

## ***Orthetrum trinacria* exuviae (Odonata: Libellulidae) from Santiago Island, Cape Verde: morphology, sexual size dimorphism and diagnostic features**

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**Abstract:** Successful breeding of the Odonata *Orthetrum trinacria* (Selys, 1841) was for the first time confirmed for Santiago Island, Republic of Cape Verde, based on exuviae found in eight localities visited during a field survey carried out in August and September 2012. The relevant diagnostic features listed in the literature for the *O. trinacria* exuviae were assessed. We concluded that one of the diagnostic features, the epiproct length to basal width ratio, was not fulfilled in 97.8% of the 46 exuviae collected by us. Besides that, studied *O. trinacria* exuviae had an average of 26.0 mm of total length and did not evidence sexual size dimorphism.

**Key words:** Odonata, Libellulidae, *Orthetrum trinacria*, exuviae, Cape Verde.

**Exuvias de *Orthetrum trinacria* (Odonata: Libellulidae) de la Isla de Santiago, Cabo Verde: morfología, dimorfismo sexual en tamaño y características diagnósticas**

**Resumen:** La reproducción de *Orthetrum trinacria* (Selys, 1841) fue confirmada por primera vez en la Isla de Santiago, República de Cabo Verde, en base a las exuvias encontradas en ocho localidades visitadas durante un estudio de campo realizado en agosto y septiembre de 2012. Se evaluaron las características específicas de diagnóstico que figuran en la bibliografía para la identificación de las exuvias de *O. trinacria*. Llegamos a la conclusión de que una de las características de diagnóstico, la relación entre la longitud del epiprocto y su anchura basal, no se cumplía en el 97,8% de las 46 exuvias estudiadas. Por otra parte, se obtuvo una media de longitud total de 26,0 mm y no se observó dimorfismo sexual en las exuvias.

**Palabras clave:** Odonata, Libellulidae, *Orthetrum trinacria*, exuvias, Cabo Verde.

**Exuvias de *Orthetrum trinacria* (Odonata: Libellulidae), da Ilha de Santiago, Cabo Verde: morfologia, dimorfismo sexual e características de diagnóstico para identificação**

**Resumo:** A reprodução de *Orthetrum trinacria* (Selys, 1841) foi confirmada pela primeira vez na Ilha de Santiago, República de Cabo Verde, a partir de exuvias encontradas em oito locais visitados durante uma missão realizada em Agosto e Setembro de 2012. As características específicas de diagnóstico referidas na bibliografia, para a identificação inequívoca das exuvias de *O. trinacria*, foram analisadas. Concluiu-se que uma delas, a relação entre o comprimento do epiprocto e a largura basal no mesmo, não se verificou em 97,8% das 46 exuvias estudadas. Para além disso, determinou-se um comprimento total médio de 26,0 mm e não se observou dimorfismo sexual.

**Palavras chave:** Odonata, Libellulidae, *Orthetrum trinacria*, exuvias, Cabo Verde.

### **Introduction**

The Cape Verde Odonata assemblage is composed by a reduced number of species. Only seven dragonfly species were reported as residents in the compilation of the several field surveys carried out since the beginning of the 21<sup>st</sup> century (Aistleitner *et al.*, 2008; Vieira, 2008; Martens, 2010; Martens & Hazevoet, 2010; Bußmann, 2012), and a few other species occasionally sighted were considered as accidental migrants. Libellulidae dominates the assemblage but from the genus *Orthetrum* Newman, 1833 only *Orthetrum trinacria* (Selys, 1841) occurs in the Cape Verde Islands.

*O. trinacria* was included in the Checklist of Capeverdean Odonata when it was firstly established by Martin (1907), after the study of the results of the 1897-98 campaign of the Italian naturalist Leonardo Fea. In the 21<sup>st</sup> century the occurrence of adults on the wing was confirmed to the islands of Santo Antão (Aistleitner *et al.*, 2008; Martens, 2010), São Vicente (Martens & Hazevoet, 2010), São Nicolau (Aistleitner *et al.*, 2008), Boavista (Aistleitner *et al.*, 2008; Bußmann, 2012), Maio (S. Martins, pers. comm.), Santiago (Aistleitner *et al.*, 2008) and Brava (Aistleitner *et al.*, 2008). Successful breeding was confirmed through exuviae finding to the islands of Santo Antão (Martens, 2010), Boavista (Bußmann, 2012), Maio (S. Martins, pers. comm.) and Brava (Aistleitner *et al.*, 2008).

