New data on the spatial distribution of endemic ground beetles (Coleoptera: Carabidae) from Madeira Island

MÁRIO BOIEIRO, MAB STUDY GROUP* & ARTUR R.M. SERRANO

Boieiro, M., MAB Study Group & A.R.M. Serrano (*in press*). New data on the spatial distribution of endemic ground beetles (Coleoptera: Carabidae) from Madeira Island. *Arquipelago*. Life and Marine Sciences 29: 15-23.

Based on standardised sampling methods covering a large fraction of native forest on Madeira Island, new distribution data is reported for 33 species of endemic ground beetles. Most of these species have been found in new localities and their distribution range is now better known. *Dromius angustus alutaceus* Wollaston, 1857 was "rediscovered" after more than fifty years since the last known record and two rare *Philorhizus* species (*P. conicipennis* (Fauvel, 1905) and *P. vieirai* Mateu, 1957) were also located. Furthermore, two other arboreal endemics (*Olisthopus ericae* Wollaston, 1854 and *O. maderensis* Wollaston, 1854) were recorded from many new localities. This work represents a considerable improvement of the knowledge on the distribution of ground beetle species endemic to Madeira, hence contributing to future management plans targeting the conservation of endemic biota.

Key words: island biodiversity, Laurisilva, Macaronesia, endemic rare species

*Mário Boieiro (e-mail: mboieiro@fc.ul.pt) & Artur R.M. Serrano, Centro de Biologia Ambiental, Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa,Ed. C2, 2º Piso, Campo Grande, PT-1749-016 Lisboa, Portugal. *MAB Study Group – Madeiran Arthropod Biodiversity Study Group: Carlos Aguiar, Carla Barrinha & Israel de Faria e Silva, Centro de Biologia Ambiental, Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa, Ed. C2, 2º Piso, Campo Grande, PT-1749-016 Lisboa, Portugal; Isabel R. Amorim, Paulo A.V. Borges, Pedro Cardoso, Fernando Pereira & Carla Rego, CITA-A (Azorean Biodiversity Group), Departamento de Ciências Agrárias, Universidade dos Açores. Pico da Urze, PT-9700-042 Angra do Heroísmo, Terceira, Açores, Portugal; Dília Menezes, Parque Natural da Madeira, Qta. do Bom Sucesso, Caminho do Meio, PT-9064-512 Funchal, Madeira, Portugal; Sérvio Ribeiro, CITA-A (Azorean Biodiversity Group), Departamento de Ciências Agrárias, Universidade dos Açores. Pico da Urze, PT-9700-042 Angra do Heroísmo, Terceira, Açores, Portugal; Lab. Evolutionary Ecology of Canopy Insects, Department of Biodiversity, Evolution and Environment, Instituto de Ciências Exatas e Biológicas, Universidade Federal de Ouro Preto, Brazil.*

INTRODUCTION

Madeira Island is a biodiversity hotspot due to its unique taxonomic diversity and large number of endemic species (Jardim & Francisco 2000; Cook 2007; Borges et al. 2008). For this reason Madeira (as well as every other Macaronesian island) forms part of the Mediterranean hotspot and is therefore included in the Global Biodiversity Hotspots network (Myers et al. 2000). Nevertheless, the endemic biodiversity of Madeira faces several conservation threats common to other island environments (Whittaker & Fernández-Palacios 2007; New 2008; Silva et al. 2008). Human-driven extinctions have been reported since the Portuguese arrival in the 15th century (Goodfriend et al. 1994; Gardiner 2003; Fontaine et al. 2007) and the survival and conservation status of many en-

demic species is of concern (Becker 1992; Assing 1997; Martín et al. 2008).

The taxonomic diversity of Madeiran ground beetles is reasonably well known. During the last two decades some genera have been thoroughly revised and new species described (Erber 1990a; Machado 1995; Wrase & Jaeger 1996; Lompe 1997; 1999; Donabauer 2008; Serrano & Boieiro 2008; Serrano et al. 2009; Wrase 2010). More ver, studies on species distribution and general biology have also been published (Erber 1990b; Erber & Aguiar 1996). Seventy-three ground beetle species and subspecies are endemic to the Madeiran archipelago, most of which occur in Madeira Island (Serrano & Boieiro 2008; Wrase 2010). Some genera are particularly speciose, being represented by a considerable number of endemic species on the island (e.g. *Calathus*, *O thomus* and *Trechus*), but for most of them information on abundance, distribution, phenology and ecology is still limited. In this study we provide information on the distribution and abundance of Madeiran endemic ground beetles, particularly those species associated with the native forest – the *Laurisilva*. We also report the third record of *Dromius angustus alutaceus* Wollaston, 1857 and provide a picture of this rare endemic subspecies.

