Identification and distribution of *Arhopalus* species (Coleoptera: Cerambycidae: Aseminae) in Australia and New Zealand

Qiao Wang[1,3] and Richard A. B. Leschen[2]

[1] Institute of Natural Resources, Massey University, Private Bag 11 222, Palmerston North

[2] New Zealand Arthropod Collection, Landcare Research, Private Bag 92170, 120 Mt Albert Road, Auckland

[3] Corresponding author: Wang@massey.ac.nz

Abstract

Arhopalus is a Northern Hemisphere cerambycid genus, mainly associated with coniferous plants, particularly *Pinus* and *Picea*. In the past few decades, three of its species were unintentionally introduced to the Australasian region: *A. rusticus* (Linnaeus), *A. syriacus* (Reitter), and *A. ferus* (Mulsant). An illustrated key to the three species, diagnoses for the genus and species, and biology and distribution of each species are provided. Morphometrics and sexual dimorphism were analysed using ANOVA, providing useful means for sex and species identification when specimens are incomplete or when diagnosticians are not familiar with *Arhopalus*.

Introduction

Arhopalus (a member of the subfamily Aseminae) is a large and diverse Northern Hemisphere cerambycid genus with about 25 species and subspecies and now occurs in all major biogeographic regions of the world through the spread of commerce (Aurivillius, 1912; Linsley, 1962; Chemsak and Linsley, 1965; Hua, 1982; Bense, 1995). Known host records show that *Arhopalus* is mainly associated with coniferous plants, particularly *Pinus* and *Picea* (Bense, 1995). Some *Arhopalus* species are important pests of processed or fired damaged *Pinus* around the world (Linsley, 1962; Duffy, 1968; Hosking & Bain, 1977; Bradbury, 1998).

During the last century, at least three species of *Arhopalus* (*A. syriacus* (Reitter), *A. ferus* (Mulsant), and *A. rusticus* (Linnaeus)) were introduced to Australia and New Zealand, causing damage to sickly and dead pines, and more importantly, creating political problems in the timber trade between these two, and other countries. However, the identification of many specimens in museums and research collections in Australia and New Zealand seemed questionable and the current geographic distribution of these introduced species was poorly known. Furthermore, there was no reliable key for identifying *Arhopalus* beetles found in Australasia. These problems have made it difficult for New Zealand authorities to respond quickly to the detection of *Arhopalus* on imported material and to assess the risk posed to New Zealand by Australian timber and *vice versa*. Therefore, there was an urgent need for a reliable and user-friendly key to identify *Arhopalus* beetles established in Australia and New Zealand and for information on their current distribution in these two countries. This study clarifies the identity and distribution of the *Arhopalus* species in Australasia.

Materials and Methods

For this research all Australian museums were visited and major New Zealand insect collections contacted for *Arhopalus* specimens. Specimens were borrowed from, or examined in, following collections.

Australia: Australian Quarantine and Inspection Service (AQIS, Melbourne, G. Maynard); AQIS (Sydney, R. Richard); Diagnostic Services, Department of Primary Industries, Water and Environment (New Town, O. Seeman); Environment Forest Science Centre and Forestry Commission of New South Wales Insect Collection (Sydney, D. Kent); South Australia Museum (Adelaide, E. Matthews); University of Adelaide, South Australian Research and Development; Victoria Department of Natural Resources and Environment Forest Science Centre (Melbourne, I. W. Smith).

New Zealand: Auckland War Memorial Museum (J. Early and S. Thorpe); Entomology Research Museum Lincoln University (Lincoln, J. Marris); Museum of New Zealand Te Papa Tongarewa (Wellington, R. Palma and P. Sirvid); New Zealand Arthropod Collection (Auckland, NZAC); Nunn Private Insect Collection (Dunedin, J. Nunn).

Distributional records of *A. ferus* in New Zealand were obtained from the Ministry of Agriculture and Food (MAF) woodborer/bark beetle survey in

2000/2001, which was collated by J. Hutcheson and sent to us for inclusion in our study: voucher specimens were deposited in the NZAC. Specimens were compared with material borrowed from the following museums in Europe and North America: Hunterian Museum, Glasgow University (Scotland, G. Hancock); INRA-ENSA UFR d'Ecologie Animale et de Zoologie Agricole (Montpellier, France, C. Cocquempot); Institute of Entomology, Czech Academy of Sciences (Ceske Budejovice, P. Svacha); Mehl Private Insect Collection (Copenhagen, Denmark, O. Mehl); Sama Private Insect Collection (Sesena, Italy, G. Sama); United States National Museum, Smithsonian Institution (Washington, D.C., S. Lingafelter); Zoological Museum, University of Copenhagen (Denmark, O. Martin).

