BIHAREAN BIOLOGIST 18 (2): 83 – 89
Article No.: e241203

http://biozoojournals.ro/bihbiol/index.html

Phenology of *Androctonus australis* (Linnaeus, 1758) from the Sahara Desert of Algeria (Scorpiones: Buthidae)

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Received: 10 August 2024 / Accepted: 12 September 2024 / Available online: December 2024 / Printed: December 2024

Abstract. With its enormous geographical extent and various ecosystems, Algeria has more than 54 species of scorpions. Among these species, *Androctonus australis* (Linnaeus, 1758) is the species with the highest medical importance. This study particularly concerned this species' seasonal variation and developmental stages, which were collected from various environments in the Sahara Desert of Algeria. The present study focuses on the annual activity of scorpions (phenology) of *A. australis* in the region of Ghardaïa. Twelve nocturnal outings at mid-month during 2022 made it possible to collect 208 scorpions. Results allowed us to define the favorable mating season of *A. australis* that occurs during the autumn period (15th November to 10th August) when climatic conditions are favorable for courtship, which means temperatures relatively low (around 18°C) and winds blowing at a regular speed and constant direction. We also noted that the species develops a winter diapause lasting from 5 to 6 months, covering the whole winter season and a few weeks of spring. During spring and summer, as a result of parturition, a huge number of juveniles are observed.

Keywords: phenology, scorpions, *Androctonus australis*, Sahara, Algeria.

Introduction

Phenology is the science that studies the correspondence between the stages of development of organisms and seasonal conditions (Leith 1974, Odum 1997). The phenological cycle of a species concerns the seasonal variation of its stages of development and, therefore, lasts, on average, one year (Touffet 1982). We chose scorpions as an animal model because they are considered one of the most important taxa for ecological studies (Polis 1990, Schwerdt et al. 2016, Sadine et al. 2023).

In the world, there are more than 2807 identified scorpion species worldwide (Rein 2024). In particular, with its enormous geographical extent and various ecosystems, Algeria has more than 54 species of scorpions (Dupré et al. 2023). Among those species, *Androctonus australis* (Linnaeus, 1758) is the species with the highest medical importance (Chippaux & Goyffon 2008, Haddad et al. 2022, Telli et al. 2022) and it is the most abundant species in the Algerian Septentrional Sahara, with more than 47% (Sadine et al. 2018, 2023).

This study particularly concerned seasonal

variation and developmental stages of the *Androctonus australis*, which were collected from various environments in the Sahara Desert of Algeria.

Material and methods

Study area

The area of this study is represented by the Ghardaïa Province (29°19′ N–32°57′ N, 02°03′ E–04°54′ E) with a surface area of 21,352.58 km² (Figure 1), located in the Sahara Desert of Algeria. The Saharan climate characterizes this region (Saharan bioclimatic stage) with mild winters (Benkenzou et al. 2007, Sam 2012). The xeric climatic characteristics of our study region constitute a favorable refuge for the life and evolution of scorpions (Sadine et al. 2014).

This climate is linked to significant thermal amplitude in the day between day and night and even between winter and summer, with a dry period in which the hot period begins in February and continues until December. The average temperature recorded in July was 41.8°C. The average temperature recorded in January does not exceed 6.2 °C for the winter period. Precipitation is very low and irregular, with an average of 80.2 mm per year (Sadine et al. 2023). Humidity rates in the region vary between 55.5% and 21.6% values for December and July, respectively. Sand winds are encountered from the northwest in the fall, spring, and winter. The hot winds (Sirocco) from south-north, which dominate in summer, are very dry and cause strong evapotranspiration.

