

Amphibians of the Oriental Region and the Moulouya River Basin of Morocco: distribution and conservation notes

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Monitoring amphibian populations, especially over fragile ecosystems such as arid and semiarid landscapes, helps to detect demographic trends and ecological risks. During several campaigns carried out between 2013 and 2017 across the Moulouya River Basin and the Oriental Region of Morocco, we identified nine amphibian species from the 11 previously recorded. Amphibian population threats were also detected. In this work, we focused on the amphibians of the Oriental Region of Morocco with the aims to (1) update their distribution providing new records, (2) confirm the prevalence of some vulnerable species in the region, and (3) provide an overview of the ecology and conservation status of each species at a regional level.

Key words: conservation; endemic species; faunistic inventory; *Gambusia*; habitat loss; new records.

Amphibian population declines are observed worldwide (BLAUSTEIN & WAKE, 1990; STUART *et al.* 2004). These declines are generally driven by the combination of climate change, chemical pollution, infectious diseases, habitat degradation and introduction of predators (KIESECKER *et al.*, 2001; BLAUSTEIN *et al.*, 2003, DASZAK *et al.*, 2003). In the last decades, many species have seen their numbers diminished, suffering local or complete extinctions (HOULAHAN *et al.*, 2000).

Amphibians constitute a key component of vertebrate diversity in the western Mediterranean, representing the most vul-

nerable group among vertebrates (ANTHONY *et al.*, 2008). Particularly, amphibian diversity in northern Africa is formed by groups originated from different biogeographic regions. Species richness of Morocco differs from most of the African countries by the presence of a high proportion of relict elements of Eurosiberian origin, several of which are currently endemic (SCHLEICH *et al.*, 1996; BEUKEMA *et al.*, 2013; REQUES *et al.*, 2013). Unfortunately, many threats are having profound effects on this particular diversity that inhabits aquatic ecosystems and wetlands. In this sense, the Oriental Region of Morocco and

the Moulouya River Basin are suffering from severe environmental degradation by domestic, industrial and agricultural pollution sources (MABROUKI *et al.*, 2016a, 2017a; TAYBI *et al.*, 2016a; BENSAAID *et al.*, 2017; YAHYA *et al.*, 2017). These anthropic pressures over the few wetlands present in the arid eastern Morocco result in significant disturbances to the local biodiversity (MABROUKI *et al.*, 2016b; TAYBI *et al.*, 2016b, 2017a).

Eleven species of amphibians have been recorded within the Oriental Region and the Moulouya River Basin (BONS & GENIEZ, 1996; BEUKEMA *et al.*, 2013; MEDIANI *et al.*, 2015). Among them, one species is considered as Vulnerable (*Salamandra algira*), three as Near Threatened (*Pleurodeles waltl*, *Alytes maurus* and *Barbarophryne brongersmai*), and six as of Least Concern (*Discoglossus pictus*, *Discoglossus scovazzi*, *Bufoles boulengeri*, *Sclerophrys mauritanica*, *Hyla meridionalis* and *Pelophylax saharicus*) based on IUCN Red List criteria. The conservation status of *Bufo spinosus*, currently considered a distinct species from *B. bufo* (RECUERO *et al.* 2012), has not been eval-

uated at a global level; however, PLEGUEZUELOS *et al.* (2010) suggested that Moroccan populations of the common toad could be considered as Near Threatened (Table 1).

Basic information from distribution data within a temporal framework together to the identification of species potential threats are important starting points for monitoring amphibian populations and help to detect population trends and threats. It also could allow for identification of broad ecological problems related to global change (STUART *et al.*, 2008). This work aims to contribute to the knowledge of amphibians in the Oriental Region of Morocco by (1) updating their distribution and providing new records, (2) confirming the prevalence of some vulnerable species in the region, and (3) providing an overview of the ecology and conservation status of each species at a regional level.

MATERIALS AND METHODS

Study area

The field work was carried out over the Oriental Region of Morocco, one of the 12 regions of the country that extends along

Table 1: Amphibian species of Eastern Morocco .

