Oikos

Appendix o20062

Fayle, T. M., Edwards, D. P., Turner, E. C., Dumbrell, A. J., Eggleton, P. and Foster, W. A. 2011. Public goods, public services and by-product mutualism in an ant–fern symbiosis. – Oikos 121: 1279–1286.

Appendix 1

Public goods, public services, and by-product mutualism in an ant–fern symbiosis.

Table A1. Methods used to measure the variables used in all analyses.

Variable	Measurement
Fern size	Ferns dried to constant mass in a drying oven and weighed using electronic scales (accuracy ± 0.1 g)
Height in canopy	Measured from ground level using a laser rangefinder (accuracy ± 0.01 m)
Canopy cover	Standard concave spherical densiometer (Lemmon, P. E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2: 314–320), average of three readings taken facing directly away from the supporting structure and at 90° angles to this
Substrate diameter	Diameter of the trunk, branch or vine supporting the fern
Canopy openness	Measured by taking horizontal readings at 12 evenly spaced compass points using a laser rangefinder and calculating an average distance to the nearest structure
Fern species	Identified morphologically using Holttum, R. E. (1976. *Asplenium* Linn., sect. Thamnopteris Presl. Gardens' Bull., Singapore 27: 143–154) and by sequencing of the *trn*L intron (Fayle et al. 2009).

Table A2. CCA ordination of resident ant community structure in the ferns. F- and p-values are from a permutation test for the different environmental variables and factors. Predictors with the most significant p-values (< 0.05) were added into the model in a stepwise manner. Significant p-values are in bold type. 999 permutations were used for each test. The environmental variables included accounted for 8.5% of variance of species data (eigenvalue for axis 1 = 0.457, axis 2 = 0.290, sum of all eigenvalues = 9.263).

Environmental variables and factors	F-value	p-value
Fern size	2.101	**0.001**
Height in canopy	1.765	**0.002**
Canopy cover	1.256	0.118
Substrate diameter	1.209	0.161
Canopy openness	0.911	0.653
Fern species	0.777	0.862

Table A3. The effects of environmental variables on number of ant colonies, ant biomass and ant abundance in bird's nest ferns. p-values in bold ($p < 0.05$) and italics ($p > 0.05$) are for variables included in final model. ΔAIC is the change in AIC (Akaike information criterion) for removing variables from the final model. For variables that were not included in the final model, t, p and ΔAIC are quoted for these variables when added back into the final model. See Fig. 3 for plots.

Variable	Ant colonies			Ant biomass			Ant abundance		
	t	p	ΔAIC	t	p	ΔAIC	t	p	ΔAIC
Fern size	8.00	**>0.001**	46.8	8.75	**>0.001**	53.7	8.10	**>0.001**	48.1
Height in canopy	1.16	0.249	0.6	0.63	0.534	1.6	0.49	0.626	1.7
Canopy cover	–1.85	*0.067*	1.5	1.24	0.218	0.4	0.38	0.701	1.8
Substrate diameter	1.34	0.185	0.1	–0.18	0.858	2.0	–0.63	0.531	1.6
Canopy openness	0.77	0.443	1.4	–0.03	0.974	2.0	1.78	*0.078*	1.3
Fern species	0.36	0.720	1.9	1.76	*0.082*	1.6	3.00	**0.004**	7.0