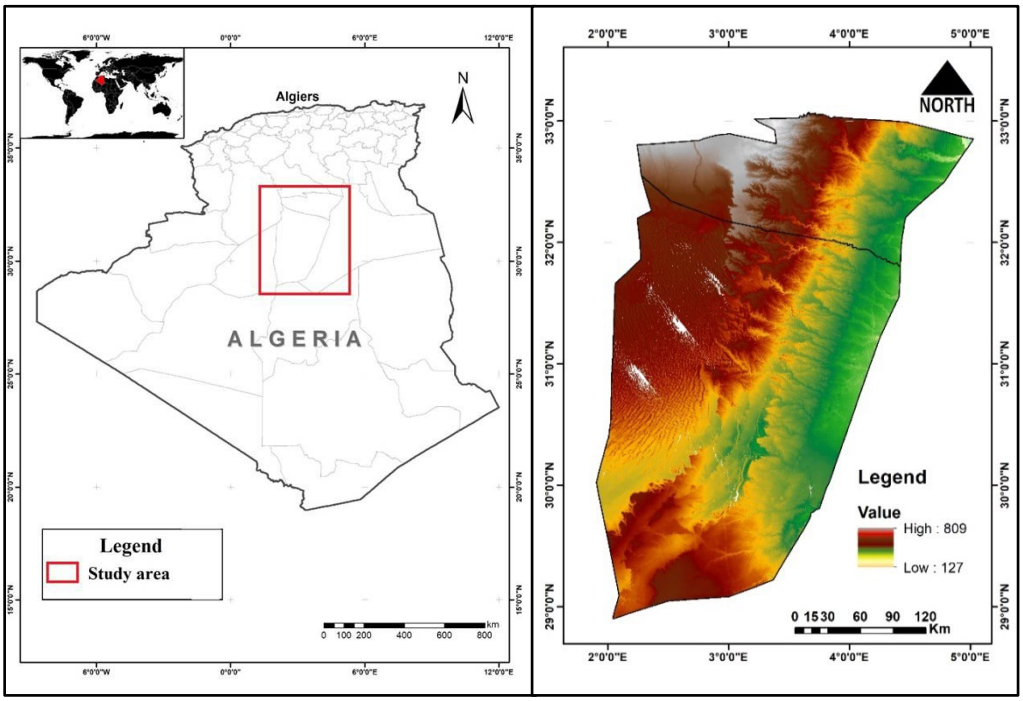

Figure 1. Geographic location of study area (Ghardaïa), Central Algerian Saharan

Animal materiel

The genus *Androctonus* belongs to the Buthidae family (Lourenço & Duhem 2009). Among the dominant species of this genus in the Ghardaïa region are *A. amoreuxi* and *A. australis* (42%) (Sadine et al. 2018).

Androctonus australis (Linnaeus, 1758) measured around 10 cm. The morphological characteristics of this large species make it easy to recognize. It presents itself with its thickest

tail, straw yellow, with parts of the body (claws and last rings of the tail) more or less darkened (Vachon 1952). The fingers are fixed and movable, with 12 –14 semi-oblique series of dark-colored granules. It has 30-36 pectinal teeth in males and 22-26 in females (Vachon 1952, Lourenço 2005).

This species is distributed in Africa, particularly in Algeria, Chad, Egypt, Libya, Mauritania, Somalia, Sudan, and Tunisia (Lourenço 2005). In North Africa, *A. australis* occupies the northern Algerian and Tunisian Sahara and extends to the east into Libya (Vachon 1952, Aboshaala et al. 2022) (Figure 2). Nevertheless, in Morocco, the presence of *Androctonus australis* remains unconfirmed (Vachon 1952, Lourenço 2005, El Hidan et al. 2018, Touloun 2019).

Sampling of scorpion

The species *A. australis* is the focal species for this study thanks to its distribution in the Ghardaïa region (Sadine et al. 2023). Scorpion sampling was carried out randomly through nocturnal scientific field trips in the middle of each month in 2022. Individual scorpions were detected with an ultraviolet lamp, which detects scorpions by their reflective properties (Lowe et al. 2003). Finally, using version 10.8.1 of the ArcGIS software for Desktop: Esri®, we created a map representing the geographic location of the study area (Ghardaïa), Central Algerian Saharan.