The aim of the present report is to adjoin new data about the occurrence of *O. trinacria* in Santiago Island, with a focus on the confirmation of life cycle closing there. Additionally, the key diagnostic features usually inspected to ensure the unequivocal identification of the *O. trinacria* exuviae will be assessed, using to that a collection of 46 exuviae. Predictors of the body size of the F-0 larvae and of sexual size dimorphism (SSD) at emergence also will be studied and presented. Cape Verde has a peculiar status for studies with *O. trinacria* exuviae as, even when emergence was not sighted, there is no possi-

bility of confounding the *O. trinacria* exuviae with the ones from the other resident species (*Anax imperator* Leach, 1815, *Anax ephippiger* (Burmeister, 1839), *Crocothemis erythraea* (Brullé, 1832), *Pantala flavescens* (Fabricius, 1798), *Trithemis annulata* (Palisot de Beauvois, 1807) and *Zygonyx torridus* (Kirby, 1889)).

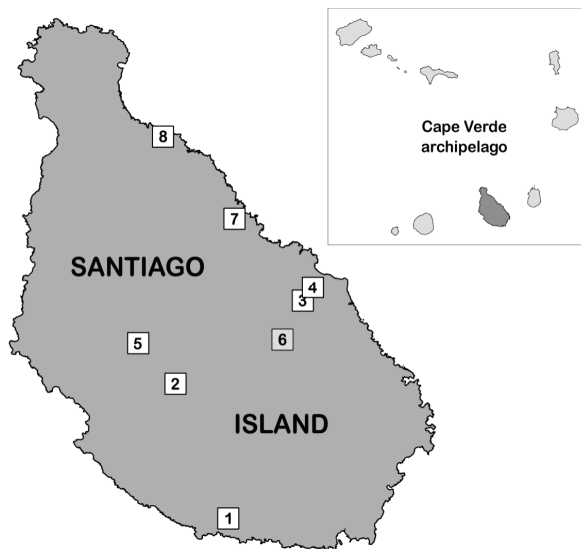
### **Material and methods**

#### **Santiago Island**

Located in the Atlantic Ocean, approximately 650 km off the coast of Africa, between latitudes 14° to 17° N and longitudes 23° to 25° W, the Cape Verde volcanic archipelago has a hot desert climate (BWh type, Köppen-Geiger climate classification) (Kottek *et al.*, 2006), with a dry season of nine months (November to July) and a wet one of three months (McSweeney *et al.*, 2010), but precipitation shows a great interannual variability and the Archipelago is periodically affected by droughts. May to July are the warmest months, and November to January the coolest ones (McSweeney *et al.*, 2010). Santiago, with 990 km<sup>2</sup>, is the largest of the ten islands and three islets that set up the Archipelago.

#### ***Orthetrum trinacria* exuvia**

*Orthetrum* spp. exuviae are characterized by a 'spoon-shaped' prementum, small and regular 'teeth' in the labial palps, small eyes (< ½ of the head length), and absence of a mid-dorsal spine on the seventh abdominal segment, or S7 (Doucet, 2011). The most relevant diagnostic features of the *O. trinacria* exuviae are the presence of mid-dorsal and lateral spines on some particular abdominal segments, long caudal appendages, and a very distinctive ratio between the epiproct length and its basal width. To the mid-dorsal spines Conesa-García (1990) and Butler (1993) refer the presence on S4 and S5 but



**Fig. 1.** The Cape Verde Archipelago. The Santiago Island magnified and presenting the position of the seven localities where *Orthetrum trinacria* exuviae were collected.

Gerken & Sternberg (1999) refer on S3 to S6. To the lateral spines Conesa-García (1990) and Butler (1993) refer the presence of small ones on S8 and S9. With figures Carchini (1983) shows the presence of mid-dorsal spines on S4 and S5, and of lateral ones on S8 and S9, and the absence of any other spines on the abdominal segments. To the caudal appendages Gerken & Sternberg (1999) refer a minimum epiproct length of 2.6 mm, and Conesa-García (1990) refers that paraprocts and epiproct have comparable lengths. To the epiproct length to basal width ratio, a highlighted diagnostic feature, Carchini (1983), Conesa-García (1985; 1990) and Butler (1993) agree in a minimum cutoff of 2.5. Finally, to the minimum total length of the exuvia Butler (1993) refers 23.0 mm whereas Carchini (1983) and Conesa-García (1990) refer 25.0 mm, and to the maximum one the mentioned authors agree in 30.0 mm.

Gender determination is possible, based on the structure of the developing secondary genitalia of the males on the sternites of S2 and S3. Females lack this secondary genitalia and therefore their sternites do not show the mentioned feature. This method should be preferred rather a study of the first genitalia of males and ovipositor of females, which are not always visible.

#### Field survey and exuviae measurements

A field survey in Santiago Island was conducted by N. Loureiro and A. Correia between 24 Aug and 4 Sep 2012. A total of 54 potential localities for Odonata reproduction were visited, being the majority of them irrigation tanks.

