

Fig. 2: Canonical discriminant analysis of worker individuals of the sibling species *C. atalanta* (grey bars, n = 48) and *C. nuda* (black bars, n = 84). The position of the holotypes of both taxa is marked by arrows.

With PLG/CS and MpGR/CS given in %, a canonical vector 1 of this DA is described by
 $18.481*CL/CW - 0.147*SL + 36.377*PEW/CS - 47.829*PPW/CS + 20.917*SP/CS + 0.416*sqPDG - 0.00466*PLG/CS - 15.449*PEH/CS + 88.464*PPH/CS - 0.137*dFov - 10.407*EYE/CS + 25.715*PoOc/CL - 3.68*MpGr/CS - 13.38*CS - 31.385$

and canonical vector 2 by

$18.481*CL/CW - 5.062*SL - 59.433*PEW/CS + 49.329*PPW/CS + 50.300*SP/CS + 0.911*sqPDG - 0.00704*PLG/CS + 52.246*PEH/CS - 69.680*PPH/CS + 0.358*dFov + 4.483*EYE/CS - 25.763*PoOc/CL - 6.23*MpGr/CS - 11.648*CS - 16.301.$

98.6 % of the 214 samples were determined with *a-posteriori*-probabilities of $p > 0.95$, and the LOOCV test indicated an error rate of 0 %. Figure 1 also suggests the *C. mauritanica* and *C. kagutsuchi* clade to be more closely related, while the *C. nuda et atalanta* clade is more distant from these two clades. Molecular analysis of mtDNA and 16S RNA (HEINZE & al. 2005) seem to support the relationship among the three clades, although only one sample of the *C. nuda et atalanta* clade was used in the previous study.

Evidence for heterospecificity of *C. atalanta*

With PLG/CS and MpGR/CS given in %, a discriminant D(14) is calculated with the following 14 morphological characters as

$D(14) = -0.818*CL/CW + 17.558*SL - 11.006*PEW/CS - 0.864*PPW/CS + 17.78*SP/CS - 2.201*sqPDG + 1.902*PLG/CS - 5.085*PEH/CS + 26.639*PPH/CS + 0.081*dFov + 3.558*EYE/CS + 45.912*PoOc/CL - 0.307*MpGr/CS - 10.105*CS - 49.533.$

All *a-priori*-determinations of 48 *C. atalanta* and 84 *C. nuda* worker specimens were confirmed, and 90.9 % of the determinations had *a-posteriori*-probabilities of $p > 0.95$. The holotypes of *C. atalanta* and *C. nuda* were exactly allocated to the corresponding cluster, with $p = 0.999$ and $p = 1.000$, respectively (Fig. 2). The Leave-One-Out Cross-Validation (LOOCV) test indicated an error rate of 0 % and allocated the holotypes of *C. atalanta* and *C. nuda* to the right cluster with *a-posteriori*-probabilities of

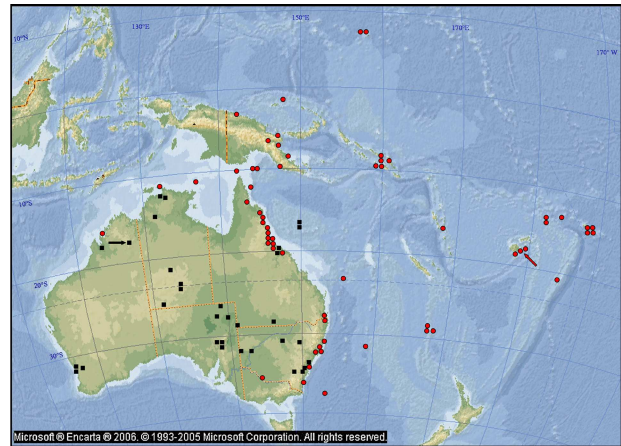


Fig. 3: Distribution map of *Cardiocondyla nuda* (red circles) and *C. atalanta* (black squares) in the Australasian region. Red and black arrows point to the type localities. Original map with permission of Microsoft Corporation.

$p = 0.987$ and $p = 1.000$ respectively. An analysis based on sample means was not performed because 57 % of the 86 samples (including the type samples of *C. nuda* and *C. atalanta*) consisted of only one specimen and because the remaining samples were mainly based upon random surface collecting and should usually not represent nest samples. This situation could distort the covariance, and mixed samples could generate confusion. In fact, one sample from eastern Australia had both *C. nuda* and *C. atalanta* mounted on the same pin.

The zoogeography of *C. nuda* and *C. atalanta* provides additional evidence for regarding them as different biological species. Figure 3 shows the distribution of both sister species in Australia, New Guinea and Polynesia. There is an area of sympatric occurrence in east Australia in which no signs of morphological convergence were evident. Only 1.7 % of the 60 *C. nuda* samples were found more than 120 km from the sea coast. The only exception (Barham, New South Wales) is 256 km from the sea. *Cardiocondyla atalanta* ranges all over the Australian continent, including its innermost parts, and is only exceptionally found on offshore islands of Australia. 61 % of the 33 known samples of *C. atalanta* were more than 120 km from the sea. From these data, the probability that *C. nuda* occurs at the type locality of *C. atalanta* in Kimberley district (about 250 km from the coast line) is very low.

The two species also show clear differences in relation to climatic factors. *Cardiocondyla nuda* avoids continental parts of Australia and is apparently adapted to climatic zones with higher annual rainfall, whereas *C. atalanta* is apparently better adapted to extremely dry climate (Tab. 1).

Tab. 1: Annual rainfall of sites with reliably determined worker material of *Cardiocondyla nuda* and *C. atalanta* given as arithmetic mean \pm standard deviation [minimum, maximum]. Data are taken from BARTHOLOMEW AND TIMES BOOKS (1991).

	<i>C. nuda</i> (n = 58)	<i>C. atalanta</i> (n = 28)
annual rainfall (mm)	2381 \pm 1277 [500, 4500]	629 \pm 396 [150, 1250]