Odonatologica 39(3): 185-193 *September 1, 2010*

HABITAT ASSOCIATIONS OF ODONATA IN MOUNTAINOUS WATER SITES IN NORTHEASTERN PORTUGAL

P. ARNALDO[1,*], J. MOREIRA[2] and I. OLIVEIRA[3]
[1] Forest and Landscape Department, University of Trás-os-Montes and Alto Douro, PT-5000-911 Vila Real, Portugal
[2] Colmus Consultores, LDA, rua Ponte da Pedra 406, Ed. AAA escritório G, PT-4470-108 Gueifães, Maia, Portugal
[3] Mathematics Department, University of Trás-os-Montes and Alto Douro, PT-5000-911 Vila Real, Portugal

Received September 19, 2008 / Revised and Accepted May 12, 2010

A total of 19 spp. (9 Zygoptera and 11 Anisoptera) was recorded in a survey carried out at 28 water sites located in the Alvão Natural Park, NE Portugal. Multivariate statistical procedures were used to analyse the relationship between the spp. and the characteristics of their habitat, in order to determine different spp. biotope preferences. Aside from spp. with unspecific habitat requirements, 2 main species assemblages could be detected. *Enallagma cyathigerum, Sympetrum fonscolombeii, S. sanguineum, Ischnura pumilio, Lestes virens* and *Anax imperator* preferred permanent water bodies characterized by high temperatures, while *Calopteryx virgo, Pyrrhosoma nymphula, Cordulegaster boltonii* and *Onychogomphus uncatus* preferred sites with fast-flowing water characterized by low and moderate temperatures. Conservation strategies should take these patterns and habitat requirements into consideration.

INTRODUCTION

Odonata are among the most important and remarkable arthropods found in freshwater habitats. With origins spanning back some 300 million years, they are the oldest known insects with close to 6000 species identified so far (ASKEW, 1988). However, many species have shown a significant decline in Europe over the last decade and they are included in red lists of threatened species. The destruction of suitable habitats, as a consequence of human activity, habitat fragmenta-

* **Corresponding author**: parnaldo@utad.pt

tion and the drying up of smaller freshwater ecosystems are the common causes of decline. Ecological studies have revealed that Odonata population surveys have been recognised as essential tools in the ecological assessment of aquatic ecosystems, since dragonflies are reliable indicators of biotope health (CORBET, 1993; CLARK & SAMWAYS, 1996, CHOVANEC & WARINGER, 2001, SCHINDLER et al., 2003). Odonata distribution depends on a large number of environmental factors (CORBET, 1999), and the characteristics of the habitat determines which species will appear there (HAWKING & NEW, 1999; GIBBONS et al., 2002; CARCHINI et al, 2005; HOFMANN & MASON, 2005; ROUQUETTE & THOMPSON, 2005; SCHER & THIÈRY, 2005). Thus, the odonate abundance and distribution patterns are a result of the interaction between the species concerned, the physical parameters of the freshwater ecosystems and the interaction with other living organisms. The relationship between Odonata and their habitats has been shown to vary between different geographical and topographical regions (SAHLÉN & EKESTUBBE, 2001). In Portugal, several studies have supplied further information (SEABRA, 1942; AGUIAR & AGUIAR, 1985; MALKMUS, 2002; BEKKER et al., 2004; FERREIRA et al., 2005) and a total of 65 species was so far recorded (FERREIRA et al., 2006). However, field mapping and distribution studies are still in their early stages (FERREIRA et al., 2006). The main goal of the present work was to analyse the relationships between odonate species recorded in the mountainous water sites of the Alvão Natural Park (NE Portugal) and the selected habitat variables using multivariate analysis. This could help to explain the status and biodiversity observed in the Park and help in their future management.

