming species were sourced from Reed & Reed (1965).

The illustrations of the male terminalia (hypopygium) and larval head capsule are from specimens cleared in KOH and displayed in glycerol. Descriptive terminology follows Alexander & Byers (1981), McAlpine (1981) and Brown *et al.* (2009). The wing venational terms given in brackets refer to the system used in the recent *Manual of Afrotropical Diptera*, based on Wootton & Ennos (1989) and Saigusa (2006).

A strongly sclerotized posteromedian structure, very variable in shape, between the gonocoxites/gonostyli and always associated with the tip of the aedeagus is considered as an aedeagal guide in descriptions and key of this paper. It was, for more than 50 years, variously termed “phallosomic structure”, “may be tergite”, “possible tergal structure” and “apparent tergite” by Alexander (1926–1978).

Abbreviations as used in figures. *a* or *ae*—aedeagus; *c*—cercus or cerci; *e*—epandrium; *gex*—gonocoxite; *gst*—gonostylus; *ht*—hypoproct; *od*—outer gonostylus; *t9*—tergite 9; *bt CuA1* (= *m-cu*)—basal transverse section of vein CuA1.

Table 1. BOLD BINs and GenBank Accession Numbers for specimen sequences used in this study.

species	BIN	accession number
<i>Amphineurus (Amphineurus) kandu</i>	ACM3216	MG895839
<i>Erioptera (Erioptera) lucerna</i>	ACM3486	MG895840
<i>Gonomyia (Leiponeura) skusei</i>	ABW4448	MG895833
<i>Molophilus (Molophilus) fergusonianus</i>	ABA7041	MG895832
<i>Ozeoura</i> sp larva	ABX1154	MG895834
<i>Ozeoura</i> sp larva	ABX1154	MG895842
<i>Ozeoura</i> sp larva	ABX1154	MG895837
<i>Ozeoura</i> sp larva	ABX1154	MG895841
<i>Ozeoura</i> sp larva	ABX1154	MG895838
<i>Ozeoura</i> sp larva	ABX1152	MG895836
<i>Ozeoura</i> sp larva	ABX1152	MG895835
<i>Ozeoura</i> sp adult	ABX1152	MG895843

Systematics

Adults

Ozeoura g. nov.

Theischinger & Billingham

Figs 4, 5, 9, 15–50

Type species: *Ozeoura billeang* Theischinger & Billingham sp. nov.

Diagnosis. Tiny (wing 3.5–5.0 mm) limoniid tipuloids. Head with rostrum short, antenna 16-segmented. Thorax short and narrow, with V-shaped thoracic suture developed; no tibial spurs, claws simple. Wings of normal size. Wing venation, with the terms in brackets referring to the system used in the recent Afrotropical Manual, based on Wootton & Ennos (1989) and Saigusa (2006) (Fig. 5): Rs markedly longer than R2+3+4, originating at, to slightly beyond, midway between levels of humeral crossvein and R2 (well before level of Sc2), and running in direct and straight alignment with vein R5; R2+3 almost straight, markedly shorter than R2+3+4 which is distinctly curved and also markedly longer than r-m; dm open; CuA2 (CuA), A1 (CuP) and A2 (A1) almost straight. Male terminalia (Fig. 9) with at least the phallosomic parts withdrawn into the body; base of gonocoxites not covered by epandrium, cerci and hypoproct jutting out freely (8 of 9 species) or covered (1 of 9 species); gonocoxites very short (8 of 9 species) or moderately long (1 of 9 species), ventrally completely fused only in 1 of 9 species; one pair of gonostyli, simple to complex, terminal; aedeagal guide prominent between gonostyli and strongly sclerotized; aedeagus strongly convoluted. Female terminalia: ovipositor with valves short and fleshy, very small and blunt.

Etymology. The generic name refers to the known distribution of the new genus which is considered to be possibly restricted to Australia (Oz) and the morphologic similarity to *Baeoura*. Gender feminine.

Discussion. *Ozeoura g. nov.* is similar to both *Baeoura* and *Cryptolabis*. It can be distinguished from the type species of both these genera by having Rs in direct and straight alignment with vein R5 (Fig. 5) versus Rs ending in cell R4 (*Baeoura*, Fig. 6) or aligned with R5 at a distinct angle (*Cryptolabis*, Figs 7, 8). Rs is long (originating well before Sc2), and CuA2 (CuA) is at the most evenly and widely curved (almost straight) in *Ozeoura* (Fig. 5) versus Rs short (originating well beyond level of Sc2) and CuA2 (CuA) distinctly bowed at bt CuA1 (m-cu) in *Cryptolabis* (*Cryptolabis paradoxa* (Fig. 7) and *Cryptolabis* (*Procryptolabis*) *argentinensis* (similar to Fig. 8). *Ozeoura* has only one pair of terminal gonostyli (Fig. 9) versus subterminal gonostyli (Fig. 10) in *Baeoura nigrolateralis* and two pairs of gonostyli in *Cryptolabis* (*Procryptolabis*) (Fig. 14). *Ozeoura* generally has the base of the gonocoxites not covered by the epandrium (Fig. 9) versus covered in *Baeoura nigrolateralis* (Fig. 10), *Cryptolabis* (*Cryptolabis*) *paradoxa* (Figs 11–13) and *Cryptolabis* (*Procryptolabis*) (Alexander, 1929). This means cerci and hypoproct jut out freely in eight of nine species of *Ozeoura*. Only in *Ozeoura* the aedeagus is strongly convoluted versus simply or at most

sinuously curved. Future detailed studies may show that some of the numerous species placed in *Cryptolabis* belong elsewhere. Some may be found to be closer to *Ozeoura* than to *C. paradoxa* and even belong in *Ozeoura* which is at the present considered Australian versus the New World (mainly Neotropical) in *Cryptolabis* and almost exclusively Old-World in *Baeoura*.

Phylogenetic position of *Ozeoura g. nov.* Using larval and pupal morphology Oosterbroek & Theowald (1991) have *Baeoura*, *Cryptolabis*, *Cladura* Osten Sacken, 1860 and *Chionea* Dalman, 1816 as basal monophyletic group, next to the Chioneinae. They discuss the following characters:

Character 36: “Last larval segment constricted” is given as a synapomorphy for the Eriopterinae. Also found in *Ozeoura* (see under larva below: “terminal abdominal segment constricted at base, considerably narrower than the preceding segment”).

Character 37: Pupal “sheaths of middle legs the shortest” is given as a synapomorphy for the Eriopterinae. Also found in *Ozeoura* (see under pupa below: “fore and hind leg sheaths noticeably longer than the mid leg sheath”).

Character 38: “Pupae without respiratory horns”. Also in *Ozeoura* (see under pupa below: “mesothorax smooth and lacking respiratory horns”).

Character 39: “Labral papilla”. Also found in *Ozeoura* (see under larva below: “cylindrical papillae”). This places *Ozeoura* (as can be expected) in the *Baeoura-Chionea* clade.

Characters 40 (“Last larval segment not constricted”), 41 (“Spiracular lobes absent”) and 48 (“Larvae with ventral creeping welts”) place *Ozeoura* outside the *Cladura-Chionea* clade.

In the large phylogenetic study of Petersen *et al.* (2010) *Cladura* and *Chionea* are given as a well-resolved sister-group but *Baeoura* and *Cryptolabis* are not taken into account. Therefore, concerning the phylogenetic position of *Ozeoura*, Oosterbroek & Theowald (1991) is apparently the only reference paper.

Ozeoura convoluta

(Alexander, 1931) comb. nov.

Figs 15–19, 39

Cryptolabis (*Cryptolabis*) *convoluta* Alexander, 1931: 29.

Baeoura convoluta (Alexander, 1931).—Alexander, 1978: 170.

Material examined. New South Wales: Holotype ♂: Australia, Brooklana, Eastern Dorrigo (AC); 2♂♂, Bimberamala (AM); 1♂, Upper Hastings River, Werrikimbi N.P., G. Theischinger (AM); 1♂, 2♀♀, Wilson River Res., 15 km NW Bellangry, 7-xii-1986, G. Theischinger (AM). **Victoria:** 7♂♂, 6♀♀, Cobungra River, Anglers Rest, 15-i-1982, A. Wells (AM); 1♂, same locality, 4-ii-1974, A. Neboiss (MV); 14♂♂, 10♀♀, Gibbo River-Morass Creek jn 1-ii-1974, A. Neboiss (MV); 1♂, 1♀, Wellington-Carey River jn, 15-ii-1977, A.A. Calder (ANIC). **Queensland:** 1♂, Freshwater Creek nr Cairns, 11-vii-1993, M. Ball (AM).

From the original description of *Cryptolabis convoluta* Alexander, 1931. “Venation: r-m before or close to the fork of Rs; m-cu nearly its own length beyond the fork of M” (Fig. 15). “Hypopygium: Basistyles short and stout. Dististyle fleshy, provided with long setae, those at the

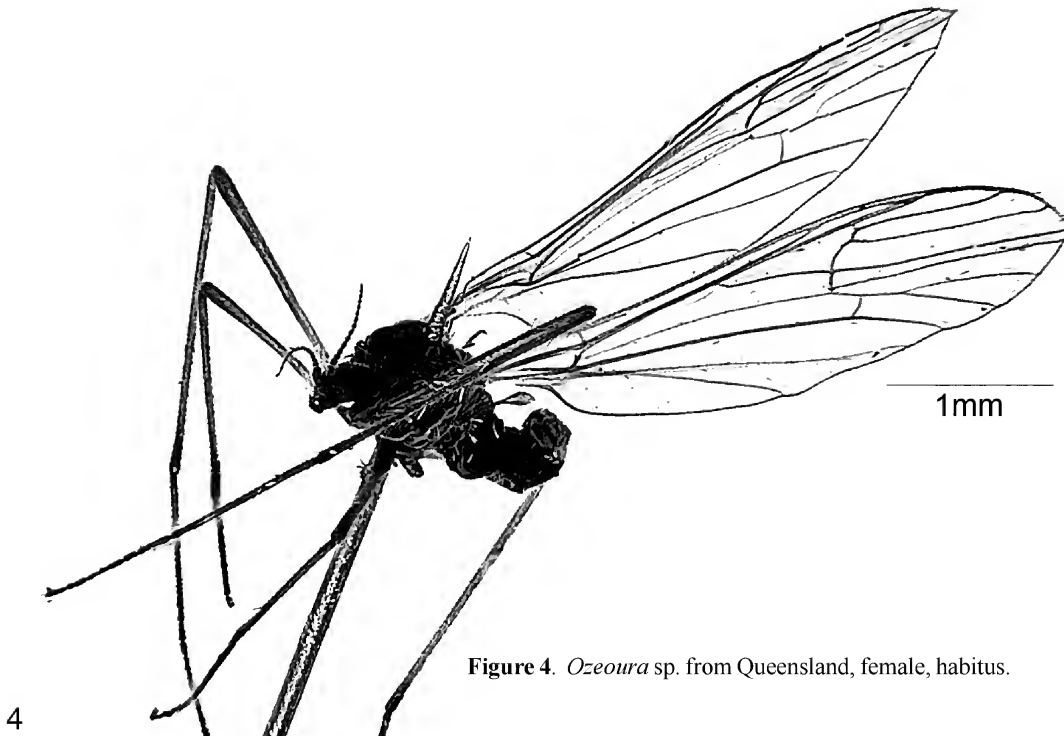


Figure 4. *Ozeoura* sp. from Queensland, female, habitus.

apex more spinous, with one or two similar stout setae on the lateral face. Aedeagus elongate, convoluted, beyond the base directed cephalad, thence bent on itself and directed caudad, narrowed apically. Phallosomic structure massive, the posterior portion microscopically roughened, the caudal margin with a broad V-shaped notch” (Figs 16, 18, 19).

