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## Monograph

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# Small crickets of New Zealand (Orthoptera: Grylloidea: Trigonidiidae and Mogoplistidae), with the description of two new genera and species

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**Abstract.** Crickets (Order Orthoptera, Infraorder Gryllidea) are under-represented in New Zealand, with a total of eight species identified and formally described thus far. These include three endemic species in the family Trigonidiidae: the trig *Trigonidium* (*Metioche*) *maoricum* (Walker, 1869) and the ground crickets *Bobilla nigrova* (Swan, 1972) and *B. bigelowi* (Swan, 1972). Scaly crickets (family Mogoplistidae) are naturally absent in New Zealand, but one species, *Ornebius aperta* Otte & Alexander, 1983, has established after introduction from Australia in the 1970s. In this work, I re-examine the small crickets (families Trigonidiidae and Mogoplistidae) from New Zealand based on 368 specimens collected throughout the country, their morphology, and their song. In the subfamily Nemobiinae, I provide new diagnostic characters to discriminate between the two native species in the genus *Bobilla* Otte & Alexander, 1983. Additionally, I identify two species in the genus *Pteronemobius* Jacobson, 1904; these are *P. truncatus* (Saussure, 1877) and *P. cf. arima* Otte & Alexander, 1983, both of which are believed to be recent arrivals from Australia. The latter had been thus far undetected in New Zealand. Finally, I describe two new species of mute Nemobiinae belonging to new monotypic genera, *Austronemobius chelatus* gen. et sp. nov. and *Mutonemobius marmoratus* gen. et sp. nov. In the subfamily Trigonidiinae, the species *Trigonidium* (*Metioche*) *maoricum* is moved back to the subgenus *Trigonidium* (*Trigonidium*) Rambur, 1838 based on morphology. Amended descriptions are provided for this genus and species. The Australian species *Trigonidomorpha sjostedti* Chopard, 1925 is synonymised with *Trigonidium australianum* (Chopard, 1925), and the genus *Trigonidomorpha* Chopard, 1925 is synonymised with *Trigonidium* Rambur, 1838. In the family Mogoplistidae, I show that *Ornebius aperta* has established in the Auckland, Waikato, Taranaki and Coromandel regions. Based on song and morphology of the male terminalia, populations in Northland may belong to a separate species, referred to in this work as *Ornebius* aff. *aperta* Otte & Alexander, 1983.

**Keywords.** Cricket, Trigonidiidae, Mogoplistidae, New Zealand, systematics.

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## Introduction

Crickets (order Orthoptera, infraorder Gryllidea) are under-represented in New Zealand, with a total of eight species identified and formally described thus far (Trewick *et al.* 2022). These include one endemic mole cricket, *Triamescaptor aotea* Tindale, 1928, three Gryllidae Bolívar, 1878, *Teleogryllus commodus* (Walker, 1869), *Lepidogryllus parvulus* (Walker, 1869) and *Gryllodes sigillatus* (Walker, 1869), two endemic ground crickets (Trigonidiidae: Nemobiinae), *Bobilla nigrova* (Swan, 1972) and *B. bigelowi* (Swan, 1972), one endemic trig (Trigonidiidae: Trigonidiinae), *Trigonidium (Metioche) maoricum* (Walker, 1869), and one scaly cricket (Mogoplistidae), *Ornebius aperta* Otte & Alexander, 1983 (Trewick *et al.* 2022). An additional species belonging to the family Gryllidae, *Gryllopsis maoria* (Saussure, 1877), is not included in this list, since there is no evidence of it being present in New Zealand, and it is most likely an Australian species belonging in the genus *Velarifictorus (Buangina)* Otte & Alexander, 1983. The scope of this paper is limited to the smaller crickets (body length under 10 mm), i.e., the families Trigonidiidae Saussure, 1874 and Mogoplistidae Costa, 1855.

Ground crickets (family Trigonidiidae, subfamily Nemobiinae) are present in New Zealand with two described species, *Bobilla nigrova* and *B. bigelowi*. Both species were originally placed in the genus *Pteronemobius* Jacobson, 1904 (Swan 1972) and were later moved to the genus *Bobilla* Otte & Alexander, 1983, based on the morphology of the male terminalia (Otte *et al.* 1987). The two species are known to be sympatric throughout their distribution range and can be differentiated from one another by morphology (Swan 1972) and song (McIntyre 1977a), although identification to species level remains difficult in the field and relies on examination under the microscope.

Caudell (1927) recorded a female ground cricket collected in Auckland, that “does not agree with any described species from the Australian regions known to the writer. It seems nearer to [*Nemobius*] *truncatus* and *femoratus* Saussure than to any other species”. The two species mentioned by Caudell, known today as *Pteronemobius truncatus* (Saussure, 1877) and *Bobilla bivittata* (Walker, 1869), are both from Australia; the former from coastal regions around the country; the latter from Australia’s South-West. It seems most likely that this specimen would have belonged to one of the two species of *Bobilla* later described by Swan (1972). Hudson (1973) recorded the presence of the Australian species *Bobilla bivittata* at several localities between Porters Pass (Canterbury) and Little Barrier Island (Auckland). In her work, however, Hudson did not mention the two species of *Bobilla* described by Swan (1972), nor did she cite Swan’s paper in her list of references. It is highly likely that Hudson would have submitted her work before Swan’s 1972 paper was published, and that her records of *Bobilla bivittata* were in fact a misidentification of our two native species. There is no evidence of *B. bivittata* being present in New Zealand (Trewick *et al.* 2022).

Messenger (1991) recorded swarms of the Australian *Pteronemobius truncatus/tarrios* in New Zealand at Mangaturoto, Dargaville and Whangarei (Northland) during March 1991, with fully winged males and females being attracted to lights at night. A similar phenomenon had occurred during autumn 1990, with swarms of winged crickets being found as far south as Campbell’s Beach, Warkworth (Messenger 1991). Noting that the two species *Pteronemobius truncatus* and *P. tarrios* Otte & Alexander, 1983 can only be differentiated by their song (Otte & Alexander 1983), the presence of the genus *Pteronemobius* in New Zealand is accepted beyond doubt, but remains taxonomically unresolved (Trewick *et al.* 2022).

Trigs (family Trigonidiidae, subfamily Trigonidiinae) are only known in New Zealand from one species, *Trigonidium (Metioche) maoricum*. The species was originally described by Walker (1869) as *Scleropterus maoricus* based on the examination of one adult male and two adult female specimens and has never been revised since. Without giving any explanation, Kirby (1906) moved the species to the genus *Trigonidium* Rambur, 1838; without any explanation again, Chopard (1968) moved this and all Australian species of *Trigonidium* to *Metioche* Stål, 1877. Otte & Alexander (1983) moved most



Australian species back to *Trigonidium*, but they did not revisit the New Zealand species *Metioche maorica*. Gorochov (1987) redesignated *Metioche* as a sub-genus of *Trigonidium*, leading to the current classification of *Trigonidium (Metioche) maoricum* (see also Rentz & Su 2019; Cigliano *et al.* 2023).

An unresolved issue arises from the occurrence, in New Zealand like in Australia, of trigs that have no hindwings and no auditory tympana, and of trigs that have both hindwings and auditory tympana; the two morphs look otherwise the same. Chopard (1925) assigned the two morphs in Australian trigs to different genera. Wingless trigs without auditory tympana were designated as a new species, *Metioche australiana* Chopard, 1925, and were later reassigned to the genus *Trigonidium* (Otte & Alexander 1983); winged trigs with auditory tympana were placed by Chopard in a separate genus and species, *Trigonidomorpha sjostedti* Chopard, 1925. Chopard's classification remains valid today (see also Otte & Alexander 1983; Rentz & Su 2019; Cigliano *et al.* 2023). Ingrisch (1977), however, reared the European species *Trigonidium cicindeloides* Rambur, 1838 in captivity and observed that out of 67 eggs laid by wingless adults without tympana, 39 developed to adult insects with hindwings and with auditory tympana, one specimen developed to an adult without hindwings but with small auditory tympana, and the remaining 27 specimens developed to adults without hindwings or auditory tympana. He concluded that *Trigonidium cicindeloides* comes mainly in two morphs, either without hindwings or auditory tympana, or with hindwings and with auditory tympana. Ingrisch's observations are clearly at odds with the assumption of *Trigonidomorpha* Chopard, 1925 being a valid genus.

Scaly crickets (family Mogoplistidae) are absent from New Zealand's native fauna. A single specimen of the Polynesian species *Ornebius novarae* (Saussure, 1877) was allegedly collected near Rotorua by a University of Iowa expedition in 1922 (Caudell 1927). The species has never been recorded in New Zealand since, and the genus *Ornebius* Guérin-Méneville, 1844 is absent from the Rotorua region today. The University of Iowa record should be treated as dubious at best (Ramsay 1991; Trewick *et al.* 2022).

The next record of Mogoplistidae in New Zealand originates from Auckland in 1989 (Ramsay 1990, 1991); the species was identified as *Ornebius aperta* based on morphology alone. Ramsay (1990) mentioned that *Ornebius* crickets had been collected in Paihia, Northland, in 1977, but had never been identified to species level. Ramsay did not follow up on the Northland population either; the question of whether New Zealand's *Ornebius* population includes one or more species has never been addressed since. All Mogoplistidae in New Zealand at present are blindly assigned to the species *Ornebius aperta* (iNaturalist 2023).

Scaly crickets in the genus *Ornebius* are also known to be on the Kermadec Islands, an archipelago in New Zealand territory 800 to 1000 km to the north-east of the North Island (iNaturalist 8954002). Because of the lack of physical specimens or of any sound recordings, the Kermadec Island crickets are excluded from this work.

Here, the small crickets of New Zealand (superfamily Grylloidea, families Trigonidiidae and Mogoplistidae) are re-examined based on morphology and song, from a large sample collected throughout the country. Additional diagnostic characters are provided for the two native species in the genus *Bobilla*. Based on morphology and on song, two Australian species of crickets in the genus *Pteronemobius* are identified. Additionally, two new monotypic genera of silent nemobiine crickets endemic to the forests of New Zealand's North and South Islands are identified and described. The classification of the endemic trig *Trigonidium (Metioche) maoricum* at genus and sub-genus level is re-evaluated based on morphology, and the classification of two different morphs with or without hindwings and auditory tympana is re-examined with molecular techniques. Amended descriptions for the genus and species are given based on the results of the above analyses. Finally, the song of *Ornebius* crickets in northern New Zealand is analysed to test their identity at the species level.

## Material and methods

### Collection and morphological methods

Crickets were collected opportunistically around New Zealand, including Chatham Islands, between 2021 and 2024, during day or night depending on species, searching open grasslands, parks, urban gardens and forests. Singing crickets (*Bobilla* spp., *Pteronemobius* spp., *Ornebius* spp.) were located by sound, then collected by sweep netting in long grass or in tree foliage, or by digging with a trowel in short vegetation. Trigs (subfamily Trigonidiinae) were captured by sweep netting in tall grass. Mute ground crickets (subfamily Nemobiinae) were collected by night searching through the leaf litter on the forest floor, often using a trowel to dig through the detritus, then trapping them in an empty collecting jar.

368 adult specimens were catalogued, examined under a stereo microscope (Leica M205C with 1.0× planapochromatic objective) and measured in Leica Application Suite X ver. 3.7.6. (RRID:SCR\_013673; Leica Microsystems). Adults were distinguished from immature individuals by their fully formed wings or, in the case of wingless crickets, by their fully formed external genital structures or ovipositor. For each species and sex, basic statistics of all linear measurements and count data were calculated in JASP ver. 0.18.1.0 (RRID:SCR\_015823; JASP Team 2023).

All specimens are held in the Phoenix Lab collection at Massey University, Palmerston North, New Zealand (MPN), except for type material, which is lodged at the New Zealand Arthropod Collection in Auckland (NZAC).

### Nomenclature and abbreviations for selected morphological features and measurements

The nomenclature and abbreviations for cricket body parts used in this work are largely taken from Desutter-Grandcolas *et al.* (2016, 2021) and from Tan *et al.* (2021), with a few alterations and additions.

#### Nomenclature relating to wing development

Crickets have traditionally been referred to as “apterous”, “brachypterous” or “macropterous” to indicate absence of wings, presence of forewings only, or presence of fully developed forewings and hindwings. More recently some authors (e.g., Rentz & Su 2019) have preferred the use of the terms “wingless”, “short-winged” and “long-winged” to describe the same configurations. Either way, I consider this terminology unsatisfactory, as it neglects the fact that females in several nemobiine cricket species may have short or long forewings, when the hindwings are absent. While it is known that adults in several species of Trigonidiidae may shed their hindwings after a few days (Swan 1972; Rentz & Su 2019: 46), we cannot rule out individual crickets developing long forewings and no hindwings. For clarity, in this work I will therefore use the following terminology:

“apterous”, or “wingless” = no forewings and no hindwings (Fig. 17)  
“with short forewings” = short forewings present; hindwings absent (Figs 9B, 12B, 16B, E, 28B, F)  
“with long forewings” = long forewings present; hindwings absent (Fig. 16F)  
“fully winged” = long forewings present; hindwings present and fully developed (Figs 12A, 16D, 28C, E, 32D). Fully winged specimens are able to fly.

#### General morphology

I, II, III = fore, middle, hind, respectively (legs or leg parts)  
F = femur  
FW = forewing  
HW = hindwing  
SF = stridulatory file  
T = tibia

tai1 to tai3	=	inner apical spurs on Tibia III, ventral (1) to dorsal (3) (Fig. 1A)
tao1 to tao3	=	outer apical spurs on Tibia III, ventral (1) to dorsal (3)
Tarsomere III-1	=	basal segment of hind leg tarsus
tmai	=	inner apical spur on Tarsomere III-1 (Fig. 1A)
tmao	=	outer apical spur on Tarsomere III-1
tsai1 to tsai4	=	inner sub-apical spurs on Tibia III, 1 being closest to the apex of the tibia (Fig. 1A)
tsao1 to tsao4	=	outer sub-apical spurs on Tibia III, 1 being closest to the apex of the tibia

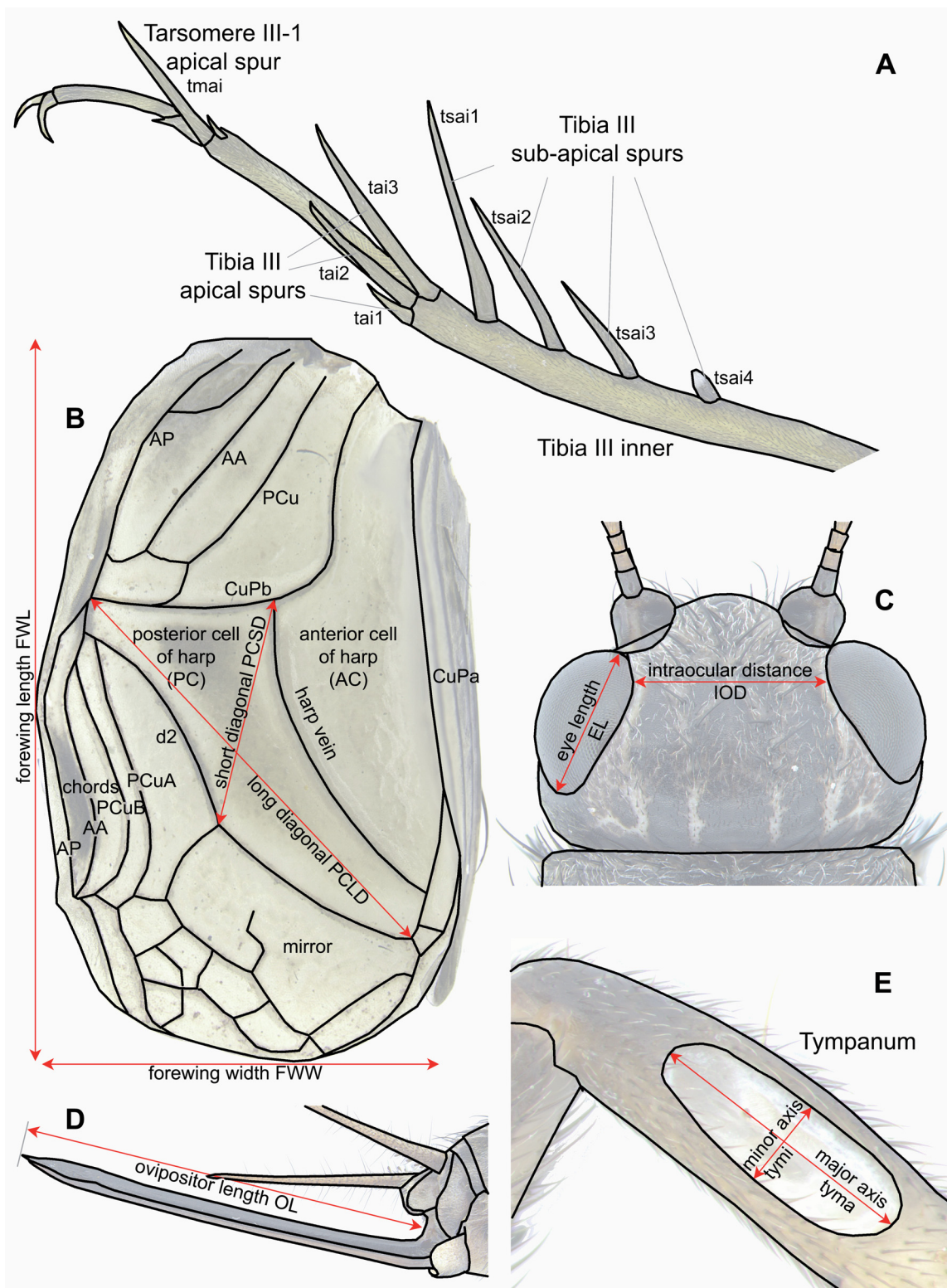
### Measurements

BL	=	body length, measured from vertex of rostrum to apex of terminalia (males) or to base of ovipositor (females)
EL	=	eye length (Fig. 1C)
FIIIL	=	length of hind femur
FWL	=	maximum forewing length (Fig. 1B)
FWW	=	maximum forewing width (Fig. 1B)
HWL	=	hindwing length
IOD	=	intraocular distance (Fig. 1C)
-L	=	generic suffix for 'Length'
OL	=	ovipositor length (Fig. 1D)
PC	=	posterior cell of harp – in a male nemobiine cricket's right forewing, the part of the harp that is posterior to the harp vein (Fig. 1B)
PCSD/PCLD	=	ratio of the short/long diagonals in male right forewing's posterior cell of harp (subfamily Nemobiinae) (Fig. 1B)
PronL	=	pronotum length at centre
PronW	=	maximum pronotum width
SFL	=	length of stridulatory file in male cricket forewing, measured by approximating the curve of the stridulatory file with a segmented line in ImageJ ver. 1.54.d (RRID:SCR_003070; ImageJ 2023)
ST	=	number of teeth in stridulatory file in male cricket forewing
TIIL	=	length of hind tibia
TaIIIi	=	number of dorsal spines on inner edge of Tarsomere III-1, not including the apical spine
TaIIIo	=	number of dorsal spines on outer edge of Tarsomere III-1, not including the apical spine
Tid	=	number of dorsal spines on inner edge of Tibia III (Mogoplistidae only)
Tod	=	number of dorsal spines on outer edge of Tibia III (Mogoplistidae only)
tyma	=	length of major axis of tympanum (Fig. 1E)
tymi	=	length of minor axis of tympanum (Fig. 1E)

### Male genitalia

Structures of the male genitalia are named after Desutter (1987), Ingrisch (2006) and Desutter-Grandcolas *et al.* (2016).

AL	=	apical lobe of pseudepiphallic sclerite
DCav	=	dorsal cavity
EcF	=	ectophallic fold
EnS	=	endophallic sclerite
Gl	=	paired gland of ejaculatory duct
LL	=	lateral lobe of pseudepiphallic sclerite
ML	=	median lobe of pseudepiphallic sclerite



**Fig. 1.** Nomenclature and abbreviations in cricket body parts. **A.** Hind leg, inner view of tibia and tarsus in Trigonidiidae. Labelling of spurs after Desutter-Grandcolas *et al.* (2016: fig. 8d). ‘i’ is for ‘inner’ in all abbreviations and is replaced by ‘o’ for outer in the opposite view, not shown. **B.** Dorsal view of right forewing in ground cricket (subfamily Nemobiinae). Labelling of wing veins after Josse *et al.* (2023). **C.** Dorsal view of head. **D.** Lateral view of ovipositor. **E.** Tympanum on right Tibia I (rear facing).



MV	=	medial valve of central phallic lobe
Pp	=	paraproct
PS	=	pseudepiphallic sclerite
PSP	=	pseudepiphallic paramere
SP	=	subgenital plate
SS	=	spermatophore sac

### **Imaging of male genitalia**

All crickets used for imaging of male genitalia were preserved in 70% ethanol solution.

#### **Microscopy**

Male genitalia were extracted after dissecting the cricket's abdomen and soaking it twelve hours in cold 10% KOH solution. Optical imaging was performed with a Leica Flexacam C3 camera mounted on a Leica M205C microscope with 1.0× planapochromatic objective. Images were focus stacked in Leica Application Suite X ver. 3.7.6. (RRID:SCR\_013673; Leica Microsystems).

#### **MicroCT scanning**

The procedure for preparing specimens for MicroCT scanning was adapted from Metscher (2009). Specimens were cut at the base of the abdomen to enable chemicals to penetrate the sample. The insect's abdomen was then fixed by submerging it in a 1% formalin solution in 70% ethanol for 24 hours, then stained overnight in 1% iodine metal (I<sub>2</sub>) solution in 70% ethanol. The samples were wet mounted in 70% ethanol inside a sealed inverted pipette tip wrapped in WOD MPFT2 silver Mylar film tape. Three-dimensional imaging was obtained in a Bruker Skyscan 1272 (Bruker, Kontich, Belgium). The images were reconstructed using InstaRecon CBR Server Premium 15K (InstaRecon Inc., Champaign, IL, USA) in conjunction with Nrecon ver. 2.2.2 (Bruker) and subsequently visualised in 3D using CTVOX ver. 3.3 (Bruker). DataView ver. 1.5.4.0 (Bruker) was used to adjust rotational and tilt orientation to give comparable views of all samples.

### **Sound recordings and analysis**

Sound recordings of cricket calls were taken in the field (unless specified otherwise) with a Zoom H4n Pro Handy Recorder (Zoom Corporation, Tokyo, JP) at 24-bit/96 kHz sampling frequency. Air and ground temperature were measured with a Testo 810 IR & Ambient Temperature Meter (Testo SE & Co. KGaA, Lenzkirch, DE).

All sound recordings were processed and analysed in Raven Pro ver. 1.6.5 (RRID:SCR\_016190; K. Lisa Yang Center for Conservation Bioacoustics 2023). Spectrograms and power spectra were generated using a Hanning window of 512 samples.

For consistency with previous work on crickets in the New Zealand/Australian region, the terminology used here when describing cricket songs follows McIntyre (1977a) and Otte & Alexander (1983). It is worth noting that some of the terms used here have been given a different interpretation in recent work by other authors (e.g., Tan *et al.* 2021, 2023). The terminology used in this work is defined as follows:

“pulse”	=	a group of tooth strikes isolated in time, generally corresponding to a single complete stridulatory movement (i.e., opening and closing of the wings)
“pulse interval”	=	silent interval between two pulses within the same chirp
“pulse rate”	=	the number of pulses per second
“chirp”	=	a short sequence of pulses, separated from the next chirp by an interval longer than the interval between pulses within the same chirp
“chirp interval”	=	silent interval between two chirps within the same song

“trill” = a long sequence of pulses. This may be indefinitely long  
“song” = a sequence of chirps or trills

### Molecular analysis

To test whether morphologically different trigs (subfamily Trigonidiinae) are conspecific, genomic DNA was extracted from leg tissue of eight putative *Trigonidium* and *Trigonidomorpha* specimens using a one-step Chelex double-stranded DNA extraction protocol modified from Casquet *et al.* (2011). Cricket leg tissue was submerged in 300 µl 5% Chelex-100 (BioRad) and 40 µg Proteinase K. After overnight incubation, samples were heated to 90°C for 10 minutes then centrifuged at 20 000 g for 10 minutes. The cytochrome c oxidase I (COI) gene of the mitochondrial genome was amplified using polymerase chain reaction (PCR) on a single fragment spanning 1044 base pairs (bp) using the invertebrate primers LCO1490 (Folmer *et al.* 1994) and H7005-mod1 (Donald *et al.* 2005). Amplified DNAs were purified using an iNtRON MEGAquick-spin Plus Total Fragment DNA Purification Kit (iNtRON Biotechnology, Republic of Korea) and sequenced using the BigDye Terminator ver. 3.1 Cycle Sequencing Kit on an ABI 3730xl DNA Analyser (Applied Biosystems Inc., Carlsbad, CA).

Eight sequences were submitted to GenBank (Benson *et al.* 2013); accession numbers (PP761109–PP761116) are listed in the Material examined section. The sequences for an additional 14 specimens of *Trigonidium* and *Trigonidomorpha* and one of *Anaxipha tinnulenta* Walker & Funk, 2014 were obtained from GenBank (Benson *et al.* 2013) and BOLD (Ratnasingham & Hebert 2007) databases. Detailed information on the origin of each specimen included in the analysis can be found in Supp. file 1: Table S11.



**Fig. 2.** New Zealand entomological regions and abbreviations (Crosby *et al.* 1998). **North Island:** AK = Auckland, BP = Bay of Plenty, CL = Coromandel, GB = Gisborne, HB = Hawkes Bay, ND = Northland, RI = Rangitikei, TK = Taranaki, TO = Taupō, WA = Wairarapa, WI = Wanganui, WN = Wellington, WO = Waikato. **South Island:** BR = Buller, CO = Central Otago, DN = Dunedin, FD = Fiordland, KA = Kaikōura, MB = Marlborough, MC = Mid Canterbury, MK = Mackenzie, NC = North Canterbury, NN = Nelson, OL = Otago Lakes, SC = South Canterbury, SD = Marlborough Sounds, SI = Stewart Island, SL = Southland, WD = Westland. Scale bar = 200 km.

Nucleotide sequences were edited using Sequencher ver. 5.1 (Gene Codes Corporation, Ann Arbor, MI, USA) and aligned in ClustalX ver. 2.1 (Thompson *et al.* 1997; Larkin *et al.* 2007). Phylogenetic relationships were inferred by using the Maximum Likelihood method and the Tamura-Nei model (Tamura & Nei 1993) in MEGA11 (Tamura *et al.* 2021). Initial tree(s) for the heuristic search were obtained automatically by applying the Maximum Parsimony method.

### Collection acronyms

ANIC	=	Australian National Insect Collection, Canberra, ACT, Australia
iNaturalist	=	Available from iNaturalist.org [accessed 26 Oct. 2023]
MNHN	=	Muséum National d'Histoire Naturelle, Paris, France
MPN	=	Phoenix Lab, Massey University, Palmerston North, New Zealand
NHMUK	=	National History Museum, London, United Kingdom
NZAC	=	New Zealand Arthropod Collection, Auckland, New Zealand

Two-letter codes in the 'Material examined' sections refer to the New Zealand entomological regions (Crosby *et al.* 1998) (Fig. 2).

## Results

### *Diagnosis of ground crickets in the genus Bobilla Otte & Alexander, 1983*

Out of 368 crickets examined, 138 belong to the genus *Bobilla*. These include 69 *Bobilla bigelowi*, 65 *Bobilla nigrova* and 4 specimens from the southern Waikato region that seem to fall in between the two species.

A careful examination of this material supports five out of six of the differences between the two species of *Bobilla* highlighted by Swan (1972); these differences are reported in Table 1. In addition to these, Swan (1972) had suggested the number of large bristles on each side of the suranal plate in adult females as a useful trait to differentiate between species (2 to 5 in *B. nigrova*; 6 to 10 in *Bobilla bigelowi*). These bristles however are prone to rubbing off, and their number seems to be more variable than indicated by Swan. I suggest that there is little merit in referring to this trait when identifying *Bobilla* to species level; I have therefore omitted it from the summary in Table 1.

Tooth count in the stridulatory file and song analysis yield numbers that are generally in good agreement with the values reported by McIntyre (1977a) (see Tables 1–2). Male crickets are reliably identified to species level by the number of teeth in the stridulatory file (Fig. 3B); this however requires removing the insect's right forewing.

The songs of the two species of *Bobilla* differ mainly in their pulse rate, which is around 10 pulses/s in *B. nigrova*, around 20 pulses/s in *B. bigelowi* (Table 2; Figs 11, 14). The analysis of *Bobilla* songs recorded in the field, however, can be difficult; this is explained in detail in this paper's discussion.

In addition to the differences already identified by Swan (1972) and by McIntyre (1977a, 1977b), here I report four more measurements that are significantly different between the two New Zealand species of *Bobilla* (Table 1). The first one is the ratio of the short and long diagonals in the right male forewing's posterior cell of the harp (see Figs 1B, 3A). This ratio PCSD/PCLD is greater than 0.49 in *B. bigelowi*, less than 0.49 in *B. nigrova* (Mainland New Zealand only, not including Chatham Islands). The measurements for the two species do not overlap, making this a reliable and not destructive method to differentiate between male *B. nigrova* and *B. bigelowi* based on their forewings. The second measurement is the ratio between the maximum eye length and the intraocular distance, in a dorsal view of the head (see Figs 1C, 3C). The ratio EL/IOD is greater than 0.79 in *B. bigelowi* and less than 0.8 in

**Table 1.** Genus *Bobilla* Otte & Alexander, 1983. Summary of morphological differences between adults of the two New Zealand species, *Bobilla nigrova* (Swan, 1972) and *Bobilla bigelowi* (Swan, 1972). All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Morphological trait	<i>Bobilla nigrova</i> (Swan, 1972)	<i>Bobilla bigelowi</i> (Swan, 1972)	t-test result	Figures
<i>Males</i>				
Spike-like tufts of bristles on each side of the suranal plate (Swan 1972).	present	absent		Fig. 10A Fig. 11D
Ratio PCSD/PCLD Mainland NZ only	0.478 (0.438–0.488) <i>N</i> = 13	0.522 (0.496–0.558) <i>N</i> = 30	$p < 10^{-10}$	Fig. 1B Fig. 3A
Number of teeth in stridulatory file (McIntyre 1977)	(188–283) <i>N</i> = 85	(123–190) <i>N</i> = 83		
Number of teeth in stridulatory file (this study)	204 (180–246) <i>N</i> = 11	152 (118–171) <i>N</i> = 30	$p < 10^{-12}$	Fig. 3B
Song: pulse rate (pulses/s) (McIntyre 1977)	13 (11–15) <i>N</i> = 36	21 (20–22) <i>N</i> = 61		Fig. 12 Fig. 15
Song: Main frequency (McIntyre 1977)	8.0 kHz at 27°C	7.5 kHz 27°C		Fig. 12 Fig. 15
<i>Females</i>				
Dorsal surface of abdomen (Swan 1972)	grey or black, with pale markings	uniform black		Fig. 10B Fig. 13B
Lateral valves of ovipositor (Swan 1972)	strongly denticulate	weakly denticulate		Fig. 11G–H Fig. 14F–G
Egg colour (Swan 1972)	black	pale		Fig. 11F Fig. 14E
Ovipositor length (mm) (Swan 1972)	long (mean 4.9 mm) <sup>1</sup>	short (mean 4.1 mm)		Fig. 3D
Ovipositor length (mm) (this study)	5.9 (4.0–6.7) <i>N</i> = 20	4.0 (3.1–4.9) <i>N</i> = 26	$p < 10^{-13}$	Fig. 3D
<i>Both sexes</i>				
Ratio eye length/ intraocular distance	0.754 (0.705–0.806) <i>N</i> = 18	0.840 (0.789–0.901) <i>N</i> = 37	$p < 10^{-16}$	Fig. 1C Fig. 3C
Minor axis of tympanum (µm)	119 (105–154) <i>N</i> = 32	95 (67–122) <i>N</i> = 76	$p < 10^{-6}$	Fig. 1E Fig. 3E
Length ratio of middle and dorsal inner spurs at apex of tibia III	0.882 (0.833–0.959) <i>N</i> = 18	0.822 (0.744–0.912) <i>N</i> = 38	$p < 10^{-5}$	Fig. 3F

<sup>1</sup> Note the discrepancy between Swan’s and this study’s measurements. After re-measuring Swan’s paratypes (*N* = 40) I calculated a mean ovipositor length of 5.3 mm in *B. nigrova*.



**Table 2** (continued on next page). Adult male and female measurements in the New Zealand species of *Bobilla* Otte & Alexander, 1983. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Bobilla nigrova</i> (Swan, 1972)		<i>Bobilla bigelowi</i> (Swan, 1972)	
	male	female	male	female
Body length (mm)	6.6 (5.9–7.1) <i>N</i> = 11	8.1 (5.6–9.6) <i>N</i> = 19	6.2 (5.4–7.2) <i>N</i> = 30	6.7 (5.3–8.6) <i>N</i> = 28
Pronotum width (mm)	2.0 (1.9–2.2) <i>N</i> = 9	2.3 (1.8–2.7) <i>N</i> = 15	2.0 (1.7–2.1) <i>N</i> = 27	2.0 (1.6–2.4) <i>N</i> = 22
Pronotum length (mm)	1.3 (1.1–1.4) <i>N</i> = 9	1.5 (1.3–1.6) <i>N</i> = 15	1.2 (1.1–1.9) <i>N</i> = 22	1.4 (1.1–2.0) <i>N</i> = 27
Femur III length (mm)	4.8 (4.6–4.9) <i>N</i> = 6	5.6 (4.9–6.1) <i>N</i> = 12	4.6 (4.2–5.0) <i>N</i> = 22	5.0 (4.4–5.6) <i>N</i> = 18
Tibia III length (mm)	3.7 (3.5–4.2) <i>N</i> = 6	4.4 (3.8–5.2) <i>N</i> = 12	3.6 (3.3–4.1) <i>N</i> = 22	4.0 (3.4–4.7) <i>N</i> = 18
Number of subapical spurs on TIII inner	3	3	3	3
Number of subapical spurs on TIII outer	3	3	3	3
Ovipositor length (mm)	–	5.9 (4.0–6.7) <i>N</i> = 20	–	4.0 (3.1–4.9) <i>N</i> = 26
EL / IOD	0.77 (0.71–0.77) <i>N</i> = 6	0.75 (0.72–0.81) <i>N</i> = 12	0.84 (0.80–0.90) <i>N</i> = 20	0.84 (0.79–0.88) <i>N</i> = 17
Wing morphs	Short FW	–	17	–
	Long FW	8	2	25
	Fully winged	0	2	2
FWW (mm)	2.2 (2.1–2.4) <i>N</i> = 7	1.5 (1.3–1.8) <i>N</i> = 12	2.0 (1.9–2.4) <i>N</i> = 25	1.3 (0.9–1.6) <i>N</i> = 18
FWL (mm)	3.2 (2.9–3.6) <i>N</i> = 8	Short 2.5 (1.7–3.1) Long 4.7 (4.6–4.8)	3.1 (2.5–3.7) <i>N</i> = 27	Short 2.1 (1.5–2.7) Long 3.9 (3.6–4.2)
HWL (mm)	–	–	8.0 (8.0–8.0) <i>N</i> = 2	–
PCSD / PCLD (Mainland NZ only)	0.478 (0.438–0.488) <i>N</i> = 13	–	0.522 (0.496–0.558) <i>N</i> = 30	–
ST	204 (180–246) <i>N</i> = 11	–	152 (118–171) <i>N</i> = 30	–
SFL (µm)	1354 (1284–1554) <i>N</i> = 6	–	1265 (944–1384) <i>N</i> = 8	–
tmao / tmai	0.59 (0.52–0.65) <i>N</i> = 6	0.61 (0.54–0.69) <i>N</i> = 11	0.66 (0.59–0.72) <i>N</i> = 20	0.64 (0.56–0.74) <i>N</i> = 17
tao1 / tai1	0.97 (0.88–1.07) <i>N</i> = 6	0.99 (0.78–1.08) <i>N</i> = 12	0.98 (0.82–1.12) <i>N</i> = 20	0.94 (0.81–1.08) <i>N</i> = 18

**Table 2** (continued). Adult male and female measurements in the New Zealand species of *Bobilla* Otte & Alexander, 1983. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Bobilla nigrova</i> (Swan, 1972)		<i>Bobilla bigelowi</i> (Swan, 1972)	
	male	female	male	female
	Song (21°C)		Song (22°C)	
Peak frequency (kHz)	8.1	–	7.9	–
Pulse duration (ms)	33	–	24	–
Pulse interval (ms)	69	–	23	–
Pulse rate (pulses/s)	10.1	–	20.3	–
Chirp duration (s)	0.4–0.7	–	0.5–0.6	–
Chirp interval (s)	0.4–0.6	–	0.2–0.3	–

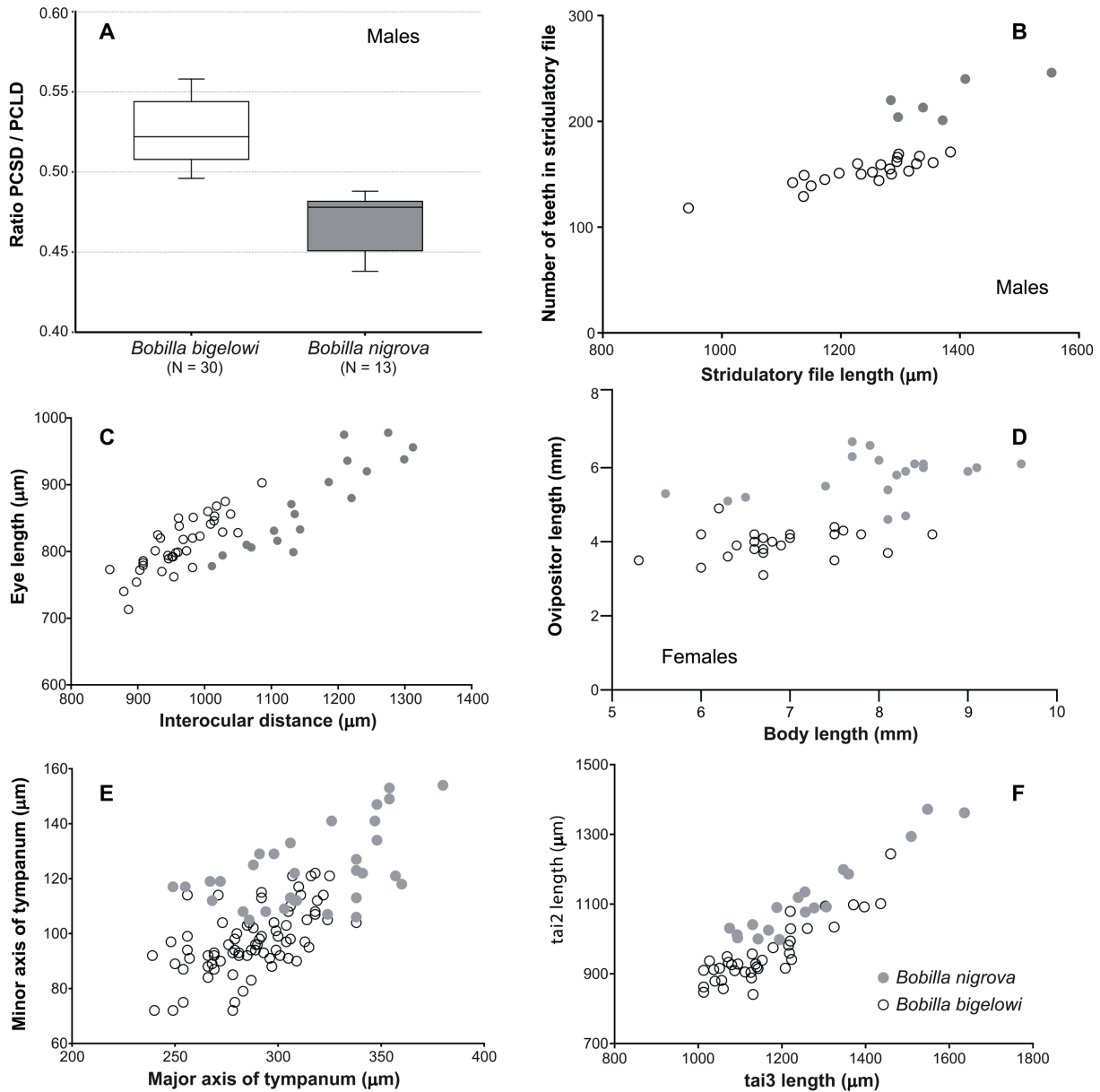
*B. nigrova*, with only a small range of values where the two species overlap. The third difference lies in the width of the tympanal openings on the posterior surface of tibia I. While the length of the tympana is the same in the two species, *B. bigelowi* has narrower openings (Fig. 3E). The fourth measurement is the length ratio of the middle vs dorsal inner apical spurs on tibia III, which is around 0.9 in *B. nigrova*, 0.8 in *B. bigelowi* (see Figs 3F, 4). While the width of the tympana and the length of the apical spurs on tibia III differ significantly between species (Table 1), there is too much overlap in their ranges to rely on these measurements for the purpose of species identification.

