Amphibians of Algeria: New data on the occurrence and natural history

JIHÈNE BEN HASSINE[1,2*] & DANIEL ESCORIZA[2,3]

[1]Faculty of Sciences of Tunis, Department of Biology, University of Tunis-El Manar. 2092 Tunis, Tunisia
[2]Laboratory Ecology, Biodiversity and Environment, University Abdelmalek Essaâdi, El M'Hannech II, 93030, Tétouan, Morocco
[3]Institut Català de la Salut. Gran Via de les Corts Catalanes, 587–589, 08004 Barcelona, Spain
[*]Corresponding author Email: jihenbenhassine@gmail.com

ABSTRACT - Algeria is a country from the Maghreb with a little known batrachofauna. In order to improve knowledge of the distribution of amphibians in this country we carried out several surveys in northern Algeria between 2010 and 2017. Maps with original data on the distribution ranges and niche model for every species have been made for the first time. This includes original data on breeding phenology, breeding habitat and terrestrial habitat features of the observed species. Our data indicated that several species could be more widespread in Algeria than previously suggested. The apparent discontinuity of their ranges and the supposed rarity of some species such as *Pleurodeles nebulosus*, *Salamandra algira algira* and *Bufo spinosus* is likely due to a lack of previous survey effort. Some species, such as *Discoglossus pictus*, *Pelophylax saharicus, Hyla meridionalis* and *Sclerophrys mauritanica* are widely distributed and abundant in the studied region. Our results confirmed the presence of several species in historical sites, but also the presence of numerous new populations. Some historical records of *P. nebulosus*, *S. algira algira* and *H. meridionalis* were not confirmed. This could be due to a possible recent extinction of marginal populations, but also to errors in the classical literature, since some of these localities are likely to be outside the limits of the environmental tolerance of these species.

INTRODUCTION

Algeria has a key location as a biogeographical contact area between the Maghreb and Europe, where several amphibians' species are endemic or show a restricted distribution. However, Algeria is one of the less studied countries on the Maghreb in terms of herpetology (Pasteur & Bons, 1959; Bons & Geniez, 1996; Schleich et al., 1996; Ben Hassine & Nouira, 2009; 2012; Ben Hassine et al., 2013; Beukema et al., 2013). Preliminary inventories of the Algerian herpetofauna appeared during the late 18th century and mainly comprised compilations of collected specimens, providing zoological studies, species descriptions and anecdotic data on their natural history (Poiret, 1789; Rozet, 1833; Gervais, 1835; 1836; 1844; Boulenger, 1891; Doumergue, 1901; Llabador, 1947). However, at the present time the available data on the status and the ecology of Algerian amphibians are still scarce, except for some groups such as Salamandridae [see Escoriza & Ben Hassine (2015); Ben Hassine et al. (2016 a, b); Escoriza et al. (2016)] and some regions such as Oranie (Doumergue, 1901) and Numidia (Samraoui et al., 2012).

There is increasing concern about habitat loss in Algeria, particularly affecting critical habitats for amphibians, for example forest and wetlands (Zaimeche, 1994 a, b; Samraoui et al., 2011; Samraoui et al., 2012). In this context, increasing our knowledge of amphibian ecology is crucially needed to implement successful conservation strategies (Stuart et al., 2008). In this paper the scattered and sparse information on Algerian amphibians is summarised, reviewed along with additional new data to improve our understanding of their ecology and distribution. This will improve the database on the distributional records in Algeria. Additionally, we have produced distributional maps and analysed how the climatic factors could influence the potential distribution of the studied species using Maxent models. Our data were then compared with those available in literature. Finally we describe new data on the breeding phenology and aquatic and terrestrial habitat features.

MATERIAL AND METHODS

Study area and sampling

The study area was the north of Algeria, encompassing the region between the Tunisian and the Moroccan borders (Fig. 1). The region shows an important climatic contrast between the coastal regions, with a relatively humid Mediterranean climate (*Csa* type, Köppen classification; Peel et al., 2007); particularly in the extreme north-east, with rainfall values of 923 mm y^{-1}, at El Collo Massif), and the inland regions that become progressively more arid. At Batna, 170 km from the coast of El Collo Massif, rainfall values drop to 329 mm y^{-1}, typical values of steppic climates (*Bsk* type; Peel et al., 2007).

Several surveys were conducted as a part of a broader study on the ecology and phylogeny of the north-African amphibians (Escoriza et al., 2014; 2016; Escoriza & Ben Hassine, 2015; Ben Hassine et al., 2016 a, b). These surveys were carried out over an eight year period (2010–2017), mainly from February to August (with punctual prospections between October and December). Previous surveys showed that this period covered most of the breeding activity of Maghrebian amphibians (Doumergue, 1901; Schleich et al., 1996; Ben Hassine & Nouira, 2012; Escoriza & Ben

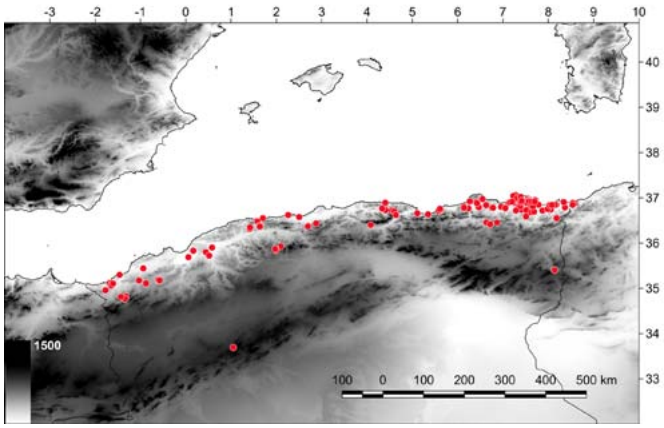

Figure 1. Topographical overview map of the study area indicating the amphibians observations sites in Algeria included in Appendix 1. Darker colours indicate higher altitude.

Hassine, 2014). Sampling was performed in aquatic and surrounding terrestrial habitats and included visual and acoustic detection and dip-netting, the latter with the purpose to assess the presence of eggs and larvae (Wilkinson, 2015). In addition, we also included some records using road-kills, when identification was possible. The coordinates of each locality were collected in situ with a Global Positioning System (Garmin Dakota 100; Garmin Ltd., Olathe, KS, USA).

Breeding habitat characterisation

We surveyed temporary ponds, permanent ponds, springs and stream pools using dip netting. Habitat characterisation comprised two assembles of variables, one describing the characteristics of the water bodies: average depth (cm) and surface area (m^2), and other water physical and chemical parameters: temperature (ºC), dissolved oxygen ($mg{\cdot}L^{-1}$), pH, and conductivity ($\mu S{\cdot}cm^{-1}$). Average depth was taken as the mean value of five successive measurements from the shore to the centre. The surface area was estimated using a Garmin Dakota 100. Turbidity was assessed using a scale ranging from 1 (transparent waters/10 Nephelometric Turbidity Units; NTU) to 3 (very turbid waters/300 NTU) based on light extinction estimated at Secchi disk depth. The percent of emergent vegetation covering the pond surface was estimated from photographs. The physical and chemical parameters of the aquatic habitats were measured between 12:00 hrs and 15:00 hrs (local time) to maintain homogeneity in the measurements.

