

# EMERGENCE ECOLOGY OF THE CRITICALLY ENDANGERED UROTHEMIS EDWARDSII IN A NEW COLONIZED SITE IN EL KALA NATIONAL PARK (ALGERIA): CONSERVATION IMPLICATIONS

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#### Keywords:

Body size; conservation; threatened species; exuviae; Odonata; dragonfly; North Africa **Abstract.** *Urothemis edwardsii* is one of the most threatened dragonfly species in the Mediterranean. Recent investigations and conservation efforts have increased the local geographic distribution of the species in Northeast Algeria, where a new population (named El Graeate) has been discovered. In the absence of information about the biology and behavior of *U. edwardsii* in this new site, a study was conducted on the emergence ecology of the species taking into account the temporal pattern of emergence, sex ratio, body size and microhabitat selection. Emergence, which was quite asynchronous, lasted for 50 days, with 50% of the population emerging within the first half of the period. Sex ratio at emergence was slightly female biased despite the absence of sexual size dimorphism, suggesting that size is not the only driving force behind mortality bias during the larval stage. There was a slight seasonal increase in the body size of exuviae (exoskeletons) in both sexes. Microhabitat selection, assessed as the vertical stratification of exuviae at ecdysis, was positively correlated with the height of supporting plants, but the relationship reached a plateau suggesting that there are predetermined limits to the vertical distribution of exuviae. These data will be essential for the future species protection, restoration and management attempts in the region.

# **INTRODUCTION**

Effective conservation of threatened species requires a good understanding of habitat selection (Orians and Wittenberger 1991; Stamps and Swaisgood 2007), which is of critical importance for the species that are targeted for restoration and reintroduction (Lipsey et al. 2007; Corlett 2016). In aquatic insects, habitat selection might encompass the complex relationship of individuals with local abiotic and biotic factors (Morrison et al. 2012), one example of which is how insects use plants to fulfill important biological requirements such as foraging, thermoregulation, and metamorphosis (Samways et al. 2010).

Odonates represent a widespread trophic level in freshwater ecosystems. Many species worldwide have undergone severe population decline during past decades, mainly due to habitat degradation and climate change. In the Mediterranean, approximately one-fifth of the 165 existing species are threatened with extinction and four are currently regionally extinct (Riservato et al. 2009). In this region, Northeast Algeria is one of the most diverse areas harbouring several species endemic to the Mediterranean or North Africa. Yet, many species are on the verge of extinction and are in need of urgent conservation plans (Khelifa and Mellal 2017). *Urothemis edwardsii* (Libellulidae: Anisoptera) is among the most (if not the most) threatened odonate species in the region. Although common in sub-Saharan Africa, there is only a small critically endangered relictual population in North Africa. After a series of extinction events in several countries in the Mediterranean, the species was restricted to a single location in Northeast Algeria -Lake Bleu (Khelifa et al. 2016). Only recently have new local populations been detected in the region, i.e. El Graeate (Northeast Algeria). These locations are historically novel and where promising numbers of individuals and breeding pairs have been recorded. Most of the data available on the species come from Lake Bleu (Khelifa et al. 2013a; c). However, there is nothing known about the biology and behavior of the species in this new locality. To establish an effective conservation plan, management of the species should start with a good understanding of important natural history information at the level of locality (Purse et al. 2003; Samways 2003; Foster and Soluk 2004; Raebel et al. 2010; Khelifa et al. 2016).

The transition from aquatic to terrestrial stages in odonates goes through ecdysis (Corbet 1956). In this phase, larvae select a suitable site (plants, stones, soil...) to undergo metamorphosis. As this process is long and might last for several hours, individuals are at great risk of predation (Corbet 1999; Jakob and Suhling 1999). Importantly, at the end of metamorphosis, individuals leave their exuviae (exoskeletons) on the exact location where ecdysis took place (Corbet 1999). Collection of exuviae allows the survey of ecologically-relevant parameters such as population size, sex ratio, and habitat choice (Cordero 1995; Khelifa et al. 2013b; Hadjoudj et al. 2014; Zebsa et al. 2014a, b). Moreover, being an indirect way of population sampling, collection of exuviae is a great tool for studying species of conservation concern (Foster and Soluk 2004; Raebel et al. 2010).

Since U. edwardsii requires urgent management intervention aimed at maintaining population size and expanding its range, the intrinsic and extrinsic factors that potentially influence emergence ecology of the species were studied in the newly colonized site, El Graeate (National Park of El Kala, Northeast Algeria). Through the exuviae-based approach, population size, temporal pattern of emergence, and habitat choice for emergence were assessed. I hypothesized that (1) given that the size of the wetland of El Graeate is larger than that of the Lake Bleu, the population size of the former is likely to be larger (Khelifa et al. 2018); (2) the sex ratio is biased towards the larger sex because mortality of the larger sex during the larval stage is higher (Johansson et al. 2005); and (3) there is a positive relationship between the height at which the ecdysis takes place (He) and the support height (Hs), as has been found in other odonates (Hadjoudj et al. 2014; Zebsa et al. 2014a, b).