MATERIAL AND METHODS

Thirty-six sites were sampled in Madeira Island, most of them located within the *Laurisilva* (Fig. 1). Two standardised sampling techniques were applied, namely: (1) pitfall trapping with baited (Turquin solution) and unbaited (ethyleneglycol 10%) traps and (2) direct sampling of four microhabitats (dead trees, living trees, under stones and leaf litter). Pitfall trapping was conducted during a two-week period and was performed both in May-June 2006 (sites 1 to 28) and June 2007 (sites 29 to 36). Direct sampling was performed controlling for effort time in each location during June 2007 in most of the sampling sites. Direct sampling included the ground, dead tree trunks and subcortical searching. The sampling design was semi-quantitative with a sampling unit defined as 30 minute/person of effective fieldwork. For each species we present information on the technique used for sampling, site location code (see Table 1) and number of males and females captured. More information concerning the study areas and sampling date/period are provided in Table 1. The specimens collected during this study are deposited in the entomological collection of the Faculty of Sciences of the University of Lisbon (Portugal).

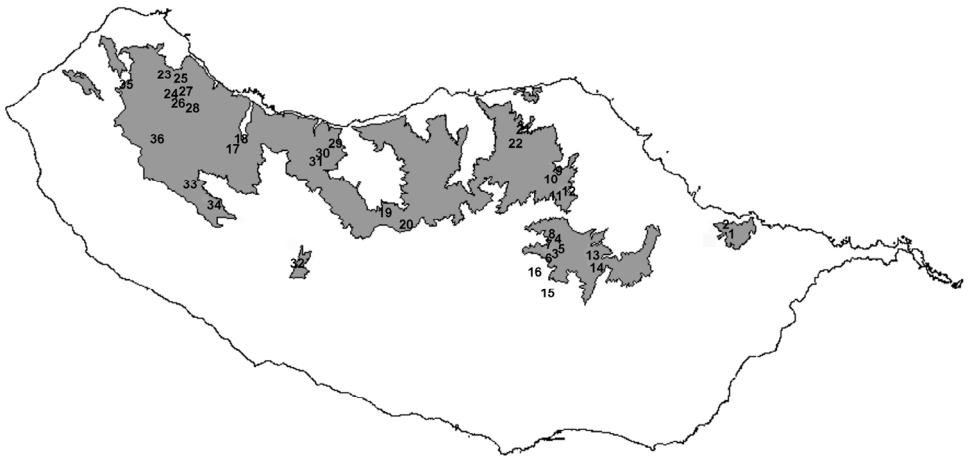

Fig. 1. Spatial distribution of the sampling sites in Madeira Island. *Laurisilva* cover is marked in grey. Sites 15 and 16 were not located in *Laurisilva*. See Table 1 for more information on site location.

Table 1. Site code, location (geographic coordinates in decimal degrees) and altitude of the study areas and indication of the sampling date/period according to the technique applied (pitfall trapping or direct sampling).

