

Phylogenetic relationships within the genus *Cranothrips* (Thysanoptera, Melanthripidae) with consideration of host associations and disjunct distributions within the family

VERONICA PEREYRA¹ and LAURENCE A. MOUND²

¹CONICET-Instituto Superior de Entomología “Dr Abraham Willink”, Tucumán, Argentina and ²CSIRO Entomology, Canberra, Australia

Abstract. A phylogenetic analysis of the Melanthripidae genus *Cranothrips* Bagnall is presented. A data matrix with continuous and discrete characters was analysed under parsimony criteria. Continuous and discrete characters were analysed, separately and in combination. When the different blocks of characters were analysed separately, important differences in tree topologies occurred. The optimal tree obtained from discrete characters alone was similar to the tree resulting from total evidence. For most groups, the support values resulting from all the evidence analysis were higher than those obtained from the discrete-only analysis. Two new species from Australia are described and illustrated, *Cranothrips ibisca* sp.n. and *Cranothrips conostylus* sp.n. A key to the 12 species in the genus is provided. Additionally, the host associations and the distributional patterns of the four worldwide genera of Melanthripidae are discussed.

Introduction

Among the nine families that comprise the insect order Thysanoptera (Mound & Morris, 2007), the species of Melanthripidae, Merothripidae and Aeolothripidae retain several plesiomorphies that have been lost in all the members of the other six families. Biologically, these three families represent strikingly different radiations, in that Merothripidae species are fungus feeders, Melanthripidae are flower feeders, and Aeolothripidae are usually facultative, or even obligate predators on other arthropods in flowers or on leaves. The family Aeolothripidae is distinguished from the other two primarily because females have completely lost the eighth abdominal sternite. In Merothripidae and Melanthripidae, this sternite is retained on the posterior margin of the seventh sternite as a pair of lobes, with two associated pairs of setae.

For many years, the ‘Melanthripinae’ was considered a subfamily of the Aeolothripidae, primarily because all the species have similar, relatively broad, fore wings with

several cross veins. In that classification, melanthripine species were distinguished from aeolothripine species by the presence of long setae on the pronotum. More recent studies have demonstrated not only the sternite difference indicated above, but have recorded melanthripids with pronotal setae no longer than those of typical aeolothripids (Mound & Marullo, 1998). In contrast, distinguishing the Melanthripidae from the Merothripidae continues to prove difficult, with no unequivocal autapomorphy recognized, although the general habitus of the members of these two families, in addition to their feeding habits, are very different.

The family Melanthripidae comprises four extant genera, and each exhibits a remarkable discontinuity in geographical distribution. These discontinuities suggest that the radiation within these genera is relatively ancient. The primary objective of this study was to explore the relationships within one of these genera, *Cranothrips* Bagnall, and to consider the position of two new species from Australia described below. Moreover, given that all of the species are phytophagous, and at least some are monophagous, we attempted to look for correlations with host plant systematics, and to consider these in the context of the four genera recognized worldwide in the Melanthripidae.

Correspondence: Veronica Pereyra, CONICET, Instituto Superior de Entomología ‘Dr. Abraham Willink’, Miguel Lillo 205, Tucumán, Argentina. E-mail: vpereyra@csnat.unt.edu.ar

The present analysis made use of quantitative characters, in addition to the (standard) discrete characters. The use of continuous characters in phylogenetic analysis has been very controversial (e.g. Baum, 1988; Stevens, 1991; Rae, 1998). Most of the methods proposed to analyse this kind of character (Thiele, 1993; Wiens, 1998, 2001; Goloboff *et al.*, 2006) convert the continuous variation inherent to those characters into a series of discrete states, which is inherently problematic (Goloboff *et al.*, 2006). Perhaps the worst problem with these methods is that they can assign the same character state to terminals that differ significantly, or attribute different states to terminals that do not differ significantly (Farris, 1990). In recent years, a new implementation for analysis of continuous characters in phylogenetic reconstruction was included in the computer program TNT (Goloboff *et al.*, 2008). As noted by Goloboff *et al.* (2006), continuous characters are simply regular additive characters, and can thus be optimized using standard algorithms for optimization of additive characters (Farris, 1970; Goloboff, 1994). These algorithms are defined in terms of intervals (= ranges) and therefore no modification is needed for their application (Goloboff *et al.*, 2006). If more variable terminals are assigned wider ranges (e.g. mean plus or minus a standard deviation), then the ranges of terminals that do not differ significantly do not overlap (i.e. requiring no steps), and vice versa. Goloboff *et al.* (2006) observed that, when continuous characters are analysed as such, they seem to carry useful phylogenetic information, as measured by an increase in group supports relative to the discrete characters alone. In this study, we evaluated the influence of continuous characters in the degree of resolution and support in *Cranothrips* phylogeny, using the method implemented in TNT (Goloboff *et al.*, 2006, 2008).

Materials and methods

Taxon sampling

Sixty-eight specimens (males and females) were used for this study, representing the ten described species of *Cranothrips*, together with two new species described here (see Table 1). Information on females only was included for *Cranothrips poultoni*, *Cranothrips ibisca* **sp.n.** and *Cranothrips conostylus* **sp.n.** because males of these three remain unknown. The taxa used for the tree rooting were *Melanthrips fuscus* and *Melanthrips nigricornis*. This genus is the most diverse of the four genera comprising the Melanthripidae, and displays several traits that may support the assumption that it is the 'basal group' of this family, as sister group to the remainder of the taxa (Mound & Morris, 2007).

Character coding

Forty-two morphological characters were coded (see Supporting Information S1, S2), most of which had been

Table 1. Material examined for the analysis (number and sex) and depositaries.