Discussion. Males of *Ozeoura convoluta*, *O. hemmingseni* and *O. tasmanica* share a massive square aedeagal guide which is bilobed in *O. convoluta* and *O. hemmingseni* only. Whereas the tropical *O. hemmingseni* has differentiated gonostyli, they are simple in the more southeastern species *O. convoluta*, *O. tasmanica* and *O. tonnoiri*, the only species with the aedeagal guide spine-like. The characters most useful for the identification of male *O. convoluta* are the massive bilobed aedeagal guide together with very bulky hairy simple gonostyli. *Ozeoura convoluta*, ranging from tropical northeastern Queensland to Victoria, is apparently the most widely distributed species of the genus.

***Ozeoura hemmingseni*
(Alexander, 1978) comb. nov.**

Figs 20–22, 40, 44

Baeoura hemmingseni Alexander, 1978: 168.

Material examined. Holotype ♂: Australia, Atherton (AC); (slide of wing, see Fig. 20); parts of holotype supposedly deposited in ANIC were not found; 1 paratype ♂ (slide of terminalia, see Fig. 22).

From the original description of *Baeoura hemmingseni* Alexander, 1978. Venation: “Sc1 relatively short, nearly one-half Rs; R2+3+4 suberect, R5 in direct alignment with Rs; vein 2nd A long” (Fig. 20). “Hypopygium with the apparent tergite, t, a subquadrate yellow structure, posterior margin bilobed, with shallow median emargination;

surface of plate with abundant short erect setae. Dististyle, d, distinctive (shown in two aspects in figure); a simple structure, basal two-thirds more expanded, bearing a short-clavate dusky more basal lobe provided with scattered erect slender setae and a paler subapical more slender lobe with six long stout yellow setae; apical third of style narrowed into a long straight darkened rod, apex obtuse, without setae. Phallosome, p, about as shown, narrowed outwardly, the enclosed darkened aedeagus, a, short and stout, strongly coiled basally” (Figs 21, 22).

Discussion. Differences between males of *Ozeoura convoluta*, *O. hemmingseni*, *O. tasmanica* and *O. tonnoiri* are described above, under *O. convoluta*. The characters most useful for the identification of male *O. hemmingseni* are the massive bilobed aedeagal guide together with the elongate differentiated gonostyli. In the original description Alexander (1978) describes the gonostylus as bearing a short-clavate dusky more basal lobe, but two basal lobes can be detected in the paratype slide. *Ozeoura hemmingseni* is known only from the type locality, Atherton in tropical Queensland.

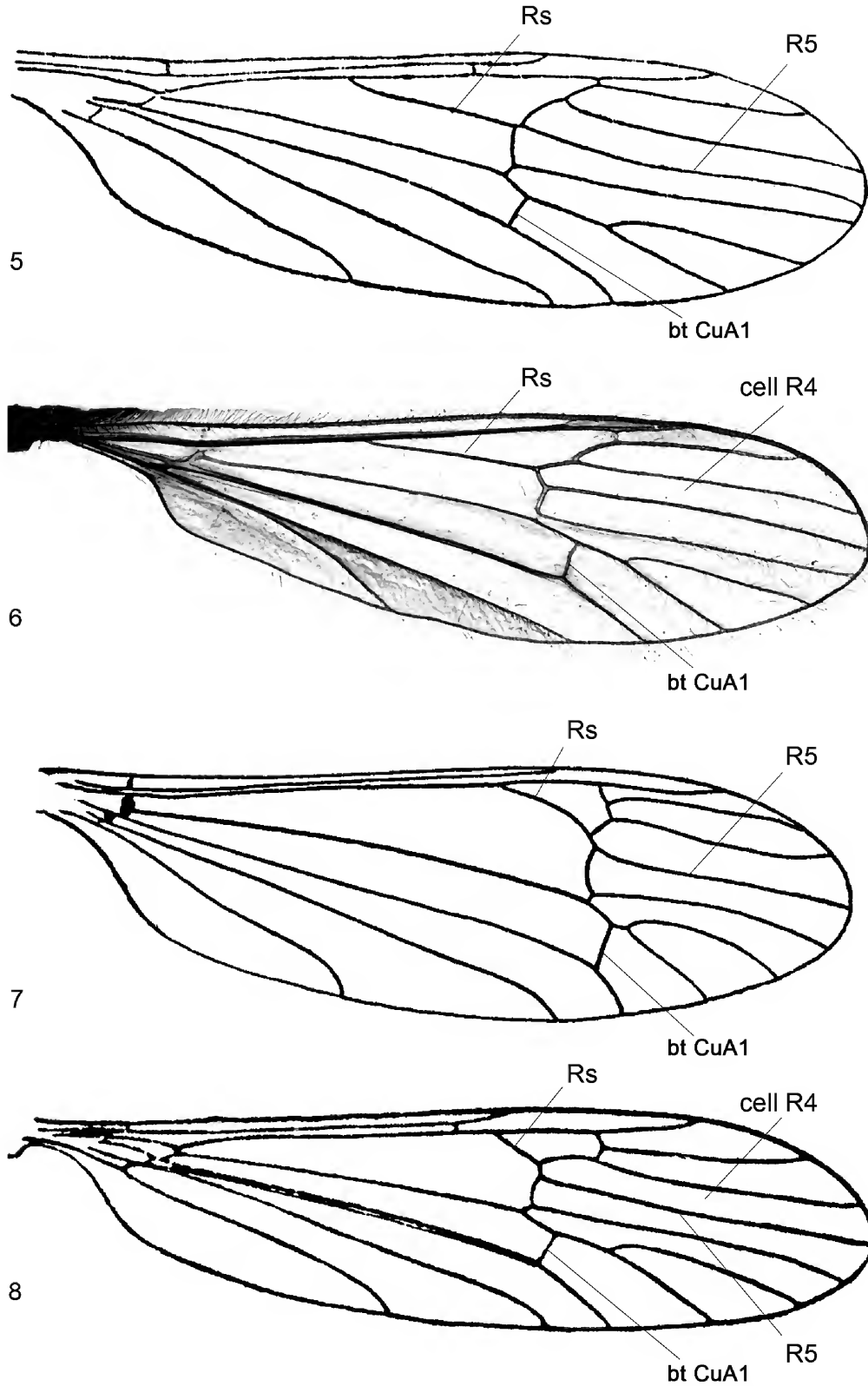
***Ozeoura tasmanica*
(Alexander, 1926) comb. nov.**

Figs 23, 24, 38

Cryptolabis tasmanica Alexander, 1926: 178.

Baeoura tasmanica (Alexander, 1926).—Alexander, 1978: 170.

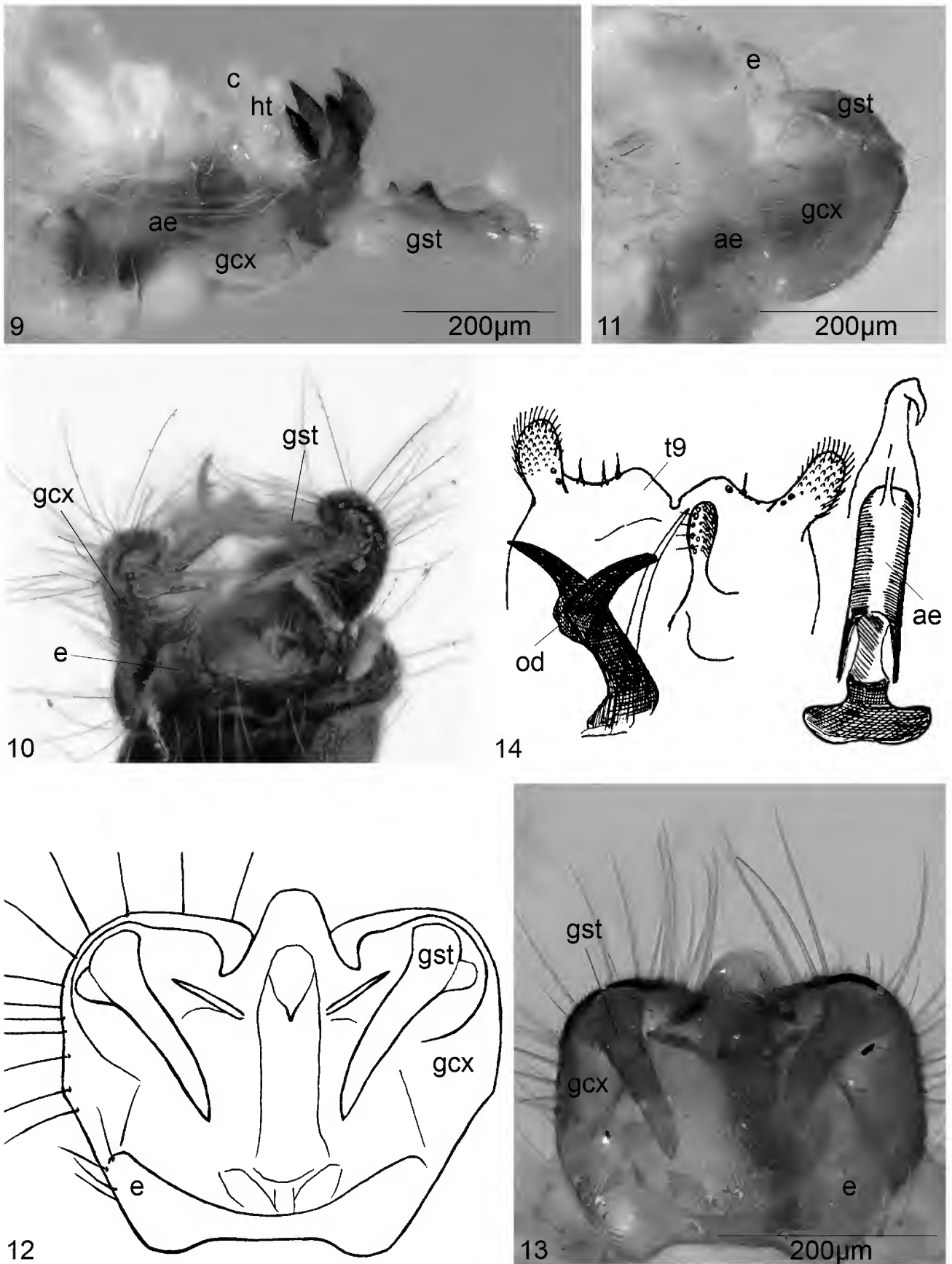
Material examined. Tasmania: Holotype ♂, Australia, Tasmania, Burnie, January 31, 1923, A. Tonnoir (ANIC); only thorax, 1 leg, 1 wing, base of abdomen and badly damaged slide on the pin left; 1 ♀ (paratype), same data as holotype (ANIC); 1 ♀ (allotype), Tasmania, Geeveston, December 7, 1922, A. Tonnoir (ANIC).



