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Description of the Final Instar Exuvia of Urothemis edwardsii with reference to its Emergence site Selection (Odonata: Liballulidae)

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The last instar exuviae of the critically endangered *Urothemis edwardsii* Sélys 1849 is described and illustrated based on exuviae collected from Lake Bleu, Numidia (Northeast Algeria). The species is readily distinguishable from other local libellulids by its large size, coloration pattern, and long dorsal spines. The presence of spiniform setae on dorsal spies 6–8 seems to be a key trait to identify the species. The dragonfly usually emerged on water lilies (*Nymphaea alba*) at about 10 cm above the water surface at water depths ranging from 50–200 cm with a marked preference to stratum between 100 and 150 cm.

Key words: *Urothemis edwardsii* (Sélys 1849) – Afrotropical – Algeria – critically endangered – taxonomy – Exuvia

1 Introduction

In the latest assessment of North African odonata status [SaQmraoui et al 2010], *Urothemis edwardsii* (Selys 1849) was ranked one of the six critically endangered species in the region. This species is an afrotropical libellulid presenting a large distribution over Africa restricted from the North by the southern limits of the Sahara [Suhling & Clausnitzer 2009]. In addition, some relict populations were observed in Southwest Asia (Southeastern Arabia, Oman, Israel, and Palestine) and North Africa (Algeria and Tunisia with no evidence of population) [Schmidt 1938, Dumont 1975, 1991, Waterston 1985, Schneider 1986, Waterston & Pittaway 1991, Samraoui et al 1993, Schneider & Dumont 1997, Jödicke et al 2000]. However, almost all relict populations of the Mediterranean region have been recorded extinct during the last 20 years [Riservato et al 2009].

In Algeria, earlier records were limited to three localities situated in the extreme Northeast: Lake Oubeïra [Selys-Longchamps 1849], Lake Bleu, and Lake Noir [Samraoui et al 1993]. In Lake Oubeïra, where the species was first described, only one female was observed nearly a century and three-quarters ago [Selys-Longchamps 1849]. Studies that have been carried out the last two decades did not record the species in this site [Samraoui et al 1993, Samraoui & Menai 1999, Samraoui & Corbet 2000]. Small reproductive populations were observed in Lake Bleu and Lake Noir in 1992 [Samraoui et al 1993]. After severe anthropogenic pressure during the last two decades, Lake Bleu was the only locality where this dragonfly could be found [Samraoui et al 2010].

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Based on regular visits in the latter site, Risevato et al [2009] stated that last individual adults were reported in 2006 assuming that this population has probably been extinct since that year. In 2012, it has been shown through adults and exuviae observations that this relict population is still in existence.

It is well known that water depth plays an important role in structuring odonata communities in lentic water bodies [Thorp & Diggins 1982, Wissinger 1988]. Determining water depths at which a species emerges is crucial (especially for threatened odonates) because it provides information on spatial distribution of final instar larvae during the emergence season which is an important asset for species conservation. Unfortunately, most studies dealing with emergence considered only vertical stratification of exuviae [Corbet 1957, Bennett & Mill 1993, Cordero 1995] and not water depth of the support used to emerge.

In order to promote a monitoring scheme to this relict subpopulation, final instar larva systematic and ecology should be well known in order to promote exuviae based-studies which give the most reliable estimates of population size [Reabel et al 2010, Samways et al 2010]. In the current paper a detailed description of the final instar exuviae of *U edwardsii* is first presented, and then preferred habitats where emergence occurred are described.

2 Material and methods

Lake Bleu (36°54'33.75"N, 8°20'17.53"E) is a 2 ha pond with sandy substratum surrounded by helophytes like *Iris pseudacorus*, *Schoenoplectus triqueter*, *Phragmites australis*, and *Scirpus lacustris* with floating hydrophytes dominated by *Nymphaea alba*.

Exuviae sampling and description: Some biometric parameters and ratios used by Heidemann & Seidenbusch [2002] for final instar exuvia libellulids were measured. The present exuvia description was then compared to the key of Seidenbusch [2010].

Emergence site selection: Considering the status of the species, collection frequency was minimized to avoid habitat destruction and trampling effect on potential emergence supports. Therefore, only two exuviae collections at the end of emergence season in mid July and mid August 2012 were carried out. Eight plots of 10 x 5 m including water depths ranging from shallow to deep water (0–50, 51–100, 101–150, 151–200, > 200 cm) were chosen and sampled. Within each plot, exuviae of *U edwardsii* were intensely searched and collected noting the plant species where exuvia was climbed, exuvia height (from the water surface), and water depth.