Ecological niche models

We were also interested in evaluating the potential distribution of the target species, based on proxies of their fundamental niches (Pearson et al., 2007). These models were performed using four variables, one topographic (altitude) and three climatic (mean annual precipitation, temperature seasonality and mean annual temperature; Hijmans et al., 2005), which are relevant to explain the occurrence of amphibians in the region (Ben Hassine et al., 2016 b). The ecological niche models were performed with Maxent 3.4.1 (Philips et al., 2017), using the default settings and 25% of the localities as random tests. In order to provide robustness to the models, we also included presence records of the same species of amphibians in Tunisia from Ben Hassine & Nouira (2012). The projections showed the minimum training presence threshold and 10th percentile training presence thresholds (Pearson et al., 2007).

RESULTS AND DISCUSSION

We compiled 306 new distribution records from 162 localities of eight amphibian species from a total of 12 known species occurring in Algeria according to Schleich et al. (1996) (Appendix 1, Figs. 1 and 2). These include 87 breeding sites (Tables 1 and 2; Fig. 3) belonging to two species of urodela [*Pleurodeles nebulosus* (Guichenot, 1850) and *Salamandra algira algira* Bedriaga, 1883] and six anurans [*Discoglossus pictus* Otth, 1837, *Pelophylax saharicus* (Boulenger, 1913), *Hyla meridionalis* Boettger, 1874, *Sclerophrys mauritanica* (Schlegel, 1841), *Bufo spinosus* Daudin, 1803 and *Bufotes boulengeri* (Lataste, 1879)]. Specific richness per site varies between 1 species (43% of the sampled localities) and up to 5 species (at one site) (Appendix 1).

Mateo et al. (2013) reported on a finding of *Barbarophryne brongersmai* (Hoogmoed, 1972) caught by Jesús Peña in 1990 in four sites in the Saharan Atlas of north-western Algeria. Because of it cryptic nature and the punctual distribution, this species was not found during our prospections. *Hoplobatrachus occipitalis* (Günther, 1858) and *Sclerophrys xeros* (Tandy, Tandy, Keith & Duff-MacKay, 1976) are present in southern Algeria in the mountains of the Tassili and the Hoggar (Cox et al., 2006) and where not treated in this paper. *Alytes maurus* Pasteur & Bons, 1962 is allegedly cited to occur in western Algeria (Mateo et al., 2013). However data on the ecology, distribution, larvae description and genetic assessment of the micro endemic *Pleurodeles poireti* (Gervais, 1835) could be consulted in recent published papers by Escoriza & Ben Hassine (2015), Ben Hassine et al. (2016 b), Escoriza et al. (2016) and Escoriza & Ben Hassine (2017a).

Ecological niche models

The projections of the ecological model were robust (AUC, mean = 0.93, range 0.87-0.97; Table 3) and showed that amphibians responded divergently to the environmental gradient. The occurrence of *S. algira algira* and *B. spinosus*, both Palaeartic relics, was highly influenced by precipitation, whereas the influence of this variable was lower in other species as *B. boulengeri* and *P. saharicus* (Table 3). These models also suggested that the real distribution of these species could be largely underestimated.

Species accounts

North African fire salamander

***Salamandra algira algira* Bedriaga, 1883**

After the initial Bedriaga's description (1883) of the North African fire salamander based on specimens from Edough Peninsula (north-eastern Algeria), data on the distribution and ecology of the Algerian populations of *S. algira*

Figure 2. Adults specimens of the eight studied amphibians species from Algeria. **A-** and **B-** Two different patterns of *S. algira algira* from the population from Seraïdi (Province of Annaba); **C-** *P. nebulosus* (Province of Aïn Defla). **D-** *D. pictus* (Province of Skikda); **E-** *S. mauritanica* (Province of Skikda); **F-** *S. mauritanica* (Province of Tlemcen); **G-** *B. spinosus* (Kabylia); **H-** *B. boulengeri* (Province of Annaba); **I-** *H. meridionalis* (Province of Annaba); **J-** *H. meridionalis* (Province of Skikda); **K-** *P. saharicus* (Province of Skikda); **L-** *P. saharicus* (Province of Tlemcen). Photos **A** - **K**: Jihène Ben Hassine; Photo **L**: Daniel Escoriza.

Figure 3. Breeding habitats of amphibians in northern Algeria. **A-** Breeding habitat of *S. algira algira* in Kabylia; **B-** Breeding habitat of *S. algira algira*, *D. pictus*, *H. meridionalis* and *P. poireti* in Edough Peninsula; **C-** Breeding habitat of *B. boulengeri* in Tacheta Zoughagha; **D-** Breeding habitat of *P. nebulosus* and *D. pictus* in Chlef; **E-** Breeding habitat of *P. nebulosus* in Theniet el Had (rock pool); **F-** Breeding habitat of *P. nebulosus*, *H. meridionalis*, *D. pictus*, *S. mauritanica* and *P. saharicus* in Theniet El Had (Cedar forest); **G-** Breeding habitat of *P. nebulosus*, *H. meridionalis*, *P. saharicus* and *S. mauritanica* in Bouchtata; **H-** Breeding habitat of *H. meridionalis* and *S. mauritanica* in Hounaine; **I-** Breeding habitat of *S. mauritanica* and *D. pictus* in Edough Peninsula. Photo C: Daniel Escoriza; Photos A - B; D - I Jihène Ben Hassine.

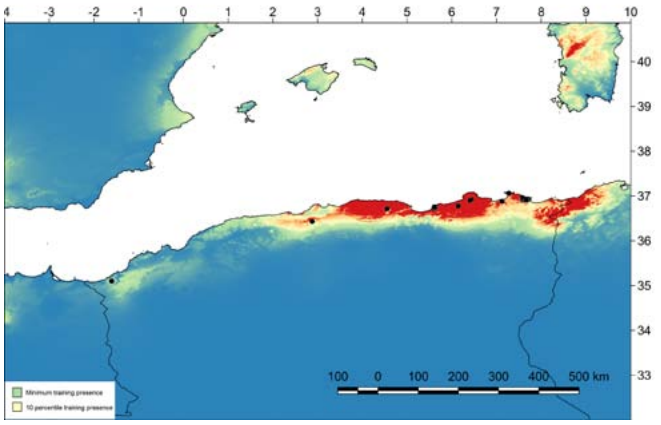

Figure 4. Niche model and distribution records of *S. algira algira* in Algeria. Warmer colours indicate higher climate suitability. Red: 10th percentile training presence thresholds; Yellow: minimum training presence thresholds; Blue: Null predicted suitability.

algira remain scarce (Samraoui et al., 2012; Escoriza & Ben Hassine, 2014). Recently, Ben Hassine et al. (2016 a) provided new data on the patterns of genetic, ecological variation, distribution records and coloration patterns of the Algerian populations.