Order	Family	Species	IUCN category	Detected
Caudata	Salamandridae	<i>Salamandra algira</i> Bedriaga, 1883	Vulnerable	No
		<i>Pleurodeles waltl</i> Michahelles, 1830	Near Threatened	No
Anura	Alytidae	<i>Alytes maurus</i> Pasteur & Bons, 1962	Near Threatened	Yes
	Bufonidae	<i>Barbarophryne brongersmai</i> (Hoogmoed, 1972)	Near Threatened	Yes
		<i>Bufo spinosus</i> Daudin, 1803	Not evaluated	Yes
		<i>Sclerophrys mauritanica</i> (Schlegel, 1841)	Least Concern	Yes
		<i>Bufoles boulengeri</i> (Lataste, 1879)	Least Concern	Yes
	Discoglossidae	<i>Discoglossus pictus</i> Otth, 1837	Least Concern	Yes
		<i>Discoglossus scovazzi</i> Camerano, 1878	Least Concern	Yes
Ranidae	<i>Pelophylax saharicus</i> (Boulenger, 1913)	Least Concern	Yes	
Hylidae	<i>Hyla meridionalis</i> Boettger, 1874	Least Concern	Yes	

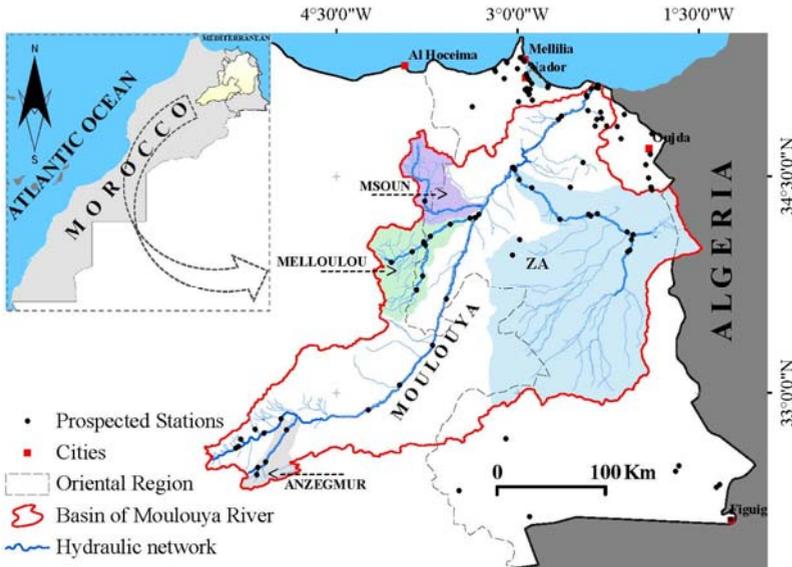


Figure 1: Sampled localities of the Oriental Region of Morocco and the Moulouya River Basin. For a correct visualization, the reader is referred to the online, colored version of the article.

most of the eastern side (Fig. 1). This region covers 90 127 km² (see TAYBI *et al.*, 2017b), and is formed by the *wilaya* of Oujda (Oujda-Angad prefecture) and the provinces of Berkane, Taourirt, Jerada, Nador, Figuig, Driouch and Guercif. The watershed of the Moulouya (Fig. 1), with an area of 43 412 km², covers a great portion of the Oriental Region. Moulouya River is the largest Moroccan river that flows into the Mediterranean, extending along 600 km. The principal tributaries of Moulouya river are the Oued Anzegmir, Melloulou, Za and Msoun, all of which are permanent, while other minor tributaries flow sporadically (3-5 flashfloods on average per year) (MABROUKI *et al.*, 2016b).

Field surveys and mapping

Field surveys were carried out between 2013 and 2017. A total of 103 localities were sampled (Table S1), including 45 within the Moulouya watershed (18 in the main river; 4 in the Oued Anzegmir, High

Atlas; 11 in the Oued Melloulou, Middle Atlas; and 12 in the Oued Za, High Plateau) and 58 over other areas of the Oriental Region (25 in the Oujda prefecture in the north-east, 24 in the Nador province in the north, and 9 in the Figuig province in the south). Data about the environmental impacts affecting some of these sampling sites are also provided by MABROUKI *et al.* (2016a,b, 2017a,b) and TAYBI *et al.* (2016a,b, 2017a,b, 2018).

Tadpoles were collected using a dip net, fixed and preserved in ethanol for subsequent identification. Adults and juveniles were not collected, and were directly identified in the field.

