APPROACH TO THE KNOWLEDGE OF COCCINELLIDADE (COLEOPTERA) SPECIES DIVERSITY OF MADEIRA AND PORTO SANTO ISLANDS

A.O. SOARES, R.B. ELIAS & A. RAIMUNDO

We present a list of coccinellids collected in Madeira archipelago and notice the presence of two new species; of *Scymnini*; *Scymnus (Scymnus) abietis* (Paykull) and *Nephus hiekei* Fürsch. We analyse the distribution and abundance at the community level, using the following measures: species richness index, abundance and relative abundance, similarity index, diversity, and evenness. 13 species from 3 families were recorded. *Hippodamia variegata* was the most abundant one with 29.7 % of the 141 specimens collected. Two main groups of relative abundance were identified. The first group included the 6 most common *H. variegata*, *S. interruptus*, *C. arcuatus*, *C. septempunctata*, *S. levaillanti* and *R. litura* and the second one included *S. abietis*, *L. lophante* and *R. chrysomeloides*. Diversity index values are relatively high. The 6 most common species comprised more than 90 % of the individuals without a very different relative abundance.

Many factors other than extinction and immigration could explain the variation of the number of species on islands. The highest number of species collected in Madeira island, compared to Porto Santo, could be related with its higher elevation, soil and substrate types, plant species richness, number of habitat, habitats diversity, structure and heterogeneity of the former.

António O Soares (e-mail: onofre@notes.uac.pt), R.B. Elias, Department of Biology, University of the Azores, Rua da Mãe de Deus, Apart. 1422, PT-9501-801 Ponta Delgada, Portugal & A. Raimundo, Department of Biology, University of Évora, PT-7000 Évora, Portugal.

INTRODUCTION

According to the MACARTHUR and WILSON'S (1967) equilibrium theory of island biogeography, the number of species on islands balances regional process governing immigration against local process governing extinction. The immigration rate of new species to the island will be dependent on the potential mainland colonists and the extinctions rate increases with the number of species already present on the island. The extinction rate through competition between species on islands increases more rapidly as species diversity also increases. According to the same model, small and more isolated islands are thought to support fewer species. However, many factors not included in the model, other than extinction and immigration, could explain the variation on the number of species on islands such as elevation, number of soil types, substrate types, plant species richness, number of habitats, habitat diversity, structure and heterogeneity (BORGES 1992; BORGES & BROWN 1999).

Species diversity is an expression of community structure. High species diversity indicates a highly complex community, for a greater variety of species allows for a larger array of species interactions (ZAR 1984). Information on community characteristics, mainly diversity, has remained a central issue in ecology and measures of diversity are frequently seen as indicators of the stability and maturity of the

community and the well being of ecological systems. Diversity can be divided into two components: the variety or species richness and the relative abundance of species or heterogeneity (MAGURRAN 1991). Diversity measures can be a useful tool in environmental monitoring and conservation management (MAGURRAN 1991), used to evaluate how far the impact of immigration, extinctions and environmental factors, namely human activity, can affect its components. Thus all information concerning previous history of the community, such as the permanence of community in time is very important.

The main characteristics of the Madeiran archipelago are as follows. *Geography and geology*: located in the North Atlantic Ocean between 32º20'-33º10' N latitude and 16º20'-17º20' W longitude. Is 978 km distant from Lisbon and 630 km from the west coast of Morocco, to the Azores it roughly 800 km and to Canary Islands 380 Km. It is formed by two main islands (Madeira - 728 km^2 and Porto Santo - 57 km^2) and three small islands located at 24 km southeast of Madeira (Chão, Deserta Grande e Bugio). Pico Ruivo (1862 m) and Pico do Facho (478 m) are Madeira's and Porto Santo's highest elevations. The archipelago has a volcanic origin. It was formed 60-70 million years ago but Porto Santo has been subaerial for only 12-13 million years whereas Madeira has been aerial for 2-3 million years. *Climate*: Mediterranean type, rather homogenous, but varies depending on the elevation and exposure. The annual precipitation varies much depending on the altitude (Funchal, 645 mm; Encumeada 2675 mm and Porto Santo 338 mm). Monthly temperatures range from 6 to 20 ºC, depending on the region. Porto Santo is semi-arid. *Vegetation*: Madeira presents an evergreen laurel forest, called laurisilva, which covers about 10 % of the island. The vegetation on most of the southern part of the island, as well as along portions of the northern coast and into the valleys presents many introduced plants and

trees. The natural vegetation of Porto Santo has also been totally destroyed. It was probably thermophilous laurel forest (KARSHOLT 2000).