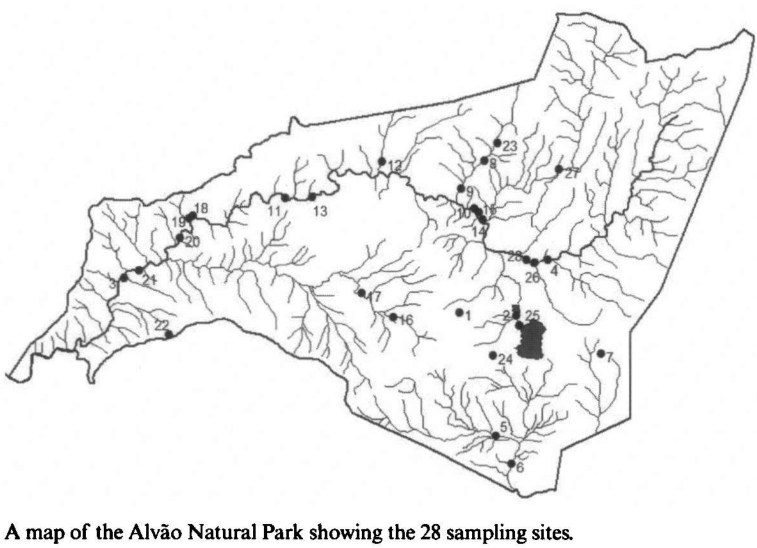

Fig. 1. A map of the Alvão Natural Park showing the 28 sampling sites.

MATERIAL AND METHODS

STUDY SITE AND METHODS. – This survey was conducted on 28 water sites located in the Alvão Natural Park, in northeastern Portugal (Fig. 1) where the geographical location and altitude of each site were recorded. From May 2006 to September 2006, each site was sampled three times, when also the physical parameters, such as pH, water temperature and dissolved oxygen were measured and average values were calculated. In addition, the site parameters were also recorded: the distance of the margins, with a distance of <1m between margins classed as (1) and >1m classed as (2); the presence of floating vegetation was registered as (1) with vegetation and (2) without vegetation; the presence of exposed rocks registered as (1) with rocks and (2) without rocks; the use of adjacent land was classified as (1) agricultural use, (2) forest and (3) uncultivated; and the water flow classified as (1) fast-flowing water and (2) slow-flowing water and permanent bodies of water.

The odonate assessment was performed on sunny days between 10:00 and 16:00 h, when most species were active. The adults were caught and the species identified using ASKEW (2004) and D'AGUILAR & DOMMANGET (1998). The occurrence estimates were ranked within a two-class system (0 = absent and 1 = present) and abundance estimates were ranked within a five-class system: D = dominant (>21 individuals), A = abundant (11-20 individuals), C = common (6-10 individuals), O = occasional (2-5 individuals) and R = rare (1 individual).

DATA ANALYSIS. – The specimens were separated per suborder and families. A cluster analysis was performed in order to group 27 out of the 28 study sites on the basis of their environmental characteristics (at site 23 the environmental physical parameters could not be measured). For the

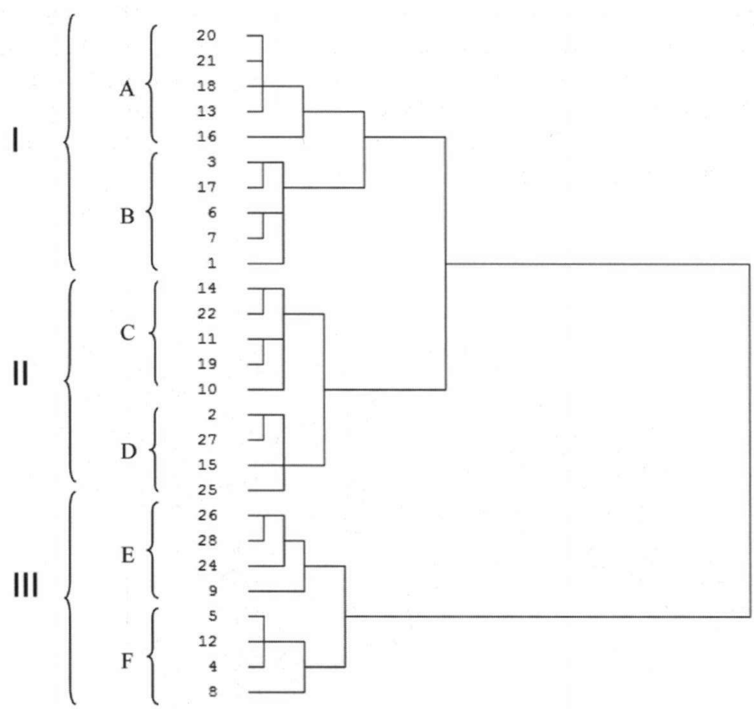

Fig. 2. Cluster analysis classification of 27 study sites based on the selected environmental variables. Squared Euclidean distance and linkage rule: Ward's method). – [I-III: clusters; – A-F: groups].