Statistical analyses: SPSS 17.0 was used to conduct a chi square test in order to examine whether there was a significant difference in the distribution of exuviae in five different water depth strata. Values are presented as mean ± SD.

3 Results

A total of 86 final instar exuviae were collected but all measurements and ratios were only based on 25 specimens.

3.1 Description of the final instar exuvia

Final instar exuviae of *U edwardsii* has a total length of 23.31 ± 0.55 mm and a head width of 6.31 ± 0.17 mm.

Head: It is larger than long, light to dark brownish. Compound eyes elongated backwards. Ocelli are conspicuous and pale. A downward arrow shaped pale spot extending from the basal ocellus to anterior margin of postclypeus. Sometimes area between ocelli is also pale revealing a large pale spot in the middle of the head (in frontal view). Postocular tuft of relatively long upward curved setae and small spiniform ones extending to the postocciput (**Fig 2**).

Fig 1: Body of *Urothemis edwardsii* final instar exuviae.

Fig 2: Head of of *Urothemis edwardsii* (lateral view).

Dark circle (antennal sclerite) surrounding antennae insertion. A pale bulge linking the scape to the antennal sclerite. Anternnae 7-segmented. The scape (1st antennomer) is always the shorter antennomer while the longest is either the 3rd or 6th one. Antennomers 3 to 6 are uniformly cylindrical with the same diameter while the last one is more slender and acute. Ratio of scape diameter : 2nd antennomer diameter is 1 : 1.5. Second antennomer diameter : 3rd antennomer diameter 1 : 1.9.

The pattern of antennomers coloration is relatively variable but usually the 1st and 2nd antennomers are the darkest while 3rd and 7th (final) antennomers are the palest. Labium reaches second coxae. Prementum as long as wide (sometimes slightly longer). It is provided with one pair of symmetric set of long setae (13 in each set) forming a W-shaped line interrupted at the center (**Fig 3**). Distal part of prementum is covered with a field of hairy setae. Distal margin of prementum is not crenate and carry usually 20 equidistant spiniform setae, 10 on each side of the apical margin (**Fig 3**).

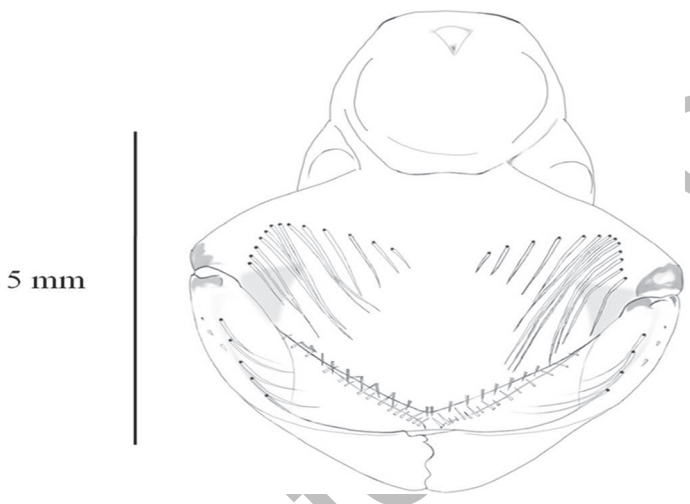

Fig 3: Prementum (inner surface).

Palpus presents a pattern of small scattered brown dots, more visible from the external side (**Fig 4a**), become larger and more abundant near moveable hook articulation. Ratio of moveable hook length : mentum width 1:3. A set of 9 long palpal setae on labial palpus (**Fig 4b**). Distal border of palpus is undulate presenting ten equally distant and shallow crenations (**Fig 4a, b**). Prominent parts carry usually 4 juxtaposed spines (2–3 for the first and final convections) with an obvious decreasing length (the first upper spine is longer than the next one and so forth) (**Fig 4c**). Three small spines in the basal part of palpus outer margin. A field of small spiniform setae in the inner surface near palpus insertion to the mentum (**Fig 3**). Inner margin is bordered with 19 spines, closer and more abundant in the distal part then become relatively distant, long ones separated by small ones (**Fig 3**).

