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SEASONAL ACTIVITY OF A GROUND-BEETLE (COLEOPTERA: CARABIDAE) ASSEMBLAGE IN THE REMNANT OF A SALTY-LAKE FROM TERCEIRA (AZORES)

Paulo A. V. Borges

Universidade dos Açores,

Departamento de Ciências Agrárias, Terra-Chã

9702 ANGRA DO HEROÍSMO CODEX. TERCEIRA, AÇORES. PORTUGAL.

ABSTRACT

Seasonal Activity of a Ground-Beetle (Coleoptera: Carabidae) assemblage in the remnant of a Salty-Lake from Terceira (Azores).

Ground-beetle species were sampled on the remnant of a salty-lake from Terceira (Azores) during one year using pitfall trapping. Three strongly hygrophilous species were found to be dominant: *Notaphus* (s. str.) *semipunctatus* (Donovan, 1806), *Omaseus aterrimus nigerrimus* Dejean, 1828 and *Agonum marginatum* (Linnaeus, 1758). The former and top dominant one, *N. semipunctatus*, is a new record for the Azores and Macaronesia. The activity density peak of these dominant species occurred in July. Thus, a «spring-breeder» ground-beetle guild was found to be characteristic of this heterogeneous salty biotope.

Key words: Coleoptera, Carabidae, pitfall, species activity density (sAD), Salty-Lake, Azores.

INTRODUCTION

The Paúl da Praia da Vitória (Terceira, Azores) is the only known remnant of Azorean salty-lake. Recently, a bio-ecological study has been carried out in this area, as part of an effort to establish conservational directives for Macaronesian habitats (see DIAS *et al.*, manuscript). The present study deals with the ground-beetles (Coleoptera, Carabidae) inhabiting temporarily wet and remnant dry zones of the mentioned region, aiming to assess their ecological importance for potential Conservation.

A guild is defined as a «group of coexisting species at the same functional place» (DEN BOER, 1986b). Therefore, the survey of a well defined ecological group of species occupying a locality appears to be an appropriate approach for any Conservation Management study.

Carabids are an important epigeal soil-dwelling group, and their seasonal locomotory activity on the soil surface reflects a number of evolutionary and functional characteristics of the whole community (BRANDMAYR & BRANDMAYR, 1986). Therefore, ground-beetles are remarkable ecological tools and they progressively appear to be favourable taxa for comparative ecological studies (DEN BOER, 1986b).

Carabids have been subject to a large set of studies (see THIELE, 1977 and references therein). Many investigations occurred on their seasonal activity or abundance in several types of habitats including agroecosystems, wetlands, grasslands and forests (e.g. DESENDER *et al.*, 1981; BRANDMAYR & BRANDMAYR, 1986; HURKA, 1986; VITNER & VITNER, 1987; SAGASETA, 1988; NIEMELÄ *et al.*, 1989; YANO *et al.*, 1989; HEJKAL, 1990; YAHIRO *et al.*, 1990, 1992). Conservation studies using ground-beetles are also numerous (e.g. NIEMELÄ & HAILA, 1986; NIEMELÄ *et al.*, 1987; KLEINERT, 1989; ANDERSEN *et al.*, 1990).

In Macaronesia, the scarce investigations concerning the seasonal activity of Carabids have been carried out mainly by Spanish authors in the Canaries (see references in MACHADO, 1992). More recently BORGES & SERRANO (1993) have studied a new taxon of Poecilini (*Cedrorum azoricus azoricus* n.sp., n. ssp.) inhabitant of the Azorean climax pattern of autochthonous forest from Terceira island. So far, no ecological studies have been reported on the ground-beetles in the Azores and the only data available concerning the ecology of the resident species are those of LINDROTH (1960). MACHADO (1992) used Museum collections to obtain the seasonal activity of a large set of Canarian ground-beetle species. However, in the Azores such analysis is not possible, due to the sporadic collection activity in this archipelago (see BORGES, 1991), which makes any effort to establish a valid phenogram very difficult. The phenograms presented here are based on quantitative field sampling.

The use of pitfalls as well as the type of killing-preserving agents carry some methodological problems (see revision in ADIS, 1979), but as pointed out by DEN BOER (1986a) sampling with pitfalls is desirable because «it makes possible to study a number of (dynamically) different carabid species simultaneously at the same sites, and thus to contribute to a comparative approach to population ecology». BORGES (1992a) using three killing-preserving agents (formalin solution, vinegar solution and Turquin's liquid) studied the seasonal diversity of the soil surface arthropods in an area of pine woodland of Terceira island (Azores), and accurately sampled the seasonal activity of the epigeal soil arthropods.