Species	Number/sex	Depositary
<i>Melanthrips fuscus</i>	3♀ 4♂	ANIC/SMF
<i>Melanthrips nigricornis</i>	1♀ 1♂	MCNLP
<i>Cranothrips bellisi</i>	4♀ 4♂	ANIC
<i>Cranothrips emersoni</i>	2♀ 1♂	ANIC
<i>Cranothrips kartus</i>	3♀ 2♂	ANIC
<i>Cranothrips karoensis</i>	3♀ 3♂	SMF
<i>Cranothrips lauriei</i>	2♀ 2♂	ANIC
<i>Cranothrips conostylus</i>	3♀	ANIC
<i>Cranothrips poultoni</i>	2♀	ANIC
<i>Cranothrips ravidus</i>	3♀ 3♂	ANIC/MCNLP
<i>Cranothrips ibisca</i>	2♀	ANIC
<i>Cranothrips sititor</i>	6♀ 2♂	ANIC/MCNLP
<i>Cranothrips symoni</i>	3♀ 3♂	ANIC
<i>Cranothrips vesper</i>	5♀ 1♂	ANIC/MCNLP

ANIC, Australian National Collection; CSIRO Entomology, Canberra; MCNLP, Museo de Ciencias Naturales de La Plata; SMF, Senckenberg Museum Frankfurt.

used previously to distinguish *Cranothrips* species (Bagnall, 1915; Mound, 1972; Mound & Marullo, 1998). Also included in the present analysis were characters used in the generic definition, as well as potentially informative new characters.

Intraspecific variation within the order Thysanoptera may involve differences in size, coloration and the sculpture pattern on certain structures. In *Cranothrips*, such variation is evident within one sex as well as between sexes. However, sexual dimorphism is less obvious within the Melanthripidae than among many other Thysanoptera (Tyagi *et al.*, 2008).

Some characters used corresponded to ratios of several structures, such as antennal segments or thoracic setae. Many of these ratios present values that either overlap or are very close to one another. The continuous characters used corresponded to ratios between the length and the width of the pronotum, head, mesosternellum, antennal and abdominal segments, maxillary palps and thorax setae with one another (see Supporting Information S1). We found that allometry still played a role, even if ratios are supposed to handle this. Most of the continuous characters used in the analysis are new, the rest are characters used currently in taxonomy as discrete characters, such as ratios between antennal segments with one other. The measurement units used were microns (μm), and figures are given to two decimal places. The measurements used were not chosen at random, but were those that seemed to show some correlation with taxonomic groupings.

All continuous characters were rescaled between 0 and 2 to diminish the influence of measures of parts of very different sizes (in addition, the analysis used implied weighting, which often diminished problems due to different scales; Goloboff *et al.*, 2006).

Intraspecific variation was taken into account by assigning to each species its mean value, plus or minus their standard deviation. Despite this variation, the values

obtained were mainly constant for each species, and the deviations were minimal. Sexual dimorphism was not always evident in all the species of the internal group; for this reason, with characters presenting slight sexual dimorphism (i.e. minor differences between measurements of males and females) the measurements for males and females were pooled; those characters where the male–female differences were significant (12 of 18) were treated by coding male and female measurements separately. Thus, five continuous characters with male–female information, five male-only characters, and five female-only characters were coded (see Supporting Information S1, S2).

One of the criticisms of continuous characters is that statistical parameters, such as the mean and standard deviation, have no cladistic meaning (Cranston & Humphries, 1988) when it comes to higher taxa. The use of such characters, however, may be warranted at low taxonomic levels (as is the case for this analysis), because within-taxon variation is more likely to correspond merely to phenotypic differences rather than genetic differences due to actual cladogenesis (Goloboff *et al.*, 2006).

Regarding discrete characters, the relative position of the mesonotal medial and lateral setae (Figs 11, 18, 19), as well as the sculpture pattern of the mesonotum and metanotum, are potentially informative. Because of this, they were included here as characters 28, 29 and 30. The metanotal sculpture pattern (Figs 11, 18, 19), but not that of the mesonotum, was

coded as non-additive, given that no relative degrees of similarity could be established between states.

Most of the material studied had been cleared (in NaOH solution) prior to being slide mounted. Although the original coloration was therefore lost, the pattern of clear and dark areas in certain structures (such as antennae and wings) remained (Figs 5–8). This was coded and included in the analysis. In order to code antennal coloration, segments I and II were taken as a unit because they showed joint variation; the rest of the segments were considered separately.

Intraspecific variation of discrete characters within one sex is represented by polymorphic characters in the matrix (Supporting Information S2). Therefore, species with more than one state for a unique character were included. Discrete characters presenting sexual dimorphism (i.e. different states for males and females) were treated by coding male and female characters separately.

Phylogenetic analysis

The data matrix (Supporting Information S2) was analysed using implied weighting (implemented in TNT ver. 1.1.; Goloboff *et al.*, 2008), under four concavity values (i.e. $K = 4–7$). Relative Bremer support (Goloboff & Farris, 2001) and symmetric resampling (Goloboff *et al.*, 2003) were used as support measures. The relative Bremer support was