We selected four measures to be taken in this study: total length and hind leg tibia length, as estimators of the body size of the F-0 larvae, epiproct length and its basal width, as decisive diagnostic features. The other relevant diagnostic features, namely the presence or absence of mid-dorsal and lateral spines on some particular abdominal segments, were observed and recorded.

Our exuviae collection was transported to the Netherlands where measurements were ensured by E. v.d. Ploeg and C. Brochard, using a digital caliper and a calibrated Olympus SZ4045 stereomicroscope with micrometer eyepiece. The digital caliper was solely used for the total length measures, taken from the tip of the head to the tip of the anal pyramid, once exuviae are too large to be measured with the stereomicroscope. However, if the head is strongly bent upwards (or missing) this measurement cannot be carried out. For the other features the stereomicroscope was used to get the most accurate measurements. The hind leg tibia length was measured from the base of the lobe connecting the tibia with the femur, to the tip of the tibia next to the joint to the tarsus. Epiproct length was measured from the connection between the epiproct and S10, to the tip of the epiproct. The basal width of the epiproct was measured at its left and right margins where it connects to S10.

After measurements, twenty exuviae were deposited in the collection of the Museu Nacional de História Natural e da Ciência, Lisbon. The other exuviae were deposited in the private collections of N. Loureiro and C. Brochard.

#### Statistical analysis

Wilcoxon rank-sum test, a nonparametric procedure described by Bhattacharyya & Johnson (1977), was used to discuss the hypothesis ( $H_0$ ) that there is no SSD vs. the one-sided alternative ( $H_1$ ), which assumes that the size of one sex is shifted to one side of the distribution, and  $H_0$  is rejected with a specified level of significance ( $P$ -value < 0.001).

#### Results

##### *O. trinacria* life cycle closing

For the first time it is demonstrated that *O. trinacria* completes its life cycle in Santiago Island, Cape Verde, as we found *O. trinacria* exuviae in 6 irrigation tanks, 1 reservoir, and 1 puddle maintained by a temporary stream. We carefully collected by hand a total of 46 exuviae (see Table I, and Figs. 1 and 2), but we do not tried to carry out an exhaustive collecting effort. Apparently, it is a widespread species (see Fig. 1) and we are convinced that after an increased survey effort other localities where the species successfully breeds will be found.

##### *O. trinacria* exuvia body size and sexual size dimorphism

Descriptive statistics of total length and of epiproct length to basal width ratio by gender are summarized in Table II. No significant differences in length between males and females were found.

##### *O. trinacria* exuvia unequivocal identification features

As expected, the general *Orthetrum* spp. exuvia diagnostic features listed by Doucet (2011) were fulfilled. In what concerns the diagnostic features for the species level we obtained the following results:

- Mid-dorsal spines: were observed on S4 and S5 in every one of the 46 exuviae; the absence on S6 was the dominant pattern: 44 out 46 (95.7%) exuviae did not have a mid-dorsal spine on S6, 1 had on S6, and the last 1 had a very small one on S6; none of the exuviae had on S3.
- Lateral spines: were observed on S8 and S9 in every one of the 46 exuviae; the absence on the other abdominal segments was confirmed.
- Long caudal appendages: were observed in every one of the 46 exuviae; the minimum epiproct length of 2.6 mm was completely fulfilled.
- Epiproct length to basal width ratio: average of 2.30 (range: 2.14 - 2.52) and only 1 (2.2%) out of 46 exuviae had a ratio  $\geq 2.5$ ; this diagnostic feature was not fulfilled.

Descriptive statistics of epiproct length and of epiproct length to basal width ratio are summarized in Table II.

#### Discussion

Apparently, our field survey results suggest that successful breeding of *O. trinacria* in Santiago Island is strongly dependent from man-made body waters, since none of the localities where exuviae were found are natural reproductive habitats. In an Archipelago characterized by a hot desert climate and periodical droughts, where demography shows positive balances and pressures over the scarce water resources are continuously increasing, conservation measures will be welcomed to ensure the future of the Cape Verde Odonata fauna.

Total lengths of the studied *O. trinacria* exuviae fall inside the larger range mentioned in the literature but 6 (14.6%) out 41 exuviae are smaller than the 25.0 mm cutoff. To the best of our knowledge, this study is the first presenting figures about hind leg tibia length, and about SSD at emergence whenever the two predictors (total length and hind leg tibia length) are accepted as valid estimators to the body size of the F-0 larvae. Consequently, we cannot discuss our findings in the framework of a comparison with other studies carried out in Cape Verde or in other regions where *O. trinacria* successfully breeds.