Classified as Vulnerable by IUCN, *S. algira algira*, (as part of *S. algira*; IUCN, 2017) is endemic to Algeria, and present in a continuous range between Edough Peninsula and Blida Atlas (Escoriza & Ben Hassine, 2014; Ben Hassine et al., 2016 a; Fig. 4). This species also appears in a small region of the north-western part of Algeria, close to the Moroccan border where it was previously signaled in the 19th century (Guichenot, 1850; Doumergue, 1901). Here we confirmed its presence in this western part of Algeria in the region of Beni Menir (Fig. 4) where we found larvae in 2011. In the extreme eastern part of the species distribution, we confirmed the presence of *S. algira algira* in Bône (actually "Annaba") (Ben Hassine et al., 2016 a). Moreover we extended its known range with the discovery of several new populations in Edough Peninsula and its surroundings between Cap de Fer, Aïn Barbar and Oued l'Aneb (Fig. 4). The North African fire salamander was recently discovered at El Collo Massif in Skikda (Escoriza & Ben Hassine, 2014). Barkat (2014) reported its presence in Sétif (at Djebel Ouled Massoud). However, the occurrence of this species in some historical sites, such as Constantine, Laarba (Guichenot, 1850) and Alger (Boulenger, 1882; 1891) remain to be confirmed. In the wet forests of Edough Peninsula, Kabylies and Blida Atlas, this salamander has a continuous distribution area including a large part of the coastal mountainous areas [Edough, Collo, Jijel, Béjaia, Tikjda, Tizi n'Kouilal, Iboudraren Darna, Tala-Guilef, Aghribs, Tiz-Ouzou, Djurdjura, Haïser, Akfadou, Fort National (actually "Larbaa-Nath-Irathen")]. It was previously reported in some of these localities (Guichenot, 1850; Boulenger, 1891; Doumergue, 1901; Seurat, 1930; Bons, 1972; Bouali & Oneimi, 2005; Ben Hassine et al., 2016a).

The niche model on Fig. 4 shows a proxy of the fundamental niche of *S. algira algira* in Algeria. The model indicates that the distribution in Algeria is possibly well known and structured in two geographical nuclei, separated by the Oran semi-arid depression. Following this model, its presence in El Kala, the Tunisian border and in the north-east of Tunisia could be possible, although we could not confirm this (Ben Hassine & Nouira, 2012).

Recently, the combination of colour pattern of *S. algira algira* was described by Ben Hassine et al. (2016a). However, intra population variation is quite common on the Algerian populations where specimens from the same localities may show different patterns of coloration across its distribution. For example, *S. algira algira* from Seraïdi (Edough Peninsula, north-eastern Algeria) may have red discoloration in different parts of the body (parotids, head, tail, members…). Irregularly shaped tiny whitish specks may also be present on the gular, members, toes, and ventral regions. White rounded spots located asymmetrically on both sides of the body may be present or totally absent (the number varies between 0 and 12 white spots). These spots may be mixed or not with pronounced red coloration (Fig. 2 A and B). To the lateral white spots could be also associated lateral yellow spots. These patterns of coloration appear all over *S. algira algira* distribution in Algeria.

Our data and those of previous publications indicate that this salamander may be a common species in Edough Peninsula and Kabylies. *Salamandra algira algira* was found at altitudes between 20 m and 1280 m above sea level, inhabit in meso-thermic broad-leaved forests (composed by *Quercus canariensis* and *Quercus suber*). This species occurs in habitats mostly located under the humid to sub-humid ombroclimates with mean annual precipitation = 913.27 mm/year and mean annual temperatures = 15.62 °C (Table 1).

This subspecies breeds in lotic and lentic habitats such as temporary ponds, stream pools, rock pools, springs, and man-made fountains (Fig. 3A, B). They are small aquatic habitats, with an average surface area of 24.59 m^2, which is clear with a low-cover of emergent vegetation (mean = 21.45%; Table 2). As indicated previously (Escoriza & Ben Hassine, 2015), the larvae are mainly found in association with lower water temperatures than other amphibians of Algeria, possibly because the former mainly breed during the autumn and winter, and other species are late winter-spring breeders (Table 2). During our surveys, we found larvae between November and late April. Pellegrin (1927a) and Seurat (1930) found larvae of *S. algira algira* in the Blida Atlas between March and April at 1300 m of altitude. However larvae could be found until summer in some localities (e.g., August in Edough Peninsula, personal observation). We observed cannibalism in *S. algira algira* larvae that could also prey on *D. pictus* tadpoles. *Salamandra algira algira* larvae can co-occur with *H. meridionalis*, *P. saharicus* and *D. pictus* larvae.

Algerian ribbed newt
***Pleurodeles nebulosus* (Guichenot, 1850)**

Listed as a vulnerable species (IUCN, 2017), *P. nebulosus*, is endemic to northern Algeria and Tunisia (Fig. 2 C). The species occurs over a continuous range from Bizerte (Tunisia) to north-western Algeria with some relict Tunisian populations in Cap Bon (Ben Hassine et al.,

Table 1. Summary of the prospected localities in Algeria. n: number of sampled breeding habitats; N: Total number of the localities where a species was recorded; Altitude: Mean and range values of altitude (m); P: Mean and range of annual value of precipitation (mm/year); T: mean and range of annual value of temperature in the year (°C); P.n.: *P. nebulosus*; S.a.a.: *S. algira algira*; D.p.: *D. pictus*; S.m.: *S. mauritanica*; B.s.: *B. spinosus*; B.bl.: *B. boulengeri*; H.m.: *H. meridionalis*; P.s.: *P. saharicus*; * See Table 3 and Appendix 1 for additional details.

	P.n.	*S.a.a.*	*D.p.*	*S.m.*	*B.s.*	*B.bl.*	*H.m.*	*P.s.*
n*	10	24	56	5	0	1	29	28
N*	16	33	99	18	2	4	43	62
Altitude	555.06	495.36	274.36	321.94	882.5	656.25	232.93	369.5
(m)	26–1378	20–1281	0–1378	0–1378	501–1264	11–1340	4–1378	0–1378
P	787.62	913.27	740.19	643.72	957.5	518	753.83	743.83
(mm/y)	527–1027	445–1414	339–1365	146–955	888–1027	273–736	444–961	273–1027
T	15.93	15.62	17.08	16.80	14.25	16.22	17.33	16.73
(°C)	12.2–18.5	11.2–18	12.2–19.1	12.2–18.4	12.5–16	14.2–18.3	11.9–18.9	12.2–19.1

Table 2. Breeding habitat characteristics (mean and range) of amphibians in Algeria. n: number of sampled ponds; AD: Water body average depth (cm); BS: Water body surface area (m^2); T: Water temperature en °C; O^2: Dissolved oxygen in water ($mg{\cdot}L^{-1}$); pH: Water pH; Cond: Water conductivity ($\mu S{\cdot}cm^{-1}$); Turb: Water turbidity; EV: Emergent vegetation cover (%).