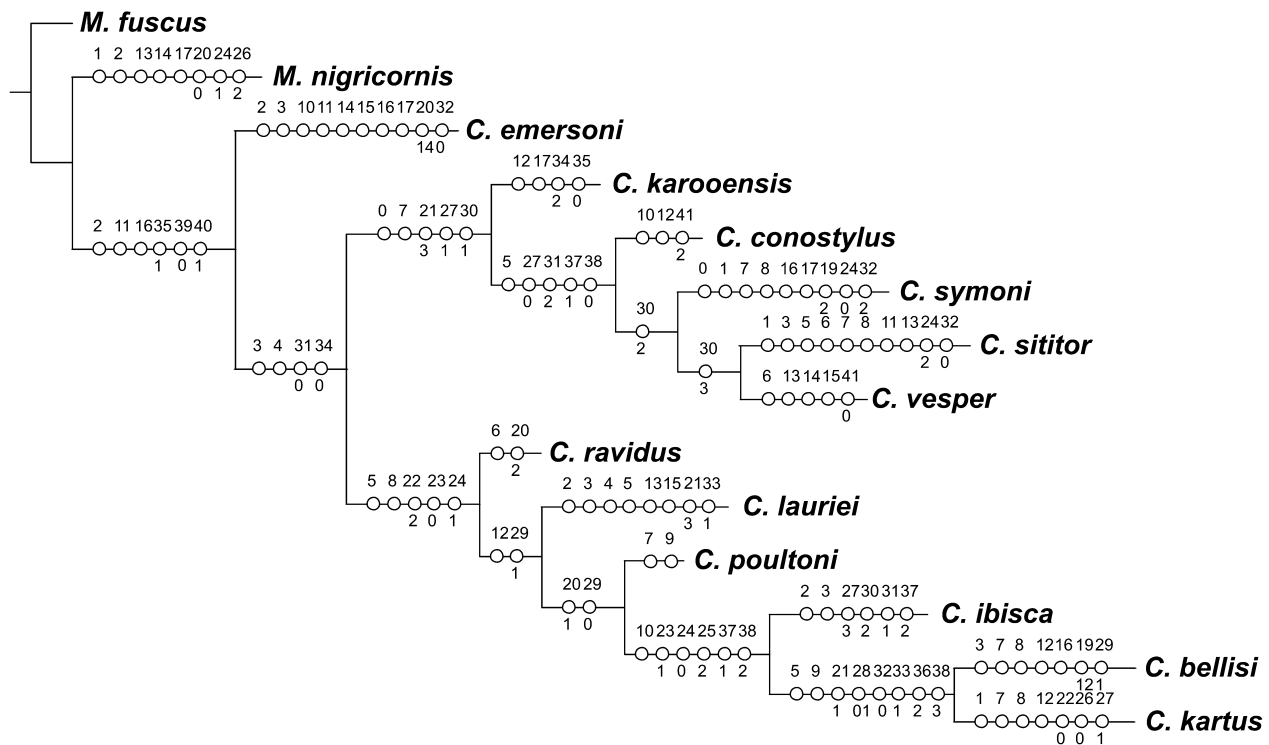


Fig. 1. *Cranothrips* relationships, optimal tree from the parsimony analysis. The numbers on the branches indicate the character and state synapomorphies that support each branch.

calculated from 5449 suboptimal trees, found in nine rounds, searching in each round 1000 additional trees with a fit up to 0.1 units lower than the previous trees; searching in nine rounds precludes the overestimation of supports for weakly supported groups. Symmetric resampling was calculated using 20 random addition sequences for each replication (1000 in total) followed by tree bisection–reconnection and keeping five optimal trees per random addition sequence.

Phylogenetic results

The same tree was obtained under the entire range of concavities used, and is referred to as the optimal tree (Fig. 1).

One group of species, *Cranothrips kartus*, *C. bellisi*, *C. symoni* and *C. sititor*, whose main characteristic is to have few or no long setae on the head and pronotum (Mound & Marullo, 1998), appeared as paraphyletic (Fig. 1), and each of these four species is considered to be host specific. *Cranothrips kartus* and *C. bellisi* appeared as the apical group of the tree, *C. ibisca* being the sister species of both. The characters that supported the clade that contains these three species, together with *C. ravidus*, *C. lauriei* and *C. poultoni*, were the length–width mesosternellum ratio (character 5), interocellar setae and posterior ocellus length ratio in males (character 8), the sensoria on antennal segment III/IV that reaches half the apical diameter (character 22), the sensoria without internal marks in antennal segments III/IV (character 23) and the postocular setae pair II–IV developed or any pair of setae developed (character 24). *Cranothrips sititor* appears to be a sister species to *C. vesper* (Fig. 1), and these two, together with

C. karoensis, *C. conostylus* and *C. symoni*, were grouped on the length–width pronotum ratio (character 0), interocellar setae and posterior ocellus length ratio in females (character 7), the pale coloration of antennal segment IV (character 21), posterior third of mesopreepisternum fused (character 27), the mesonotum with microtrichia (character 30). This group had only medium support (Fig. 2), unlike the previous one where only the node *C. kartus* + *C. bellisi* had high values for both support measures (Fig. 2). The rest of the nodes in this clade showed low values under resampling, which indicates that these groups might easily disappear if new evidence were to be included. On the contrary, the values of relative Bremer support were medium to high, thus indicating that there were no characters directly contradicting the groups. As for *C. emersoni*, it was the sister group of all the other *Cranothrips* species (Fig. 1), which formed a group with medium support for both support measures (Fig. 2).

To evaluate the congruence between the discrete and continuous data sets (Supporting Information S2) they were also analysed separately. The groups obtained in the analysis of discrete characters alone were identical to the tree based on all the evidence, but the groups obtained for continuous characters alone were quite different (Fig. 3). The strict consensus of both trees was completely unresolved. Comparing similarity measures for the observed pair of trees (i.e. optimal trees for discrete and continuous data sets) suggests that the differences were significant. The agreement subtree of the trees for the discrete and continuous data sets had only seven taxa (Fig. 4); out of 10 000 pairs of random trees (with 14 taxa), 32.6% had agreement subtrees with seven or more taxa, indicating that obtaining identical relationships for seven out of 14 taxa by chance is rather likely. A similar assessment was obtained by comparing the

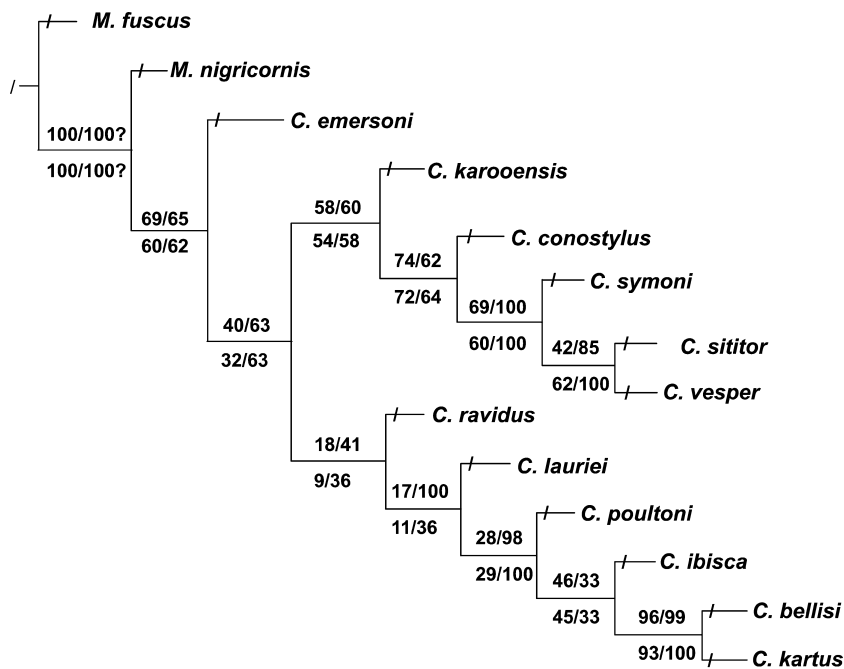


Fig. 2. Support measures for the optimal tree obtained in the analysis of all the evidence and discrete characters alone. The numbers on the branches indicate values of symmetric re-sampling and relative Bremer support for the groups supported by the discrete-only data set (below branches), and when the continuous characters are added (above branches).