It is known to several species that F-0 larvae body size declines through the emergence season, which introduces in the size figures a variation or a seasonal trend not studied here. To Cape Verde, where Odonata is admitted to be reproductively active all the year (Martens, 2010), these body size variations may not exist or, on the contrary, may have a more complex interpretation. Moreover, environmental parameters and food availability also conditionate body size at emergence, and in a broad sense also conditionate the body condition and fitness (e.g. Sokolovska *et al.*, 2000; De Block & Stoks, 2005; Mikolajewski *et al.*, 2007).

Our preliminary data points to the absence of SSD at emergence for *O. trinacria*. Serrano-Meneses *et al.* (2008) concluded not only that the Odonata ranges from female-biased to male-biased body size species passing by monomorphic species, but also that SSD at F-0 does not allow any prediction regarding SSD at adult stage. Hence,



Fig. 2. *Orthetrum trinacria* male exuvia.

**Table I.** Geographical coordinates, reproductive habitat characteristics and names of the localities where *Orthetrum trinacria* exuviae were found. Visit dates. Numbers of observed or collected exuviae.

Locality	Latitude	Longitude	Description	Date	Exuviae collected
(1)	14°55'39"N	23°36'01"W	Ribeira Grande valley, irrigation tank	25/08/2012	4
(2)	15°02'18"N	23°38'38"W	Ribeira de Belém valley, irrigation tank	26/08/2012	1
(3)	15°06'24"N	23°32'19"W	Ribeira Seca valley, irrigation tank	29/08/2012	30
(4)	15°07'05"N	23°31'49"W	Ribeira Seca valley, irrigation tank	29/08/2012	3
(5)	15°04'18"N	23°40'29"W	Ribeira do Mato Gégé stream	30/08/2012	2
(6)	15°04'28"N	23°33'21"W	Barragem do Poilão reservoir	31/08/2012	0 (>50 observed)
(7)	15°10'30"N	23°35'43"W	Ribeira dos Flamengos valley, irrigation tank	03/09/2012	1
(8)	15°14'34"N	23°39'15"W	Ribeira Principal valley, irrigation tank	03/09/2012	5

**Table II.** Measurements made in the *Orthetrum trinacria* exuviae and descriptive statistics.

	Total	Males	Females	Wilcoxon P-value
<b>TOTAL LENGTH</b>				
average (number)	26.0 mm (n=41)	25.8 mm (n=19)	26.2 mm (n=22)	
min - max (st dev)	24.1 - 27.9 mm (0.85)	24.1 - 27.4 mm (0.90)	24.7 - 27.9 mm (0.79)	0.1423
<b>HIND LEG TIBIA LENGTH</b>				
average (number)	6.8 mm (n=46)	6.7 mm (n=22)	6.9 mm (n=24)	
min - max (st dev)	6.0 - 7.2 mm (0.25)	6.0 - 7.2 mm (0.27)	6.4 - 7.2 mm (0.22)	0.1922
<b>EPIPROCT LENGTH</b>				
average (number)	3.11 mm (n=46)	3.10 mm (n=22)	3.11 mm (n=24)	
min - max (st dev)	2.87 - 3.33 mm (0.11)	2.87 - 3.33 mm (0.12)	2.93 - 3.27 mm (0.09)	0.3632
<b>EPIPROCT BASAL WIDTH</b>				
average (number)	1.35 mm (n=46)	1.33 mm (n=22)	1.37 mm (n=24)	
min - max (st dev)	1.28 - 1.45 mm (0.04)	1.28 - 1.43 mm (0.03)	1.28 - 1.45 mm (0.05)	0.0166
<b>EPIPROCT LENGTH TO BASAL WIDTH RATIO</b>				
average (number)	2.30 (n=46)	2.33 (n=22)	2.27 (n=24)	
min - max (st dev)	2.14 - 2.52 (0.08)	2.18 - 2.52 (0.08)	2.14 - 2.44 (0.07)	0.0104

our findings need to be considered only as the first record from a dataset that is being built, which in the future will contribute to a deeper knowledge of the species.

Finally, one of the diagnostic features for the species level mentioned in the literature, the epiproct length to basal width ratio, was not fulfilled. Further studies are requested to understand the extension of this finding and, perhaps, other diagnostic features need to be established to ensure an unequivocal identification of the *O. trinacria* exuviae. Until nowadays *Orthetrum cancellatum* (Linnaeus, 1758) was never seen in Cape Verde but some diagnostic features presented in the literature (e.g. Carchini, 1983; Conesa-García, 1985; Conesa-García, 1990; Butler, 1993; Doucet, 2011) for this species (e.g. mid-dorsal spine on S6, epiproct length to basal width ratio approximately equal to 2.0, total length approximately equal to 25.0 mm) overlaps with some features of a few *O. trinacria* exuviae deposited in the studied collection.

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