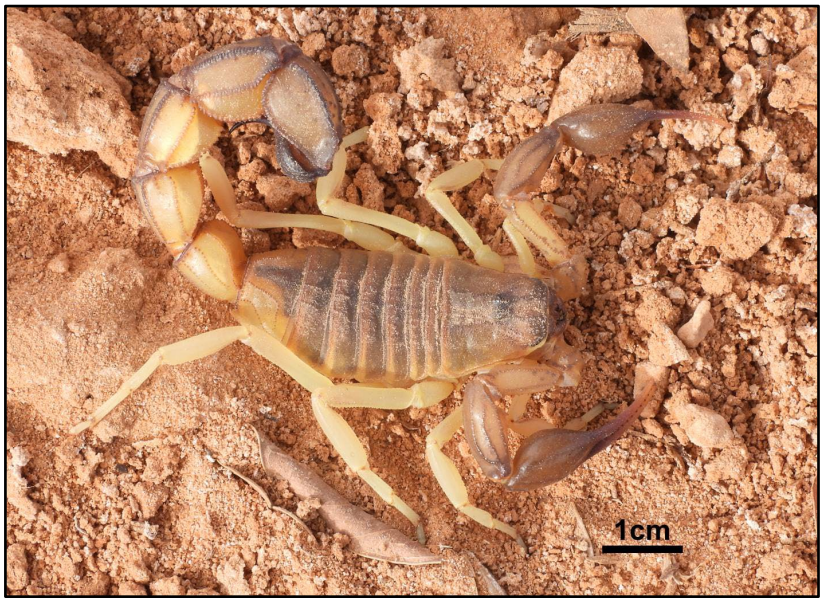

Figure 2. Adult *Androctonus australis* from the Sahara Desert of Algeria

Results and discussion

The results of this study show that approximately 208 individuals of *A. australis*, distributed in males, females, and juveniles, were collected in the Ghardaïa region during the 12-month period of 2022.

Phenological dynamics

Desert habitats exhibit a significant diversity of scorpions that are easily detected with ultraviolet light (Stahnke 1970, Polis & Farley 1979). Scorpions are often cannibalistic (Alexander 1956, 1957, 1959). These characteristics make scorpions very important types in the study of behavioral analysis.

The analyzed results show that the activity of scorpions of the species *A. australis* in the Ghardaïa region presents an important and potential dynamic in 2022. This activity is more

important at night than during the day, from one month to the next, and from one season to the next. Unlike in the summer, scorpions are almost non-existent in the winter (Figure 3).

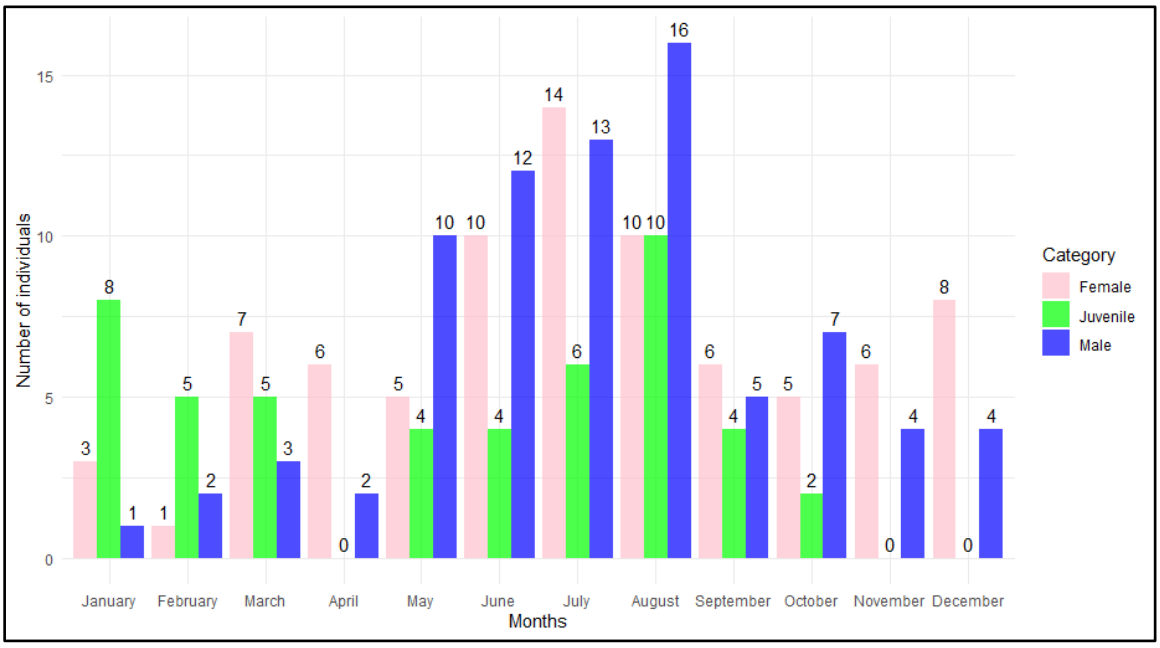

Figure 3. Collection of *A. australis* (male, female, and juvenile) in Ghardaïa, central Algerian Sahara, in 2022