Table I
Species occurrence and their status at the study sites: (D) dominant, (A) abundant, (C) common, (O) occasional, (R) rare

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Platycnemididae																												
Platycnemis acutipennis											O,O		O,O							O	O							
Platycnemis latipes											O							O										
Coenagrionidae																												
Enallagma cyathigerum		D																										
Ischnura pumilio																								O	O			
Pyrrhosoma nymphula	O			C	O	O	O	O			O	O	O															
Lestidae																												
Lestes virens																								O	O			
Calopterygidae																												
Calopteryx haemorrhoidalis																				R	O	R						
C. virgo				C	C,O	A,O	A	C	A	D	O,O	D	C,O	O		C	O	O	O	C	O		O	R		C	O	R
C. xanthostoma			O								C							O										
Aeshnidae																												
Aeshna cyanea																								O				R
Anax imperator		O,C									R													R				
Boyeria irene											O															R	R	R
Gomphidae																												
Onychogomphus uncatus						O					A	R	R,C				R	O	R	O	C	O				R	R	
Cordulegastridae																												
Cordulegaster boltonii					R	R,R				R		R	O,O	R		R	R			R	O	R	R			R	R	
Cordullidae																												
Oxygastra curtisii											R																	
Libellulidae																												
Libellula depressa		R																										
Orthetrum coerulescens													R		O							R		O				
Sympetrum fonscolombii		A,D																							R		R	
S. sanguineum																								O				

Cluster I, group A: localities 13, 16, 18, 20, 21, group B: localities 1, 3, 6, 7, 17; – Cluster II, group C: localities 10, 11, 14, 19, 22, group D: localities 2, 15, 25, 27; – Cluster III, group E: localities 9, 24, 26, 28, group F: localities 4, 5, 8, 12.

analysis, Squared Euclidean distance and Ward's method were used to measure distance and linkage rule, respectively. Floating vegetation was not used as a cluster variable because it occurred in all sites studied.

In order to find any possible relationships between species occurrence and the environmental variables, the Categorical Principal Component Analysis (CAT-PCA) was performed, in which the presence/absence matrix of species and habitat variables such as water flow, the use of adjacent land, distance of margins, exposed rocks and categorized water temperature, pH, dissolved oxygen and the altitude were used. A biplot scaling was chosen for graphical outputs. All the calculations were performed using SPSS, version 13.

RESULTS

A total of 19 species were recorded (Tab. I). The status of species assessment ranged from dominant (D) to rare (R). Dominance was observed locally for *Enallagma cyathigerum, Calopteryx virgo* and *Sympetrum fonscolombii* which had more than 21 individuals recorded.

C. virgo was the most widely observed species, recorded from 22 sites, followed by *Cordulegaster boltonii* and *Onychogomphus uncatus*, which were present at 15 and 12 sites, respectively.

The cluster analysis of habitat structure, based on the selected environmental variables, resulted in three main clusters with two groups each (Fig. 2). Clusters I and II comprised sites with a high pH while cluster III included sites with low pH. The main difference between cluster I and II was the use of adjacent land, with agriculture and forest sites for cluster I and uncultivated sites for cluster II. From cluster I, groups A and B comprised sites with both fast-flowing and limpid water and presence of rocks, while water temperature and dissolved oxygen levels were higher in group A. From cluster II, groups C and D were made up of sites with a high water temperature and high levels of dissolved oxygen, with both fast-flowing and limpid water sites in group C and permanent bodies of water in group D. From cluster III, groups E and F comprised sites with low levels of dissolved oxygen. Group E were also made up of sites with moderate water temperature while group F comprised sites with fast-flowing and limpid water sites, low temperature and adjacent margins used for agriculture.

The Cat-PCA ordination resulted in three initial axes that explain 21%, 15% and 12% of the species/environment relationship, respectively. The reliability of the axes was given by Cronbach's Alpha and shows values higher than 0.7 (Tab. II).