The aims of the present work are: a) to establish the pattern of the species Activity Density (sAD) for the more common Carabid species; b) to classify the species populations of ground-beetles occurring in the studied site according to their developmental (breeding) types (*sensu* LARSSON, 1933).

MATERIAL AND METHODS

Study area

The field work was carried out in Paúl da Praia da Vitória, a set of small remnants of an ancient larger «Coastal Salty-Lake» located in the geologically oldest part of Terceira island (Azores, Portugal), with U.T.M.: MH 49500-428703. The altitude is about 0-1 m. The studied area was a fenced field (50 x 64 m) divided into three different zones (see also DIAS *et al.*, manuscript).

Zone 1.- A salty-lake dominated by the vascular species *Ruppia maritima* L., until now known in the Azores only from S. Jorge. Trapping in this zone was possible in May, June, July and August (1991) (Fig. 1).

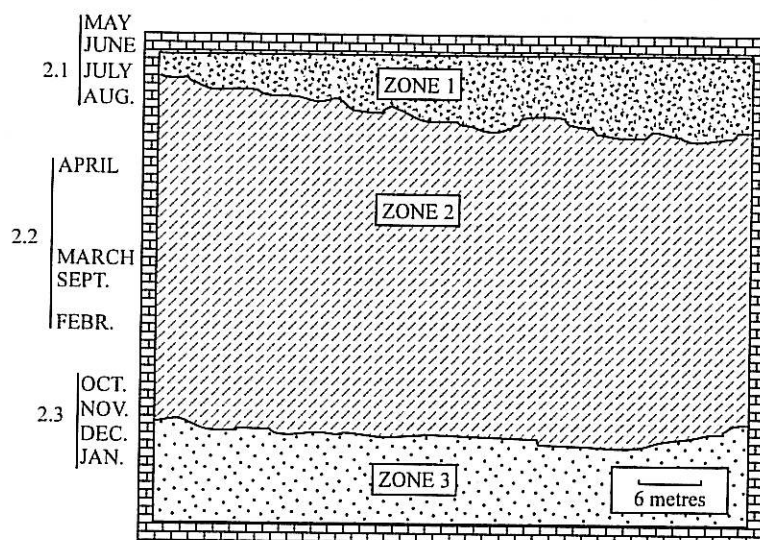


Fig. 1: Different zones within the study area: Zone 1 - with maximum inundation almost all the year (salty-lake); Zone 2 - temporarily waterlogged halophitic area; Zone 3 - permanently dry pasture (see text for further explanations).

Zone 2.- Wet area with complex water dynamics during the year, being almost flooded in October, November, December (1991) and January (1992). It is possible to find some vascular species typical of marshy zones like *Alisma lanceolatum* With., *Apium nodiflorum* (L.) Lag., *Cyperus eragrostis* Lam., *Scirpus cernuus* Vahl., *Lythrum hyssopifolium* L., *L. junceum* Banks & Solander, and also the halophilous species *Atriplex prostrata* Boucher ex DC. and *Scirpus maritimus* L.

Zone 3.- A permanently dry zone with a diversity typical of the Azorean pastures with the species *Trifolium pratense* L., *Lotus uliginosus* L., *Bromus molliformis* Lloyd., *Poa trivialis* L. and *Lolium perenne* L.

Sampling methods

A set of eighteen pitfall traps sampled the area on the last week of each month during one year (from March 1991 to February 1992). The pitfall traps used (radius = 22 mm and depth = 80 mm) were dug into the ground, approximately 5 m apart. To protect the traps against rainfall, plastic plates were set 5-8 cm above ground level. The plastic jars were placed as close as possible to the edge of maximum water logging (see Fig. 1). The killing-preserving agents used were: a 5 % Formalin solution with 1 ml of detergent added in one liter; modified Turquin liquid (ASHMOLE & ASHMOLE, 1987) (10 g chloral hydrate, 5 ml formalin, 5 ml glacial acetic acid, 1 ml detergent and dark beer to 1 liter); Vinegar solution (modified from IACOVONE, 1985) (50 % of commercial vinegar and 50 % of water, and 10 ml of formalin and 1 ml of detergent for each liter of solution). Six traps were used with each killing-preserving agent. For more details on the efficiency of these killing-preserving agents see BORGES (1992a).

Data analysis

The captures have been expressed as **species Activity Density** (sAD) - individuals of a species caught in one trap during a standard period of 10 days (adapted from the tAD of BRANDMAYR & BRANDMAYR, 1986). In October of 1991 the samples were lost due to flooding. The sAD plots were only computed for the three most frequent species of ground-beetles.

For the nomenclature of the ground-beetle species we followed the recent work of ZABALLOS & JEANNE (1994).