## **MATERIALS AND METHODS**

## Study sites

The study was conducted in Graeate located in the National Park of El Kala (36°51'14"N, 8°10'33"E). It is a 34 ha-marshy pond dominated by *Iris pseudacorus*, *Schoenoplectus triqueter*, *Phragmites australis*, and *Scirpus lacustris* and *Nymphaea alba*, and in which a large population of *Urothemis edwardsii* has been recently discovered (Khelifa et al. 2016). The dragonfly community was dominated by *Acisoma inflatum*, *Orthetrum trinacria*, *Crocothemis erythraea*, and *Brachythemis impartita*.

#### Exuviae sampling

Urothemis edwardsii was collected from 11 vegetation patches sized  $2 \times 1 \text{ m}^2$  where water depth was about 1.5 m (Khelifa et al. 2013c) (Figure 1). In order to reduce potential negative effects of our sampling on the local population of this critically endangered species, weekly sampling was conducted starting from the third week of May 2016 until the end of the emergence season (mid-July). Along with exuviae collection, the height of exuvia fixation (He) (distance between the water surface and the tip of exuvia abdomen) and the height of the chosen support (Hs) were measured for each exuvia to the nearest 1 cm. To investigate potential effects of the body size and sex, exuviae were sexed and the length of the body was measured to the nearest 0.01 mm using a digital caliper in the laboratory. We also calculated EM50 as the number of days when 50% of the population had emerged. The damaged exuviae, whose body size and sex were not measured or identified, were excluded from statistical analyses.



Figure 1. Exuviae of Urothemis edwardsii in the field.

### Statistical analysis

Statistical analyses were carried out using R3.3.2 (R Development Core Team 2019). Chi-square tests were conducted to clarify whether sex ratio at emergence deviates from unity (1:1). Multiple linear regressions were performed to look for the seasonal body size pattern using days of the year (Julian dates) and sex as explanatory variables and body length as a response variable. Mann Whitney U-tests were carried out to test for differences in body length between males and females. To investigate the effect of Hs, body size and sex (explanatory variables) on He (response variable), we conducted multiple linear regressions. Values are mean  $\pm$  sd.

## RESULTS

#### Temporal pattern of emergence

A total of 170 exuviae were collected during eight sampling occasions. The first exuvia was recorded on 21 May 2016 and the last one on 10 July 2016. Duration of the emergence season was about 50 days, during which half of the population (EM50) emerged within 23 days. Cattle grazing on aquatic plants were observed not far from emergence sites during all sampling occasions. Sex ratio was slightly female biased (54.1%,  $\chi^2 = 29.2$ , p < 0.0001). The analysis of the body size of exuviae showed that females and males had a similar body length (body length: 22.37 ± 0.86 mm vs. 22.18 ± 0.90 mm, W = 3203, p = 0.23). There was a weak (R<sup>2</sup> = 0.07) but significant seasonal increase in the body length of both sexes (Table 1, Figure 2).

Table 1. Summary results of the linear regression investigating the seasonal pattern of body size during emergence season of *Urothemis edwardsii* in Northeast Algeria.

	Estimate	Std. Error	<i>t</i> -value	<i>p</i> -value
Intercept	19.107	1.528	12.499	< 0.0001
Season	0.017	0.009	1.993	0.0490
Sex [Male]	-0.756	2.330	-0.324	0.7465
Season: Sex [Male]	0.005	0.013	0.358	0.7214



Figure 2. Seasonal pattern of body length of exuviae in *Urothemis edwardsii*. Dashed and solid lines represent males and females, respectively.

#### Microhabitat selection

Overall, the height at which ecdysis took place (He) was  $3.76 \pm 3.93$  cm and He was best explained by the height of support, but not by sex and body length (Table 2), revealing that the vertical stratification of males and females was similar. There was a positive logarithmic relationship determined between He and Hs (Figure 3), suggesting that ecdysis was conducted at higher positions when the support was higher, but this increase slowed down in longer supports.

Table 2. Summary results of the linear regression investigating factors affecting the height of exuvia fixation during ecdysis of *Urothemis edwardsii* in Northeast Algeria.

	Estimate	Std. Error	<i>t</i> -value	<i>p</i> -value
(Intercept)	0.869	1.898	0.458	0.6476
Log (Hs)	1.892	0.245	7.724	< 0.0001
Sex [Male]	-1.102	0.402	-2.742	0.0068
Body length	-0.086	0.077	-1.123	0.2632



Figure 3. Relationship between the height of exuvia fixation and support height in *Urothemis edwardsii*. Dashed and solid lines represent males and females, respectively.