Code	Site	Lat (N)	Lon (W)	Altitude (m)	Pitfall trapping period	Direct sampling
1	Funduras	32.7493	-16.8114	500	22-05 to 05-06-2006	04-06-2007
2	Funduras	32.7540	-16.8099	552	22-05 to 05-06-2006	04-06-2007
3	Fajã da Nogueira – Lvda. Pte. Roquete	32.7391	-16.9156	1074	23-05 to 06-06-2006	-
4	Fajã da Nogueira – Mtdo. do Leacoque	32.7415	-16.9161	630	23-05 to 06-06-2006	06-06-2007
5	Fajã da Nogueira – Casa do Levadeiro	32.7406	-16.9136	989	23-05 to 06-06-2006	-
6	Fajã da Nogueira – Mtdo. do Leacoque	32.7418	-16.9177	614	23-05 to 06-06-2006	06-06-2007
7	Fajã da Nogueira – Tanque	32.7425	-16.9168	845	23-05 to 06-06-2006	06-06-2007
8	Fajã da Nogueira - Til Gigante	32.7457	-16.9150	841	23-05 to 06-06-2006	06-06-2007
9	Queimadas	32.7873	-16.9047	841	24-05 to 07-06-2006	05-06-2007
10	Pico das Pedras	32.7841	-16.9055	883	24-05 to 07-06-2006	05-06-2007
11	Achada do Teixeira	32.7733	-16.9081	1211	24-05 to 07-06-2006	05-06-2007
12	Achada do Teixeira	32.7762	-16.9022	1103	24-05 to 07-06-2006	05-06-2007
13	Ribeiro Frio – Viveiro	32.7354	-16.8864	906	24-05 to 07-06-2006	05-06-2007
14	Ribeiro Frio – Cottages	32.7319	-16.8861	994	24-05 to 07-06-2006	05-06-2007
15	Pico do Areeiro	32.7231	-16.9109	1533	24-05 to 07-06-2006	-
16	Pico do Areeiro	32.7287	-16.9202	1594	24-05 to 07-06-2006	-
17	Chão da Ribeira	32.7933	-17.1122	519	25-05 to 08-06-2006	07-06-2007
18	Chão da Ribeira	32.7957	-17.1117	491	25-05 to 08-06-2006	07-06-2007
19	Chão dos Louros	32.7636	-17.0190	748	25-05 to 08-06-2006	07-06-2007
20	Encumeada	32.7558	-17.0143	999	25-05 to 08-06-2006	-
21	Ribeiro Bonito – Levada	32.8047	-16.9346	568	25-05 to 08-06-2006	09-06-2007
22	Ribeiro Bonito - Ribeiro	32.7985	-16.9360	560	25-05 to 08-06-2006	09-06-2007
23	Fanal	32.8302	-17.1585	755	26-05 to 09-06-2006	-
24	Fanal (Lvda. Cedros)	32.8259	-17.1580	820	26-05 to 09-06-2006	09-06-2007
25	Fanal	32.8236	-17.1560	890	26-05 to 09-06-2006	09-06-2007
26	Fanal	32.8226	-17.1539	889	26-05 to 09-06-2006	09-06-2007
27	Fanal	32.8182	-17.1521	1023	26-05 to 09-06-2006	09-06-2007
28	Fanal	32.8062	-17.1409	1134	26-05 to 09-06-2006	10-06-2007
29	Ginjas	32.7758	-17.0534	869	08-06 to 22-06-2007	23-06-2007
30	Caramujo	32.7722	-17.0529	981	08-06 to 22-06-2007	-
31	Caramujo	32.7746	-17.0559	1001	08-06 to 22-06-2007	-
32	Rabaças	32.7413	-17.0783	993	10-06 to 24-06-2007	-
33	Rabaçal	32.7647	-17.1341	930	10-06 to 24-06-2007	25-06-2007
34	Risco	32.7608	-17.1256	1048	10-06 to 24-06-2007	25-06-2007
35	Casa do Elias	32.8268	-17.1883	814	26-06 to 10-07-2007	-
36	Galhano	32.7971	-17.1729	975	27-06 to 11-07-2007	-

RESULTS

During this study a total of 33 ground beetle species and subspecies endemic to Madeira were sampled. The species collected are herein listed alphabetically and follow the nomenclature proposed in Löbl & Smetana (2003). Numbers refer to the site codes in Table 1.

Bradycellus assingi Wrase & Jaeger, 1996
Pitfall: 5 (1♂), 11 (9♂, 2♀), 12 (3♂), 20 (2♂, 1♀)
Direct sampling: 11 (1♂), 12 (1♂)

Bradycellus excultus Wollaston, 1854
Pitfall: 3 (1♂), 5 (3♂), 23 (1♂, 1♀), 25 (1♀), 27 (1♂, 1♀), 28 (1♀), 29 (3♂, 2♀), 31 (8♂), 36 (1♂)
Direct sampling: 27 (1♀)
This species was found for the first time at Ginjas, Caramujo and Galhano.

Bradycellus maderensis Mateu, 1958
Pitfall: 14 (3♂)
Direct sampling: 14 (2♂)

Bradycellus wollastoni Wrase & Jaeger, 1996
Pitfall**:** 5 (1♂), 14 (1♂), 26 (1♂), 28 (1♂, 1♀), 35 (1♂, 6♀)

Calathus colasianus Mateu, 1970
Pitfall: 1 (1♂, 1♀), 2 (2♂, 1♀), 3 (1♂, 1♀), 17 (1♂), 19 (1♀), 27 (1♂), 30 (1♂), 31 (1♀)
Direct sampling: 1 (5♂, 4♀), 4 (3♂, 1♀), 6 (2♂), 11 (1♂), 17 (1♂), 19 (1♂)
Knowledge on the distribution of *C. colasianus* improved considerably and this endemic is actually more widespread than previously thought.

Calathus complanatus Dejean, 1828
Pitfall: 11 (1♂)

Calathus vividus (Fabricius, 1801)
Pitfall: 11 (2♂, 1♀), 33 (2♂, 2♀), 34 (1♂, 2♀)
Two new records from areas in the vicinity of previously known occurrence sites.

