World Journal of Environmental Biosciences

Available Online at: **www.environmentaljournals.org**

Volume7, Issue 2: 89-94

ISSN 2277- 8047

Biometric characterization of the Atlas Goundi (*Ctenodactylus gundi*) (ROTHMAN, 1776) (Rodentia, Ctenodactylidae) in eastern Algeria

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ABSTRACT

Out of 89 individuals of Ctenodactylus gundi trapped in the Algerian Aures massif, the captured females (Ni = 47) outnumbered the males (Ni = 42). Most of the animals belonged to the age class of adults (70.8%). The females (7 months) were often more captured than the males (3 months), with a peak in December 2016 (8 ♀ / 7 ♂). Juveniles had been noted from April to July 2017, while the sub-adults had been captured from April until August 2017. Regarding the morphometry, the females were slightly larger than males, whereas it was the opposite for the cranial measurements. Overall, the measurements varied according to the age classes. In addition, the body size was positively correlated with the most body parameters.

Keywords: *Ctenodactylus gundi, Morphometry, Craniometry, Sex ratio, Algeria.*

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Received: 12 December 2017
Accepted: 27 March 2018

1. INTRODUCTION

Several works have focused on the study of rodents as they are available, widespread and useful, particularly in ecological and medical terms (Mccormick 2003; Meerburg et al. 2009). They are also very diverse in many ways based on morphological characteristics, physical aptitudes and ecological niches (Aulagnier & Thevenot. 1986; Ouzaouit 2000). Unfortunately, ecological studies in recent years have become insubstantial because of the confusion caused by the similarity that exists between species, especially in case of twin species, which have not been very well documented (Denys et al. 2012). This is the case of the three species of Ctenodactylidae family in Algeria (*Massoutiera mzabi*, *Ctenodactylus vali* and *C. gundi*). This latter has been recognized essentially based on the morphometric characteristics (body and muzzle size), especially for the genus *Ctenodactylus* (George 1982). Indeed, very few studies have been carried out on the biometric of the Atlas Goundi in the world, namely those of George (1978, 1981, 1982) and Ghawar et al. (2017) in Tunisia. In Algeria, however, the works on morphometry (Gouat 1988) and craniometry (no studies) of this species have been really rare. Hence, in this context, the present study aimed to find out the biometric characteristics (morphometry, craniometry) of *Ctenodactylus gundi* in the southern Aures massif (Algeria). The study has been affected by variations in age classes and sex-ratios to specify the biology of the reproduction in this species during the experimental year.

2. MATERIALS AND METHODS

Study Area

This study was carried out in the southern Aures massif (34°50′ à 35°30′N; 5°37′ à 7°10′E). It is the region that is located in the northeastern Algeria on the altitude of 950 m. It corresponds to the eastern part of the Atlas Massif, belonging to the whole of Saharan Atlas and separating the High Constantine Plains from the Sahara. It spreads over 200 km long and 90 km wide.

The climate is defined by a semi-arid bioclimatic stage. The average temperatures vary between 2° C (January) and 26° C (July). The rainfalls are irregular with an annual cumulative rainfall of 210 mm.

Within this region, two stations were chosen:

Station 1 (Agherbi) (35°08'59.51''N, 5°59'22.11''E): it was located at 80 km in the southwest of the province of Batna (Algeria), on an altitude of 851 m. The vegetation cover was clear and formed by a tree stratum dominated by Juniper (*Juniperus communis*) with a minor presence of *Ziziphus spina-christi* and an herbaceous stratum represented by the white wormwood (*Artemisia herba alba*) and Rosemary (*Rosmarinus officinalis*).

Station 2 (Tiloukache): It (35°08'49.39''N, 5°55'30.22''E) was about 6 km from the west of station 1 on an altitude of 922 m. It was a natural environment characterized by a rocky texture and dense vegetation compared to the Station 1, with a dominance of the white wormwood and *Ampelodesmos mauritanica*.