Nine specimens of *Bobilla* collected on Pitt Island (Chathams), 800 km east of New Zealand, all fit the description of *B. nigrova* in their morphology, song, and male genitalia. The mean ratio PCSD/PCLD, however, is 0.511 (min 0.493, max 0.576, *N* = 5), typical of *B. bigelowi* on mainland New Zealand. This suggests that the *Bobilla* population on Chatham Islands may have been isolated for some time.

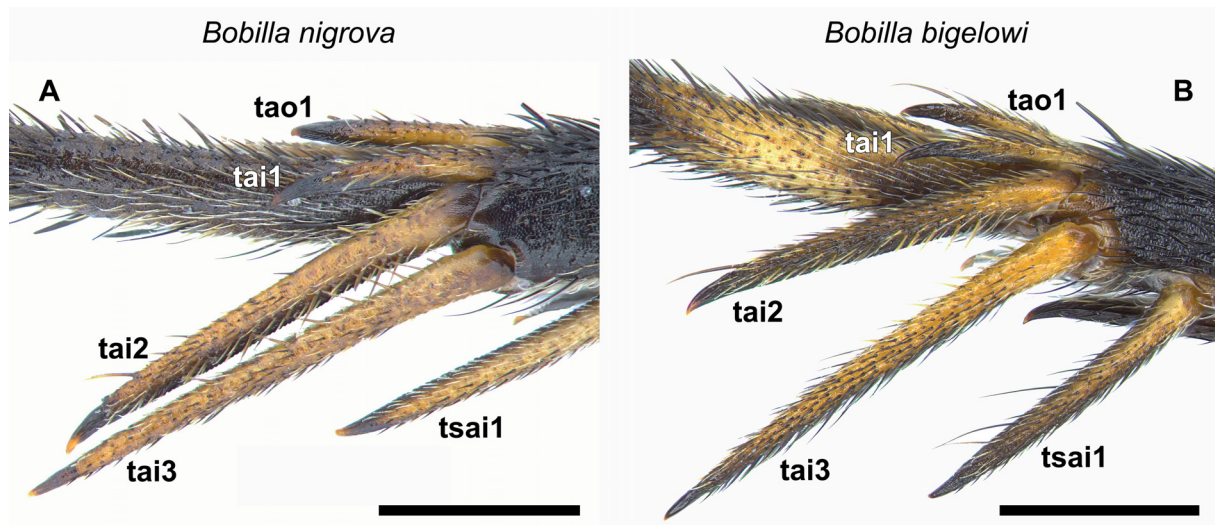
Two adult male *Bobilla bigelowi* collected at Lake Ōhau, Mackenzie Country, had fully developed hindwings (Fig. 12A). This contradicts Swan’s (1972) statement that “[*Bobilla bigelowi*] males are always apterous, but macropterous females with hindwings extending beyond the tip of the ovipositor are not uncommon (3–6 percent of a population)”. Fully winged specimens occur in both sexes and in both species but are rare.

Of interest is a population in the southern Waikato region, where nine out of twelve female specimens of *Bobilla* collected had long forewings, the remaining three having short forewings. This contrasts with 1 out of 16 *B. bigelowi* with long forewings and 1 out of 14 *B. nigrova* with long forewings from the rest of the country, the morph with short forewings being by far the most common in both species. Four of the specimens from this southern Waikato region could not be assigned with certainty to either of the two species; rather, they seem to fall in between. Females have the dark colour and white eggs of *B. bigelowi*, but the long ovipositor with denticulate lateral valves of *B. nigrova*. The number of teeth

in the stridulatory file and the ratio of eye length over intraocular distance lie half-way between the typical ranges for the two species. It seems most likely that this would be a hybrid population arising from interbreeding between the two species of *Bobilla*. For more information about the origin of these specimens, see Supp. file 1: Table S3.



**Fig. 3.** Morphometric measurements for the New Zealand species of *Bobilla* Otte & Alexander, 1983. In all graphs, white shapes indicate *B. bigelowi* (Swan, 1972), dark shapes indicate *B. nigrova* (Swan, 1972). Both sexes are included unless stated otherwise. **A.** Boxplot of the ratio of the short and long diagonals in the right male forewing's posterior cell of the harp (see Fig. 1B). The whiskers include the minimum and maximum values. **B.** Stridulatory file in male cricket's right forewing. **C.** Intraocular distance vs eye length (Fig. 1C). **D.** Body length vs ovipositor length (Fig. 1D). **E.** Major vs minor axis of tympanum (Fig. 1E). For each cricket, the measurements of both left and right tympana are included. **F.** Length of middle vs dorsal inner apical spurs on tibia III (Fig. 1A).



**Fig. 4.** Inner spurs at apex of tibia III in *Bobilla nigrova* (Swan, 1972) and in *B. bigelowi* (Swan, 1972). Apical spurs tai2 and tai3 are generally subequal in length in *B. nigrova*, whereas tai2 is shorter in *B. bigelowi* (see Fig. 3F). Scale bars = 500 μm.

### *Silent ground crickets*

Out of 368 crickets examined, 41 are ground crickets (subfamily Nemobiinae) lacking a stridulatory apparatus or tympana and belonging to two clearly distinct taxa, one from the forests of New Zealand's South Island and from Mt Ruapehu, the other one exclusively from North Island. No silent ground crickets have previously been described from New Zealand.

Several genera of silent nemobiine crickets have been described from other regions in the Southern hemisphere. These include seven genera from Australia (Rentz & Su 2019: 319): *Narellina* Otte, 1994; *Eumarinemobius* Gorochov & Tan, 2018; *Tincanita* Otte & Alexander, 1983; *Silvinella* Otte & Alexander, 1983; *Nambungia* Otte & Alexander, 1983; *Territirritia* Rentz & Su, 1996; and *Calperum* Rentz & Su, 1996; six genera from South America: *Absonemobius* Desutter-Grandcolas, 1993; *Phoremia* Desutter-Grandcolas, 1993; *Amanayara* de Mello & Jacomini, 1994; *Monopteropsis* de Mello & Jacomini, 1994; *Kevanemobius* Bolfarini & de Mello, 2012; and *Pepoapua* Jesus & Pereira, 2017; one genus from Vanuatu and Samoa (Desutter-Grandcolas 2009): *Cophonemobius* Chopard, 1929; three genera from New Caledonia (Anso *et al.* 2016; Desutter-Grandcolas *et al.* 2016): *Paniella* Otte, Alexander & Cade, 1987; *Orintia* Gorochov, 1986; and *Kanakinemobius* Desutter-Grandcolas, 2016.

The two New Zealand taxa have been carefully compared with descriptions and photographs of all of the above genera (Table 3), and don't match any of these. The southern taxon is apterous in both males and females and has characteristic male genitalia with articulated pseudepiphallic parameres, modified for clasping. While it looks deceptively similar to *Absonemobius* in photograph, the latter genus has a head that is wider than it is high in frontal view (Desutter-Grandcolas 1993) and macroscopically different male genitalia (see Desutter-Grandcolas & Hugel 2016). Among Australian genera, it most resembles *Territirritia* Rentz & Su, 1996, but has a different number of sub-apical spines on the hind tibiae and again different male genitalia. Here, the southern species is assigned to a new monotypic genus, *Austronemobius* gen. nov.

The northern taxon is noticeably larger and has reduced forewings that look identical in males and females, without a stridulatory apparatus in males. While superficially similar to New Caledonia's



**Table 3.** Comparison of different genera of silent nemobiine crickets in the Southern hemisphere by morphology (after Rentz & Su 2019: table 8).

Genus	Auditory tympanum		Forewings		SF	Ovipositor tip	Subapical spurs on Tibia III					
	♂		♀		♂	♀	♂		♀			
	Ant.	Post.	Ant.	Post.			i.	o.	i.	o.		
<b>New Zealand</b>												
<i>Austronemobius</i> gen. nov.	–	–	–	–	–	–	–	Tuberculated	3	3	3	3
<i>Mutonemobius</i> gen. nov.	–	–	–	–	+	+	–	Smooth	4	3,4 <sup>a</sup>	4	3,4 <sup>a</sup>
<b>Australia</b>												
<i>Calperum</i>	–	–	–	–	–	–	–	Serrated	3	3	3	3
<i>Eumarinemobius</i>	–	–	–	–	–	–	–	Smooth	2	3	2	3
<i>Nambungia</i>	–	–	–	–	–	–	–	Smooth	3	3	3	3
<i>Narellina</i>	–	–	–	–	+	+	–	Serrated	4	3	4	3
<i>Silvinella</i>	–	–	–	–	–	–	–	Smooth	3	3	3	3
<i>Territirritia</i>	–	–	–	–	–	–	–	Serrated	2	2	2	2
<i>Tincanita</i>	–	–	–	–	+	–	–	Smooth	3	3	3	3
<b>Vanuatu and Samoa</b>												
<i>Cophonemobius</i>	–	–	–	–	+	+	–	Smooth	3	3	3	3
<b>New Caledonia</b>												
<i>Kanakinemobius</i>	–	–	–	–	+	+	+	Smooth	4	4	4	4
<i>Orintia</i>	–	+	–	+	–	–	–	Serrated	3	3	3	3
<i>Paniella</i>	–	–	–	–	–	–	–	Serrated	3	3	3	3
<b>South America</b>												
<i>Absonemobius</i>	–	–	–	–	–	–	–	Smooth or serrated <sup>b</sup>	3,4 <sup>b</sup>	3,4 <sup>b</sup>	3,4 <sup>b</sup>	3,4 <sup>b</sup>
<i>Amanayara</i>	–	–	–	–	–	–	–	Serrated	4	3	3	3
<i>Kevanemobius</i>	–	–	–	–	+	+	–	Serrated	4	4	4	4
<i>Monopteropsis</i>	–	–	–	–	+	–	+	Smooth	4	3	4	3
<i>Pepoapua</i>	–	–	–	–	+	+	–	Serrated	4	3	4	3
<i>Phoremia</i>	–	–	–	–	–	–	–	Serrated	3	3	3	3

<sup>a</sup> individual variation within species and population.<sup>b</sup> varies between species.

**Table 4.** Adult male and female measurements in the New Zealand species of silent Nemobiinae Saussure, 1877. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Austronemobius chelatus</i> gen. et sp. nov.		<i>Mutonemobius marmoratus</i> gen. et sp. nov.	
	male	female	male	female
Body length (mm)	6.4 (5.4–8.3) <i>N</i> = 4	6.2 (5.8–7.9) <i>N</i> = 5	7.3 (7.0–8.4) <i>N</i> = 7	8.3 (7.6–9.2) <i>N</i> = 16
Pronotum width (mm)	1.7 (1.6–1.9) <i>N</i> = 4	1.9 (1.8–2.1) <i>N</i> = 5	2.3 (2.0–2.4) <i>N</i> = 7	2.4 (2.2–2.7) <i>N</i> = 16
Pronotum length (mm)	1.3 (1.2–1.4) <i>N</i> = 4	1.5 (1.4–1.7) <i>N</i> = 5	1.7 (1.5–1.9) <i>N</i> = 7	1.8 (1.6–2.0) <i>N</i> = 16
Femur III length (mm)	4.1 (3.9–4.2) <i>N</i> = 4	4.4 (4.1–4.6) <i>N</i> = 4	5.1 (4.5–5.7) <i>N</i> = 7	5.5 (5.1–5.8) <i>N</i> = 15
Tibia III length (mm)	2.8 (2.7–2.9) <i>N</i> = 4	3.0 (2.9–3.0) <i>N</i> = 4	3.6 (3.1–4.1) <i>N</i> = 6	3.8 (3.6–4.2) <i>N</i> = 15
Number of subapical spurs on TIII inner	3	3	4	4
Number of subapical spurs on TIII outer	3	3	3 ( <i>N</i> = 6 out of 7) 4 ( <i>N</i> = 1 out of 7)	3 ( <i>N</i> = 14 out of 16) 4 ( <i>N</i> = 2 out of 16)
Ovipositor length (mm)	–	2.9 (2.6–3.1) <i>N</i> = 5	–	4.9 (4.5–5.6) <i>N</i> = 14
OL / BL	–	0.45 (0.40–0.50) <i>N</i> = 5	–	0.59 (0.54–0.66) <i>N</i> = 14
FWW (mm)	–	–	1.3 (1.1–1.5) <i>N</i> = 7	1.4 (1.1–1.6) <i>N</i> = 16
FWL (mm)	–	–	0.8 (0.7–1.2) <i>N</i> = 7	0.7 (0.6–1.1) <i>N</i> = 16
tmao / tmai	0.80 (0.48–0.94) <i>N</i> = 4	0.86 (0.68–0.92) <i>N</i> = 4	0.69 (0.62–0.72) <i>N</i> = 5	0.73 (0.66–0.81) <i>N</i> = 15
tao1 / tai1	0.85 (0.79–0.87) <i>N</i> = 4	0.90 (0.83–0.99) <i>N</i> = 4	0.80 (0.75–0.97) <i>N</i> = 6	0.84 (0.75–0.96) <i>N</i> = 15

*Kanakinemobius*, the structure of the male forewings places it in a separate genus. The male genitalia of the northern taxon resemble those of *Amanayara* from South America, but the latter genus is entirely apterous and has two glandular subapical spurs on the inner side of the hind tibia in males (de Mello & Jacomini 1994). The structure of the wings closely resembles that of the South American genus *Pepoapua*, but the latter genus has different male genitalia and a serrated ovipositor in females (Jesus *et al.* 2017). Here, the northern taxon is assigned to a new monotypic genus, *Mutonemobius* gen. nov.

**Table 5.** Parameters of *Pteronemobius truncatus* (Saussure, 1877) song at different localities and temperatures.

Locality	Air Temperature [°C]	Ground Temperature [°C]	Peak Frequency [kHz]	Pulse Rate [p/s]	Pulse Duration [ms]	Pulse Interval [ms]	Chirp Duration [s]	Chirp Interval [s]
Mangonui	20.4	10.4	5.6	49.2	14.7	5.5	0.6–0.7	1.9–3.3
Mangonui	24.0	22.0	6.6	51.6	14.4	4.6	0.9–1.1	0.7–1.1
Te Paki	16.8	13.0	5.6	42.7	16.4	6.8	1.1–1.4	1.5–1.9
Te Paki	13.8	13.0	5.4	39.8	16.3	9.3	1.2–1.5	2.0–2.4

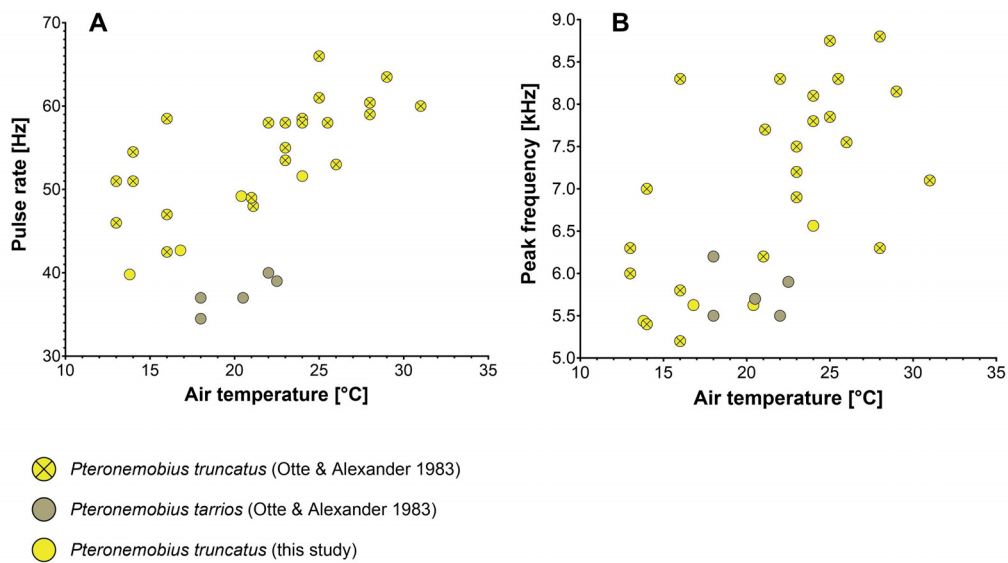
Both new genera, *Austronemobius* gen. nov. and *Mutonemobius* gen. nov., are placed in the tribe Nemobiini Vickery, 1973 based on the absence of a glandular subapical spur on the inner edge of Tibia III in males (Vickery 1973).

#### ***Identification of species in the genus Pteronemobius Jacobson, 1904***

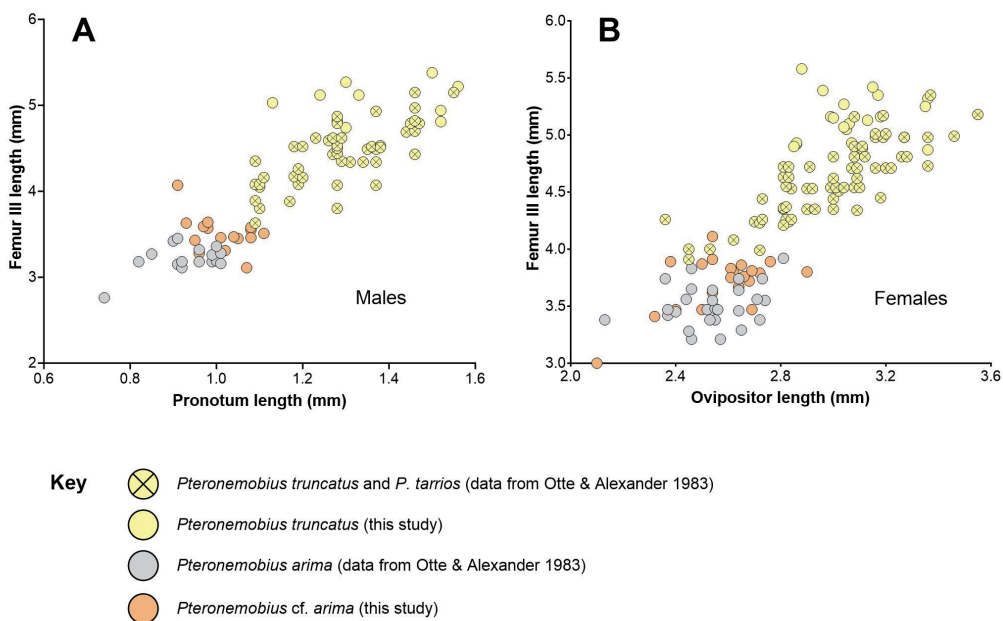
Out of 368 crickets examined, 99 fit the diagnosis for the genus *Pteronemobius* (Otte & Alexander 1983; Rentz & Su 2019). The genus is easily recognizable because of the presence of a short, thickened, conical sub-apical spur (tsai4) on the dorsal inner edge of tibia III in males (Figs 1A, 23C, 25C).

Out of 99 crickets in the genus *Pteronemobius*, 49 fit the description of *P. truncatus/tarrios* based on morphology, as previously identified by Messenger (1991). It should be noted that the two species *P. truncatus* and *P. tarrios* can only be separated from one another based on their song, not by their morphology (Otte & Alexander 1983). Even their songs are deceptively similar, and are distinguished mainly by the pulse rate, which is faster in *P. truncatus* (40 to 65 Hz), slower in *P. tarrios* (30 to 40 Hz) in temperature ranges typical for Australia (Otte & Alexander 1983) (Fig. 5). Based on analysis of the song, the New Zealand specimens are assigned to the species *P. truncatus* (see Table 5, Fig. 5).

The remaining 50 specimens of *Pteronemobius* fit the description of *P. arima* Otte & Alexander, 1983 based on morphology (Figs 6, 8). This species had never been detected in New Zealand before. The original species description by Otte & Alexander (1983) does not include a drawing of the genitalia, or a spectrogram of the song. Rentz & Su (2019) identified *P. arima* and a closely related taxon they treated as “*Pteronemobius* sp. near *arima*” and presented a spectrogram of the song for both. According to Rentz & Su (2019), *P. arima* sings at a frequency of 7 kHz and produces short chirps (0.1 s to 0.2 s) separated by intervals of 0.5 s or longer, whereas “*Pteronemobius* sp. near *arima*” sings at a frequency of 5.5 kHz and produces longer chirps (0.5 s) separated by shorter intervals (0.15 s). No temperature data are given for either of the above recordings. My recordings (T = 18°C) show chirps with duration and interval in between the two above taxa, and a frequency that matches that of *P. arima* (Table 6; Fig. 26). To complicate things further, two adult male specimens of *P. arima* I collected at Oxley Creek Commons in Brisbane, Queensland, in November 2023 are identical to the New Zealand specimens in their measurements, but different in four morphological traits. The two Australian specimens are (1) darker in colour, almost entirely black; (2) have shiny forewings, not textured or wrinkled; (3) have a different wing geometry, with PCSD/PCLD values of 0.586 and 0.610, compared to a range between 0.665 and 0.796 in New Zealand specimens; and (4) have a stridulatory file that stops short of the harp vein. While Brisbane falls within the geographic distribution range for *P. arima* indicated



**Fig. 5.** Comparing the song of *Pteronemobius truncatus* (Saussure, 1877) and of *P. tarrios* Otte & Alexander, 1983. Data from Otte & Alexander (1983) and from this study. **A.** Pulse rate as a function of air temperature. **B.** Peak frequency as a function of air temperature.



**Fig. 6.** Morphometric measurements for the New Zealand species of *Pteronemobius* Jacobson, 1904. This figure replicates Otte & Alexander (1983: fig. 129). Measurements for the Australian specimens of *P. truncatus* (Saussure, 1877) and of *P. arima* Otte & Alexander, 1983 were extracted from Otte & Alexander (1983). Measurements for the New Zealand specimens of *P. truncatus* and of *P. cf. arima* are from the materials examined in this study. **A.** Relationship between pronotum length and hind femur length in males of *Pteronemobius* (Otte & Alexander 1983: fig. 129a–b). **B.** Relationship between ovipositor length and hind femur length in females of *Pteronemobius* (Otte & Alexander 1983: fig. 129c).



by Otte & Alexander (1983), it is a long way away from the type locality in the Northern Territory. Based on the information available, I suggest that *Pteronemobius arima* Otte & Alexander, 1983 might be a species complex rather than a single species. I am not comfortable assigning the New Zealand specimens to *P. arima* without the examination of additional reference material from the species type locality. I therefore refer to the New Zealand taxon as *Pteronemobius* cf. *arima* Otte & Alexander, 1983, where the abbreviation ‘cf.’ is used as suggested by Sigovini *et al.* (2016).

The two New Zealand species of *Pteronemobius* are easily separated by size, *P. truncatus* being nearly double the size of *P.* cf. *arima* in all dimensions (Table 6; Fig. 7). The wing structure (Fig. 8) and texture are also different; the forewings of *P. truncatus* are shiny and reflect light like a mirror, whereas the forewings of *P.* cf. *arima* are wrinkled and textured and matt in their look. The songs differ mainly in the length of the chirp (Figs 24, 26) and in the sound volume, the call of *P.* cf. *arima* being a mere whisper that is easily overheard and very hard to record in the field.

### ***Subfamily Trigonidiinae Saussure, 1874***

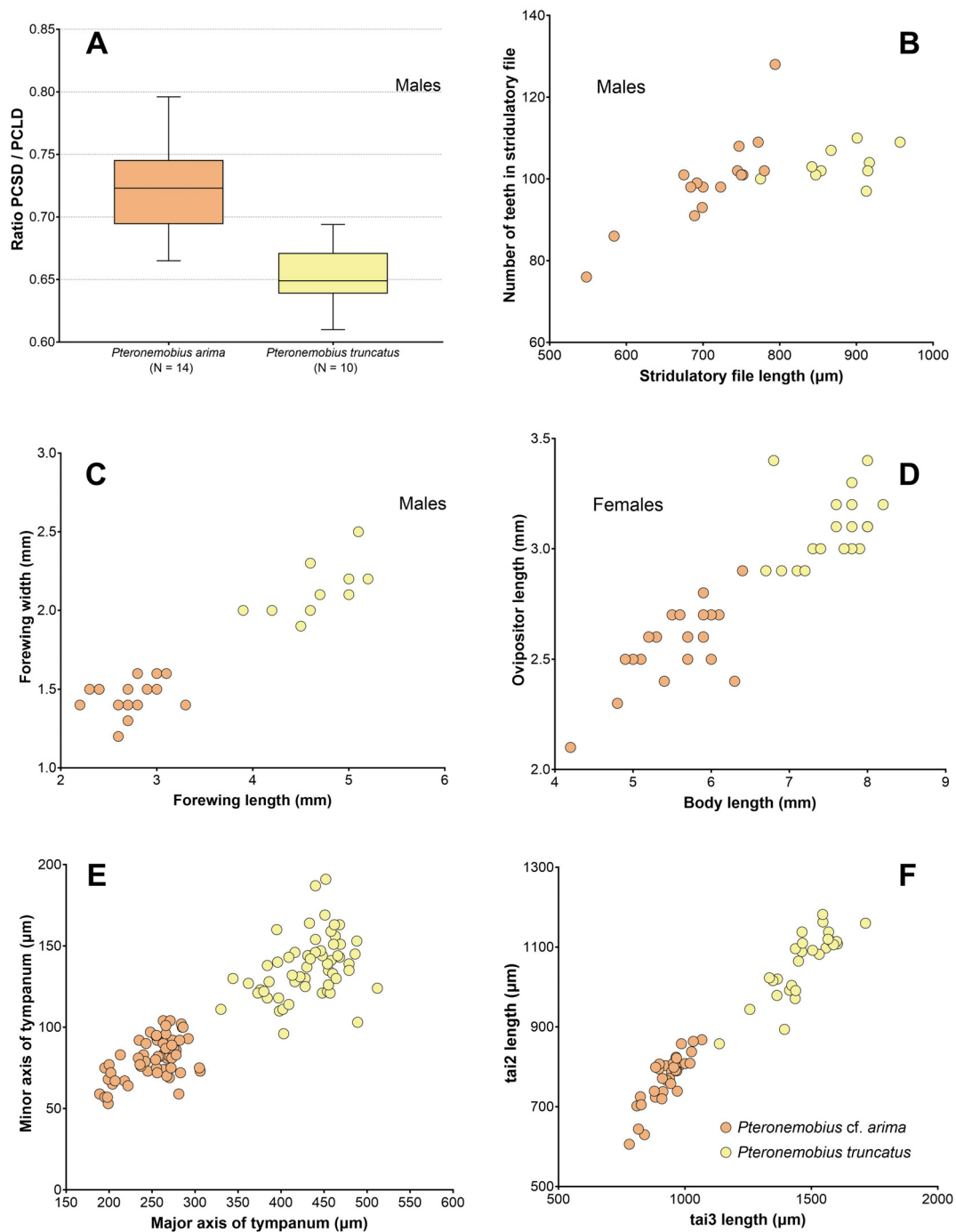
Out of 368 crickets examined, forty-three are trigs (subfamily Trigonidiinae). Thirty of these fit the original description and the type material for *Trigonidium (Metioche) maoricum*, with a black, shining body, arcuate ovipositor, hind tibiae with three pairs of dorsal spurs, no auditory tympana on the anterior tibiae, and no hindwings. *Trigonidium (Metioche) maoricum* has no abdominal gland and has a stridulum with 30–40 teeth on the male forewing.

While Chopard (1968) placed the species in *Metioche*, the description of *Metioche* clearly states that insects have forewings without a stridulum in both males and females (Stål 1877; Otte & Alexander 1983; Rentz & Su 2019). *Trigonidium*, on the other hand, has a stridulum on the right forewing in males (Rambur 1838; Otte & Alexander 1983; Rentz & Su 2019). As a result, the species *Trigonidium (Metioche) maoricum* is reassigned here to *Trigonidium (Trigonidium) maoricum* Rambur, 1838. This is in agreement with Otte & Alexander (1983), who moved most Australian species placed by Chopard (1968) in *Metioche* back to *Trigonidium*.

The remaining thirteen trigs examined in this study don’t fit the original description of *Trigonidium (Trigonidium) maoricum*, in that they have auditory tympana on both the anterior and posterior sides of the fore tibiae, a stridulum with 30 to 40 teeth in males, and a set of hindwings. These characters fit the genus *Trigonidomorpha* (Chopard 1925; Otte & Alexander 1983; Rentz & Su 2019) and appear to be most closely related to *Trigonidomorpha sjostedti*. One male trig from Whitianga, Coromandel (NZAC 03037192) had hindwings when it was collected, but had shed its hindwings five days later.

All male New Zealand trigs I examined have the same genitalia and the same stridulum with 30 to 40 teeth, regardless of the presence or absence of hindwings and/or auditory tympana. Mitochondrial DNA analysis at the COI locus supports the hypothesis that the two morphs belong to the same species (Fig. 31) and validates the observations made by Ingrisch (1977). I am therefore giving an amended description and diagnosis for the genus *Trigonidium* and for the species *Trigonidium (Trigonidium) maoricum*. I am also synonymising the Australian species *Trigonidomorpha sjostedti* with *Trigonidium australianum* (Chopard, 1925). Since *Trigonidomorpha sjostedti* is the type species for the genus *Trigonidomorpha*, the latter genus is synonymised with *Trigonidium*. The species *Trigonidomorpha obscuripennis* Chopard, 1957 from Réunion Island, used by Chintauan-Marquier *et al.* (2016) to reinstate the genus *Trigonidomorpha*, should be reassigned to a new genus based on molecular data and on its macroscopically different tegmina.

Mitochondrial DNA analysis at the COI locus fails to separate the Australian species *Trigonidium (Trigonidium) australianum* from *Trigonidium (Trigonidium) maoricum* (Fig. 31). The two taxa seem to



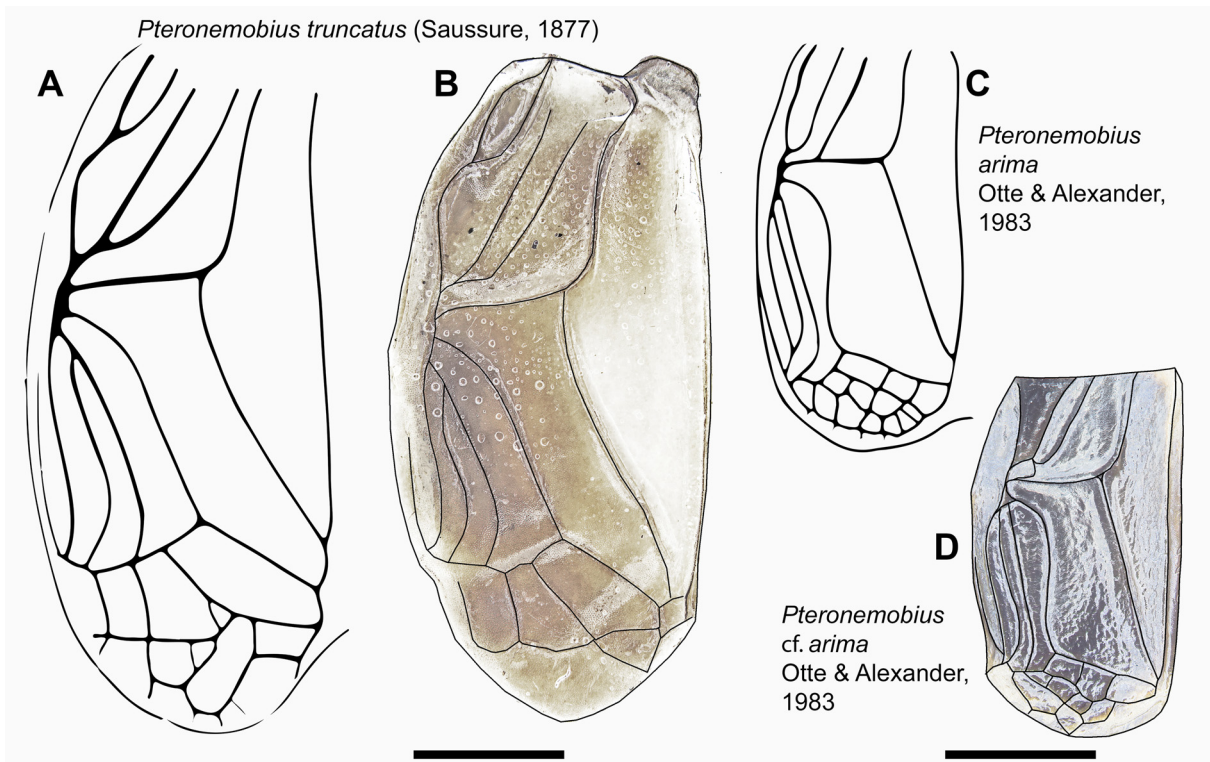
**Fig. 7.** Morphometric measurements for the New Zealand species of *Pteronemobius* Jacobson, 1904. In all graphs, orange shapes indicate *P. cf. arima* Otte & Alexander, 1983; yellow shapes indicate *P. truncatus* (Saussure, 1877). Both sexes are included unless stated otherwise. **A.** Boxplot of the ratio of the short and long diagonals in the right male forewing's posterior cell of the harp (see Fig. 1B). The whiskers include the minimum and maximum values. **B.** Stridulatory file in male cricket's right forewing. **C.** Dimensions of male cricket's right forewing (Fig. 1B). **D.** Body length vs ovipositor length (Fig. 1D). **E.** Major vs minor axis of tympanum (Fig. 1E). For each cricket, the measurements of both left and right tympana are included. **F.** Length of middle vs dorsal inner apical spurs on tibia III (Fig. 1A).

only differ in a few measurements (Table 7), including the number of teeth in the stridulatory file, which is less than 20 in *T. australianum* (Otte & Alexander 1983; Table 7 in this paper). Since I have been unable to examine the male genitalia of *T. australianum*, I am not committing to a synonymy of these two taxa just yet. I do suggest, however, that they are likely to be the same species, and at the most two different subspecies.

### **Identification of *Ornebius* Guérin-Méneville, 1844 by sound**

*Ornebius* sound recordings taken in Auckland, Coromandel, Waikato and in New Plymouth yield a song with a peak frequency between 4.5 and 5.6 kHz. Chirps are approximately one second apart and consist of three pulses; a single pulse followed by a pause of 0.3 seconds then two more pulses close together (Fig. 34). This song matches that of *Ornebius aperta* (Otte & Alexander 1983: fig. 314; Gwynne *et al.* 1988). As previously observed by Ramsay (1990, 1991), the paraprocts are also a good match for *Ornebius aperta*, club-like in shape, narrowest at the base and widest one fifth of the length from the apex (Fig. 33G–I).

*Ornebius* crickets around Whangārei and Kerikeri in Northland sing at a peak frequency of 4 kHz ( $T = 23^{\circ}\text{C}$ ). Chirps are approximately two seconds apart and consist of four to five pulses; a single pulse followed by a pause longer than half a second then three to four pulses close together (Fig. 35). This song does not match any known species of *Ornebius*. The male paraprocts are subtly different from those of *O. aperta*, with a longer narrow neck at the base, and the widest point one fourth of the length from



**Fig. 8.** Dorsal view of the right forewing in the New Zealand species of *Pteronemobius* Jacobson, 1904. **A–B.** *Pteronemobius truncatus* (Saussure, 1877). **A.** Drawing from Otte & Alexander (1983: fig. 132b). **B.** Kohuroanaki Loop Track, Te Pahi (MPN OR0197). **C.** *Pteronemobius arima* Otte & Alexander, 1983. Drawing from Otte & Alexander (1983: fig. 132m). **D.** *Pteronemobius* cf. *arima* Otte & Alexander, 1983. Maitai Bay, Karikari Peninsula, Northland (MPN OR0246). Scale bars = 1 mm.

the apex (Fig. 33K). While this shape may resemble more closely the paraprocts of *Ornebius wandella* Otte & Alexander, 1983, the latter species has two very prominent hair tufts projecting backwards from the posterior margin of the suranal plate (Otte & Alexander 1983: fig. 312y); these are missing in *Ornebius aperta* and in *Ornebius* crickets from Northland (Fig. 33D–E). Except for the subtle difference in the shape of the male paraprocts, male and female *Ornebius* crickets from Northland cannot be differentiated from *Ornebius aperta* by morphology.

Based on this information, *Ornebius* crickets from Northland might be a species other than *Ornebius aperta*, but I am not confident enough to state that they definitely are, let alone to designate a new species. This really needs to be done in the context of a comprehensive revision of *Ornebius* from the east coast of Australia and from the wider Pacific region, based on morphology, song and molecular data. I will therefore refer to the *Ornebius* population in Northland as *Ornebius* aff. *aperta* Otte & Alexander, 1983, where the abbreviation ‘aff.’ is used as suggested by Sigovini *et al.* (2016).

The boundary between the Auckland and Northland *Ornebius* populations is unknown.

### ***Taxonomic key for the identification of New Zealand crickets smaller than 10 mm***

The key applies to males and females, but only to adults; juveniles may be difficult to identify, even at genus level. The key is specific to New Zealand, and only applies to crickets with a body length under 10 mm.