Maps of the study region were made using ArcGIS software. For species' range maps, we used the available published information (BONS & GENIEZ, 1996; VENCES *et al.*, 2014; BEUKEMA *et al.*, 2013; MEDIANI *et al.*, 2015) and completed them with the records identified from the present study.

Figure 2: Distribution maps of the amphibian species found during the course of the study. Photos: authors.

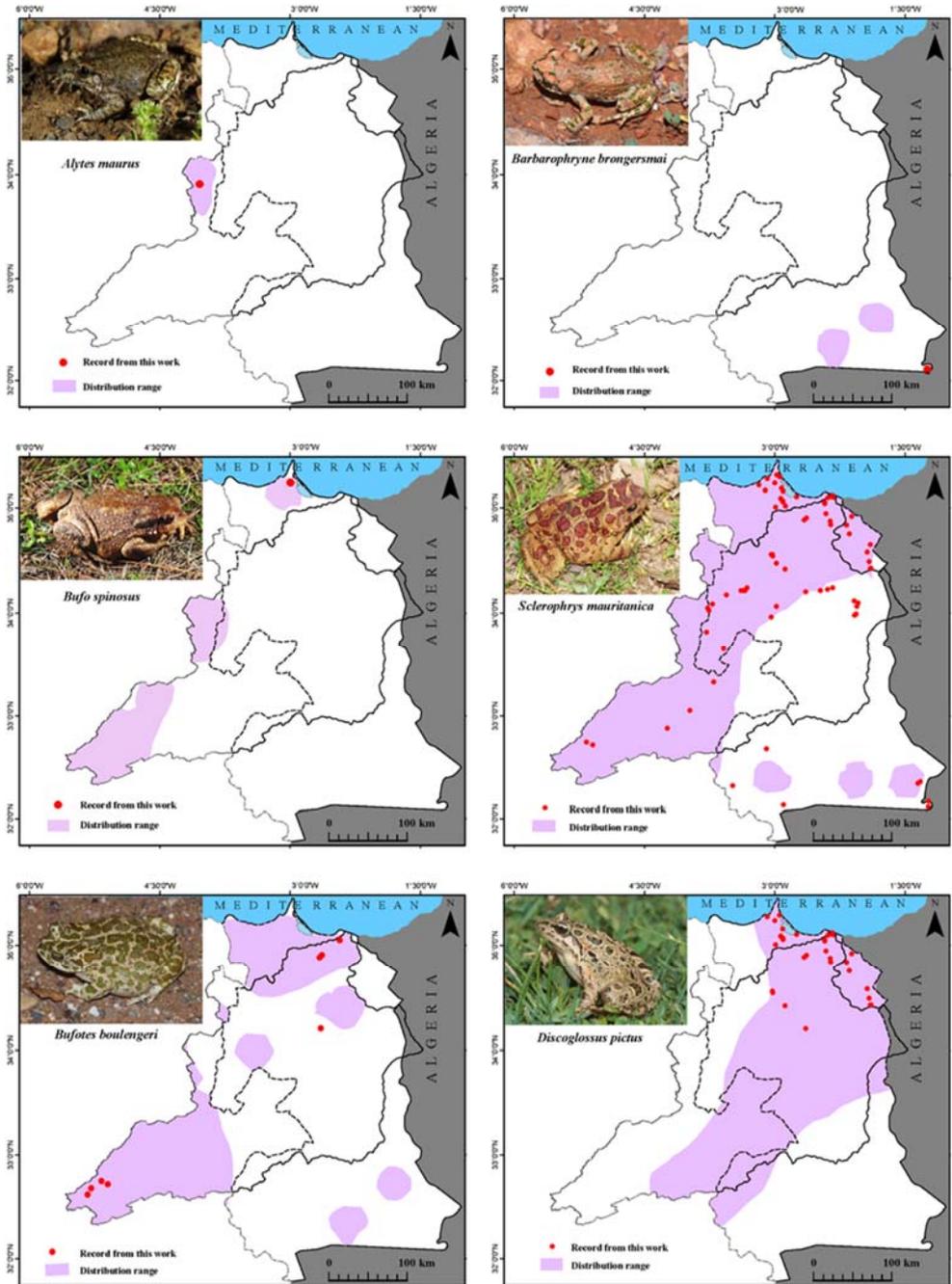
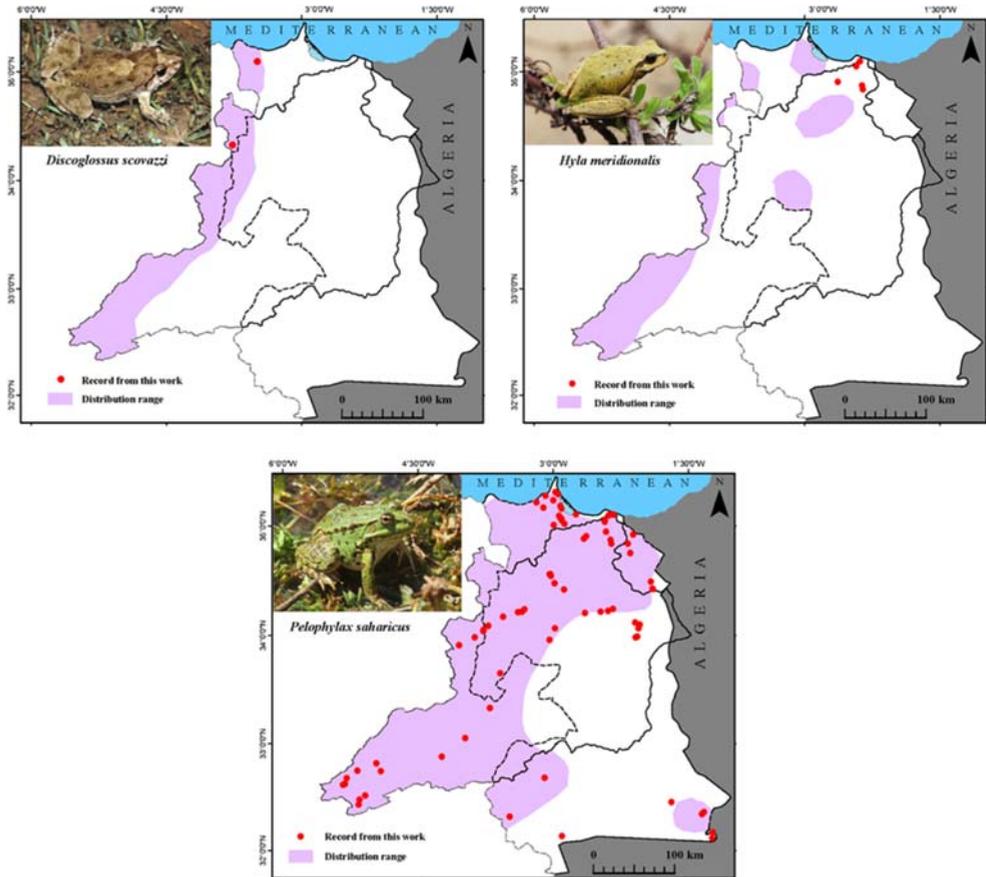