To determine sexual dimorphism in external morphology and to enable correct identification of incomplete specimens (such as specimens without head, abdomen, or antennae), we made extensive measurements of 30 specimens of each sex for every Australasian *Arhopalus* species. We randomly selected specimens from Europe, North America, Australia and New Zealand for measurement. Measurements were made under a stereomicroscope using an ocular micrometer. All lengths are given at their longest dimensions (i.e., the length of the elytra is between the shoulder and apex). Morphometric relationships between antennal and elytral length were analysed by regression analysis. All other data were analysed using ANOVA. Means were separated using LSD and rejection levels were set at $P > 0.05$. All analyses were carried out on SAS (SAS 1996).

Taxonomy

Arhopalus species in Australia and New Zealand

Diagnosis. *Arhopalus* is the only asemine genus occurring in Australasian region and can be distinguished from other Australasian longhorn beetles by: mesonotum with a finely striated stridulatory plate divided by a median vitta; front coxal cavities open behind and intercoxal process not dilated at apex; mesocoxal cavities open and in contact with the mesepimeron; head very short; antennal segment 2 longer than wide and nearly 1/2 as long as segment 3; eyes slightly emarginate; front tibia with 1 apical spur.

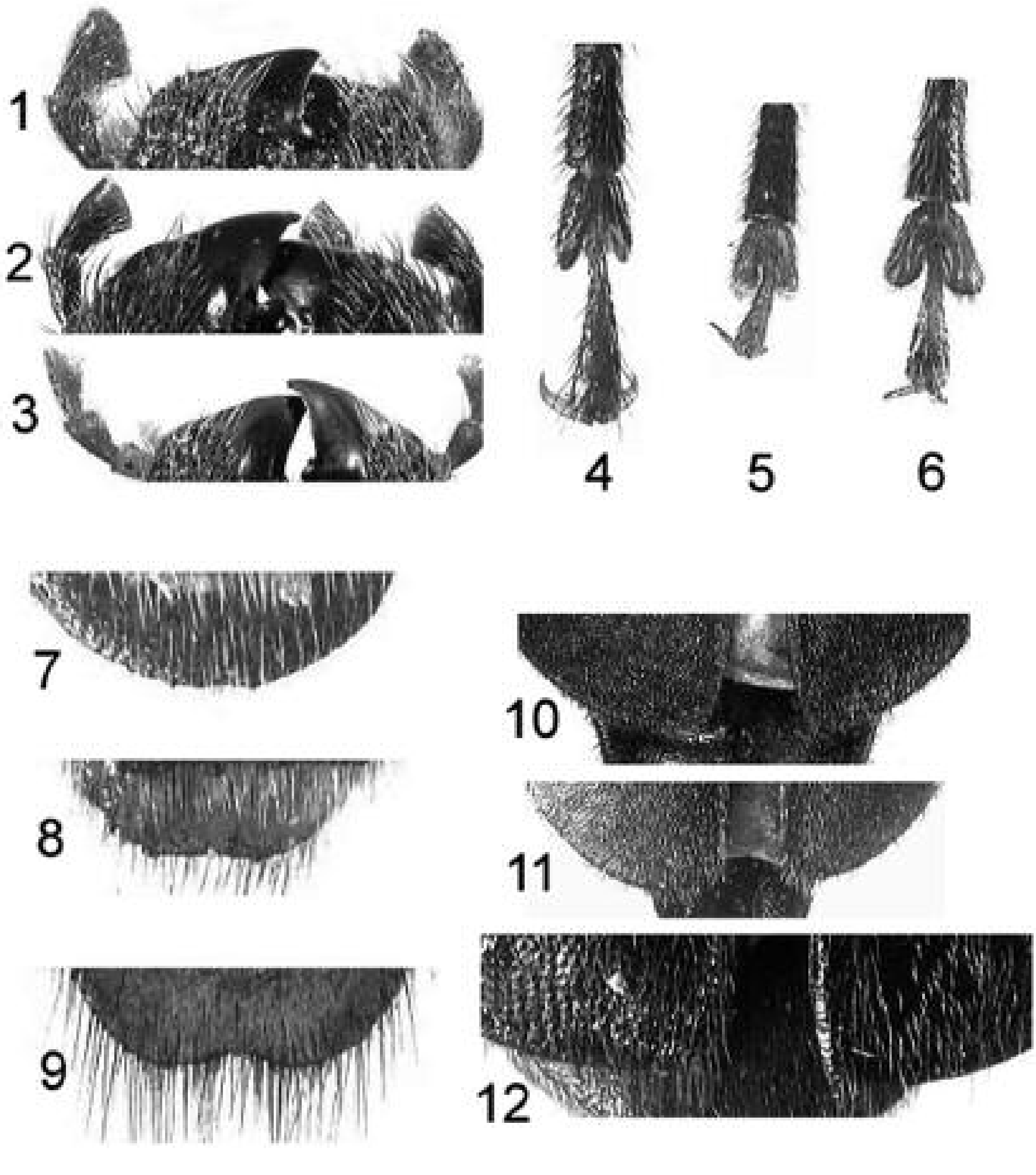
Species taxonomy. All three species are very similar in body form (Figs. 13, 14) and differ in characters that must be examined with a dissecting microscope. Otherwise subtle body proportions and structures (which vary among specimens of each species) must be measured for species identity (see below). Comparison of Australasian specimens with authenticated specimens from European and American museums confirmed that the Australian species are *A. rusticus* and *A. syriacus*, and the New Zealand species is *A. ferus*.