	Pleurodeles nebulosus	*Salamandra algira algira*	*Discoglossus pictus*	*Sclerophrys mauritanica*	*Bufotes boulengeri*	*Hyla meridionalis*	*Pelophylax saharicus*
n	10	24	56	5	1	29	28
AD (cm)	38.36	20.02	31.05	45.49	21.6	37.86	43.87
	19.4–66	3.2–91	7–95.2	21.2–83.8		6.1–93	8.4–117.4
BS (m^2)	1761.06	24.59	1735.52	1925.65	24	1418.94	421.32
	117.59–9112.8	0.18–361	1.35–26702.75	10.5–5089.9		1.26–5775.9	0.28–4328.2
T (˚C)	19.21	12.1	14.49	16.44	16.5	14.82	14.9
	13.5–28.7	6.1–16	8.2–23.8	13.4–21		6.1–28.7	8.4–28.7
O_2 ($mg{\cdot}L^{-1}$)	6.69	7.51	7.27	8.54	-	7.11	8.64
	3.58–8.82	4.3–11.2	3.29–11.7	7.54–9.62		3.29–11.7	3.6–11.7
pH	8.11	7.37	7.67	7,68	8.3	7.69	7.92
	7.4–8.9	5.9–9.05	5.7–9.2	6.7–8.8		5.7–8.59	6.7–9.05
Cond ($\mu S{\cdot}cm^{-1}$)	727.35	441.66	623.39	634.24	449	409.51	380.4
	114.5–3550	108.2–1611	94.2–3550	94.2–1479		94.2–1972	94.2–1025
Turb	1.7	1.12	1.78	1.4	3	1.55	1.35
	1–3	1–2	1–3	1–3		1–3	1–3
EV (%)	64	21.45	54.64	31.2	0	56.76	32.17
	5–90	0–100	0–99	1–70		0–95	0–90

2013). In Algeria, *P. nebulosus* mostly occurs in the circum-coastal regions (between Tunisian border and Blida Atlas) penetrating weakly in the interior (about 80-100 km; Fig. 5).

In this study we confirmed the presence of *P. nebulosus* in the Blida Atlas and the Algérois, where it was already reported at Laarba, Tamazguida, Mouzaïa and Blida (Boulenger, 1891; Pellegrin, 1927 a; Pasteur & Bons, 1959; Matz, 2007; Escoriza et al., 2016). In north-western and north central Algeria, we confirmed its presence in the provinces of Chlef, Tissemsilt, Médéa, Tiz-Ouzou and Béjaia (Strauch, 1862; Lataste, 1881; Boulenger, 1891; Olivier, 1894; Doumergue, 1901; Pellegrin, 1927 a; Gervais, 1936; Dahmana et al., 2006; Escoriza et al., 2016; Ferrer et al., 2016) and reported its presence for the first time at Aïn Defla. We confirmed its presence in Skikda where it was previously reported by Escoriza & Ben Hassine (2014), Jijel (Escoriza & Ben Hassine, 2014), and El-Taref (Samraoui et al., 2012, Escoriza & Ben Hassine, 2014). Recently Samraoui et al. (2012) signaled *P. nebulosus* at Souk Ahras. The species can be locally common in the Kabylies where it occurs in several localities between Tiz-Ouzou (Friha and Afkadou) and Jijel. However, some historical records are still not confirmed. The presence of the species should be confirmed in Alger, Laarba, Mouzaïa (Gervais, 1839; Guichenot, 1850; Lallemant, 1867; Boulenger, 1882; Matz, 2007), Guyotville (Aïn Benian, Boulenger, 1891; Pellegrin, 1927a), Bab Ezzouar (Matz, 2007), carrière de la porte Bab-El Oued (Strauch, 1862) and Oued Sebdou (Lallemant, 1867; Olivier, 1894). In the eastern part of the country, *P. nebulosus* was reported in Constantine (Lataste, 1881; Seurat, 1930; Salvador, 1996). The westernmost records of the species are located in Mascara at Sidi Daho from where two specimens where collected in February 1911 by Dr. Collozi (Doumergue, 1911 a, b), and Oran "intérieur des terres" (Guichenot, 1850). The southernmost historical records are in Biskra

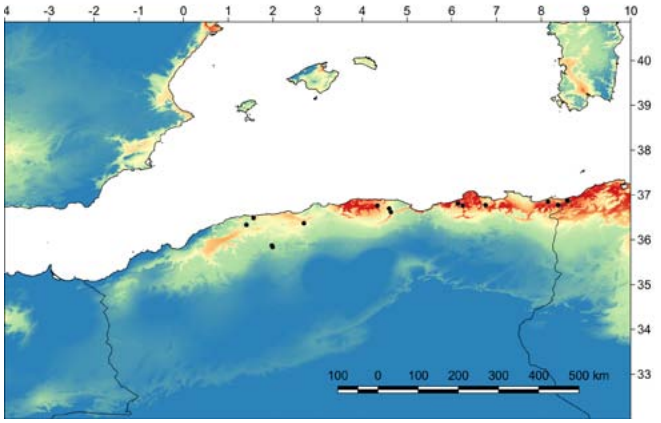

Figure 5. Niche model and distribution records of *P. nebulosus* in Algeria. Warmer colours indicate higher climate suitability.

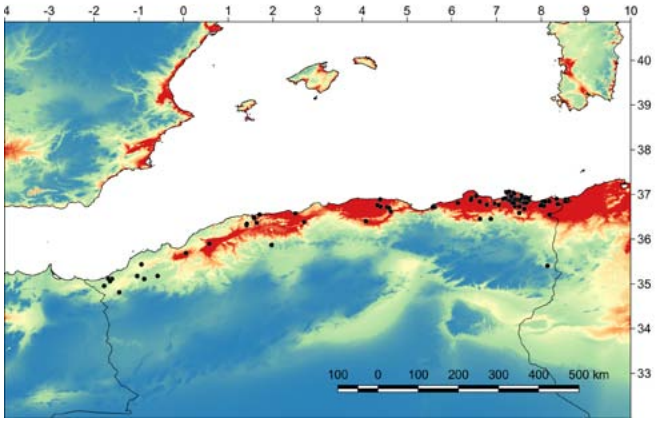

Figure 6. Niche model and distribution records of *D. pictus* in Algeria. Warmer colours indicate higher climate suitability.

(Böettger, 1885; Boulenger, 1891; Pellegrin, 1926; Seurat, 1930; Le Berre, 1989) and south of Chott Echergui (at el Kreider, Kolar, 1955). The latter record is a desert region (salty water Chott) possibly unsuitable for *P. nebulosus*. For this reason we considered that this record could be doubtful. The niche model also supported this statement (Fig. 5).

A highly terrestrial newt *P. nebulosus* becomes aquatic during the reproductive period (Fig. 2C). It has been found in Algeria in open weakly structured agricultural and steppic landscapes, similar to the Tunisian populations (Ben Hassine & Nouira, 2012; Ben Hassine et al., 2013). However, it also occurs in mountainous evergreen oaks and cedar forests reaching 1378 m of altitude in central Algeria. The distribution of *P. nebulosus* comprises humid to semi-arid areas with annual precipitation ranging between 527-1027 mm/year (Table 1, Appendix 1).

The broad variation in the parameters of the breeding habitats highlight the ecological plasticity of *P. nebulosus* similar to those observed in other *Pleurodeles* species in Maghreb (Ben Hassine & Escoriza, 2014a; Escoriza & Ben Hassine, 2015; Ben Hassine et al., 2016). Reproduction takes place in moderate to large dimensions temporary ponds (117.59-9112.80 m^2), where usually the water is turbid, with a low to dense layer of emergent vegetation (5-90%) (Table 2; Fig. 3 D-G). The mating season depends on altitude and temperature and it begins with the onset of the seasonal rains. Similarly to that previously described for the Tunisian populations (Ben Hassine & Nouira, 2012; Ben Hassine et al., 2013), larvae of *P. nebulosus* in Algeria could be found between December and late May (until June in Kabylies and Médea, personal observation). The larvae of this newt co-exist with some anuran species that breed in ponds with moderate to large hydroperiods such as *H. meridionalis* (31%), and more generalist species such as *D. pictus* (50%) and *S. mauritanica* (16%). Syntopy between *S. algira algira* and *P. nebulous* in the breeding habitats was not observed. However the occurrence of this syntopy is highly possible as it was previously observed for *P. poireti* and *S. algira algira* in Edough peninsula (Fig. 3 B; Escoriza and Ben Hassine, 2017b).

