

First observations on cave breeding in *Salamandra algira splendens* from north-eastern Morocco

AXEL HERNANDEZ

Department of Environmental Sciences, Faculty of Sciences and Technics, University Pasquale Paoli of Corsica,
Corte, 20250, France

Author e-mail: hernandez.axel.1989@gmail.com

ABSTRACT - Two Moroccan subspecies of *Salamandra algira* were recently observed in caves- *S. algira splendens* and *S. algira spelaea*. Here, I report the first observations of cave breeding in *S. algira splendens*, in the Chaâra and Friouato caves of the north-eastern Middle Atlas (Taza region, Morocco). Twenty-two salamander and newt species are known to be facultative or obligate cave-dwellers in the Mediterranean ecoregion. They can inhabit or breed in caves so avoiding hot and very dry summer conditions. Caves with groundwater and stable humidity act as thermal refugia, winter or summer shelters, hiding places, feeding areas or, in some cases, as regular breeding sites.

INTRODUCTION

In Morocco, the genus *Salamandra* (Amphibia: Urodela) is represented by one species, *Salamandra algira* Bedriaga, 1883 which is widely distributed from northern Morocco to north-eastern Algeria (Beukema et al., 2013; Escoriza & Ben Hassine, 2015, 2019). A sub-species *S. algira splendens* is confined to humid, sub-humid and semi-arid mountainous habitats forested with *Abies pinsapo*, *Cedrus atlantica*, *Pinus* sp. and *Quercus* sp. (Beukema et al., 2013; Escoriza & Ben Hassine, 2015, 2019). This sub-species occurs in two well separated major groups: one in the Rif mountains the other in the Middle Atlas (Beukema et al., 2013; Raffaëlli, 2013; Hernandez, 2018a & b). Recently discovered locations for this endemic subspecies include the easternmost record from the Bokkoyas Massif, Al-Hocéima region, central Rif mountains (Hernandez & Escoriza, 2017) and Jbel Sidi Ali, central Middle Atlas, northern Morocco (Hernandez, 2018a). Recent records have also confirmed its presence in caves of the north-eastern Middle Atlas where adult salamanders were observed during speleological expeditions (Hernandez, 2018b). Here I report the first observations on cave breeding by *S. algira splendens* and discuss the caves inhabited by this subspecies in the Middle Atlas.

METHODS

During two periods, 12-15 February 2017 and 16-22 February 2019, we surveyed the natural caves of the north-eastern Middle Atlas (Taza region, Morocco) using the Visual Encounter Survey (VES) method (Heyer et al., 1994). Field work was conducted from approximately 10:00 h to 15:30 h. Survey sites with permanent or non-permanent water sources and streams were selected based on cave data from previous speleological expeditions, including the Association de Spéléologie Marocaine, Randoxygène, and data on cave topography (Camus & Lamouroux,

1981). On site, we surveyed almost all types of habitat including permanent and temporary streams and pools, and surrounding terrestrial habitats, stumps and stones to record *Salamandra algira splendens* larvae, juveniles and adults. Each taxon observed was photographed to aid identification (Sony Nex-5; Sony Ltd., Japan). Coordinates, geographic and elevational data were collected in situ using a Global Positioning System (Garmin Montana 680; Garmin Ltd., Olathe, KS, USA) and located on maps. Water chemical parameters were measured in situ using an Expresstech @ LCD pH Medidor Digital (Expresstech; Kingpow Company Limited; Hong-Kong; China) for pH and temperatures.

RESULTS

Five adults, one juvenile and 22 larvae of *S. algira splendens* were discovered at Grotte de Chaâra (33° 57'24.33" N, 4° 14'44.95" W) located 1,213 m a.s.l.. The adults and juvenile were walking on rocks (Fig. 1 A, B). They were located from a few hundred meters up to 2 km into the cave and near a large permanent stream in a large chamber (Fig. 2 A, B). Larvae were generally found inside the cave at 160-400 m from the entrance in five pools, about 68-185 cm in length and 32-55 cm deep (Fig. 3A, B). In all the pools containing larvae, water quality was acidic to neutral with a pH between 6.13 - 7.11, air temperature at midday was 13.1-16.2 °C and water temperature 11.1-12.6 °C. The habitat was characterised by various rocks and small to large pools in complete darkness. The external habitat comprised pine and oak forests with *Pinus* sp. and *Quercus suber*.