RESULTS

Seasonal activity-density variation

A total of 1,029 individuals belonging to ten (10) species were collected during the survey (see Table 1). Specimens of the three most frequent species numbered 971, which is 94.4 % of the total figure. These were *Notaphus* (s. str.) *semipunctatus* (Donovan, 1806), *Omasus aterrimus nigerrimus* Dejean, 1828 and *Agonum marginatum* (Linnaeus, 1758). *N. semipunctatus* was the most commonly collected (75.4 % of the total). Seven of the species numbered fewer than 20 individuals.

Notaphus semipunctatus (Donovan, 1806), is new for the Azorean and Macaronesian ground-beetle fauna (see BORGES, 1990 and MACHADO, 1992 and in press). The other nine species are common but differently distributed on the nine Azorean islands (see Table 2).

Notaphus* (s. str.) *semipunctatus (Donovan, 1806) (New for the Azores)
= *Ocydromus* (*Notaphus*) *obliquum* (Sturm, 1825): MACHADO (1992)

Recently, MACHADO (1992) cited the presence of *Ocydromus* (*Notaphus*) *obliquum* Sturm in Praia da Vitória (Terceira) living in the same habitat studied as the present work. A careful investigation of the Systematic status of the *Notaphus* specimens collected by me in the same area led to the conclusion that the MACHADO (*op. cit.*) record was probably a misidentification, recently confirmed by MACHADO (personal communication; see also in press).

N. semipunctatus prefers moist, silty sites with a moderately developed vegetation, often somewhat shaded (Zone 1, Fig. 1). This species is not considered to be salt-tolerant (see Discussion). The specimens of this Bembidiini species were seen running about in the sun on the substratum surface, which agrees with the behaviour of the northern European Bembidiini (ANDERSEN, 1985). *N. semipunctatus* is a strongly hygrophilous species active at 100 % r.h. above surface during sunny weather (ANDERSEN, *op. cit.*), and as most Bembidiini it is diurnally active (LUFF, 1978).

N. semipunctatus was active throughout the season, showing highest activity around June-July-August, with a maximum in July and August (Fig. 2). Following LARSSON (1939), the July-August peak is consistent with the «autumn-breeder» type of development. However, the Zone 1 (Fig. 1) is a Salty-Lagoon which has a seasonal water-content pattern, and the peak of activity found in *N. semipunctatus* during 1991 seems to be adapted to those conditions. Moreover, larvae were collected in the pitfalls mainly in May, June and July (personal observation), being the adult female specimens collected in July and August most probably dominated

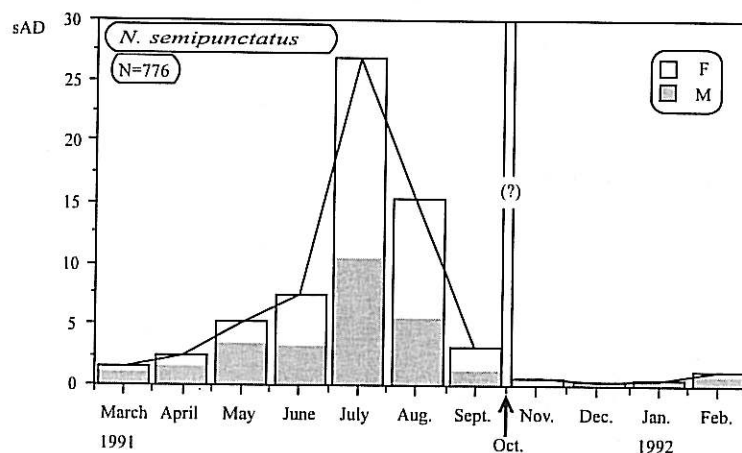


Fig. 2: Activity density (sAD) of *Notaphus (s. str.) semipunctatus* (Donovan) in a salty-lake, Paúl da Praia da Vitória (Terceira, Azores).

by post-reproductive females. Thus, following THIELE (1977) we may consider this species as a true «spring-breeder», but with flexible reproductive periods.

The small activity found by the new generation in the end of September would agree with the «spring-breeder without autumn activity» (sensu LARSSON, 1939) pattern. MACHADO (1992) using Museum data found a peak of activity during the autumn (September-October) in the Canarian Bembidiini, *Ocydromus (Nepha) schmidtii subcallosus* (Wollaston, 1854) and *O. (s. str.) atlanticus atlanticus* (Wollaston, 1854). During September and October (1991) the precipitation was high in the studied area, and therefore the water reached the Zone 2 (Fig. 1), consequently was the only Zone that could be sampled. Unfortunately, the October sample was destroyed by flooding of the traps. Thus, we cannot affirm that *N. semipunctatus* has always less activity in the autumn months in Terceira (Azores).