Mediterranean painted frog
***Discoglossus pictus* Otth 1837**

The painted frog is listed as Least Concern (IUCN, 2017). Our surveys showed that the distribution of *D. pictus* in northern Algeria is likely to be continuous from the Tunisian border westwards to the border of Morocco (Figs. 2 D and 6). The painted frog is a very common species in Algeria, where it was found in 60% of the prospected localities (Fig. 6; Appendix 1).

We found *D. pictus* in Seraïdi, Bouzizi, Tebessa, Constantine, El Collo Massif, Béjaia, Azagza, Theniet El Had and Tlemcen and confirmed its presence in Annaba, El-Taref, Lac Fetzara, the Guerbes-Senhadja wetlands complex and El Kala, where it was previously mentioned by Samraoui et al. (2012), Jijel (Escoriza et al., 2014), Skikda (Warner, 1894; 1892), Kabylies [Akfadou and El Milia (Zangari et al., 2006), Yakouren, Tiwidiwine, Iguerssafen, Tala-Guilef, Freha, Aghribs (Bouali & Oneimi, 2005) and Tizi-Ouzou (Warner, 1914)], and Chlef (Brunet et al., 2009; Ferrer et al., 2016). The presence of *D. pictus* is also confirmed in the northern part of central Algeria, where it was previously reported in Alger (Strauch, 1862; Boulenger, 1882; Taïbi et al., 2009), Médéa, and Chréa National Park (Warner, 1894, 1892). In western Algeria, we confirmed its presence between Oran and Tlemcen. In this area, it was collected previously in Oran, Kristel, Saint-Cloud, Saint-Lucien, le Tlélat, Misserghin, Bou-Sfer, le Sig, Aïn-Témouchent, Arlal, Tafna Valee close to Sebdou, Daya, Saïda, Marnia, Tlemcen (Olivier, 1894; Doumergue, 1901; Zangari et al., 2006), Souk El Ténine (Sura, 1983) and Tiaret (Brunet et al., 2009; Ferrer et al., 2016). This species was mentioned at Tazoult (Warner, 1894; 1892), Sétif (Salvador, 1996; Barkat, 2014), Biskra (Salvador, 1996) and Batna (Boulenger, 1891; Olivier, 1894; Salvador, 1996). According to our data, *D. pictus* occurs in northern Algeria between the sea level and 1378 m of altitude. Following Seurat (1930), it can reach up to 1700 m. The southern distribution limits of *D. pictus* in Algeria are not known. The niche model of *D. pictus* represents the realised distribution of the species in northern Algeria and shows the potential wide range of suitable habitats for the species (Table 3; Fig. 6).

The painted frog is common in the northern part of the country, inhabiting cultivated and semi-arid steppes,

though it also occupies humid mountainous forests areas (Fig. 6). This species tolerates a broad variation of rainfall (339-1365 mm/year) and temperature (12.2-19.1 °C; Table 1). *Discoglossus pictus* shows a wide ecological plasticity in terms of breeding habitat selection (Table 2). The opportunism displayed in its foraging behaviour (Ben Hassine & Nouira, 2009), and its extensive reproductive season between autumn to late spring time (Ben Hassine & Nouira, 2012, Escoriza et al., 2014), are possibly important factors in *D. pictus* being one of the most common amphibians in northern Algeria.

The painted frog is an explosive generalist breeder, using rain puddles, rock pools, seasonal streams and ephemeral ponds (Fig. 3 B, D, F and I). However, it also breeds in rivers, large semi-permanent and permanent ponds. The surface area of these water bodies range between 1.35 m^2 and 26702.75 m^2 (Table 2). The breeding activity of *D. pictus* is highly depending on rainfall in humid areas, being continuous almost over the year in some artificial oasis of southern Tunisia (Ben Hassine & Nouira, 2012). Tadpoles in different Gosner's stages could be found almost all year round in Algeria. Doumergue (1901) observed mating activity from February to late June in Oran. He stated that *D. pictus* tadpole needs about two months to achieve metamorphosis. These tadpoles could be found in syntopy with *H. meridionalis* tadpoles (28%) and *S. algira algira* larvae (10%).

Berber toad
***Sclerophrys mauritanica* (Schlegel, 1841)**

The Berber toad *S. mauritanica* is listed as Least Concern (IUCN, 2017) and found throughout northern Algeria in an apparently continuous distribution between the Tunisian and the Moroccan borders (Figs. 2 E-F, 7). We discovered *S. mauritanica* in Constantine, Relizane and Tlemcen and confirmed its occurrence in El-Kala and Annaba (Samraoui et al., 2012), Oran (Doumergue, 1901) and Chlef (Brunet et al., 2009; Ferrer et al., 2016). Several records where reported recently from different areas in Algeria: Kabylies [at Bouira (Harris & Perera, 2009); Jijel (Boumezbeur & Ameur, 2002); Sidi-Khlifa and Oued Diss in Freha (Bouali & Oneimi, 2005); Azzafoun, Aghribs, Azagza, Freha, Iboudrarene and Draâ-El-Mizan (Targa, 2013)], Tiaret (Brunet et al., 2009; Ferrer et al., 2016), Batna (Harris & Perera, 2009), Sétif (Barkat, 2014) and Timerganine (Samraoui et al., 2012). Historical records indicate its occurrence over all northern Algeria (Lallemant, 1867; Boulenger, 1891), being common around Alger, Blida (Gervais, 1836; Strauch, 1862; Lallemant, 1867; Boulenger, 1882) and Annaba (Gervais, 1836).

The presence of this toad was reported at Biskra and Sâada (Olivier, 1894), Oran, Sania, Sig, Pérrégaux, La Macta, Terny, Saïda and Géryville (Doumergue, 1901; Seurat, 1930), Ghazouet (Llabador, 1947) and Kherrata (Sura, 1983). Boulenger (1891) stated that *S. mauritanica* was collected by Lataste at Biskra, Bou-Saada and Laghouat and that it could be found as far southwards to the margins of the Sahara. According to Salvador (1996), this species occurs in the Saharan Atlas and western Hamadas. Schleich et al. (1996) considered that *S. mauritanica* is the only toad species that could be found in the Tassili Mountains, where it is a relict species but records of its presence in south-eastern Algeria (Angel & Lhote, 1938; Joger, 1981; Schleich et al., 1996) correspond in fact to a Sahelian species, the Savanna toad, *Sclerophrys xeros* (Mateo et al., 2013; Philippe Geniez, pers. com.). The exact southern limits of *S. mauritanica* in Algeria are not known.

The Berber toad inhabits all types of landscapes ranging from 0 to 1378 m above sea level. All the mountainous ranges of northern Algeria could be suitable habitat (Fig. 7; Table 3). Its ecological range included humid Mediterranean forests (cedar and oaks), agricultural lands and semi-arid steppes. It occurs in sites where mean annual precipitation varies between 146 and 955 mm/year and mean annual temperatures of 18.4°C (Table 1).