Aurivillius (1912) synonymised *A. tristis* (= *Callidium triste* Fabricius) with *A. rusticus*. Prior to our study, Silfverberg (1979) and Sama (1991) re-examined the types and concluded that *A. tristis* should be synonymised with *A. rusticus*. Our examination of the male type specimen of *A. tristis* and authentic European specimens of *A. rusticus* confirms that *A. tristis* is a synonym of *A. rusticus* and therefore, the name *A. tristis*, widely used in New Zealand over the past twenty or so years, is erroneous.

Apart from morphological similarities, these three species have many traits in common, for example, all of them attack dead or dying coniferous trees and the nocturnal adults are attracted to light (Bense 1995). Below we summarise the distribution and biology of all of the species and the following key can be used to identify these three species (modified from Spilman, 1977 and Bense, 1995).

Key to Australasian species of *Arhopalus*

1. Third segment of tarsus incised apically to about 1/2 its total length (Fig. 4); male eighth tergite strongly emarginated (Fig. 9) . . . . *A. ferus*
   Third segment of tarsus incised almost to base (Figs 5,6) 2
2. Terminal segment of maxillary palpus strongly securiform, with length 1 to 1.26 times its apical width (Fig. 1); elytra with sutural angles always rounded (Fig. 11); male eighth tergite slightly emarginate at apex (Fig. 8) .... *A. syriacus* (Figs 13, 14)
   Terminal segment of maxillary palpus slightly widened apically, with length 1.34-1.39 times its apical width (Fig. 3); elytra with sutural angles usually angulate, sometimes with a weak spine (Fig. 12); male eighth tergite rounded at apex (Fig. 7) .... *A. rusticus*



Figs. 1-12. *Arhopalus* spp.: diagnostic characters. **1-3.** Maxillary palps. **1,** *A. syriacus*; **2,** *A. ferus*; **3,** *A. rusticus*. **4-6.** Tarsi. **4,** *A. ferus*; **5,** *A. syriacus*; **6,** *A. rusticus*. **7-9.** Apices of eighth tergites of males. **7,** *A. rusticus*; **8,** *A. syriacus*; **9,** *A. ferus*. **10-12.** Elytral apices. **10,** *A. ferus*; **11,** *A. syriacus*; **12,** *A. rusticus*.

Arhopalus ferus (Mulsant)

(Figs 2,4,9,10)

Diagnosis. Body 8.3-27 mm in length and reddish brown to black in colour; terminal segment of maxillary palpus moderately widened apically, with length 1.27-1.29 times its apical width; segment 3 of hind tarsus incised apically to about $1/2$ its total length; elytra with rounded sutural angles; male eighth tergite deeply emarginate at apex.