3. METHODOLOGY

For capturing *Ctenodactylus gundi*, monthly exits were made in these two stations, from September 2016 until August 2017. For this, three capturing methods were used. The first one was manual according to the protocol developed by Grenot (1973), which was simply waiting for the appearance of Goundi, disposing of a piece of cloth around the rock where it has camouflaged, and taking care to leave a small opening through which it can be observed. Subsequently, a stick was introduced to scare the animal, which usually took the opposite direction where it was trapped in the piece of cloth. This method of capture allows a very good exploitation of animal because it is captured alive. The second method was the use of sticky traps in places where the Goundi sunbathe. However, the disadvantage of this method is that it leaves the animal an easy prey for diurnal raptors. The third method was to use mesh traps (BTS), but unfortunately this method was not effective, because no Goundi has been captured because of the slope soil which made the traps always reversed by the animals during the process.

The captured individuals were slaughtered, measured, weighed and sexed. The external measurements were, the length of the head and body (T + C) taken from the muzzle to the anal orifice, the tail (Q) taken from the anal orifice to the end of the hairs, the hind legs (Pp) taken from the heel to the tip of the claws of the longest fingers, and the ears (Or) taken from the ear gap to the margin away from the pavilion (Fig. 1).

The age classes were estimated from dental wear (Barreau et al. 1991; Lalis et al. 2006). The osculating of the teeth revealed four stages of development, namely juveniles, sub-adults, adults and elders, according to the height of the tooth crown and its inlay (Barreau et al. 1991). In addition, adults lose their premolars and have only three teeth at each half-jaw (Grasse et al. 1955).

A cranial and long bones studies were performed using a caliper FINDER (0.01 mm). Two cranial measurements and two mandibular measures were taken into consideration (Fig. 1): Maximum skull Length (LC), upper molar row length (LRMs), length of the mandible between the tip of the incisor and the process (LM) and the length of lower molar row (LRMi) were measured. For long bones, the length and width were measured.

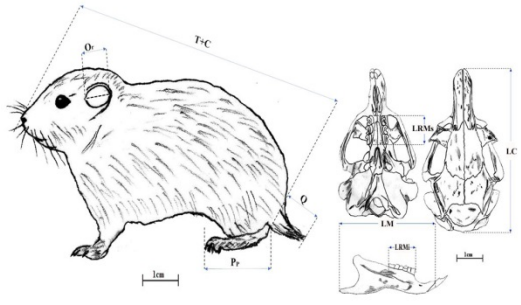


Fig. 1. Different measurements take into consideration on the Atlas Goundi

Statistical analysis

The statistical analyses were used in comparison tests: the analysis of variance (ANOVA) was used for the normal data, and Kruskal-Wallis test was applied for the abnormal data. To detect the relationships that existed between the biometric parameters, the Pearson correlation was used. All the statistical analyses were carried out by using Statistical program v. 10.0 (StatoSoft).

4. RESULTS

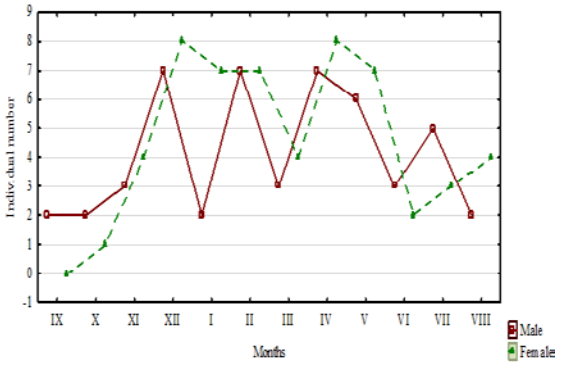
Monthly variation

Sex ratio

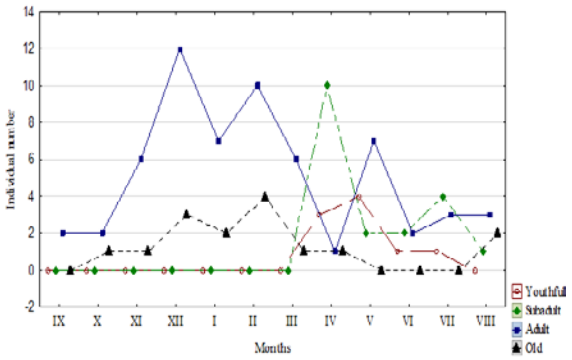
Among all the captured individuals of *C. gundi* (N = 89), the females (52.8%) were slightly higher than the males (47.2%), with a sex ratio of 0.9 (♂/♀). Depending on the months, the females (7 months) were often the most captured compared to the males (3 months) (Fig. 2. a). While during September 2016, only males were captured. However, the two sexes were captured even in February 2017. From an effective viewpoint, the maximum captures were noted in December, 2016 (♂/♀ = 7/8).