Figure 2 (cont.)



RESULTS AND DISCUSSION

General results

Nine of the 11 amphibian species reported in the Oriental Region were found during our field surveys (Table 1). Two taxa were not found during our field surveys: *S. algira spelaea* Escoriza and Comas, 2007 and *Pleurodeles waltl* (Michahelles, 1830), which are listed as Vulnerable and Near Threatened, respectively, being therefore two of the most threatened amphibians of the Region. Distribution maps for each detected species are shown in Fig.

2.

Several local threats have been found in the study region, including (1) deforestation in the Gourougou forest, (2) intensification of agriculture over the high and the low Moulouya, (3) use of fertilizers and pesticides along the plain of Triffa, and (4) water pollution by wastewaters and drainage of water bodies in the watershed of the Za river and in the Nador lagoon. The latter specially affects to species that occur in large water bodies such as *S. mauritanica* and *P. saharicus*.

During the breeding season of *S. mau-*

ritanica, we found a high mortality caused by road traffic in the northern region, at Selouan and Beni Snassen (Fig. 3). This could represent a local threat that affects populations inhabiting close to the roads and / or crossing them during breeding migrations, as noted in the Iberian Peninsula for different species (MATOS *et al.*, 2012). Infrastructures like water cisterns and irrigation channels have been also recorded in some sites within the Oriental Region, including Bni Tadjjite (geographic coordinates 32.313743°N, 3.47864°W), Selouan (35.074753°N, 2.927405°W) and Oujda (locality O6, Table S1), where a considerable number of adults, tadpoles and juveniles of *S. mauritanica* and *D. pictus* were found dead, probably because of drowning. Similar observations have been reported in water cisterns from western Morocco (GARCÍA-CARDENETE *et al.*, 2014).

The occurrence of exotic species can also bring severe threats to the amphibian diversity and population stability. In fact, several individuals of the American freshwater fish genus *Gambusia* (Actinopterygii: Poeciliidae) have been found during our surveys in the handled hydrosystems (i.e. irrigation channels or dams) from the eastern Rif to Figuig surroundings (Fig. 4). Moreover, we detected these invasive fish in protected areas such as SIBE (Site of Biological and Ecological Interest) or Ramsar sites, including the wetlands of the Moulouya River mouth, the Nador lagoon (Marchica) and the Mohamed V Dam. The presence of this exotic fish species could have severe consequences for native amphibians (e.g. DONAIRE-BARROSO & BOGAERTS, 2003; DE POUS *et al.*, 2012).

Some of the records of the present study are of special interest. *Bufo spinosus* has been rediscovered at the massif of Gourougou. The easternmost localities of *B. spinosus* in Morocco had been recorded at the Gourougou Mountains (YUS RAMOS & CABO HERNÁNDEZ, 1986) and the Beni Snassen Massif (MELLADO & MATEO, 1992). However, these records were unconfirmed as no additional specimens had been found after the original discovery, and, as suggested by BEUKEMA *et al.*, (2013), the presence of this species in Beni Snassen is still doubtful and needs confirmation. During a rainy day, we found a single *B. spinosus* individual close to a small, semi-temporary stream on a mountain slope of Gourougou Massif (locality N10, Table S1). The low abundance and detectability of this species in the Gourougou region emphasizes the need to conserve the permanent and semi-permanent water points as breeding habitats for the species. In this sense, deforestation represents the main threat to this species in the Gourougou Massif (see the Data by species section below). Additional records of special interest found during the present study are some discovered populations of *H. meridionalis* from the arid extreme of northeastern Morocco, which fill a gap over its distribution in the Oriental Region. These new records based on adult specimens suggest that this species could occur in other unknown and arid localities between Morocco and Tunisia.

Data by species

Alytes maurus is confined to the humid mountainous areas of northern Morocco encompassing the Rif and the Middle At-

las regions (BONS & GENIEZ, 1996). In the study area, this species has been recorded in the eastern Middle Atlas. Adults inhabit open forest, rocky valleys, cork oak forest and agricultural terraces close to permanent streams, pools and other water bodies (MEDIANI *et al.*, 2015). We recorded a single specimen in the upstream of Melloulou River, in the Eastern Middle Atlas (locality S1, Table S1). The specimen was found close to a small mountain stream with vegetated banks and supplied mainly by the snowmelt. This region is characterized by a humid bio-climate zone. *Alytes maurus* is listed as Near Threatened by the IUCN. Despite the lack of data on population trends, its narrow distributional range (less than 5000 km²) together with its sensitivity to chytridiomycosis (DONAIRE-BARROSO *et al.*, 2009a; FISHER *et al.*, 2009),



Figure 3: Examples of individuals of *Sceloporus mauritanica* found dead on the road over the study area. Photos: authors.

could suggest that a reevaluation of its conservation status would be necessary. The main threats to this species found in the study area are agricultural practices, habitat destruction, deforestation and unreasonable pumping of water for irrigation or domestic use (Fig. 5).