Term community used in this work, has its broadest sense, *i.e.*, a set of coccinellid individuals present in a given habitat at a particular time (HODEK & HONĚK 1996). Thus we will consider each island as a whole despite the differences in habitats and the mosaic of environments that each habitat can have. The aims of this work were (i) to provide a contribution to the knowledge of the biological control agents of the *Coccinellidae* family, in Madeira Archipelago (ii) to characterise species diversity of the *Coccinellidae* community, and (iii) to test the species-area hypothesis, which predicts that assemblages will be more species rich on larger islands.

MATERIAL & METHODS

Twenty-three sampling sites located in Madeira and Porto Santo was selected. In which one 30 samples were taken [MADEIRA: Funchal (1), Camacha (1), Santo da Serra (2) Caniçal (1), Câmara de Lobos (1), Quinta Grande (1), Anjos (1), Laranjeiras (1), Porto Moniz (1), Seixal (1), Chão da Ribeira (1), Santana (2), Faial (1), Curral das Freiras (1), Fajã da Rocha do Barco (1); PORTO SANTO: Pico do Castelo (1), Fonte da Areia (1), Aeroporto (1), Portela (2) and Pedrogal (1)] (Fig. 1). Depending on the type of vegetation, different methods were used such as direct observation, beating and sweeping methods, collecting the ladybeetles with a suction tube aspirator. We never took more than an hour in each plot. The collected specimens were preserved in 70% alcohol and afterwards mounted and classified. The specimens collected are deposited at the Ecology Section of the Biology Department of the Azores University (ref. CC-UA-SC-MAD).
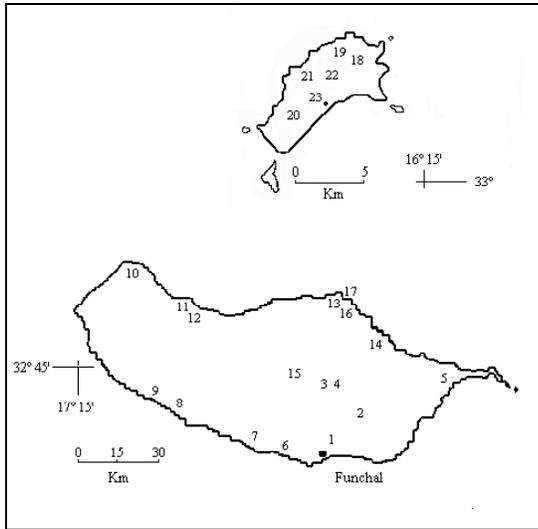
Fig. 1. Madeira and Porto Santo Islands with reference to the 23 sites; 1-Funchal, 2-Camacha, 3 and 4-Santo da Serra, 5-Caniçal, 6-Câmara de Lobos, 7-Quinta Grande, 8-Anjos, 9-Laranjeiras, 10-Porto Moniz, 11-Seixal, 12 Chão da Ribeira, 13 and 16-Santana, 14-Faial, 15-Curral das Freiras, 17-Fajã da Rocha do Barco, 18-Pico do Castelo, 19-Fonte da Areia, 20-Aeroporto, 21 and 23-Portela and 22-Pedrogal.

To characterise the community structure of the *Coccinellidae* fauna, the following measures of diversity were used:

Species richness index (D): Species richness provides an extremely useful measure of diversity. A number of simple indices have been derived using some combination of S (number of species recorded) and N (total number of individuals summed over all species) such as the Margalef's index (MAGURRAN 1991):

$$D_{Mg} = \frac{(S-1)}{\ln N} \qquad (1)$$

Abundance (n_i) and relative abundance (p_i): Relative proportions of different species in the community can be measured. The abundance and relative abundance express the total number of individuals collected and the distribution of individuals among species, respectively. If n_1, n_2, n_3, ... n_i, are the abundance of species 1, 2, 3 ..., i, the relative abundance expressed in percentage, becomes (MAGURRAN 1991):

$$p\mathrm{i} = \left[\frac{n\mathrm{i}}{(n1 + n2 + n3 ... + n\mathrm{i})} \right] 100 \qquad (2)$$

Similarity index (C_s): This is a simple measure of the extent to which two habitats have species (or individuals) in common. Applied as defined, purely in terms of species number, this coefficient gives equal weight to all species and hence tends to place too much significance on the rare species, whose capture will depend heavily on chance (SOUTHWOOD & HENDERSON 2000). In this case we use this index to evaluate to which extent two species have common habitats. It was calculated from the Czekanowski or Sørensen equation:

$$C_s = \frac{2j}{(a+b)} \qquad (3)$$

where *j* is the number of habitats common to the two species, and *a* and *b* are the total numbers of habitats, where the species are present, respectively.