The difference in this activity of scorpions is linked to the influence of the climatic and environmental conditions that surround them all year. The number of females was slightly higher than the number of males and the number of juveniles during the twelve months of the study. Except for the summer season, males become greater than females, particularly in August. Mekahlia et al. (2021) indicated that *A. australis* is active almost all the time in the desertic region of eastern Algeria. However, it is observed only in the summer and spring seasons in semiarid and arid areas. In the arid ecosystems of central Algeria, *A. australis* and *A. amoreuxi* are the two most abundant species of scorpion in both 2016 and 2017 (Sadine et al. 2023).

The females of *A. australis*, like the majority of Buthidae, give birth once a year, generally in spring periods. The males of this species are present only at reasonable times, essentially during mating. However, the females keep up their activity even in the cold months. Benton (1992) has proved that the male of *Euscopius flavicaudis* appears only at reasonable times, mainly during summer and mating.

The number of juveniles is almost nonexistent at the beginning of winter and is noticeable at the beginning of spring, where it reaches its peak at the beginning of summer. These results confirm the study of Sadine (2018) in the Ouargla region (Eastern Algeria). In *E. flavicaudis*, Benton (1992) found that birth is limited to two months of autumn (August and September).

Mating behavior

Numerous works report courtship and mating in several species of scorpions (Garnier & Stockman 1972). The recognition of sexual partners and the aggressive and escape behaviors of these species of scorpions are not clearly shown in these works (Polis & Farley 1979). Mating behavior is often complicated by conflicting stimuli that simultaneously produce incompatible tendencies to flee, attack, and mate

(Tinbergen 1953, Morris 1956). The function of the introductory phase in the courtship of other scorpions is probably to reduce cannibalism (Polis & Farley 1979, Benton 1992).

The number of pairs remains low in winter until spring (mid-April), when it reaches its maximum in July (the hot period), representing the summer season. The number of pairs decreases at the end of the summer season, where it remains stable and weak (Figure 4). Sadine's results (2005, 2018) confirm that in the arid ecosystem of the Algerian northern Sahara, August until September is the appropriate and favored period to begin mating for this species. Benton (1992) noted that at *E. flavicaudis*, the number of couples is very important between August and October, with the maximum being in September. Dionisio-da-Silva et al. (2018) estimated that the reproductive period of *Tityus pusillus* was October to January based on the higher number of males obtained in this period. In the arid ecosystem of the Algerian northern Sahara, the mating period of *Andrctonus amoreuxi* is visible between September and October, and the same climatic conditions characterize it but less late (Sadine 2018).