Table 2. Distribution and host associations of *Cranothrips* species.

Species and authority	Localities	Host association
<i>bellisi</i> Mound & Marullo, 1998	NT: Darwin; Torres Strait Is.	<i>Calytrix</i> (Myrtaceae)
<i>conostylus</i> sp.n.	WA: Perth	<i>Conostylus</i> (Haemodoraceae)
<i>emersoni</i> Girault, 1929	Qld: Brisbane, Idalia	<i>Thryptomene</i> (Myrtaceae)
<i>ibisca</i> sp.n.	Qld: Lamington	<i>Pentaceras</i> (Rutaceae)
<i>kartus</i> Mound, 1972	WA: Perth, Cervantes, Geraldton; Barrow Island	<i>Beaufortia</i> ; <i>Calothamnus</i> (Myrtaceae)
<i>lauriei</i> Marullo, 1995	NT: Tennant Creek; WA: Lake Grace	<i>Hakea</i> (Proteaceae)
<i>poultoni</i> Bagnall, 1915	WA: Perth	<i>Grevillea</i> (Proteaceae)
<i>ravidus</i> Mound, 1972	WA: Perth, Kalannie, Meekathera	<i>Casuarina</i> (Casuarinaceae)
<i>sititor</i> Mound, 1972	NT: Yulara; NSW, Tibooburra	<i>Calandrinia</i> (Portulacaceae)
<i>symoni</i> Mound, 1972	WA: Kaninjini; NSW, Gilgandra; NT: Simpson Desert	<i>Brunonia</i> (Goodeniaceae)
<i>vesper</i> Mound, 1972	WA: Nullarbor	?
<i>karooensis</i> Jacot-Guillarmod, 1937	South Africa: Cape Province	<i>Aridaria</i> (Aizoaceae)

of the genus *Cranothrips*, draws attention to a potential weakness in the generic classification of the Melanthripidae. Of the four genera in this family, *Ankothrips* Crawford, *Cranothrips* Bagnall and *Dorythrips* Hood are distinguished from *Melanthrips* Haliday by the presence of unusual structures either on the basal antennal segments or on the anterior margin of the head. In *Dorythrips* species, the interantennal process on the vertex is unusually long, extending between the bases of the antennae, although one new species from Argentina (courtesy of Carlos de Borbon) has this process short. In *Cranothrips* species, the first antennal segment is prolonged into a tooth, although this is scarcely visible in specimens of some species. In *Ankothrips* species, the second antennal segment is prolonged into a tooth, although this is weakly developed in some specimens. In contrast, *Melanthrips* species have no comparable structures on the head or basal antennal segments, but the apex of each fore tibia bears an exceptionally broadly based, short spur-like seta that is much stouter than the tibial setae found in species of the other three genera. The functional significance of these various structures has never been established by direct observation or experiment, but it is probable that each of them is involved in facilitating the emergence of an adult from the pupal cocoon. If these processes and tibial spurs do have such a functional significance, then the similarity between the South African *C. karooensis* and the Australian *Cranothrips* species may be the result of homoplasy rather than a close relationship. The position of *C. karooensis* as a sister species to *M. nigricornis* (Fig. 3), and these two as a sister group to the rest of the genus *Cranothrips*, draws attention to this point. However, this observation is based on the analysis of the continuous data set; in the analysis of total evidence, *Cranothrips* appears monophyletic (Fig. 1).

Cranothrips Bagnall

Cranothrips Bagnall, 1915: 315. Type species *Cranothrips poultoni* Bagnall, by monotypy.

Detailed accounts of the genus *Cranothrips* and its species have been given by Mound (1972) and Mound & Marullo

(1998), and almost no further specimens of this genus have been collected since, despite much field work. These thrips are probably univoltine, emerging in spring, and possibly host specific, thus limiting the possibilities of finding them. Interpopulation structural variation between samples of *C. vesper* was discussed by Mound (1972), and specimens that were recorded under that name from white everlasting flowers in Western Australia are particularly similar to the two crushed specimens from Brisbane on which *C. emersoni* Girault is based. Similar problems of interpopulation variation occur in *C. lauriei* and *C. ravidus*, species that live in the arid regions of Central and Western Australia (Mound, 1972; Marullo, 1995).

Key to *Cranothrips* species

- Abdominal tergite VIII with distance of campaniform sensilla from tergal posterior margin less than distance of median paired setae from margin; sternite VII lateral marginal setae much shorter than median pair of marginal setae [South Africa] *karooensis* Jacot-Guillarmod
- Abdominal tergite VIII with distance of median paired setae from tergal posterior margin less than distance of campaniform sensilla from margin, or these distances about equal; sternite VII lateral marginal setae not shorter than median pair of marginal setae [Australia] 2
- Head and pronotum without any long setae (Figs 15, 17) 3
 - Head or pronotum with at least one pair of prominent setae (Figs 14, 16) 6
- Antennal segment III at least 4.0 times as long as wide (Fig. 10); ocellar setae III very close together, distance between their bases scarcely twice the diameter of their basal insertion (Fig. 15); mesothoracic preepisternum fused to episternum ventrally; metanotum boldly reticulate, microtrichia present only on posterior half (Fig. 18); sternites III–VI with three pairs of postero-marginal setae; body dark brown, mid and hind tibiae bicoloured *ibisca* sp.n.