Diversity index (H'): Species diversity (sometimes called species heterogeneity), a characteristic unique to the community level of biological organisation, is an expression of community structure. Diversity can be measured recording the number of species and describing their relative abundance, (MAGURRAN 1991). We used the Shannon and Wiener diversity index. It assumes that individuals are randomly sampled from an "indefinitely large" population (PIELOU 1975), and is calculated from the equation:

$$H' = -\sum p\mathrm{i} \log p\mathrm{i} \qquad (4)$$

where p_i is the proportion of individuals found in *i*th species estimated as

$$p\mathrm{i} = \frac{n\mathrm{i}}{N} \qquad (5)$$

Evenness (J): This diversity index takes into account both species richness and evenness of the individuals' distribution among the species. Evenness (also referred as homogeneity) may be

expressed by considering how close a set of observed species abundances is to those from an aggregation of species having maximum possible diversity for a given N and S (ZAR 1984). It is calculated as follows:

$$J = \frac{H'}{H'_{max}} \qquad (6)$$

$H'_{máx}$ is the maximum possible diversity for a collection of N individuals in a total of S species, when the N individuals are distributed as evenly as possible among the S species. It is calculated as follows:

$$H'_{max} = \log S \qquad (7)$$

J is constrained between 0 and 1 with 1 representing a situation in which all species are equally abundant.

RESULTS & DISCUSSION

Species richness and species richness index (D):
We collected 141 specimens distributed by 13 species of 9 genus, 4 tribes and 3 subfamilies.

For the first time it was recorded the presence of *Scymnus (Scymnus) abietis* (Paykull) and *Nephus hiekei* Fürsch in Madeira archipelago. In Porto Santo Island we collected *Coccinella septempunctata* L. and *Hippodamia variegata* (Goeze) (Table 1). Among all the *Coccinellidae* species already known from Madeira archipelago (33 species) (JANSSON 1940; LUNBLAD 1958; BIELAWSKY 1963; MITTER 1984; FÜRSCH 1987; RAIMUNDO & LVES 1986; ERBER & HINTERSEHER 1988, 1990; ERBER 1990; ERBER & AGUIAR 1996) we r ecollected 33% (11 species), from which some of them were little abundant. The short period of time selected to carry out the samples, could explain the reason of the low number of species recollected.

Many factors other than extinction and immigration could explain the variation on species numbers on islands. For instance, elevation, number of soil types, substrate types, plant species richness, number of habitats, habitat diversity, structure and heterogeneity (BORGES 1992; BORGES & BROWN 1999). Thus, the higher variability of environmental conditions in Madeira island could explain the higher number of species collected.

Table 1

List of coccinellid species collected on Madeira (Mad) and Porto Santo (Ps) Islands. Legend: + Present on island; * New species to the archipelago

Subfamilies	Tribes	Genus	Species	Mad	Ps	Note
Scymninae	Scymnini	*Stethorus*	*S. wollastoni* Kapur	+		
		Clitostethus	*C. arcuatus* (Rossi)	+		
		Scymnus	*S. interruptus* (Goeze)	+		
			S. levaillanti Muls.	+		
			S. abietis (Paykull)	+		*
		Nephus	*N. flavopictus* Woll.	+		
			N. hiekei Fürsch	+		*
Coccidulinae	Coccidulini	*Lindorus*	*L. lophante* (Blaisds.)	+		
		Rhizobius	*R. litura* F.	+		
			R. chrysomeloides (Herbst.)	+		
Coccinellinae	Coccinellini	*Adalia*	*A. decempunctata* (L.)	+		
		Coccinella	*C. septempunctata* (L.)		+	
	Hippodamiini	*Hippodamia*	*H. variegata* (Goeze)	+	+	

The values of species richness based on the number of species, were 2.627 and 2.519 to the archipelago and Madeira Island alone, respectively (Table 2).

Abundance (n_i) and relative abundance (p_i):
In figure 2, values of abundance and relative abundance are given. Almost 75% of all individuals collected (n_i =89) belong to the following species: *H. variegata* (n_i =42, p_i =29.7%), *Scymnus interruptus* (Goeze) (n_i =29, p_i =20.6%) and *Clitostethus arcuatus* (Rossi) (n_i =18, p_i =12.8%). Those values rise up to 81%

(n_i=101) and 87% (n_i=112) when we include *C. septempunctata* and *Scymnus levaillanti* Mulsant, respectively. The rare species collected, with a uniform distribution of the individuals, were *S. abietis*, *Lindorus lophante* (Blaisds.) and *Rhizobius chrysomeloides* (Herbst.), with only one female in each (0.7%).