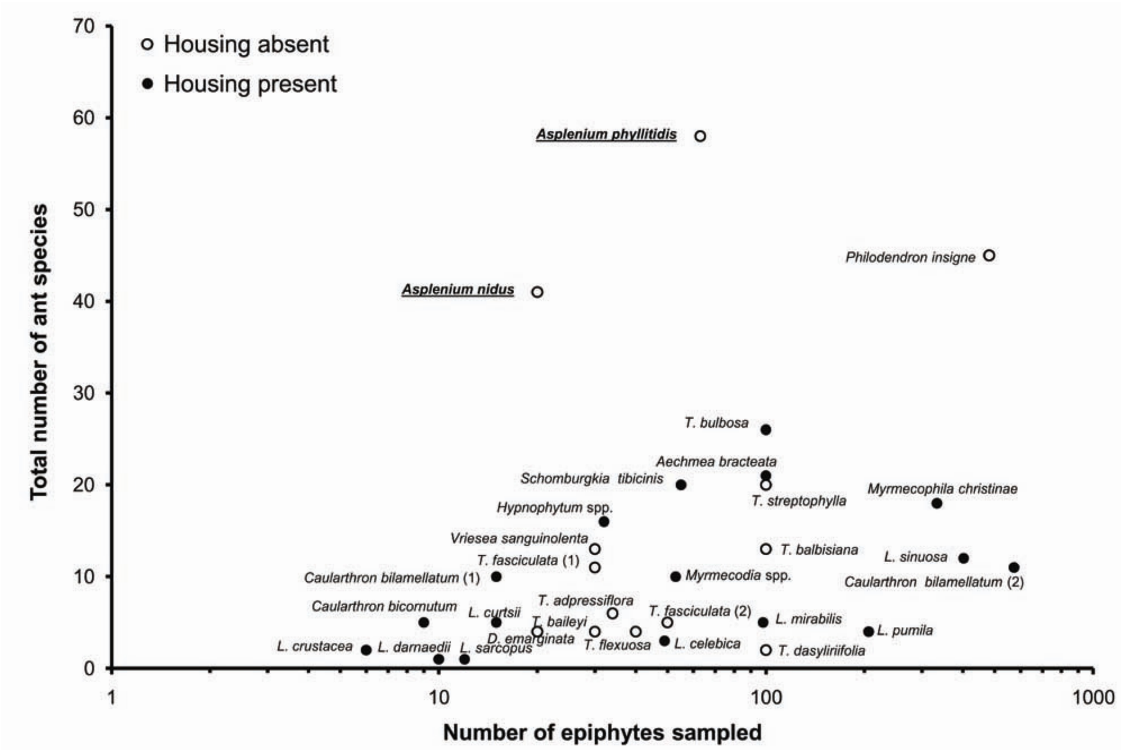

Figure A1. Species richness of epiphyte-inhabiting ant communities in relation to the number of epiphytes sampled and the provision of specific structures for housing ants. Source references are given below. The data for *Asplenium phyllitidis* and *Asplenium nidus* (bold, underlined) are from this study.

Source references for Fig. A1.

Blüthgen, N. et al. 2000. Ant nests in tank bromeliads – an example of non-specific interaction. – Insectes Soc. 47: 313–316. (Epiphyte species: *Guzmania lingulata, Tillandsia adpressiflora, Vriesea procera, Vriesea rubra.*)

Dejean, A. et al. 2003. Nest site selection by ants in a flooded Mexican mangrove, with special reference to the epiphytic orchid *Myrmecophila christinae*. – J. Trop. Ecol. 19: 325–331. (Epiphyte species: *Myrmecophila christinae.*)

Dejean, A. et al. 1995. Tree–epiphyte-ant relationships in the low inundated forest of Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico. – Biotropica 27: 57–70. (Epiphyte species: *Tillandsia dasyliriifolia, Tillandsia baileyi, Tillandsia flexuosa, Tillandsia fasciculate* (2), *Tillandsia balbisiana, Tillandsia streptophylla, Tillandsia bulbosa, Aechmea bracteata, Schomburgkia tibicinis.*)

Dutra, D. and Wetterer, J. K. 2008. Ants in myrmecophytic orchids of Trinidad (Hymenoptera: Formicidae). – Sociobiology 51: 249–254. (Epiphyte species: *Caularthron bilamellatum* (1)*, Caularthron bicornutum.*)

Fisher, B. L. and Zimmerman, J. K. 1988. Ant/orchid associations in the Barro Colorado National Monument, Panama. – Lindleyana 3: 12–16. (Epiphyte species: *Caularthron bilamellatum* (2).)

Gay, H. and Hensen, R. 1992. Ant specificity and behaviour in mutualisms with epiphytes: the case of *Lecanopteris* (Polypodiaceae). – Biol. J. Linn. Soc. 47: 261–284. (Epiphyte species: *Lecanopteris sinuosa, Lecanopteris mirabilis, Lecanopteris curtsii, Lecanopteris pumila, Lecanopteris crustacean, Lecanopteris celebica, Lecanopteris darnaedii, Lecanopteris sarcopus.*)

Gibernau, M. et al. 2007. An asymmetrical relationship between an arboreal ponerine ant and a trash-basket epiphyte (Araceae). – Biol. J. Linn. Soc. 91: 341–346. (Epiphyte species: *Philodendron insigne.*)

Huxley, C. R. 1978. The ant-plants *Myrmecodia* and *Hydnophytum* (Rubiaceae), and the relationships between their morphology, ant occupants, physiology and ecology. – New Phytol. 80: 213–268. (Epiphyte species: *Myrmecodia* (21 species), *Hydnophytum* (unknown number of species).)