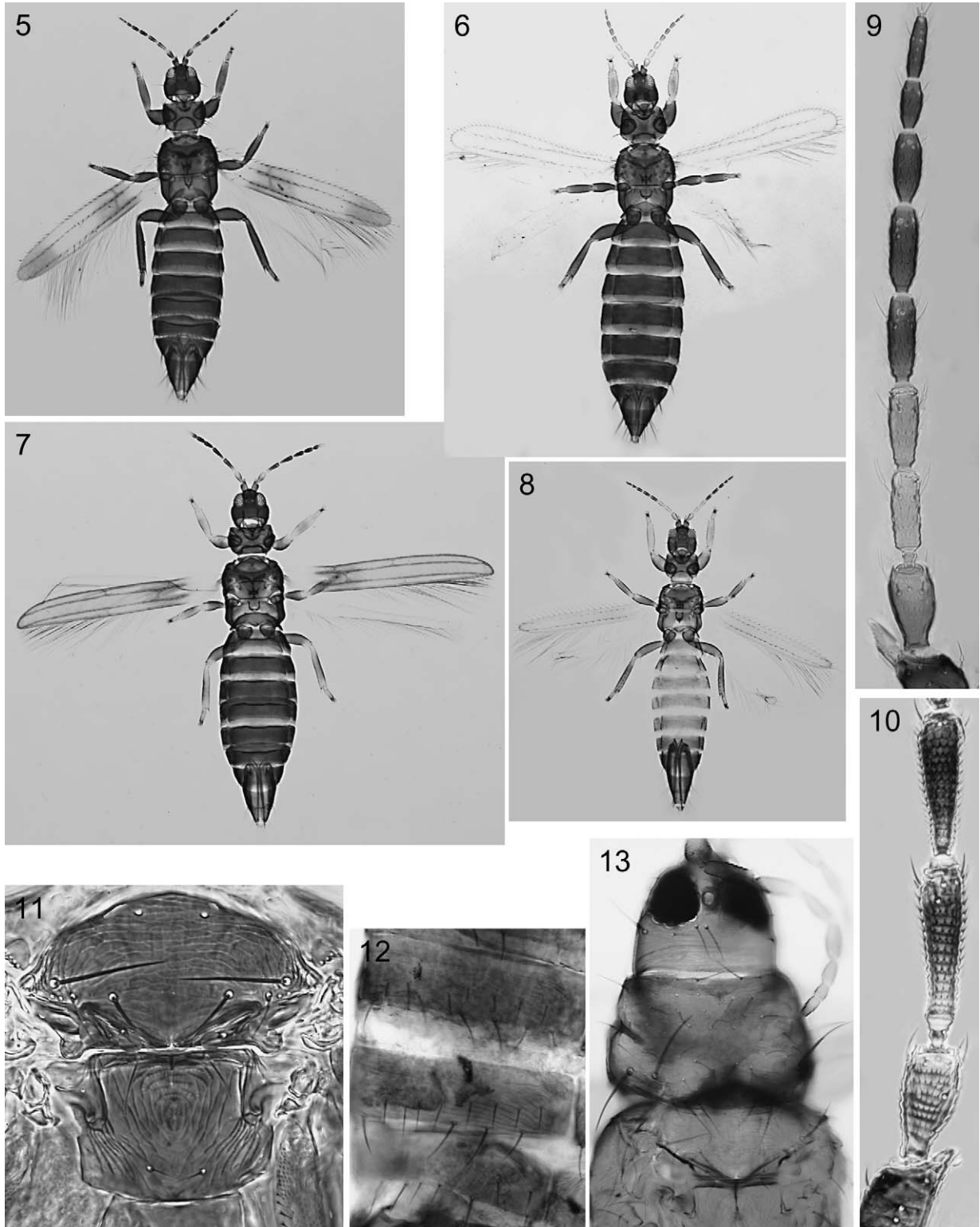
- Antennal segment III less than 3.0 times as long as wide; distance between ocellar setae III at least 5.0 times the diameter of their basal pores; mesothoracic preepisternum largely or completely distinct from episternum ventrally; metanotum not strongly sculptured, if microtrichia present these are on anterior area; sternites III–VI with four pairs of posteromarginal setae; body colour various from pale to medium brown, if brown then mid and hind tibiae uniformly brown 4
- 4. Ocellar setae III arise anterior to posterior ocelli, on or close to margins of ocellar triangle; usually with only one seta medially behind each eye; median area of mesonotum and median area of sternites with no microtrichia *symoni* Mound
 - Ocellar setae III arise between posterior ocelli or between their anterior margins; at least three pairs of setae medially behind each eye; mesonotum and sternites almost covered with many microtrichia 5
- 5. Head with about six setae on vertex posterior to ocelli and between compound eyes (Fig. 17); antennal segment III with sensorium incomplete dorsally; fore tibia with prominent spine at inner apex *bellisi* Mound
 - Head with about ten setae on vertex posterior to ocelli and between compound eyes; antennal segment III with sensorium complete dorsally; fore tibia without a prominent spine at inner apex *kartus* Mound
- 6. Pronotum with no long setae on anterior margin (Fig. 16) 7
 - Pronotum with one or more pairs of long setae on anterior margin (Fig. 14) 10
- 7. Pronotum with only one pair of posteroangular setae; lateral postocular setae on head less than 0.5 times as long as median postoculars; forewing costal setae scarcely longer than width of vein *sitor* Mound
 - Pronotum with two pairs of prominent posteroangular setae; lateral postocular setae on head at least as long as median postoculars; forewing costal setae at least as long as distance between costa and first vein 8
- 8. Mesonotum with no microtrichia on lines of sculpture between the major setae (Fig. 11); pronotum with no more than 12 discal setae (Fig. 16), anteromedian pair twice as long as remaining discal setae; sternites V–VI without microtrichia medially *conostylus* sp.n.
 - Mesonotum at least with a median transverse band of microtrichia; pronotum with about 20 discal setae, all equal in length; sternites V–VI with many microtrichia medially 9
- 9. Sternites V–VI marginal setae long, at least 0.5 times as long as sternite (Fig. 12); antennal segment III brown except at base, 3.0 times as long as width (Fig. 13) *emersoni* Girault
 - Sternites V–VI marginal setae short, no more than 0.3 times as long as sternite; antennal segment III largely yellow, paler than IV, 2.5 times as long as width *vesper* Mound
- 10. Forewing with distinct transverse bands, pale medially and at base except jugum, dark at apex and sub-basally (Fig. 5) *poultoni* Bagnall
 - Forewing not strongly bicoloured, varying from pale through fuscous to weakly banded 11
- 11. Major cheek setae on head no more than 1.15 times as long as interocellar setae *lauriei* Marullo
 - Major cheek setae on head at least 1.25 times as long as interocellar setae *ravidus* Mound