Cymindis maderae Wollaston, 1857
Pitfall: 11 (1♂, 1♀), 32 (20♂, 13♀)
Direct sampling: 11 (1♀)
Record of this species at Rabaças is interesting due to the isolation of this small forest fragment.

Dromius angustus alutaceus Wollaston, 1857
Direct sampling: 13 (1♂)
This is the first finding of this endemic subspecies in the last fifty years (Fig. 2). A single specimen was found at Ribeiro Frio about 5 km from the nearest historical citation.

Loricera wollastonii Javet, 1852
Pitfall: 12 (1♀), 27 (1♂, 2♀), 28 (1♂, 1♀)
A widespread but uncommon ground beetle now found at lower altitudes in the Fanal region.

Nesarpalus gregarius (Fauvel, 1897)
Pitfall: 3 (1♂)
A widespread endemic now recorded in the vicinity of the Levada da Ponte do Roquete (Fajã da Nogueira), near two known areas of occurrence.

Olisthopus ericae Wollaston, 1854
Pitfall: 11 (1♂, 1♀)
Direct sampling: 1 (2♂, 5♀), 2 (18♂, 7♀), 4 (1♂, 3♀), 6 (39♂, 53♀), 7 (3♂), 8 (8♂, 6♀), 9 (6♂, 4♀), 10 (10♂, 7♀), 11 (38♂, 29♀), 12 (20♂, 17♀), 13 (14♂, 19♀), 14 (10♂, 7♀), 17 (3♂, 2♀), 19 (31♂, 22♀), 21 (2♀), 24 (118♂, 92♀), 25 (36♂, 29♀), 26 (10♂, 10♀), 27 (42♂, 33♀), 28 (31♂, 21♀), 29 (20♂, 11♀), 33 (17♂, 22♀), 34 (17♂, 11♀)
The distribution of this endemic was greatly improved and the species is now known from a number of localities between Fanal on the west and Funduras on the east of Madeira Island.

Olisthopus madeirensis Wollaston, 1854
Pitfall: 20 (1♀)
Direct sampling: 1 (1♀), 2 (3♂, 1♀), 4 (1♂), 9 (2♂), 10 (10♂, 17♀), 11 (4♂, 4♀), 12 (1♂, 3♀), 17 (6♂, 1♀), 19 (1♀), 21 (3♂, 1♀), 24 (19♂, 10♀), 25 (2♂, 1♀), 26 (3♀), 27 (1♂, 3♀), 28 (1♂, 1♀), 29 (4♂)
The known distribution of *O. madeirensis* was broadened to a range similar to that of its congener (from Fanal eastwards to Funduras). However, this endemic seems much less abundant than its close relative.

Fig. 2. Dorsal view of a male *Dromius angustus alutaceus* Wollaston, 1857

Orthomus annae (Donabauer, 2008)
= *Orthomus susanae* Serrano & Borges, 2009
Pitfall: 21 (2 ♂), 22 (1♂), 24 (7♂, 17♀), 25 (3♂, 8♀), 26 (6♂, 17♀), 27 (8♂, 5♀)
Direct sampling: 22 (1♂), 25 (1♂, 1♀), 27 (2♂, 1♀)
A recently described species apparently restricted to only two areas in Madeira Island. Jiménez-Valverde and colleagues (2008) used predictive distribution modelling to evaluate the potential distribution of this species in Madeira and identified several additional areas with a high probability of occurrence.

Orthomus berrai (Battoni, 1987)
Pitfall: 1 (2♂, 5♀), 2 (4♂, 10♀), 21 (2♂, 2♀), 22 (1♂, 2♀)
Direct sampling: 1 (1♀), 2 (1♂, 2♀), 8 (2♂), 13 (1♂), 22 (1♂, 1♀)
This species was believed to be restricted to the eastern part of Madeira Island but has now been found in new localities in the north.

Orthomus curtus (Wollaston, 1854)
Pitfall: 1 (9♂, 5♀), 2 (12♂, 9♀), 3 (1♀), 4 (1♂, 1♀), 5 (29♂, 23♀), 6 (2♂, 4♀), 7 (1♂), 8 (9♂, 4♀), 9 (18♂, 5♀), 10 (16♂, 7♀), 11 (7♂, 1♀), 12 (27♂, 11♀), 13 (4♂, 10♀), 14 (5♂, 5♀), 19 (13♂, 24♀), 20 (30♂, 27♀), 21 (7♂, 6♀), 22 (2♂, 3♀), 23 (2♀), 29 (37♂, 33♀), 30 (20♂, 16♀), 31 (18♂, 16♀)
Direct sampling: 2 (2♂), 7 (1♂), 9 (2♂, 4♀), 12 (3♂), 13 (1♀), 19 (2♂, 1♀)
This common endemic is now known to occur in several locations between Fanal and Funduras.