Table II
Summary statistics of the Categorical Principal Component Analysis (Cat-PCA)

Axes	1	2	3	Total
Eigenvalues	5.709	4.109	3.360	13.259
Cumulative percentage variance	21.14	36.56	49.00	
Cronbach's Alpha	0.857	0.791	0.729	0.96

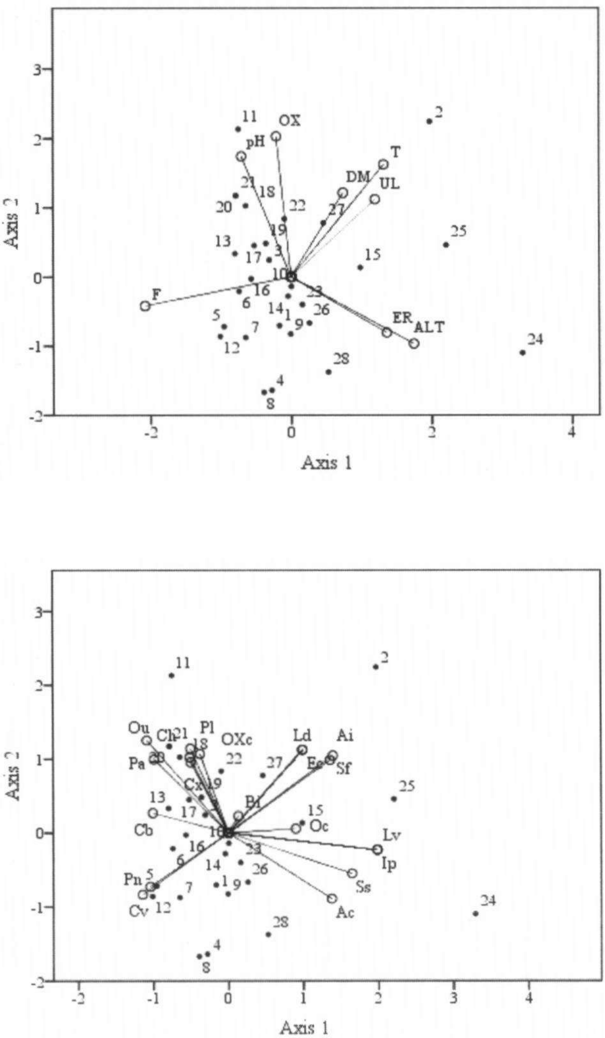

Fig. 3. Categorical PCA biplot of: (A) environmental variables, and (B) presence/absence of species at the 28 study sites. – [For the environmental variables and species codes, see Table III]

The water flow, the dissolved oxygen, the pH, the altitude and the water temperature were the major environmental factors that affected the distribution of Odonata (Tab. III). The first two axes indicate that environmental variables and species (Figs 3a, 3b) were related, with the cluster sites defined by the above cluster analysis (Fig. 2). In the first axis, altitude and water temperature plotted against water flow created three main groups (D, E, F) (Fig. 4). Group D is characterized by the occurrence of *E. cyathigerum, S. fonscolombii, I. pumilio, L. virens* and *A. imperator.* Group F runs along the negative part of the first axis with *C. virgo* and *P. nymphula* occurring in all the sites studied, while *C. boltonii* and *O. uncatus* occurred at least at one site. In the second axis, the dissolved oxygen and the pH plotted against the altitude create two main groups (A and E) (Fig. 4). Group A is characterized by the occurrence of *C. virgo* in all the sites, *C. boltonii* and *O. uncatus* occurred at four of the five sites while *P. acutipennis* and *C. haemorrhoidalis* occurred mainly at the lowest altitude sites. Group E is characterized by the occurrence of *S. sanguineum, A. cyanea* (a species that only occurred in this group) and *I. pumilio* and *L. virens*. The other species recorded exhibited unspecific habitat requirements.

DISCUSSION

In this study, a total of 19 Odonata species was recorded. In the same area, previous studies had shown different results with a total of 18, 22 and 10 species being recorded by MALKMUS (2002), BEKKER et al. (2004) and FERREIRA et al. (2005) respectively. *Calopteryx virgo* was the most widely occurring species in the Alvão Natural Park, recorded from 22 sites and was the dominant species there. *C. boltonii* and *O. uncatus* were present at 15 and 12 study sites, respectively.