Stuntz, S. et al. 2002. Diversity and structure of the arthropod fauna within three canopy epiphyte species in central Panama. – J. Trop. Ecol. 18: 161–176. (Epiphyte species: *Vriesea sanguinolenta, Tillandsia fasciculata* (1)*, Dimerandra emarginata.*)

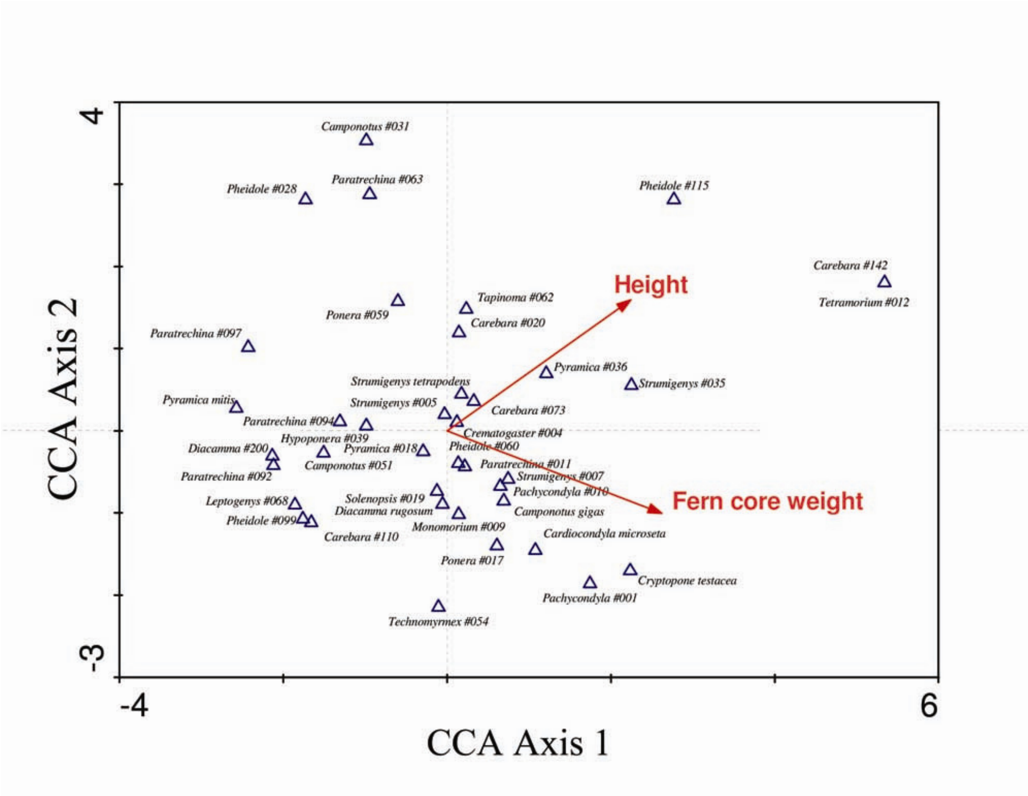

Figure A2. Canonical correspondence analysis of ant communities inhabiting bird's nest ferns. Communities showed partitioning in terms of height in the canopy and size of fern, but did not differ between the two species of fern present. See Table A3 for statistics.