1. Cricket body and legs covered by scales. Scaly crickets (family Mogoplistidae) ..... 2
  - Cricket body and legs not covered by scales. Family Trigonidiidae ..... 3
2. Male song a sequence of chirps consisting of three pulses; interval between chirps approx. 1 second. Paraprocts in male genitalia strongly constricted at the base (Fig. 33G–I) ..... *Ornebius aperta* Otte & Alexander, 1983
  - Male song a sequence of chirps consisting of four or five pulses; interval between pulses between 2 and 3 seconds. Paraprocts in male genitalia not strongly constricted at the base (Fig. 33K) ..... *Ornebius* aff. *aperta* Otte & Alexander, 1983
3. Slender cricket with shiny black body and yellow-orange legs; middle tarsal segment with prominent adhesive pad; two inner apical spurs on Tibia III ..... *Trigonidium maoricum* (Walker, 1869)
  - Body and legs of same or similar colour; middle tarsal segment without prominent adhesive pad; three inner apical spurs on Tibia III ..... Subfamily Nemobiinae 4
4. Auditory tympana present ..... 5
  - Auditory tympana absent ..... 8
5. Primarily diurnal crickets. Body and legs grey/black. Ovipositor black. Males without glandular subapical spur tsai4 on Tibia III. Number of inner and outer subapical spurs on Tibia III is always 3 in both sexes ..... Genus *Bobilla* Otte & Alexander, 1983 6
  - Primarily nocturnal crickets. Body and legs light or dark brown. Ovipositor brown. Males with glandular subapical spur tsai4 on Tibia III. Number of inner subapical spurs on Tibia III is always 4 in males; 3 or 4 in females ..... Genus *Pteronemobius* Jacobson, 1904 7
6. Males with spike-like tufts of bristles on each side of the suranal plate. Number of teeth in stridulatory file > 180. Females with long ovipositor; lateral valves of ovipositor strongly denticulate ..... *Bobilla nigrova* (Swan, 1972)



- Males without spike-like tufts of bristles on each side of the suranal plate. Number of teeth in stridulatory file <180. Females with short ovipositor; lateral valves of ovipositor weakly denticulate ..... *Bobilla bigelowi* (Swan, 1972)
- 7. Body length >6 mm in both sexes. Song clearly audible; long chirps (duration >0.6 s) at 2 to 3 second intervals. Females with four outer subapical spurs on Tibia III. Male forewing as in Fig. 8A–B ..... *Pteronemobius truncatus* (Saussure, 1877)
- Body length <6 mm in both sexes. Song has very low volume; short chirps (duration 0.1 s to 0.3 s) at 0.5 second intervals. Females with three outer subapical spurs on Tibia III. Male forewing as in Fig. 8C–D ..... *Pteronemobius* cf. *arima* Otte & Alexander, 1983
- 8. Forewings absent in males and females. South Island and Mt Ruapehu .....  
..... *Austronemobius chelatus* gen. et sp. nov.
- Forewings present, identical in males and females, shorter than they are wide, without stridulatory apparatus in males. North Island only ..... *Mutonemobius marmoratus* gen. et sp. nov.

### Taxonomy

Class Insecta Linnaeus, 1758  
 Order Orthoptera Latreille, 1793  
 Suborder Ensifera Chopard, 1921  
 Infraorder Gryllidea Vickery, 1977  
 Superfamily Grylloidea Laicharting, 1781  
 Family Trigonidiidae Saussure, 1874  
 Subfamily Nemobiinae Saussure, 1877  
 Tribe Nemobiini Saussure, 1877

Genus *Bobilla* Otte & Alexander, 1983

*Bobilla* Otte & Alexander, 1983: 180, table 11.

*Bobilla* – Otte *et al.* 1987: 399, fig. 15a–b. — Su & Rentz 2000: 8, figs 2–4, tables 1–2. — Desutter-Grandcolas *et al.* 2016: 418. — Rentz & Su 2019: 320.

### Type species

*Bobilla bivittata* (Walker, 1869) by original designation.

### Etymology

From *Bobo*, ‘grass’, and the locative suffix ‘-illa’, (‘found’) in grass. From one of “several small dictionaries covering a number of languages spread across Australia” (D. Otte pers. com. 2023). *Bobilla* species live in grasslands. The name *Bobilla* is female gender.

### Diagnosis (after Otte & Alexander 1983; Rentz & Su 2019)

Medium- to large-sized Nemobiinae, body length typically between 6 and 9 mm; coloration variegated grey to black. Forewings fully developed in both sexes. Eighty to ninety percent of females with short forewings (Fig. 16B, E); 10% to 20% with long forewings (Fig. 16F). Hindwings occasionally present in either sex but rarely so (Fig. 16D). Stridulatory apparatus complete. Tympana present on posterior side of Tibia I. Tibia III with three inner and three outer subapical spurs in both sexes, alternate. Tibia III ventral apical spurs subequal in length. Length of Tarsomere III-1 outer apical spur approx. 60% of inner apical spur.



### Measurements

See Table 2. Sexual dimorphism in body length, with females being larger than males by 10% to 20%.

For a detailed description of this genus, see Otte & Alexander (1983: 180); Desutter-Grandcolas *et al.* (2016: 418); Rentz & Su (2019: 320).

### Habitat and ecology

Primarily diurnal singers, may sing through the night on warm nights only. Active at temperatures below 10°C on sunny days. Found exclusively in grasslands, both in short and long vegetation, from sea level to 1800 m a.s.l.

### Distribution

All of New Zealand, including Chatham Islands, except for Rakiura/Stewart Island and subantarctic islands. Overseas also in Australia (11 species) and in New Caledonia (1 species).

***Bobilla nigrova*** (Swan, 1972)  
Figs 3, 4A, 9–11, 15A–F, 16A–B, 38C

*Pteronemobius nigrovus* Swan, 1972: 534–535, figs 3–4.

*Pteronemobius bivittatus* – Hudson 1973: 167–169 (pars).

*Pteronemobius nigrovus* – McIntyre 1977a: 63–72; 1977b: 319–323; 1978: 3–10.

*Pteronemobius (Bobilla) nigrovus* – Masaki *et al.* 1987: 354, fig. 8.

*Bobilla nigrova* – Otte *et al.* 1987: 399.

### Diagnosis

A medium- to large-sized ground cricket (body length 6 to 9 mm), dark gray to black colour. Males with spike-like tufts of bristles on each side of the suranal plate. Male tegmina with more than 180 teeth in stridulatory file; ratio PCSD/PCLD between 0.438 and 0.488 (mainland New Zealand only, excluding Chatham Islands). Females with long ovipositor (4.0 mm to 6.7 mm), strongly denticulate at apex. Disambiguation from *Bobilla bigelowi* generally requires microscope examination (see Table 1) or sound analysis.

### Etymology

From the Latin ‘*nīgēr*’ (adj.), ‘black’, and ‘*ōva*’ (noun, pl.), ‘eggs’. The eggs of *Bobilla nigrova* are black (Fig. 10F). *Nigrovus* is an adjective. As per Section 34.2 in the ICZN Code, “the ending of a Latin or latinized adjectival or participial species-group name must agree in gender with the generic name with which it is at any time combined” (ICZN 1999). Since *Bobilla* is female gender, the adjective *nigrovus* must take female gender also.

**Material examined** (see also Supp. file 1: Table S1)

#### Holotype

NEW ZEALAND • ♂, adult; Mid Canterbury (MC), Ilam; 43.52318° S, 172.58565° E; 14 m a.s.l.; 21 May 1970; D.I. Swan leg.; in grassland; NZAC 03016349.

#### Paratypes

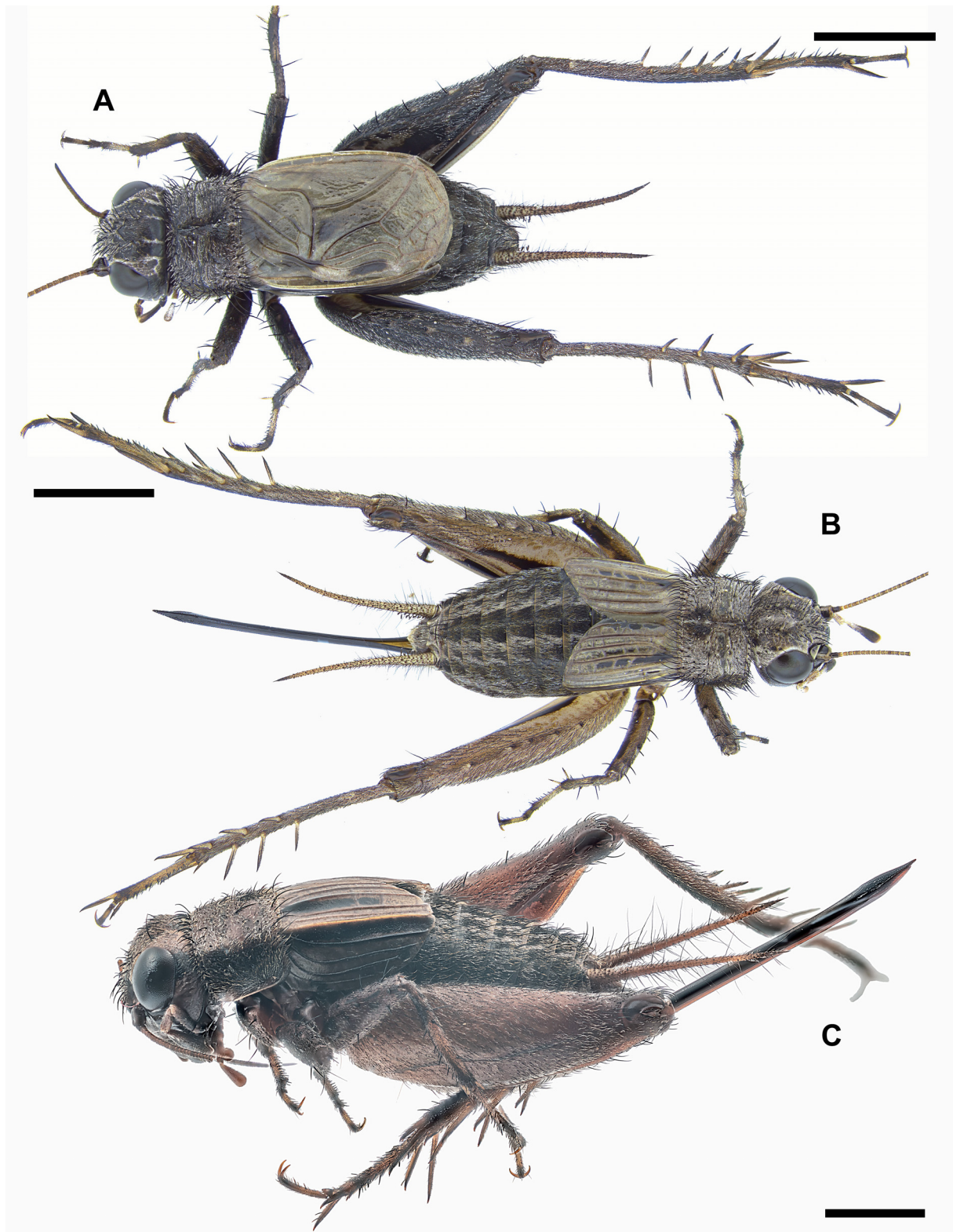
NEW ZEALAND • 25 ♂♂, 41 ♀♀, adults; same data as for holotype; NZAC 03016448 • 1 ♂, adult; same data as for holotype; 28 Aug. 1970; D.I. Swan leg.; in grassland; NZAC 03016361.

**Other material**

NEW ZEALAND – **Dunedin (DN)** • 2 ♂♂, 1 ♀; Signal Hill, Dunedin; 45.86207° S, 170.53995° E; 200 m a.s.l.; 14 Apr. 2024; D. Hegg leg.; grassland; trowel and jar; MPN OR0409 to OR0411 • 2 ♂♂, 2 ♀♀; McGregors Hill, Dunedin; 45.83906° S, 170.56957° E; 270 m a.s.l.; 15 Apr. 2024; D. Hegg leg.; grassland; insect net; MPN OR0412 to OR0415. – **Central Otago (CO)** • 5 ♂♂, 3 ♀♀; Clutha Gold Trail; 45.85559° S, 169.59715° E; 160 m a.s.l.; 31 Jan. 2024; D. Hegg leg.; grassland; insect net; MPN OR0125 to OR0132 • 1 ♂; Big Hut track, Rock and Pillar Range; 45.44488° S, 170.09697° E; 750 m a.s.l.; 1 Jul. 2021; D. Hegg leg.; mixed grass and snow; insect net; MPN OR0478 • 2 ♀♀; Earnsclough Tailings, Alexandra; 45.24063° S, 169.36048° E; 140 m a.s.l.; 18 Mar. 2021; D. Hegg leg.; dirt track; insect net; MPN OR0043, OR0044. – **Mackenzie (MK)** • 1 ♀; Lake Ōhau; 44.26171° S, 169.81649° E; 600 m a.s.l.; 1 May 2022; D. Hegg leg.; grassland; insect net; MPN OR110 • 1 ♂, 3 ♀♀; Lake Ōhau; 44.25812° S, 169.81463° E; 620 m a.s.l.; 24–26 Feb. 2023; D. Hegg leg.; grassland; insect net; MPN OR0108, OR0109, OR0111, OR0112 • 1 ♂; Tekapo; 44.00842° S, 170.49794° E; 720 m a.s.l.; 4 Apr. 2021; D. Hegg leg.; in short grass; jar; MPN OR0045 • 1 ♂; Patersons Terrace, Tekapo; 44.05623° S, 170.42581° E; 700 m a.s.l.; 17 Feb. 2022; D. Hegg leg.; on 4WD track; insect net; MPN OR0134. – **South Canterbury (SC)** • 1 ♂, 4 ♀♀; Fairlie; 44.09342° S, 170.82757° E; 300 m a.s.l.; 4 Apr. 2021; D. Hegg leg.; in short grass in picnic area; jar; MPN OR0451 to OR0455. – **Mid Canterbury (MC)** • 1 ♀; Glenrock Stream, Rakaia River; 43.33354° S, 171.37505° E; 630 m a.s.l.; 28 Jul. 2023; D. Hegg leg.; grassy 4WD track; jar; MPN OR0136. – **Buller (BR)** • 1 ♀; Boyle River; 42.55859° S, 172.35076° E; 520 m a.s.l.; 3 Apr. 2021; D. Hegg leg.; short grass on road verge; insect net; MPN OR0046. – **Kaikōura (KA)** • 1 ♀; Kahutara River; 42.37725° S, 173.44202° E; 270 m a.s.l.; 12 Mar. 2023; D. Hegg leg.; on gravel road; insect net; MPN OR0133. – **Wanganui (WI)** • 1 ♂; McPhersons Bush; 39.94103° S, 175.33579° E; 150 m a.s.l.; 17 Mar. 2023; D. Hegg leg.; tall grass on road verge; insect net; MPN OR0147. – **Rangitikei (RI)** • 1 ♂, 1 ♀; Waipawa Forks Hut; 39.79859° S, 176.17517° E; 720 m a.s.l.; 14 Mar. 2024; D. Hegg leg.; in lawn outside hut; insect net; MPN OR0310, OR0311. – **Rangitikei/Taupō (RI/TO)** • 2 ♀♀; Ohakune; 39.42592° S, 175.44136° E; 650 m a.s.l.; 13 May 2023; D. Hegg leg.; in road pull-out; jar; MPN OR0121, OR0122. – **Waikato (WO)** • 2 ♂♂, 2 ♀♀; Manganui Road, Awakino; 38.61659° S, 174.67720° E; 50 m a.s.l.; 29–30 Mar. 2022; D. Hegg leg.; tall grass on road verge; trowel and jar; MPN OR0113 to OR0116. – **Bay of Plenty (BP)** • 1 ♂; Hurunui Hut, Kaimai Range; 37.81700° S, 175.92802° E; 540 m a.s.l.; 15 Apr. 2023; D. Hegg leg.; in grass; insect net; MPN OR0124 • 2 ♂♂, 3 ♀♀; Little Manganuku Saddle; 38.27295° S, 177.38828° E; 550 m a.s.l.; 18 Apr. 2021; D. Hegg leg.; on walking track; insect net; MPN OR0443 to OR0447. – **Gisborne (GB)** • 1 ♀; Hikurangi; 37.90100° S, 178.06144° E; 1020 m a.s.l.; 19 Apr. 2024; D. Hegg leg.; on 4WD track; jar; MPN OR0416. – **Bay of Plenty/Coromandel (BP/CL)** • 1 ♂; Waihi; 37.38992° S, 175.83290° E; 100 m a.s.l.; 25 Mar. 2024; D. Hegg leg.; in lawn; jar; MPN OR0343. – **Coromandel (CL)** • 1 ♀; Coromandel; 36.76217° S, 175.49142° E; 10 m a.s.l.; 13 Apr. 2021; D. Hegg leg.; short grass in picnic area; jar; MPN OR0481 • 1 ♂; same data as for preceding; 6 Apr. 2024; MPN OR0398. – **Auckland (AK)** • 1 ♀; Avondale Motor Park, Auckland; 36.89795° S, 174.70778° E; 40 m a.s.l.; 28 Mar. 2022; D. Hegg leg.; on sparsely vegetated ground; jar; MPN OR0123 • 2 ♂♂, 1 ♀; Kaipara Harbour; 36.48248° S, 174.45069° E; 20 m a.s.l.; 2 May 2021; short grass on road verge; jar; MPN OR0475 to OR0477. – **Northland (ND)** • 1 ♀; Kerikeri; 35.24029° S, 173.93822° E; 100 m a.s.l.; 23 Mar. 2022; D. Hegg leg.; in tall grass; insect net; MPN OR0135 • 1 ♂, 1 ♀; Maitai Bay, Karikari Peninsula; 34.82342° S, 173.40619° E; 30 m a.s.l.; 28 Mar. 2024; D. Hegg leg.; in grass; trowel and jar; MPN OR0357, OR0358. – **Chatham Islands (CH)** • 1 ♂; Canister Cove, Pitt Island; 44.33332° S, 176.22676° W; 50 m a.s.l.; 15 Feb. 2024; D. Hegg leg.; short ground cover; jar; MPN OR0137 • 7 ♂♂, 2 ♀♀; Pitt Island; 44.3235° S, 176.2337° W; 120 m a.s.l.; 16 Feb. 2024; D. Hegg and S. Purdie leg.; pasture grass; jar; MPN OR0138 to OR0146.

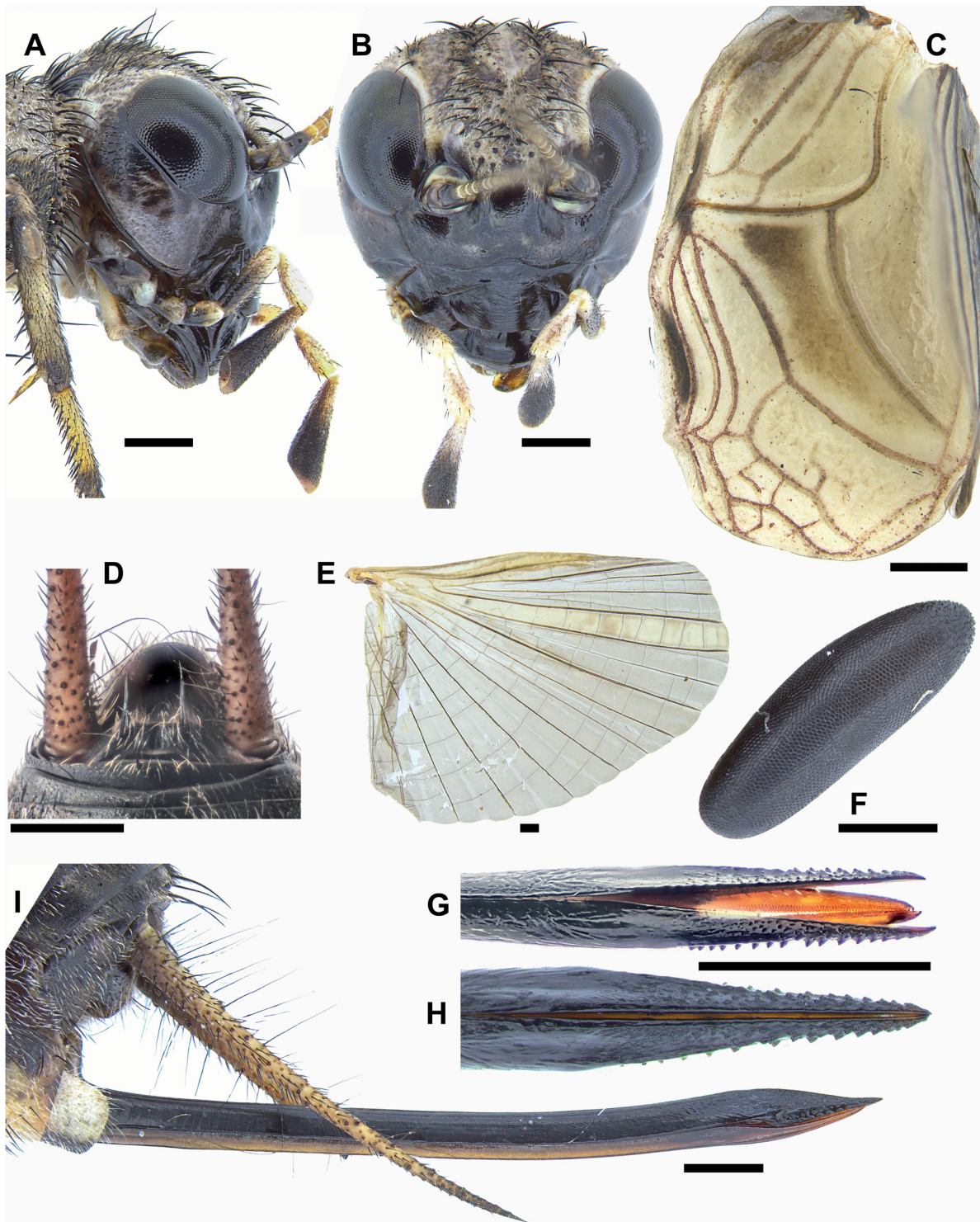
**Description**

Refer to the detailed description in Swan (1972). See also Fig. 10 in this work.

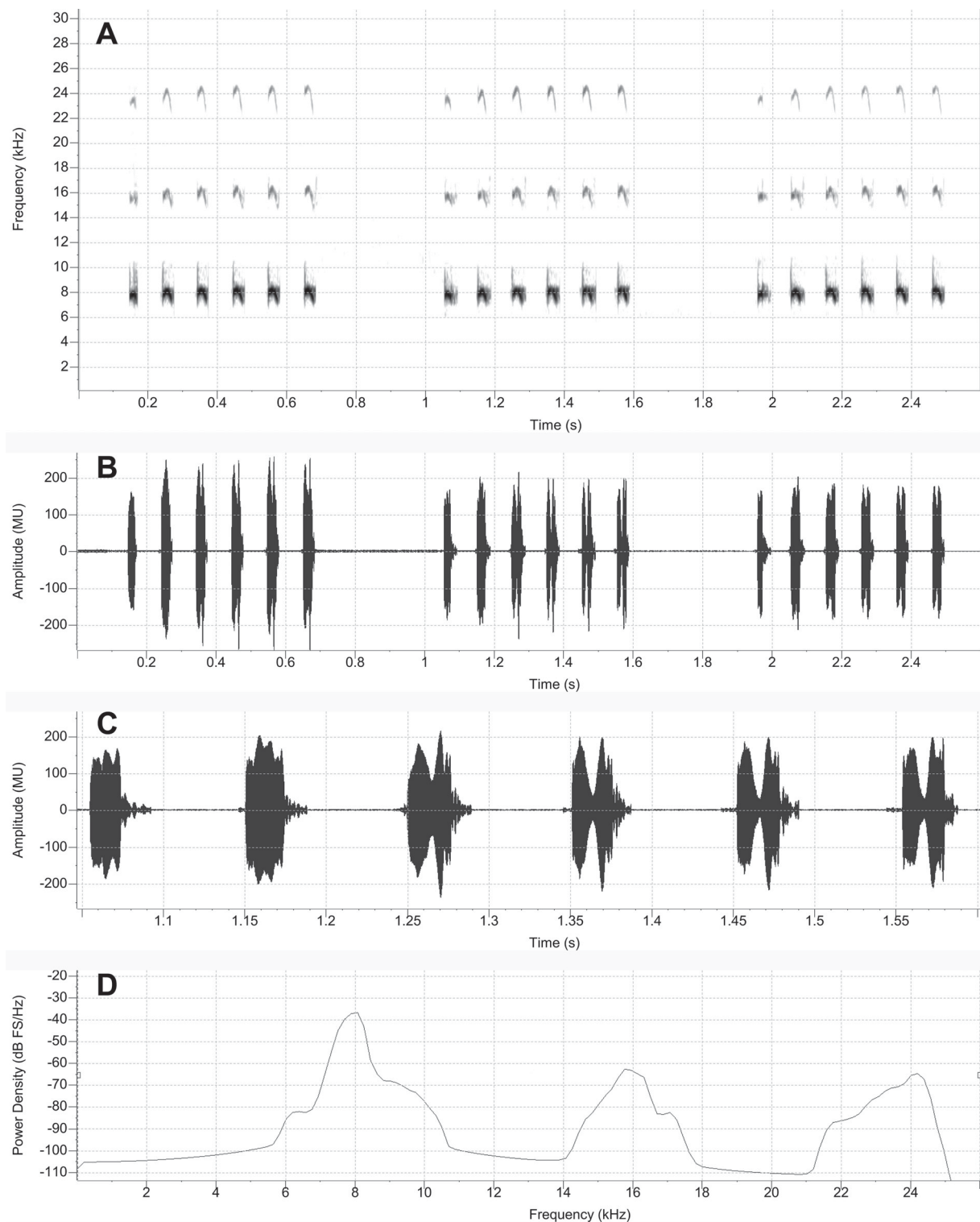


**Fig. 9.** *Bobilla nigrova* (Swan, 1972). **A–B.** Lake Ōhau, Mackenzie Country. **A.** Dorsal view of adult ♂ (MPN OR0108). **B.** Dorsal view of adult ♀ (MPN OR0109). **C.** Earnsclough Tailings, Alexandra. Lateral view of adult ♀ (MPN OR0044). Scale bars = 2 mm.





**Fig. 10.** *Bobilla nigrova* (Swan, 1972). **A.** Lateral view of head, adult ♀. **B.** Frontal view of head, adult ♀. **C.** Dorsal view of right forewing in adult ♂. **D.** Dorsal view of male terminalia showing conspicuous hair tufts. **E.** Right hindwing in adult female, dorsal view. **F.** Egg. **G–H.** Apex of ovipositor, dorsal view showing strong denticulation on lateral valves. **I.** Ovipositor, lateral view. All images Lake Ōhau, Mackenzie Country (♂ MPN OR0108; ♀ MPN OR0109), except for D (MPN OR0446) and G (MPN OR0443) from Little Manganuku Saddle, Bay of Plenty, and E (MPN OR0131) from Clutha Gold Trail, Otago. Scale bars = 500 µm.



**Fig. 11.** *Bobilla nigrova* (Swan, 1972) song, recorded in captivity at 21°C. Specimen collected at Lake Ōhau, Mackenzie Country. **A.** Spectrogram of a sequence of three chirps. **B.** Oscillogram of a sequence of three chirps. **C.** Oscillogram of one chirp consisting of six pulses. **D.** Power spectrum of a sequence of three chirps.



MEASUREMENTS. See Tables 1 and 2. Females are larger than males.

SONG. *Bobilla nigrova* sings at a frequency of 8 kHz at 27°C, with a pulse rate of 10 to 15 pulses per second. Refer to the detailed description in McIntyre 1977a. See also Fig. 11 and Table 2 in this work. The low pulse rate (<15 pulses/s) is the main feature that distinguishes the song of *B. nigrova* from the song of *B. bigelowi*.

### Habitat and ecology

Common and widespread in meadows and grasslands throughout New Zealand, including sports fields and urban parks, *Bobilla nigrova* is mainly active during the day; it may sing through the night on warm nights only. *Bobilla nigrova* is a seasonal species; adults are most frequently encountered in late summer and autumn. *Bobilla nigrova* forms mixed populations with *B. bigelowi* and with species in the genus *Pteronemobius*, with which it can easily be confused.

### Distribution

All of New Zealand, including Chatham Islands, but excluding Rakiura/Stewart Island and subantarctic islands (Fig. 38C).

*Bobilla bigelowi* (Swan, 1972)  
Figs 3, 4B, 12–14, 15G–L, 16C–F, 38B

*Pteronemobius bigelowi* Swan, 1972: 533–534, figs 1–2.

*Pteronemobius bivittatus* – Hudson 1973: 167–169 (pars).

*Pteronemobius bigelowi* – McIntyre 1977a: 63–72; 1977b: 319–323; 1978: 3–10.

*Bobilla bigelowi* – Otte *et al.* 1987: 399.

### Diagnosis

A medium- to large-sized ground cricket (body length 6 to 9 mm), coloured dark grey or black. Males without spike-like tufts of bristles on each side of the suranal plate. Male tegmina with less than 180 teeth in stridulatory file; ratio PCSD/PCLD between 0.496 and 0.558. Females with short ovipositor (3.1 mm to 4.9 mm), weakly denticulate at apex. Disambiguation from *Bobilla nigrova* generally requires microscope examination (See Table 1) or sound analysis.

### Etymology

Named for Robert Sidney Bigelow, New Zealand entomologist (1918–2000).

**Material examined** (see also Supp. file 1: Table S2)

#### Holotype

NEW ZEALAND • ♂, adult; Kaikōura (KA), Conway Flat, Parnassus; 42.61893° S, 173.45750° E; 10 m a.s.l.; 12 May 1970; D.I. Swan leg.; grassland; NZAC 03015213.

#### Paratypes

NEW ZEALAND • 5 ♂♂, 4 ♀♀, adult; same data as for holotype; NZAC 03015516 • 6 ♂♂; Nelson (NN), Richmond; 41.333° S, 173.183° E; 10 m a.s.l.; 15 May 1970; A. Edgar leg.; grassland (sports field); NZAC 03015522 • 2 ♂♂, 3 ♀♀; Mid Canterbury (MC), Ilam; 43.52318° S, 172.58565° E; 14 m a.s.l.; 29 August 1970; D.I. Swan leg.; grassland; NZAC 03015677.

#### Other material

NEW ZEALAND – **Dunedin (DN)** • 2 ♀♀; Signal Hill, Dunedin; 45.86207° S, 170.53995° E; 200 m a.s.l.; 14 Apr. 2024; D. Hegg leg.; grassland; trowel and jar; MPN OR0406, OR0407. – **Central**

**Otago (CO)** • 5 ♂♂, 4 ♀♀; Big Hut track, Rock and Pillar Range; 45.44488° S, 170.09697° E; 750 m a.s.l.; 1 Jul. 2021; D. Hegg leg.; mixed grass and snow; insect net; MPN OR0456 to OR0464. – **Mackenzie (MK)** • 2 ♂♂; Lake Ōhau; 44.25812° S, 169.81463° E; 620 m a.s.l.; 24 Feb. 2023; D. Hegg leg.; grassland; insect net; MPN OR0436, OR0437. – **South Canterbury (SC)** • 1 ♂; Little Mt Peel; 43.8811° S, 171.2321° E; 930 m a.s.l.; 27 May 2023; D. Hegg leg.; on walking track; jar; MPN OR0162. – **Mid Canterbury (MC)** • 1 ♀; Māhoe Reserve, Lincoln; 43.63296° S, 172.48729° E; 20 m a.s.l.; 25 Oct. 2021; D. Hegg leg.; grassland; insect net; MPN OR0182 • 5 ♂♂, 2 ♀♀; Tumbledown Bay, Banks Peninsula; 43.85050° S, 172.77288° E; 10 m a.s.l.; 12 Aug. 2023; D. Hegg leg.; on 4WD track; insect net; MPNOR0174 to OR0180 • 1 ♂, 1 ♀; Mt Hutt Ski-field Road; 43.54992° S, 171.56014° E; 600 m a.s.l.; 21 Jan. 2024; D. Hegg leg.; roadside vegetation; insect net; MPN OR0183, OR0184 • 1 ♂, 1 ♀; Glenrock Stream, Rakaia River; 43.33354° S, 171.37505° E; 630 m a.s.l.; 28 Jul. 2023; D. Hegg leg.; grassy 4WD track; jar; MPN OR0168, OR0169 • 2 ♂♂, 2 ♀♀; Turtons Saddle, Rakaia River; 43.35823° S, 171.36818° E; 1100 m a.s.l.; 30 Jul. 2023; D. Hegg leg.; on 4WD track; jar; MPN OR0164 to OR0167. – **North Canterbury (NC)** • 2 ♂♂, 2 ♀♀; Poulter River; 42.97195° S, 171.88941° E; 550 m a.s.l.; 2 Oct. 2021; D. Hegg leg.; on 4WD track; insect net; MPN OR0170 to OR0173. – **Buller (BR)** • 1 ♂; Haupiri River; 42.65391° S, 171.77393° E; 300 m a.s.l.; 23 Oct. 2023; D. Hegg leg.; grassland; jar; MPN OR0187. – **Kaikōura (KA)** • 1 ♀; Mt Fyffe car park, Kaikōura; 42.35158° S, 173.56781° E; 180 m a.s.l.; 5 Jul. 2021; D. Hegg leg.; roadside vegetation; insect net; MPN OR0480. – **Marlborough (MB)** • 1 ♀; Jacks Pass; 42.47697° S, 172.82517° E; 850 m a.s.l.; 12 Apr. 2022; D. Hegg leg.; roadside vegetation; insect net; MPN OR0185 • 1 ♀; Onamalutu Road, Wairau River; 41.47056° S, 173.73139° E; 80 m a.s.l.; 7 Mar. 2022; D. Hegg leg.; in roadside ditch; jar; MPN OR0181. – **Rangitikei (RI)** • 4 ♂♂, 1 ♀; Waipawa Forks Hut; 39.79859° S, 176.17517° E; 720 m a.s.l.; 14 Mar. 2024; D. Hegg leg.; in lawn outside hut; insect net; MPN OR0312 to OR0316. – **Taranaki (TK)** • 1 ♂; Awakino Gorge; 38.62087° S, 174.74416° E; 130 m a.s.l.; 19 Mar. 2024; D. Hegg leg.; in lawn; jar; MPN OR0317. – **Waikato (WO)** • 7 ♂♂, 7 ♀♀; Leitchs Clearing, Herangi Range; 38.43453° S, 174.76800° E; 270 m a.s.l.; 2 Apr. 2022; D. Hegg leg.; in tall grass; trowel and jar; MPN OR0148 to OR0161. – **Bay of Plenty (BP)** • 1 ♂; Hurunui Hut, Kaimai Range; 37.81700° S, 175.92802° E; 540 m a.s.l.; 15 Apr. 2023; D. Hegg leg.; in grass; insect net; MPN OR0163 • 3 ♂♂, 5 ♀♀; Little Manganuku Stream; 38.26649° S, 177.38991° E; 360 m a.s.l.; 18 Apr. 2021; D. Hegg leg.; stony river bed; insect net; MPN OR0465 to OR0472. – **Gisborne (GB)** • 1 ♂; Hikurangi; 37.86112° S, 178.08154° E; 390 m a.s.l.; 17 Apr. 2024; D. Hegg leg.; on 4WD track; jar; MPN OR0417. – **Northland (ND)** • 1 ♀; Kohuroanaki Loop Track, Te Pahi; 34.50864° S, 172.82443° E; 90 m a.s.l.; 26 Mar. 2022; D. Hegg leg.; on 4WD track; insect net; MPN OR0186.

## Description

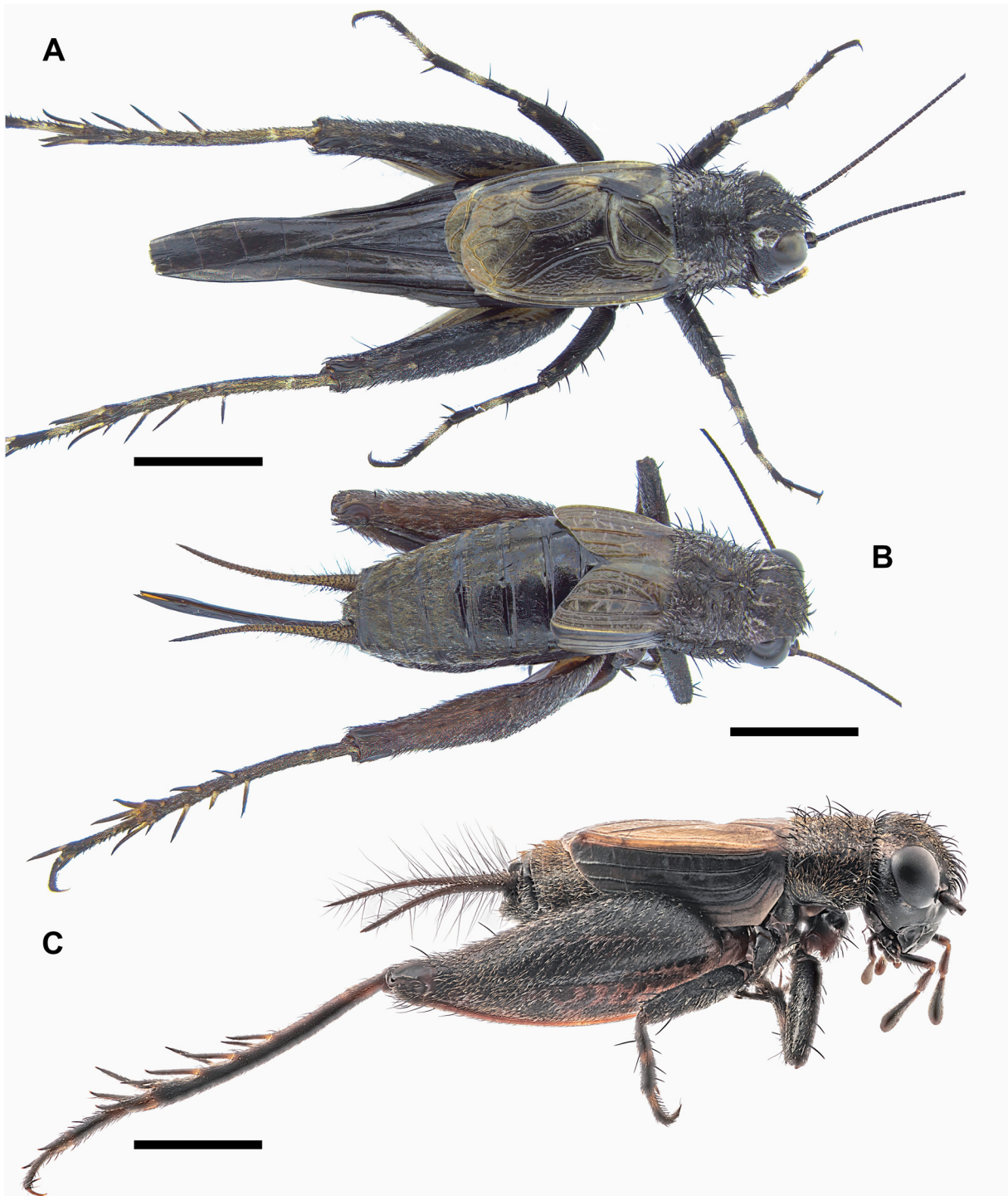
Refer to the detailed description in Swan (1972). See also Fig. 13 in this work.