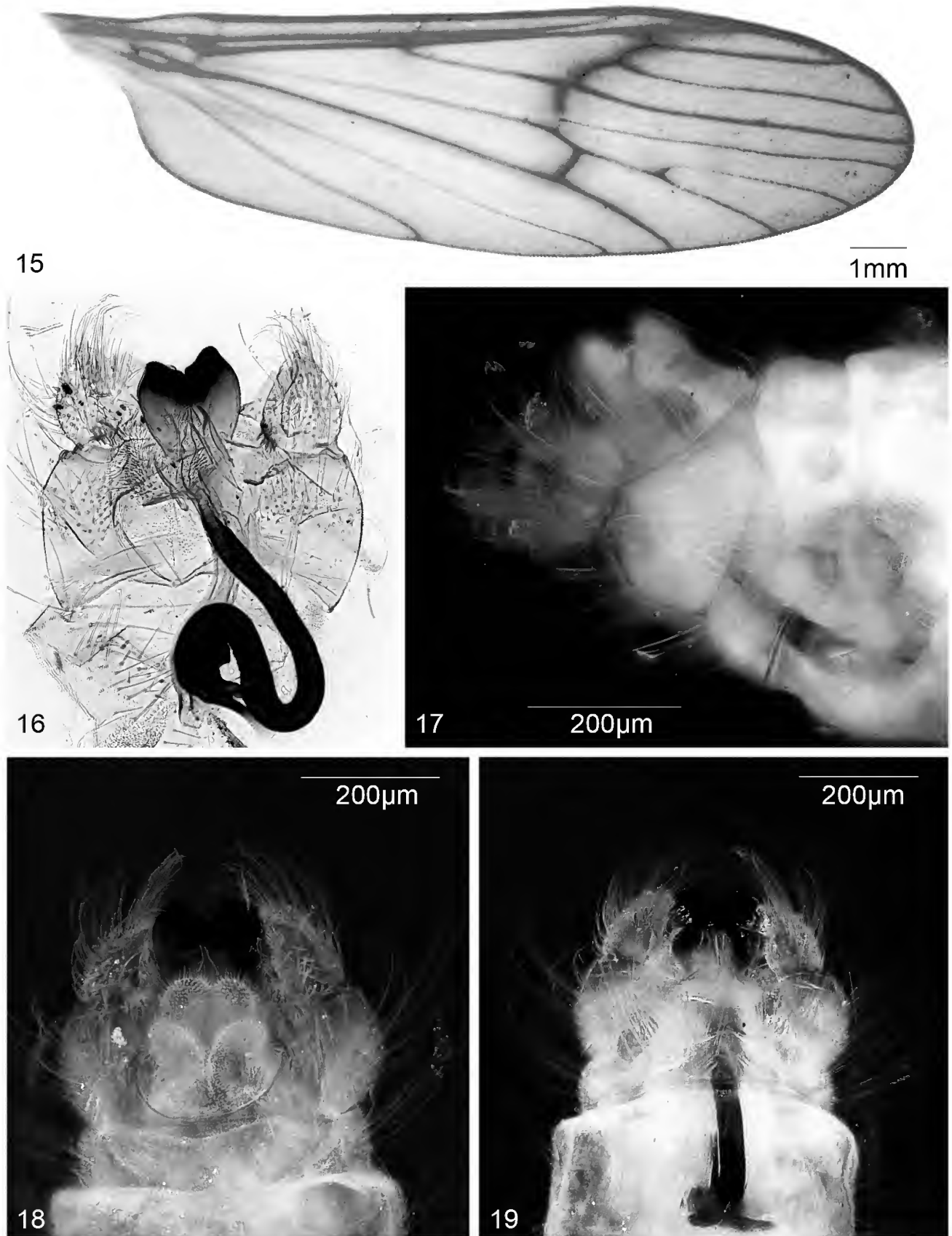
Figures 5–8. Wing venation. (5) *Ozeoura tasmanica*, modified from Alexander (1926); (6) *Baeoura nigrolateralis*, holotype; (7) *Cryptolabis (Cryptolabis) paradoxa*, modified from Alexander (1919); (8) *Cryptolabis (Procryptolabis) bariloehensis*, modified from Alexander (1947).

From the original description of *Cryptolabis tasmanica* Alexander, 1926. “Venation: m-cu less than its length beyond the fork of M” (Fig. 23). “Hypopygium: Dististyle (d) entirely fleshy, not at all produced into a spine, provided with conspicuous setae that are larger and more striking at the apex. Basistyle (b) very broad, the mesal apical angle with two dense groups of setae. The spinous structure in

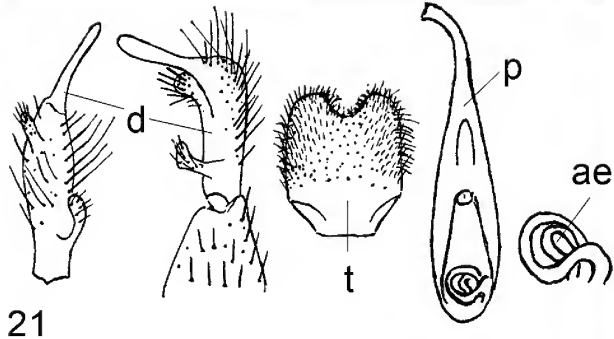
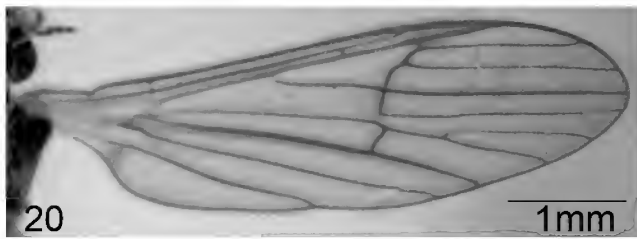
tonnoiri that was suggested as possibly being tergal is here represented by a massive, roughly quadrate structure (t?), the caudal margin truncated and microscopically serrulate. The phallosome (p) is less elongate, more bulbous at base, the apex not conspicuously blackened, the basal bars slender and widely divergent” (Fig. 24).



Figures 9–14. Male terminalia. (9) *Ozeoura billeang*, lateral; (10) *Baeoura nigrolateralis*, holotype, dorsal; (11–13) *Cryptolabis (Cryptolabis) paradoxa*: 11, lateral; 12, 13, dorsal; (14) *Cryptolabis (Procryptolabis) barilochensis*, modified from Alexander (1929). Abbreviations: *a* or *ae*, aedeagus; *c*, cercus; *e*, epandrium; *gcx*, gonocoxite; *gst*, gonostylus; *ht*, hypoproct; *od*, outer gonostylus; *t9*, tergite 9.

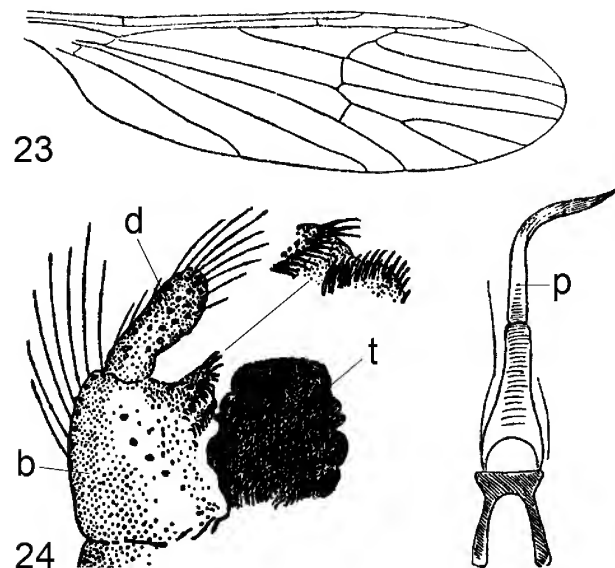


Figures 15–19. *Ozeoura convoluta* (Alexander), male. (15) paratype, wing; (16–19) terminalia: 16, paratype, slide; 17–19, from Queensland: 17, lateral; 18, dorsal; 19, ventral.



Figures 20–22. *Ozeoura hemmingseni* (Alexander), wing, hypopygial details. (20) holotype, slide; (21) modified from Alexander (1978); (22) paratype.

Discussion. Differences between males of *Ozeoura convoluta*, *O. hemmingseni*, *O. tasmanica* and *O. tonnoiri* are described above, under *O. convoluta*. The characters most useful for the identification of male *O. tasmanica* are the massive truncate aedeagal guide together with very simple, apically rounded gonostyli. *Ozeoura tasmanica* is apparently restricted to Tasmania.



Figures 23, 24. *Ozeoura tasmanica* (Alexander), modified from Alexander (1926). (23) wing; (24) terminalia details.

***Ozeoura tonnoiri*
(Alexander, 1926) comb. nov.**

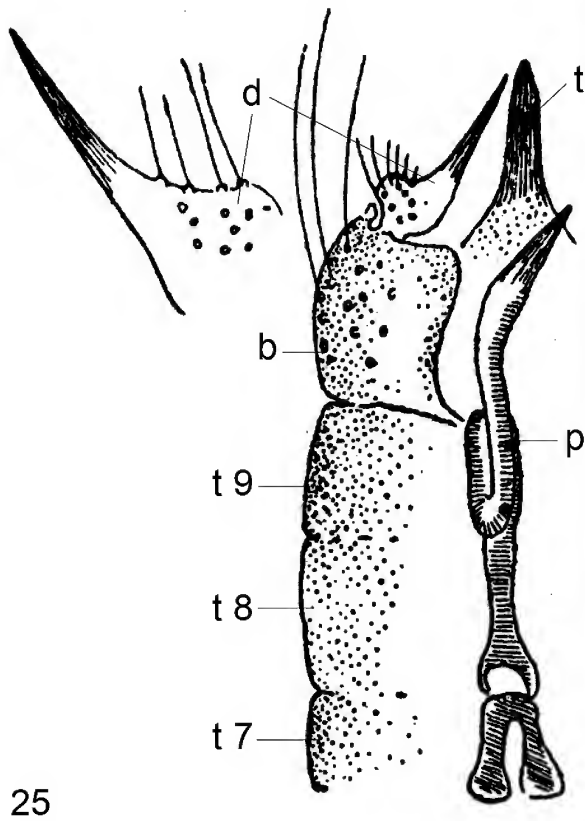
Figs 25, 26, 45

Cryptolabis tonnoiri Alexander, 1926: 174.

Baeoura tonnoiri (Alexander, 1926).—Alexander, 1978: 170.

Material examined. New South Wales: Holotype ♂ in ANIC, Australia, New South Wales, Narara, November 3, 1921, A. Tonnoir; only head, thorax, 1 wing, base of abdomen and badly damaged slide on the pin left. 1♂, Cathedral Rock, 13-ii-1992, G. Theischinger (AM); 1♂, Dingo Tops Forest Park, 950 m, rainforest, malaise, 20-ii–23. iii.1993, G. Williams (AM). **Victoria:** 1♂, Lima East, along Moonee Creek off Monee Monee Creek Track (-36.85987° 145.93786°), 11-xi-2012, Z. Billingham; 2♂♂, Cabbage Tree Creek, along Arte River by Arte River Ralls (-37.57160° 148.76613°), 7-i-2015, Z. Billingham; 1♂, Powelltown, along Blackwood Creek off Reids Mill Walking Track (-37.86039° 145.76248°), 17-i-2016, Z. Billingham (ZB). 2♂♂, 1♀, Erinundra Plateau, Result Creek Falls, 900m, 6-xii-1994, B. Sinclair (AM). **ACT:** 1♂, 1♀, Blundell's, 21-i-1931, A.L. Tonnoir (ANIC).

From the original description of *Cryptolabis tonnoiri* Alexander, 1926. “Venation: Sc1 ending opposite the fork of R2+3, Sc2 opposite the fork of Rs, the latter in alignment with R4+5; m-cu near mid-length of M3+4, the petiole of cell M3 a little longer than m-cu”. “Hypopygium with the basistyles stout, their bases nearly glabrous, the outer lateral portions with setae that become long and conspicuous near the outer lateral angles. Dististyle (d) fleshy at base, the apex produced into a slender, straight, black spine, the tip acute. From between the styli juts a powerful median spine, whose homologies cannot be stated, but which may represent the tergite (t?). The phallosome (p) is a stout, sinuous, or slightly convoluted blackened tube that extends back into the abdomen to the seventh segment, the apex terminating into a long acute spine, the base with two bars that are broadly expanded at tips, the notch between very deep and narrowly U-shaped” (Figs 25, 26).



Figures 25, 26. *Ozeoura tonnoiri* (Alexander), terminalia and details. (25) dorsal, modified from Alexander (1931); (26) ventral, specimen from Australian Capital Territory.

Discussion. Differences between males of *Ozeoura convoluta*, *O. hemmingseni*, *O. tasmanica* and *O. tonnoiri* are described above, under *O. convoluta*. The characters most useful for the identification of male *O. tonnoiri* are the powerful spine-tipped aedeagal guide and simple acutely pointed gonostyli. *Ozeoura tonnoiri* is known from a number of localities in eastern New South Wales, Australian Capital Territory and Victoria.

***Ozeoura billeang* sp. nov.**
Theischinger & Billingham

Figs 5, 9, 27, 28, 42

Holotype ♂, ANIC 040810, Australia, Queensland, -15.23° 145.12°, 7 km N of Hope Vale Mission (at light), 4-x-1980, D. H. Colless; specimen dry, pinned, terminalia preserved (glycerol) in microvial on the pin. **Paratypes:** 2♂♂ (ANIC 040811, 040812), same data as holotype.

Description ♂ (♀ unknown).