Biology. This species attacks mainly dead or dying *Pinus* and *Picea* injured by fire or other damage (Duffy 1968, Hosking and Bain 1977) but will occasionally attack growing and apparently quite healthy trees (Duffy 1968). It needs 3 to 4 years to complete its lifecycle in Europe and adults can be found from early summer to early autumn (Duffy 1968; Bense 1995). In areas with mild weather such as New Zealand, its lifecycle can be as short as 1 to 2 years (Hosking and Bain 1977).

Distribution. This species is widely distributed in most parts of Europe except northern Europe, and in North Africa (Duffy 1968, Bense 1995). It was first reported to occur in Australasia in 1970 by Milligan (1970). *Arhopalus ferus* has established only in New Zealand in Australasia, distributed throughout the country except most of Otago, Fiordland, and Stewart Island.

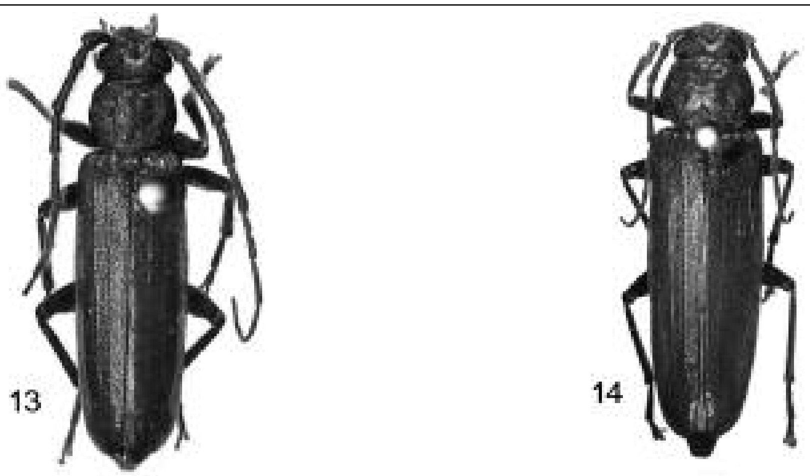
Arhopalus rusticus (Linnaeus)

(Figs 3,6,7,12)

Diagnosis. Body 10.3-28.6 mm in length and light brown to dark brown in colour; segment 3 of tarsus incised almost to base; terminal segment of maxillary palpus slightly widened apically, with length 1.34-1.39 times its apical width; elytra with sutural angles usually angulate, sometimes with a weak spine; male eighth tergite rounded at apex.

Biology. *Arhopalus rusticus* is a common species in pine forests of Europe and North Africa and it also develops in other trees (*Picea, Abies, Larix, Cupressus, Cryptomeria, and Juniperus*) (Cheo 1935, Duffy 1968, Bense 1995). It mainly attacks dead or heavily stressed trees (Bense 1995) and occasionally damages structural timbers (Duffy 1968). Smith (2001) reported a mass death of mature pine trees in Melbourne between 2000 and 2001 and its possible association with the transmission of a nematode disease (*Bursaphelenchus* sp.) by newly introduced *A. rusticus*. Lifecycle is between 2 and 3 years and adults are active in summer and autumn (Bense 1995).

Distribution. This species occurs throughout Europe, North Africa (Bense 1995) and Asia (Hua 1982). It was first introduced to Australasia between late 1990s and 2000, and is currently only found in Melbourne (Smith 2001). No evidence for establishment of *A. rusticus* in other Australian states has been found but according to its wide distribution in Northern Hemisphere, it may have potential to spread to and establish in other states of Australia.



Figs. 13, 14. *Arhopalus syriacus*: **13,** male; **14,** female.

***Arhopalus syriacus* (Reitter)**
(Figs 1,5,8,11,13,14)

Diagnosis. Body 11.4-22.1 mm in length and yellowish brown to dark brown; segment 3 of tarsus incised almost to base; terminal segment of maxillary palpus strongly securiform, with length as long as or slightly longer than its apical width; elytra with sutural angles always rounded; male eighth tergite slightly emarginate at apex.