MEASUREMENTS. See Tables 1 and 2. Females are larger than males.

SONG. *Bobilla bigelowi* sings at a frequency of 7.5 k to 8 Hz at 27°C, with a pulse rate greater than 20 pulses per second. Refer to the detailed description in McIntyre 1977a. See also Fig. 14 and Table 2 in this work. The high pulse rate (>20 pulses/s) is the main feature that distinguishes the song of *B. bigelowi* from the song of *B. nigrova*.

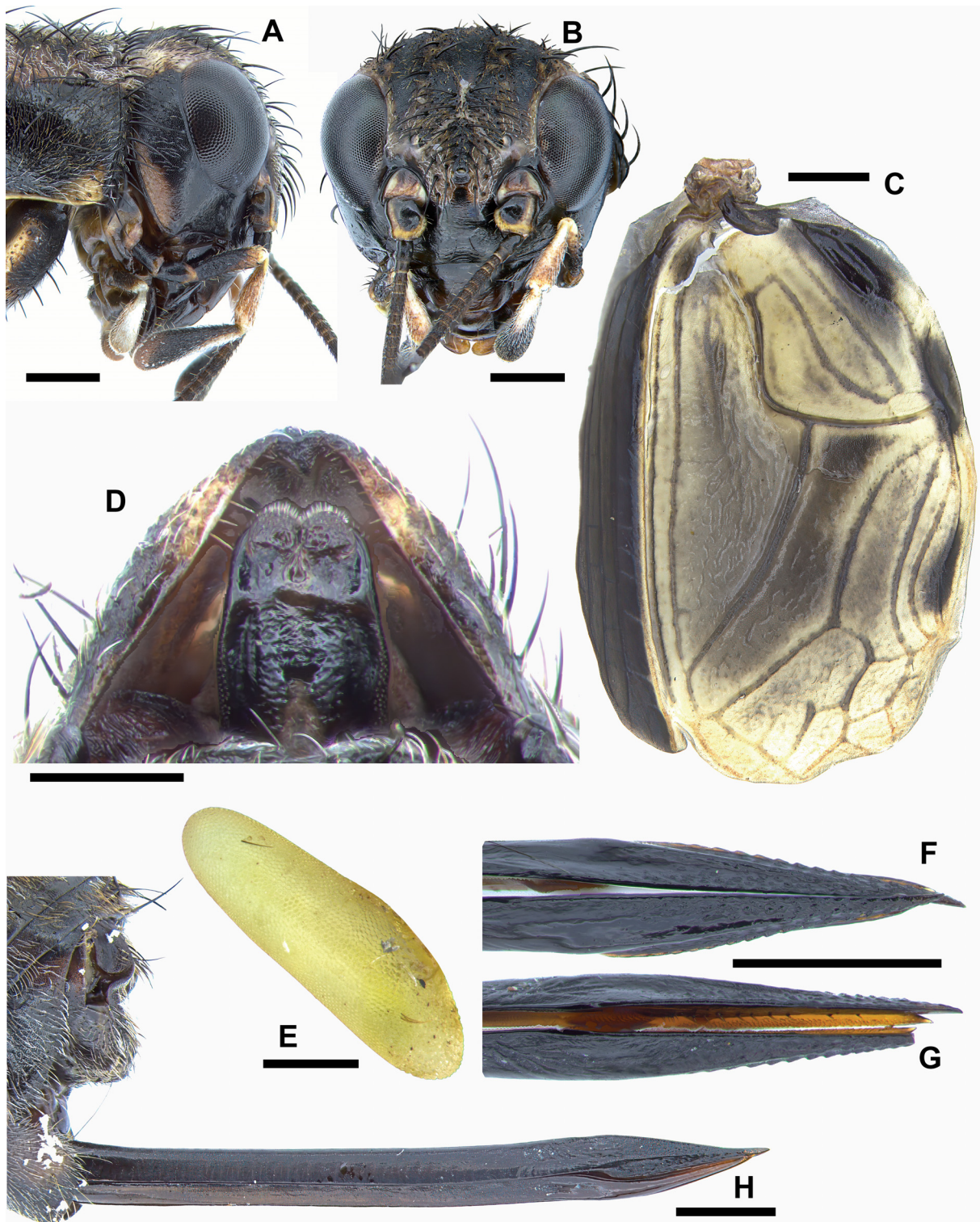
## Habitat and ecology

Common and widespread in meadows and grasslands throughout New Zealand, including sports fields and urban parks, *Bobilla bigelowi* is mainly active during the day; it may sing through the night on warm nights only. It is a frost tolerant species; adults often survive winter and may be encountered at any time of the year. *Bobilla bigelowi* is generally found on ground with a high level of humidity. It forms mixed populations with *B. nigrova* and with species in the genus *Pteronemobius*, with which it can easily be confused.

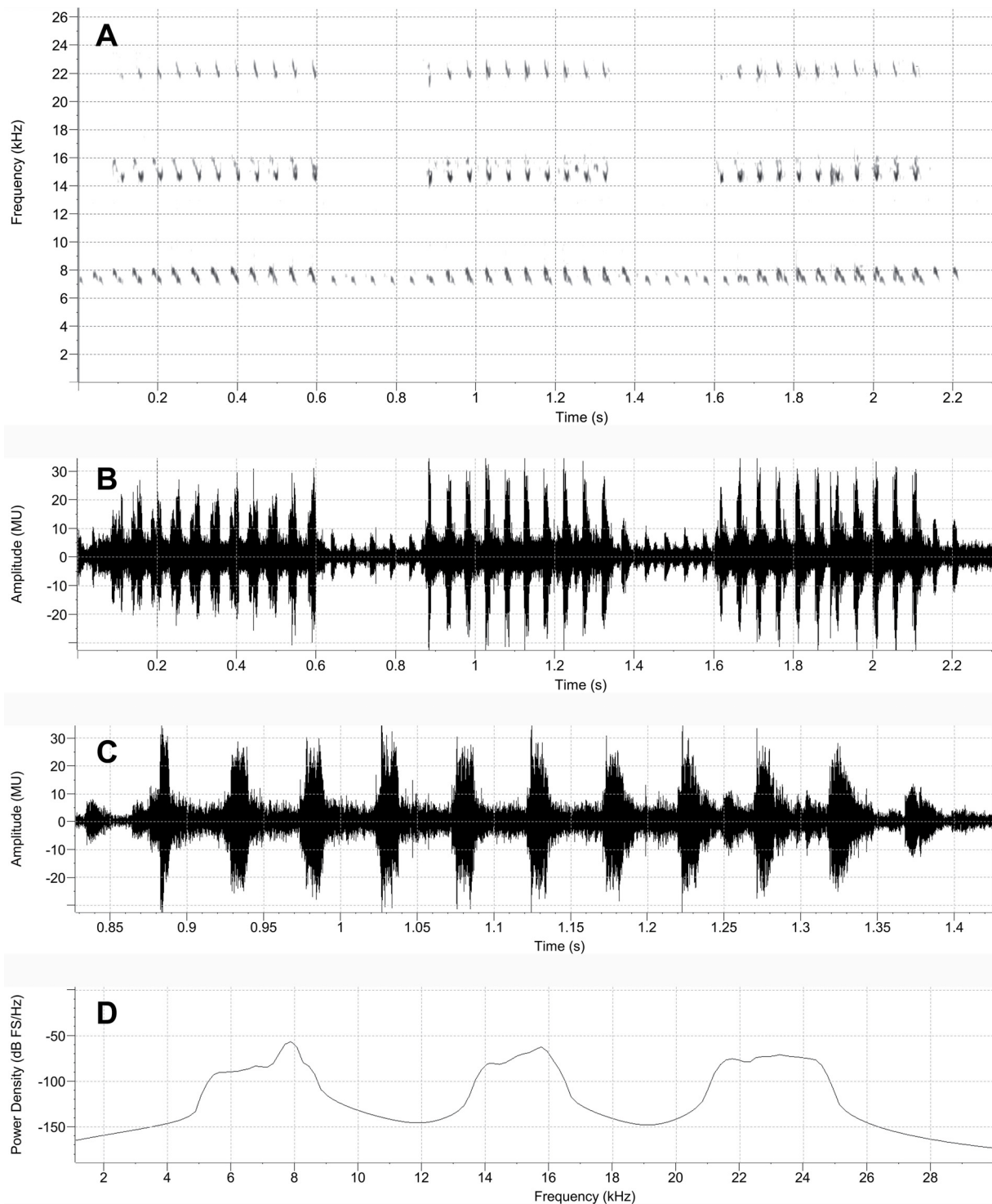


**Fig. 12.** *Bobilla bigelowi* (Swan, 1972). **A.** Winged adult ♂, dorsal view. Lake Ōhau, Mackenzie Country (MPN OR0437). **B.** Dorsal view of adult ♀ with short forewings. Tumbledown Bay, Banks Peninsula (MPN OR0174). **C.** Adult ♂, lateral view. Little Manganuku Stream, Bay of Plenty (MPN OR0470). Scale bars = 2 mm.



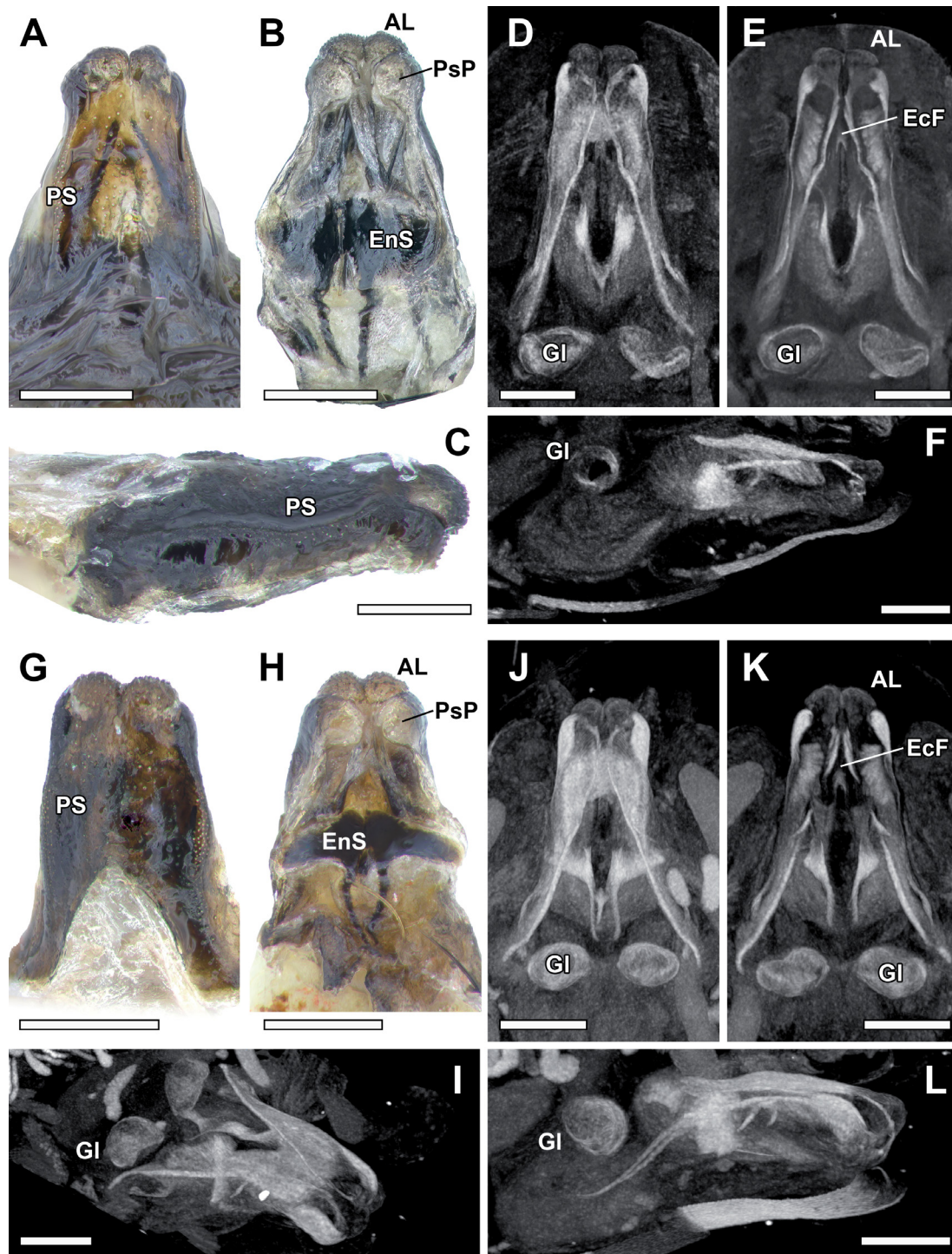


**Fig. 13.** *Bobilla bigelowi* (Swan, 1972). **A–B.** Lateral and frontal view of head, adult ♀. Jacks Pass, North Canterbury (MPN OR0185). **C.** Dorsal view of right forewing in adult ♂. Lake Ōhau, Mackenzie Country (MPN OR0436). **D.** Male genitalia, external view, dorsal. Tumbledown Bay, Banks Peninsula (MPN OR0180). **E.** Egg. Mt Hutt, Canterbury (MPN OR0184). **F–G.** Apex of ovipositor, dorsal view, showing weak denticulation on lateral valves (F. MPN OR0153; G. MPN OR0174). **H.** Ovipositor, lateral view. Tumbledown Bay, Banks Peninsula (MPN OR0174). Scale bars = 500 µm.



**Fig. 14.** *Bobilla bigelowi* (Swan, 1972) song, recorded in the field at 22°C. Whangārei, Northland. **A.** Spectrogram of a sequence of three chirps. **B.** Oscillogram of a sequence of three chirps. **C.** Oscillogram of one chirp consisting of eleven pulses. **D.** Power spectrum of one chirp.





**Fig. 15.** *Bobilla* Otte & Alexander, 1983, ♂ genitalia of New Zealand species. **A–F.** *Bobilla nigrova* (Swan, 1972). **A–C.** Microscope images of pseudepiphallid sclerite. Coromandel (MPN OR0481). **A.** Dorsal view. **B.** Ventral view. **C.** Lateral view. **D–F.** Micro CT scans. Ruahine Forest (MPN OR0310). **D.** Dorsal view, Maximum Intensity Projection (MIP). **E.** Cross-section, dorsal view, Volume Blending. **F.** Lateral view, MIP. **G–L.** *Bobilla bigelowi* (Swan, 1972). Ruahine Forest. **G–H.** Microscope images of pseudepiphallid sclerite (MPN OR0313). **G.** Dorsal view. **H.** Ventral view. **I–L.** Micro CT scans, MIP (MPN OR0312). **I.** Posterior-lateral view (45° angle). **J.** Ventral view. **K.** Cross-section, dorsal view. **L.** Lateral view. Scale bars = 250 µm.



### Distribution

All of New Zealand except for Rakiura/Stewart Island, Chatham Islands and subantarctic islands (Fig. 38B).



**Fig. 16.** Live *Bobilla* Otte & Alexander, 1983. **A–B.** *Bobilla nigrova* (Swan, 1972). **A.** Adult ♂, Hurunui Hut, Kaimai Range. **B.** Adult ♀. Earnsclough Tailings, Alexandra, Central Otago. **C–F.** *Bobilla bigelowi* (Swan, 1972). **C.** Adult ♂, Poulter River, Arthur’s Pass National Park. **D.** Fully winged adult ♂, Lake Ōhau. **E.** Adult ♀ with short forewings. Kaikōura. **F.** Adult ♀ with long forewings. Leitchs Clearing, Herangi Range. Note: only B is photographed in its natural environment. All other specimens are posed on unnatural backgrounds in captivity.

Genus *Austronemobius* gen. nov.

urn:lsid:zoobank.org:act:35A147A3-82F6-41A2-8A43-532C479E6370

### Type species

*Austronemobius chelatus* gen. et sp. nov.

### Etymology

From the Latin ‘*austrālis*’ (adj.), ‘southern’, *Austronemobius* means ‘Southern *Nemobius*’. *Austronemobius* is male gender.

### Diagnosis

Medium-sized Nemobiinae, with body length between 5 and 8 mm. Forewings, hindwings and tympana absent in both sexes. Head small, about as tall as it is wide in frontal view, with large, bulging eyes. Pronotum patterned, with three glabrous, raised areas either side of the median line. Tibia III with three subapical spurs on both inner and outer edges in both sexes. Length of outer ventral apical spur on Tibia III approx. 80% to 90% that of inner ventral apical spur. Outer apical spur on Tarsomere III-1 long, approx. 80% that of inner apical spur. Male genitalia with long, external, articulated pseudepiphallic parameres, modified for clasping (Fig. 19). Ovipositor with lateral valves dotted by numerous, small tubercles at the apex.

### Habitat and ecology

Nocturnal, *Austronemobius* crickets live in moss and in damp leaf litter in forest habitat.

*Austronemobius chelatus* gen. et sp. nov.

urn:lsid:zoobank.org:act:98D85C82-8E3A-4B1B-B2E0-41EEBB69B3DF

Figs 17–19, 22A–B, 38D

### Diagnosis

Refer to the above diagnosis for the genus.

### Etymology

From the Latin ‘*chēla, chēlae*’, the arms of the constellation Scorpio, after the articulated pseudepiphallic parameres in the cricket’s male genitalia. *Chelatus* is used as an adjective. The species has been gifted the common name ‘Tarakihi Kahurangi’ by the local iwi Ngati Waewae.

### Material examined (see also Supp. file 1: Table S4)

#### Holotype

NEW ZEALAND • ♂, adult; Nelson (NN), Kahurangi National Park, Heaphy River; 40.94927° S, 172.14033° E; 40 m a.s.l.; 21 Feb. 2023; Department of Conservation leg.; in leaf litter on forest floor; jar; NZAC 03037179.

#### Paratypes

NEW ZEALAND • 1 ♀, adult; Buller (BR), Lake Christabel Hut; 42.43696° S, 172.25594° E; 680 m a.s.l.; 4 Jan. 2023; D. Hegg leg.; in beech leaf litter; jar; NZAC 03037180 • 1 ♂, 4 ♀♀; same data as for holotype; NZAC 03037182 to 03037186.

#### Other material

NEW ZEALAND – Westland (WD) • 2 ♀♀; Kellys Creek, Ōtira River; 42.80101° S, 171.57103° E; 360 m a.s.l.; 8 Apr. 2019; W. Fox leg.; pitfall trap; iNaturalist 24558958. – Buller (BR) • 1 ♂; Camp



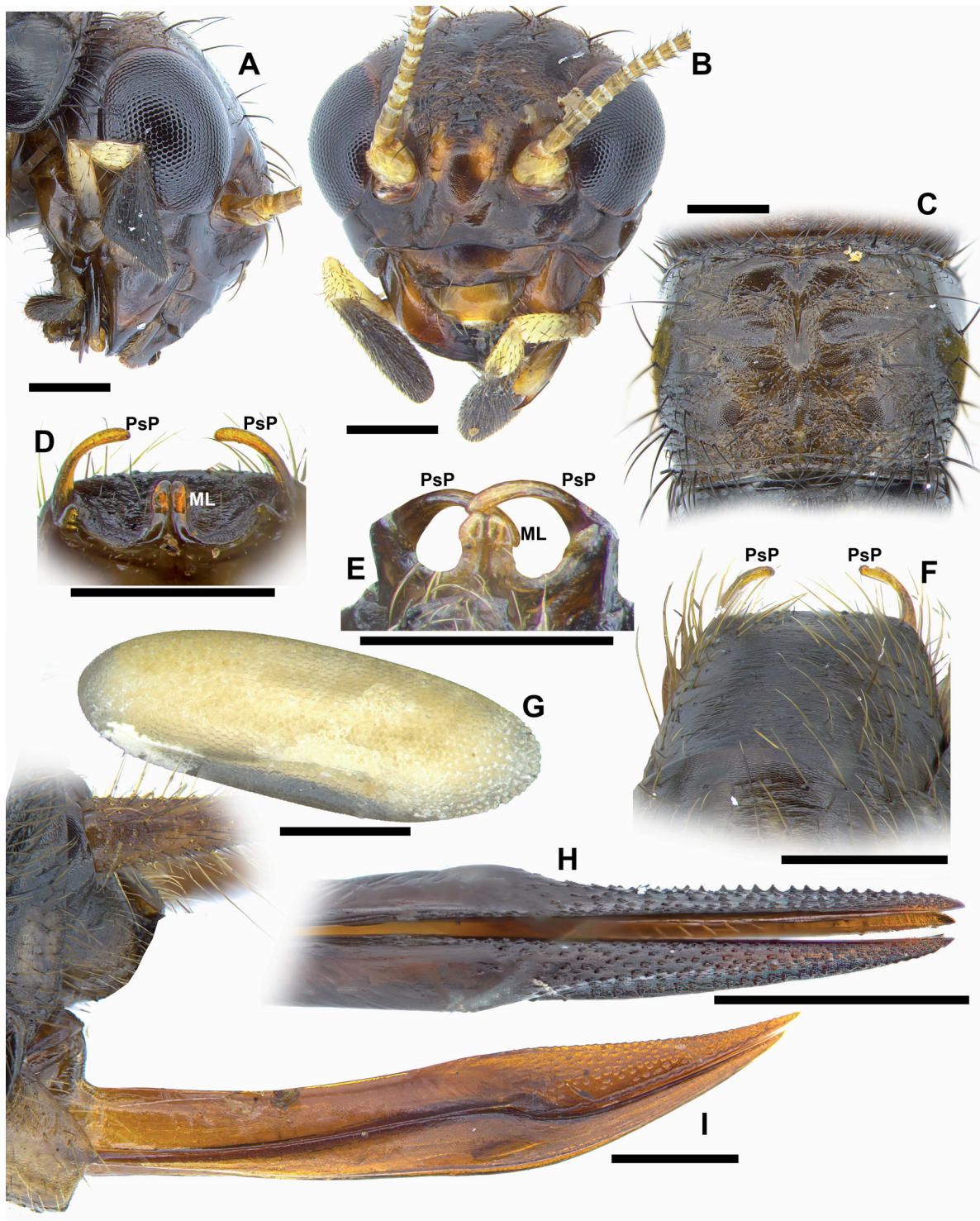
Creek Hut; 42.70600° S, 171.56134° E; 760 m a.s.l.; 19 Feb. 2023; D. Hegg leg.; in hut's fire bath; jar; MPN OR0189 • 1 ♂; Bullock Creek, Punakaiki; 42.09341° S, 171.38956° E; 100 m a.s.l.; 28 Jan. 2022; D. Lamont leg.; photograph only; iNaturalist 111192612 • 1 ♂; Lake Christabel outlet; 42.40342° S, 172.22788° E; 660 m a.s.l.; 5 Jan. 2023; D. Hegg leg.; in beech leaf litter; jar; MPN OR0188 • 1 ♂; Lewis Pass; 42.37957° S, 172.40177° E; 860 m a.s.l.; 1 Feb. 2022; M. Bowie leg.; photograph only; iNaturalist 110563700 • 1 ♀; Black Hill, St Arnaud; 41.79774° S, 172.83513° E; 740 m a.s.l.; 9 Apr. 2022; O. Dove leg.; photograph only; iNaturalist 117424945 • 1 ♂; Black Hill, St Arnaud; 41.79989° S, 172.83631° E; 700 m a.s.l.; 13 Jan. 2024; D. Hegg leg.; in moss on forest floor; jar; MPN OR0190. – **Marlborough/Nelson (MB/NN)** • 1 ♀; Red Hills Hut, Richmond Range; 41.73080° S, 172.99098° E; 900 m a.s.l.; 20 Dec. 2012; M. Thorsen leg.; photograph only; iNaturalist 18226726. – **Nelson (NN)** • 1 ♀; Porters Creek Hut, Richmond Range; 41.65332° S, 172.99737° E; 900 m a.s.l.; 3 Jan. 2022; D. Hegg leg.; in sparse, tall grass; insect net; MPN OR0448 • 1 ♂; Wangapeka Biv; 41.37988° S, 172.27673° E; 580 m a.s.l.; 27 Jan. 2023; O. Dove leg.; photograph only; iNaturalist 148354097 • 1 ♀; Scotts Beach; 41.09349° S, 172.10517° E; 30 m a.s.l.; Dec. 2022; J. Williams leg.; pitfall trap; NZAC 03037181. – **Taupō (TO)** • 1 ♀; Mangawhero Forest Walk, Ohakune; 39.39937° S, 175.41610° E; 620 m a.s.l.; 16 Feb. 2024; S. Trewick leg.; in leaf litter; MPN OR0494.

### Description

MASUREMENTS. See Table 4. No sexual dimorphism.



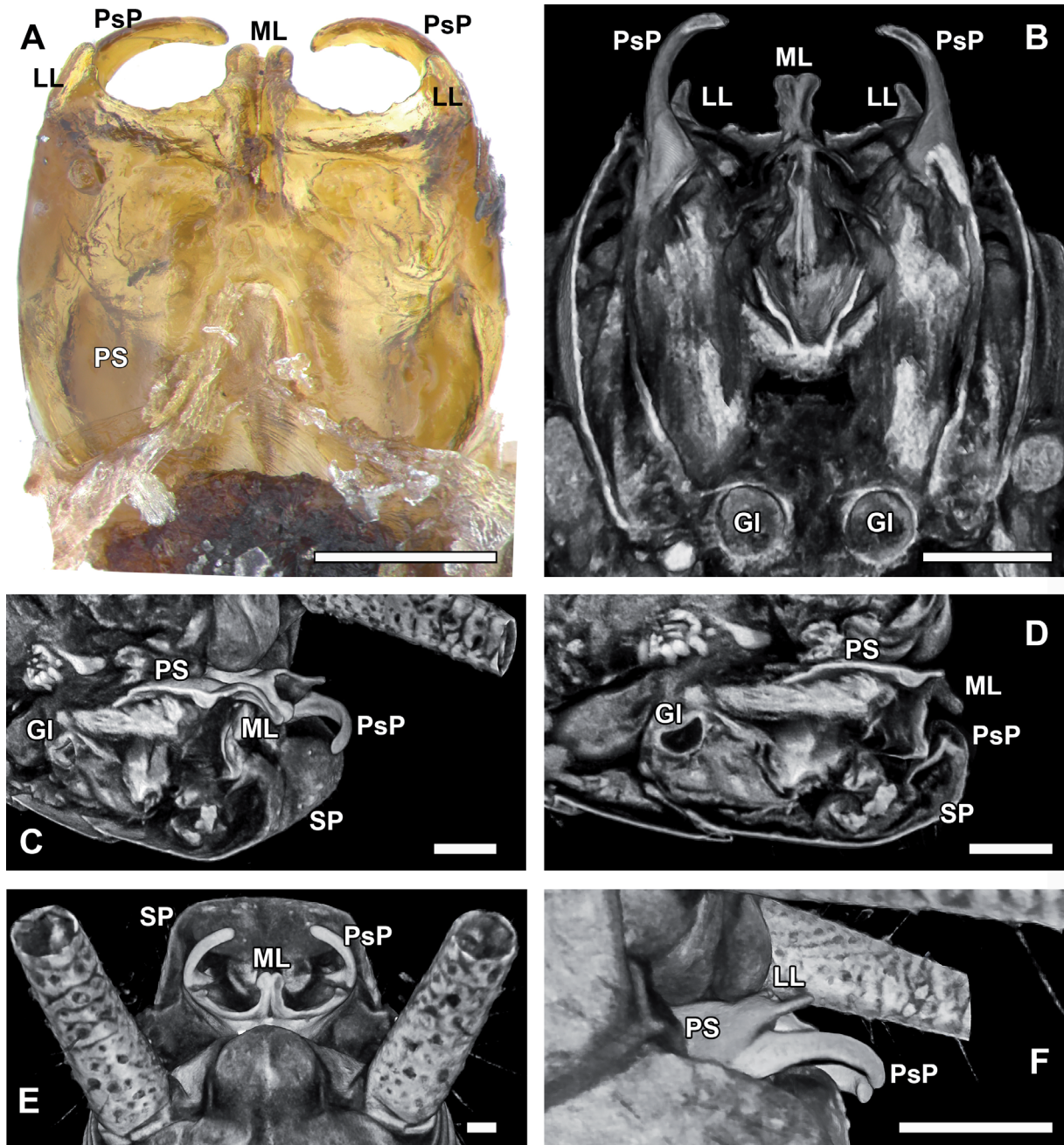
**Fig. 17.** *Austronemobius chelatus* gen. et sp. nov., holotype, adult ♂, Heaphy River, Kahurangi National Park (NZAC 03037179), dorsal view. Scale bar = 2 mm.



**Fig. 18.** *Austronemobius chelatus* gen. et sp. nov. **A–B.** Lateral and frontal views of head, adult ♂. **A.** Heaphy River, Kahurangi National Park (NZAC03037182). **B.** Lake Christabel (MPN OR0188). **C.** Dorsal view of pronotum, adult ♂. Heaphy River (NZAC 03037179). **D–F.** External male terminalia. **D.** Dorsal view, with pseudepiphallic parameres (PsP) open (NZAC 03037179). **E.** Dorsal view, with pseudepiphallic parameres (PsP) closed (NZAC03037182). **F.** Ventral view. Heaphy River (NZAC 03037179). **G.** Egg. Heaphy River (NZAC03037186). **H.** Apex of ovipositor, dorsal view. Heaphy River (NZAC03037183). **I.** Ovipositor, lateral view. Heaphy River (NZAC03037184). Scale bars = 500 µm.



HEAD (Fig. 18A–B). Width and height subequal in frontal view. Compound eyes large and bulging; measuring half of head height in their longest dimension. Ocelli present. Head colour a dark chestnut brown throughout, except for pale labrum and pale patches either side of rostrum. Stout bristles on vertex and on frons above and on sides of rostrum. Soft, pale setae around upper and lateral edges of



**Fig. 19.** *Austronemobius chelatus* gen. et sp. nov., ♂ genitalia. **A.** Microscope image of pseudepiphallic sclerite, dorsal view. Heaphy River, Kahurangi National Park (NZAC 03037182). **B–F.** Micro CT scans. St Arnaud, Nelson Lakes National Park (MPN OR0190). **B.** Ventral view. **C.** Longitudinal cross section, posterior-lateral view (45° angle). **D.** Longitudinal cross section, lateral view. **E.** Exterior, dorsal view. **F.** Exterior lateral view. Scale bars = 500 µm.

labrum. Antennae: scapes yellow, flagelli pale brown. Maxillari palps pale and sparsely hairy, except for terminal segment, which is dark brown and covered in short, dense hairs.

THORAX (Fig. 18C). Pronotum 25% wider than long, widest at centre, narrowest at anterior and posterior edges. Colour uniform chestnut brown. Cuticle heavily textured, with three smooth protuberances either side of median line. Strong bristles on lateral lobes and on anterior and posterior edges.

WINGS. Forewings and hindwings absent.

LEGS. Fore and middle legs uniform yellow-brown; posterior legs variegated pale and brown. Femur I with sparse, strong bristles. Tibia I only with sparse bristles on dorsal and ventral surfaces; bearing two ventral spurs at apex, posterior spur only one third of length of anterior one. Auditory tympana absent. Tarsomere I-1 bearing two rows of short spinules ventrally. Femur II and Tibia II each with three pairs of strong bristles dorsally, one to two pairs ventrally. Tibia II bearing two long spurs at apex, subequal in length. Tarsomere II-1 bearing two rows of short spinules ventrally. Femur III glabrous and mostly of uniform colour inside; covered in hair outside, especially on dorsal surface. Femur III outer surface alternating yellow and brown diagonal stripes in proximal half; uniform brown in distal half. Tibia III armed with three pairs of subapical spurs dorsally, alternate. All apical and subapical spurs pale at base and at apex, brown in between; glabrous. Tibia III inner apical spurs 2 and 3 each covered by a row of setae facing one another, giving these spurs a feathered look. Length of outer ventral apical spur on Tibia III 85% to 90% of inner ventral apical spur length. Length of outer apical spur on Tarsomere III-1 80% of inner apical spur length.

ABDOMEN (Fig. 17). Uniform chestnut brown in colour, except for some very faint pale markings on lateral edges of dorsal surface. Dorsum covered in sparse, thin tomentum throughout.

MALE TERMINALIA (Figs 18D–F, 19). Subgenital plate trapezoidal, covered in long, sparse tomentum. Median lobe of pseudepiphallic sclerite protruding beyond suranal plate; visible in dorsal view. Pseudepiphallic parameres articulated, modified for clasping, protruding beyond posterior edge of subgenital plate and visible in dorsal and in ventral view.

FEMALE TERMINALIA (Fig. 18H–I). Subgenital plate trapezoidal. Ovipositor 40% to 50% of body length; enlarged near apex. Lateral valves dotted with numerous small tubercles at apex.

EGGS (Fig. 18G). Yellow; approx. 2 mm long and 550 µm wide.

### Distribution

The species is only known from native forests in the north-west of New Zealand's South Island, from sea level to tree-line, and from Mt Ruapehu in the central North Island (Fig. 38D). No other forest crickets are known in these regions.

Genus *Mutonemobius* gen. nov.

urn:lsid:zoobank.org:act:2B391E11-9118-4190-98BF-162B69795392

### Type species

*Mutonemobius marmoratus* gen. et sp. nov.

### Etymology

From the Latin 'mūtus' (adj.), 'mute', 'silent'; *Mutonemobius* means 'silent *Nemobius*'. *Mutonemobius* is male gender.

### Diagnosis

Large-sized Nemobiinae, with body length between 7 and 9 mm. Forewings vestigial only, identical in both sexes, lacking stridulatory apparatus in males; hindwings and tympana absent. Head large and bulbous; eyes not bulging. Tibia III in both sexes with four subapical spurs on inner edge and three or four subapical spurs on outer edge. Length of outer ventral apical spur on Tibia III approx. 80% to 85% that of inner ventral apical spur. Outer apical spur on Tarsomere III-1 approx. 70% that of inner apical spur. Male genitalia as in Fig. 21. Ovipositor smooth, slender, with lateral valves divaricating at apex.

### Habitat and ecology

Nocturnal, *Mutonemobius* crickets live in leaf litter in forest habitat and in tall, damp grass, where they can locally reach very high population densities.

#### *Mutonemobius marmoratus* gen. et sp. nov.

urn:lsid:zoobank.org:act:6F5B2451-C29A-4EFB-8CCC-6718DB8571F9

Figs 20–21, 22C–D, 38G

### Diagnosis

Refer to the above diagnosis for the genus.

### Etymology

‘*Marmörātus*’ (adj.) is Latin for ‘marbled’, because of the colour pattern on the cricket’s dorsal parts.

### Material examined (see also Supp. file 1: Table S5)

#### Holotype

NEW ZEALAND • ♂, adult; Waikato (WO), Manganui Road, Awakino; 38.61659° S, 174.67720° E; 50 m a.s.l.; 29 Mar. 2022; D. Hegg leg.; in tall grass on road verge; trowel and jar; NZAC 03036039.

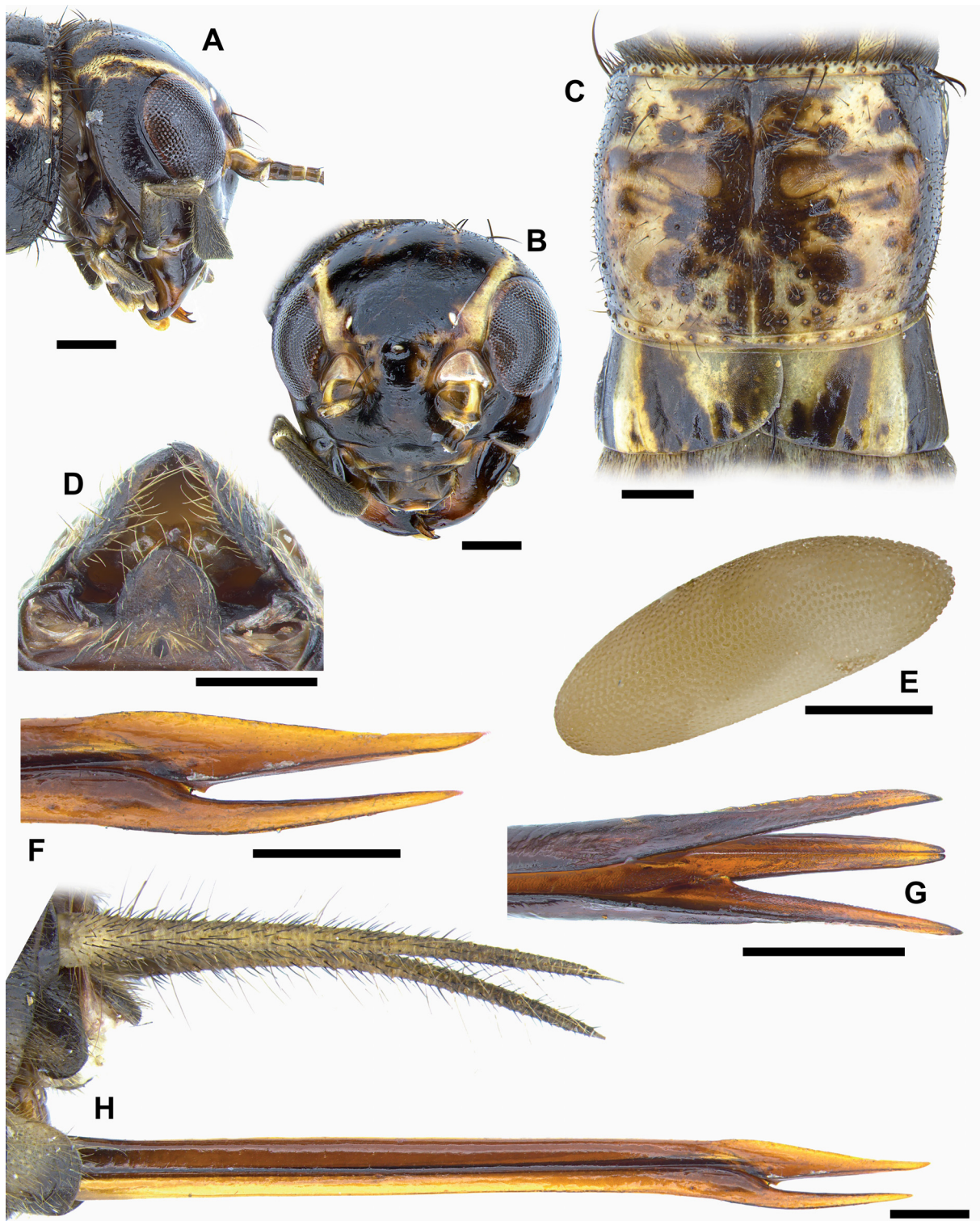
#### Paratypes

NEW ZEALAND • 1 ♀, adult; Taranaki (TK), Araheke Stream, New Plymouth; 39.10385° S, 174.11622° E; 80 m a.s.l.; 4 Apr. 2023; D. Hegg leg.; on footpath; jar; NZAC 03036040 • 4 ♂♂, 9 ♀♀; same data as for holotype; NZAC 03036041 to NZAC 03036053.