Cranothrips ibisca sp.n.
(Figs 7, 10, 15, 18)

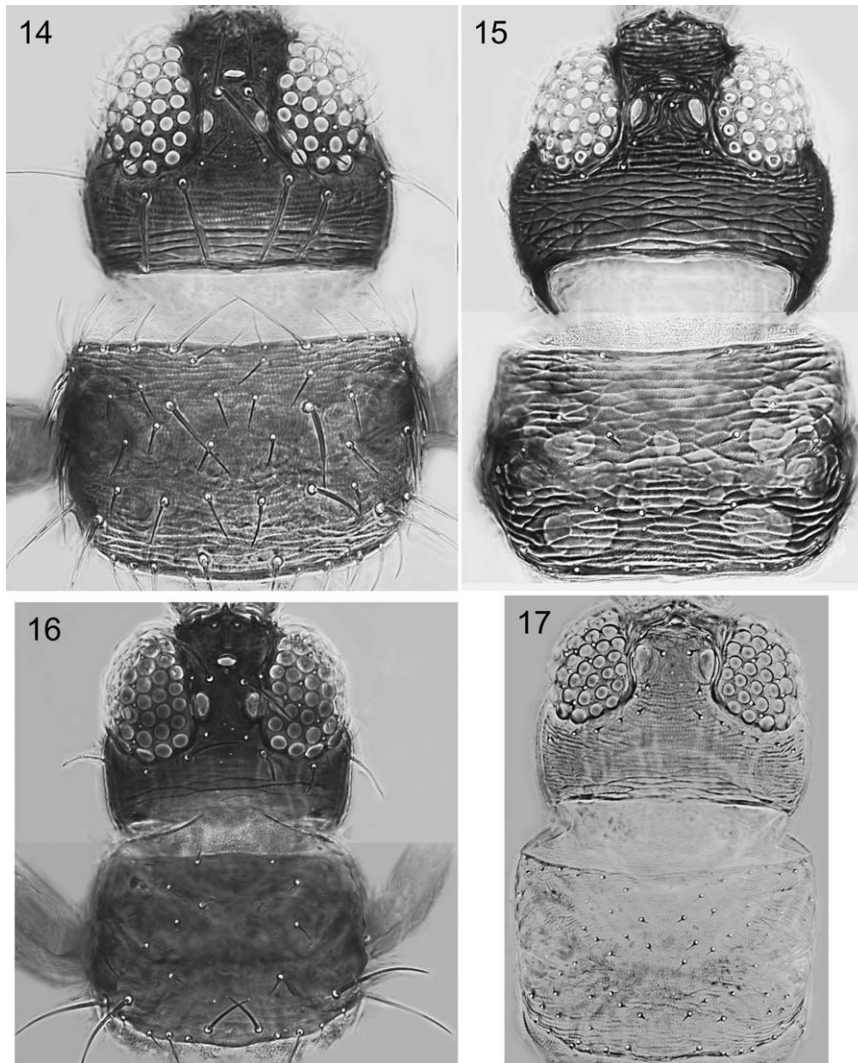
Female macroptera. Body and femora brown to dark brown, tibiae brown medially, but yellow at base and apex, tarsi yellow; antennae brown with segment III yellow in basal fifth and segments VIII–IX almost yellow; forewing pale sub-basally including distal half of clavus, then with dark brown transverse band, distal two-thirds lighter brown. Antennae nine-segmented, segment I with process not elongate, slightly toothed distally; segment III long, external margin slightly concave in basal third (Fig. 10); sensoria on III–IV incomplete dorsally, with weak internal markings; IX slightly shorter than VIII. Head produced in front of eyes bearing ocellar setae pair I; pair II arising on anterior margins of ocellar triangle, pair III small and arising between posterior ocelli; three to five pairs of postocular setae in widely spaced row; vertex with bold transverse lines of sculpture, cheeks strongly convex (Fig. 15); anterior tentorial arms stout. Pronotum with transverse reticulation, posterior margin with five pairs of small setae; prosternal ferna entire. Mesonotum transversely reticulate, with no microtrichia (Fig. 18); mesopreepisternum fused to episternum ventrally. Metanotum with reticulation forming concentric circles on anterior half (Fig. 18); sculpture lines on posterior half with stout microtrichia. Forewing veinal setae short, scarcely longer than width of a vein; clavus with seven to nine veinal and one discal setae. Fore tibial apex with two stout ventrolateral setae. Abdominal tergite I with transverse lines of sculpture medially bearing small microtrichia; II–VIII with narrow transverse reticulation medially, bearing small microtrichia on anterior lines of each segment; tergite VIII median setae more than 0.5 times as long as tergite; dorsal setae on IX–X relatively short. Sternite II with two pairs of posteromarginal setae, III–VI with three pairs, also a transverse row of approximately 13–16 discal setae.

Material studied. Holotype: ♀, AUSTRALIA: Queensland, O'Reilly's car park, Lamington National Park, *Pentaceras australis* (Rutaceae) flowers, 10.x.2006 (LAM 4943) (ANIC). Paratypes: two females collected with holotype.