Age class

In addition, the captured number of *C. gundi* in the study area was represented by the four age categories (Fig. 2. b). The class of adults was the most important (70.8%), followed by the old individuals (15.7%), unlike, the sub-adults and juveniles which were hardly ever captured (6.7% each). According to the months, the adults were greatly trapped during the 10 months, against a month for the sub-adults (April 2017). It should be mentioned that the appearance of juveniles was noted for 4 months (April to July 2017), while the sub-adults were observed during 5 months (April to August 2017).



a) Sex ratio



b) Age class

Fig. 2. Monthly variation of *C. gundi* captured in the study area according to months

Morphometric Variations

In the Atlas Goundi, the length of the head plus the body was positively correlated with the most body parameters, especially the weight (r = 0.39; p = 0.0001) and the hind legs (r = 0.26; p = 0.0012) (Tab 1). These latter also presented a correlation with ears (p = 0.0041). However, the length of the tail evolved independently from the other parts of this species, except for a weak negative correlation with the length of T + C (r =-0.21; p = 0.040).

Table 1. Applied Pearson correlation matrix for the different morphometric characters of Algeria's Goundi

r\p	Weight	T+C	Q	Pp	Or
Weight	-	0.00013	0.43443	0.01309	0.063161
T+C	**0.39414**	-	0.040094	0.00122	0.0011625
Q	-0.083892	-0.2181	-	0.38353	0.70524
Pp	0.26212	**0.33754**	0.093488	-	0.0040744
Or	0.1978	**0.33883**	0.040654	**0.30161**	-

The bold value is different from 0 to a significance level alpha = 0,05

For the similarities of morphometric parameters, the formation of 3 classes was apparent (Fig. 3). The first class included the length of head and body, which had the highest similarity with the length of ears (0.35), to which the languor of hind legs (0.30) was added. The second class was represented only by the length of tail, while the third class counted exclusively by the weight, where it represented an intermediate class between the two other classes.

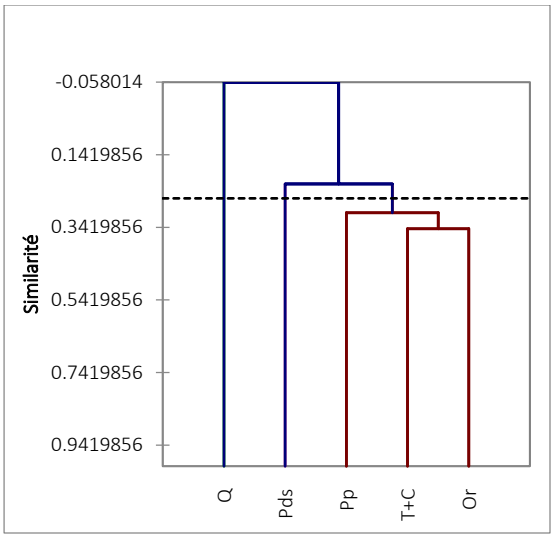


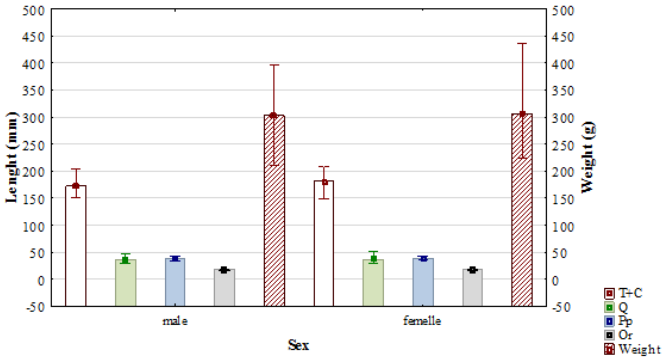
Fig. 3. Dendrogram of morphometric measurements of *C. gundi*