#### Other material

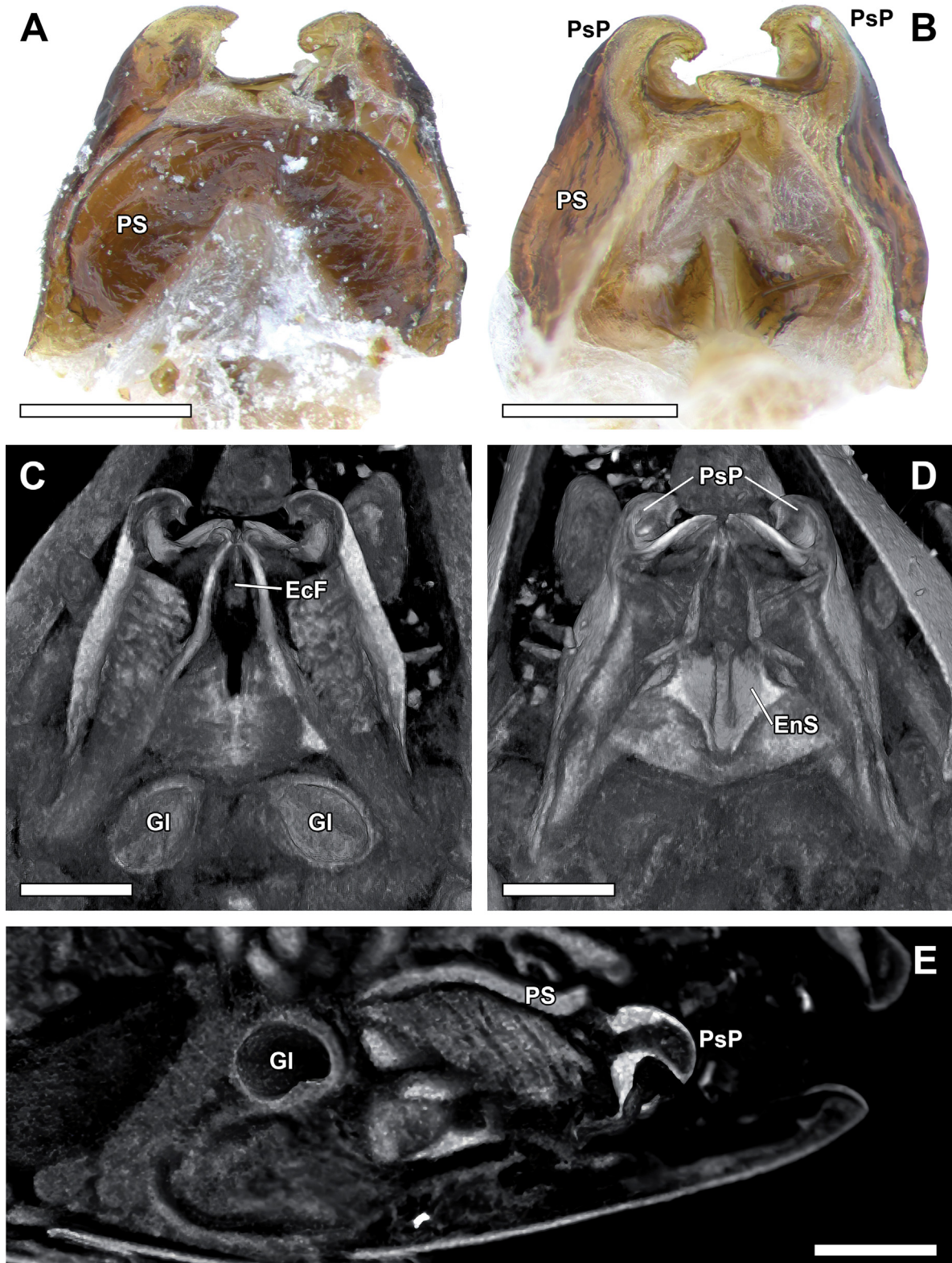
NEW ZEALAND – **Taranaki (TK)** • 1 ♀; Dawson Falls, Taranaki Mouna; 39.31854° S, 174.09918° E; 960 m a.s.l.; 18 Feb. 2023; E. Roberts leg.; on forest floor; photograph only; iNaturalist 149086855 • 1 ♀; Pukeiti, Taranaki Mouna; 39.19956° S, 173.97880° E; 380 m a.s.l.; 28 Apr. 2023; E. Roberts leg.; on forest floor; photograph only; iNaturalist 157080123 • 1 ♀; Pukeiti, Taranaki Mouna; 39.20146° S, 173.98211° E; 400 m a.s.l.; 29 Jan. 2023; A. Gray leg.; on forest floor; photograph only; iNaturalist 147681550 • 1 ♀; Araheke Stream, New Plymouth; 39.10385° S, 174.11622° E; 80 m a.s.l.; 29 Mar. 2023; D. Hegg leg.; in tall grass; trowel and jar; MPN OR0259 • 2 ♂♂, 5 ♀♀; same data as for preceding; 4 Apr. 2023; MPN OR0260 to OR0266 • 4 ♂♂, 2 ♀♀; same data as for preceding; 19 Mar. 2024; MPN OR0318 to OR0323. – **Waikato (WO)** • 2 ♂♂, 1 ♀; Mangatoa Saddle; 38.41638° S, 174.72193° E; 300 m a.s.l.; 22 Mar. 2024; D. Hegg leg.; dry dirt in car park; trowel and jar; MPN OR0337 to OR0339. – **Rangitikei (RI)** • 1 ♀; Matemateaonga; 39.42344° S, 174.65279° E; 450 m a.s.l.; 9 Sep. 2023; A. Gray leg.; on forest floor; photograph only; iNaturalist 182907207. – **Taupō (TO)** • 1 ♀; Pukawa Bay, Lake Taupō; 38.92056° S, 175.74662° E; 460 m a.s.l.; 15 Aug. 2023; S. Mae leg.; on forest floor; photograph only; iNaturalist 180997201. – **Bay of Plenty (BP)** • 1 ♂; Lake Rotokawa, Rotorua; 38.11320° S, 176.32150° E; 280 m a.s.l.; 11 May 2022; D. Holland leg.; grassland; photograph only; iNaturalist 116515690.





**Fig. 20.** *Mutonemobius marmoratus* gen. et sp. nov. **A–B.** Lateral and frontal views of head, adult ♀. Araheke Stream, New Plymouth (NZAC03036040). **C.** Dorsal view of pronotum and forewings, adult ♀. Manganui Road, Awakino (NZAC03036051). **D.** Male genitalia, dorsal view, exterior (NZAC03036039). **E.** Egg. Araheke Stream, New Plymouth (MPN OR0322). **F–G.** Apex of ovipositor. Araheke Stream, New Plymouth. **F.** Lateral view (NZAC03036040). **G.** Dorsal view (MPN OR0265). **H.** Ovipositor, lateral view. Araheke Stream, New Plymouth (NZAC03036040). Scale bars = 500 µm.





**Fig. 21.** *Mutonemobius marmoratus* gen. et sp. nov., ♂ genitalia. Araheke Stream, New Plymouth. A–B. Microscope images of pseudepiphallic sclerite (MPN OR0266). A. Dorsal view. B. Ventral view. C–E. Micro CT scans (MPN OR0318). C–D. Cross-section, dorsal view, Volume Blending. E. Lateral view, Maximum Intensity Projection (MIP). Scale bars = 250  $\mu$ m.



## Description

MEASUREMENTS. See Table 4. Females are larger than males.

HEAD (Fig. 20A–B). Rounded, bulbous, approximately 10% taller than wide in frontal view. Compound eyes measuring one third of head height in their longest dimension, black. Ocelli present, white. Head colour a very dark brown/black throughout, except for very conspicuous pale stripes arching over compound eyes from anterior margin of pronotum to scapes of antennae, and for faint pale patches either side of rostrum and along edges of labrum and clypeus. Head mostly glabrous, smooth and shiny, except for few stout bristles on vertex and on frons on sides of rostrum. Antennae: scapes with longitudinal brown and yellow stripes; flagelli pale brown. Labial and maxillari palps uniform dark brown and sparsely hairy; terminal segment of maxillary palps covered in short, dense hairs.

THORAX (Fig. 20C). Pronotum 25% wider than long, widest at centre, narrowest at anterior and posterior edges. Colour marbled yellow and dark brown. Cuticle smooth, with sparse, short hairs, barely noticeable. Strong bristles on lateral lobes and on anterior and posterior edges.

WINGS (Fig. 20C). Forewings present, vestigial only, almost twice as wide as long; identical in males and females, lacking stridulatory apparatus in males. With longitudinal veins only; colour alternating yellow and dark brown longitudinal stripes. Hindwings always absent.



**Fig. 22.** Live silent Nemobiinae Saussure, 1877. **A–B.** *Austronemobius chelatus* gen. et sp. nov., photographed in its natural environment. **A.** Adult ♂, Heaphy River, Kahurangi National Park. **B.** Adult ♀, Lake Christabel. **C–D.** *Mutonemobius marmoratus* gen. et sp. nov., Awakino, Waikato. Photographed in captivity on unnatural background. **C.** Adult ♂. **D.** Adult ♀.

**LEGS.** Fore and middle legs banded yellow and brown; with sparse strong bristles on all sides. Posterior legs variegated pale and brown. Tibia I with two ventral spurs at apex, subequal in length. Auditory tympana absent. Tarsomere I-1 bearing two rows of short spinules ventrally. Tibia II armed with three long spurs at apex, subequal in length; two ventral and one dorsal on posterior side. Tarsomere II-1 bearing two rows of short spinules ventrally. Femur III glabrous and of variegated colour inside; covered in hair outside, especially on dorsal surface. Femur III outer surface marked by a longitudinal line along its whole length, parallel to lower edge, about  $\frac{1}{3}$  from femur lower edge and  $\frac{2}{3}$  from upper edge. Area above longitudinal line marked with alternating yellow and brown diagonal stripes; area below longitudinal line with diagonal stripes only in proximal half, variegated pale and brown in distal half. Tibia III armed with four subapical dorsal spurs on inner edge, three subapical dorsal spurs on outer edge, although one out of seven individuals have four subapical spurs on outer edge also, in both sexes. All apical and subapical spurs pale at base and at apex, brown in between; covered with short hairs. Length of outer ventral apical spur on Tibia III 80% to 85% that of inner ventral apical spur. Length of outer apical spur on Tarsomere III-1 70% that of inner apical spur.

**ABDOMEN** (Fig. 22C–D). Marbled yellow and brown. Dorsum covered in relatively dense, thin tomentum throughout.

**MALE TERMINALIA.** Subgenital plate trapezoidal, with sparse hairs, curled upwards and wrapped around genitalia. Suranal plate with a petal-shaped lobe projecting backwards from posterior margin and covering genitalia from above (Fig. 20D). Internal genitalia internal as in Fig. 21.

**FEMALE TERMINALIA** (Fig. 20F–H). Subgenital plate small, trapezoidal. Ovipositor 60% of body length; straight and slender; smooth throughout. Lateral valves divaricating at apex.

**EGGS** (Fig. 20E). Brown; approx. 1.5 mm long and 600  $\mu\text{m}$  wide.

### **Distribution**

The species is only known from native forests in the central western North Island of New Zealand (Fig. 38G), from sea level to near tree-line.

Tribe Pteronemobiini Vickery, 1973

Genus *Pteronemobius* Jacobson, 1904

*Pteronemobius* Jacobson in Jacobson & Bianchi, 1904: 450.

*Pteronemobius* – Otte & Alexander 1983: 164–167, figs 124–125, table 10. — Rentz & Su 2019: 335–336, table 9.

### **Type species**

*Pteronemobius heydenii tartarus* (Saussure, 1874) by designation.

### **Etymology**

From the Ancient Greek πτερόν ('pterón'), 'wing'. *Pteronemobius* means 'winged *Nemobius*'. In contrast to the wingless genus *Nemobius* Serville, 1838, *Pteronemobius* often have hindwings and are able to fly. *Pteronemobius* is male gender. Ground crickets in this genus are often referred to as 'common pygmy crickets' in English.

### Diagnosis

Highly variable in size, from small to relatively large ground crickets, with a body length between 4 mm and 9 mm depending on species; coloration variegated light to dark brown. Forewings fully developed in both sexes and exceeding the combined length of head and pronotum. Twenty-five to forty percent of females have short forewings (Fig. 28B, F); 20% to 25% have long forewings (Fig. 28C, E). Hindwings are present in up to 40% of individuals in both sexes (Fig. 28C, F). Stridulatory apparatus complete. Tympana present on posterior side of Tibia I. Tibia III with three or four outer and four inner subapical spurs in both sexes, alternate. The fourth inner subapical spur in males is small, glandular (Figs 23C, 25C). Length of Tibia III outer ventral apical spur approx. 80% that of ventral inner apical spur. Length of Tarsomere III-1 outer apical spur approx. 50% to 60% that of inner apical spur.

### Measurements

See Table 6. No sexual dimorphism in body length.

For a detailed description of this genus in the Australian region, see Otte & Alexander (1983: 164–167); Rentz & Su (2019: 335–336).

### Habitat and ecology

Primarily nocturnal singers, may start singing in the late afternoon or evening on overcast days. Most commonly found next to water, or in saturated meadows.

### Distribution

In New Zealand, primarily in North Island, but range expanding; *Pteronemobius truncatus* was first recorded in the northern South Island in March 2023 (iNaturalist 152116367). Not a New Zealand native genus; both species are recent introductions from Australia. Also found on Norfolk Island; possibly in New Caledonia.

### Remarks

The genus *Pteronemobius* currently includes 104 species spread across all continents except for Antarctica (Cigliano *et al.* 2023). The type species is *Pteronemobius heydenii tartarus* (Saussure, 1874), from the regions surrounding the Caspian Sea. Chopard (1951) moved the Australian species *Nemobius truncatus* Saussure, 1877 to *Pteronemobius* based on the presence of a glandular subapical spur (tsai4) on the inner edge of Tibia III in males. Vickery (1973) defined the tribe Pteronemobiini based on the same character and noted that “many species which still remain in *Pteronemobius* (sensu Chopard) should be studied”, and that “*Pteronemobius* (sensu Chopard) is a heterogeneous assemblage, according to current morphological and cytological information”. Nonetheless, Otte & Alexander (1983) and Rentz & Su (2019) kept the Australian species in *Pteronemobius*; the former in fact added several species to the genus. Desutter-Grandcolas (2016) designated the new genus *Caledonina* from New Caledonia, which also has a glandular subapical spur on Tibia III in males, but placed it in the tribe Nemobiini based on molecular data, noting that her data “validate the occurrence of species with a tibial gland in males within the Nemobiini, a character used up to now to separate Pteronemobiini”. Indeed, the male genitalia of *Caledonina chopardi* Desutter-Grandcolas, 2016 strongly resemble those of the Australian species *Pteronemobius regulus* (Saussure, 1877) (compare Desutter-Grandcolas 2016: fig. 9f–h with Otte & Alexander 1983: fig. 130j). Based on this information, I believe the two species included here in *Pteronemobius* may not belong to this genus at all and could even be placed in the wrong tribe. It is, however, outside of the scope of this work to resolve the wider systematics of Nemobiinae from the Australian region. The brief diagnosis for *Pteronemobius* given here is based on Rentz & Su (2019), is valid for species of *Pteronemobius* in the Australian region, and may not apply to *Pteronemobius* s. str.

**Table 6** (continued on next page). Adult male and female measurements in the New Zealand species of *Pteronemobius* Jacobson, 1904. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Pteronemobius truncatus</i> (Saussure, 1877)		<i>Pteronemobius cf. arima</i> Otte & Alexander, 1983	
	male	female	male	female
Body length (mm)	7.5 (6.8–8.8) <i>N</i> = 10	7.8 (6.7–8.2) <i>N</i> = 20	5.0 (4.3–6.0) <i>N</i> = 15	5.6 (4.2–6.4) <i>N</i> = 21
Pronotum width (mm)	2.4 (2.1–2.6) <i>N</i> = 10	2.4 (2.1–2.6) <i>N</i> = 21	1.7 (1.3–1.9) <i>N</i> = 16	1.6 (1.4–1.7) <i>N</i> = 20
Pronotum length (mm)	1.3 (1.1–1.6) <i>N</i> = 10	1.4 (1.1–1.7) <i>N</i> = 21	1.0 (0.9–1.1) <i>N</i> = 16	1.1 (0.9–1.3) <i>N</i> = 20
Femur III length (mm)	5.1 (4.7–5.4) <i>N</i> = 10	5.1 (4.9–5.6) <i>N</i> = 21	3.5 (3.1–4.1) <i>N</i> = 16	3.8 (3.0–4.1) <i>N</i> = 21
Tibia III length (mm)	3.7 (3.2–3.9) <i>N</i> = 10	3.8 (3.4–4.2) <i>N</i> = 21	2.5 (2.2–2.9) <i>N</i> = 16	2.7 (2.4–3.1) <i>N</i> = 20
Number of subapical spurs on TIII inner	4	4	4	3
Number of subapical spurs on TIII outer	4	4	3	3
Ovipositor length (mm)	–	3.1 (2.9–3.4) <i>N</i> = 21	–	2.6 (2.1–2.9) <i>N</i> = 21
OL / BL	–	0.40 (0.38–0.49) <i>N</i> = 20	–	0.47 (0.38–0.51) <i>N</i> = 21
Wing morphs	Short FW	–	5	–
	Long FW	7	4	12
	Fully winged	3	10	4
FWW (mm)	2.1 (1.9–2.5) <i>N</i> = 10	1.5 (1.3–1.8) <i>N</i> = 19	1.5 (1.2–1.6) <i>N</i> = 16	1.1 (0.9–1.6) <i>N</i> = 21
FWL (mm)	4.7 (3.9–5.2) <i>N</i> = 10	Short 3.1 (2.9–3.5) Long 5.2 (4.8–5.4)	2.7 (2.2–3.3) <i>N</i> = 16	Short 1.9 (1.4–2.5) Long 3.3 (3.0–3.7)
HWL (mm)	11.4 (10.6–11.8) <i>N</i> = 3	11.3 (10.6–11.8) <i>N</i> = 10	8.1 (7.7–8.5) <i>N</i> = 4	8.0 (7.6–8.5) <i>N</i> = 8
PCSD / PCLD	0.649 (0.610–0.694) <i>N</i> = 10	–	0.723 (0.665–0.796) <i>N</i> = 14	–
ST	103 (97–110) <i>N</i> = 10	–	100 (76–128) <i>N</i> = 16	–
SFL (µm)	884 (775–957) <i>N</i> = 10	–	712 (548–794) <i>N</i> = 16	–
tmao / tmai	0.57 (0.48–0.59) <i>N</i> = 10	0.58 (0.50–0.66) <i>N</i> = 18	0.55 (0.50–0.71) <i>N</i> = 16	0.55 (0.50–0.75) <i>N</i> = 20
tao1 / tail	0.82 (0.76–1.00) <i>N</i> = 10	0.79 (0.65–0.95) <i>N</i> = 19	0.79 (0.65–0.93) <i>N</i> = 16	0.76 (0.64–0.98) <i>N</i> = 20



**Table 6** (continued). Adult male and female measurements in the New Zealand species of *Pteronemobius* Jacobson, 1904. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Pteronemobius truncatus</i> (Saussure, 1877)		<i>Pteronemobius cf. arima</i> Otte & Alexander, 1983	
	male	female	male	female
	Song (20°C)		Song (18°C)	
Peak frequency (kHz)	5.6	–	6.6	–
Pulse duration (ms)	14.7	–	10.0	–
Pulse interval (ms)	5.5	–	14.5	–
Pulse rate (pulses/s)	49.2	–	41.5	–
Chirp duration (s)	0.6–0.7	–	0.1–0.3	–
Chirp interval (s)	1.9–3.3	–	0.4–0.7	–

*Pteronemobius truncatus* (Saussure, 1877)  
Figs 5–7, 8A–B, 23–24, 27A–F, 28A–C, 38E

*Nemobius truncatus* Saussure, 1877: 259.

*Nemobius laparinthae* Tepper, 1896: 378.

*Pteronemobius mjobergi* Chopard, 1925: 9.

*Nemobius larapinthae* [sic] – Kirby 1906: 16.

*Pteronemobius truncatus* – Chopard 1951: 427. — Otte & Alexander 1983: 167–169, figs 124, 128–129, 130a–b, 132b, s. — Baehr 1989: 19. — Messenger 1991: 22. — Hollier *et al.* 2013: 528. — Rentz & Su 2019: 339–340.

### Diagnosis

A medium- to large-sized ground cricket (body length 6 to 9 mm), coloured brown. Legs with four subapical spurs on both inner and outer edge of Tibia III in both males and females; fourth inner subapical spur is glandular in males. Male forewing light brown in colour, shiny; it reflects light like a mirror (Fig. 8A–B); stridulatory file with 97 to 110 teeth. Female forewing has both short (Fig. 28B) and long (Fig. 28C) morphs; individuals with fully developed hindwings are common.

### Etymology

Latin, ‘*truncatus*’ (adj. perf. inf. of ‘*trunco*’) means ‘maimed’, ‘mutilated’. No explanation for the name was given in Saussure (1877).

**Material examined** (see also Supp. file 1: Table S6)

#### Holotype

AUSTRALIA • ♀, adult; 1847; J. Verraux leg.; MNHN EO-ENSIF10379.

### Paratypes

AUSTRALIA • 1 ♀; Queensland, Alice River; E. Mjöberg leg.; MNHN EO-ENSIF10381 • 1 ♂; Queensland, Malanda; E. Mjöberg leg.; MNHN EO-ENSIF10382.

### Other material

NEW ZEALAND – **Nelson (NN)** • 1 ♀; Kaiteriteri, Tasman Bay; 41.04248° S, 173.01902° E; 0 m a.s.l.; 18 Mar. 2023; C. Stephens leg.; on beach; photograph only; iNaturalist 152116367. – **Wanganui (WI)** • 1 ♀; Foxton Beach; 40.46270° S, 175.22160° E; 10 m a.s.l.; 4 May 2019; M. Pélissié leg.; near pond; MPN OR0029 • 1 ♀; Ashhurst; 40.28221° S, 175.74729° E; 100 m a.s.l.; 27 Jan. 2023; G. Smith leg.; in house porch; photograph only; iNaturalist 147712667. – **Taupō (TO)** • 1 ♂; Lake Rotopounamu; 39.02648° S, 175.7308° E; 715 m a.s.l.; 30 Mar. 2019; M. Pélissié leg.; on lake shore; MPN OR0023. – **Taranaki (TK)** • 2 ♂♂, 1 ♀; Bell Block, New Plymouth; 39.02314° S, 174.14505° E; 20 m a.s.l.; 30–31 Mar. 2022; D. Hegg leg.; in lawn near pond; insect net at night; MPN OR0199 to OR0201 • 1 ♀; Awakino Gorge; 38.62087° S, 174.74416° E; 130 m a.s.l.; 19 Mar. 2024; D. Hegg leg.; in lawn; trowel and jar; MPN OR0324. – **Waikato (WO)** • 1 ♀; Manganui Road, Awakino; 38.61659° S, 174.67720° E; 50 m a.s.l.; 29 Mar. 2022; D. Hegg; on grassy road verge; insect net; MPN OR218 • 2 ♀♀; Leitchs Clearing, Herangi Range; 38.43453° S, 174.76800° E; 270 m a.s.l.; 2 Apr. 2022; D. Hegg leg.; in tall grass; trowel and jar; MPN OR0219, OR0220 • 4 ♂♂, 12 ♀♀; Top10 Holiday Park, Cambridge; 37.90592° S, 175.47985° E; 60 m a.s.l.; 13–14 Mar. 2022; D. Hegg leg.; in men’s bathroom; jar; MPN OR0202 to OR0217 • 2 ♂♂, 3 ♀♀; same data as for preceding; 24 Mar. 2024; MPN OR0344 to OR0348 • 1 ♀; Leitchs Hut, Herangi Range; 38.43333° S, 174.77956° E; 250 m a.s.l.; 21 Mar. 2024; D. Hegg leg.; in tall grass; trowel and jar; MPN OR0335 • 1 ♂; Mangatoa Saddle; 38.41638° S, 174.72193° E; 300 m a.s.l.; 22 Mar. 2024; D. Hegg leg.; dry dirt in car park; trowel and jar; MPN OR0336. – **Bay of Plenty (BP)** • 1 ♂, 1 ♀; Hurunui Hut, Kaimai Range; 37.81712° S, 175.92802° E; 540 m a.s.l.; 15–16 Apr. 2023; D. Hegg leg.; next to stream; insect net; MPN iNat OR0221, OR0222. – **Bay of Plenty/Coromandel (BP/CL)** • 1 ♂, 4 ♀♀; Waihi; 37.38992° S, 175.83290° E; 100 m a.s.l.; 25 Mar. 2024; D. Hegg leg.; in lawn; jar; MPN OR0349 to OR0353. – **Coromandel (CL)** • 1 ♀; Coromandel; 36.76166° S, 175.49129° E; 5 m a.s.l.; 6 Apr. 2024; D. Hegg leg.; in lawn; jar; MPN OR0397. – **Auckland (AK)** • 1 ♀; Tahuna Torea Reserve, Auckland; 36.87249° S, 174.88177° E; 0 m a.s.l.; 26 Mar. 2024; D. Hegg leg.; in lawn; jar; MPN OR0354 • 2 ♂♂; Eilerslie Palms Motel, Auckland; 36.89635° S, 174.83458° E; 30 m a.s.l.; 26 Mar. 2024; D. Hegg leg.; in lawn; jar; MPN OR0355, OR0356. – **Northland (ND)** • 1 ♀; Springbank Rd, Kerikeri; 35.24249° S, 173.92505° E; 100 m a.s.l.; 1 Apr. 2024; D. Hegg leg.; in lawn; jar; MPN OR0386 • 3 ♂♂, 4 ♀♀; Kohuroanaki Loop Track, Te Pahi; 34.50864° S, 172.82443° E; 90 m a.s.l.; 4 Dec. 2022; D. Hegg leg.; near water on 4WD track; insect net; MPN OR0191 to OR0198.

### Description

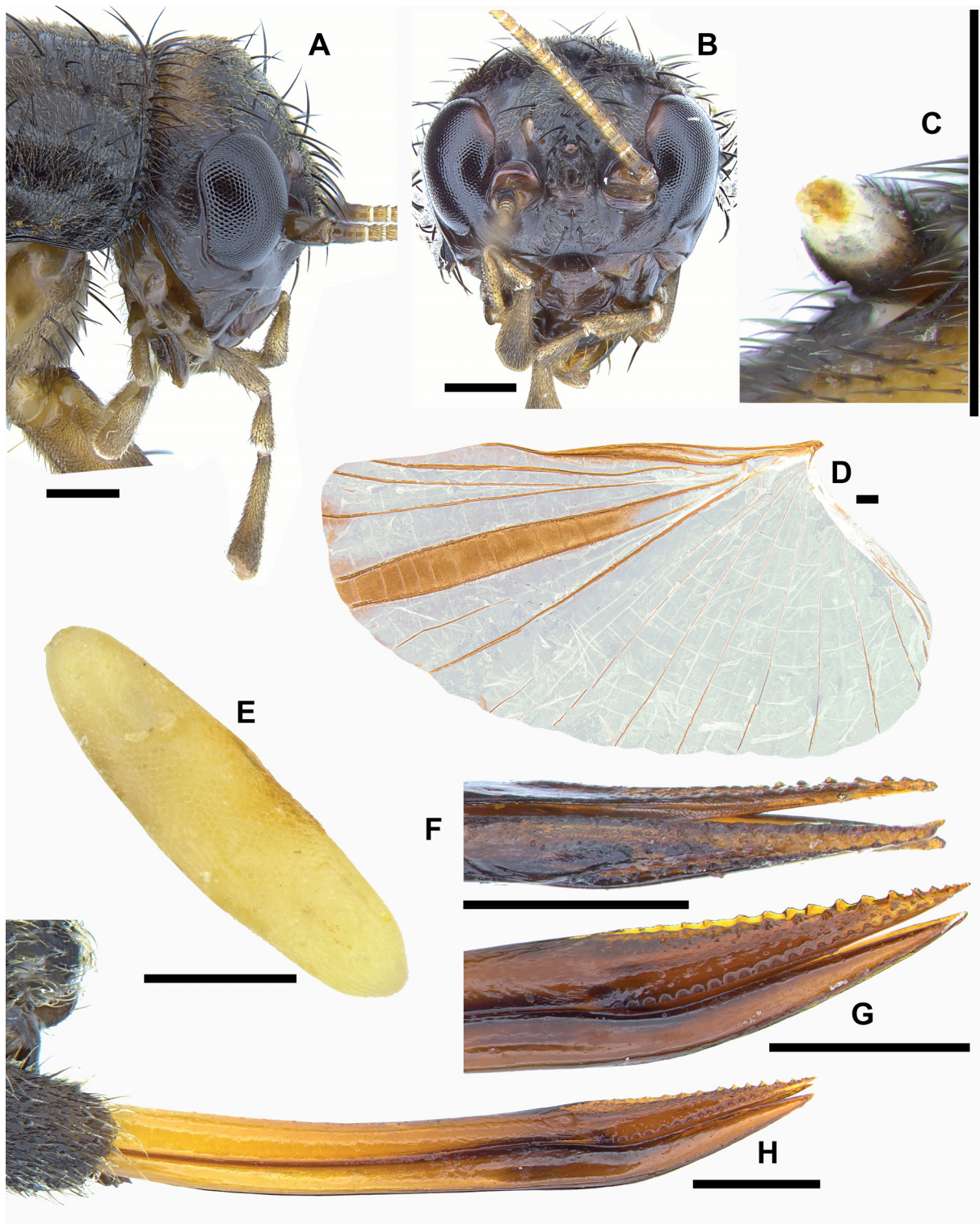
Refer to the detailed description in Otte & Alexander (1983: 167–169). See also Fig. 23 in this work.

MEASUREMENTS. See Table 6, also Figs 6–7. No sexual dimorphism.

SONG. A sequence of thrills with a peak frequency between 5.5 kHz and 7 kHz, each thrill up to one and a half seconds in length; interval between thrills between one and three seconds long (Figs 5, 24; Table 5). See also the detailed description in Otte & Alexander (1983: 167–169).

### Habitat and ecology

*Pteronemobius truncatus* is a nocturnal species, almost always found in the proximity of water, including at the edge of ephemeral puddles and in saturated lawns. Swarms of winged individuals are known to form in late summer (Messenger 1991). *Pteronemobius truncatus* often forms mixed populations with the smaller *Pteronemobius* cf. *arima* and with ground crickets in the genus *Bobilla*, with which it could easily be confused.

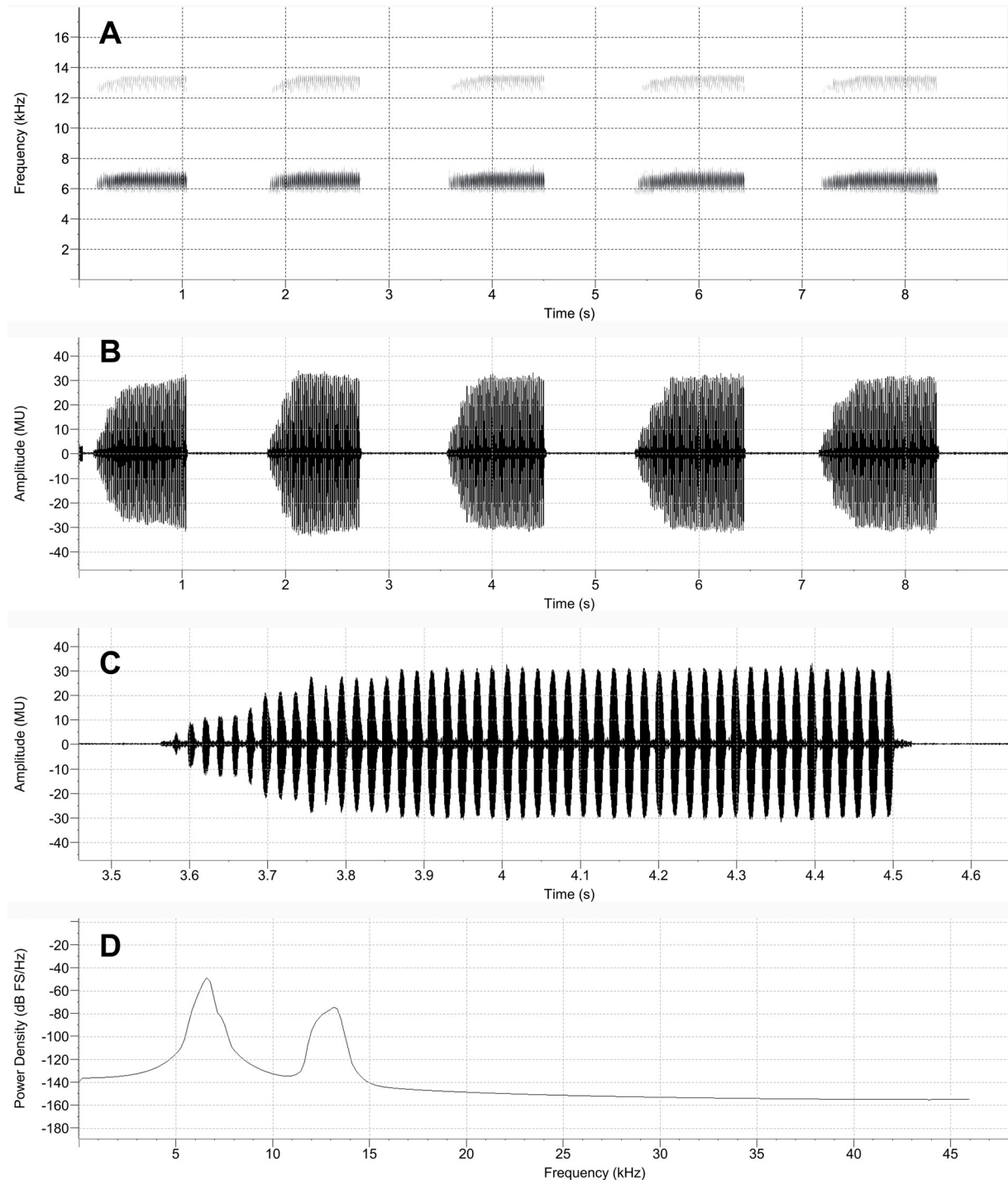


**Fig. 23.** *Pteronemobius truncatus* (Saussure, 1877). **A–B.** Lateral and frontal view of head, adult ♀. Herangi Range (MPN OR0219). **C.** Glandular sub-apical spur (tsai4) on dorsal inner edge of tibia III in adult ♂. Cambridge, Waikato (MPN OR0214). **D.** Left hindwing in female, dorsal view. Cambridge, Waikato (MPN OR0346). **E.** Egg. Coromandel (MPN OR0397). **F–G.** Apex of ovipositor. Herangi Range (MPN OR0219). **F.** Dorsal view. **G.** Lateral view. **H.** Ovipositor, lateral view. Cambridge, Waikato (MPN OR0204). Scale bars = 500 µm.



**Distribution**

Native of Australia, where it is found in all coastal regions, except in the south-west (Rentz & Su 2019). New Zealand: relatively common in much of North Island; recently also found in the Nelson Region, South Island (Fig. 38E). Geographic range expanding southwards.



**Fig. 24.** *Pteronemobius truncatus* (Saussure, 1877) song, recorded in the field at 24°C. Mangonui, Northland. **A.** Spectrogram of a sequence of five thrills. **B.** Oscillogram of a sequence of five thrills. **C.** Oscillogram of one thrill consisting of 48 pulses. **D.** Power spectrum of one thrill.



*Pteronemobius arima* Otte & Alexander, 1983

*Pteronemobius arima* Otte & Alexander, 1983: 427.

*Pteronemobius arima* – Rentz & Su 2019: 343–345.

**Etymology**

After *arima*, ‘reed’. From one of “several small dictionaries covering a number of languages spread across Australia” (D. Otte pers. com. 2023). *Arima* is used as a name in apposition.

**Material examined** (see also Supp. file 1: Table S7)

**Holotype**

AUSTRALIA • ♂, adult; Northern Territory, Holmes Jungle, Palm Creek; 12.39970° S, 130.92743° E; 25 Nov. 1968; D. Otte and R.D. Alexander leg.; moist ground; ANIC 14 008970.

**Other material**

AUSTRALIA • 2 ♂♂; Queensland, Brisbane, Oxley Creek Commons; 27.53566° S, 152.99306° E; 10 m a.s.l.; 17 Nov. 2023; D. Hegg leg.; in short grass; jar; MPN OR0420, OR0421.

**Description**

For a detailed description of *Pteronemobius arima* see Otte & Alexander (1983: 427); Rentz & Su (2019: 343–345).

*Pteronemobius* cf. *arima* Otte & Alexander, 1983

Figs 6–7, 8C–D, 25–26, 27G–L, 28D–F, 38F

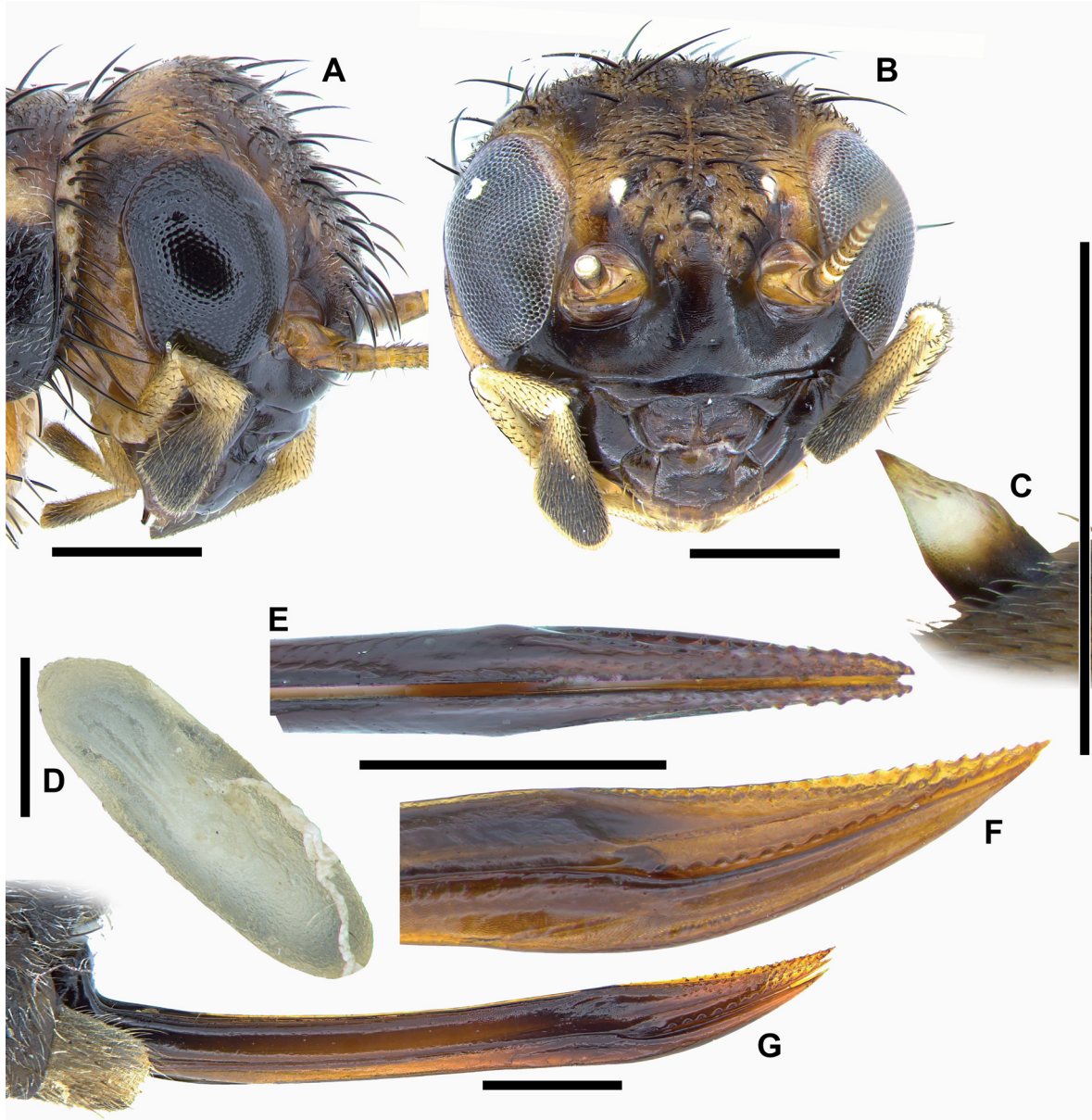
**Diagnosis**

A small ground cricket (body length 4 to 6 mm), coloured brown, with individual variation from light reddish/brown to almost black. Three subapical spurs on outer edge of Tibia III in both males and females; three subapical spurs on inner edge in females, four in males, the fourth spur being glandular. Male forewing dark with a pale stripe running along the edges; upper surface of wing is textured, matt (Fig. 8C–D); stridulatory file with 75 to 130 teeth. Female forewing with both short (Fig. 28F) and long (Fig. 28E) morphs; individuals with fully developed hindwings common.