Thorax: Pronotum anterior margin is bordered with short spiniform setae while its posterior margin is fringed basolaterally with both short spiniform and long hairy setae, absent at the center. In the ventral view, anterior border of furcasternite is covered with relatively dense hairy setae with some spiniform ones. A small tuft of long, aggregated, downward curved setae in the outer margin of basisternite. In the basisternite, two tufts of setae are disposed mesolaterally on either side of 2 long submedian setae. A few long hairy setae on coxae (relatively abundant in coxa 1 and 2). Wing pads borders and wing venations covered with small spiniform setae. Posterior wing pads reach and sometimes exceed the posterior margin of the 5th abdominal segment. Hind wing length : mentum length is 1:1. Femurs with 2 brown bands. Posterior femur length: posterior tibia length 1:1.1. Long hairy setae very sparse in all femurs.

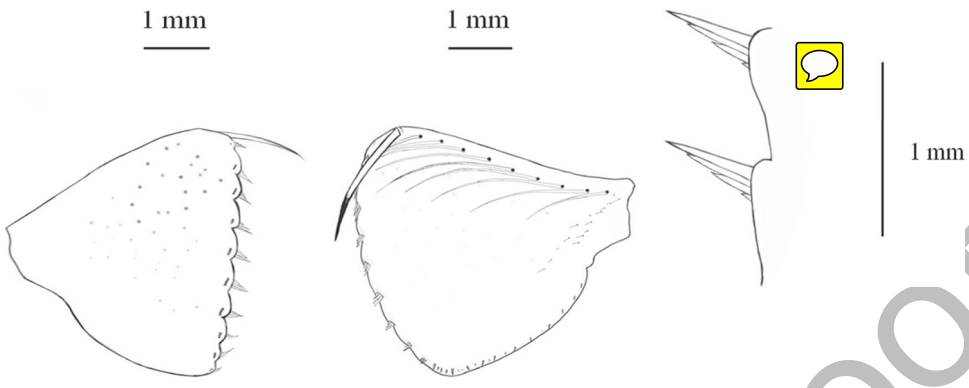

Fig 4: Labial palpus: (a) external surface; (b) inner surface; (c) Palpal lobe crenation and spines on prominent parts.

Metafemur is 3-edged with a line of small spines bordering each edge. Metatibia is bordered ventrally and dorsally with 2 parallel lines of small spines. Meta- and midtibia are fringed ventrally and dorsally with a crest-like line of dense hairy setae.

Abdomen: Brownish with the 5 first segments paler than the others, the 6th one is usually light brown while the followings are relatively dark (**Fig 1**). Anteromedian, anterolateral and mesolateral pale spots in abdominal tergites (except tergum 10), not well visible in pale segments (**Fig 5**). It is dorsally covered with a furry layer of small setae; sparser ventrally and limited to sternites 7 to 9, rather abundant in sternite 8 (**Fig 7**). In ventral view, the occurrence and size of a median dark line in the three basal sternites are variable; it occurs usually between sternites 8 and 10.

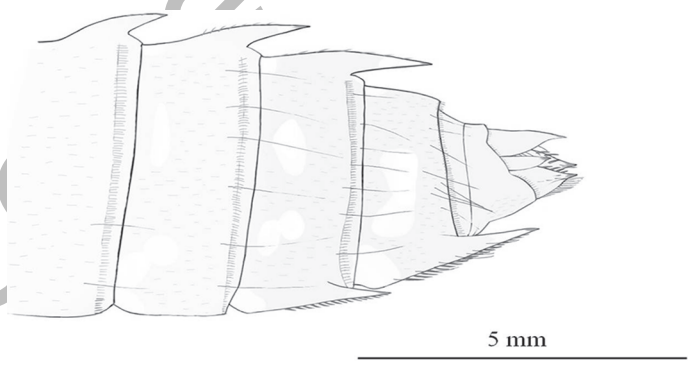

Fig 5: Lateral view of five final abdominal segments.

Dorsal spines from segment 3 to 8 with an increasing size trend. The 8th one is the longest, almost horizontal in lateral view and rarely reaches the posterior margin of the 9th segment (usually reaches the 2/3th to 3/4th) (Fig 5). Ratio of 8th lateral spine length : 8th segment length is approximately 1:2.5.