Orthomus dilaticollis (Wollaston, 1854)
Pitfall: 12 (1♂), 17 (1♂, 1♀), 25 (3♂), 27 (20♂, 17♀), 28 (7♂, 8♀), 33 (2♂, 2♀), 34 (1♂)
Direct sampling: 12 (1♂)
This endemic species was only known from a few locations in Madeira (Wollaston 1854; Jeannel 1938; Serrano & Aguiar 1997; Donabauer 2008). It has now been recorded from a number of sites in western Madeira as well as from Achada do Teixeira.

Orthomus gracilipes (Wollaston, 1854)
Pitfall: 12 (2♂, 1♀), 13 (1♀), 17 (1♂, 1♀), 18 (2♀), 19 (6♂, 3♀), 24 (1♂, 1♀), 25 (2♂, 1♀), 29 (1♂, 2♀), 30 (1♀), 31 (1♀), 33 (1♂), 35 (1♀)
Direct sampling: 6 (1♀)
New localities of occurrence of this endemic were found in western Madeira, all lying within the limits of the known species distribution range.

Orthomus lundbladi Jeannel, 1938
Pitfall: 32 (1♂), 34 (3♂, 9♀)
This endemic is apparently restricted to western Madeira and was now found in the Rabaças forest fragment.

Paradromius insularis (Wollaston, 1854)
Pitfall: 25 (1♂)
Direct sampling: 1 (1♀), 6 (2♀), 8 (2♂, 2♀), 9 (1♂), 13 (3♂, 1♀), 14 (2♂, 3♀), 18 (1♂), 25 (1♀), 26 (6♂, 1♀), 29 (3♂, 1♀)
Several new localities were recorded within the previously known range of this widespread endemic.

Philorhizus conicipennis (Fauvel, 1905)
Direct sampling: 6 (1♀), 8 (1♀)
This rare species was found near areas of previous citations.

Philorhizus vieirai Mateu, 1957
Direct sampling: 11 (1♂)
This rare endemic was known from only two locations and this new record lies close to one of them.

Scarites abbreviatus Dejean, 1825
Pitfall: 1 (4♂, 9♀), 2 (8♂, 16♀), 3 (2♂), 4 (10♂), 5 (1♂), 6 (4♂), 7 (2♂, 2♀), 8 (6♂), 9 (3♂), 10 (2♂), 11 (2♂), 12 (2♂, 2♀), 13 (13♂, 5♀), 14 (13♂), 19 (12♂), 21 (5♀), 22 (2♀), 24 (1♂), 25 (17♂, 1♀), 26 (13♂), 27 (1♂), 29 (1♂), 31 (1♂), 33 (1♂), 34 (4♂, 3♀), 35 (3♂)
Direct sampling: 4 (1♂) 8 (2♂) 13 (2♂, 1♀), 21 (1♀), 27 (1♂, 1♀), 28 (1♀)
Some new localities are reported within the distribution range of this widespread endemic.

Syntomus lundbladi (Jeannel, 1938)
Pitfall: 16 (2♀)

Trechus custos Wollaston, 1854
Pitfall: 19 (2♂, 2♀), 29 (1♀)
Direct sampling: 1 (5♂, 2♀), 2 (10♂, 7♀), 4 (13♂, 2♀), 6 (8♂, 4♀), 7 (9♂, 3♀), 10 (2♂, 2♀), 11 (3♂, 1♀), 12 (2♂), 13 (2♂), 14 (3♂), 17 (5♂, 2♀), 18 (8♂, 2♀), 19 (5♂, 2♀), 21 (5♂, 5♀), 34 (1♀)
Some new localities are reported within the range of this widespread endemic.

Trechus decolor Jeannel, 1938
Pitfall: 17 (2♀), 18 (4♂, 11♀), 20 (3♀)
All records lie within the previously known distribution limits of this species.

Trechus dilutus Wollaston, 1854
Pitfall: 24 (9♂, 2♀), 35 (1♂)
Two new localities are reported at the western limit of the species range.

Trechus flavomarginatus Wollaston, 1854
Pitfall: 11 (6♂, 7♀), 20 (1♂, 3♀)
Two new localities are reported lying within the known range of the species.

Trechus maderensis Csiki, 1928
Pitfall: 17 (1♀), 34 (1♂)
Reported for the first time from Chão da Ribeira.