Morphometric variations according to sex

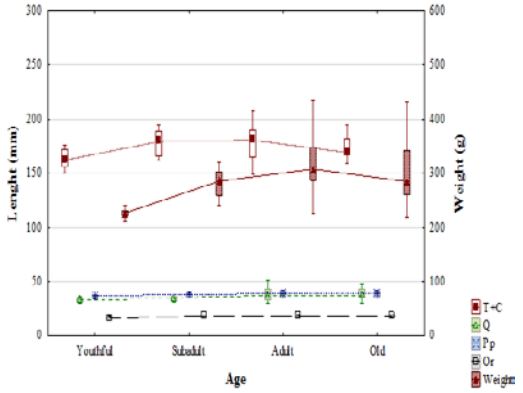
Generally, the length of head plus body (T + C) in the Goundi varied between 149 and 20 mm (177.3 ± 14.4mm), while the weight (Pds) varied between 131.8 and 435.2 g (305.8 ± 57.1g). For the sexes, it seemed that the females were relatively bigger than the males, notably the length of the head plus body (♀ = 179.7 ± 11.4 > ♂ = 174.9 ± 12.1mm) was bigger (Fig. 4. a). It was the same for the weight (♀ = 320.1 ± 48.8 > ♂ = 289.9 ± 40.7mm). For the other parameters, the differences were really insignificant, especially for the ears (♀ = 17.6 ± 0.8 ≤ ♂ = 17.6 ± 0.9mm) and the hind legs (♀ = 38.6 ± 1.5 ≥ ♂ = 38.4 ± 1.7mm).

Morphometric variations according to age category

Depending on age classes, the size (T + C) in this species increased progressively from one class to another (Fig. 4. b). The lowest values were recorded for juveniles (163.3 ± 8.0mm), and higher values were for adults (179 ± 12.3mm), exceeding the old individuals (175.1 ± 9.8mm). It was the same for the weight (juveniles = 210 ± 26.1g < adults = 318.1 ± 38.4), where the elders (301.8 ± 53.6g) presented lower values than the adults. For the other parameters, there was no significant variation between the length of tail (Q), the length of hind legs (Pp), and the length of ears (Or) of the different age categories.



a) According to sex



b) Age class

Fig. 4. Morphometric variations of *C. gundi* captured in the study area

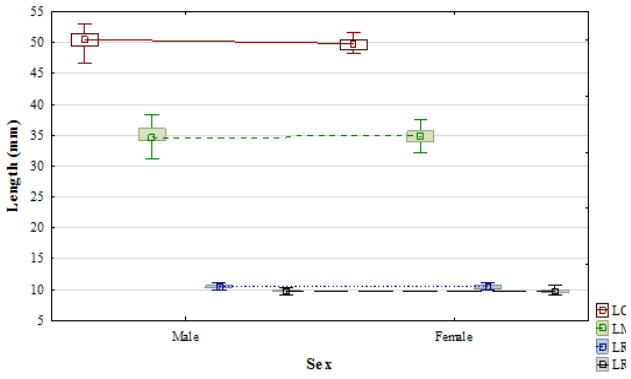
Cranial and mandibular measurements of *C. gundi*

Cranial Variations according to sex

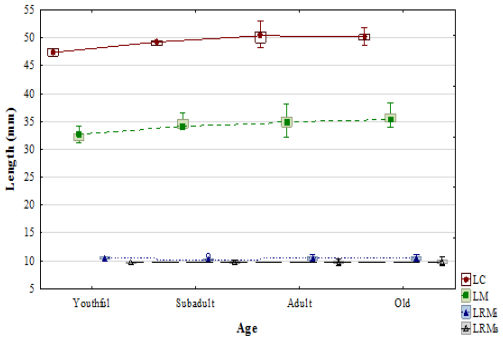
In terms of cranial measurements depending on sex, it seemed that the males were slightly bigger in size than the females, notably for maximal length of skull (LC) (♂ = 50.3 ± 1.2mm ≥ ♀ = 49.7 ± 0.8 mm) (Fig. 5. a). Ditto for the length of the males' mandible (LM) (34.8 ± 1.6mm) and the females' (34.6 ± 1.6mm). It should be mentioned that there was no difference between the length of the upper molar row (LRMs = 9.8 ± 0.3mm) of males and females, as well as the length of the lower molar row (LRMi = 10.5 ± 0.3mm) of both sexes (Fig. 5. a).