***Omasus aterrimus nigerrimus* Dejean, 1828**

The data confirmed that this species is strongly hygrophilous, occurring in marshes and at the border of freshwater, often on peaty soil, as pointed out by LINDROTH (1960). *O. aterrimus nigerrimus* has a peak of activity early in the spring (end of March), and very low activity during the summer (Fig. 3). However, the maximum activity is displaced to early summer, coincident with the females' peak of activity. Therefore this species behaves as «spring-breeder» in the Azores, which agrees with data from Central Europe (HURKA, 1986). Like the former, it is a species without larval dormancy.

O. aterrimus nigerrimus was sampled mainly in the Zone 2 (March, April) (Fig. 1), but also in Zone 1 (May to July).

In Terceira we usually collect many specimens of this species during the spring (April) and summer (August), generally at the edges of lakes under stones and associated with *Lagarus vernalis* (Panzer, 1796), *Paranchus albipes* (Fabricius, 1801) (= *Anchus ruficornis* (Goeze, 1777)), *Stenolophus teutonius* (Schrank, 1781) and *Agonum marginatum* (Linnaeus, 1758).

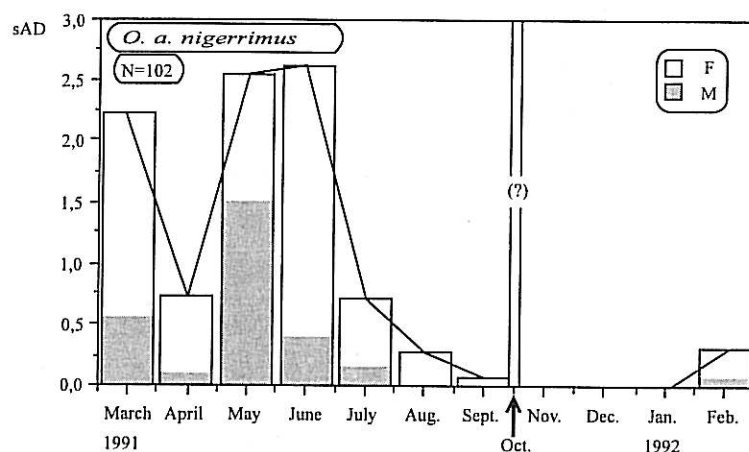


Fig. 3: Activity density (sAD) of *Omaseus aterrimus nigerrimus* Dejean in a salty-lake, Paúl da Praia da Vitória (Terceira, Azores).

***Agonum marginatum* (Linnaeus, 1758)**

The results obtained validate observations by LINDROTH (1960) that this is a strongly hygrophilous species, confined to the margins of freshwaters and the sea-shore, where the soil is more or less clayish and some grassy vegetation is present.

The species activity density of *Agonum marginatum* (Fig. 4) shows a typical activity pattern of a «spring-breeder», with a spring peak of activity, a summer dormancy and an autumn (i.e. September) period of activity by the new generation. MACHADO (1992) using Museum data found a slightly dissimilar pattern in the Canarian populations, without the autumn peak.

In Terceira, we also collected this species in Lagoa do Ginjal during the spring and summer together with *Lagarus vernalis* (Panzer), *Paranchus albipes* (Fabricius), *Stenolophus teutonius* (Schrank) and *Omaseus aterrimus nigerrimus* Dejean.

DISCUSSION

The destruction of the natural environments of the Azores by human activities have been quicker than advances in the knowledge and understanding of the ecological systems of this archipelago. Not only does the inventory of the main Azorean biotopes remain to be compiled, but also the dynamics of the arthropod communities occurring in most of them are totally unknown.

Given these restrictions, what do the conclusions of the former analysis tell us about the ecology of the ground-beetle guild of the «Paúl da Praia da Vitória» salty-lake? The most obvious conclusion is that the three most frequent species showed a significantly similar developmental pattern, as a response to the physical features of the habitat studied. The peculiar differences found between them are easily explained not only by the fact that they occupy different microhabitats (see below),

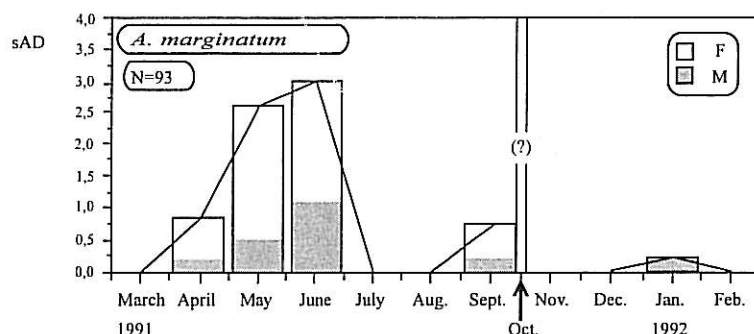


Fig. 4: Activity density (sAD) of *Agonum marginatum* (Linnaeus) in a salty-lake, Paúl da Praia da Vitória (Terceira, Azores).

but also because as postulated by THIELE (1977), carabid species respond differently to basic physical and chemical properties of their environment.