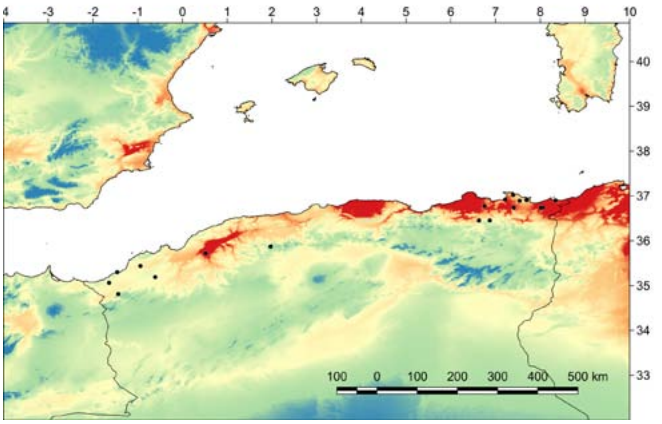

Figure 7. Niche model and distribution records of *S. mauritanica* in Algeria. Warmer colours indicate higher climate suitability.

Doumergue (1901) commented that the breeding season in Oran depends on the onset of the rains and that *S. mauritanica* could start breeding from early April or mid May. However, isolated reproductive episodes may occur over summer; tadpole metamorphosis occurs within 45 days (Doumergue, 1901). We observed tadpoles at different Gosner's stages between March and April in northern Algeria and recently metamorphosed toads were observed during early April in Tlemcen. The Berber toad breeds in small to large water bodies, including temporary and semi-permanent to permanent ponds and streams and rivers (mean depth = 45.49 cm; area range: 10.5-5089.9 m^2; Table 2; Fig. 3 F, G, H and I). These habitats may or may not have a layer of emergent aquatic vegetation (1-70 %). Tadpoles of *S. mauritanica* could be found in syntopy with tadpoles of *D. pictus*, *H. meridionalis*, *P. saharicus* and *P. nebulosus* larvae.

Mediterranean common toad
***Bufo spinosus* Daudin, 1803**

Classified as Least Concern by IUCN (as part of *Bufo bufo* (Linnaeus, 1758), IUCN, 2017) *B. spinosus* appears to be confined to the mountainous areas of northern Algeria (Figs. 2G, 8). The historical records of *B. spinosus* in Algeria are scarce and previous publications considered it

Table 3. Variables contribution to the ecological niche models (only those variables that contributed more than 10%)

	AUC	Variables	Contribution
P. nebulosus	0.931	Altitude	39.1
		Precipitation	36.9
		Seasonality	20.3
S.algira algira	0.969	Precipitation	85.0
B. boulengeri	0.913	Altitude	50.6
		Precipitation	19.5
		Seasonality	18.7
		Temperature	11.2
B. spinosus	0.943	Precipitation	64.8
		Altitude	15.0
		Temperature	11.7
D. pictus	0.928	Altitude	29.7
		Precipitation	27.9
		Seasonality	24.3
		Temperature	18.1
H. meridionalis	0.947	Precipitation	48.9
		Altitude	33.7
		Seasonality	11.3
P. saharicus	0.905	Altitude	49.3
		Precipitation	25.0
		Seasonality	16.8
S. mauritanica	0.866	Precipitation	52.2
		Altitude	30.1
		Seasonality	10.5

rare (Lallemant, 1867; Boulenger, 1891; Seurat, 1930). We confirmed its presence in the Kabylies where it was recently observed by Targa (2013) in several localities (Azzafoun, Aghribs, Azagza, Freha, Iboudrarene and Draâ-El-Mizan). We confirmed also the record of Hagenmüller (1882) in Edough region (Annaba, northeastern Algeria), although our record was in Seraïdi (Fig. 8).

Recently, Samraoui et al. (2012) reported its presence at El Ghorra Mountains where it was reported from the Tunisian side of this mountainous range (Ben Hassine & Nouira, 2012; Ben Hassine & Escoriza, 2014b). *Bufo spinosus* was mentioned in Alger and Blida Atlas (Guichenot, 1850; Lataste, 1881; Strauch, 1862; Salvador, 1996; Schleich et al., 1996), Jijel (Raouag, 1997), El Kala and El Taref (Salvador, 1996) and Skikda (Schleich, 1996). Isolated occurrences have been reported from Oran (Salvador, 1996) and Tlemcen (Böettger, 1880-1881; Salvador, 1996). However, its presence at the latter localities in the north-western part of Algeria require confirmation, as there are suitable habitats for the species in the region (Fig. 8), when taking into account its occurrence in semi-arid areas in other parts of its range (Bons & Geniez, 1996; Garcia-Paris et al., 2004).

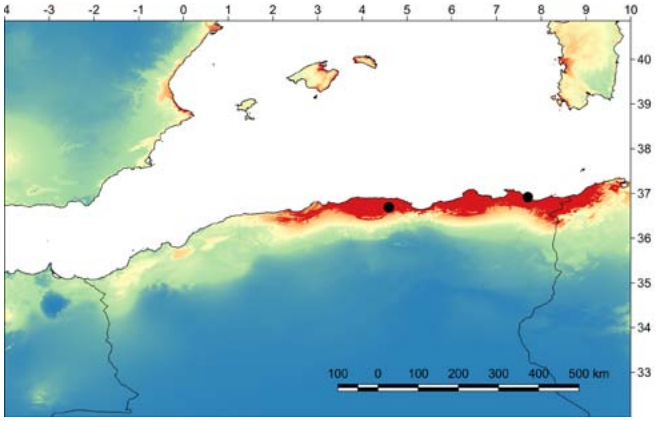

Figure 8. Niche model and distribution records of *B. spinosus* in Algeria. Warmer colours indicate higher climate suitability.

The niche model predicted the presence of continuous suitable conditions from the Tunisian border to the Blida Atlas, and in a small region in the north-western part of the country (Fig. 8; Table 3). The common toad has been found at elevations of 501 and 1264 m above sea level (Table 1). This toad inhabits broad-leaved forests composed by evergreen and deciduous oaks (*Quercus canariensis*, *Quercus suber* and *Quercus ilex*), similarly to the Tunisian populations (Ben Hassine et al., 2012; Ben Hassine & Escoriza, 2014b). However in Algeria, *B. spinosus* may be found at higher altitudes, occurring in *Cedrus atlantica* formations. It could be the most common Bufonidae in the Kabylies given the presence of highly suitable habitats in the region. The few observations could be due to its discreet behaviour and nocturnal activity. However more surveys would be necessary to better define the limits of its distribution.

African green toad
***Bufotes boulengeri* (Lataste, 1879)**

Listed as Least Concern (IUCN, 2017), *B. boulengeri*, could be considered one of the most widely distributed and ubiquitous amphibians in North Africa (Schleich et al., 1996; Joger, 2003). Historical records indicated *B. boulengeri* was found all over Algeria, being common around "l'Oranie" (Strauch, 1862; Lallemant, 1867; Boulenger, 1891; Olivier, 1894; Doumergue, 1901) an area from where we found it in Tlemcen (Figs. 2 H and 9). We also found it at el Bayadh and Aïn Defla and confirmed its occurrence in Djebel Edough at Jnène el Bey, where it was previously mentioned by Boulenger (1891). Samraoui et al. (2012) also recorded this toad in Skikda and Timerganine. Recently, it has been recorded at Tizi-Ouzou (Targa, 2013), Tiaret (Brunet et al., 2009; Ferrer et al., 2016), Souf, Taibet and Touggourt (Mouane, 2010), Ghardaia (Stöck et al., 2006) and Ouargla (Mebarki, 2012).