**Material examined** (see also Supp. file 1: Table S7)

NEW ZEALAND – **Taranaki (TK)** • 1 ♂; Bell Block, New Plymouth; 39.02408° S, 174.14423° E; 20 m a.s.l.; 30 Mar. 2022; D. Hegg leg.; in grass; insect net; MPN OR0249 • 1 ♂; Bell Block, New Plymouth; 39.02314° S, 174.14505° E; 20 m a.s.l.; 31 Mar. 2022; D. Hegg leg.; in grass; insect net; MPN OR0250 • 1 ♂; Awakino Gorge; 38.62087° S, 174.74416° E; 130 m a.s.l.; 19 Mar. 2024; D. Hegg leg.; in lawn; trowel and jar; MPN OR0325. – **Taupō (TO)** • 1 ♂, 2 ♀♀; Taumarunui; 38.88301° S, 175.26033° E; 200 m a.s.l.; 2 Apr. 2022; D. Hegg leg.; in lawn; jar; MPN OR0252 to OR0254. – **Coromandel/Bay of Plenty (CL/BP)** • 1 ♀; Waihi; 37.39444° S, 175.84915° E; 100 m a.s.l.; 12 Apr. 2023; D. Hegg leg.; on footpath; insect net; MPN OR0251. – **Auckland (AK)** • 2 ♂♂, 1 ♀; Avondale Motor Park, Auckland; 36.89795° S, 174.70778° E; 40 m a.s.l.; 28 Mar. 2022; D. Hegg leg.; on sparsely vegetated ground; jar; MPN OR0256 to OR0258. – **Northland (ND)** • 1 ♂; Whangārei; 35.70408° S, 174.3532° E; 100 m a.s.l.; 1 Aug. 2023; D. Hegg leg.; in car park; jar; MPN OR0255 • 1 ♂, 1 ♀; Kerikeri; 35.24029° S, 173.93822° E; 100 m a.s.l.; 22 Mar. 2022; D. Hegg leg.; in tall grass; insect net; MPN OR0223, OR0234 • 5 ♂♂, 10 ♀♀; Kerikeri; 35.22795° S, 173.94853° E; 50 m a.s.l.; 21 Mar. 2022; D. Hegg leg.; on footpath; jar; MPN OR0224 to OR0233, OR0235 to OR0239 • 1 ♂;

Springbank Rd, Kerikeri; 35.24249° S, 173.92505° E; 100 m a.s.l.; 1 Apr. 2024; D. Hegg leg.; in lawn; jar; MPN OR0385 • 1 ♀; Mahinepua Peninsula Track; 34.99595° S, 173.84891° E; 20 m a.s.l.; 30 Apr. 2021; D. Hegg leg.; short grass on walking track; insect net; MPN OR0482 • 4 ♂♂, 4 ♀♀; Maitai Bay, Karikari Peninsula; 34.82342° S, 173.40619° E; 30 m a.s.l.; 5 Dec. 2022; D. Hegg leg.; in grass; trowel and jar; MPN OR0240 to OR0247 • 7 ♂♂, 4 ♀♀; same data as for preceding; 28 Mar. 2024; MPN OR0359 to OR0369 • 1 ♀; Kapowairua campsite, Spirits Bay; 34.42586° S, 172.86203° E; 10 m a.s.l.; 25 Mar. 2022; D. Hegg leg.; in grass; jar; MPN OR0248.

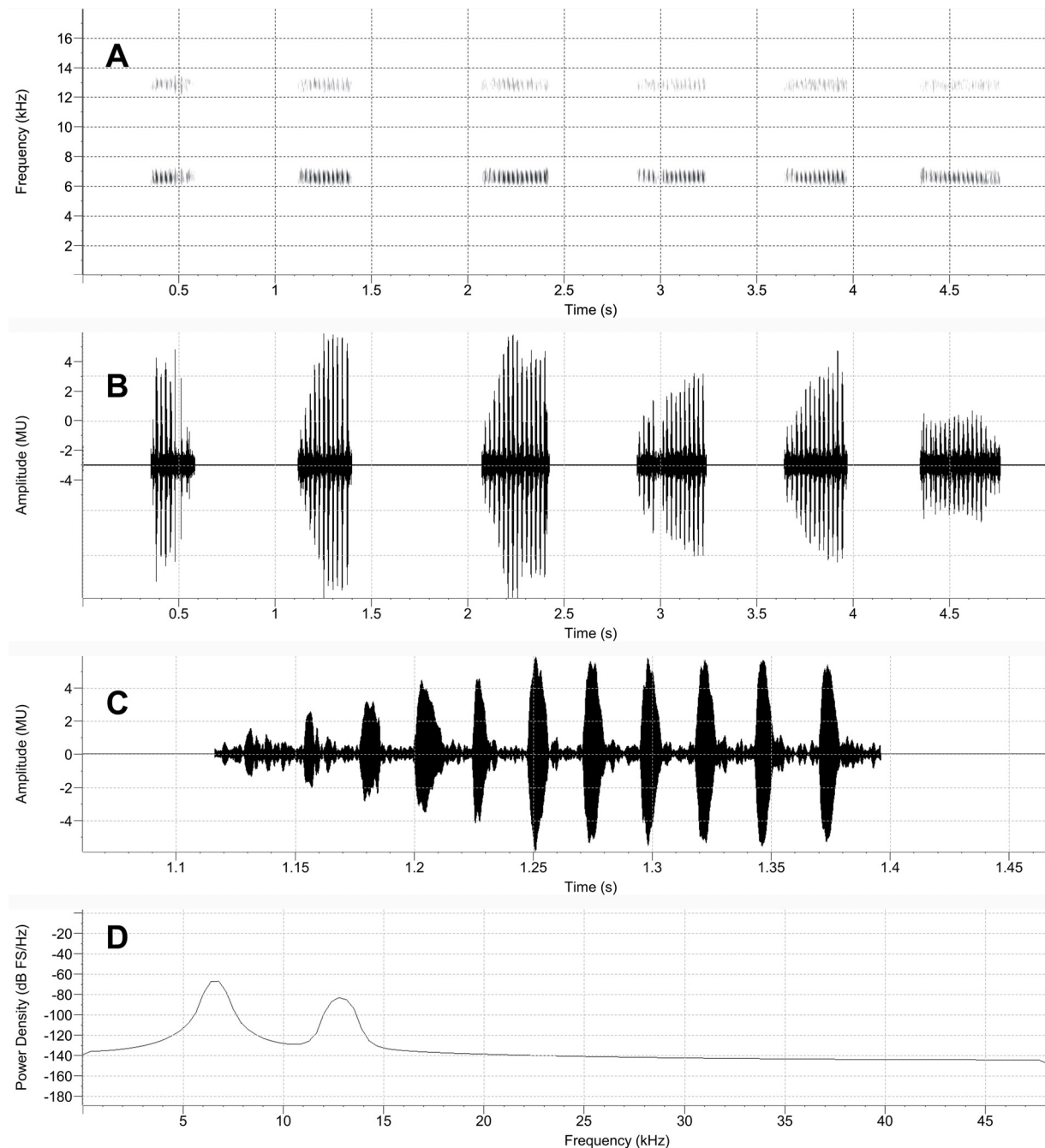


**Fig. 25.** *Pteronemobius cf. arima* Otte & Alexander, 1983. A–B. Lateral and frontal view of head, adult ♀. A. Spirits Bay, Northland (MPN OR0248). B. Kerikeri, Northland (MPN OR0223). C. Glandular sub-apical spur (tsai4) on dorsal inner edge of tibia III in adult ♂. Kerikeri (MPN OR0234). D. Egg. Maitai Bay, Northland (MPN OR0366). E–F. Apex of ovipositor. Spirits Bay (MPN OR0248). E. Dorsal view. F. Lateral view. G. Ovipositor, lateral view. Kerikeri (MPN OR0225). Scale bars = 500 µm.

## Description

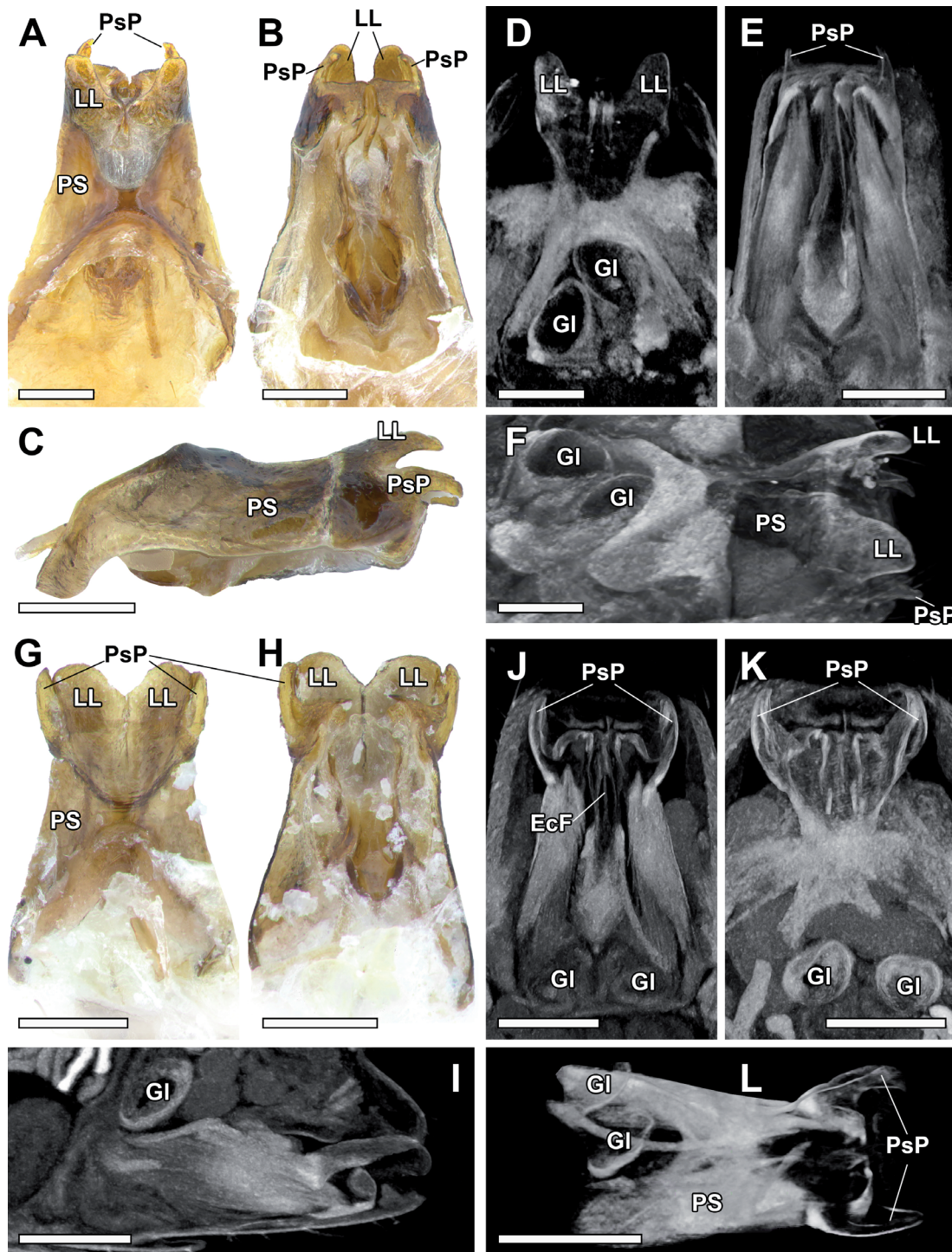
A detailed description of *Pteronemobius* cf. *arima* is not included here, since I am not designating or describing a new species, nor would I know how to differentiate it from *P. arima* proper, assuming it is different at all. Images of the main characters are in Figs 8D, 25 and 27G–L.

MEASUREMENTS. See Table 6, also Figs 6–7. No sexual dimorphism.



**Fig. 26.** *Pteronemobius* cf. *arima* Otte & Alexander, 1983 song, recorded in the field at 18°C. Maitai Bay, Karikari Peninsula. **A.** Spectrogram of a sequence of six chirps. **B.** Oscillogram of a sequence of six chirps. **C.** Oscillogram of one chirp consisting of eleven pulses. **D.** Power spectrum of one chirp.





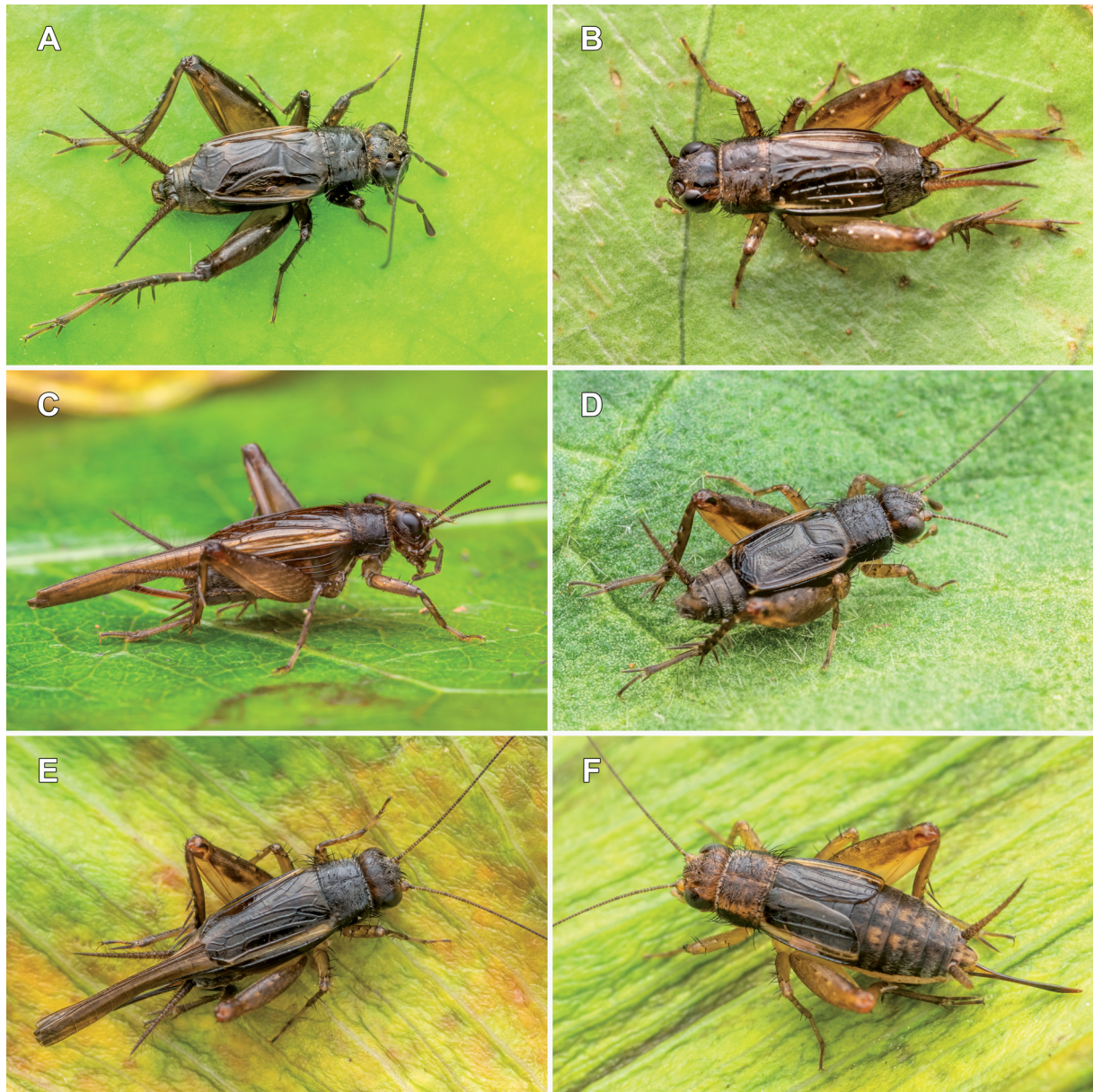
**Fig. 27.** *Pteronemobius* Jacobson, 1904, ♂ genitalia of New Zealand species. **A–F.** *Pteronemobius truncatus* (Saussure, 1877). Cambridge, Waikato. **A–C.** Microscope images of pseudepiphallic sclerite (MPN OR0344). **A.** Dorsal view. **B.** Ventral view. **C.** Lateral view. **D–F.** Micro CT scans, Volume Blending (MPN OR0345). **D.** Dorsal view. **E.** Ventral view, cross-section. **F.** Dorso-lateral view (45° angle). **G–L.** *Pteronemobius* cf. *arima* Otte & Alexander, 1983. Maitai Bay, Northland (MPN OR0359). **G–H.** Microscope images of pseudepiphallic sclerite. **G.** Dorsal view. **H.** Ventral view. **I–L.** Micro CT scans, Volume Blending. Kerikeri, Northland (MPN OR0385). **I.** Lateral view. **J–K.** Dorsal view. **L.** Dorso-lateral view (45° angle). Scale bars = 250 µm.



SONG. A very quiet sequence of chirps, rather like a mere whisper, difficult to record. Peak frequency between 6 kHz and 7 kHz, each chirp approx. 0.2 seconds in length; interval between chirps between 0.4 and 0.7 seconds long. Pulse rate approx. 40 pulses per second. See also Fig. 26 and Table 6.

#### Habitat and ecology

*Pteronemobius* cf. *arima* is a nocturnal species, more tolerant of dry conditions than *P. truncatus*. It inhabits a variety of grassland habitats, including swamp, rank grass, lawns and sports fields.



**Fig. 28.** Live *Pteronemobius* Jacobson, 1904. **A–C.** *Pteronemobius truncatus* (Saussure, 1877). **A.** Adult ♂, Kohuroanaki Loop Track, Te Pahi, Northland. **B.** Adult ♀ with short forewings. Awakino, Waikato. **C.** Fully winged adult ♀. Leitchs Clearing, Herangi Range. **D–F.** *Pteronemobius* cf. *arima* Otte & Alexander, 1983. **D.** Adult ♂, Auckland. **E.** Fully winged adult ♀. Kerikeri, Northland. **F.** Adult ♀ with short forewings. Kerikeri, Northland. Note: all specimens are posed on unnatural backgrounds in captivity.

*Pteronemobius* cf. *arima* often forms mixed populations with the larger *Pteronembius truncatus* and with ground crickets in the genus *Bobilla*, with which it could easily be confused.

### Distribution

Native of Australia, region unknown. New Zealand: relatively common in northern half of North Island (Fig. 38F).

Subfamily Trigonidiinae Saussure, 1874

Tribe **Trigonidiini** Saussure, 1874

### Remarks

Trigonidiinae in the Australian region include a number of genera and subgenera that have been giving taxonomists headaches for decades. To start with, the genus *Trigonidium* was designated with type species *Trigonidium cicindeloides* from Spain, Europe. The subgenus *Trigonidium* (*Trigonidium*) was later proposed by Gorochov (1987). At present, it is doubtful whether all Australian species assigned to *Trigonidium* actually belong in *Trigonidium* sensu stricto at all (Tan *et al.* 2019). Several closely related genera and subgenera were designated based on the presence or absence of auditory tympana on the anterior tibiae and of a stridulatory apparatus in males (Otte & Alexander 1983). Examples are the subgenera *Trigonidium* (*Metioche*), *Trigonidium* (*Balamara*) Otte & Alexander, 1983, *Trigonidium* (*Parametioche*) Otte & Alexander, 1983, and the genus *Trigonidomorpha*. Because acoustic communication has been lost several times independently in crickets, some of these genera are likely to be polyphyletic (Otte & Alexander 1983: 197; Chintauan-Marquier *et al.* 2016; Rentz & Su 2019: 316; Tan *et al.* 2019). To complicate things, different morphs with or without auditory tympana can appear in the same species (Ingrisch 1977; Rentz & Su 2019).

It is outside of the scope of this work to resolve the wider systematics of Trigonidiinae in the Australian region. Based on the strong similarities between *Trigonidium* (*Trigonidium*) *maoricum* and *Trigonidium* (*Trigonidium*) *cicindeloides* and on the analysis of molecular data (Fig. 31), I am confident that *T. maoricum* belongs to the genus *Trigonidium* s. str. The genus *Trigonidomorpha* is synonymised here with *Trigonidium* (*Trigonidium*).

Genus ***Trigonidium*** Rambur, 1838

Subgenus ***Trigonidium*** Rambur, 1838

*Trigonidium* Rambur, 1838: 39.

*Trigonidomorpha* Chopard, 1925: 40 **syn. nov.**

*Trigonidomorpha* – Chopard 1968: 328. — Otte & Alexander 1983: 222. — Desutter-Grandcolas *et al.* 2016: 416. — Tan *et al.* 2019: 577–578. — Rentz & Su 2019: 316.

*Trigonidium* – Otte & Alexander 1983: 225–227, fig. 177, table 15.

*Trigonidium* (*Trigonidium*) – Gorochov 1987: 5–17. — Rentz & Su 2019: 303. — Tan *et al.* 2019: 573–587.

*Trigonidiomorpha* [sic] – Baehr 1989: 20.

*Trigonidium* (*Trigonidomorpha*) – Otte 1994: 46. — Gorochov *et al.* 2018: 317.

### Type species

*Trigonidium cicindeloides* Rambur, 1838 by original monotypy.



### Amended diagnosis

Small trigs, body length <6 mm; body black with yellow legs, or entirely yellow, or in between. Eyes large and bulging, facing forwards. Short stridulum present on right tegmen in males, not used to generate any sound. Adults come in two morphs, wingless and winged. In wingless morph, tegmina rounded in lateral profile, thin, transparent, appressed to the abdomen; hindwings absent. Auditory tympana absent. In winged morph, tegmina thick and coloured yellow-brown; hindwings present, although they might be chewed off or dropped after a few days. Auditory tympana present on both anterior and posterior sides of Tibia I, the anterior tympana larger than the posterior ones. Intermediate morphs (i.e., wingless with reduced tympana, or winged without tympana) possible but rare.

### Etymology

Meaning unknown; not explained by Rambur (1838). *Trigonidium* is neuter gender.

### Measurements

See Table 7.

### Habitat and ecology

Diurnal, predatory crickets; living primarily in meadows with tall grass, although occasionally found in the foliage or on the flowers of shrubs. While the New Zealand species is not known to produce any sound, the European species *Trigonidium (Trigonidium) cicindeloides* generates sound by rubbing the spurs of the last two segments in the maxillary palpi against one another (Ingrisch 1977).

### Distribution

New Zealand, country-wide except for Rakiura/Stewart Island and subantarctic islands. Also Australia, tropical and subtropical Asia, Africa and Europe.

*Trigonidium (Trigonidium) maoricum* (Walker, 1869)  
Figs 29–31, 32A–D, 38A

*Scleropterus maoricus* Walker, 1869: 74–75.

*Scleropterus maoricus* – Hutton 1881: 79.

*Trigonidium maoricum* – Kirby 1906: 78. — Caudell 1927: 22.

*Metioche maorica* – Chopard 1968: 334–335.

### Diagnosis

A small trig (body length 4.5 to 6 mm), with black body and yellow legs. Two morphs in adult insect, without hindwings or auditory tympana, or with hindwings and auditory tympana, as per generic diagnosis.

### Etymology

The Latin adjective *maoricus* refers to the native inhabitants of New Zealand.

### Material examined (see also Supp. file 1: Table S8)

Note: Walker's original type series includes three syntypes. Here, I designate one of these as lectotype, the remaining two as paralectotypes.

### Lectotype

NEW ZEALAND • ♂, adult; NHMUK 014666694.

**Paralectotypes**

NEW ZEALAND • 2 ♀♀; NHMUK 014666695, 014666696.

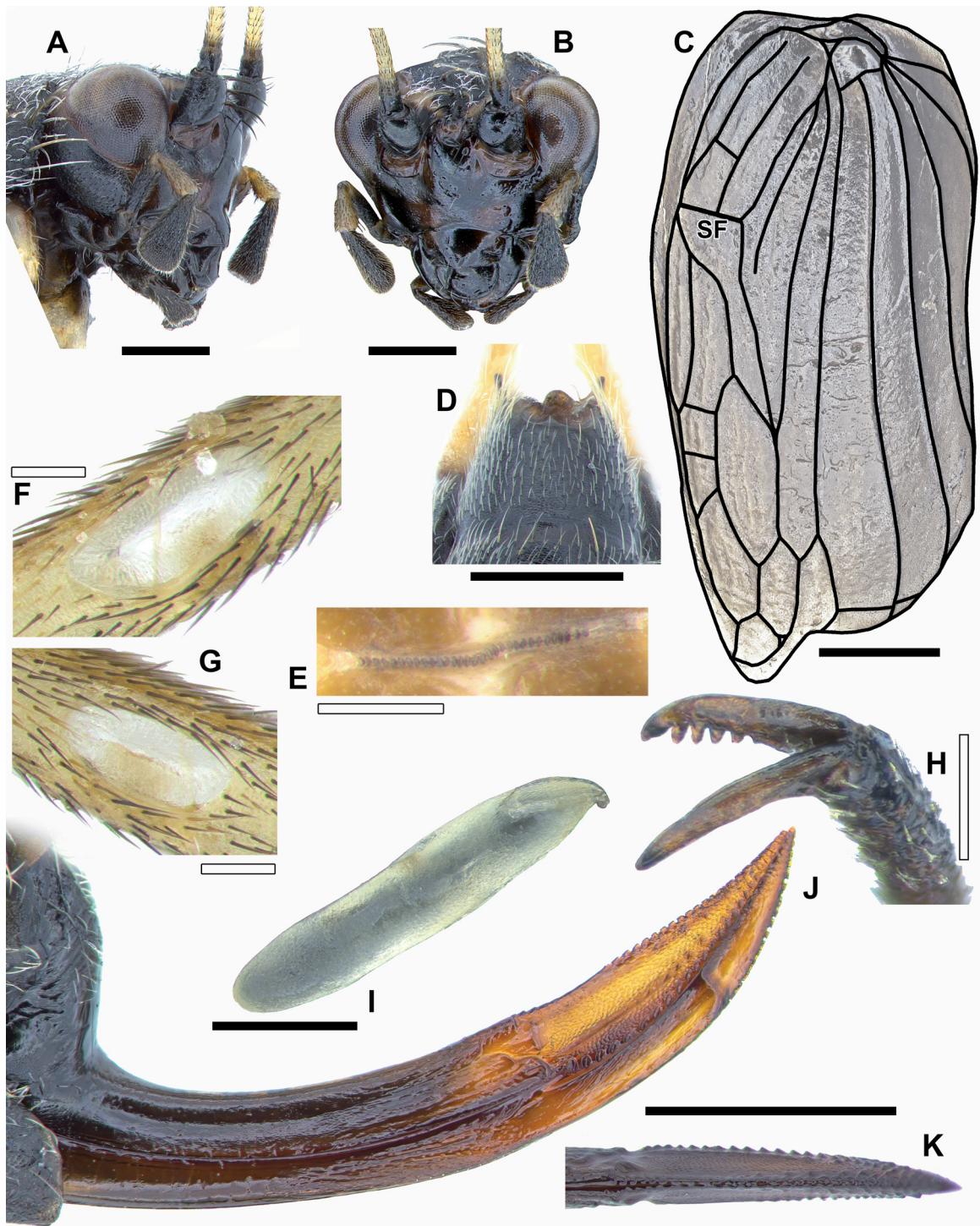
**Other material**

NEW ZEALAND – **Otago Lakes (OL)** • 1 ♂; Glendhu Bay, Lake Wānaka; 44.67430° S, 169.01891° E; 300 m a.s.l.; 11 Apr. 2021; M. Bowie leg.; photograph only; iNaturalist 73602690. – **South Canterbury (SC)** • 1 ♀; Makikihi; 44.62642° S, 171.15641° E; 10 m a.s.l.; 17 Feb. 2024; S. Saito leg.; photograph only; iNaturalist 199549116. – **Mid Canterbury (MC)** • 4 ♀♀; Māhoe Reserve, Lincoln; 43.63415° S, 172.48679° E; 20 m a.s.l.; 25 Oct. 2021; D. Hegg leg.; grassland; insect net; MPN OR0274 to OR0277 • 1 ♂, 1 ♀; Tumbledown Bay, Banks Peninsula; 43.85050° S, 172.77288° E; 10 m a.s.l.; 12 Aug. 2023; D. Hegg leg.; grassland; insect net; MPN OR0267, OR0268 • 2 ♂♂; same data as for preceding; 15 Dec. 2023; MPN OR0269, OR0271 • 1 ♂; same data as for preceding; GenBank: PP761111; MPN OR0270 • 2 ♂♂; same data as for preceding; 14 Jan. 2024; MPN OR0272, OR0273. – **Kaikōura (KA)** • 1 ♀; Oaro; 42.51485° S, 173.50538° E; 40 m a.s.l.; 26 Feb. 2024; J. Stokes leg.; built area; photograph only; iNaturalist 200904066. – **Marlborough Sounds (SD)** • 1 ♀; Picton; 41.28492° S, 174.01132° E; 20 m a.s.l.; 11 Dec. 2018; D. Hegg leg.; on flowering shrubs; photograph only; iNaturalist 33506134. – **Wellington (WN)** • 1 adult; Johnsonville, Wellington; 41.21371° S, 174.80224° E; 200 m a.s.l.; 10 Apr. 2022; B. Wright leg.; built area; photograph only; iNaturalist 111076401. – **Wairarapa (WA)** • 1 ♀; Riversdale Beach; 41.08263° S, 176.06787° E; 20 m a.s.l.; 5 Mar. 2022; L. Bennett; built area; photograph only; iNaturalist 108557205. – **Wanganui (WI)** • 1 ♀; Palmerston North; 40.35795° S, 175.62735° E; 60 m a.s.l.; 26 Mar. 2022; J. Charles leg.; built area; photograph only; iNaturalist 109511014 • 1 ♀; Ashhurst; 40.28196° S, 175.74777° E; 100 m a.s.l.; 15 Mar. 2019; G. Smith leg.; built area; photograph only; iNaturalist 21238691. – **Hawke's Bay (HB)** • 1 ♂, 3 ♀♀; Waimārama Domain; 39.81606° S, 176.99426° E; 10 m a.s.l.; 15 Mar. 2024; D. Hegg leg.; grassland; insect net; MPN OR0328 to OR0331 • 1 ♀; same data as for preceding; GenBank: PP761110; MPN OR0327 • 1 ♀; Te Wainohu Beach, Waimārama; 39.84155° S, 176.99671° E; 10 m a.s.l.; 16 Mar. 2024; D. Hegg leg.; grassland; insect net; GenBank: PP761113; MPN OR0332. – **Taranaki (TK)** • 1 ♀; Awakino Gorge; 38.62087° S, 174.74416° E; 130 m a.s.l.; 19 Mar. 2024; D. Hegg leg.; uncultivated grass; insect net; MPN OR0326. – **Taupō (TO)** • 1 adult; Pukawa Bay, Lake Taupō; 38.937° S, 175.750° E; 460 m a.s.l.; 24 Mar. 2019; D. Clarke; photograph only; iNaturalist 21549888. – **Bay of Plenty (BP)** • 1 ♂; Springfield, Rotorua; 38.15950° S, 176.23428° E; 300 m a.s.l.; 7 Mar. 2022; A. MacArthur leg.; built area; photograph only; iNaturalist 108097615 • 1 ♀; Ōhope, Whakatane; 37.97699° S, 177.07931° E; 10 m a.s.l.; 18 Feb. 2021; K. Steeds leg.; photograph only; iNaturalist 69740141. – **Waikato (WO)** • 1 ♀; Top10 Holiday Park, Cambridge; 37.90602° S, 175.47978° E; 60 m a.s.l.; 24 Mar. 2024; D. Hegg leg.; built area; jar; GenBank: PP761114; MPN OR0342. – **Coromandel (CL)** • 2 ♂♂, 1 ♀; Coromandel; 36.76220° S, 175.49157° E; 5 m a.s.l.; 6 Apr. 2024; D. Hegg leg.; grassland; insect net; MPN OR0394 to OR0396 • 1 ♂; Whitianga; 36.81413° S, 175.69529° E; 10 m a.s.l.; 30 Jan. 2024; C. McCollum leg.; built area; jar; NZAC 03037192. – **Auckland (AK)** • 1 ♂; Point England, Auckland; 36.88352° S, 174.85972° E; 10 m a.s.l.; 27 Feb. 2024; C. Winks leg.; in lighted porch at night; MPN OR0309. – **Northland (ND)** • 4 ♂♂, 5 ♀♀; Kerikeri; 35.24029° S, 173.93822° E; 100 m a.s.l.; 22 Mar. 2022; D. Hegg leg.; grassland; insect net; MPN OR0278 to OR0286 • 3 ♂♂, 2 ♀♀, adult; same data as for preceding; NZAC 03037187 to NZAC 03037191 • 3 ♂♂; Coopers Beach; 34.99248° S, 173.50334° E; 20 m a.s.l.; 30 Mar. 2024; D. Hegg leg.; grassland; insect net; MPN OR0372 to OR0374 • 1 ♂; same data as for preceding; GenBank: PP761112; MPN OR0371 • 1 ♂; Te Pahi; 34.50872° S, 172.82424° E; 90 m a.s.l.; 29 Mar. 2024; D. Hegg leg.; grassland; insect net; MPN OR0370.

**Emended description**

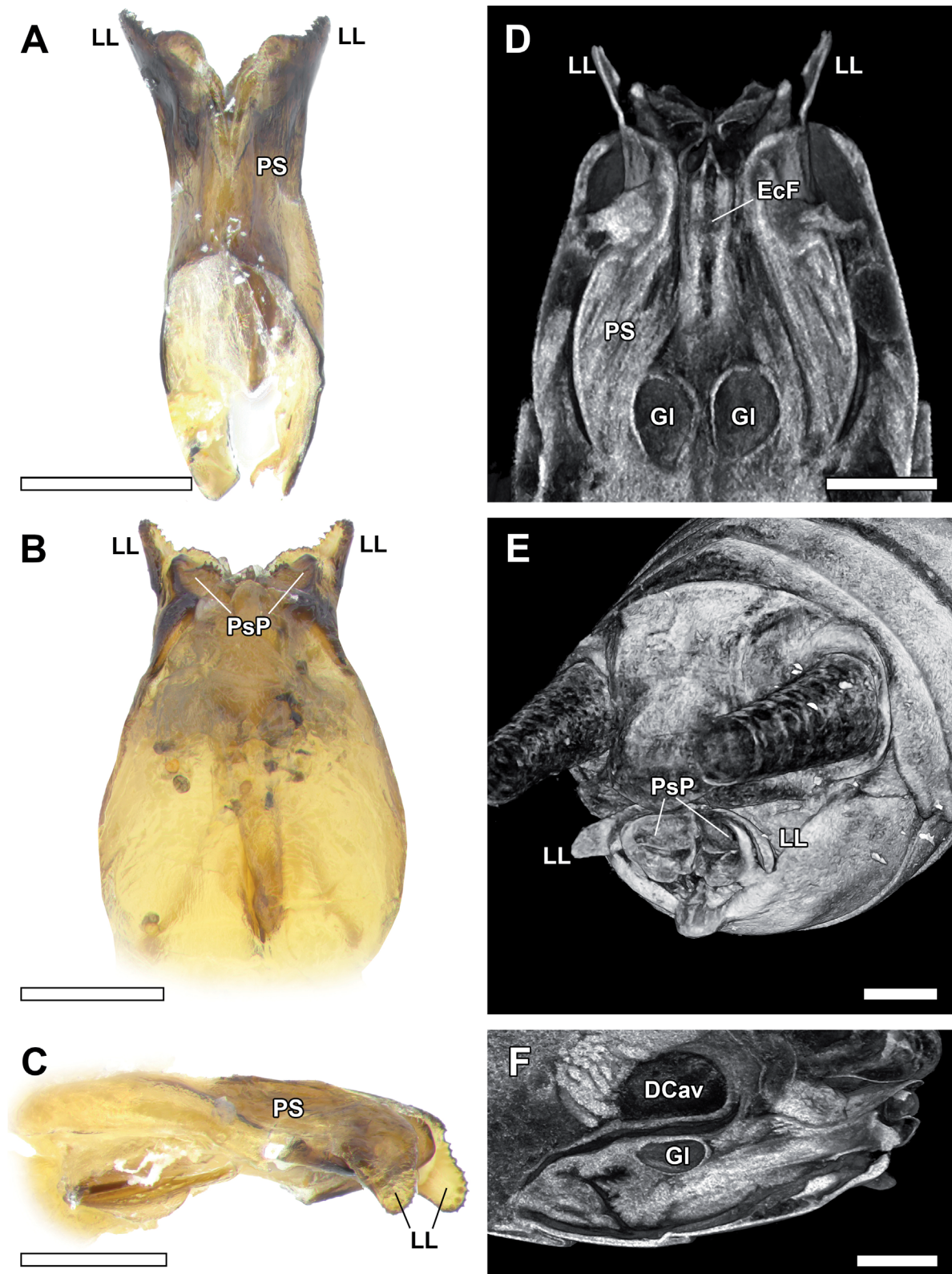
The species is redescribed here, since Walker's original description (1869) is extremely scant and is for the female only.