Biology. This species develops mainly in pines (*Pinus pinaster, P. salzmanni, P. laricio, P. halepensis, P. radiata, and P. elliottii*) (Bense 1995, Webb & Eldridge 1997). It attacks pine trees debilitated or killed by fire or other damage with no evidence of injuring healthy trees (Moore 1963). Lifecycle lasts 1 to 3 years and adults occur in spring to late summer (Webb & Eldridge 1997).

Distribution. In comparison to the other two species, *A. syriacus* has a much narrower distribution range in Europe, only occurring in southern Europe along the Mediterranean region (Bense 1995) and Middle East (note that we have examined only one specimen from Israel). This species has established in New South Wales in forests around Sydney since late 1950s (Webb and Edridge 1997). Based on our study it hasn't spread from this area, suggesting that its distribution is limited.

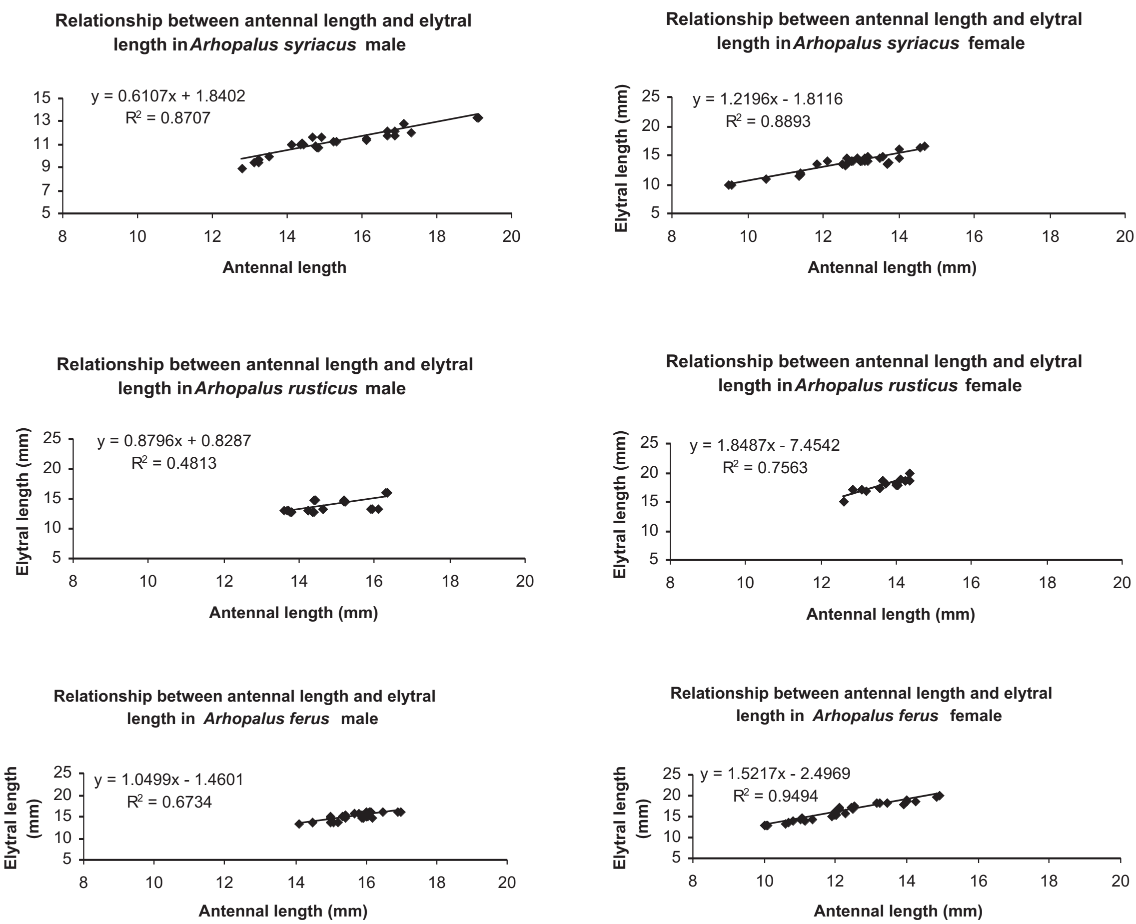


Fig. 15. Morphometric relationships between antennal and elytral length of Australasian *Arhopalus*.