Head: including rostrum, palp, scape and pedicel pale to dark greyish brown, antennal flagellum slightly paler, side of vertex pale to medium yellow.

Thorax: Pronotum pale to dull yellow. Remainder pale to dark greyish brown; scutellum and mediotergite with or without ill-defined brownish yellow lateral patch, a small irregular ill-defined brownish yellow patch may be present at about the junction of the pleura. Legs with coxa, trochanter and femur pale to dark greyish yellow, tibia, tarsus and claws pale to dark greyish brown. Wing base and halter brownish

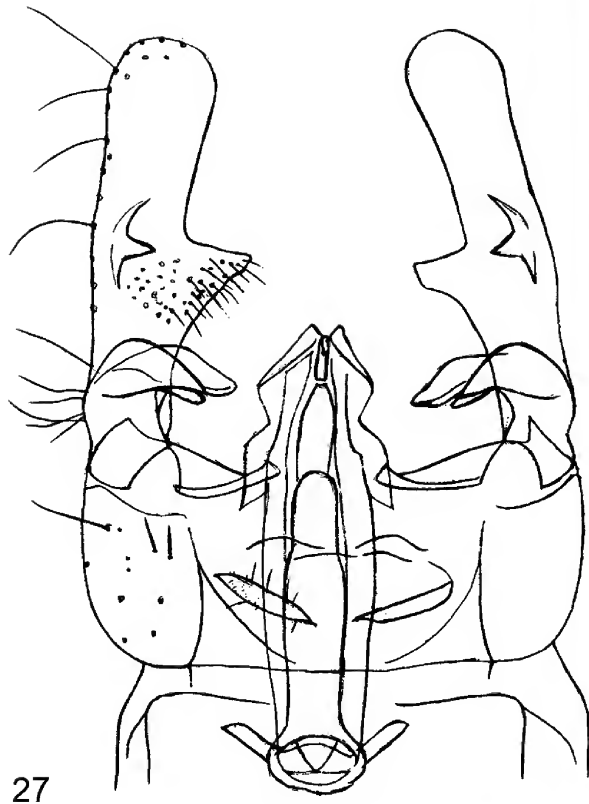
yellow, remainder of wing suffused with pale greyish brown. **Abdomen:** greyish brown.

Terminalia (Figs 9, 27, 28): Gonocoxites only about half as long as gonostyli; gonostyli with apex rounded and with mesal tooth and dorsal spine at about mid-length, and including a trifid basal dorsomesal structure that appears bifid from most aspects as the middle lobe is very small and between the two other lobes. Aedeagus with apical portion simple and very thin; aedeagal guide ending in two small subtriangular lobes; epandrium not covering base of gonocoxites.

Dimensions: Wing length 3.6–4.0 mm.

Etymology. Billeang is from one of Australia’s Aboriginal languages and is a word for “bat”; a noun in apposition to the generic name alluding to small, crepuscular, flight.

Discussion. *Ozeoura billeang* sp. nov. is very similar to *O. bonelya* sp. nov., differing from it by the simply rounded apex of the gonostyli and the slightly bilobed rather parallel sided aedeagal guide versus apically bird-head-shaped gonostyli and a subtriangular aedeagal guide. In both of these species the gonostyli bear a mesal tooth and have a three lobed dorsomesal basal structure, whereas in *O. lottheggi*, the species similar to both of them the apically conical gonostyli do not bear a mesal tooth and have four basal lobes. Thus, the most useful diagnostic characters of *O. billeang* are the apically rounded gonostyli with mesal tooth, dorsal spine and trifid dorsomesal basal structure and the slightly bilobed rather parallel sided aedeagal guide. *Ozeoura billeang* is known only from the type locality, 7 km N of Hope Vale Mission, in tropical northeastern Queensland.



Figures 27, 28. *Ozeoura billeang* sp. nov., holotype male, terminalia, dorsal.

***Ozeoura bonelya* sp. nov.**
Theischinger & Billingham

Figs 29, 30, 43

Holotype ♂, ANIC 040813, Australia, Queensland, The Boulders, Babinda, 10-v-1967, D. H. Colless; specimen dry, pinned, terminalia preserved (glycerol) in microvial on the pin.

Description ♂ (♀ unknown).

Head: including rostrum, palp, scape and pedicel dark brownish grey, antennal flagellum slightly paler, side of vertex greyish yellow to dull orange.

Thorax: Pronotum pale yellowish brown. Remainder with scutum dark greyish to blackish brown, scutellum, mediotergite, laterotergite and pleura greyish brown. Legs with coxae and trochanter yellowish brown, femur greyish yellow, tibia, tarsus and claws greyish brown. Wing base and halter greyish yellow, remainder of wing suffused with pale grey.

Abdomen: greyish brown.

Terminalia (Figs 29, 30): Gonocoxites only about half as long as gonostyli; gonostyli with tooth-shaped mesal lobe at about mid-length, with bird-head-shaped mesally directed apex and with a dorsomesal, trifold basal structure that appears bifid from most aspects as the middle lobe is very small and between the two other lobes; aedeagus with apical portion simple and very thin; aedeagal guide widely triangular; epandrium not covering base of gonocoxites.

Dimensions: Wing length 3.5 mm.

Etymology. Bonelya is from one of Australia's Aboriginal languages and is a word for "bat"; a noun in apposition to

the generic name alluding to small, crepuscular, flight.

Discussion. The differences between male *Ozeoura bonelya* sp. nov., *O. billeang* sp. nov. and *O. lottheggi* sp. nov. are described above, under *O. billeang*. The most useful diagnostic characters of *O. bonelya* are the apically bird-head-shaped gonostyli with mesal tooth and trifold dorsomesal basal structure and the subtriangular aedeagal guide. *Ozeoura bonelya* is known only from the type locality, The Boulders, Babinda, in tropical northeastern Queensland.

***Ozeoura lottheggi* sp. nov.**
Theischinger & Billingham

Figs 31–33, 48

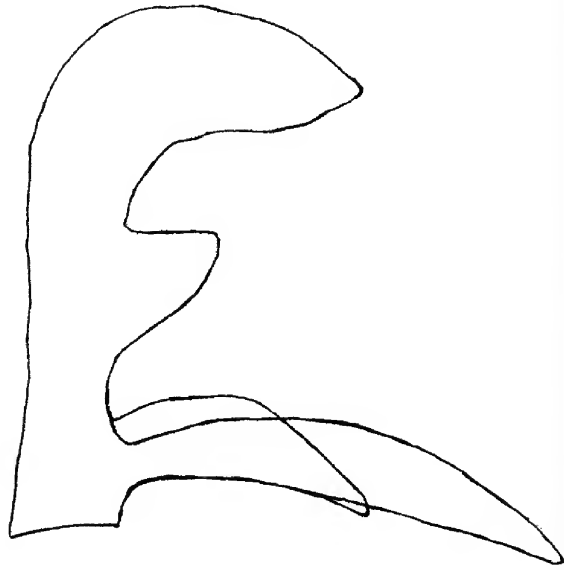
Holotype ♂, ANIC 040814, Australia, Queensland, -17.03° 145.12°, 3 km N by E of Mt Tip Tree, at light, 20-x-1980, D. H. Colless; specimen dry, pinned, terminalia preserved (glycerol) in microvial on the pin.

Description ♂ (♀ unknown).

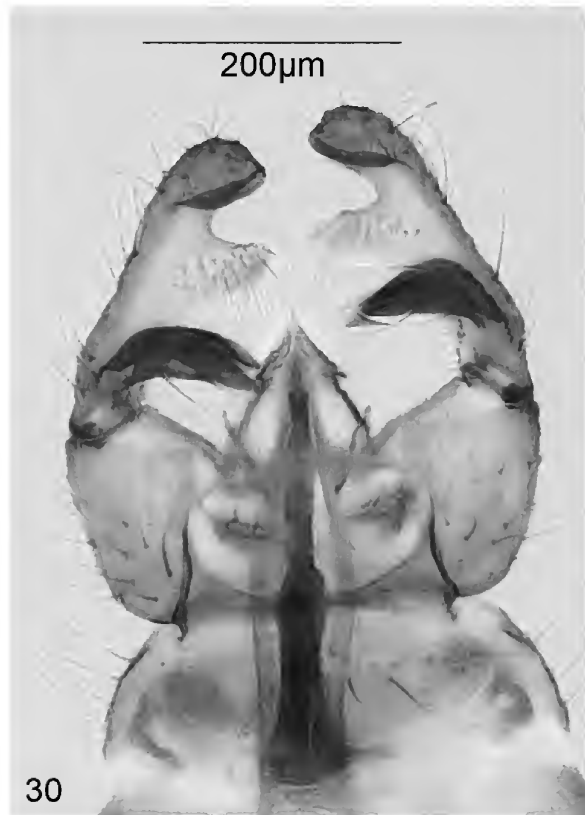
Head: on top largely brownish yellow to medium brown; rostrum, palp and antenna medium to dark brown, side of vertex greyish yellow to dull orange.

Thorax: Pronotum greyish yellow. Remainder with scutum blackish brown, scutellum, mediotergite, laterotergite, pleura and meron greyish brown. Legs brownish yellow to yellowish brown, increasingly darker from coxa to tarsus. Wing base and halter brownish yellow, remainder of wing suffused with yellowish brown.

Abdomen: brown.



29



30

Figures 29, 30. *Ozeoura bonelya* sp. nov., holotype male, terminalia. (29) gonostyle; (30) dorsal.

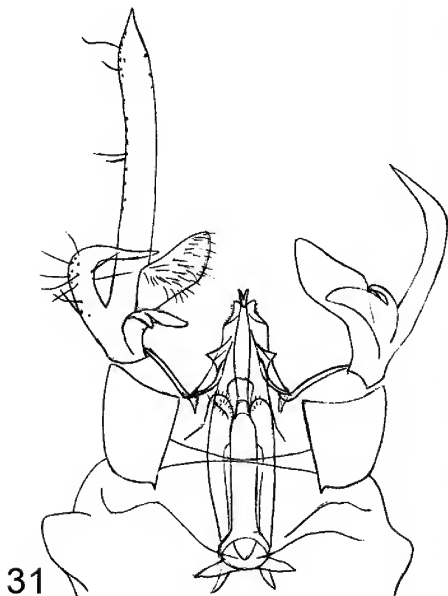
Terminalia (Figs 31–33): Gonocoxites short; the straight slender pointed gonostyli at least twice as long as gonocoxites and with four basal lobes of various shapes and sizes; aedeagus with apical portion very thin and apparently bifid; aedeagal guide rather narrow with triangular lobe each side and ending in two small subtriangular lobes; epandrium not covering base of gonocoxites.

Dimensions: Wing length 4.8 mm.

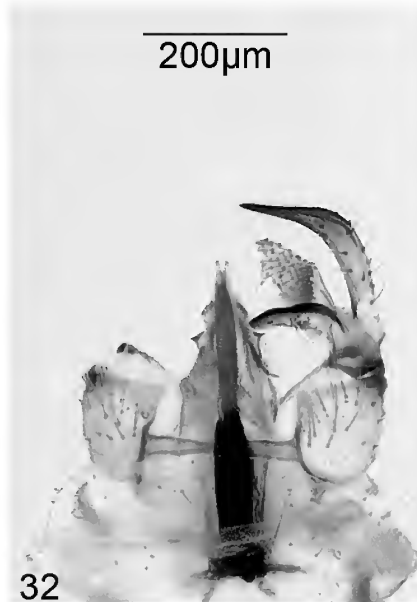
Etymology. Lottheggi is from one of Australia’s Aboriginal languages and is a word for “bat”; a noun in apposition to the

generic name alluding to small, crepuscular, flight.

Discussion. The differences between male *Ozeoura bonelya* sp. nov., *O. billeang* sp. nov. and *O. lottheggi* sp. nov. are described above, under *O. billeang*. The most useful diagnostic characters of male *O. lottheggi* are the apically conical gonostyli with four basal lobes of various size and shape but without mesal tooth at about mid-length, and the rather narrow trapezoidal aedeagal guide. *Ozeoura lottheggi* is known only from the type locality, 3 km N by E of Mt Tip Tree, in tropical northeastern Queensland.