Trechus minyops Wollaston, 1862
Pitfall: 4 (1♂), 7 (1♂), 11 (1♂, 1♀), 12 (1♀)
Reported for the first time from Fajã da Nogueira.

Trechus nugax Lompe, 1997
Pitfall: 24 (1♂, 1♀), 27 (8♂, 3♀), 28 (5♂, 2♀), 35 (2♂)
Several new records are reported near known localities of this restricted endemic.

Trechus umbricola Wollaston, 1854
Pitfall: 5 (1♂), 6 (1♂), 9 (25♂, 62♀), 10 (1♂, 13♀), 12 (1♀), 14 (1♀), 20 (4♂, 7♀), 22 (2♀), 24 (2♀), 25 (1♀), 26 (1♀), 28 (1♀)
Direct sampling: 9 (4♂, 2♀), 10 (5♂, 1♀), 19 (1♂), 22 (1♀), 25 (1♀), 28 (1♂), 34 (1♂)
Several new records are reported within the distribution area of this widespread endemic.

Zargus pellucidus Wollaston, 1854
Direct sampling: 8 (2♂)
A new distribution record is reported for this rare endemic species.

DISCUSSION

The standardised and extensive sampling design adopted in our study (Fig. 1) contributes with crucial information to the knowledge on the spatial distribution of Madeiran endemic ground beetles associated with *Laurisilva*. New localities have been identified even for some widespread species such as *Bradycellus excultus*, *Orthomus curtus*, *O. gracilipes*, *Scarites abbreviatus*, *Tre-*

chus custos and *T. umbricola*, which in some cases implied a redefinition of the species range. Furthermore, more restricted species such as *Orthomus berrai*, *O. dilaticollis*, *O. lundbladi*, *Trechus nugax* and *Syntomus lundbladi* were found in some areas at a distance from their historical locations. In the case of the two former species these additional records implied a considerable increase to the known distribution range.

Very interesting results were also obtained from direct sampling in living and dead trees. The endemic *Dromius angustus alutaceus* was "rediscovered" following its latest finding more than 50 years ago. Wollaston (1857) reported a single specimen from the proximity of Santo António da Serra and several others at Monte and Camacha, considering this endemic as very restricted. One hundred years later, Mateu (1957) cited a few specimens from Queimadas, Santo António da Serra and Santa Ana and provided a redescription of this endemic subspecies. The paucity of citations during the last 50 years generated some concern on the possible extinction of this endemic. We found a single specimen of *D. angustus alutaceus* at Ribeiro Frio by direct sampling on living trees on the 5 June 2007. The specimen morphology (Fig. 2) agrees with the original description as well as with the redescription of Mateu (1957): elytra are opaque with a strong microsculpture, elytral striae are well marked and male genitalia is provided with an apical hook. Machado (1992) highlighted the singular distribution of *Dromius angustus* and its relictual occurrence in Madeira and the Canary Islands, where distinct subspecies are known to occur. Taking into consideration the consistency in morphological variation in specimens from the different islands, it could be interesting to assess the degree of genetic differentiation among island populations in order to evaluate their taxonomic distinctness.

Interesting findings were also made among other arboreal species. Two rare *Philorhizus* species have been recorded in this study, both as singletons at each site of occurrence. Moreover, the number of known localities more than doubled for the two endemic *Olisthopus* and the distribution range of these species is now better known. These results on the distribution and abundance of arboreal ground beetles reinforce the idea that in groups with a somewhat heterogeneous ecology a combination of sampling techniques (e.g., direct sampling, pitfall trapping, Berlese extraction) should be adopted for species inventories and assessing species abundance (e.g. Cardoso 2009).

Basic information on species abundance and distribution is the raw material upon which to make inferences on species conservation status. During the last decade there has been a growing concern for the need to address specific conservation measures for invertebrates, in spite of some bias towards the conservation of emblematic and charismatic species or groups (e.g. Cardoso et al. 2011a, b). Some relevant information on Madeiran insect biodiversity and conservation has recently been published (e.g. Borges et al. 2008; Martín et al. 2008, 2010; Silva et al. 2008; Boieiro et al. 2010). However, major efforts must still be undertaken to further enhance our knowledge on species assemblages and ecology if we are to conserve the unique invertebrate fauna of Madeira.

ACKNOWLEDGEMENTS

We acknowledge Madeira Nature Park Service particularly its former director Susana Fontinha for the help in fieldwork planning and implementation. We are also thankful to the nature wardens H. Fernandes and M. Gomes for their valuable support during fieldwork. Financial support was provided by Science and Technology Foundation (FCT, Portugal) through projects PDCT/BIA-BDE/59202/2004 and PTDC/BIA-BEC/99138/2008. I.R. Amorim and C. Rego were supported by FCT fellowships (BPD/29578/2006 and BPD/66934/2009 respectively).