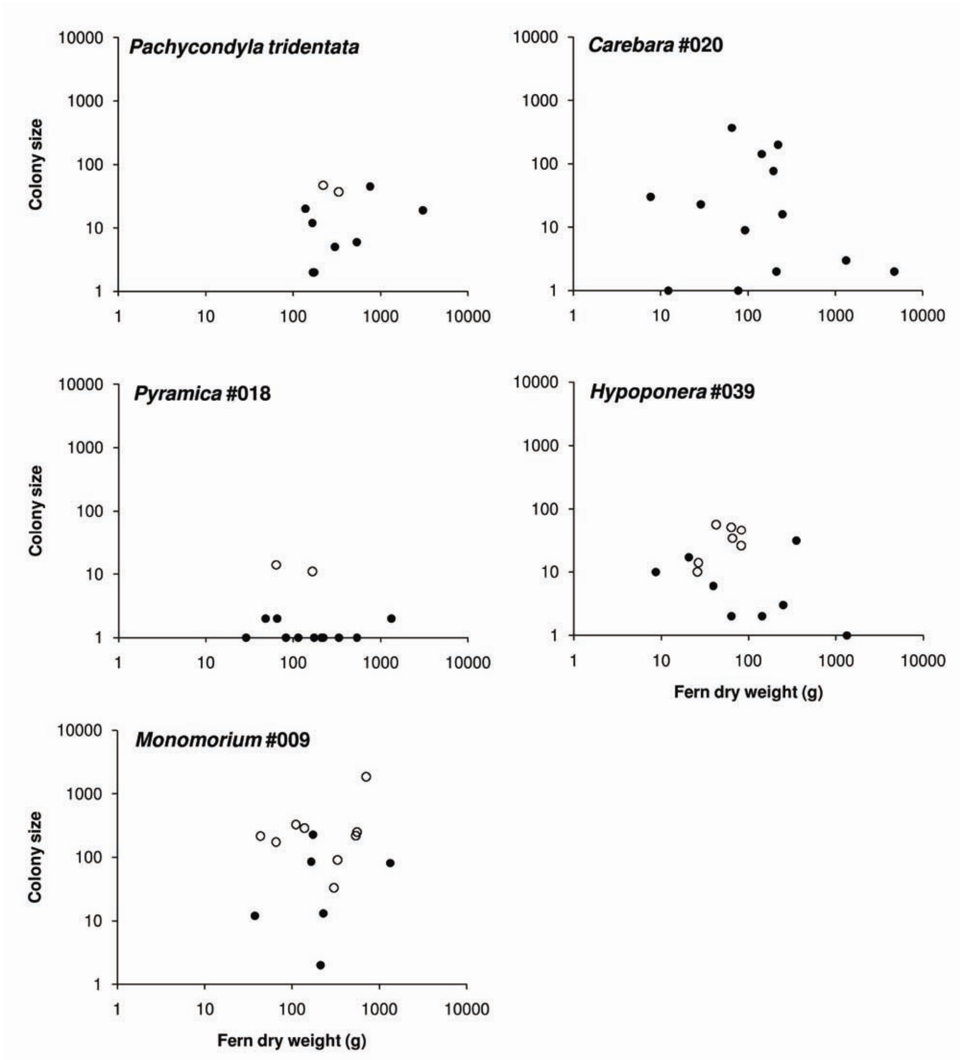

Figure A3**.** There was no relationship between fern size and ant colony size for the five most widely occurring species in the ferns (*Pachycondyla tridentata*: $F_{1,8} = 0.88$, $p = 0.374$; *Carebara* no. 020: $F_{1,12} = 0.17$, $p = 0.692$; *Pyramica* no. 018: $F_{1,11} = 0.27$, $p = 0.612$; *Hypoponera* no. 039: $F_{1,13} = 2.30$, $p = 0.153$; *Monomorium* no. 009: $F_{1,13} = 0.50$, $p = 0.492$). Colonies in larger ferns did not support more reproductive individuals than those in smaller ferns (two species with more than five ferns supporting reproductives: *Hypoponera* no.039: $F_{1,13} = 0.17$, $p = 0.684$; *Monomorium* no. 009: $F_{1,13} = 2.60$, $p = 0.133$). Colonies with reproductives denoted by open data-points and those without by closed data-points.

Identification references used in Appendix 1.

Bolton, B. 1977. The ant tribe Tetramoriini (Hymenoptera: Formicinae. The genus *Tetramorium* Mayr in the Oriental and Indo-Australian regions and in Australia. – Bull. Br. Mus. Natl Hist.: Entomol. Ser. 36: 68–151.

Bolton, B. 1994. Identification guide to the ant genera of the world. – Harvard Univ. Press.

Brown, W. L. 1978. Contributions towards a reclassification of the Formicidae. Part VI. Ponerinae, tribe Ponerini, subtribe Odontomachiti. Section B. Genus *Anochetus* and bibliography. – Studia Entomol. 20: 549–651.

Fisher, B. L. 2009. <www.antweb.org>.

Hashimoto, Y. 2007. Identification guide to ant genera of Borneo <http://homepage.mac.com/aenictus/AntsofBorneo.htm>.

Lattke, J. E. 2004. A taxonomic revision and phylogenetic analysis of the ant genus *Gnamptogenys* Roger in southeast Asia and Australasia (Hymenoptera: Formicidae: Ponerinae). – Entomology 122: 1–266.

Pfeiffer, M. 2009. Antbase: a taxonomic ant picturebase of Asia and Europe. – <www.antbase.net/>, retrieved during October 2009.