31

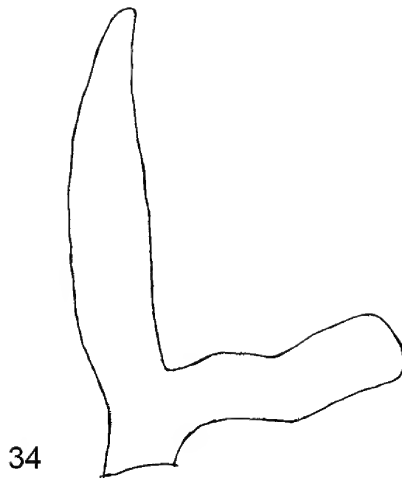


32



33

Figures 31–33. *Ozeoura lottheggi* sp. nov., holotype male, terminalia. (31, 32) dorsal; (33) gonostylus.



Figures 34, 35. *Ozeoura dingo* sp. nov., holotype male, terminalia. (34) gonostylus; (35) ventral.



***Ozeoura dingo* sp. nov.**
Theischinger & Billingham

Figs 34, 35, 46, 47

Holotype. ♂ AM K.421141, Australia, New South Wales, Dingo Tops Forest Park, 950 m, rainforest, malaise, 20 Feb.–23 Mar. 1993, G. Williams; specimen in 70% ethanol, therefore bleached, terminalia preserved (glycerol) in microvial in glassvial together with specimen. **Paratype:** 1♂ (terminalia missing), same data as holotype, AM K.421142.

Description ♂ (♀ unknown).

Head: including rostrum, palp and antenna yellow.

Thorax: Pronotum whitish yellow. Remainder yellow, slightly darkened to brownish at anterior face of prescutum. Legs whitish yellow. Wing and halter yellowish white.

Abdomen: yellowish white.

Terminalia (Figs 34, 35): Gonocoxites short and ventrally completely fused; gonostyli about as long as gonocoxites, slim with apical third continuously narrowing, and basally with a medially directed, somewhat bowed lobe with apex rounded, darkened and setose; aedeagus convoluted, with apical portion simple and very thin; aedeagal guide largely parallel sided, distally bilobed.

Dimensions: Wing length 4.5 mm.

Etymology. Dingo after the type locality Dingo Tops Forest Park; it is treated as a noun in apposition to the generic name.

Discussion. Male *Ozeoura dingo* sp. nov. does not appear particularly close to any of the other *Ozeoura* species. It stands out from all of them by ventrally completely fused gonocoxites and two-armed gonostyli which at the present time seem to be the only available useful characters for its identification. *Ozeoura dingo* is known only from the type locality, Dingo Tops Forest Park in northeastern New South Wales, where it was found to coexist with *O. tonnoiri*.

***Ozeoura narahdarn* sp. nov.**
Theischinger & Billingham

Figs 36, 37, 41

Holotype ♂, ANIC 040815, Australia, Queensland, Moses Creek, 4 km N by E of Mt Finnegan (at light), 15-x-1980, D. H. Colless; specimen dry, pinned, terminalia preserved (glycerol) in microvial on the pin. **Paratypes** 1♂ (AM K.421143), Australia, Queensland, Cape Tribulation, Pilgrim Sands, 16-i-1992, G. Theischinger; 1♂ (AM K.421144), Australia, Queensland, Tully River Gorge, 8-iv-1997, G. Theischinger & L. Mueller.

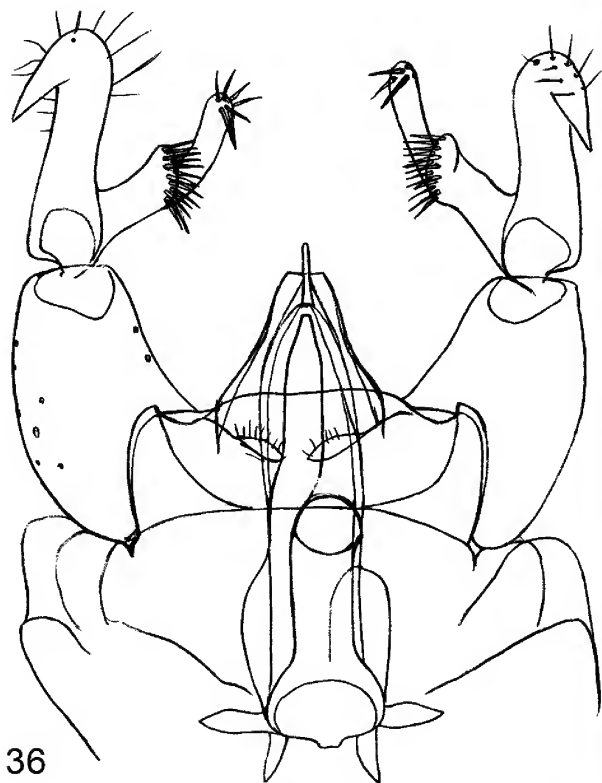
Description ♂ (♀ unknown).

Head: with top brownish yellow to pale brown; rostrum, palp and antenna medium brown, side of vertex greyish yellow to dull orange.

Thorax: Pronotum dull yellow. Remainder yellowish brown, only anterior portion of prescutum dark to blackish brown and scutellum and mediotergite pale greyish brown. Legs brownish yellow becoming increasingly but only slightly darker from coxa to middle of tarsus, only apical portion of tarsus dark greyish brown. Wing base and halter brownish yellow, remainder of wing suffused with pale grey.

Abdomen: greyish brown.

Terminalia (Figs 36, 37): Gonocoxites long, at least as long as gonostyli which are forked near the base with one arm bowed and pointed and the other (mesal) arm with



Figures 36, 37. *Ozeoura narahdarn* sp. nov., holotype male, terminalia, dorsal.

additional branch, both with apex rounded and strongly setose; aedeagus with apical portion simple and thin; aedeagal guide roughly narrowly trapezoidal; epandrium apparently bilobed and partly covering base of gonocoxites.

Dimensions: Wing length 4.2 mm.

Etymology. Narahdarn is from one of Australia’s Aboriginal languages and is a word for “bat”; a noun in apposition to the generic name alluding to small, crepuscular, flight.

Discussion. Male *Ozeoura narahdarn* sp. nov. differs

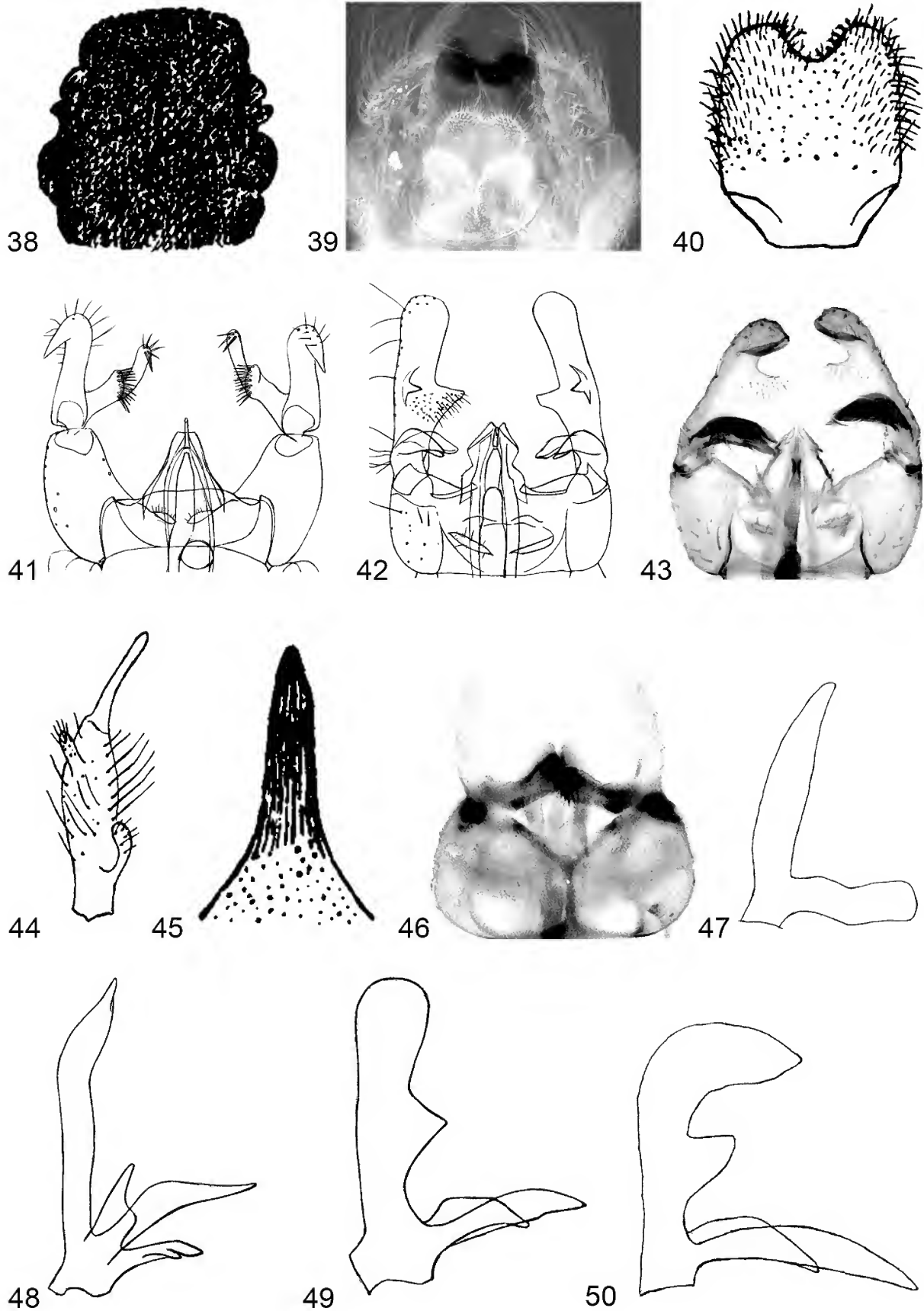
significantly from all other species assigned here to *Ozeoura* by having much longer gonocoxites and an epandrium covering their base, which, together with the particular shape of gonostyli and aedeagal guide, are the characters useful for its identification. However *O. narahdarn* fits well into genus *Ozeoura* based on wing venation, number and position of gonostyli and geographic distribution. *Ozeoura narahdarn* is known from three localities, all in tropical Queensland: Moses Creek, 4 km N by E of Mt Finnegan; Cape Tribulation, Pilgrim Sands; Tully River Gorge.

Key to the males of *Ozeoura* g. nov.

For explanation of the term *aedeagal guide*, see above under *Material and methods*.

- 1 Aedeagal guide compact, almost square (Figs 38–40) 2
- Aedeagal guide at least caudally much narrower than long (Figs 41–43, 45, 46) 4
- 2 Aedeagal guide with caudal margin truncate (Fig. 38) *tasmanica*
- Aedeagal guide with caudal margin bilobed (as in Figs 39, 40) 3
- 3 Gonostyli simple without distinct mesal lobes (Fig. 39) *convoluta*
- Gonostyli complex with mesal lobes (Fig. 44) *hemmingseni*
- 4 Aedeagal guide terminates in a simple powerful spine (Fig. 45) *tonnoiri*
- Aedeagal guide roughly rectangular, trapezoidal or subtriangular or bilobed (Figs 41–43, 46) 5
- 5 Epandrium covering base of elongate gonocoxites (Fig. 41) *narahdarn*
- Epandrium not overing base of roughly square gonocoxites (Figs 42, 43, 46) 6

... / key continues on p. 462



Figures 38–50. Male terminalia: aedeagal guide (ag), gonostylus (g), epandrium (e), basal portion of terminalia dorsal (t), of *Ozeoura* spp. (38) *O. tasmanica*, ag; (39) *O. convoluta*, t; (40) *O. tasmanica*, ag; (41) *O. narahdarn*, t; (42) *O. billeang*, t; (43) *O. bonelya*, t; (44) *O. hemmingseni*, g; (45) *O. tonnoiri*, ag (46) *O. dingo*, t, ventral; (47) *O. dingo*, g; (48) *O. lotheggi*, g; (49) *O. billeang*, g; (50) *O. bonelya*, g.