The autumn-breeder species undergoing larval dormancy prefer habitats with very little variation in microclimate (HURKA, 1986). For instance, *Cedrorum azoricus azoricus* Borges & Serrano, 1993 living in the natural climax Azorean forests of Terceira, is a true «autumn-breeder» (see BORGES & SERRANO, 1993). Therefore, the «spring-breeding» pattern observed in our study site is almost certainly a consequence of adaptation to an environment undergoing drastic seasonal changes. Moreover, all the commonest species occurring in Paúl da Praia da Vitória are macropterous, which indicates that are well adapted to a changing environment. In addition, only the species without larval dormancy can develop in swamp and marsh habitats, as larvae would not survive winter and early spring there (HURKA, 1986).

There was considerable overlap in the activity of some species within this small salty area, creating a possibility of competition. ANDERSEN (1985) demonstrated that different species of Bembidiini have different habitat moisture preferences, and probably the same is true for other carabid groups (see also THIELE, 1977; RUSHTON, *et al.*, 1991). Thus, the three «soil water content» zones defined within the study site may be occupied differently by the species as follows (see Fig. 1):

Zone 1 (a salty, highly waterlogged area) - *Notaphus semipunctatus*, *Eotachys micros* (Fisher, 1828) and *Acupalpus dubius* Schilsky, 1888 with an activity peak in July. In Europe these three species are adapted to freshwater habitats (*E. micros* in river banks and *A. dubius* in reed beds), being *Notaphus semipunctatus* not a salt-tolerant species. This may signify that the salt content of this environment is low and that we have here a remarkable case of adaptation to new conditions in an insular free niche space. Other similar cases of habitat shift are well documented in the Azores, namely with endemic species of *Tarphius* (Colydiidae) (see BORGES 1991, 1992b).

Zone 2 (a winter flooded area) - *O. aterrimus nigerrimus*, *Agonum marginatum* and *Stenolophus teutonius*, with an activity peak earlier in the spring.

Zone 3 (a pasture like area) - *Paranchus albipes*, *Lagarus vernalis*, *Anisodactylus* (s. str.) *binotatus* (Fabricius 1787) and *Pseudophonus rufipes* (De Geer, 1774) all common species in the Azorean pastures (BORGES, 1995).

TAXA	21-27.III.91			21-27.IV.91			18-25.V.91			21-28.VI.91		
	F1	V1	T1	F2	V2	T2	F3	V3	T3	F4	V4	T4
<i>Notaphus</i> (s. str.) <i>semipunctatus</i> (Donovan)	3;1	2;2	-	1;1	5;5	11;3	7;5	28;13	11;1	7;12	14;14	22;25
<i>Eotachys micros</i> (Fisher)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lagarus vernalis</i> (Panzer)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Omaseus aterrimus nigerrimus</i> Dejean	0;2	0;4	3;3	0;2	0;1	1;4	8;2	7;3	4;8	0;7	0;6	5;15
<i>Agonum marginatum</i> (Linnaeus)	-	-	-	1;6	0;1	1;0	1;6	4;13	1;8	3;11	8;7	3;6
<i>Paranchus albipes</i> (Fabricius)	0;3	-	-	-	-	-	-	0;1	-	-	-	-
<i>Anisodactylus</i> (s. str.) <i>binotatus</i> (Fabricius)	-	-	-	-	-	-	-	-	-	-	0;1	0;1
<i>Stenolopus teutonius</i> (Schränk)	-	-	-	0;1	0;3	0;4	0;2	2;0	3;0	0;1	-	0;1
<i>Acupalpus dubius</i> Schilsky	-	-	-	-	-	-	-	-	0;1	-	-	-
<i>Pseudophonus rufipes</i> (De Geer)	-	-	-	-	-	-	-	-	-	-	-	-