The North African green toad was confirmed present at: Mouzaia and Alger (Strauch, 1862), Méchéria and Kreider (Doumergue, 1901), Hauts plateaux (Aïn Oussera: Seurat, 1930), Aurès, Saharan Atlas, western Hamadas (Seurat, 1930) and the Grand Erg occidental (Salvador, 1996), Musaya on the Algerian Atlas, plateau Sersou, El Guerah and Tilremt (Boulenger, 1891). According

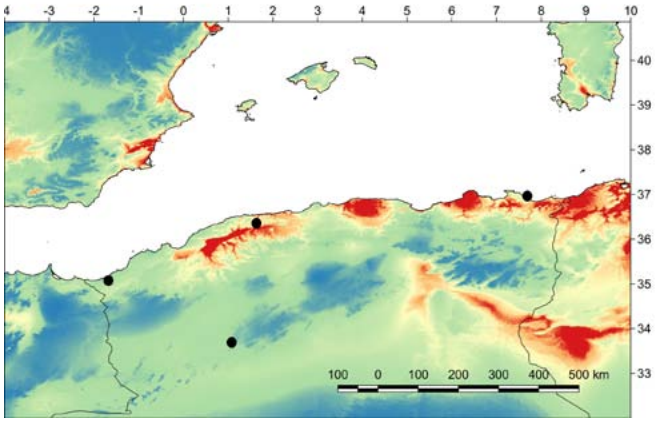

Figure 9. Niche model and distribution records of *B. boulengeri* in Algeria. Warmer colours indicate higher climate suitability.

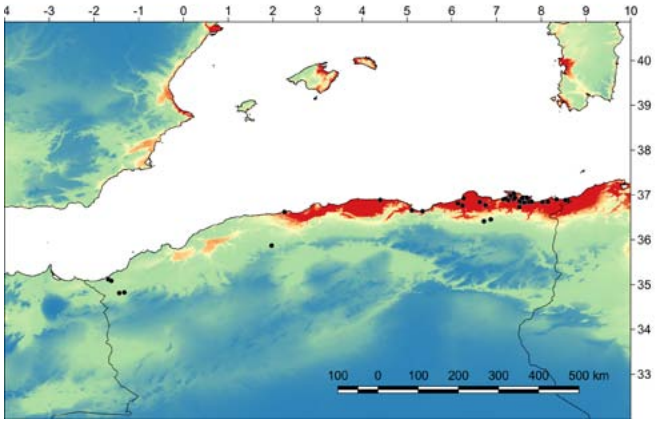

Figure 10. Niche model and distribution records of *H. meridionalis* in Algeria. Warmer colours indicate higher climate suitability.

to Seurat (1930) and Salvador (1996), in the Hoggar Mountains, *B. boulengeri* lives at elevations of 1400-2500 m above sea level close to permanent streams. In Algeria, the southernmost records of this species are in the Hoggar Mountains, Mzab and the Ahaggar Gueltas Mtajer and Tamekrest (Pellegrin, 1927b, 1934; Joger, 1981; Samraoui et al., 2012). In northern Algeria, *B. boulengeri* occurs at elevations between 11 and 1340 m above sea level (Table 1). This toad inhabits mainly open landscapes in northern Algeria but was found from littoral ponds and marshes up to the humid Oro-Mediterranean forests (Fig. 9). In northern Algeria, the localities are characterised by mean annual rainfall values of 273-736 mm/year and mean annual temperatures 14.2-18.3 °C (Table 1). This species breeds in ephemeral ponds especially in the arid areas of Algeria (Table 2; Fig. 3 C). According to Doumergue (1901), in Oran *B. boulengeri* appears some weeks earlier than *S. mauritanica* and mates between February and March. Salvador (1996) stated that after rain, they breed in any season in the Hoggar Mountains, when amplexus was observed in April, June, and August and tadpoles found in September. We observed tadpoles of *B. boulengeri* from early March to April. African green toad tadpoles may occur with those of *H. meridionalis* and *D. pictus*. The three Bufonidae species (*S. mauritanica*, *B. spinosus* and *B. boulengeri*) are sympatric in the meso-thermal forests of Algeria (Figs. 7-9; Appendix 1), in a similar pattern to that observed in Tunisia and the Atlas of Morocco (Schleich et al., 1996; Ben Hassine & Nouira, 2012; Ben Hassine & Escoriza, 2014b) but no syntopy between two of the three toad species was observed (Figs. 7-9). The reproductive strategies of the African green toad (Le Berre, 1989; Guillon et al., 2004) may provide an adaptative advantage in arid environment and could partly explain its presence in the oases and in the Hoggar Mountains.

Mediterranean tree frog
***Hyla meridionalis* Boettger, 1874**

Hyla meridionalis is listed as least Concern (IUCN, 2017). We discovered its presence in Annaba city, Seraïdi, El Collo Massif, Aïn Defla, and Béjaïa (Figs. 2 I-J, 10) and confirmed previous records in El-Taref, Skikda (Samraoui et al., 2012), Constantine (Salvador, 1996), Kabylies [Jijel (Raouag, 1997), Yakouren, Aghribs, Tigzirt, Tiwidiwine, Iguerssafen and Boudouaou (Strauch, 1862; Bouali & Oneimi, 2005)], Theniet el Had, Tlemcen (Anderson, 1892; Seurat, 1930) (Fig. 10). Recently, it was reported from Tiaret and Chlef (Brunet et al., 2009; Ferrer et al., 2016) and Sétif (Barkat, 2014). Presence in Alger (Guichenot, 1850; Strauch, 1862; Lallemant, 1867; Seraut, 1930), La Sénia, Bou-Sfer (Boulenger, 1891; Olivier, 1894; Doumergue, 1901; Seraut, 1930) and in Guelma at Hammam-Meskoutine (Seraut, 1930) remains to be confirmed although highly probable. The record of *H. meridionalis* in south-western Algeria (Méchria province) reported by Salvador (1996) could be considered far beyond the limits of suitable habitat of the species as confirmed by the niche model on Figure 10 and needs to be verified.

According to the niche model a large part of the northern region of Algeria could be suitable habitat (Fig. 10; Table 3). In the north-eastern and north-central parts of Algeria, *H. meridionalis* is a relatively common amphibian at elevations between 4 m and 1378 m above sea level (Table 1; Appendix 1). In western Algeria, the Mediterranean tree frog could be more localised and is present in Mediterranean bush land, close to temporary ponds. It occurs at sites with high level of annual rainfall (444-961 mm/year) and temperate annual temperatures (11.9-18.9 °C; Table 1). According to our findings, *H. meridionalis* is a generalist breeder breeding in permanent, semi-permanent or temporary ponds and streams. The surface area of the water bodies ranges between 1.26-5775.9 m^2 with or without aquatic emergent vegetation cover (0-95%) (Table 2; Fig. 3 B, F, G and H).