Table III
Component loadings between aquatic environmental variables and Odonata species with the first three axes of the Cat-PCA

Variables	Codes	Loadings Axis 1	Variable/component Axis 2	Axis3
Temperature	T	**0,56**	**0,58**	-0,05
pH	pH	-0,15	**0,74**	-0,39
Dissolved oxygen	OX	-0,08	**0,78**	-0,14
Altitude	ALT	**0,62**	-0,41	-0,20
Exposed rocks	ER	0,51	-0,33	-0,09
Flow	F	**-0,80**	-0,14	0,03
Distance of margins	DM	0,29	0,43	0,23
Use of adjacent land	UL	0,46	0,44	-0,03
Platycnemis acutipennis	Pa	-0,37	0,34	0,32
Platycnemis latipes	Pt	-0,20	0,35	**0,75**
Enallagma cyathigerum	Ec	0,39	0,45	-0,20
Ischnura pumilio	Ip	**0,77**	-0,14	0,20
Pyrrhossoma nymphula	Pn	-0,45	-0,34	0,22
Lestes virens	Lv	**0,77**	-0,14	0,20
Calopteryx haemorrhoidalis	Ch	-0,18	0,43	-0,20
Calopteryx virgo	Cv	-0,42	-0,36	0,33
Calopteryx xanthostoma	Cx	-0,20	0,34	**0,64**
Aeshna cyanea	Ac	**0,51**	-0,41	0,37
Anax imperator	Ai	**0,52**	0,30	**0,57**
Boyeria irene	Bi	0,03	0,00	**0,50**
Onychogomphus uncatus	Ou	-0,41	0,45	0,21
Cordulegaster boltonii	Cb	-0,37	0,11	-0,35
Oxygastra curtisii	OXc	-0,15	0,31	**0,78**
Libellula depressa	Ld	0,39	0,45	-0,20
Orthetrum coerulescens	Oc	0,35	0,02	0,02
Sympetrum fonscolombeii	Sf	**0,55**	0,39	-0,20
Sympetrum sanguineum	Ss	**0,63**	-0,27	0,36

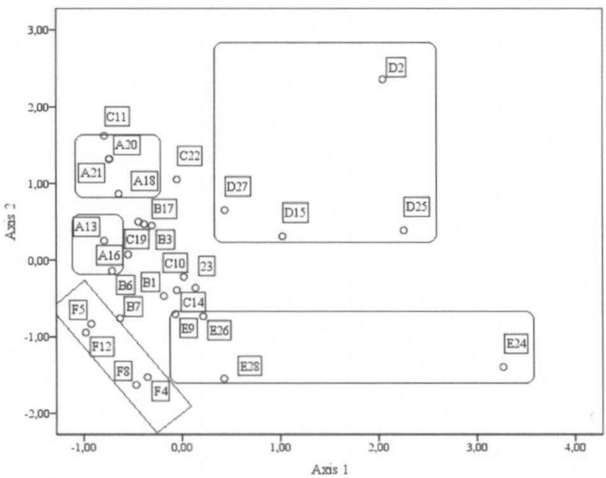

Fig. 4. Axes 1 and 2 of the Cat-PCA for the environmental variables and presence/absence of species at the study sites. – [The sites are indicated by group letter and locality numbers]

The results showed different distribution patterns across the study sites. Habitat requirements of the species recorded, as obtained by Cat-PCA analysis, show that water flow, dissolved oxygen, pH, altitude and water temperature were the major factors that affected the distribution. Previous studies on the relationship between Odonata species and habitat structure have shown varying results. There is still no agreement as to which habitat variables should be considered and, because different data analyses were used, comparing the results of different studies is not easy. The results obtained in this present study were in line with those described in the literature (CLARK & SAMWAYS, 1996; SCHINDLER et al., 2003), which point out that water permanency and flow rate are among the determinant factors in the formation of Odonata assemblages. The latter authors also considered the floating macrophytes as an important factor. The importance of macrophyte coverage of the pond surface was also observed by CARCHINI et al. (2005). However, this habitat variable could not be used in the present study, since floating vegetation was present at all the sites studied.

Through the results obtained by Cat-PCA ordination, two main species assemblages could be detected. Species such as *E. cyathigerum, S. fonscolombeii, S. sanguineum, I. pumilio, L. virens* and *A. imperator* preferred permanent bodies of water, characterized by high water temperatures, while *C. virgo, P. nymphula, C. boltonii* and *O. uncatus* preferred sites with fast-flowing water, characterized by low and moderate temperatures. Within this habitat type, *P. acutipennis* and *C. haemorrhoidalis* occurred mainly at the lowest altitude sites. The habitat preferences of these are in line with the literature (ASKEW, 1988; HOFMANN & MASON, 2005).