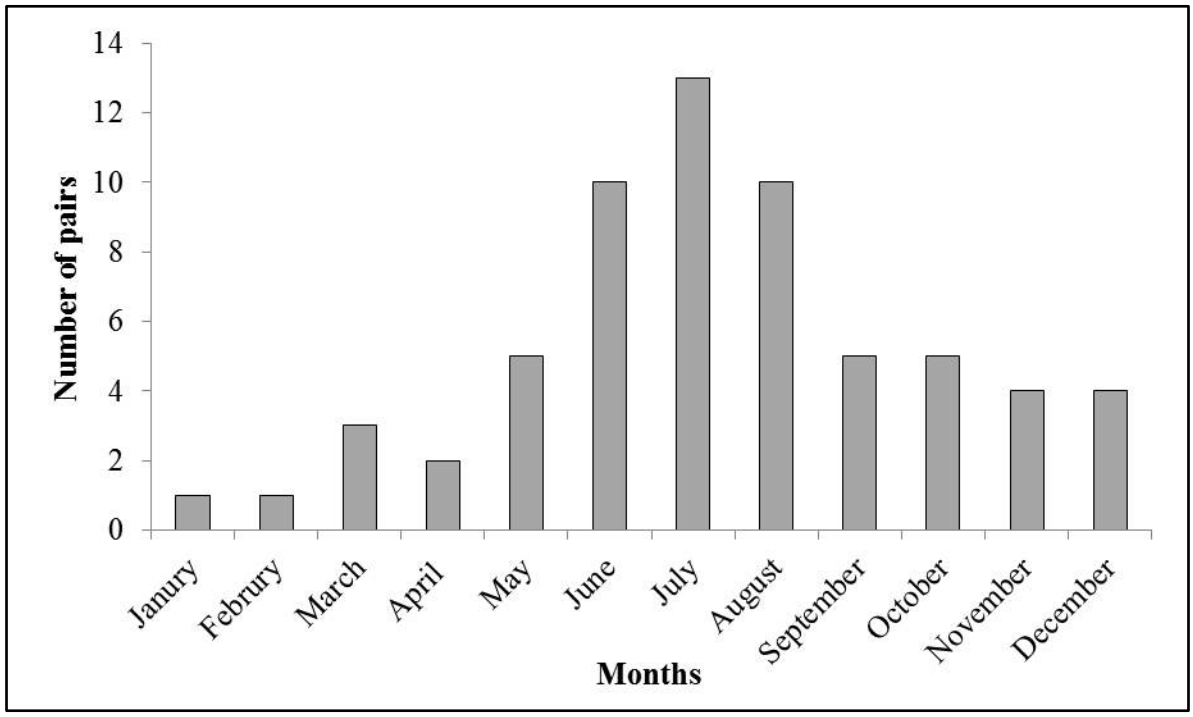

Figure 4. Observation of the number of male and female pairs of *A. australis* in Ghardaïa, central Algerian Sahara, in 2022

Conclusions

The phenological study of *A. australis* in the Ghardaïa region (Sahara Desert of Algeria) has shown that mating for this population takes place from August to October. The period for parturition starts in March, with a gestation period of 5 to 6 months during the winter and fall seasons, which are considered active periods for scorpions. However, the females keep up their activity even in the cold months. For this purpose, we used the word semi-hibernation (false winter diapause) in *A. australis*, because many scorpions conserve their potentiality in the cold months. Still, if disturbed, they prove it by guarding themselves or defending themselves (Charnot & Faure 1934).

Therefore, we can say that the climate and the

biotope play a major role in influencing scorpions' mode and life cycle. This is certainly due to their relationship with certain insects on which they depend for food. The phenological cycle of *A. australis* in the Ghardaïa region can be summarized in Figure (5).

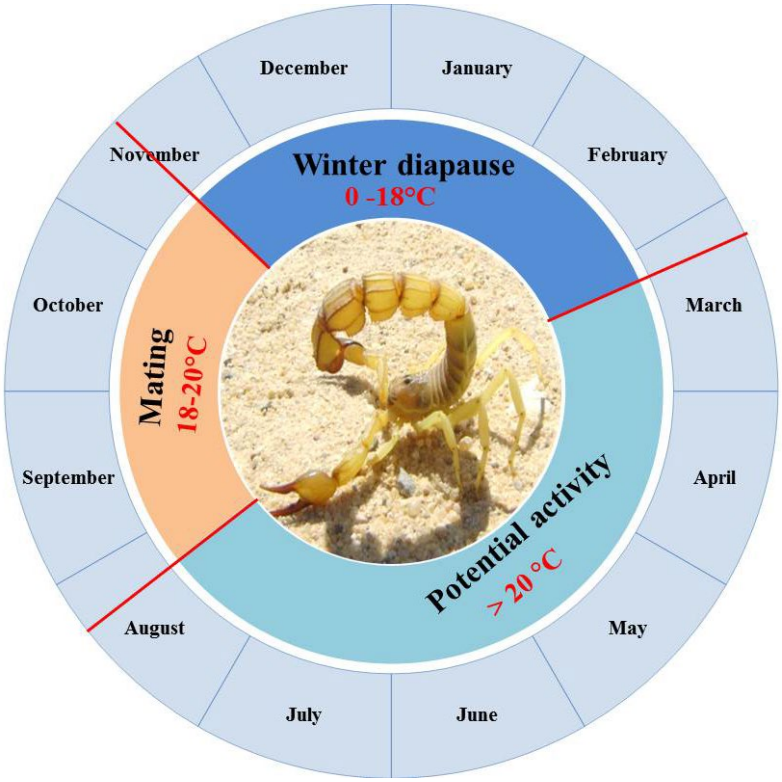

Figure 5. Summary diagram of the phenological cycle of *Androctonus australis* from the Sahara Desert of Algeria

Acknowledgments.
We are most grateful to an anonymous reviewer for helpful comments and suggestions. We also thank the Algerian Ministry of Higher Education.

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