TAXA	21-28.VII.91			17-23.VIII.91			21-29.IX.91			19-26.X.91		
	F5	V5	T5	F6	V6	T6	F7	V7	T7	F8	V8	T8
<i>Notaphus</i> (s. str.) <i>semipunctatus</i> (Donovan)	29;59	52;55	50;95	46;83	6;17	6;8	6;13	10;8	3;5	?	?	?
<i>Eotachys micros</i> (Fisher)	-	1;6	-	0;2	0;1	1;1	-	1;0	1;0	?	?	?
<i>Lagarus vernalis</i> (Panzer)	-	-	-	-	-	-	-	-	-	?	?	?
<i>Omaseus aterrimus nigerrimus</i> Dejean	0;3	0;1	2;3	0;2	-	0;1	-	-	0;1	?	?	?
<i>Agonum marginatum</i> (Linnaeus)	-	-	-	-	-	-	3;5	0;2	0;1	?	?	?
<i>Paranchus albipes</i> (Fabricius)	-	-	-	-	-	-	2;1	1;1	-	?	?	?
<i>Anisodactylus</i> (s. str.) <i>binotatus</i> (Fabricius)	-	-	-	-	-	-	1;1	-	-	?	?	?
<i>Stenolopus teutonius</i> (Schränk)	-	-	-	-	-	-	-	-	-	?	?	?
<i>Acupalpus dubius</i> Schilsky	-	-	-	1;0	-	-	-	-	-	?	?	?
<i>Pseudophonus rufipes</i> (De Geer)	-	-	-	-	-	-	-	-	-	?	?	?

TAXA	10-17.XI.91			18-23.XII.91			17-26.I.92			18-25.II.92		
	F9	V9	T9	F10	V10	T10	F11	V11	T11	F12	V12	T1
<i>Notaphus</i> (s. str.) <i>semipunctatus</i> (Donovan)	0;1	2;2	1;0	1;1	-	-	-	3;3	1;0	1;0	11;2	3;0
<i>Eotachys micros</i> (Fisher)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Lagarus vernalis</i> (Panzer)	-	1;0	-	-	-	-	-	-	-	-	-	-
<i>Omaseus aterrimus nigerrimus</i> Dejean	-	-	-	-	-	-	-	-	-	0;1	0;1	1;1
<i>Agonum marginatum</i> (Linnaeus)	-	-	-	-	-	-	1;0	-	1;0	-	-	-
<i>Paranchus albipes</i> (Fabricius)	0;1	-	-	0;1	-	-	1;1	-	2;0	1;0	1;1	-
<i>Anisodactylus</i> (s. str.) <i>binotatus</i> (Fabricius)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Stenolopus teutonius</i> (Schränk)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Acupalpus dubius</i> Schilsky	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pseudophonus rufipes</i> (De Geer)	-	1;1	0;1	-	-	-	-	-	-	-	-	-

Table 1: Pitfall captures of Ground-Beetles (males; females) in the remnant of a salty-lake (Paúl da Praia da Vitória, Terceira, Azores). F= formalin a 5%; V= vinegar; T= Turquin.

The extent of overlap between species is dependent on their size, occurring the small species in Zone 1, being at least *N. semipunctatus* a diurnal «spring-breeder» species which conforms with the results of LUFF (1978), that common diurnal species are spring-breeders. Most probably all the species of Zones 2 and 3, being larger, are nocturnal. They would have difficulty in obtaining temporary shelter from desiccation in the field during the day.

One of the major criteria from the conservation point of view is the occurrence of rare species. None of the ten species found in «Paúl da Praia da Vitória» is an Azorean endemic, but at least four of the six most common ones are autochthonous (*N. semipunctatus*, *O. aterrimus nigerrimus*, *Agonum marginatum* and *Eotachys micros*), having probably arrived by air (LINDROTH, 1960; BORGES, 1991, 1992b). Furthermore, *N. semipunctatus* (Donovan) is a new record for the Azores and Macaronesia and seems to be restricted to the study area. Moreover, this seems to be a restricted, old assemblage (Paúl da Praia da Vitória is located in the oldest

SPECIES LIST	DISTR.	COR	FLO	FAI	PIC	GRA	SJG	TER	SMG	SMR
<i>Notaphus</i> (s. str.) <i>semipunctatus</i> (Donovan)	P							+		
<i>Eotachys micros</i> (Fisher)	MT		+	+				+	+	+
<i>Lagarus vernalis</i> (Panzer)	P			+	+			+	+	
<i>Omaseus aterrimus nigerrimus</i> Dejean	P						+	+		
<i>Agonum marginatum</i> (Linnaeus)	WP	+	+	+		+	+	+	+	
<i>Paranchus albipes</i> (Fabricius)	H	+	+	+	+	+	+	+	+	+
<i>Anisodactylus</i> (s. str.) <i>binotatus</i> (Fabricius)	H	+	+	+	+	+	+	+	+	
<i>Stenolopus teutonius</i> (Schrank)	WP	+	+	+		+	+	+	+	+
<i>Acupalpus dubius</i> Schilsky	WP		+	+		+		+	+	+
<i>Pseudophonus rufipes</i> (De Geer)	H	+	+	+	+	+	+	+	+	+

Table 2: Distribution by the nine Azorean Islands of the ten Carabid species collected in the salty-lake, Paúl da Praia da Vitória, Terceira (Adapted from BORGES, 1990 with new data from BORGES, 1995). P= Palaearctic; WP= Western-Palaearctic; H= Holarctic; COR= Corvo; FLO= Flores; FAI= Faial; PIC= Pico; GRA= Graciosa; SJG= S. Jorge; TER= Terceira; SMG= S. Miguel; SMR= S. Maria.

part of Terceira, and earlier records of Azorean beetles already referred the presence of the habitat under study), adapted to a heterogeneous habitat undergoing drastic seasonal changes.