## DISCUSSION

Our study investigated aspects of the emergence ecology of probably one of the most endangered odonates in North Africa and provides information that might be useful for the conservation and management of this species. The emergence season of *U. edwardsii* was relatively long, with half of the population emerging during the first half of the emergence season. As expected, the height at which ecdysis occurred was positively correlated to the supporting plant height, but not to body size or sex.

Our sampling of *U. edwardsii* exuviae in the recently recorded population in El Graeate (Khelifa et al. 2016) suggests that the population size might be as large or even larger than that in Lake Bleu for two reasons. Firstly, although the number of sampling occasions in this study was eight and in earlier studies only five (Khelifa et al. 2013c), the density of exuviae per area and per occasion

was higher in El Graeate (170 exuviae/22 m²/8 occasions [0.96] compared to 86 exuviae/20 m²/5 occasions [0.86]). This rough comparison hints at a large population size. Secondly, the El Graeate area (35 ha) is larger than that of Lake Bleu (2 ha) suggesting that the carrying capacity of the site is most likely larger. Given that this site does not currently benefit from any conservation attention (barrier of protection, buffer zone, and signs of protected area), it is urgent that the local authorities undertake appropriate management actions in a timely manner to enable demographic growth of this probable newly established population (Khelifa et al. 2016).

U. edwardsii had a temporal pattern of emergence typical of summer species (Corbet 1954), where the population emerged asynchronously throughout late spring and early summer. This temporal pattern is similar to that recorded for the lotic dragonfly Onychogomphus costae in the region (Zebsa et al. 2014b). Taking into account this temporal pattern, it is unlikely that the species produces two generations per year (Mahdjoub et al. 2015; Khelifa 2017; Khelifa et al. 2019). Taking into account the length of the emergence season, cattle pasturing and trampling, which cause habitat fragmentation, should be prevented (Lee Foote and Rice Hornung 2005). In addition, given that adults occupy a large terrestrial area during the flight season (Khelifa et al. 2016), it is important that the size of the buffer zone of the wetland should be large and maintained throughout the season (Semlitsch 1998).

Body size shows a weak pattern of seasonal increase throughout the emergence season. Seasonal decline in body size during emergence is considered to be the norm because it has been observed in many dragonflies and damselflies (Banks and Thompson 1985; Inden-Lohmar 1997; Corbet 1999; Purse and Thompson 2003). In North Africa, there is growing evidence that a temporal increase in body size exists in local dragonflies (Hadjoudj et al. 2014; Zebsa et al. 2014b). It is likely that in North Africa (at least in the lowlands), the temperature does not fall below the developmental threshold and that winter diapause does not exist. Therefore, individuals that emerge late might benefit from longer development and thus come out larger (Blanckenhorn and Fairbairn 1995). Moreover, the hypothesis that the sex ratio is biased towards the larger sex was not confirmed. Males and females had a similar body size, but the sex ratio was female biased. In fact, in 21 species of odonates, Johansson et al. (2005) found some evidence that the larger sex suffers from higher mortality rates. This relationship indicates that larger sex might have higher energy requirements and thus engage in riskier foraging. If the sample size collected in the field was representative of the populations, this means that body size is not the only factor that affects larval mortality. The two sexes might have different larval activity and males may suffer from higher mortality because they are either more active or less vigilant (Stoks et al. 2003).

The study results show that the emergence habitat was not randomly chosen. As hypothesized, there was a positive relationship between He and Hs, which was not linear but logarithmic. A positive relationship between He and Hs has been observed in several dragonflies (Hadjoudj et al. 2014; Zebsa et al. 2014a, b; Boucenna et al. 2018; Hadjadji et al. 2019). The logarithmic relationship means that larvae had a certain height limit, which they could not exceed regardless of the height of supporting plants. This is in line with emergence site selection by Coenagrion mercurial on the Seybouse River (Northeast Algeria) (Mellal et al. 2018). Neither body size, nor sex had a significant effect on He, which is similar to what has been found in Orthetrum cancellatum (Hadjoudj et al. 2014), but different from what was reported for Gomphus lucasii and Onychogomphus costae (Zebsa et al. 2014a, b). This microhabitat choice could be a behavioural response to predation (being too high increases prey detectability by predators) or to wind (ecdysis performed at high positions increases instability of the wind-exposed support plant) (Khelifa et al. 2013b). Further studies should test these hypotheses experimentally, either in the laboratory or in the field.

Our present investigation has furnished new data on the emergence ecology of the critically endangered odonate *U. edwardsii*. It is important to determine habitat requirements for emergence in order to overcome potential disturbance-induced mortality during ecdysis, which is a sensitive period in the species' life cycle. The information presented herein is essential for preparing species conservation plans not only on the regional but also on a larger scale. Habitat degradation is known to be an important factor in the extinction of threatened species populations (Khelifa and Mellal 2017). Further studies should investigate translocation success in preferred habitat for larvae and emergence and generate a general conservation framework for threatened dragonflies locally and globally.

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