MEASUREMENTS. See Table 7. Females are slightly larger than males.



**Fig. 29.** *Trigonidium (Trigonidium) maoricum* (Walker, 1869). **A–B.** Lateral and frontal views of head, adult ♀. Tumbledown Bay, Banks Peninsula (MPN OR0267). **C.** Right ♂ forewing, dorsal view. ‘SF’ denotes the stridulum. Tumbledown Bay (MPN OR0268). **D.** Male sub-genital plate. Kerikeri, Northland (MPN OR0286). **E.** Stridulatory file. Kerikeri (NZAC03037187). **F–G.** Anterior and posterior view of tympanum. Kerikeri (NZAC03037187). **H.** Hind tarsal claw. Tumbledown Bay (MPN OR0268). **I.** Egg. Waimārama, Hawke’s Bay (MPN OR0327). **J.** Ovipositor, lateral view. Māhoe Reserve, Lincoln (MPN OR0277). **K.** Apex of ovipositor, dorsal view. Kerikeri (NZAC03037191). Black scale bars = 500 µm; white scale bars = 100 µm.



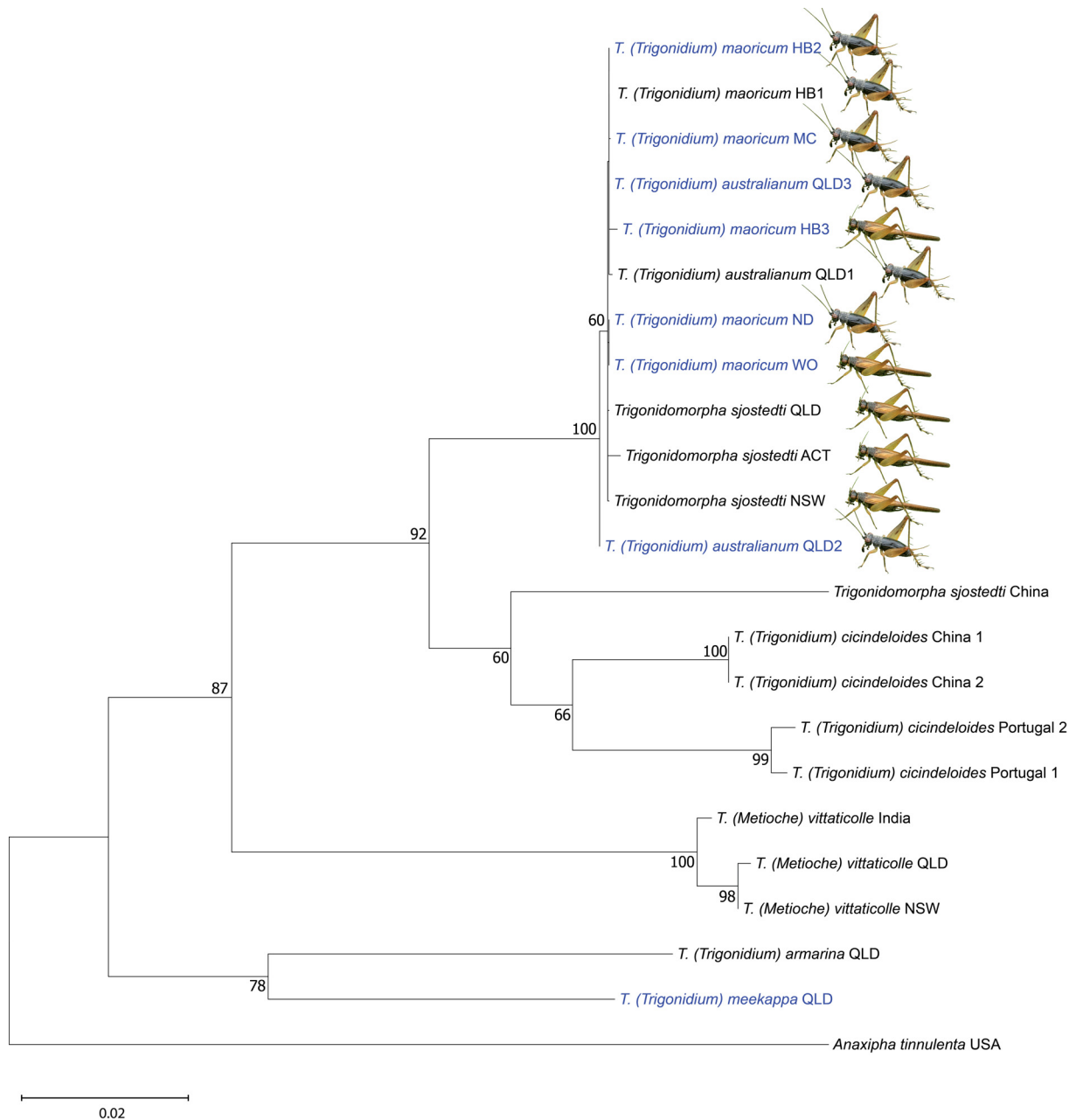


**Fig. 30.** *Trigonidium (Trigonidium) maoricum* (Walker, 1869), ♂ genitalia. Waimārama, Hawke's Bay (MPN OR0328). **A–C.** Microscope images of pseudepiphallallic sclerite. **A.** Dorsal view. **B.** Ventral view. **C.** Lateral view. **D–F.** Micro CT scans, Volume Blending. **D.** Dorsal view, cross-section. **E.** Posterior view. **F.** Lateral view. Scale bars = 250  $\mu$ m.

**Table 7.** Adult male and female measurements in *Trigonidium maoricum* (Walker, 1869) and *T. australianum* (Chopard, 1925). All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Trigonidium maoricum</i> (Walker, 1869)		<i>Trigonidium australianum</i> (Chopard, 1925)	
	male	female	male	female
Body length (mm)	5.0 (4.4–5.7) <i>N</i> = 8	5.1 (4.4–6.2) <i>N</i> = 12	4.0 (3.8–4.1) <i>N</i> = 2	4.7 (4.2–5.1) <i>N</i> = 2
Pronotum width (mm)	1.4 (1.3–1.5) <i>N</i> = 8	1.4 (1.2–1.7) <i>N</i> = 12	1.3 (1.3–1.3) <i>N</i> = 2	1.25 (1.1–1.4) <i>N</i> = 2
Pronotum length (mm)	0.9 (0.8–0.9) <i>N</i> = 8	0.9 (0.8–1.1) <i>N</i> = 12	0.8 (0.8–0.8) <i>N</i> = 2	0.85 (0.8–0.9) <i>N</i> = 2
Femur III length (mm)	4.1 (3.8–4.6) <i>N</i> = 8	4.2 (3.9–4.5) <i>N</i> = 12	3.7 (3.6–3.8) <i>N</i> = 2	4.0 (3.6–4.3) <i>N</i> = 2
Tibia III length (mm)	4.3 (4.0–4.6) <i>N</i> = 8	4.4 (3.9–4.7) <i>N</i> = 12	3.8 (3.7–3.9) <i>N</i> = 2	3.85 (3.5–4.2) <i>N</i> = 2
Number of subapical spurs on TIII inner	3	3	3	3
Number of subapical spurs on TIII outer	3	3	3	3
Ovipositor length (mm)	–	1.5 (1.4–1.6) <i>N</i> = 12	–	1.45 (1.4–1.5) <i>N</i> = 2
OL / BL	–	0.29 (0.25–0.33) <i>N</i> = 12	–	0.32 (0.30–0.34) <i>N</i> = 2
EL / IOD	1.01 (0.97–1.05) <i>N</i> = 2	–	0.99 (0.98–0.99) <i>N</i> = 2	0.99 (0.91–1.06) <i>N</i> = 2
FWW (mm)	1.1 (0.9–1.2) <i>N</i> = 8	1.1 (1.0–1.6) <i>N</i> = 12	0.9 (0.9–0.9) <i>N</i> = 2	0.95 (0.8–1.1) <i>N</i> = 2
FWL (mm)	3.2 (2.9–3.9) <i>N</i> = 8	3.3 (3.1–4.0) <i>N</i> = 12	2.4 (2.4–2.4) <i>N</i> = 2	3.1 (2.9–3.3) <i>N</i> = 2
HWL (mm)	–	9.6 <i>N</i> = 1	–	–
ST	31.5 (28–40) <i>N</i> = 6	–	18 (18–18) <i>N</i> = 2	–
SFL (µm)	205 (173–227) <i>N</i> = 6	–	102 (95–109) <i>N</i> = 2	–
tmao / tmai	0.74 (0.71–0.78) <i>N</i> = 8	0.71 (0.68–1.04) <i>N</i> = 12	0.88 (0.70–1.05) <i>N</i> = 2	0.72 (0.67–0.77) <i>N</i> = 2

HEAD (Fig. 29A–B). Shaped like an inverted triangle, widest at compound eyes, about as high as wide in frontal view. Compound eyes large and bulging, separated by a gap approximately equal to one eye length. Ocelli inconspicuous. Head colour black throughout, except for brown patches under scapes of



**Fig. 31.** Gene tree for *Trigonidium* Rambur, 1838 using Maximum Likelihood analysis of ~700 bp of mtDNA (COI) from 23 specimens and 1000 bootstrap replications. The tree with the highest log likelihood (-3571.04) is shown. Numbers next to the branches indicate the percentage of trees in which the associated taxa are clustered together. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. Specimens in blue were collected as part of this study; the remaining 15 sequences were obtained from the GenBank (Benson *et al.* 2013) and BOLD (Ratnasingham & Hebert 2007) databases. Detailed information for each specimen included in this analysis can be found in Supp. file 1: Table S11.



antennae and on rostrum. However, it should be noted that the head colour in trigs may vary over time in an adult, darkening as the insect ages (Rentz & Su 2019: 285, 317). Vertex with short, sparse hairs and three pairs of long, stout bristles either side of median suture. Frons glabrous. Antennae: scapes and pedicels black, flagelli yellow. Maxillary palps black, except for penultimate segment, which is brown. Terminal segment of maxillary palps shaped like a flattened cone, covered in dense, short hairs.

THORAX. Pronotum black, woolly in its look due to being covered in white hairs.

WINGS (Fig. 29C). Forewings mainly with longitudinal veins in both males and females, but with a stridulum approx. 200 µm long and with 28 to 40 teeth in males (Fig. 29E). In wingless morph, hindwings absent; tegmina thin, transparent and appressed to abdomen. In winged morph, hindwings present; tegmina thick and coloured yellow-brown.

LEGS. Fore and middle legs uniform yellow-red; posterior legs variegated, with yellow-red background and a complex brown pattern. All legs covered in dense, short hairs throughout. Tibia I with a long ventral spur at apex. In winged morph only, auditory tympana present on both anterior and posterior sides of Tibia I; anterior tympanal opening 30% longer than posterior tympanum (Fig. 29F–G). Tibia II bearing two ventral spurs at apex, subequal in length. Tibia III armed with three pairs of subapical spurs dorsally, alternated. All apical and subapical spurs pale in proximal half, brown in distal half; covered in dense hairs. Tibia III inner ventral apical spur absent, like in all Trigonidiinae. Length of outer apical spur on Tarsomere III-1 75% that of inner apical spur. All tarsal claws with four strong teeth inside (Fig. 29H).

ABDOMEN. Uniform black, glabrous. Abdominal gland absent.

MALE TERMINALIA (Figs 29D, 30). Subgenital plate trapezoidal, covered in short, dense tomentum, with a small, rounded lobe in middle and two sharp lateral processes on posterior edge. Pseudepiphallic sclerite with serrated edges, divaricating at apex.

FEMALE TERMINALIA (Fig. 29J–K). Ovipositor short, 30% of body length, strongly curved upwards right from base; light brown in colour. Cross-section of ovipositor quadrilateral at apex, with rows of small, sharp teeth on all four edges.

EGGS (Fig. 29I). Cylindrical, smooth, pale yellow in colour, translucent; rounded at one end, with a flat, sticky foot at other end. Dimensions approx. 1.5 mm long and 300 µm wide.

### Habitat and ecology

A predatory cricket, diurnal; inhabits uncultivated meadows with tall grass. Not known to make any sound, although it may stridulate by vibrating its maxillary palpi, like the European species *Trigonidium* (*Trigonidium*) *cicindeloides* (Ingrisch 1977).

### Distribution

New Zealand: widespread in North Island and in the warmer regions of South Island. Not known from Rakiura, Subantarctic Islands or Chatham Islands.

### *Trigonidium* (*Trigonidium*) *australianum* (Chopard, 1925)

Figs 31, 32E–F

*Metioche australiana* Chopard, 1925: 36.

*Trigonidomorpha sjostedti* Chopard, 1925: 40 **syn. nov.**

*Trigonidomorpha areolata* Chopard, 1925: 38 **syn. nov.**

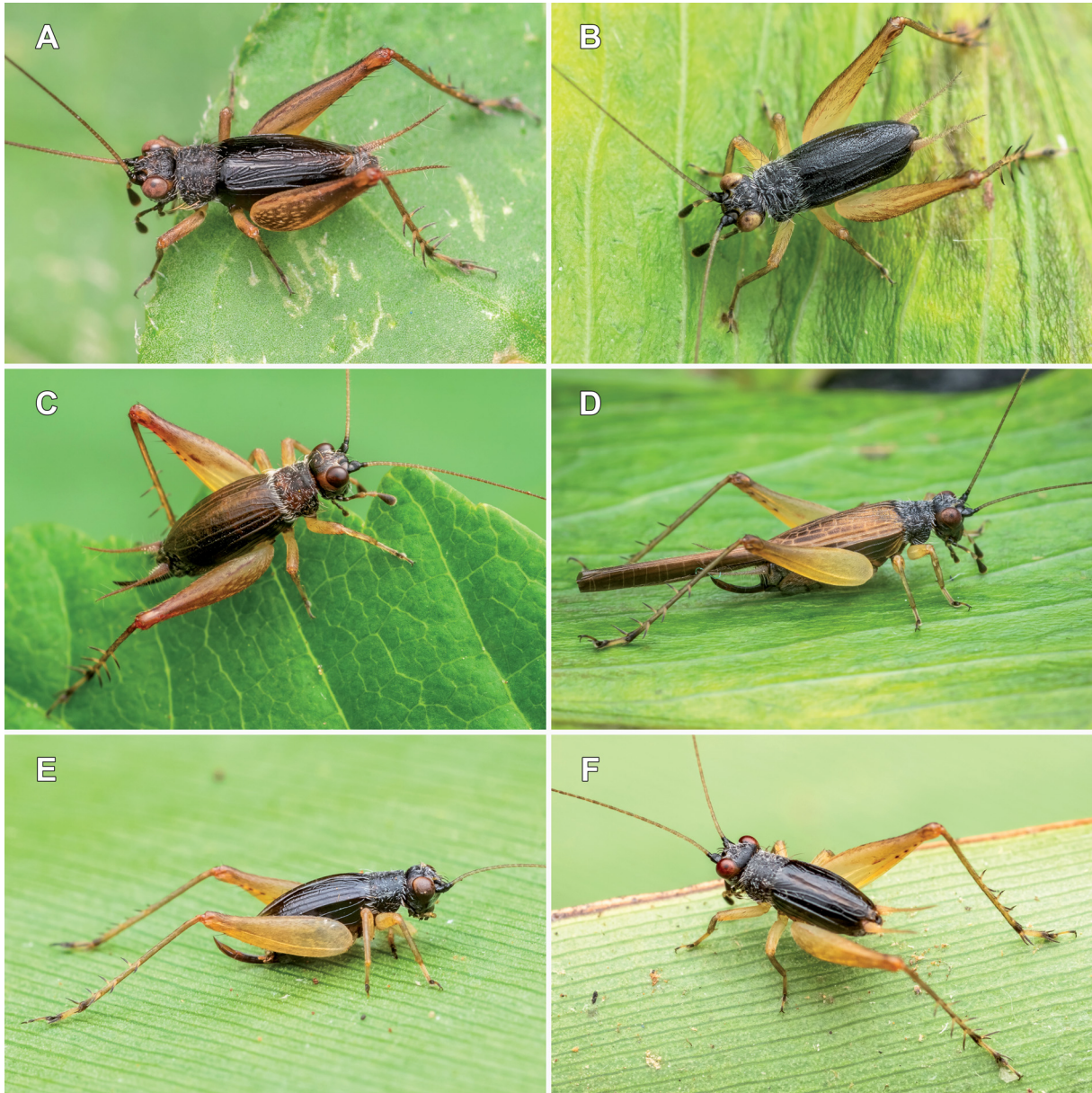
*Metioche australiana* – Chopard 1968: 334.

*Metioche areolata* – Chopard 1968: 334.

*Trigonidium australiana* – Otte & Alexander 1983: 228.

*Trigonidomorpha sjostedti* – Otte & Alexander 1983: 223. — Rentz & Su 2019: 316.

*Trigonidium (Trigonidium) australiana* – Rentz & Su 2019: 304.



**Fig. 32.** Live trigs (subfamily Trigonidiinae). **A–D.** *Trigonidium (Trigonidium) maoricum* (Walker, 1869). New Zealand. **A.** Adult ♂, Tumbledown Bay, Banks Peninsula. **B.** Adult ♂, Kerikeri, Northland. **C.** Adult ♀, Māhoe Reserve, Lincoln. **D.** Fully winged adult ♀. Kerikeri, Northland. **E–F.** *Trigonidium (Trigonidium) australianum* (Chopard, 1925). Oxley Creek Commons, Brisbane, QLD, Australia. **E.** Adult ♀. **F.** Adult ♂. Note: all specimens are posed on unnatural backgrounds in captivity.

### Amended diagnosis

A small trig (body length 4 to 5 mm), with black body and yellow legs, very similar to *Trigonidium* (*Trigonidium*) *maoricum* in every aspect. Slightly smaller than the latter, it has a shorter stridulatory file with less than 20 teeth. Adult insects come in a wingless morph without hindwings or auditory tympana, and in a winged morph with hindwings and with auditory tympana. The winged morph was previously mistaken to be a different species, *Trigonidomorpha sjostedti*.

### Etymology

The Latin adjective *australianum* refers to the country the insect is found in.

### Material examined

AUSTRALIA • 1 ♂, 1 ♀; Queensland, Brisbane, Oxley Creek Commons; 27.53566° S, 152.99306° E; 10 m a.s.l.; 17 Nov. 2023; D. Hegg leg.; in tall grass; insect net; MPN OR0403, OR0405 • 1 ♂; same data as for preceding; GenBank: PP761115; MPN OR0402 • 1 ♀; same data as for preceding; GenBank: PP761116; MPN OR0404.

### Description

Not included in this paper since this is not a New Zealand species.

MEASUREMENTS. See Table 7.

### Distribution

Australia. Northern, eastern and western coastal regions.

Family Mogoplistidae Costa, 1855  
Subfamily Mogoplistinae Costa, 1855  
Tribe Arachnocephalini Gorochov, 1984

Genus *Ornebius* Guérin-Méneville, 1844

*Ornebius* Guérin-Méneville, 1844: 331.

*Liphoplus* Saussure, 1877: 483.

*Ornebius* – Kirby 1906: 57. — Chopard 1968: 219. — Otte & Alexander 1983: 386, fig. 330. — Otte 1994: 91. — Rentz & Su 2019: 273.

### Type species

*Ornebius xanthopterus* Guérin-Méneville, 1844.

### Diagnosis (after Otte & Alexander 1983)

Difficult to differentiate from other genera of scaly crickets; this is not a problem in New Zealand, where it is the only known genus in the family. Body length generally between 6.5 mm and 8 mm in both males and females. The last dorsal segment of the abdomen is never black between the cerci; paraprocts whitish to brown, never black. Posterior margin of forewing with a continuous dark band or three darkened areas, brown or black, never red. Tibia I and II banded. Front of mirror not hidden beneath pronotum.

### Etymology

The meaning of the name *Ornebius* is unknown. *Ornebius* is male gender.



### Measurements

See Table 8.

For a detailed description of *Ornebius* in the Australian region, see Otte & Alexander (1983: 386); Rentz & Su (2019: 273).

### Habitat and ecology

Nocturnal crickets, arboreal; their melodious song is heard in the foliage of trees and shrubs.

### Distribution

New Zealand: New Plymouth, Auckland, Northland and Coromandel; Kermadec Islands. The mainland populations are introduced from Australia. Also found in Australia and wider Pacific Region, tropical and subtropical Asia and Africa, South and Central America.

*Ornebius aperta* Otte & Alexander, 1983  
Figs 33C–I, M, 34, 36A–D, 37A–B, 38H

*Ornebius aperta* Otte & Alexander, 1983: 396–397, figs 311, 312b, p, e', 314, table 31.

*Ornebius aperta* – Gwynne *et al.* 1988: 36–45, fig. 26. — Ramsay 1990: 37–38; 1991: 9–14, figs 1–6.  
— Andrade & Mason 2000: 483–495, figs 1–3. — Rentz & Su 2019: 277, fig. 34b, p, e'.

### Diagnosis

*Ornebius aperta* can be reliably differentiated from other species of *Ornebius*, and from the population further north in Northland, only by its song, a sequence of chirps made of three pulses at a peak frequency between 4.5 and 5.6 kHz. The interval between the first two pulses is much longer than the interval between the second and third pulses.

Male paraprocts pale brown, club-like in shape, narrowest at the base and widest one fifth of the length from the apex.

### Etymology

After *aperta*, ‘hill’, because of its origin from Tamborine Mountain in Australia. From one of “several small dictionaries covering a number of languages spread across Australia” (D. Otte pers. com. 2023). *Aperta* is used as a name in apposition.

**Material examined** (see also Supp. file 1: Table S9)

#### Holotype

AUSTRALIA • ♂, adult; Queensland, Tamborine Mountain; 27.973° S, 153.198° E; 500 m a.s.l.; 25 Feb. 1969; D. Otte and R. Alexander leg.; tangles of vine in rain forest; ANIC 14 008971.

#### Other material

NEW ZEALAND – **Taranaki (TK)** • 1 ♂; Bell Block, New Plymouth; 39.02029° S, 174.15025° E; 20 m a.s.l.; 20 Apr. 2023; sound recording and photograph; iNaturalist 155725347. – **Waikato (WO)** • 1 ♂; Cambridge; 37.90589° S, 175.47892° E; 60 m a.s.l.; 24 Mar. 2024; D. Hegg leg.; in hedge; sound recording; iNaturalist 203709782. – **Coromandel (CL)** • 2 ♀♀; Driving Creek, Coromandel; 36.73316° S, 175.50230° E; 50 m a.s.l.; 5 Apr. 2024; D. Hegg and S. Wagner leg.; in foliage; insect net; MPN OR0387, OR0388 • 3 ♂♂, 2 ♀♀; Coromandel; 36.76232° S, 175.49229° E; 5 m a.s.l.; 6 Apr. 2024; D. Hegg leg.; in low foliage; sound recording and insect net; MPN OR0389 to OR0393. – **Auckland (AK)** • 3 ♂♂, 6 ♀♀; Tahuna Torea Reserve, Auckland; 36.87172° S, 174.88219° E; 5 m a.s.l.; 29 Aug. 2023; D. Hegg leg.; on tree leaves in forest; sound recording and insect net; MPN OR0288 to OR0296

• 2 ♂♂; same data as for preceding; 26 Mar. 2024; D. Hegg leg.; MPN OR0340, OR0341 • 1 ♂; Orewa Beach, Auckland; 36.59544° S, 174.69950° E; 5 m a.s.l.; 25 Apr. 2023; D. Hegg leg.; on wall of building; jar; MPN OR0287 • 1 ♂, 1 ♀; Linley Reserve, Auckland; 36.79358° S, 174.73276° E; 40 m a.s.l.; 8 Apr. 2024; D. Hegg leg.; in foliage; insect net; MPN OR0399, OR0400.

### Description

For a detailed description of *Ornebius aperta* see Otte & Alexander (1983: 396–397) and Ramsay (1991). Images of the main characters are in Fig. 33. The male genitalia and the song are described in detail below, since they are the only traits that differentiate *Ornebius aperta* from other species in the genus, including *Ornebius* aff. *aperta* in Northland.

MEASUREMENTS. See Table 8. Females are larger than males.

MALE TERMINALIA (Figs 33D–E, G–I, 36A–D). Suranal plate without hair spikes projecting backwards from posterior margin (Fig. 33D–E). Paraprocts pale brown, club-like in shape, narrowest at base and widest one fifth of length from apex (Figs 33G–I, 36D).

SONG. A melodious sequence of chirps with a peak frequency between 4.5 kHz and 5.6 kHz, separated by intervals of approx. 1 second; each chirp consisting of 3 pulses, the first two pulses 280 ms apart, the second and third pulses 40 ms apart. Pulse duration is approx. 30 ms. See also Fig. 34 and Table 8.

### Habitat and ecology

An arboreal scaly cricket, nocturnal, locally abundant. Its melodious song is heard from dusk into the night in urban parks and in the streets of Auckland; the cricket is common in hedges in residential areas.

### Distribution

Auckland and surrounds; also Coromandel, Waikato and New Plymouth, Taranaki. Introduced to New Zealand by anthropogenic means. Origin in Tamborine Mountain, Queensland, Australia; accidentally introduced to Perth, Western Australia.

*Ornebius* aff. *aperta* Otte & Alexander, 1983  
Figs 33A–B, J–L, N, 35, 36E–H, 37C–D, 38I

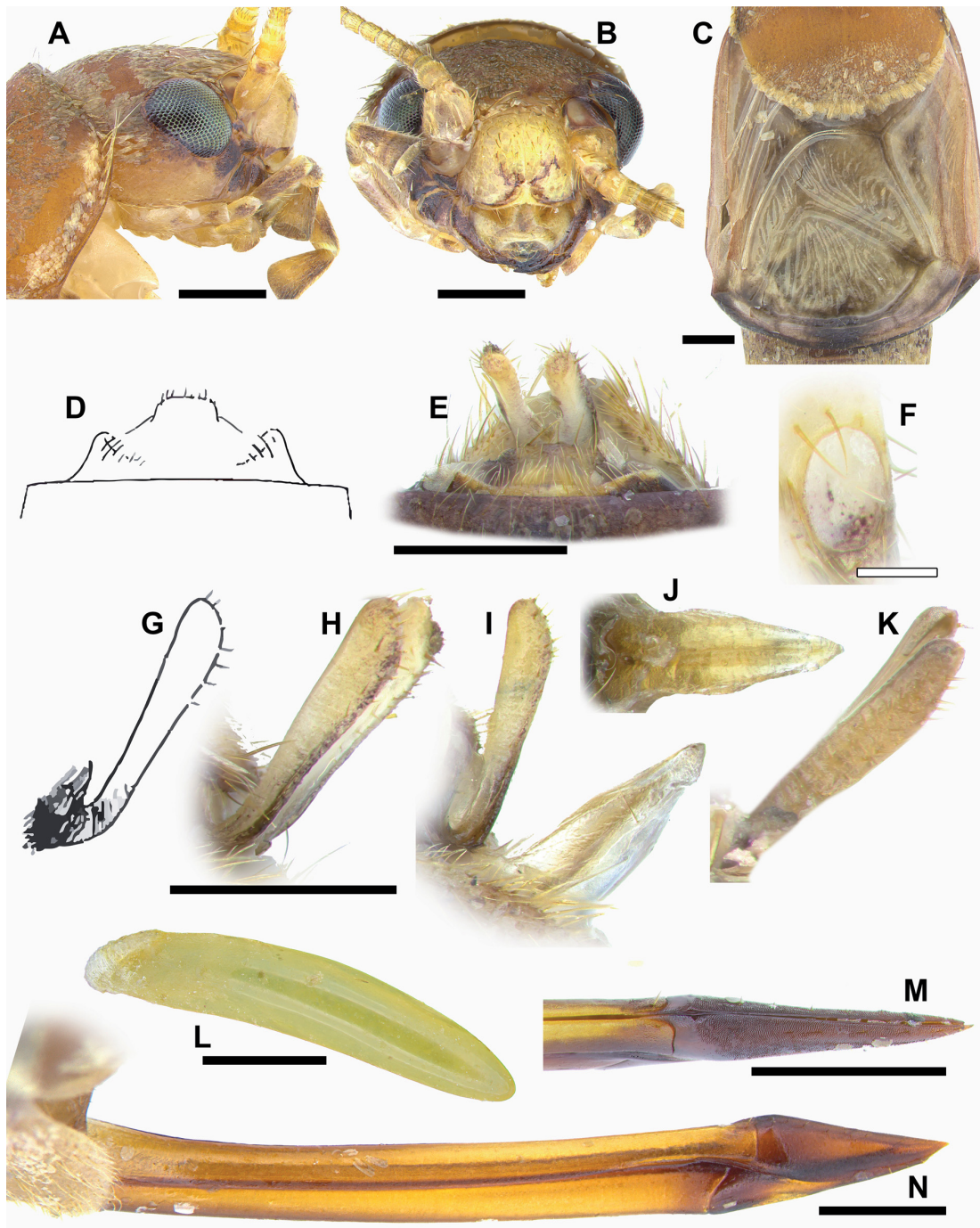
### Diagnosis

*Ornebius* aff. *aperta* can be reliably differentiated from other species of *Ornebius*, including *Ornebius aperta* in Auckland, only by its song, a sequence of chirps made of four or five pulses at a peak frequency of 4 kHz or less. The interval between the first two pulses is much longer than the interval between the remaining pulses.

Male paraprocts pale brown, club-like in shape, with a long narrow neck at the base, and widest one fourth of the length from the apex.

### Material examined (see also Supp. file 1: Table S10)

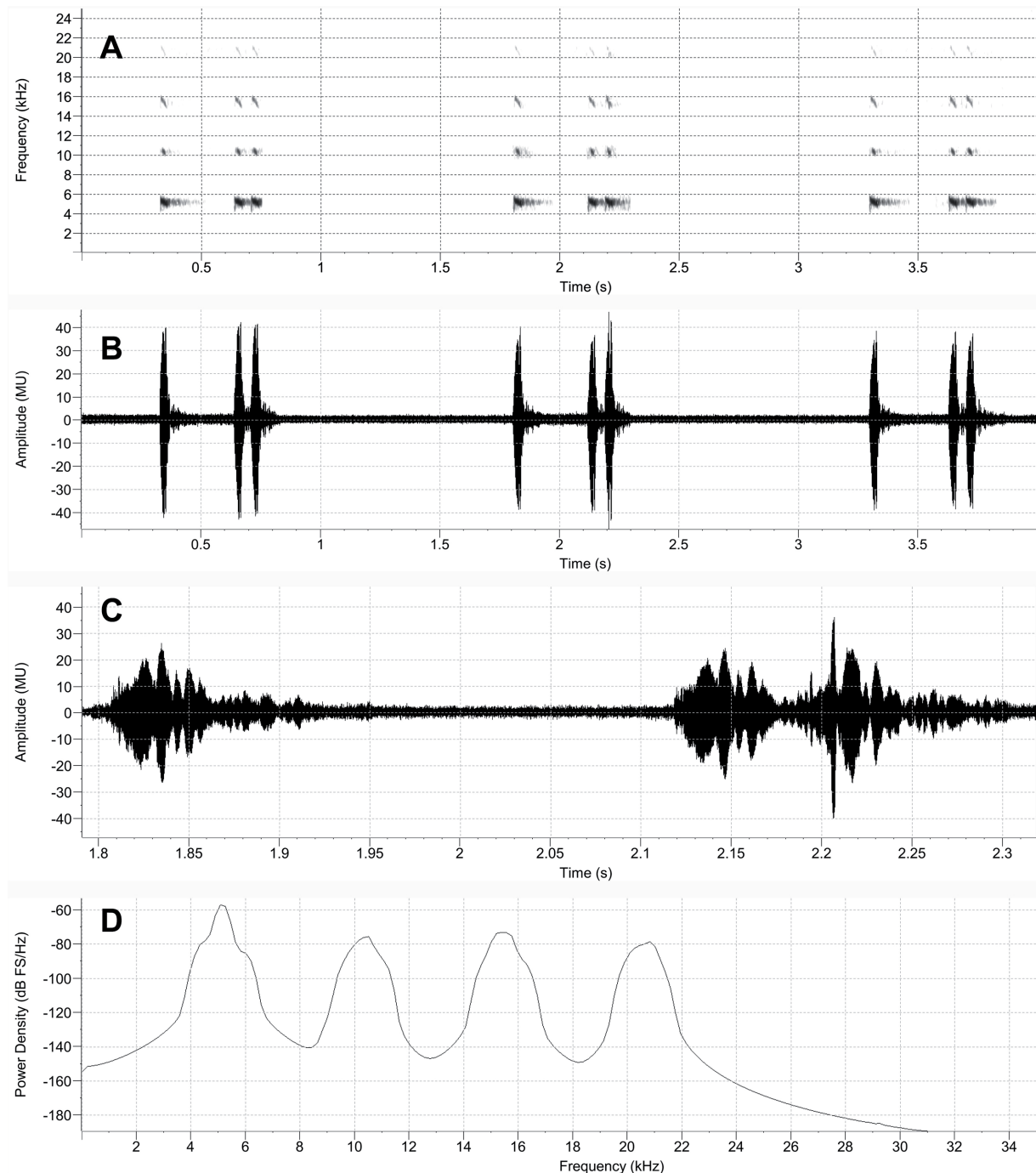
NEW ZEALAND – **Northland (ND)** • 1 ♂, 1 ♀; Mahinepua Bay; 34.99641° S, 173.84348° E; 30 m a.s.l.; 30 Apr. 2021; D. Hegg leg.; in foliage; insect net; MPN OR0473, OR0474 • 2 ♀♀; Kerikeri Holiday Park, Kerikeri; 35.22928° S, 173.94294° E; 80 m a.s.l.; 22 Nov. 2021; D. Hegg leg.; in foliage; insect net; MPN OR0303, OR0304 • 1 ♂; Kerikeri; 35.21784° S, 173.96140° E; 30 m a.s.l.; 29 Nov. 2021; D. Hegg leg.; in foliage; insect net; MPN OR0297 • 5 ♂♂; Kerikeri; 35.21875° S, 173.95472° E; 60 m a.s.l.; 19 Mar. 2022; D. Hegg leg.; in foliage; insect net; MPN OR0298 to OR0302 • 6 ♂♂, 4 ♀♀; Kerikeri; 35.21750° S, 173.96174° E; 30 m a.s.l.; 30 Mar. 2024; D. Hegg leg.; in roadside vegetation; insect



**Fig. 33.** *Ornebius aperta* Otte & Alexander, 1983 (*O.a.*) and *Ornebius* aff. *aperta* Otte & Alexander, 1983 (*O. aff. a.*). All specimens stored at MPN. **A–B.** Head, lateral and frontal view, adult ♀. *O. aff. a.*, Whangārei (OR0306). **C.** Dorsal view of forewing, adult ♂. *O.a.*, Auckland (OR0294). **D–E.** Dorsal view of terminalia, *O.a.* adult ♂. **D.** Tamborine Mtn, QLD. Drawing from Otte & Alexander (1983: fig. 312e'). **E.** Auckland (OR0294). **F.** Left tympanum. *O.a.*, Auckland (OR0294). **G–I.** Lateral view of paraprocts, *O.a.* adult ♂. **G.** Tamborine Mtn, QLD. Drawing from Otte & Alexander (1983: fig. 312p). **H–I.** Auckland. **H.** OR0294. **I.** OR0295. **J.** Dorsal view of genitalia. *O. aff. a.*, adult ♂. Kerikeri (OR0298). **K.** Lateral view of paraprocts, *O. aff. a.*, adult ♂. Kerikeri (OR0299). **L.** Egg. *O. aff. a.*, Kerikeri (OR0381). **M.** Dorsal view of ovipositor tip. *O. a.*, Auckland (OR0289). **N.** Lateral view of ovipositor. *O. aff. a.*, Whangārei (OR0307). Black scale bars = 500 µm; white scale bar = 100 µm.



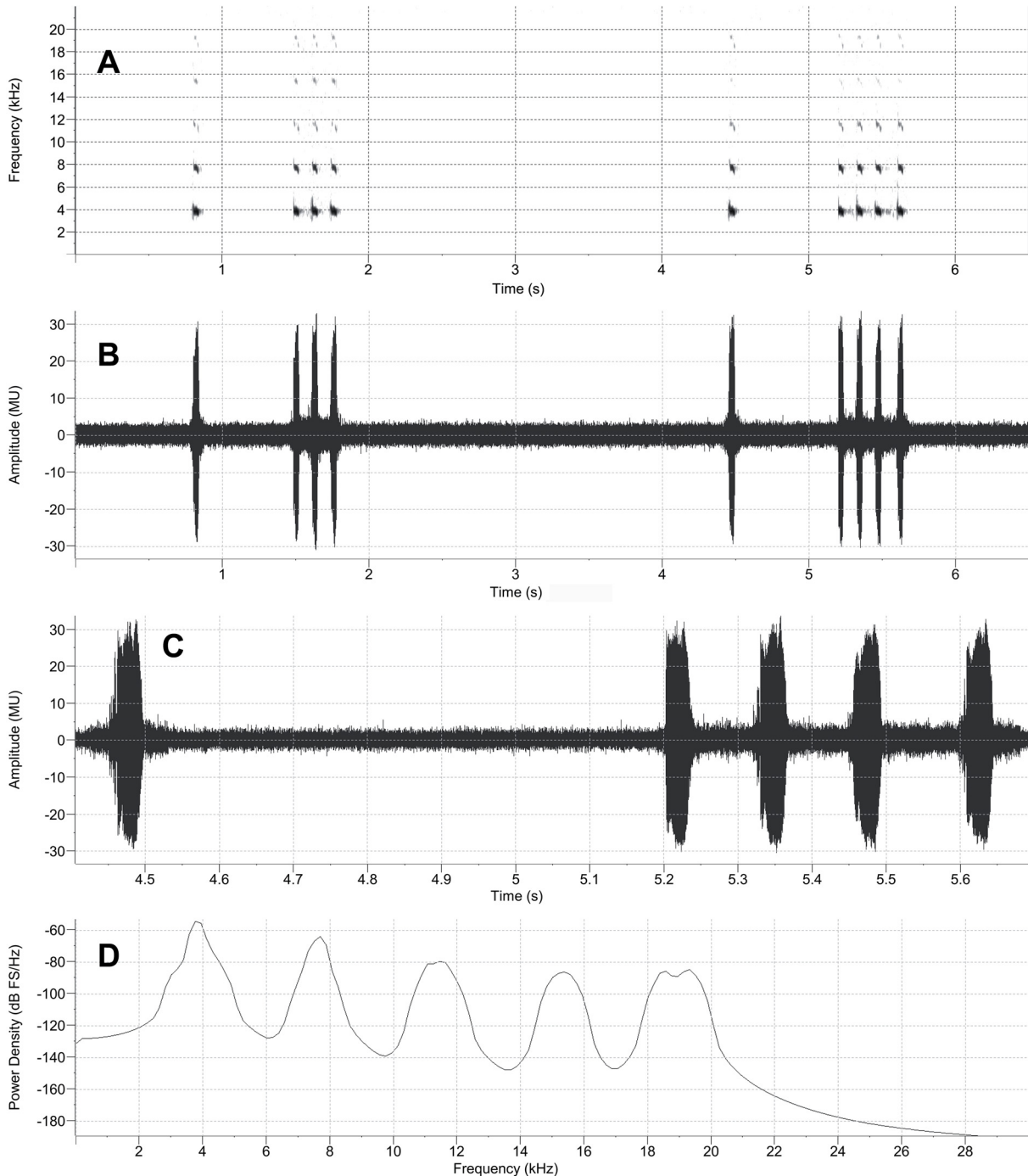
net; MPN OR0375 to OR0384 • 1 ♂, 3 ♀♀; Frank Holman Walking Track, Whangārei; 35.71306° S, 174.31493° E; 40 m a.s.l.; 1 Aug. 2023; D. Hegg leg.; in foliage; sound recording and insect net; MPN OR0305 to OR0308.