On the other hand, the plant community found in the area is composed by a large set of rare species in the Azores, and at least the dominant vascular species found in Zone 1 (Fig. 1), *Ruppia maritima* L., occurs in the Azores only in this area and in S. Jorge (DIAS, pers. comm.).

Therefore this ought to be considered among the threatened or at least vulnerable communities in the Azores, and as a management measure of protection, enlargement and preservation of the suitable «outlive» patches is imperative for the survival of these ground-beetles with specialized habitat requirements. In fact, as KLEINERT (1989) claimed «All undisturbed wet habitats offer good conditions for a motley, luxuriant plant and animal life. They are true oases of stillness in the transformed and disturbed landscape, serving as refuges, biocorridors, habitats for hibernation and reproduction for wide range of free living beings, including invertebrates and predators in particular».

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REFERENCES

- ADIS, J. 1979. Problems of Interpreting Arthropod Sampling with Pitfall Traps. *Zoologischer Anzeiger*, 202(3-4): 177-184.
- ANDERSEN, J. 1985. Humidity responses and water balance of riparian species of Bembidiini (Col., Carabidae). *Ecol. Ent.*, 10: 363-375.
- ANDERSEN, T., LIGAARD, S., PEDERSEN, T. & SOLI, G. E. E. 1990. Pitfall catches of Carabidae and Staphylinidae (Coleoptera) in a temporarily protected forest area on the Eidanger peninsula, Telemark, SE Norway. *Fauna norv. Ser. B*, 37: 13-22.
- ASHMOLE, M. J. & ASHMOLE, N. P. 1987. Arthropod communities supported by biological fallout on recent lava flows in the Canary Islands. *Entomol. scandinavica Suppl.*, 32: 67-88.
- BORGES, P. A. V. 1990. A checklist of the Coleoptera from the Azores with some systematic and biogeographic comments. *Bol. Mus. Mun. Funchal*, 42(220): 87-136.
- BORGES, P. A. V. 1991. A *Biogeografia dos Colepteros (Insecta, Coleoptera) dos Aores*. Universidade dos Aores, Angra do Heroísmo. 84 p.
- BORGES, P. A. V. 1992a. The relative efficiency of Formalin, Vinegar and Turquin in Pitfall Traps on an Azorean Pine Woodland area. *Supl. nº 3 Bolm. Soc. port. Ent.*, 1: 213-223.
- BORGES, P. A. V. 1992b. Biogeography of the Azorean Coleoptera. *Bol. Mus. Mun. Funchal*, 44(237): 5-76.
- BORGES, P. A. V. 1995. *Plant/Insect interactions in grasslands of three Azorean islands of different geological age (Pico, Terceira and S. Maria)*. Ph.D Upgrading Report, Imperial College, University of London, 116 p.
- BORGES, P. A. V. & SERRANO, A. R. M. 1993. New taxa of Poecilini (Coleoptera, Carabidae, Pterostichinae) from the Azores. *Boll. Mus. reg. Sci. nat. Torino*, 11(2): 315-329.
- BRANDMAYR, P. & BRANDMAYR, T. Z. 1986. *Phenology of Ground Beetles and its Ecological Significance in some of the Main Habitat Types of Southern Europe*. In: P.J. den Boer, M.L. Luff, D. Mossakowski & F. Weber (eds.). Carabid Beetles Their Adaptations and Dynamics. pp. 195-220. Gustav Fisher. Stuttgart. New York.
- DEN BOER, P. J. 1986a. *What Can Carabid Beetles Tell us about Dynamics of Populations?*. In: P.J. den Boer, M.L. Luff, D. Mossakowski & F. Weber (eds.). Carabid Beetles Their Adaptations and Dynamics. p. 315-330. Gustav Fisher. Stuttgart. New York.
- DEN BOER, P. J. 1986b. *Carabids as Objects of Study*. In: P.J. den Boer, M.L. Luff, D. Mossakowski & F. Weber (eds.). Carabid Beetles Their Adaptations and Dynamics. pp. 539-551. Gustav Fisher. Stuttgart. New York.
- DESENDER, K., MAELFAIT, J. P. D'HULSTER, M. & VANHERCKE, L. 1981. Ecological and faunal studies on Coleoptera in agricultural land. I. Seasonal occurrence of Carabidae in the grassy edge of a pasture. *Pedobiologia*, 22: 379-384.
- HEJKAL, J. 1990. Carabids (Coleoptera, Carabidae) of the Peat Bog Soos in W-Bohemia: A faunistic and ecological study. *Folia Mus. Rer. Natur. Bohem. Occid., Plzen, Zoologica*, 32: 3-55.
- HURKA, K. 1986. *The Developmental Type of Carabidae in the Temperate Zones as a Taxonomic Character*. In: P.J. den Boer, M.L. Luff, D. Mossakowski & F. Weber (eds.). Carabid Beetles Their Adaptations and Dynamics. pp. 187-193. Gustav Fisher. Stuttgart. New York.
- IACOVONE, C. 1985. Using vinegar as bait in pitfall traps. *Young Entomologists Society Quarterly*, 2(2): 9-11.
- JEANNEL, R. 1942. *Faune de France. 39 - Coléoptères Carabiques (1re. partie)*. Paul Lechavalier Ed. Paris, 571 p.
- KLEINERT, J. 1989. Soil surface macrofauna of watersides. Part III. The Hron river basin, central Slovakia. *Ekológia (CSSR)*, 8(4): 337-359.
- LARSSON, S. G. 1939. Entwicklungstypen und Entwicklungszeiten der dänischen Carabiden. *Entomol. Meddr.*, 27: 277-560.
- LINDROTH, C. H. 1960. The Ground-Beetles of the Azores (Coleoptera: Carabidae) with some reflexions on over-seas dispersal. *Bol. Mus. Mun. Funchal*, 13(31): 5-48.
- LUFF, M. L. 1978. Diel activity patterns of some field Carabidae. *Ecol. Ent.*, 3: 53-62.
- MACHADO, A. 1992. *Monografía de Los Carábidos de las islas Canárias (Insecta, Coleoptera)*. Instituto de Estudios Canarios, La Laguna, 734 p.
- MACHADO, A. in press. *Ground Beetles of Macaronesia, an overview (Coleoptera, Carabidae)*. Proceedings of the First Symposium «Fauna and Flora of the Atlantic Islands» (1993).
- NIEMELÄ, J. & HAILA, Y. 1986. Conservation of Carabid Beetles in Fragmented Taiga. *Proc. 3rd Eur. Cong. Ent.*: 469-472.