Ratio of 8th : 9th lateral spine length is 1:1.5–1.8. The 9th lateral spine exceeds half of cerci length. External side of the 6th to 8th dorsal spines is fringed by small curved spiniform setae, conspicous in lateral view (**Fig 6**).

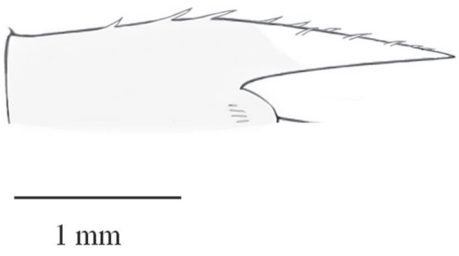

Fig 6: Lateral view of the 8th dorsal spine.

Ratio of Cerci : paraproct length is 1:1.7–1.8. Very long and relatively dense raw of black setae at the end of the 9th sternite (**Fig 7**) but shorter and very sparse on the other sternites, pleurites as well as all tergites. Lateral spines (7th and 8th) and outer margins of the same segments are covered with a set of small spiniform setae slightly curved downward mixed to another set of long hairy setae (**Fig 7**). Epiproct is fringed by relatively long setae. Paraprocts edges are covered with a few small spiniform setae in the outer side and both spiniform and long hairy setae in the inner side.

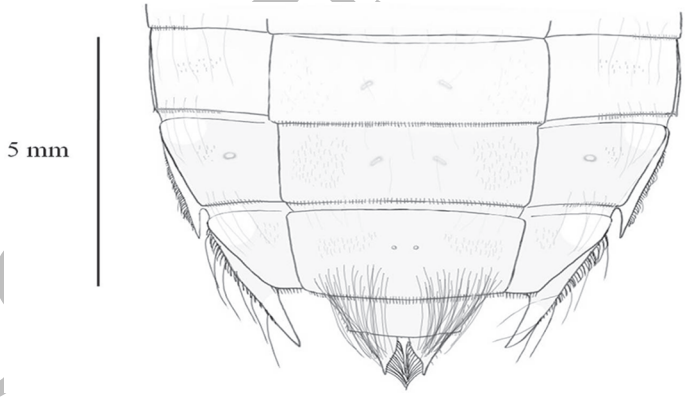

Fig 7: Ventral view of four final abdominal segments.

Cerci tips and sternite 10 are laterally (outer margin) fringed with small setae. Posterior margin of 7th to 9th abdominal sternites and from 1st to 10th tergites (dense between 6th and 9th ones) are provided with comb-like setae (**Figs 5, 7**). These kind of setae are also present on the posterior margin of pleurites 6 (about 1/2 of pleurite width), 7 (2/3), 8 (4/5), 9 (entire margin), and small lateral section of sternite 10 (**Fig 7**). In female, the line of setae on posterior margin of the 8th sternite is interrupted medially. Male primary genitalia are not obvious in contrast to secondary genitalia.

In Lake Bleu, almost all exuviae (96.55%) were collected in the Southern sector of the pond and only 2.29% and 1.14% were recorded in Northern and Eastern sector respectively.

3.2 Emergence site selection

Almost all exuviae (96.55%) were collected from the southern part of the Lake. A few ones were found in the Eastern (2.29 %) and Northern part (1.14%). Plant species used at emergence were *Nymphaea alba* (57.47%), *Cladium mariscus* (39.08%), *Phragmites australis* (2.30%) and *Iris pseudacorus* (1.15%). Individuals that used *Nymphaea alba* were found on the stem as well as the lower and upper leaf side. Two exuviae were collected from the water surface. Exuvia height (from water) ranged between 5 and 27 cm with a mean of 10.96 ± 5.39 cm (N = 84).

Exuviae were not randomly distributed throughout the different strata of water depths (Chi square test: $\chi^2 = 42$, $P < 0.0001$). **Fig 8** presents the frequency distribution of *U edwardsii* exuviae within the five different strata of water depths. Most exuviae (80.22%) preferred to emerge in a range of water depths restricted between 100 and 150 cm. Lower proportions were observed in strata of 50–100 cm and 150–200 cm with 6.59% and 13.19% respectively. No exuvia was collected in depths lower than 50 cm and exceeding 200 cm.

Fig 8: Frequency distribution of *U edwardsii exuviae* within different water depth strata in Lake Bleu. Only exuviae found in Southern sector were considered (N = 84).