**Fig. 34.** *Ornebius aperta* Otte & Alexander, 1983 song, recorded in captivity at 20°C. Tahuna Torea Reserve, Auckland. **A.** Spectrogram of a sequence of three chirps. **B.** Oscillogram of a sequence of three chirps. **C.** Oscillogram of one chirp consisting of three pulses. **D.** Power spectrum of one chirp.

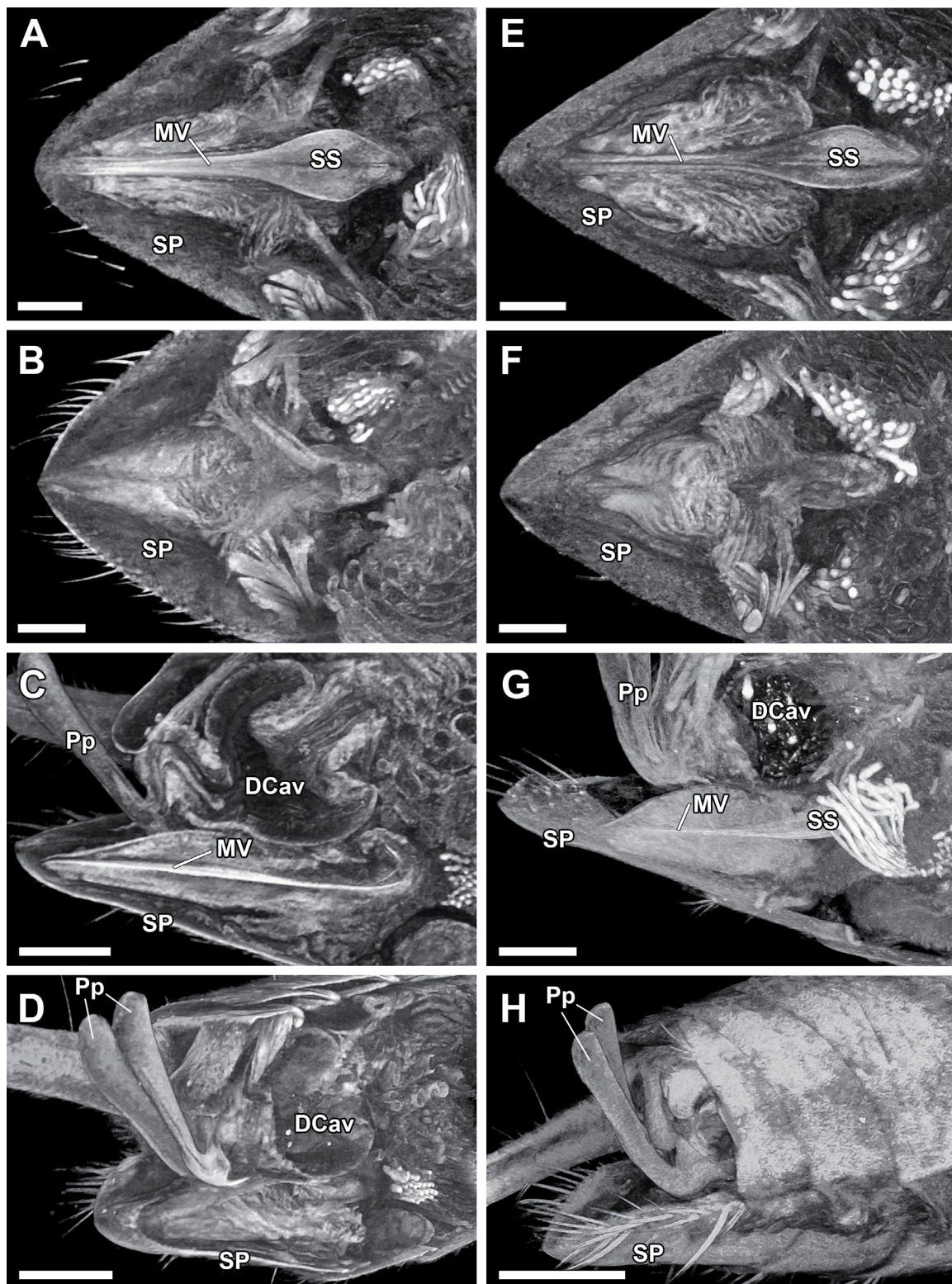
### Description

A detailed description of *Ornebius* aff. *aperta* is not included here, since I am not designating or describing a new species. Images of the main characters are in Fig. 33. The male genitalia and the song are described in detail below, since they are the only traits that differentiate *Ornebius* aff. *aperta* from other species in the genus, including *Ornebius aperta* in Auckland.



**Fig. 35.** *Ornebius* aff. *aperta* Otte & Alexander, 1983 song, recorded in the field at 23°C. Lane Cove, Northland. **A.** Spectrogram of a sequence of two chirps. **B.** Oscillogram of a sequence of two chirps. **C.** Oscillogram of one chirp consisting of five pulses. **D.** Power spectrum of one chirp.





**Fig. 36.** *Ornebius* Guérin-Méneville, 1844, micro CT scans of ♂ genitalia of New Zealand species. A–D. *Ornebius aperta* Otte & Alexander, 1983. Auckland (MPN OR0340). A–B. Dorsal view, cross-section. C. Lateral view. D. Exterior view of paraprocts. E–H. *Ornebius* aff. *aperta* Otte & Alexander, 1983. Kerikeri, Northland (MPN OR0375). E–F. Dorsal view, cross-section. G. Lateral view. H. Exterior view of paraprocts. Scale bars = 250 µm.

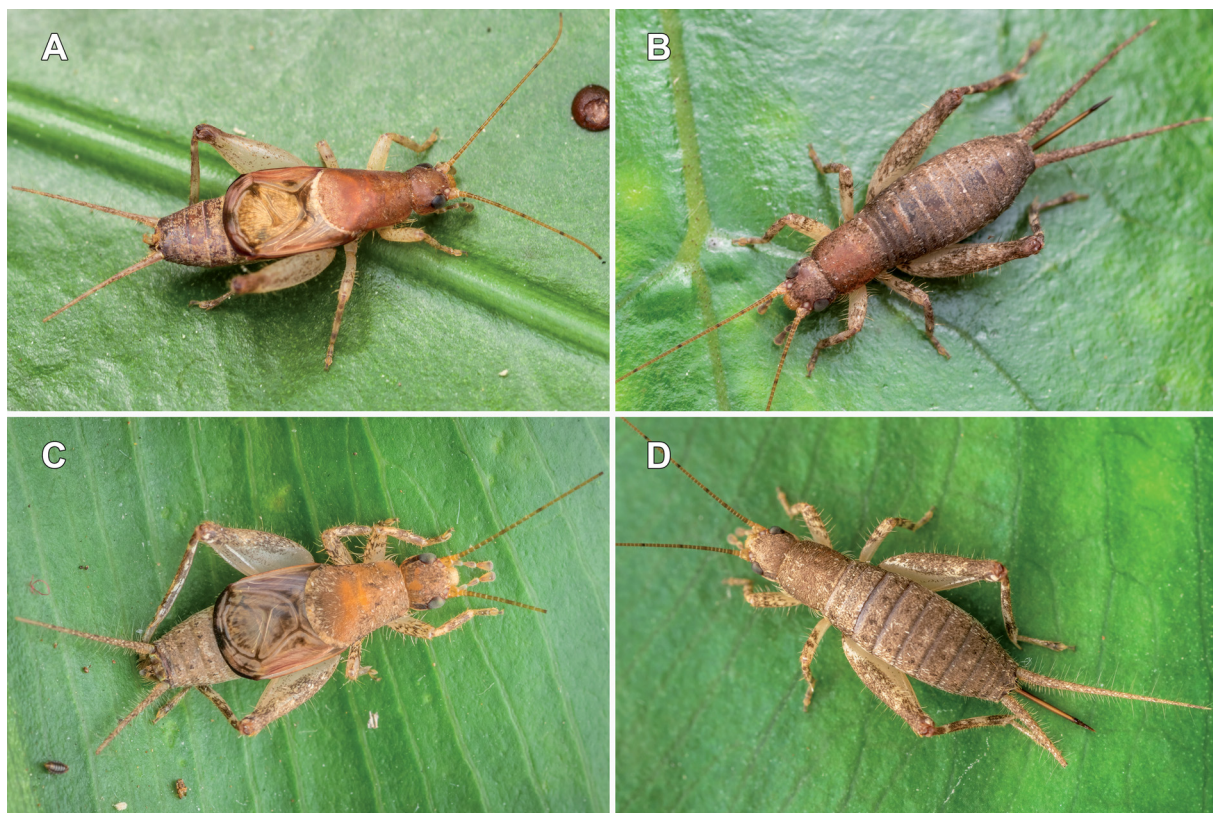


**Table 8** (continued on next page). Adult male and female measurements in the New Zealand species of *Ornebius* Guérin-Méneville, 1844. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Ornebius aperta</i> Otte & Alexander, 1983		<i>Ornebius aff. aperta</i> Otte & Alexander, 1983	
	male	female	male	female
Body length (mm)	7.2 (6.5–7.4) <i>N</i> = 4	8.1 (6.5–9.0) <i>N</i> = 6	6.8 (6.2–7.1) <i>N</i> = 7	7.3 (6.8–7.9) <i>N</i> = 5
Pronotum width (mm)	2.2 (2.1–2.2) <i>N</i> = 4	1.8 (1.7–1.9) <i>N</i> = 6	2.3 (2.1–2.5) <i>N</i> = 7	1.6 (1.4–2.0) <i>N</i> = 5
Pronotum length (mm)	2.6 (2.5–2.8) <i>N</i> = 4	1.7 (1.7–1.8) <i>N</i> = 6	2.6 (2.5–2.8) <i>N</i> = 7	1.7 (1.6–2.0) <i>N</i> = 5
Femur III length (mm)	4.0 (3.8–4.1) <i>N</i> = 4	4.4 (4.2–4.6) <i>N</i> = 6	3.9 (3.8–4.2) <i>N</i> = 7	4.4 (4.0–4.6) <i>N</i> = 5
Tibia III length (mm)	2.7 (2.5–2.9) <i>N</i> = 4	3.0 (2.7–3.1) <i>N</i> = 6	2.7 (2.5–2.9) <i>N</i> = 7	3.0 (2.6–3.1) <i>N</i> = 5
Number of dorsal spines on TIII inner	16 (14–17) <i>N</i> = 4	19 (17–20) <i>N</i> = 6	15 (14–16) <i>N</i> = 7	15 (15–16) <i>N</i> = 5
Number of dorsal spines on TIII outer	23 (19–25) <i>N</i> = 4	23 (19–27) <i>N</i> = 6	21 (19–22) <i>N</i> = 7	21 (20–23) <i>N</i> = 5
Number of dorsal spines on Tarsomere III-1 inner	4 (4–4) <i>N</i> = 4	4 (4–5) <i>N</i> = 6	4 (4–5) <i>N</i> = 7	5 (4–5) <i>N</i> = 5
Number of dorsal spines on Tarsomere III-1 outer	5 (5–6) <i>N</i> = 4	5 (4–6) <i>N</i> = 6	5 (5–6) <i>N</i> = 7	6 (5–6) <i>N</i> = 5
Ovipositor length (mm)	–	3.3 (3.1–3.7) <i>N</i> = 6	–	3.4 (3.1–3.8) <i>N</i> = 5
OL / BL	–	0.41 (0.37–0.51) <i>N</i> = 6	–	0.47 (0.43–0.52) <i>N</i> = 5
FWW (mm)	2.5 (2.3–2.5) <i>N</i> = 4	–	2.5 (2.4–2.8) <i>N</i> = 7	–
FWL (mm)	3.3 (2.8–3.4) <i>N</i> = 4	–	3.2 (2.7–3.4) <i>N</i> = 7	–
ST	164 (163–177) <i>N</i> = 3	–	177 (157–192) <i>N</i> = 6	–
SFL (mm)	1.48 (1.45–1.58) <i>N</i> = 3	–	1.50 (1.40–1.86) <i>N</i> = 6	–
tmao / tmai	0.89 (0.86–0.96) <i>N</i> = 4	0.93 (0.88–0.98) <i>N</i> = 6	0.91 (0.86–0.95) <i>N</i> = 7	0.87 (0.80–0.97) <i>N</i> = 5
tao1 / tai1	0.77 (0.71–0.87) <i>N</i> = 4	0.73 (0.69–0.95) <i>N</i> = 6	0.77 (0.55–0.82) <i>N</i> = 7	0.78 (0.60–0.90) <i>N</i> = 5

**Table 8** (continued). Adult male and female measurements in the New Zealand species of *Ornebius* Guérin-Méneville, 1844. All abbreviations used here are explained in the Material and methods section. All counts and measurements are median values, followed by minimum and maximum values in brackets. *N* indicates the sample size.

Measurement	<i>Ornebius aperta</i> Otte & Alexander, 1983		<i>Ornebius aff. aperta</i> Otte & Alexander, 1983	
	male	female	male	female
	Song (20°C)		Song (23°C)	
Peak frequency (kHz)	5.1	–	3.75	–
Pulse duration (ms)	30	–	30	–
Pulse interval 1 (ms)	280	–	650–700	–
Pulse interval 2 (ms)	42	–	90–95	–
Chirp duration (s)	0.4	–	0.95–1.2	–
Chirp interval (s)	1.1	–	2.6–2.7	–



**Fig. 37.** Live scaly crickets (genus *Ornebius*) photographed in their natural environment. **A–B.** *Ornebius aperta* Otte & Alexander, 1983. Tahuna Torea Reserve, Auckland. **A.** Adult ♂. **B.** Adult ♀. **C–D.** *Ornebius aff. aperta* Otte & Alexander, 1983. Kerikeri, Northland. **C.** Adult ♂. **D.** Adult ♀.

MEASUREMENTS. See Table 8. Females are larger than males.

MALE TERMINALIA (Figs 33J–K, 36E–H). Suranal plate without hair spikes projecting backwards from posterior margin, same as in *Ornebius aperta* (Fig. 33D–E). Paraprocts pale brown, club-like in shape, with a long narrow neck at base, and widest one fourth of length from apex (Figs 33K, 36H).

SONG. A melodious sequence of chirps with a peak frequency at 4 kHz or less, separated by intervals of two to three seconds; each chirp consisting of 4 or 5 pulses, the first two pulses 650 ms to 700 ms apart, the remaining pulses less than 100 ms apart. Pulse duration is approx. 30 ms. See also Fig. 35 and Table 8.

### Habitat and ecology

An arboreal scaly cricket, nocturnal, locally abundant. Its melodious song is heard from dusk into the night at forest edges, in urban parks and residential areas, and camping grounds.

### Distribution

Northland. Presumably introduced from Australia by anthropogenic means. Native distribution range unknown.

### Discussion

New Zealand's cricket fauna is extremely depauperate. Even though in this work I have nearly doubled the number of described Trigonidiidae, endemic ground cricket species (subfamily Nemobiinae) now sit at four, native trigs (subfamily Trigonidiinae) still just one. Two species of Nemobiinae in the genus *Pteronemobius* are recent introductions from Australia. Other families in the infraorder Gryllidea don't fare any better, with one endemic species in Gryllotalpidae Leach, 1815, one possible native species in Gryllidae (*Teleogryllus commodus*, which we share with Australia) and no native representatives in Mogoplistidae, Oecanthidae Blanchard, 1845 or Phalangopsidae Blanchard, 1845. Scaly crickets in the genus *Ornebius* are present but are recent introductions from Australia.

The low diversity in New Zealand's cricket fauna contrasts with our nearest neighbours, Australia and New Caledonia, both of which have a rich and diverse cricket fauna (Otte & Alexander 1983; Otte *et al.* 1987; Anso *et al.* 2016; Desutter-Grandcolas *et al.* 2016; Rentz & Su 2019).

New Zealand's few endemic species are mostly of Australian origin. The genus *Bobilla* is represented with eleven species in Australia's southern regions; *B. nigrova* seems most closely related to *B. victoriae* Otte & Alexander, 1983, whereas *B. bigelowi* most closely resembles the Australian species *B. kindyerra* Otte & Alexander, 1983 (Su pers. com. 2023). *Trigonidium maoricum* is most closely related to *T. australianum*; the two taxa may in fact be conspecific. Close relatives of all of the above species are also found in New Caledonia. Only the forest crickets *Austronemobius chelatus* gen. et sp. nov. and *Mutonemobius marmoratus* gen. et sp. nov. have clearly evolved in New Zealand; the former species especially appears to be unique worldwide with its articulated pseudepiphallic parameres modified for clasping in the male genitalia.

The fossil record of New Zealand crickets (infraorder Gryllidea) has never been studied. It seems likely that species diversity would have been higher in the Early Eocene (50 Ma), when the continent Zealandia was ruled by subtropical climate (Gibbs 2016). Two important geological events could have accounted for the subsequent extinction of all or almost all species of crickets in New Zealand: the near complete submergence of the continent Zealandia 22 Ma (Cooper & Cooper 1995), and the Pleistocene glaciation (Gibbs 2016: 215–221). It is worth noting that all New Zealand endemic crickets remain mobile and able to jump when kept in a fridge at temperatures between 4°C and 8°C, regardless of where in the country they were collected; *Bobilla* sp. will also survive freezing. Australian crickets in contrast go into torpor if kept in a fridge and will take several minutes to recover when exposed to ambient temperature again



(pers. obs.). This implies adaptation of New Zealand crickets to colder climates. A phylogeny of crickets in the New Zealand and Australian region combined with the use of molecular clocks is needed to gain a better understanding of the history and evolution of our cricket fauna.

#### Notes on the biology, ecology and distribution of New Zealand Trigonidiidae and Mogoplistidae

##### Genus *Bobilla* Otte & Alexander, 1983

The two New Zealand species of *Bobilla*, *B. nigrova* and *B. bigelowi*, are sympatric throughout their distribution range and frequently form mixed populations. They are the most adaptable among our small crickets, being found in grasslands ranging from coastal dunes to alpine meadows at 1800 m a.s.l. in the Southern Alps; they thrive in tall, rank grass as well as in mown lawns and sportsfields. Both species require high levels of humidity and are prone to desiccation. *Bobilla bigelowi* is especially sensitive to low humidity levels and won't survive more than a few hours in a dry environment.

The two species of *Bobilla* show some notable differences in their biology and ecology. *Bobilla nigrova* has a longer ovipositor and lays its eggs deeper into the ground. The eggs of *B. nigrova* are black, heavily sclerotised, more resistant to desiccation and most likely to hatch after a long diapause of 5 months or more (McIntyre 1978). The eggs of *B. bigelowi* are creamy white, are laid close under the surface and generally hatch after two weeks to a month (McIntyre 1978). As a result, *B. nigrova* has a univoltine life cycle, the eggs hatching in spring, the insects reaching maturity in late summer and laying in autumn. Adult *B. nigrova* are generally encountered between February and May. *Bobilla bigelowi*, on the other hand, are encountered as adults year round and are most commonly seen in late autumn and through winter. They survive frosts in the colder regions in the interior of New Zealand's South Island and can be found singing on tufts of snowgrass poking through fresh snow after a snowfall.

*Bobilla* are diurnal; males sing at temperatures below 10°C as long as they are exposed to direct solar radiation. This makes the interpretation of temperature graphs for *Bobilla* songs recorded in a lab extremely difficult, and potentially misleading. McIntyre (1977a: fig. 8) measured frequency, pulse and chirp duration, and pulses per interval in the song of *B. bigelowi* in laboratory conditions at temperatures ranging between 20°C and 35°C. In the natural environment, air temperature alone is meaningless since all of the above parameters are affected by direct solar radiation. Indeed, field recordings often show multiple individuals singing simultaneously at different frequencies and pulse rates, depending on the amount of solar radiation each cricket is exposed to in its hide. At low temperatures, identification of *B. bigelowi* and *B. nigrova* from field recordings is difficult and unreliable.

##### Silent Nemobiinae

In this paper, I have described two species of silent ground crickets, *Austronemobius chelatus* gen. et sp. nov. from New Zealand's South Island and from Mt Ruapehu, and *Mutonemobius marmoratus* gen. et sp. nov. from North Island. Both species are nocturnal, live in leaf litter and inhabit high rainfall regions in the west of the country. Neither species appears to have specific habitat requirements beyond a thick layer of leaf litter and a high level of humidity. *Austronemobius chelatus* has been collected in Nikau palm forests at sea level, in lowland podocarp forests, in montane beech forests, and in sub-alpine grasslands up to about 1000 m a.s.l. *Mutonemobius marmoratus* has been observed in meadows at low elevation in the Waikato Region, as well as in montane rainforests on Taranaki Mouna and near Lake Taupo. The latter species forms populations that can reach locally very high densities, up to one cricket every 100 cm<sup>2</sup> or more. Details on the biology of either species are lacking. Given the morphological differences between the two species, it is unlikely that they would be related to one another to any degree.

##### Genus *Pteronemobius* Jacobson, 1904

Two species of *Pteronemobius* are known from New Zealand, *P. truncatus* and *P. cf. arima*. Both species are believed to have been recently introduced from Australia by anthropogenic means.

The first reliable record of *Pteronemobius truncatus* in New Zealand is from Northland in 1990 (Messenger 1991), when the crickets were recorded to be swarming in Warkworth. The following year, Messenger (1991) recorded swarms in Whangarei (80 km north of Warkworth) and in Ahipara, another 80 km to the north-west. Given the size and geographic distribution of these populations, *P. truncatus* must have first arrived into New Zealand well before 1990. The species is now common in all western regions of North Island. The first record from South Island is from Kaiteriteri, Tasman Bay, in March 2023.

*Pteronemobius* cf. *arima* was first recorded on iNaturalist at Lake Rotopounamu (Taupō) in 2019. The species is present in all western regions of North Island from Taranaki to Cape Reinga. It is unknown when *P. cf. arima* first arrived in New Zealand.

Both species of *Pteronemobius* live in wet grasslands and in forest edge habitat, also in swamps. Like *Bobilla*, they are found both in tall, rank grass and in mown lawns and sportsfields. They are also commonly heard singing from inside manholes in urban storm-water drains. *Pteronemobius truncatus* can occasionally be observed singing right at the edge of the water, only a few mm away from puddles after rain. Most of the times, however, the crickets are well concealed and hard to locate.

Fully winged specimens are common in both species and are known to swarm in late summer or early autumn. Nocturnal, attracted to lights, they often end up in human dwellings, especially in bathrooms and showers. In Northland, adults can be observed year round, winged specimens through summer from November to April, suggesting that the climate there is warm enough for *Pteronemobius* to breed at any time of the year. Further south, their life cycle is probably univoltine.

#### **Trigs (subfamily Trigonidiinae)**

Trigs are arguably the least studied and most poorly known among New Zealand crickets. *Trigonidium maoricum* was described over 150 years ago and has never been the subject of a single study since. The winged morph with auditory tympana was not identified until this study. We can only infer some of this species' life history from studies of its close relatives overseas.

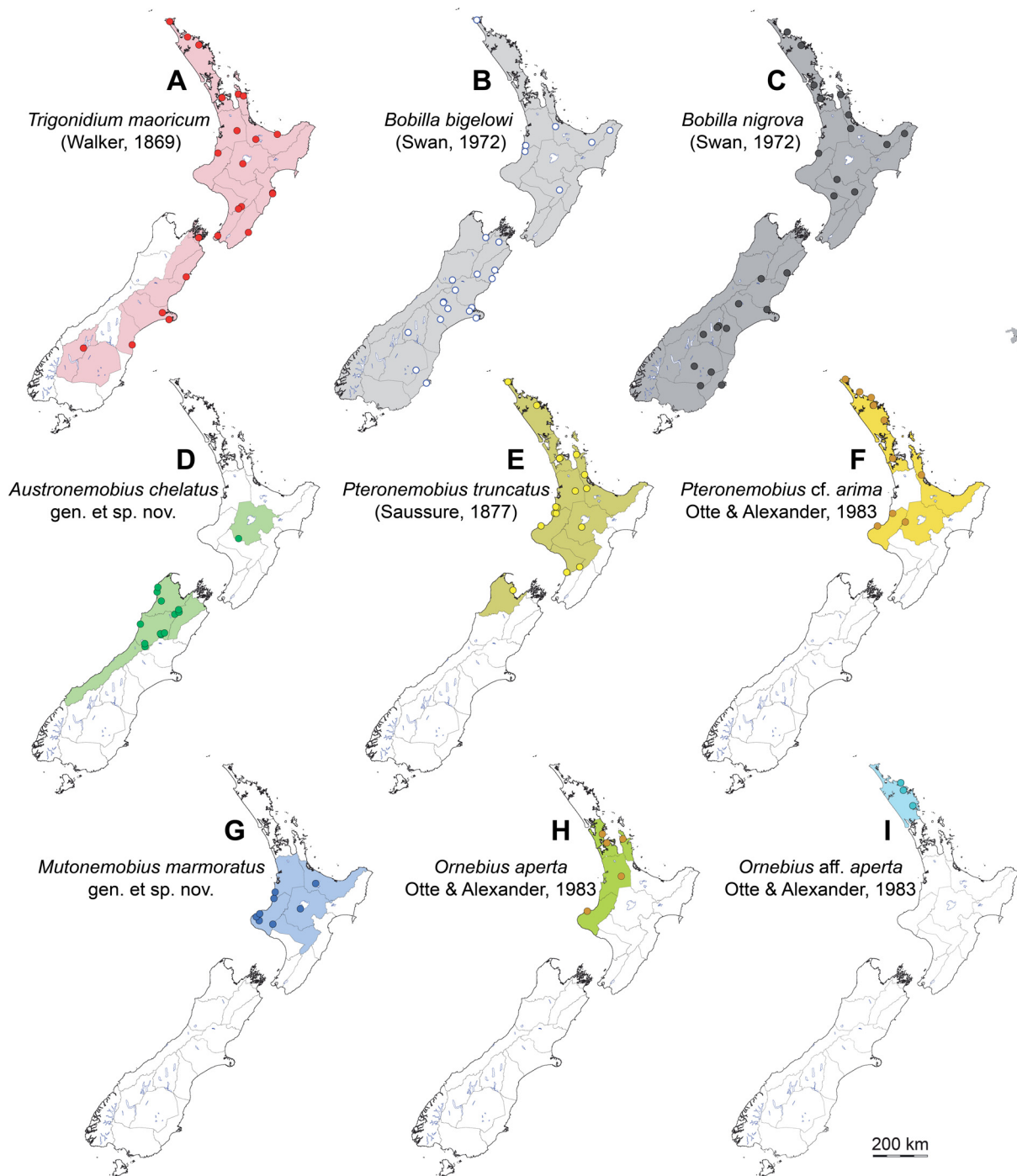
*Trigonidium maoricum* has large eyes projecting forward, the hallmark of a predator. Indeed, the closely related *T. (Metioche) vittaticollis* (Stål, 1877) is an important predator of pest insects in rice fields (Karindah *et al.* 2012). Studies conducted in rice fields in the Philippines have shown predation on nymphs and adults of the brown planthopper *Nilaparvata lugens* (Stål, 1854), on eggs of the northern armyworm *Mythimna separata* Walker, 1865, of the rice stemborer *Chilo suppressalis* (Walker, 1863) and of the rice leafroller *Cnaphalocrocis medinalis* (Guenée, 1854), and on disease carrying rice green leafhoppers (genus *Nephotettix* Matsumura, 1902) (Karindah *et al.* 2012). Spittlebugs and crambid moth eggs are likely to be among the most common prey of New Zealand trigs.

*Trigonidium (Metioche) vittaticollis* lays its eggs in the leaf sheath of rice and other herbaceous plants (Karindah *et al.* 2012). The European *Trigonidium (Trigonidium) cicindeloides* uses its serrated ovipositor to saw a slit into the stem of rushes (*Juncus* L.) and grasses inside which it lays its eggs (Ingrisch 1977). *Trigonidium maoricum* is likely to do the same, which explains why it is only found in wild meadows and grasslands, never in mown lawns. The egg of *T. maoricum* is rounded at the anterior extremity, which reaches deepest into the stem; it is flattened and thickened at the posterior end, which remains closest to the surface (Fig. 29I) (Ingrisch 1977).

Wingless adults of *Trigonidium maoricum* may be found at any time of the year. It seems highly likely that the insect can sustain multiple generations in a year. Winged specimens, however, are seen almost exclusively in February and March.

**Scaly crickets (family Mogoplistidae)**

Scaly crickets in the genus *Ornebius* established in New Zealand in two separate events. The first population was first detected in Paihia, Northland, in 1977; a second population was first detected in Auckland in 1989 (Ramsay 1990). The two populations remain separate today, although the geographical boundary between them has yet to be identified. Crickets belonging to the two populations can only be



**Fig. 38.** Map of New Zealand, showing the known distribution of taxa included in this study. Thin black lines indicate the boundaries of Crosby’s entomological regions (Crosby *et al.* 1998; Fig. 2). Coloured circles indicate the collection localities for the material examined.



identified by their song. While the Auckland population was identified as belonging to *Ornebius aperta* (Ramsay 1991), the Northland population (referred to as *Ornebius* aff. *aperta* in this work) remains unresolved.

*Ornebius aperta* was first described based on a specimen collected at Tamborine Mountain, Queensland, Australia (Otte & Alexander 1983), and is only known in its native range from the immediate vicinity of the above locality. A population has, however, established on the campus of the University of Western Australia in Perth (Gwynne *et al.* 1988), where its biology has been the subject of further studies (Andrade & Mason 2000). In New Zealand, *O. aperta* has also established in New Plymouth, Taranaki, in the Waikato Region, and in Coromandel.

*Ornebius* crickets are arboreal and nocturnal; they are active year round, including in winter. Males start singing before dark, especially on cloudy days. They are commonly heard in the foliage of trees, in urban parks, in residential gardens, and in hedges; they appear to be less common in native forests. *Ornebius* crickets can reach very high densities locally; as is often the case for invasive species, they are found in much higher numbers in New Zealand than they are in their home range in Australia (pers. obs.).

### **Wing geometry as a diagnostic character for species identification**

In this study, I explored the use of alternative measurements to disambiguate between species in the genus *Bobilla*, which are notoriously difficult to identify. Measurements analysed related to wing geometry, dimensions of the tympana, length of apical spines and intra-ocular distance. While most of these measurements showed statistically significant differences between species, one measurement in particular appears to be useful for the purpose of species identification; this is the ratio of two diagonals in the harp's posterior cell in a male cricket's right forewing (Fig. 1B). The values of the ratio PCSD/PCLD (Fig. 1B) in samples of *Bobilla nigrova* ( $N = 13$ ) and *Bobilla bigelowi* ( $N = 30$ ) collected on mainland New Zealand do not overlap, which means that this measurement alone achieved correct classification to species level with 100% accuracy. While this method still requires the use of a microscope, the ratio of the diagonals in the harp's posterior cell is much easier to obtain than the number of teeth in the stridulatory file, and it does not require removal of the right tegmen from the specimen. For the method to be used correctly, it is important that the wing is at an angle of  $90^\circ$  to the axis of the microscope. If measurements are taken at an angle other than  $90^\circ$ , the relative lengths of the diagonals are distorted, potentially leading to incorrect classification. While I have only employed this method in earnest in the disambiguation of *B. bigelowi* and *B. nigrova*, it also clearly differentiates between New Zealand specimens of *Pteronemobius* cf. *arima* ( $N = 14$ ) and putative *Pteronemobius arima* from Brisbane, QLD ( $N = 2$ ), suggesting that its application may be useful in the identification of other cryptic species of winged Nemobiinae.

The method has some solid theoretical foundations. The harp in a male cricket's forewing is the wing's main resonator (Nocke 1971; Bennet-Clark 1999; Montealegre-Z *et al.* 2009). The harp is therefore expected to be of key importance for the frequency of the song (Klingenberg *et al.* 2010). When two species of crickets sing at different frequencies, we should expect them to differ in the geometry of their harps.

Quantitative studies of the geometry of cricket wings are scarce. Klingenberg *et al.* (2010) used geometric morphometric shape analysis with 12 landmarks on the male forewings of *Gryllus firmus* Scudder, 1902 to test whether genetic and developmental integration evolve to match functional modularity. Geometric morphometric analysis of wings for the purpose of species classification has been used in other insect orders, e.g., in bees (order Hymenoptera), family Apidae Latreille, 1802 (Francoy *et al.* 2006) and Halictidae Thomson, 1869 (Landaverde-González *et al.* 2022), and in hoverflies (Diptera: Syrphidae) (Ačanski *et al.* 2023). Applications of the method for the purpose of species identification

in crickets however are lacking. In a different family of Orthoptera, Dowle *et al.* (2014) used geometric morphometric shape analysis with 14 landmarks on the pronotum of grasshoppers (family Acrididae) and achieved correct disambiguation of two closely related species, *Sigaus australis* (Hutton, 1898) and *S. childi* Jamieson, 1999.

I suggest that the quantitative analysis of male forewing geometry in Nemobiinae should be trialled more extensively to disambiguate between cryptic species. When a simple number like the ratio of the diagonals in the harp's posterior cell is not enough, geometric morphometric shape analysis is likely to prove successful.

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**Fig. S1.** *Pteronemobius truncatus* (Saussure, 1877), holotype, adult ♀ (MNHN EO-ENSIF10379). From unknown location in Australia. Images courtesy of Marion Depraetere, 2018, MNHN, reproduced under CC BY-NC-ND 4.0 licence.

**Fig. S2.** *Pteronemobius arima* Otte & Alexander, 1983, holotype, adult ♂ (ANIC14 008970). Collected by D. Otte and R. Alexander at Holmes Jungle, Palm Creek, NT, Australia, on 25 Nov. 1968. Images courtesy of Australian National Insect Collection, NRCA, CSIRO. © Commonwealth Scientific and Industrial Research Organisation, National Research. Collections of Australia [2023]. All Rights (including copyright) CSIRO (2023).

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**Fig. S3.** *Trigonidium maoricum* (Walker, 1869). **A–B.** Lectotype, adult ♂ (NHMUK 014666694). **C–F.** Paralectotypes, adult ♀♀. **C–D.** NHMUK 014666695. **E–F.** NHMUK 014666696. All photo credits: Beulah Garner, NHMUK.

**Fig. S4.** *Ornebius aperta* Otte & Alexander, 1983, holotype, adult ♂ (ANIC14 008971). Collected by D. Otte and R. Alexander at Tamborine Mountain, QLD, Australia, on 25 Feb. 1969. Images courtesy Australian National Insect Collection, NRCA, CSIRO. © Commonwealth Scientific and Industrial Research Organisation, National Research. Collections of Australia [2023]. All Rights (including copyright) CSIRO (2023). Licence: Creative Commons Attribution-Noncommercial 4.0 Licence.

**Table S1.** Material examined of *Bobilla nigrova* (Swan, 1972). All specimens collected in New Zealand. Collector abbreviations: DH = Danilo Hegg; DIS = D.I. Swan; SP = Samuel Purdie.

**Table S2.** Material examined of *Bobilla bigelowi* (Swan, 1972). All specimens collected in New Zealand. Collector abbreviations: AE = A. Edgar; DH = Danilo Hegg; DIS = D.I. Swan.

**Table S3.** Material examined of *Bobilla nigrova* × *bigelowi*. All specimens collected in New Zealand. Collector abbreviation: DH = Danilo Hegg.

**Table S4.** Material examined of *Austronemobius chelatus* gen. et sp. nov. All specimens collected in New Zealand. Collector abbreviations: DH = Danilo Hegg; DL = Dustin Lamont; JW = Jane Williams; MB = Mike Bowie; MT = Mike Thorsen; OD = Oscar Dove; ST = Steve Trewick; WF = Wendy Fox. ‘DOC Team’ included Jane Williams, Eric Edwards, Chris Green, Joyce Palmer and Danilo Hegg.

**Table S5.** Material examined of *Mutonemobius marmoratus* gen. et sp. nov. All specimens collected in New Zealand. Collector abbreviations: AG = Andrew Gray; DH = Danilo Hegg; DHOL = Dave Holland; ER = Emily Roberts; SM = Saryu Mae.

**Table S6.** Material examined of *Pteronemobius truncatus* (Saussure, 1877). All specimens collected in New Zealand, except for the holotype and paratypes, which originate from Australia. Collector abbreviations: CS = Christopher Stephens, DH = Danilo Hegg, EM = Dr Eric Mjöberg, GS = Grey Smith, JV = Jules Verreaux, MP = Mathieu Pélissié.

**Table S7.** Material examined of *Pteronemobius* cf. *arima* Otte & Alexander, 1983. All specimens collected in New Zealand, unless stated otherwise. Collector abbreviations: DH = Danilo Hegg; DO = Daniel Otte; RA = Richard Alexander.

**Table S8.** Material examined of *Trigonidium* (*Trigonidium*) *maoricum* (Walker, 1869). All specimens collected in New Zealand. Collector abbreviations: AMcA = Aimee MacArthur; BW = Benjamin Wright; CM = Carey McCollum; CW = Chris Winks; DC = Dianne Clarke; DH = Danilo Hegg; GS = Grey Smith; JC = John Charles; JS = James Stokes; KS = Kate Steeds; LB = Lisa Bennett; MB = Mike Bowie; SS = Shou Saito.

**Table S9.** Material examined of *Ornebius aperta* Otte & Alexander, 1983. All specimens collected in New Zealand, except for the holotype, which originates from Australia. Collector abbreviations: DH = Danilo Hegg; DO = Daniel Otte; HJ = Halema J; RA = Richard Alexander; SW = Saskia Wagner.

**Table S10.** Material examined of *Ornebius* aff. *aperta* Otte & Alexander, 1983. All specimens collected in New Zealand. Collector abbreviations: DH = Danilo Hegg.

**Table S11.** Material used in DNA analysis of sub-family Trigonidiinae Saussure, 1874 (Fig. 31). Abbreviation for institutions where the specimens are held are: ANSP = Academy of Natural Sciences, Philadelphia, USA; BIOUG = Centre for Biodiversity Genomics, Ontario, Canada; GVC = Research Collection of Graeme V. Cocks; MPN = Phoenix Lab, Massey University, New Zealand; NZAC = New Zealand Arthropod Collection, Auckland, New Zealand; PO = Research Center in Biodiversity and Genetic Resources, Universidade do Porto, Portugal.