Table 2

Data characterising the Coccinellid community from Madeira; S_r- species richness; D_{Mg}- species richness index, H'- diversity index, H'$_{máx}$-the maximum possible diversity and J-evenness. Legend: Mad-Madeira island;Ps-Porto Santo island

Indices	S_r	D_{Mg}	H'	H'$_{máx}$	J'
Values (Mad+Ps)	13	2.627	0.875	1.114	0.785
Values (Mad)	12	2.519	0.764	1.079	0.708

Similarity index (Cs): H. variegata (s= 1, 4, 7, 8, 9, 10, 14, 15(2x), 17) and *S. interruptus* (Goeze) (s= 4, 8, 9, 11, 12, 13, 14, 15, 16 e 17) were found in 10 samples. *S. levaillanti* were found in 7 samples (s= 7, 9, 10, 13, 24, 16, 17), *C. arcuatus* and *R. litura* in 3 samples (s= 9, 15, 16 and s= 2, 3, 12, respectively). The highest values of similarity were obtained in the following species combinations: *H. variegata*/ *S. interruptus*, *H.*

variegata/ *S. levaillanti* and *S. interruptus*/ *S. levaillanti*. The similarity index values in the following combinations *C. arcuatus - S. interruptus* and *C. arcuatus - S. levaillanti* were, 0.46 and 0.40 respectively (Table 3). Higher values of similarity suggest the possibility of population's niche apportionment and interaction such as competition and intraguild predation.
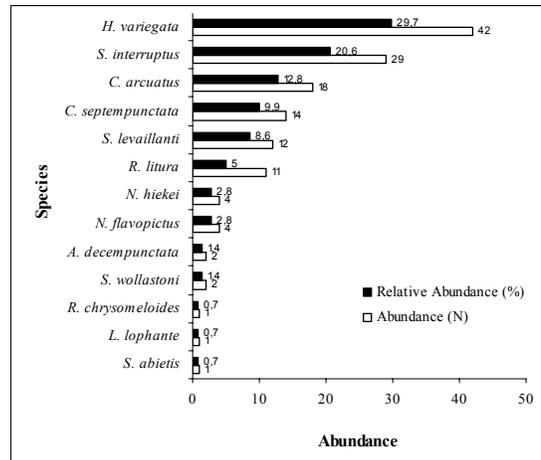
Fig. 2. Absolute and relative number of specimen and among species (Relative Abundance-%) found in Madeira and Porto Santo islands.

Table 3

Similarity index values (Czekanowski or Sørensen) between the most abundant species.

	H. variegata	S. interruptus	S. levaillanti	R. litura	C. arcuatus
H. variegata	___	0.60	0.59	0	0.31
S. interruptus		___	0.59	0.15	0.46
S. levaillanti			___	0	0.40
R. litura				___	0
C. arcuatus					___

Diversity index (H): Relatively high values of diversity were obtained in archipelago (Madeira and P. Santo) and in Madeira island (Table 2). Despite a high relative abundance of *H. variegata* in the community, we found that half of the species had more than 90% of the individuals. The relative abundance of the 6 commonest species was high, with abundance ranging from 5 to 29.7%. Diversity index and maximum possible diversity, were slightly different (Table 2). The lowest value of the diversity index obtained in Madeira island (0.764) when compared to the one

of the archipelago (0.875) can be explained by the absence of *C. septempunctata* in Madeira island.

Evenness (J): The maximum evenness is obtained when values of diversity index and maximum possible diversity are the same (Table 2). Despite not having an identical distribution of individuals among species, we found that the community presented two groups in which the relative abundance wasn't very different. The first group includes the 6 common species and the second one, the other species in which we recorded a uniform distribution of the individuals.

In our opinion this fact contributes to the relatively high values of evenness.

The amount of time spent in sampling and the temporal and spatial variations in the abundance of *Coccinellidae*, related with the life cycle of each species are, in our opinion, the main restriction to the utilization of these results in the characterisation of the distribution and abundance of the entire coccinellid community. Exhaustive sampling programmes must be carried out in order to evaluate seasonal and annual community structure. The approach that we are proposing to know species diversity in Madeira and Porto Santo islands, can be a useful tool in environmental monitoring and conservation management, and can be used to evaluate how far the impact of immigration, extinction and environmental factors namely human activity, may affect its components**.**

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