4 Discussion

Some of the most threatened odonate species (*Acisoma panorpoides ascalaphoides*, *Urothemis edwardsii*, and *Calopteryx exul*) of the Mediterranean basin exist in Numidia (Northeastern Algeria) [Samraoui & Corbet 2000, Khelifa et al 2011]. Besides human pressure on their natural habitat, lack of knowledge on their biology, ecology and larva systematics have made their conservation difficult. Recently, increasing interest on the conservation of threatened odonates has been shown in Numidia; for example, studies on the Maghrebine endemic *C exul* highlighted its adult ecology [Khelifa 2013] and larva taxonomy [Khelifa 2012] which will both serve as an important tool to determine its real geographic distribution and monitor its population size in the region. The same approach should be followed for *Acisoma panorpoides ascalaphoides* and *U edwardsii* whose geographical range within the Mediterranean basin is currently restricted to a single relic population in Northeast Algeria. *U edwardsii* population was recently assumed extinct by Riservato et al [2009]. In this paper, we confirmed that the Algerian subpopulation of *U edwardsii* is still in existence and filled the gap of knowledge on its larva systematic.

Identification of the final instar exuvia of *U edwardsii* should not pose any problem because other libellulids from the same region are substantially different. Species with relatively the same size are *Orthetrum trinacria* and *O cancellatum* but these species have small eyes and do not have dorsal spines after the 6th abdominal segment. Species with similar dorsal spines configuration (3–8 abdominal segments) are from Sympetrinae group like *Sympetrum striolatum* and *S meridionale* [Heidemann & Seidenbusch 2002], however, besides their smaller size, their 8th dorsal spine never exceeds half of the 9th segment while it is obviously longer and reaches at least its 2/3rd in *U edwardsii*. In addition, eyes orientation is almost directed laterally in *Sympetrum* spp while it is clearly backwards in *U edwardsii*. Finally, the reliable trait which appears to be specific to *U edwardsii* with respect to other libellulids from Numidia is the presence of spiniform setae on the external side of the 6th to 8th dorsal spines, readily observable in lateral view.

In his brief description based on a single exuvia of *U edwardsii*, Seidenbusch [2010] presented a body length exceeding 27 mm which is substantially longer than our collected individuals (**Tab 1**). This exuvia was collected in the same locality (Lake Bleu) and thus should probably be an unusual specimen. Moreover, some ratios presented by Seidenbusch [2010] were close to those presented in this study (cerci : epiproct and lateral spin 9 : hind wing) while others were slightly different (cerci : paraproct, paraproct : mentum, and paraproct : hindwing) (**Tab 1**).

Tab 1: Comparison of body length and some ratios of *U edwardsii* presented in this study with that of Seidenbusch [2010]. **ce:** cerci, **ep:** epiproct, **pp:** paraproct, **LS:** lateral spin, **hw:** hind wing, **m:** mentum (according to Seidenbusch [2010]).

	Body length (mm)	ce : ep	ce : pp	LS 9 : hw	pp : m	pp : hw
This study	22.6–24.5	1 : 1.4	1 : 1.7–1.8	1 : 5–5.4	1 : 3.9–4.1	1 : 3.9–4.2
Seidenbusch (2010)	> 27	1 : ≈ 1.3	1 : < 1.5	1 : ≥ 5	1 : ≈ 4.5	1 : ≈ 4.5

Vertical stratification of *U edwardsii exuviae* was substantially lower than other libellulids reported by Cordero [1995] like *Orthetrum cancellatum* (48.07 ± 3.47 cm), *Sympetrum striolatum* (34.73 ± 1.56 cm), and *Libellula depressa* (30.70 ± 1.73 cm). The spatial distribution of the species emergence was markedly concentrated in depths ranging from 100 to 150 cm. In addition, most exuviae were recorded on *Nymphaea alba* probably because it was the most dominant plant species in the region where water depth exceeded 100 cm. Emergence site selection of the species might play an important role in its conservation because shallow parts of the lake were affected by pasturing and trampling of livestock which could induce substantial mortality to larval dragonfly community and other macroinvertebrates.

An urgent management plan is required to conserve this relict population and it should promote exuviae rather than adult sampling in order to provide reliable estimates of population size. Regular population estimation in Lake Bleu as well as extensive visits in other neighboring water bodies would provide data on both population trend and potential colonization of new sites.

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