Comments. This new species is unusual, both for its structure and for the area where it was found. The collecting site at O'Reilly's lies within rainforest, whereas the other species of *Cranothrips* come from arid sites across Australia. However, the immediate area around O'Reilly's is deforested and severely disturbed, and the thrips may have been wind dispersed from more arid areas further south. The native tree, *Pentaceras australis*, is one of the most vigorous



Figs 5–13. *Cranothrips* species. 5, *Cranothrips poultoni*; 6, *C. karoensis*; 7, *C. ibisca*; 8, *C. conostylus*; 9, antenna of *C. conostylus*; 10, antennal segments I–IV of *C. ibisca*; 11, mesonotum and metanotum of *C. conostylus*; 12, sternites V–VII of *C. emersoni* syntype; 13, head and pronotum of *C. emersoni* syntype.



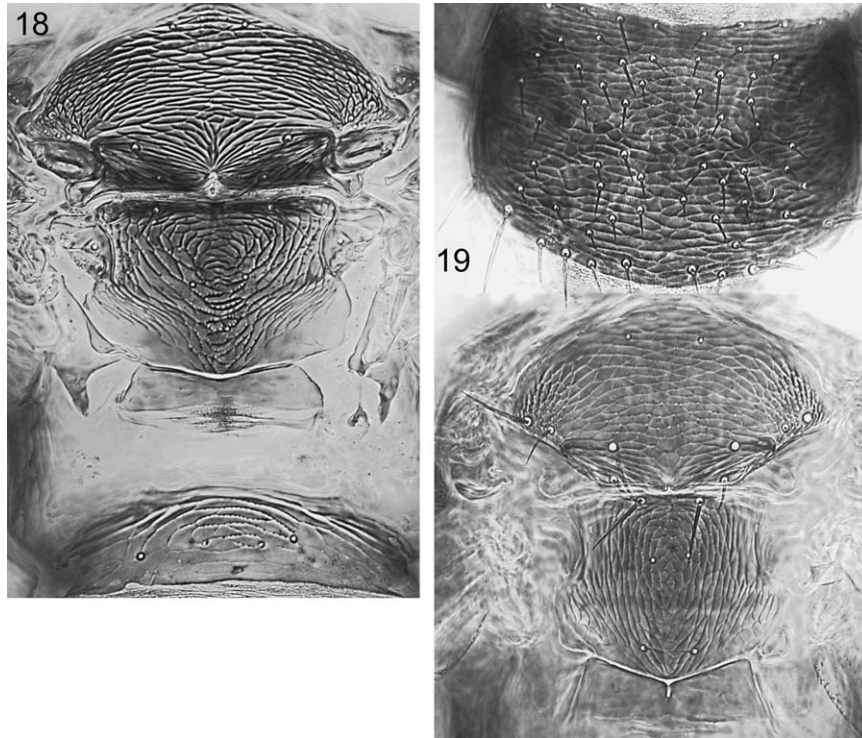
Figs 14–17. *Cranothrips* species, head and pronotum. 14, *Cranothrips poultoni*; 15, *C. ibisca*; 16, *C. conostylus*; 17, *C. bellisi*.

elements in the disturbed flora of the area. One character state of the new species is particularly unusual within the genus: the abdominal sternites bear three pairs of posteromarginal setae instead of the four pairs of other species. The species name refers to the project ‘Investigating the Biodiversity of Soil and Canopy Arthropods (IBISCA)’.

Cranothrips conostylus sp.n.
(Figs 8, 9, 11, 16)

Female macroptera. Body brown, median abdominal segments light brown; femora brown, mid and hind tibiae brown with base yellow, tarsi yellow; antennal segment I as brown as head, II paler, III–IV yellow, V–IX brown; forewings pale brown, basal area clear. Antennae nine-segmented, segment I with long toothed process; segment III parallel sided (Fig. 9); sensoria on III–IV incomplete

dorsally, with weak internal markings; IX longer than VIII. Head slightly longer than median width; ocellar setae III long, arising on anterior margins of triangle (Fig. 16); lateral postocular setae longer than median pair. Pronotum almost without sculpture lines, with four to six pairs of discal setae, anteromedian pair longest; posterior angles with two pairs of long setae. Prosternal ferna entire. Mesonotum with long lateral setae, no microtrichia on sculpture lines mesad of these setae (Fig. 11). Metanotum with concentric lines at anterior bearing microtrichia, posterior half weakly sculptured; mesopreepisternum distinct from episternum ventrally. Forewing setae longer than distance between veins; clavus with five veinal and one discal setae. Fore tibial apex with two stout ventrolateral setae. Abdominal tergites I–VIII with no sculpture lines or microtrichia medially; tergite VIII median setae scarcely 0.25 times as long as tergite; dorsal setae on IX–X slender. Sternite II with two pairs of posteromarginal setae and



Figs 18–19. *Cranothrips* species, thorax. 18, Mesonotum, metanotum and first abdominal tergite of *C. ibisca*; 19, pronotum, mesonotum and metanotum of *C. karooensis*.

none or one discal setae; sternite III with three pairs of posteromarginal setae, IV–VI with four pairs; median sternites with eight to 11 discal setae, sternite VII with discal setae laterally not medially.

Material studied. Holotype: ♀, AUSTRALIA: Western Australia, Perth, Kensington Bush, from *Conostylis candidans* flowers (Haemodoraceae), 10.ix.1995 (E. Steiner) (ANIC). Paratypes: three females taken with holotype; West Binu, 80 km north of Geraldton, one female from *Geleznowia* (Rutaceae) flowers, 4.viii.1998.

Comments. The median setae on the posterior margin of the eighth abdominal tergite are unusually short and fine, much smaller than in *C. vesper*. The lack of sculpture on much of the body surface is also unusual.

Host associations and disjunct distribution patterns among Melanthripidae

Melanthrips Haliday includes 36 species, mostly from the Mediterranean region, but with three from India and two from South Africa, as well as two from south-western U.S.A., although these latter two are not closely related to the other members of the genus (Hoddle *et al.*, 2008). Unfortunately, published host associations of most *Melanthrips* are com-

monly based only on adult specimens, and may thus involve plant species on which the thrips do not breed, but were either resting or opportunistically feeding. Despite this, it seems that flowering plants in a range of unrelated families are used as hosts, including Brassicaceae, Fabaceae, Poaceae, Polygonaceae, and Rosaceae (zur Strassen, 2003). No attempt has been made to correlate the structural diversity within *Melanthrips* with the host associations.