Cranial Variations according to age category

Depending on age categories, the maximal length of skull (LC) of *C. gundi* varied considerably (Fig. 5. b). The lowest value was noted in juveniles (47.4 ± 0.8 mm), and the highest in adults (50.3 ± 1.0mm). It was the same for the length of mandible (LM) where the increase was clearly visible, from the less aged individuals (juveniles = 32.5 ± 0.9mm) to the older ones (old = 35.3 ± 1.2mm). It was the same for the upper molar rows (LMRs) and the lower ones (LRMi). The values varied for the upper molar row between 9.5 ± 0.4mm (juveniles) and 9.9 ± 0.4mm (olds), and they varied for the lower molar row between 10.4 ± 0.3mm (juveniles) and 10.5 ± 0.3mm (olds).



a) According to sex



b) Age class

Fig. 5. Cranial and mandibular measurements of *C. gundi*

Measurements of long bones of *C. gundi*

Concerning the long bones depending on sex, the sizes were almost identical especially the length of femur (♂ = 36.8 ± 1.4mm ≥ ♀ = 36.7 ± 1.2mm), humerus (♂ = 29.4 ± 1.2mm ≥ ♀ = 29.3 ± 0.9mm), pelvis bone (♂ = 42.9 ± 1.9mm ≥ ♀ = 42.6 ± 1.6mm and tibia (♂ = 40.4 ± 1.5mm ≥ ♀ = 40.4 ± 1.0mm) (Fig. 6). It was the same for the width.

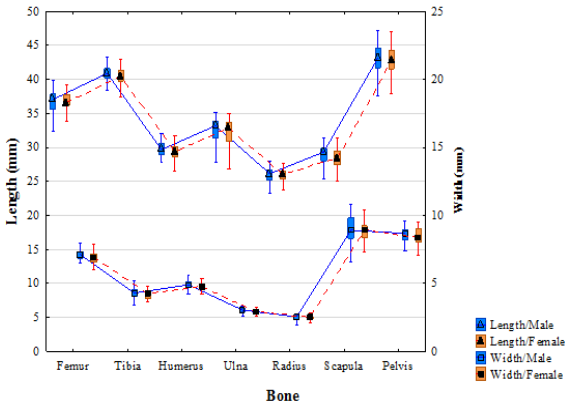


Fig. 6. Variation of long bone measurements according to sex in *C. gundi*

5. DISCUSSION

Monthly Variation

Throughout the present study, 89 individuals of *Ctenodactylus Gundi* were captured during a period of one year (September 2016 until August 2017), following a comprehensive trapping carried out in the southern Aures massif (Algeria). The sex ratio in this species was equal to 0.9 (♂/♀), slightly leaning in favor of the females (52.8%). Following a visual census carried out in the Oriental Atlas of Tunisia, Seguignes, (1979) mentioned the existence of two types of colonies, that of 4 individuals and 8 individuals. They were usually comprised of several females and of 1 to 2 males (max = 3). But in the laboratory, Gouat (1985) reported that the sex ratio at birth appeared highly unbalanced in favor of the males (59.3%; N = 27).

For the captures depending on months, the results showed that the females (7 months) were often very highly captured

compared to the males (3 months). The maximum of the captures was observed in December 2016 (8 females and 7 males). In addition, in some species of rodents notably *Psammomys obesus* and *Gerbillus gerbillus*, it was the males that were mostly captured with a max in January and February; respectively (Amirat et al. 1980; Fichet-Calvet et al. 1999).

For the age classes, the captures revealed the four age categories, where the adults were the most important (70.8%). These results confirmed those noted by Meddour et al. (2017) in the same study area, which mentioned the dominance of adult category (84.2%). Depending on months, the results of this study showed that the adults were highly trapped for 10 months. However, the appearance of juveniles was noted from April until July 2017, while the sub-adults were captured from April until August 2017. The availability of these latter in the month of April suggested that the juveniles were present a little earlier (March), even if they were not captured. On the one hand, Seguignes (1979) mentioned the presence of young individuals during the spring period, where they were forced to disperse at the end of the season. On the other hand, Gouat (1988) mentioned the appearance of young individuals between May and June of the year 1981, against March and April in 1982. These latter reached their sexual maturity between the beginning of October and the beginning of December (Gouat 1985).

It should be mentioned that the whelping of the Goundi in the Aures region was noted between the end of February until the end of May (George 1978). In addition, Gouat (1985) assumed the presence of two whelping periods in the Aures region of Algeria, the first from the end of February to the end of March, and the second in May.