6	Gonocoxites ventrally fused (Fig. 46); gonostyli with only one basal mesal lobe (Fig. 47)	<i>dingo</i>
—	Gonostyli with four basal lobes or bifid/trifid basal structure (Figs 48–50)	7
7	Gonostyli with basal lobes only (Fig. 48)	<i>lottheggi</i>
—	Gonostyli with bifid/trifid basal structure and mesal tooth at about half-length (Figs 49, 50)	8
8	Aedeagal guide narrowly rectangular to trapezoidal, slightly bilobed (Figs 42)	<i>billeang</i>
—	Aedeagal guide widely triangular (Figs 43)	<i>bonelya</i>

Immature stages

The immature stages of *Baeoura* and *Cryptolabis* are thought to be entirely aquatic and are similar to each other morphologically, as outlined by Oosterbroek and Theowald (1991). Wood (1952) provided a brief description of the larval and pupal stages of *Baeoura claripennis* Alexander, 1921 (included within the genus *Erioptera* Meigen at the time) and Hynes (1963) gave detailed descriptions of *Cryptolabis magnistyla* Alexander, 1962 larva and pupa. There is no published account of these or similar immature crane flies in Australia. By examining larval and pupal specimens sourced from aquatic macroinvertebrate surveys, as a component of routine water quality monitoring programs in Victoria, New South Wales and Tasmania, a number of larval and pupal specimens have been discovered which are morphologically very similar to those described for *Baeoura* and *Cryptolabis*. Given the apparent close affinities of *Ozeoura* to *Baeoura* and *Cryptolabis*, it is possible these larval and pupal specimens are the immature stages of *Ozeoura*. Hynes (1963) reared larvae in an artificial stream in the laboratory to confirm association of the immature stages with adult *Cryptolabis*, however without access to such a facility the present study utilizes molecular techniques to associate larval and adult stages of *Ozeoura*.

Ozeoura pupa

Figs 51–53

Material examined. **Victoria:** 1, Bindi, Tambo River at Blackfellows Flat (-37.05809° 147.827985°), 29-xi-2011, Z. Billingham; 1, Humevale, Jacks Creek off Road 10 (-37.4689° 145.16974°), 14-xii-2011, Z. Billingham; 2, Weeragua, Cann River West Branch off Monaro Hwy (-37.37295° 149.19899°), 11-xii-2012, Z. Billingham; 3, Mitta Mitta, Snowy Creek off Omeo Hwy (-36.54554° 147.40903°), 13-xii-2012, Z. Billingham; 1, Harrietville, Ovens River off Mill Rd (-36.90145° 147.05372°), 14-xii-2012, Z. Billingham; 2, Nariel Valley, Nariel Creek off Benambra-Corryong Rd (-36.44357° 147.82987°), 14-xii-2012, Z. Billingham; 5♂ *Beaoura convoluta* pharate pupae, Weeragua, Cann River West Branch off Monaro Hwy (-37.37295° 149.19899°), 10-xi-2015, Z. Billingham; 2♂ *Beaoura convoluta* pharate pupae, Glencairn, Macalister River (-37.52180° 146.56665°), 12-xi-2015, Z. Billingham; 2♂ *Beaoura convoluta* pharate pupae, Glen Valley, Big River off Omeo Hwy (-36.93300° 147.47300°), 28-xi-2015, Z. Billingham; 1♂ *Beaoura convoluta* pharate pupa, Buchan, Buchan River (-37.49570° 148.17200°), 1-xii-2015, Z. Billingham (ZB). (All Victoria).

Description. Elongate cylindrical in form, the terminal segment noticeably narrower than the remainder of abdomen. Head and thorax off-white to pale yellow, abdomen concolorous or darkening to brown in some mature specimens (Fig. 51). Head with pronounced cephalic

crest along the vertex, multiple long setae arising from the furrow formed between this crest and the antennal sheaths. Mesothorax smooth and lacking respiratory horns (Fig. 52). Wing pads not extending beyond the second abdominal segment. Leg sheaths not exceeding the third abdominal segment, the fore and hind leg sheaths noticeably longer than the mid leg sheath. Abdominal integument lacking armature and only sparsely setose. The dorsal surface of the cauda may bear the vestigial remains of the larval spiracular lobes, appearing as small curled finger-like processes or as little more than raised lumps. Dorsal cauda also bearing paired lobes, each with U-shaped distal margin, the edges drawn into fine points (Fig. 53). Cauda ventrally rounded and smooth.

Discussion. The absence of thoracic respiratory horns and the setose cephalic crest readily distinguishes the pupae of *Ozeoura* from any other known Australian limoniid pupae. Pharate male pupae can be identified to species through dissection of the cauda, insufficient material is available to identify species specific characters among non-pharate and female specimens.

Ozeoura larva

Figs 54–57

Material examined. **New South Wales:** 3, Dingo Forest, Caparra Creek off Rumba Dump Trail (-31.70148° 152.19244°), 14-iv-1997, NSW OEH; 2, Sandy Hill, Macleods Creek off Macleods Creek Rd (-28.96709° 152.27192°), 6-v-1997, NSW OEH; 1, Douglas Park, Nepean River off Douglas Park Drive (-34.19159° 150.71113°), 9-xii-1997, NSW OEH; 1, Tom Groggin, Murray River By Tom Groggin Camp Ground (-36.54413° 148.12866°), 24-iii-1998, NSW OEH; 4, Backwater, Backwater Creek off Horseshoe Bend Fire Trail (-30.06242° 151.92784°), 10-v-1998, NSW OEH; 2, Nightcap, Terania Creek by Terania Creek Picnic Ground (-28.56845° 153.31098°), 11-v-1998, NSW OEH; 3, Wadbilliga, Wadbilliga River off Wadbilliga Rd (-36.27666° 149.61194°), 26-v-1998, NSW OEH; 1, Wombeyan Caves, Mares Forest Creek off Mares Forest Rd (-34.31759° 149.92180°), 26-v-1998, NSW OEH; 2, Jinden, Jinden Creek off Jinden Ridge Rd (-35.88256° 149.56436°), 26-v-1998, NSW OEH; 2, New South Wales, Wandella, Paddy's Creek off Paddy's Fire Trail (-36.33407° 149.80830°), 2-vi-1998, NSW OEH; 4, Wonboyn North, Wonboyn River off Wonboyn Link Track (-37.25665° 149.88505°), 3-vi-1998, NSW OEH; 1, Nightcap, Terania Creek by Terania Creek Picnic Ground (-28.56845° 153.31098°), 8-x-1998, NSW OEH; 5, Never Never, Rosewood River off Rosewood Creek Track (-30.36494° 152.80733°), 9-x-1998, NSW OEH; 1, Wombeyan Caves, Mares Forest Creek off Mares Forest Rd (-34.31759° 149.92180°), 03-xi-1998, NSW OEH; 8, Jinden, Jinden Creek off Jinden Ridge Rd (-35.88256° 149.56436°), 09-xi-1998, NSW OEH; 4, Tallaganda, Mulloon Creek by Mulloon Camp Ground (-35.43827° 149.56962°), 09-xi-1998, NSW OEH; 16, Wandella, Paddy's Creek off Paddy's Fire Trail (-36.33407° 149.80830°), 10-xi-1998, NSW OEH; 4, Tom Groggin, Murray River By Tom Groggin Camp Ground (-36.54413° 148.12866°),



Figure 51. *Ozeoura convoluta* pupae.

11-xi-1998, NSW OEH; 3, Geehi, Swampy Plain River by Geehi Camp Ground (-36.37875° 148.17781°), 11-xi-1998, NSW OEH; 11, Wonboyn North, Wonboyn River off Wonboyn Link Track (-37.25665° 149.88505°), 13-xi-1998, NSW OEH; 2, Upper Kangaroo River, Kangaroo River off Upper Kangaroo River Rd (-34.68807° 150.60078°), 13-xi-1998, NSW OEH; 1, Conjola, Bunnair Creek off Calgaroo Rd (-35.23277° 150.40397°), 22-xii-1998, NSW OEH; 7, Tom Groggin, Murray River By Tom Groggin Camp Ground (-36.54413° 148.12866°), 25-iii-1999, NSW OEH; 10, Geehi, Swampy Plain River by Geehi Camp Ground (-36.37875° 148.17781°), 25-iii-1999, NSW OEH; 2, Rocky River, Nelson Creek off Rocky River Rd (-29.07364° 152.34743°), 19-iv-1999, NSW OEH; 4, Dingo Forest, Caparra Creek off Rumba Dump Trail (-31.70148° 152.19244°), 21-iv-1999, NSW OEH; 14, Megalong Valley, Megalong Creek off Nellies Glen Rd (-33.73025° 150.24451°), 29-ix-1999, NSW OEH; 3, Wolgan Valley, Wolgan River off Wolgan Rd (-33.30052° 150.12407°), 29-ix-1999, NSW OEH; 3, Tuckers Nob, Never Never River off Promised Land Rd (-30.35981° 152.90500°), 11-x-1999, NSW OEH (ZB). **Victoria:** 2, Benambra, Tambo River (-36.99945° 147.88255°), 1-v-2011, Z. Billingham; 5, Warburton, Yarra River off Whitegum Dr (-37.72144° 145.76951°), 14-ix-2011, Z. Billingham; 1, McMahons Creek, Starvation Creek off Road 17 (-37.75735° 145.85014°), 27-ix-2011, Z. Billingham; 1, Healesville, Donnelly Creek off Donnelly Weir Rd (-37.62945° 145.53388°), 11-x-2011, Z. Billingham; 3, Healesville, Graceburn Creek off Road 1 (-37.65375° 145.56664°), 11-x-2011, Z. Billingham; 3, Reefton, Bakers Creek off Road 12 (-37.72794° 146.05417°), 3-xi-2011, Z. Billingham; 4, Reefton, Woods Creek off Road 11 (-37.72866° 146.06235°), 3-xi-2011, Z. Billingham; 5, Bindi, Tambo River at Blackfellows Flat (-37.05809° 147.82798°), 29-xi-2011, Z. Billingham; 17, Bindi, Tambo River upstream of Blackfellows Flat (-37.05820° 147.83888°), 29-xi-2011, Z. Billingham; 3, Humevale, Jacks Creek off Road 10 (-37.46896° 145.16974°), 14-xii-2011, Z. Billingham; 1, Reefton, Bakers Creek off Road 12 (-37.72827° 146.05439°), 19-iii-2012, Z. Billingham; 1, East Warburton, Yarra River off Whitegum Dr