REFERENCES

Assing, V. 1997. A revision of the Madeiran species of *Geostiba* (Coleoptera: Staphylinidae). Supplement I. *Revue Suisse de Zoologie* 104: 345-355.

Becker, P. 1992. Colonization of islands by carnivorous and herbivorous Heteroptera and Coleoptera: effects of island area, plant species richness, and “extinction” rates. *Journal of Biogeography* 19: 163-171.

Boieiro, M., D. Menezes, C. Rego & A.R.M. Serrano 2010. Spatial patterns of endemism and the conservation of beetles (Carabidae and Staphylinidae) in Madeira Island. Pp. 115-132 in: Serrano, A.R.M., P.A.V. Borges, M. Boieiro & P. Oromí (Eds). *Terrestrial Arthropods of Macaronesia: Biodiversity, Ecology and Evolution.* Sociedade Portuguesa de Entomologia, Lisboa. 327 pp.

Borges, P.A.V., C. Abreu, A.M.F. Aguiar, P. Carvalho, R. Jardim, I. Melo, P. Oliveira, C. Sérgio, A.R.M. Serrano & P. Vieira (Eds) 2008. *A List of the Terrestrial Fungi, Flora and Fauna of Madeira and Selvagens Archipelagos.* Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo. 438 pp.

Cardoso, P. 2009. Standardization and optimization of arthropod inventories – the case of Iberian spiders. *Biodiversity and Conservation* 18: 3949-3962.

Cardoso, P., P.A.V. Borges, K. Triantis, M.A. Fernández & J.L. Martín 2011a. Adapting the IUCN red listing criteria for invertebrates. *Biological Conservation* 144: 2432-2440.

Cardoso, P., T.L. Erwin, P.A.V. Borges & T.R. New 2011b. The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation* 144: 2647-2655.

Cook, L.M. 2007. Species richness in Madeiran land snails, and its causes. *Journal of Biogeography* 35: 647-653.

Donabauer, M. 2008. Zwei neue Arten der Gattungen *Nesorthomus* und *Eutrichopus* (Coleoptera: Carabidae: Pterostichini). *Zeitschrift Arbeitsgemeinschaft Österrreichischer Entomologen* 60: 117-120.

Erber, D. 1990a. *Thalassophilus pieperi* n. sp., a new cavernicolous carabid beetle from Madeira. *Bocagiana* 140: 1-7.

Erber, D. 1990b. New and little known coleoptera from Madeira. Results of excursions to Madeira in the years 1986-1990. *Boletim do Museu Municipal do Funchal* 42: 147-181.

Erber, D. & F. Aguiar 1996. New and remarkable species of the coleopterous fauna of Madeira. *Boletim do Museu Municipal do Funchal* 48: 41-62.

Fontaine, B., *et al.* 2007. The European union's 2010 target: Putting rare species in focus. *Biological Conservation* 139: 167-185.

Gardiner, B.O.C. 2003. The possible cause of extinction of *Pieris brassicae wollastoni* Butler (Lepidoptera: Pieridae). *Entomologists' Gazette* 54: 267-268.

Goodfriend, G.A., R.A.D. Cameron & L.M. Cook 1994. Fossil evidence of recent human impact on the snail fauna of Madeira. *Journal of Biogeography* 21: 309–320.

Jardim, R. & D. Francisco 2000. *Endemic Flora of Madeira.* Múchia Pubs., Funchal. 339 pp.

Jeannel, R. 1938. Die Arthropodenfauna von Madeira nach den Ergebnissen der Reise von Prof. Dr. O. Lundblad Juli–August 1935. V. Coleoptera : Carabidae. *Arkiv för Zoologi* 30A(10): 1–18.

Jiménez-Valverde, A, J. Hortal, J. Lobo, P.A.V. Borges, C. Abreu, A.M.F. Aguiar, M. Boieiro, S. Fontinha, R. Jardim, P. Oliveira, C. Sérgio, A.R.M. Serrano, M. Sim-Sim, D. Nunes & E.B. Azevedo 2008. Using predictive models of species distribution to validate biodiversity data: case studies for Madeira Island. Pp. 27-56 in: Borges, P.A.V., C. Abreu, A.M.F. Aguiar, P. Carvalho, S. Fontinha, R. Jardim, I. Melo, P. Oliveira, A.R.M. Serrano & P. Vieira (Eds). *A List of the Terrestrial Fungi, Flora and Fauna of Madeira and Selvagens Archipelagos.* Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo. 438 pp.