Morphometric Variations

According to Saint Girons & Petter (1965), the weight and the body length made it possible to distinguish *C. gundi* clearly from the other species of Ctenodactylidae present in Algeria. Indeed, the length of head plus body in this species presented a positive correlation with the most of body's parameters, notably the weight ($r = 0.39$; $p = 0.0001$) and the hind legs ($r = 0.26$; $p = 0.0012$). For the dendrogram, it was found that there was a similarity of data in certain body parameters in the Goundi, in particular the body size, the ears and hind legs. On the other hand, it was the case of tail (-0.06) that evolved independently.

However, the length of head plus body (T+C) in the Goundi ranged from 149 to 208 mm (177.3 ± 14.4 mm). These results were slightly lower than those mentioned by George (1978), which indicated a value equal to 208 mm. Similarly, Saint Girons & Petter (1965) declared variant values between 190 and 210 mm. It should be recalled that the measured individuals in this study included juveniles and sub-adults, which explained the recorded small measures. Unlike in *C. vali*, the values of T + C were relatively low, varying between 145 to 184 mm (Petter 1961), with an average of 176 mm (George 1978). While *Massoutiera mzabi* was characterized by a length of head plus body measuring 185 mm (Gouat 1988).

For the weight (Pds) of the Goundi found in the study area, the measurements varied between 131.8 and 435.2 g (305.8 ± 57.1 g). These results were slightly higher than those noted by different authors, who mentioned variant values between 200 and 350 g (Gouat 1985), with an average of 289 g (George 1978). Moreover, these differences can be explained by the nature and the density of the vegetation cover that are directly related to the spring rains (Seguignes 1979).

Depending on sexes, it appeared that the females were relatively bigger in size than the males, especially the T + C and the weight. This latter varied between 224.4 and 435.2 g for ♀ against 131.8 g and 395.8 g for ♂. Seguignes (1979) displayed weights of females varying between 240 and 340 g. The results of this study were relatively bigger than those noted by the latter author, because of the presence of pregnant females trapped in this study.

In the *C. gundi*, the size increased progressively depending on the age, from juveniles (163.3 ± 8.0 mm) to adults (179 ± 12.3mm). It was the same for the weight (juveniles = 210 ± 26, 1g < adults = 318.1 ± 38.4). The results of this study confirmed those of Seguignes (1979), which stated that the size and weight of *C. gundi* were conditioned by several factors including food availability. Following a study carried out over two years, where the vegetation cover was represented by 25% in 1978 and 90% in 1979, the same author reported weight values among young *C. gundis* varying between 190g (June 1978) and 245 (June 1979) and for adults between 270 g (June 1978) and 320g (June 19 79).

Cranial and mandibular measurements of *C. gundi*

For the cranial measurements depending on sex, in the males, they were slightly bigger in size than the females, in particular the maximal length of skull ($♂_{LC}$ = 50.3 ± 1.2 mm ≥ $♀_{LC}$ = 49.7 ± 0.9 mm) and the length of mandible ($♂_{LM}$ = 34.8 ± 1.6 mm ≥ $♀_{LM}$ = 34.6 ± 1.6 mm). This same remark has been already reported in the majority of rodents, especially *Jaculus jaculus*, where there was an absence of correlation between cranial measurements and sex (Happold 1967; Ben Faleh et al. 2010, 2013). It was the same for *J. orientalis* ($p = 0.35$) (Ben Faleh et al. 2016), *Meriones shawii-grandis* (Djelaila et al. 2017), *Rattus rattus* (Ben Faleh et al. 2012), *Mastomys natalensis* (Lalis et al. 2009) and *Malacomys edwardsi* (Bohoussou et al. 2014). Unlike, Zaime & Pascal (1988) showed that *Meriones shawii* (♂ > ♀) and *M. Libycus* (♂ < ♀) presented a sexual dimorphism at the level of craniometric characters.

Depending on age categories, the cranial measurements varied considerably in *C. gundi*, from juveniles to adults. These results confirmed those of Lalis et al. (2006), which showed that there were strong differences between the age categories of rodents. They claimed that the age structure and the composition of the non-isolated populations of the same species were very changeable. Unlike, other authors reported the inverse in *Jaculus jaculus* (Ben Faleh et al. 2010) and *J. orientalis* (Ben Faleh et al. 2016).

Conflict Of Interest Statement

None Declared.

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