According to our observations, different Gosner's tadpoles and eggs clutch of this species could be found from February to late April (during May and June at high altitude). According to Doumergue (1901), in Oran the mating occurs mainly by the end of March and tadpoles metamorphose about 3 months after. Tadpoles of the Mediterranean tree frog co-occur with mainly those of *D. pictus* (93% of the localities).

North African frog
***Pelophylax saharicus* (Boulenger, 1913)**

Listed as Least Concern (IUCN, 2017), *P. saharicus*, was considered by Olivier (1894) and Doumergue (1901) as common in Algeria, occurring in all oases, and being especially abundant in the south of Biskra, Oued Djeddi, Saada, and Ouargla. We found *P. saharicus* in Rechgoune Beach, Tlemcen National Park, Theniet El Had, Collo Massif, Béjaia, and others localities in central Algeria (Figs 2 K-L, 11) and confirmed presence in Constantine (Boulenger, 1891), El-Taref, Annaba and Skikda (Samraoui et al., 2012), Jijel (Raouag, 1997), Géryville (actually "El Bayadh") and Oran (Doumergue, 1901), Chlef (Ferrer et al., 2016). Bouali & Oneimi (2005) reported its presence in the Kabylies at several localities (Tizi-Ouzou, Yakouren, Azeffoun, Freha, Tiwidiwine, Iguerssafen, Tigzirt, Aghribs and Yakouren). However, Brunet et al. (2009) and Ferrer et al. (2016) reported its presence in Tiaret. Recently Barkat (2014) recorded it in Sétif. Its occurrence was confirmed recently at Souf, Taibet and Touggourt (Mouane, 2010) and Ouargla (Boulenger, 1891; Mebarki, 2012). The North-African frog was reported from the oasis of Tidikelt (Boulenger, 1891), Sebdou, Bedeau (actually 'Ras el Ma'), Sidi-Chaib south of Daya, le Kreider, Djebel Ksel, Stitten, lake of El Goléa (actually 'El Ménia') and Igli (Doumergue, 1901). Sura (1983) reported the presence of the species at Oued Berd, Souk El Ténine, Grarem, and Monts du Hodna. In the northern margins of the Sahara, their presence is limited to oases (Salvador, 1996). According to Doumergue (1901) and Seurat (1930), *P. saharicus* inhabits the Hoggar Mountains and Ifédil in the Tassili N'Ajjer (confirmed by Philippe Geniez, pers. com., who observed it in 2009 in the latter massif).

This frog occurs in humid to arid climates (mean annual precipitation: 273-1027 mm/year; mean annual temperature: 12.2-19.1 °C; Fig. 11, Table 1). It breeds mainly in large water bodies (0.28-4328.2 m²) ranging from ponds (temporary, semi-permanent or permanent), rivers, springs, rocks pools and reservoirs with or without aquatic emergent vegetation (0-90%) (Table 2; Fig. 3 F and G). *Pelophylax saharicus* is associated to deep water bodies (reaching 117.4 cm of depth). Reproduction occurs later in the season than other amphibians in the region (Schleich et al., 1996). Doumergue (1901) reported its presence in Oran with mating in June and the presence of tadpoles between July (at La Sénia) and late September (at Sebdou). In the studied area, including in Oran, tadpoles at different Gosner's stages were found between March and April. This species occurs mainly with *H. meridionalis*, *D. pictus* and *S. algira algira* (Appendix 1).

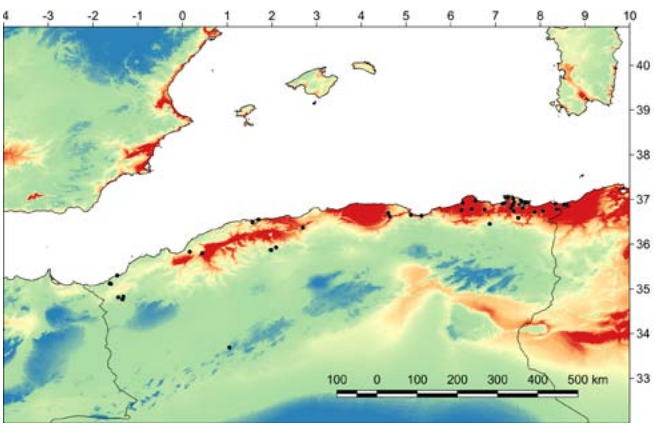

Figure 11. Niche model and distribution records of *P. saharicus* in Algeria. Warmer colours indicate higher climate suitability.

CONCLUSION

This study summarises available bibliographic data related to the Algerian batrachofauna, along with new data on the localities of different species, their terrestrial and breeding habitats characteristics and ecological status. Further research is necessary to complete this study, focusing particularly in southern Algeria.

Our data indicated that several species could be more widespread in Algeria than historical records suggested. The apparent discontinuity of their ranges and the supposed rarity of some species such as *P. poireti* and *S. algira algira* are likely due to previous low survey effort (Escoriza & Ben Hassine, 2014; Ben Hassine et al., 2016 a, b; Escoriza et al., 2016). Some historical records were not confirmed and/or could be doubtful. This could be partly explained by the former subdivision of northern Algeria until 1918 when the region was divided in three territorial areas: in the center Alger (Tizi-Ouzou, Alger, Médea, Chlef; 54,861 km²), in the west Oran (Mostaganem, Oran, Tlemcen and Tiaret; 67,262 km²) and in the east Constantine (Annaba, Béjaia, Constantine, Batna, Sétif, Tébessa and Biskra; 87,578 km²). In this sense, the record of *S. algira algira* in Constantine (Guichenot, 1850) could be attributable to the former administrative subdivision of the country.

The presence of amphibians in northern Algeria likely depends on climate gradients and on the spatial heterogeneity permitting coexistence and cohabitation of several species in sympatry or even in syntopy (Figs. 4-11, Table 1, Appendix 1). However, the habitats in northern Algeria are under intense anthropogenic pressures with the impacts affecting both forest and wetlands. The habitat destruction is particularly notable in the coastal regions. The scarce records of amphibians in western Algeria, particularly between Oran and Alger could be explained by abiotic conditions but also, anthropic degradation of the forest environments (associated to a fragmentation of natural habitats frequented by amphibians) and particularly a rarefaction of suitable sites for reproduction. Temporary ponds, that are typical breeding habitats for most Algerian amphibians, frequently suffer from water usage for irrigation (personal observation) and pollution, especially close to the cities. Many amphibian communities can be found close to urban surroundings (Ben Hassine et al., 2016 b; Escoriza et al., 2016). Associated with the expansion of urban structures, are alteration and drainage of many wetlands, overgrazing, forest fires, the spread of alien species, such as the eastern mosquito fish (*Gambusia holbrooki*) that may directly impact on reproduction success of many amphibians and are potential threat to amphibians in Algeria.

Six Algerian amphibians of the total number of twelve species have been listed as protected species under Algerian law and several listed under both global and national IUCN

regulations (Stuart, 2008; Jora, 2012). Most of these occur in national parks and protected areas of Algeria (such as Chréa National Park, Tlemcen National Park, Theniet el Had National Park, Djurdjura National Park, Gouraya National Park..). However, the actual function and status of national parks does not provide sufficient protection to ensure future persistence of most amphibian species.

ACKNOWLEDGEMENTS

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