Twelve larvae, two juveniles and four adults were observed in the Friouato caves, Taza region, north-eastern Middle Atlas (34° 6'19.217" N, 4° 4'19.667" W) located 1,426 m a.s.l.. The active adults were found at depths of 115 to 450 m from the cave entrance. Both juveniles were active on rock ledges at several meters from the cave floor. All terrestrial individuals were found in large chambers of the caves with

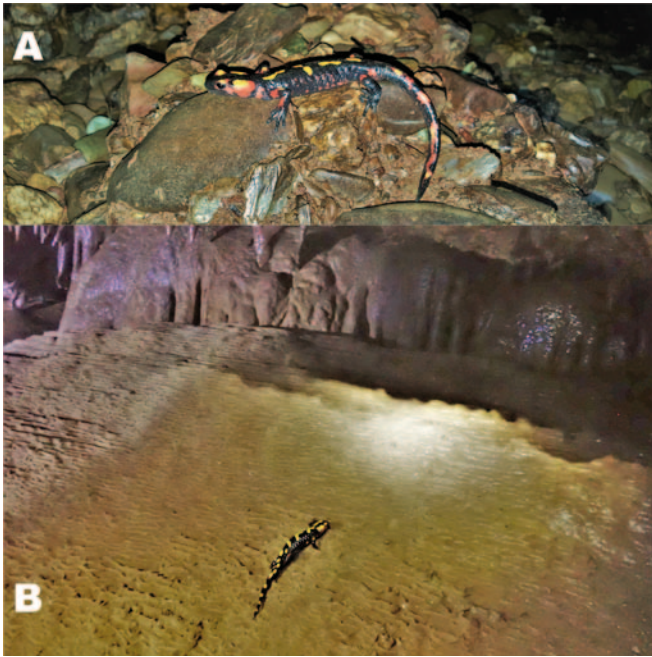


Figure 1. A. Adult female of *S. algira splendens* found at Grotte de Chaâra, Taza region, north-eastern Middle Atlas mountains, Morocco B. Adult male observed at the same site

relatively high air humidity (85-94 %) in the total darkness. Air temperature varied from 15.2 to 18.7 °C. The larvae were found in two small pools located in the cave at 120-230 m from the entrance. The pools substrates comprised sand, rocks and small gravel. The water quality was acidic to neutral with a pH between 6.62 - 7.16, air temperature at midday was 14.2-16.1 °C and water temperature 8.0-11.2 °C. The surrounding habitat comprised pine and oak forests with *Pinus* sp. and *Quercus suber*.

DISCUSSION

Cave fauna have long been a source of fascination due to their diversity and adaptations. Newts and salamanders are the only tetrapod vertebrates capable of having an exclusively subterranean life cycle (Gorički et al., 2019). In North Africa, two species were reported as facultative cave-dwellers: *Pleurodeles waltl* (Schleich et al., 1996; Hernandez, 2018b) and *Salamandra algira* (Pasteur & Bons, 1959). Two Moroccan subspecies of *Salamandra algira* were recently observed in caves *S. algira splendens* (Hernandez, 2018a, b) and *S. algira spelaea* (Escoriza & Comas, 2007). The current surveys found many adult individuals, juveniles and larvae in the Chaâra and Friouato caves of the north-eastern Middle Atlas (Figs. 1, 2 & 3). Observations of the species in other caves of the Taza region (e.g. Chiker and Zaerout) have been reported by local speleologists but need confirmation.

In both caves systems, larvae were commonly found at 120 – 350 m from the entrance, while adult individuals were observed all the year round in all parts of the caves from 0.2 – 2 km deep. At Grotte de Chaâra the main cave contains a large permanent underground stream which might have washed some larvae into the cave during periods of high rainfall. However, in the Friouato caves 12 larvae were in isolated

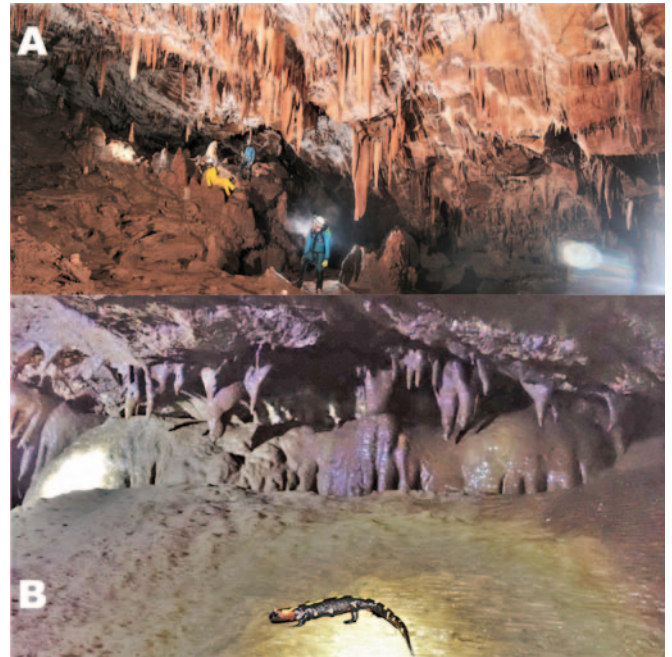


Figure 2. A. Habitat view of the largest chamber at Grotte de Chaâra where most of the adult specimens were recorded B. Another adult female specimen found in the same cave