Ankothrips Crawford includes 12 species, and of these seven are from western U.S.A., one from south-western Africa, and four from southern or eastern Europe. The European species are associated with the flowering tissues of gymnosperm species in the genera *Juniperus* or *Cupressus*. Host relationships among the seven species from western U.S.A. remain unclear, but one is common on *Yucca whipplei* (Agavaceae) flowers, and another on the flowers of *Adenostema fasciculata* (Rosaceae) (Hoddle *et al.*, 2008). Nothing is known of the biology of the species from South Africa.

Dorythrips Hood includes five described species, of which two are from Western Australia and three from Chile or Argentina. There are no reliable host data for the Australian species, but *D. chilensis* has been found breeding in the flowers of *Colliguaja odorifera* (Euphorbiaceae), and a new species is currently being described from Argentina (C. De Borbon, personal communication) from *Zuccagnia punctata* (Fabaceae).

Cranothrips Bagnall now includes 11 species from Australia and one from South Africa. The available evidence suggests that some of these species are probably host specific, but a wide range of plant families is involved (Table 2).

The above comments on the diversity of plants exploited suggest that there is little phylogenetic signal concerning the thrips in this study to be derived from host plant associations. This situation is not unusual among Thysanoptera. Only a few lineages of thrips exhibit patterns of radiation in close association with particular plant families, such as some species in the flowers of Fabaceae and also of Poaceae (Mound, 2004). Among thrips, particularly among the larger genera of flower-living species, the pattern of host exploitation typically involves monophagy by most members of a genus through adaptation to various unrelated plant species, but with a small percentage of species in that genus being polyphagous.

Supporting Information

Additional Supporting Information may be found in the online version of this article from Wiley InterScience under DOI reference: doi: 10.1111/j.1365-3113.2008.00445.x

- S1 Characters and character states.
- S2 Data matrix.

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

Acknowledgements

We thank Claudia Szumik and Pablo Goloboff for their advice and comments on the manuscript. This research was supported by a grant from Consejo Nacional de Investigaciones Científicas y Técnicas de Argentina (CONICET, grant PIP no. 6502), and the Organización Internacional para las Migraciones. CSIRO Entomology provided research facilities during a study visit (by V.P.) to the Australian National Insect Collection (ANIC), Canberra. Desley Tree of QDPI, Brisbane, kindly sent digital images of *C. emersoni* adults collected from *Thryptomene* at Idalia in central Queensland. Also we thank the Willi Hennig Society for making available the program TNT (Goloboff *et al.*, 2008).

References

- Bagnall, R.S. (1915) Brief description of new Thysanoptera V. *Annals and Magazine of Natural History*, **15**, 315–324.
- Baum, B.R. (1988) A simple procedure for establishing discrete characters from measurement data, applicable to cladistics. *Taxon*, **37**, 63–70.
- Cranston, P. & Humphries, C. (1988) Cladistics and computers: a chironomid conundrum? *Cladistics*, **4**, 72–92.
- Farris, J. (1970) Methods for computing Wagner trees. *Systematic Biology*, **19**, 83–92.
- Farris, J.S. (1990) Phenetics in camouflage. *Cladistics*, **6**, 91–100.
- Goloboff, P.A. & Farris, J. (2001) Methods for quick consensus estimation. *Cladistics*, **17**, S26–S34.
- Goloboff, P.A., Farris, J., Källersjö, M., Oxelmann, B., Ramirez, M. & Szumik, C. (2003) Improvements to resampling measures of group support. *Cladistics*, **19**, 324–332.
- Goloboff, P.A., Matoni, C. & Quinteros, S. (2006) Continuous characters analysed as such. *Cladistics*, **22**, 589–601.
- Goloboff, P.A., Farris, J.S. & Nixon, K. (2008) TNT, a free program for phylogenetic analysis. *Cladistics*, **24**, 774–786.
- Hoddle, M.S., Mound, L.A. & Paris, D. (2008) *Thrips of California*. CD-ROM published by CBIT, Brisbane.
- Marullo, R. (1995) Two new species of Aeolothripidae (Thysanoptera) from northern Australia. *Redia*, **78**, 163–171.
- Mound, L.A. (1972) Further studies on Australian Aeolothripidae (Thysanoptera). *Journal of the Australian Entomological Society*, **11**, 37–54.
- Mound, L.A. (2004) Thysanoptera – diversity and interactions. *Annual Review of Entomology*, **50**, 247–269.
- Mound, L.A. & Marullo, R. (1998) Biology and identification of Aeolothripidae (Thysanoptera) in Australia. *Invertebrate Taxonomy*, **12**, 929–950.
- Mound, L.A. & Morris, D.C. (2007) The insect order Thysanoptera: classification versus systematics. *Zootaxa*, **1668**, 395–411.
- Rae, T. (1998) The logical basis for the use of continuous characters in phylogenetic systematic. *Cladistics*, **14**, 221–228.
- Stevens, P.F. (1991) Character states, morphological variation, and phylogenetic analysis: a review. *Systematic Botany*, **16**, 553–583.
- Thiele, K. (1993) The Holy Grail of the perfect character: the cladistic treatment of morphometric data. *Cladistics*, **9**, 275–304.
- Tyagi, K., Kumar, V. & Mound, L.A. (2008) Sexual dimorphism among Thysanoptera Terebrantia, with a new species from Malaysia and remarkable species from India in Aeolothripidae and Thripidae. *Insect Systematics and Evolution*, **39**, 155–170.
- Wiens, J.J. (1998) The accuracy of methods for coding and sampling higher-level taxa for phylogenetic analysis: a simulation study. *Systematic Biology*, **47**, 381–397.
- Wiens, J. (2001) Character analysis in morphological phylogenetics: problems and solutions. *Systematic Biology*, **50**, 689–699.
- Zur Strassen, R. (2003) Die terebranten Thysanopteren Europas und des Mittelmeer-Gebietes. *Die Tierwelt Deutschlands*, **74**, 1–271.

Accepted 19 August 2008