Morphometric Analysis and Sexual Dimorphism

Body size between individuals varies greatly, and is a poor character for species and sex identification. However, proportional relationships between body parts were found to be very stable between species and/or between sexes (Table 1). These parameters are particularly useful for sex and species identification when specimens are incomplete or when diagnosticians are not familiar with *Arhopalus*.

Antennal scape length/scape width ratio (sl/sw) is correlated with species and sex. In females the sl/sw ratio is always significantly greater than that in males for all three species. If sex is known the sl/sw ratio of *A. ferus* is significantly greater than the ratio in *A. syriacus* and *A. rusticus* ($F = 62.85$; $df = 5, 174$; $P < 0.0001$). The antennal scape length/segment 2 length ratio (sl/s2) is also significantly different between sexes as well as among species, being the greatest in *A. rusticus* females and smallest in *A. syriacus* males ($F = 117.21$; $df = 5, 174$; $P < 0.0001$).

Both sexes of *A. ferus* have similar pronutom length/pronotum width ratio (pnl/pnw) ($P > 0.05$). However, in *A. rusticus* and *A. syriacus*, males have significantly greater pnl/pnw ratio than females, and pnl/pnw ratio is greatest in *A. ferus* and smallest in *A. rusticus* ($F = 71.71$; $df = 5, 174$; $P < 0.0001$). There are no sexual differences in elytral length/shoulder width (el/shw) ratio for all three species ($P > 0.05$) but el/shw ratio in *A. ferus* is significantly smaller than in *A. syriacus* and *A. rusticus* ($F = 22.86$; $df = 5, 174$; $P < 0.0001$).

Antennal length/elytral length (al/el) ratio is very useful in both sex and species identification (Fig 15) because it is significantly different between sexes as well as between the species ($F = 800.39$; $df = 5, 174$; $P < 0.00001$), with the antenna in males always longer than the elytra while the antenna in females is shorter than elytra: *A. syriacus* has the greatest al/el ratio.

There is no sexual difference in maxillary palp terminal segment length/ maxillary palp terminal segment width ratio (mpl/mpw) for *A. ferus* ($P > 0.05$). However, in *A. syriacus* and *A. rusticus*, male mpl/mpw ratio is significantly smaller than that in the female, and *A. syriacus* has significantly smaller mpl/mpw ratio than *A. ferus* male and *A. rusticus* ($F = 154.07$; $df = 5, 174$; $P < 0.0001$).

Table 1. Species comparison and sexual dimorphism (means ± SD)*

Species and sex	sl/sw	sl/s2	pnl/pnw	el/shw	al/el	mpl/mpw
A. ferus male	2.158 ± 0.103a	1.532 ± 0.094a	0.787 ± 0.022a	2.583 ± 0.060a	1.047 ± 0.035a	1.272 ± 0.056a
A. ferus female	2.316 ± 0.097b	1.743 ± 0.092b	0.771 ± 0.031ab	2.622 ± 0.115a	0.761 ± 0.028b	1.289 ± 0.051ab
A. syriacus male	1.921 ± 0.062c	1.435 ± 0.109c	0.769 ± 0.036b	2.766 ± 0.131b	1.359 ± 0.056c	1.085 ± 0.054c
A. syriacus female	2.305 ± 0.151b	1.611 ± 0.097d	0.743 ± 0.023c	2.816 ± 0.107bc	0.932 ± 0.039d	1.262 ± 0.041b
A. rusticus male	1.973 ± 0.111c	1.859 ± 0.094e	0.709 ± 0.035d	2.743 ± 0.080c	1.072 ± 0.060e	1.348 ± 0.029d
A. rusticus female	2.200 ± 0.140a	1.944 ± 0.108f	0.658 ± 0.037e	2.727 ± 0.103c	0.769 ± 0.032b	1.395 ± 0.045e

* sl = scape length, sw = scape width, s2 = segment 2 length, pnl = pronotum length, pnw = pronotum width, el = elytral length, shw = shoulder width (width of two elytra at shoulder), al = antennal length, mpl = length of maxillary palp terminal segment, mpw = width of maxillary palp terminal segment. Means with the same letter in column are not significantly different (ANOVA, means were separated by LSD, $P > 0.05$).

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