- NIEMELÄ, J., HAILA, Y., HALME, E., PAJUNEN, T. & PUNTTILA, P. 1989. The annual activity of carabid beetles in the southern Finnish taiga. *Ann. Zool. Fennici*, 26: 35-41.
- NIEMELÄ, J., HAILA, Y., HALME, E., PAJUNEN, T., PUNTTILA, P. & TUKIA, H. 1987. Habitat preferences and conservation status of *Agonum mannerheimii* Dej. in Hme, southern Finland. *Notulae Entomol.*, 67: 175-179.
- RUSHTON, S. P., LUFF, M. L. & EYRE, M. D. 1991. Habitat characteristics of grassland *Pterostichus* species (Col., Carabidae). *Ecol. Ent.*, 10: 363-375.
- SAGASETA, F. R. 1988. Inventario y fenología de los Carabidae de un encinar de la España central, con especial referencia al caso de *Harpalus wagneri* Schaubberger. *Actas III Congreso Ibérico de Entomología*: 699-709.
- THIELE, H. U. 1977. *Carabid Beetles in their Environments*. Springer-Verlag, Berlin, Heidelberg, New York, xvii + 369 p.
- VITNER, J. & VITNER, C. 1987. Comparative study on the carabid fauna of three remnants of inundated forests at the lower reaches of the Ohre river (Coleoptera, Carabidae). *Acta Entomol. Bohemoslov.*, 84: 185-199.
- YAHIRO, K., FUJIMOTO, T., TOKUDA, M. & YANO, K. 1992. Species Composition and Seasonal Abundance of Ground Beetles (Coleoptera) in Paddy Fields. *Jpn. J. Ent.*, 60(4): 805-813.
- YAHIRO, K., HIRASHIMA, T. & YANO, K. 1990. Species composition and seasonal abundance of Ground Beetles (Coleoptera) in a forest adjoining agroecosystems. *Trans. Shikoku Ent. Soc.*, 19(3): 127-133.
- YANO, K., YAHIRO, K., UWADA, M. & HIRASHIMA, T. 1989. Species composition and seasonal abundance of ground beetles (Coleoptera) in a vineyard. *Bull. Fac. Agric. Yamaguchi Univ.*, 37: 1-14.
- ZABALLOS, J. P. & JEANNE, C. 1994. Nuevo Catálogo de los Carábidos (Coleoptera) de la Península Ibérica. *Monografías S.E.A.*, 1: 1-159.

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