Löbl, I. & A. Smetana (Eds) 2003. *Catalogue of Palaearctic Coleoptera.* Vol. 1. Stenstrup, Apollo Books. 819 pp.

Lompe, A. 1997. Neue *Trechus*-Arten von Madeira (Coleoptera, Carabidae). *Entomologische Blätter* 93: 51-55.

Lompe, A. 1999. Revision der *Trechus*-Arten Madeiras und Porto Santos (Coleoptera, Carabidae). *Entomologische Blätter* 95: 93–143.

Machado, A. 1992. *Monografia de los Carabidos de las Islas Canarias*. Intituto de Estudos Canarios, La Laguna. 734 pp.

Machado, A. 1995. Ground beetles of Macaronesia, an overview (Coleoptera, Carabidae). *Boletim do Museu Municipal do Funchal Sup*. 4: 395-410.

Martín, J.L, M. Arechavaleta, P.A.V. Borges & B. Faria (Eds) 2008. *TOP 100 - As Cem Espécies Ameaçadas Prioritárias em Termos de Gestão na Região Europeia Biogeográfica da Macaronésia.* Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias. 500 pp.

Martín, J.L., P. Cardoso, M. Arechavaleta, P.A.V. Borges, B.F. Faria, C. Abreu, A.F. Aguiar, J.A. Carvalho, A.C. Costa, R.T. Cunha, F.M. Fernandes, R. Gabriel, R. Jardim, C. Lobo, A.M.F. Martins, P. Oliveira, P. Rodrigues, L. Silva, D. Teixeira, I.R. Amorim, N. Homem, B. Martins, M. Martins & E. Mendonça 2010. Using taxonomically unbiased criteria to prioritize resource allocation for oceanic island species conservation. *Biodiversity and Conservation* 19: 1659-1682.

Mateu, J. 1957. Revisión de los *Dromius* Bonelli y

Philorhizus Hope, de las Islas Canarias y Madera (Col. Carabidae). *Bulletin du Institut Royal des Sciences Naturelles de Belgique* 33 (29): 1-30.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. Fonseca & J. Kent 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

New, T. (Ed) 2008. *Insect Conservation and Islands.* Springer, Dordrecht, The Netherlands. 445 pp.

Serrano, A.R.M. & C.A.S. Aguiar 1997. An approach to the ground beetles (Coleoptera, Carabidae) of two fragments of laurel forest (Madeira Island). *Portugaliae Zoologica* 4(2): 9-19.

Serrano, A.R.M., C.A.S. Aguiar, M.C. Boieiro, P.A.V. Borges, C. Rego, I.A. Rosário, S.P. Ribeiro & F. Pereira 2009. A new species of *Orthomus* Chaudoir, 1838 (Coleoptera: Carabidae) from Madeira island (Macaronesia) and notes on related species. *Zootaxa* 1972: 20-34.

Serrano, A.R.M. & M. Boieiro 2008. Carabidae. Pp. 310-313 in: Borges, P.A.V., C. Abreu, A.M.F. Aguiar, P. Carvalho, S. Fontinha, R. Jardim, I. Melo, P. Oliveira, A.R.M. Serrano & P. Vieira (Eds). *A List of the Terrestrial Fungi, Flora and Fauna of Madeira and Selvagens Archipelagos.* Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo. 438 pp.

Silva, L., E.O. Land & J.L. Rodríguez Luengo (Eds) 2008. Invasive Terrestrial Flora & Fauna of Macaronesia. TOP 100 in Azores, Madeira and Canaries. ARENA, Ponta Delgada. 546 pp.

Whittaker, R.J. & J.M. Fernández-Palacios 2007. *Island Biogeography: Ecology, Evolution, and Conservation*. Oxford University Press, Oxford. 412 pp.

Wollaston, T.V. 1854. *Insecta Maderensia, being an Account of the Insects of the Islands of the Madeiran Group*. London. 634 pp.

Wollaston, T.V. 1857. *Catalogue of the Coleopterous Insects of Madeira in the collection of the British Museum*. London. 234 pp.

Wrase, D.W. 2010. A new species of genus *Zargus* Wollaston 1854 from Madeira (Coleoptera, Carabidae, Licinini). *Linzer biologische Beiträge* 42: 325-334.

Wrase, D.W. & B. Jaeger 1996. Revision der *Bradycellus*-Arten der Atlantischen Inseln aus der verwandtschaft des *Br. excultus* Woll. (Coleoptera, Carabidae, Harpalini). *Linzer biologische Beiträge* 28: 497-515.

Received 15 Nov 2011. Accepted 20 March 2012, Published online 22 May 2012