The identification of Odonata associations, and the knowledge on habitat requirements of the species could represent an important basis for the wetland site conservation and management.

REFERENCES

AGUIAR, C. & S. AGUIAR, 1985. Estudos odanotológicos em Portugal: odonatos portugueses, odonatos africanos em Portugal. [Actas 2 Congr. ibér. Ent.]. *Entomologia* 4: 245-267.

ASKEW, R., 1998. *The dragonflies of Europe*. Harley Books.

BEKKER, H., J.P. BEKKER, J. BOSHAMER, J. BUYS, A. HUNIA, E. KOSTEN, K. MOSTERT, F. RIENKS, J. VERBEEK & A. WAL, 2004. *Mammal survey Alvão Natural Park (Portugal)*. Ver. Zoogdierk. Zoogdierbescherming, Arnhem.

CARCHINI, G., A.G. SOLIMINI & A. RUGGIERO, 2005. Habitat characteristics and Odonata diversity in mountain ponds of central Italy. *Aquat. Conserv.* 15: 573-581.

CHOVANEC, A. & J. WARINGER, 2001. Ecological integrity of river-floodplain systems: assessment by dragonfly surveys (Insecta: Odonata). *Regul. Rivers Res. Mngmt* 17: 493-507.

CLARK, T.E. & M.J. SAMWAYS, 1996. Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South Africa. *J. appl. Ecol.* 5: 1101-1012.

CORBET, P.S., 1993. Are Odonata useful as bioindicators? *Libellula,* 12: 91-102.

CORBET, P.S., 1999. *Dragonflies: behaviour and ecology of Odonata*. Harley Books, Colchester.

D'AGUILAR, J. & J.L. DOMMANGET, 1998. *Guide des libellules d'Europe et d'Afrique du Nord.* Delachaux & Niestlé, Paris.

FERREIRA, S., J.M. GROSSO-SILVA & P. SOARES-VIEIRA, 2005. Miscellaneous records of dragonflies and damselflies (Insecta. Odonata) from continental Portugal. *Boln Soc. ent. aragon.* 36: 275-277.

FERREIRA, S., J.M. GROSSO-SILVA, M. LOHR, F. WEIHRAUCH & R. JÖDICKE, 2006. A critical checklist of the Odonata of Portugal. *Int. J. Odonatol.* 9: 133-150.

GIBBONS, L.K., J.M. REED & F.S. CHEW, 2002. Habitat requirements and local persistence of three damselfly species (Odonata: Coenagrionidae). *J. Insect Conserv.* 6: 47-55.

HAWKING, J.H. & T.R NEW, 1999. The distribution patterns of dragonflies (Insecta: Odonata) along the Kiewa River, Australia, and their relevance in conservation assessment. *Hydrobiologia* 392: 249-260.

HOFMANN, T.A. & C.F. MASON, 2005. Habitat characteristics and the distribution of Odonata in the lowland river catchments in eastern England. *Hydrobiologia* 539: 137-147.

MALKMUS, R., 2002. Die Verbreitung der Libellen Portugals, Madeiras und der Azoren. *Nachr. naturw. Mus. Aschaffenburg* 106: 117-143.

ROUQUETTE, J.R. & D.J. THOMPSON, 2005. Habitat associations of the endangered damselfly, Coenagrion mercuriale, in a water ditch in southern England. *Biol. Conserv.* 123: 225-235.

SAHLÉN, G. & K. EKESTUBBE, 2001. Identification of dragonflies (Odonata) as indicators of general species richness in boreal forest lakes. *Biodiv. Conserv.* 10: 673-690.

SCHER, O. & A. THIÈRY, 2005. Odonata. Amphibia and environmental characteristics in motorway storm water retention ponds (Southern France). *Hydrobiologia* 551: 237-251.

SCHINDLER, M., C. FESL & A. CHOVANEC, 2003. Dragonfly associations (Insecta: Odonata) in relation to habitat variables: a multivariate approach. *Hydrobiologia* 497: 169-180.

SEABRA, A.F., 1942. Contribuições para o inventário da fauna lusitânica: Insecta. Odonata. *Mems. Estud. Mus. zool. Univ. Coimbra* 129: 1-8.