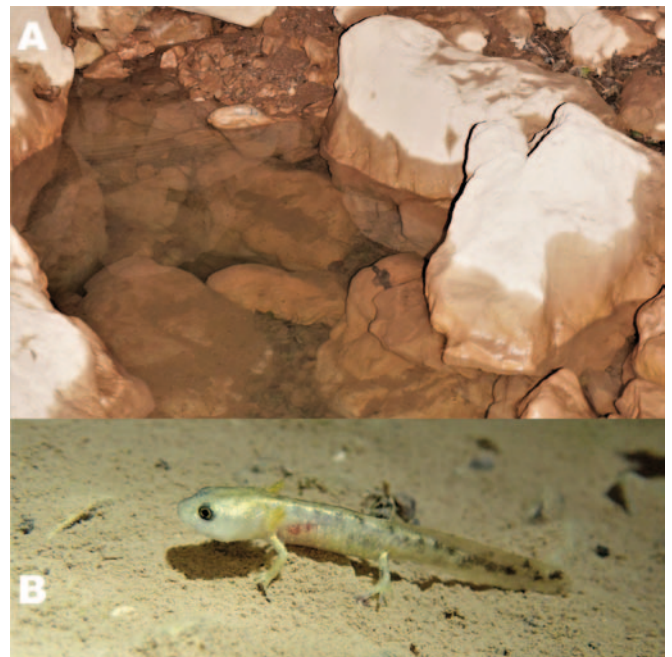


Figure 3. A. A small pool in the cave inhabited by many larvae of *S. algira splendens* B. Larva measuring 38 mm in the same pool

pools indicating that female *S. algira splendens* almost certainly deposited their larvae there. It is suggested that the species is breeding in both caves.

Within the Mediterranean ecoregion, twenty-two salamander and newt species are known to inhabit or breed in caves, especially during the hot, dry summers (Manenti et al., 2009, 2017; Hernandez, 2018b), others are more specialised cave dwellers (Table 1). Caves with groundwater and stable humidity play an essential role as thermal refugia for newts and salamanders (Hernandez, 2018b) and are also used

as winter shelters, hiding places during the active season, feeding habitats and as regular breeding sites (Herrero & Hinckley, 2014; Manenti et al., 2009, 2017; Balogová et al., 2017).

Table 2. Salamander and newt species of the Mediterranean ecoregion showing differing degrees of adaptation to cave-dwelling

Facultative cave-dwellers occasionally breeding in caves
<i>Calotriton asper</i> (Clergue-Gazeau & Martinez-Rica, 1978)
<i>Chioglossa lusitanica</i> (Gilbert & Malkmus, 1989)
<i>Euproctus platycephalus</i> (Lanza, 1983)
<i>Ichthyosaura alpestris</i> (Melega & Fusini, 2000)
<i>Lissotriton boscai</i> (Herrero & Hinckley, 2014)
<i>L. vulgaris</i> (Uhrin & Lesinsky, 1997)
<i>Pleurodeles waltl</i> (Herrero & Hinckley, 2014; Hernandez, 2018b)
<i>Salamandra salamandra</i> (Manenti et al., 2009, 2017)
<i>Salamandrina perspicillata</i> (Razzetti et al., 2001)
<i>S. terdigitata</i> (Lanza, 1983)
<i>Triturus cristatus</i> (Lanza, 1983; Uhrin & Lesinsky, 1997)
<i>T. marmoratus</i> (Giménez-Lopéz & Guarner Deu, 1982)
Highly adapted cave-dwellers usually breeding in caves
<i>Speleomantes flavus</i> (Raffaëlli, 2013)
<i>S. supramontis</i> (Raffaëlli, 2013)
<i>S. imperialis</i> (Raffaëlli, 2013)
<i>S. sarrausensis</i> (Raffaëlli, 2013)
<i>S. genei</i> (Raffaëlli, 2013)
<i>S. italicus</i> (Raffaëlli, 2013)
<i>S. ambrosii</i> (Raffaëlli, 2013)
<i>S. strinati</i> (Raffaëlli, 2013)
Obligate cave-dwelling species
<i>Proteus anguinus</i> (Gorički et al., 2019)

These observations hint at the importance of subterranean habitats for salamanders living across the Mediterranean ecoregion but both they, and their associated invertebrate communities, require further study. This should consider the body condition of the animals to indicate how successful they are as cave-dwellers.

ACKNOWLEDGEMENTS

My particular thanks to Daniel Escoriza, John Baker, Jean Raffaëlli, Jérôme Maran, Emmanuel Jelsch, Mian Hou for their guidance. I also thank Ayoub Nehili, Arnaud Jamin and Bebel for field survey and a special thanks to the following associations: Moroccan Explorers, ARS, Randoxygènes and AMEC.

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Accepted: 3 July 2019