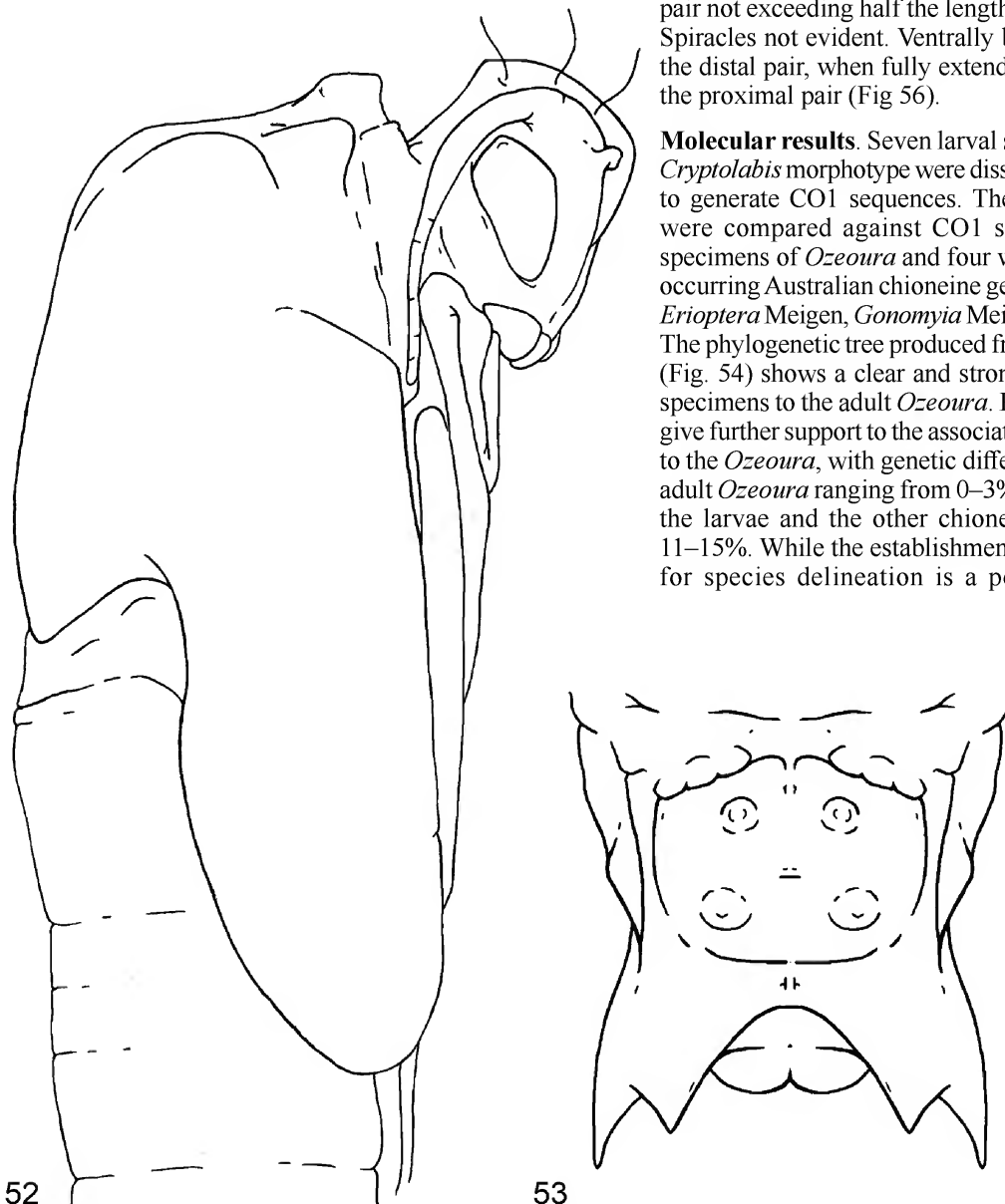
(-37.72144° 145.76951°), 3-iv-2012, Z. Billingham; 7, Rawson, Coopers Creek (-37.96061° 146.40477°), 19-iv-2012, Z. Billingham; 1, The Basin, Dobsons Creek off Basin Olinda Rd (-37.85657° 145.32459°), 15-x-2012, Z. Billingham; 4, Glencairn, Macalister River (-37.52230° 146.56620°), 5-xii-2012, Z. Billingham; 2, Weeragua, Cann River West Branch off Monaro Hwy (-37.37295° 149.19899°), 11-xii-2012, Z. Billingham; 2, Shannonvale, Big River off Omeo Hwy (-36.93300° 147.47300°), 12-xii-2012, Z. Billingham; 1, Suggan Buggan, Suggan Buggan River (-36.95260° 148.32520°), 12-xii-2012, Z. Billingham; 9, Mitta Mitta, Snowy Creek at Omeo Hwy (-36.54600° 147.41045°), 13-xii-2012, Z. Billingham; 20, Nariel Valley, Nariel Creek off Benambra-Corryong Rd (-36.44357° 147.82987°), 14-xii-2012, Z. Billingham; 12, Harrierville, Ovens River off Mill Rd (-36.90145° 147.05372°), 14-xii-2012, Z. Billingham; 2, Matong North, Dandongadale River (-36.80725° 146.63114°), 15-xii-2012, Z. Billingham; 9, McMahons Creek, Starvation Creek off Starvation Creek Rd (-37.71905° 145.80258°), 17-xii-2012, Z. Billingham; 2, Reefton, Tributary of Alderman Creek off Road 19 (-37.72178° 145.94089°), 17-xii-2012, Z. Billingham; 13, McMahons Creek, O'Shannassy River (-37.70119° 145.79151°), 2-v-2013, Z. Billingham; 7, Reefton, Woods Creek off Road 11 (-37.72898° 146.06312°), 27-xi-2013, Z. Billingham; 1, Reefton, Tributary of Alderman Creek off Road 19 (-37.72178° 145.94089°), 28-iv-2014, Z. Billingham; 2, Rawson, Coopers Creek (-37.95948° 146.40448°), 30-iv-2014, Z. Billingham; 2, Rawson, Coopers Creek (-37.95948° 146.40448°), 12-xi-2014, Z. Billingham; 6, Reefton, Woods Creek off Road 11 (-37.72898° 146.06312°), 10-xii-2014, Z. Billingham; 3, Reefton, Armstrong Creek off Armstrong Creek Rd (-37.63615° 145.86061°), 11-xii-2014, Z. Billingham; 1, Clonbinane, Plenty River at Road 54 (-37.45954° 145.16346°), 11-xii-2014, Z. Billingham; 7, Weeragua, Cann River West Branch off Monaro Hwy (-37.37295° 149.19899°), 11-x-2015, Z. Billingham; 3, Glencairn, Macalister River (-37.52230° 146.56600°), 12-xii-2015, Z. Billingham; 2, Jamieson, Goulburn River off Mansfield Woods Point Rd (-37.33836° 146.13557°), 17-xi-2015, Z. Billingham; 1, Shannonvale, Big River

off Omeo Hwy (-36.93300° 147.47300°), 28-xi-2015, Z. Billingham; 1, Reefton, Yarra River at Rd 12 (-37.73295° 146.06704°), 21-xi-2017, Z. Billingham (ZB). **Tasmania:** 2, South Springfield, Forester River (-41.27069° 147.51335°), 2-xii-2013, GHD; 1, Tayene, St. Patrick River (-41.31784° 147.49182°), 4-xii-2013, GHD (ZB).

Description. Mature larvae long cylindrical and rarely exceeding 11mm (Figs 55–57). Off white to yellow in colour, a short downy pubescence, which thickens noticeably around the groves in the thoracic segments and the base of the terminal abdominal segment, lends a deep gold to brown colour to some individuals. Head capsule with frontoclypeal apotome elongate rectangular, moderately sclerotised throughout, the posterior margin minutely notched. Genae heavily sclerotised along the margins, central area lightly sclerotised to membranous. Eye spots on dorsolateral margin of head capsule, just anterior to the articulation of the genae with the frontoclypeal apotome and posterior to the antennal pedestal. Antenna two segmented beyond the pedestal, not extending further than the distal margin of the labrum. First

antennal segment elongate, terminally bearing two short stout setae and a third long fine seta reaching approximately three quarters the length of the maxillary palp; the second antennal segment short, globose and fleshy. At the anterior margin of the frontoclypeal apotome arise two “cylindrical papillae” their distal ends heavily setose so as to form a brush like structure, Hynes (1963) describes these structures in *Cryptolabis* as belonging to the labrum, this is difficult to discern but is most likely the case also in *Ozeoura*. The labrum is large and triangular in shape, fleshy and greatly setose along its distal margin and ventral surface (Fig 57). The thick labral setation obscures much of the structure of the ventral oral cavity. The mandibles however are discernible through dissection, 7–8 toothed and with molar surface often bearing a setal tuft (Fig 57). The basal sections of the maxilla are obscured, the greatly developed, membranous, maxillary palp is clearly discernible and extends anteriorly well beyond the labral brush. Terminal abdominal segment constricted at base, considerably narrower than the preceding segment. Spiracular disc with four lobes, the shorter dorsal pair not exceeding half the length of the longer ventral pair. Spiracles not evident. Ventrally bearing four anal papillae, the distal pair, when fully extended, somewhat longer than the proximal pair (Fig 56).

Molecular results. Seven larval specimens of the *Baeoura/Cryptolabis* morphotype were dissected and their tissues used to generate CO1 sequences. These larval CO1 sequences were compared against CO1 sequence data from adult specimens of *Ozeoura* and four widespread and commonly occurring Australian chioneine genera: *Amphineurus* Skuse, *Erioptera* Meigen, *Gonomyia* Meigen and *Molophilus* Curtis. The phylogenetic tree produced from the CO1 sequence data (Fig. 54) shows a clear and strong association of all larval specimens to the adult *Ozeoura*. P-distance values (Table 2) give further support to the association of the larval specimens to the *Ozeoura*, with genetic differences between larval and adult *Ozeoura* ranging from 0–3%, and differences between the larvae and the other chioneine genera ranging from 11–15%. While the establishment of divergence thresholds for species delineation is a point of some contention



Figures 52, 53. *Ozeoura* pupa. (52) head and thorax, lateral; (53) cauda, dorsal.

(Herbert *et al.*, 2003; Rubinoff *et al.*, 2006), the intrageneric divergence values (0–3%) compared against the intergeneric divergence (11–15%) illustrate a clear association of larval *Ozeoura* at the generic level.

Discussion. The structure of the spiracular disc readily distinguishes the larvae of *Ozeoura* from any other known Australian crane fly larvae. Insufficient material is available to identify species specific characters among larvae.

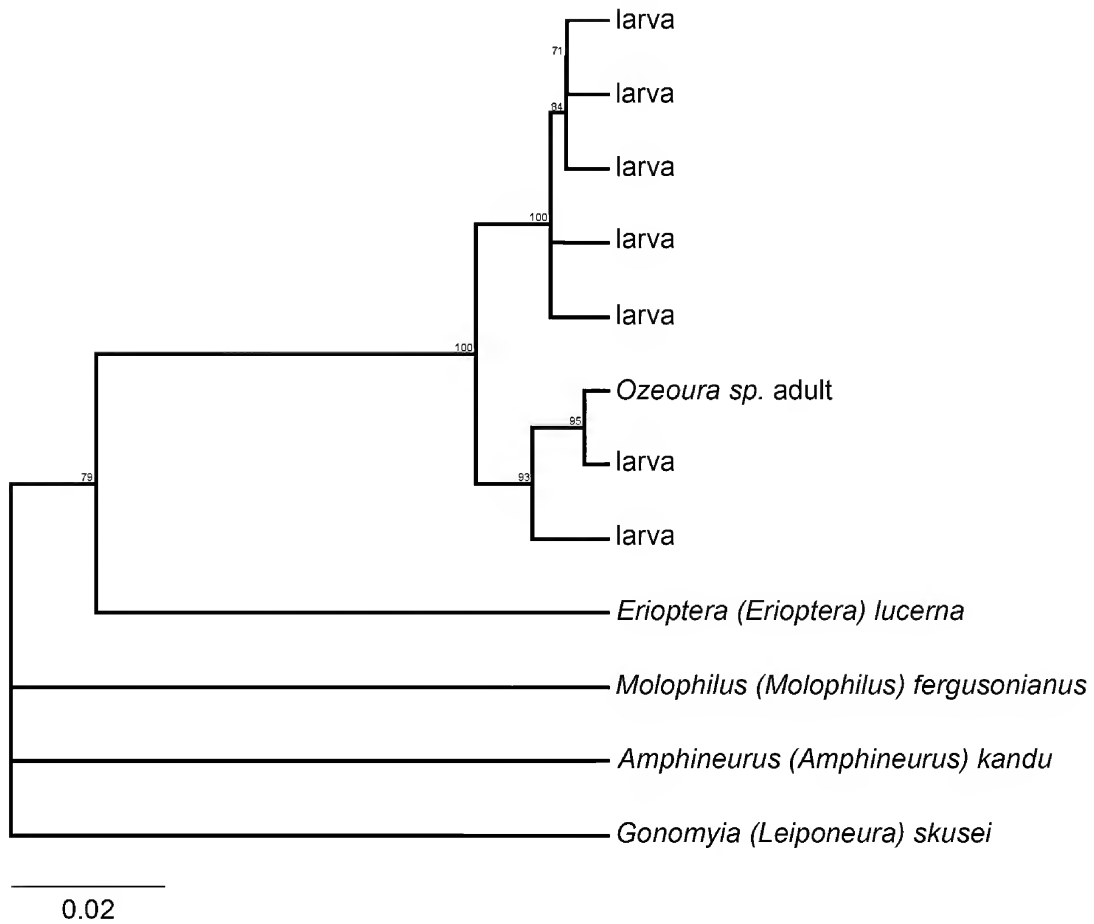
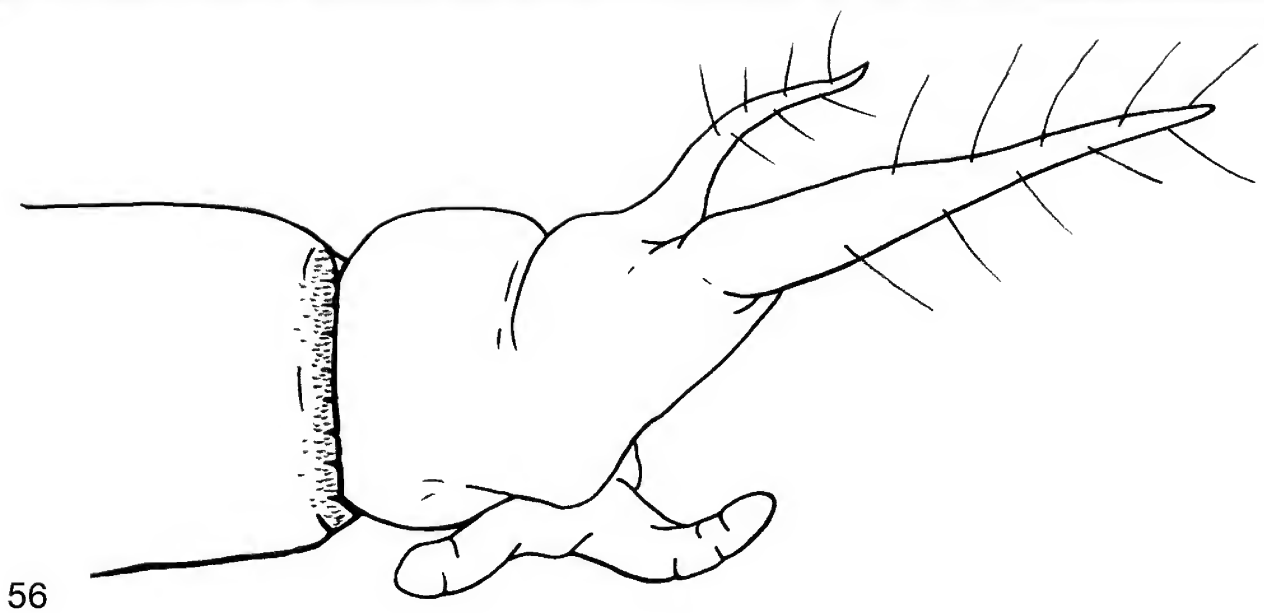
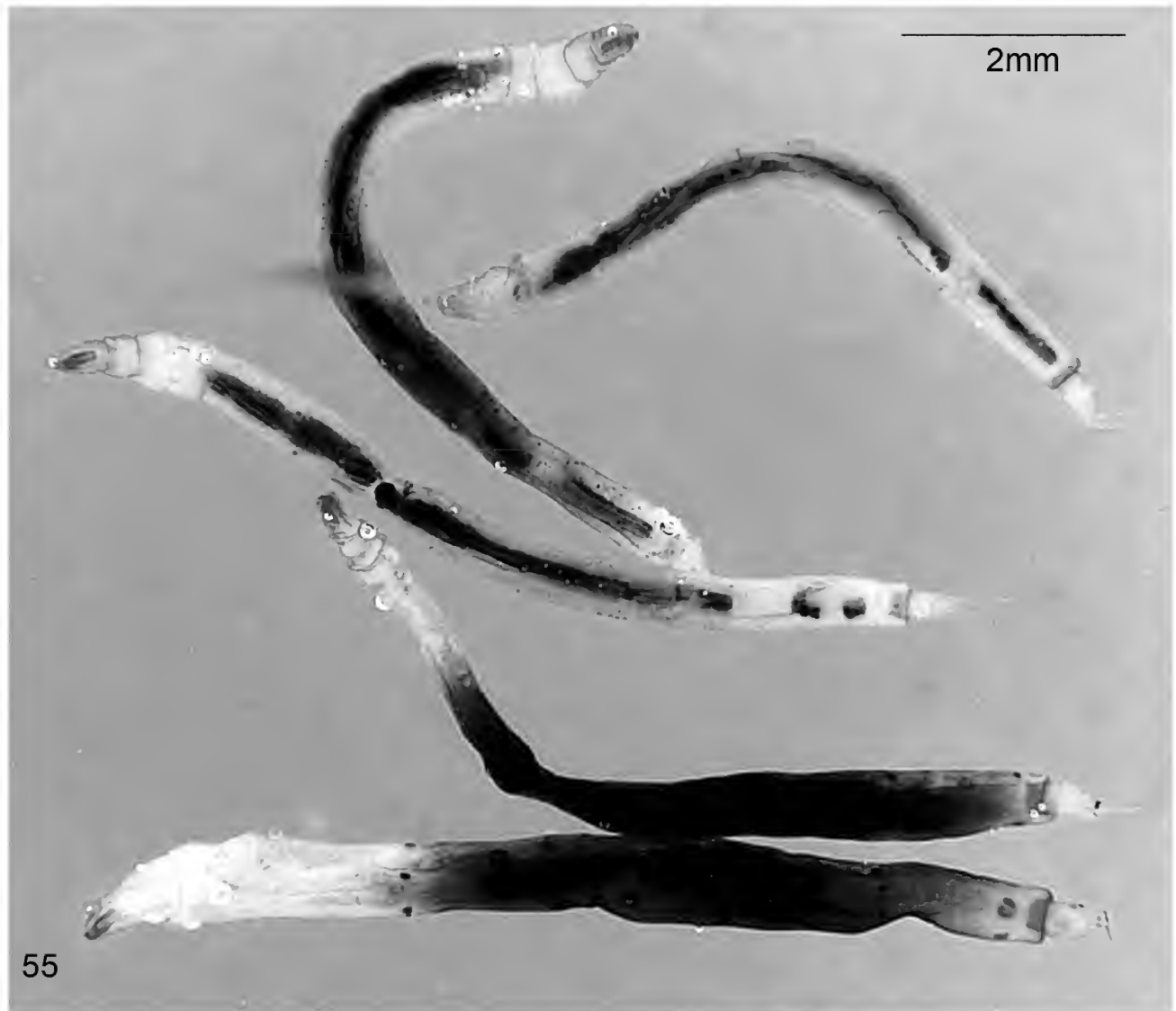


Figure 54. Phylogenetic tree produced using CO1 sequence data, Geneious 9.0.5 (Kearse *et al.*, 2012).

Table 2. P-distance values between CO1 sequences produced for larval and adult specimens, Geneious 9.0.5 (Kearse *et al.*, 2012).

species	1	2	3	4	5	6	7	8	9	10	11	12
1 <i>Molophilus (Molophilus) fergusonianus</i>	—											
2 <i>Amphineurus (Amphineurus) kandu</i>	0.14	—										
3 <i>Gonomyia (Leiponeura) skusei</i>	0.13	0.14	—									
4 <i>Erioptera (Erioptera) lucerna</i>	0.12	0.14	0.12	—								
5 larva	0.14	0.15	0.13	0.11	—							
6 larva	0.14	0.15	0.13	0.11	0.00	—						
7 larva	0.14	0.15	0.13	0.11	0.01	0.00	—					
8 larva	0.14	0.15	0.13	0.11	0.00	0.00	0.00	—				
9 larva	0.14	0.15	0.13	0.11	0.00	0.00	0.00	0.00	—			
10 larva	0.14	0.15	0.14	0.11	0.03	0.03	0.03	0.03	0.03	—		
11 larva	0.14	0.15	0.14	0.11	0.03	0.03	0.03	0.03	0.03	0.02	—	
12 <i>Ozeoura</i> sp. adult	0.14	0.15	0.14	0.11	0.03	0.03	0.03	0.03	0.03	0.02	0.01	—



Figures 55, 56. *Ozeoura* larvae. (55) general habitus; (56) spiracular disc, lateral.

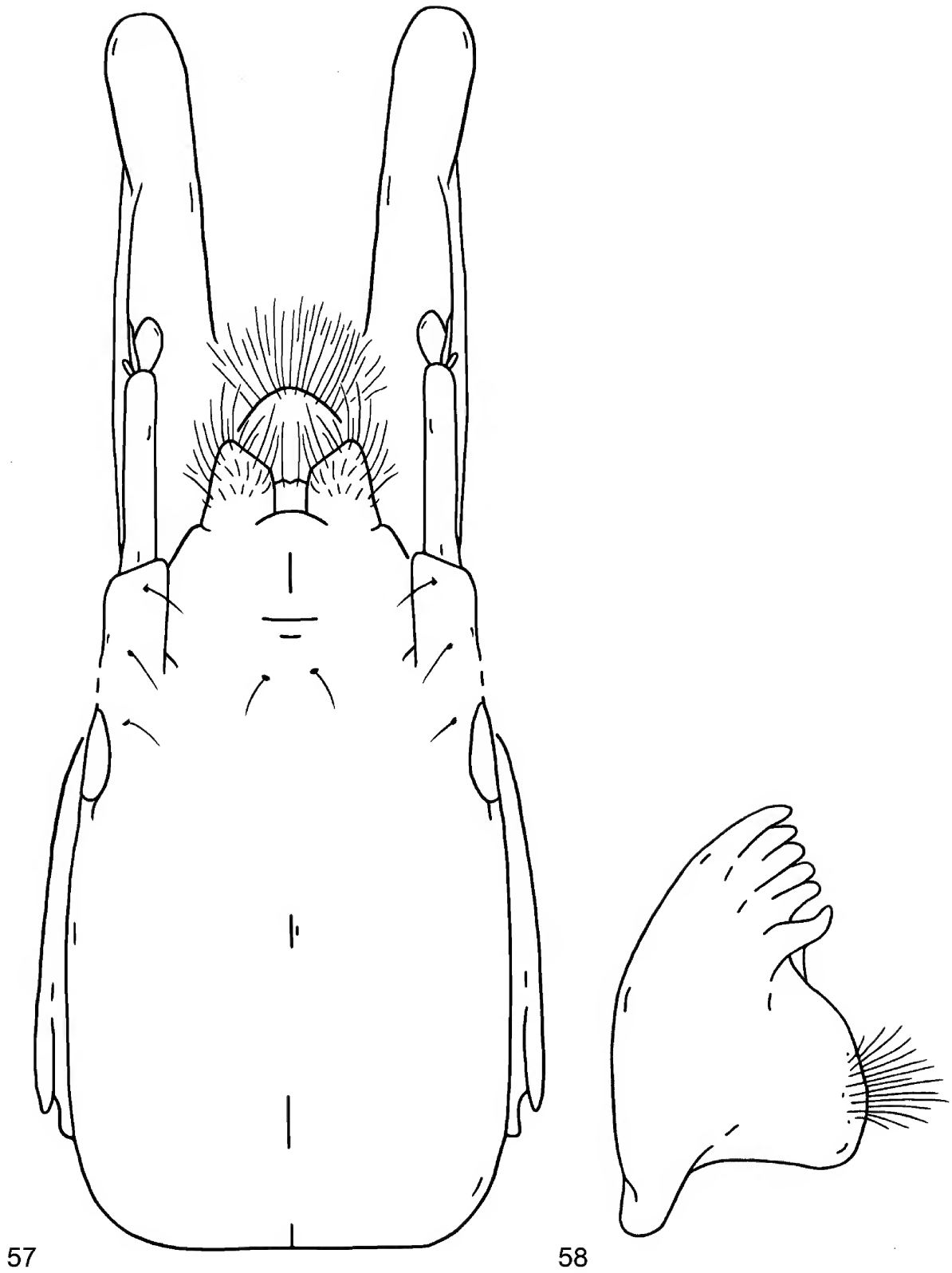


Figure 57, 58. *Ozeoura* larva. (57) head capsule, dorsal; (58) mandible.

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