Barbarophryne brongersmai is an endemic species of the western Maghreb (Morocco and western Algeria). In Morocco, it is mainly distributed across the southern Anti-Atlas region and Souss Valley, with localized and dispersed populations over the northern High Atlas (BONS & GENIEZ, 1996). Within the Oriental Region, it has been recorded from Figuig surroundings (BONS & GENIEZ, 1996). It is found in semi-arid landscapes with grasses in rocky areas and also inhabits anthropized areas such as crop fields or small dams (SCHLEICH *et al.*, 1996). We provided an additional record (locality F4, Table S1), based on a single specimen that was found buried under a rock. The habitat where the specimen was found is formed by permanent streams with small ponds remaining in the major riverbed after the regression of the water level. According to the IUCN criteria, *B. brongersmai* is classified as Near Threatened, due to the alarming loss and contamination of the breeding water bodies in semi-arid landscapes. The presence of *Gambusia* has been detected in the irrigation system of the surroundings of Figuig where the species occurs.

In Morocco, *B. spinosus* is mainly found in the Rif, Middle Atlas and High Atlas, with scattered records in the Mediterranean coast (BONS & GENIEZ, 1996; BEUKEMA *et al.*, 2013). Within the Oriental Region, the species has been scarcely report-

ed; there are doubtful records in the Beni-Snassen and Nador surroundings (MELLADO & MATEO, 1992; BEUKEMA *et al.*, 2013). Moroccan populations of *B. spinosus* are confined to the wettest and coolest areas of the country, where it breeds in permanent or mostly permanent water bodies (BONS & GENIEZ, 1996; SÁNCHEZ-VIALAS *et al.*, 2016). During our surveys, we found a single adult male in the Gourougou Mountain (locality N10, Table S1) close to a small and semi-temporary stream. Currently, *B. spinosus* is considered a distinct taxon from *B. bufo* (which is classified as of Least Concern by the IUCN) and its conservation status has not been evaluated by the IUCN. However, it has been suggested that Moroccan populations of *B. spinosus* could be considered as Near Threatened (PLEGUEZUELOS *et al.*, 2010; REQUES *et al.*, 2013). Indeed, a special conservation emphasis should be given to the Mediterranean populations of *B. spinosus*. The Gourougou forest is subject to a high anthropic pressure, driven by urban

development, habitats loss, deforestation and fires.

The Maghrebian endemism *Sclerophrys mauritanica* is one of the most widespread and abundant amphibians in Morocco (BEUKEMA *et al.*, 2013). It occupies different water bodies like streams and pools, with the exception of the smallest ones, where it is commonly replaced by *B. boulengeri* or *B. brongersmai* (SCHOUTEN & THEVENOT, 1988). However, it is rare or absent in the Sahara region (BONS & GENIEZ, 1996). We recorded *S. mauritanica* at several localities where it seems to be abundant (localities M4, M5, M11, M12, M13, M14, M15, M16, M17, M18, M19, M20, M21, M22, S5, S6, S7, S8, S9, S10, S11, Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8, Z9, Z10, Z11, Z12, O1, O2, O3, O4, O5, O6, O7, O8, O9, O10, O11, O12, O13, O14, O15, O16, O17, N1, N2, N3, N4, N5, N6, N7, N8, N9, N10, N11, N12, N13, N14, N15, F2, F3, F4, F5, F7, F8 and F9, Table S1). Within the Oriental Region, the species has been found occupying most of the aquatic environments, including the lentic portions of large rivers, small mountain streams, coastal areas such as the wetlands of the Moulouya River mouth and the Nador lagoon, and even within urban areas. It is cataloged by the IUCN as of Least Concern because of its wide distribution, relative tolerance to anthropic disturbances, wide ecological niche and presumed high abundance (DONAIRE-BARROSO *et al.*, 2009b). We have detected several local threats such as habitat destruction, water pollution (Fig. 5), and also the occurrence in its breeding habitats of *Gambusia* (Fig. 4), which is especially common in the SIBE and protected areas, like the lagoon of



Figure 4: *Gambusia* specimens collected from the Lower Moulouya (locality M21, see Table S1). Photo: authors.



Figure 5: Examples of activities contributing to alteration or destruction of aquatic habitats. Top pictures show excessive pumping water at (from left to right): Krouchene (locality M4), pond Oued Charef (locality Z2), Douar Imzaghrou (locality S8), and Ait Boulman (locality M1). Bottom pictures show different sources of pollution in water bodies at several localities of the study area (from left to right): industrial wastewater close to locality Z11, industrial wastewater close to locality N5, solid pollution and domestic wastewater at locality M12, and domestic wastewater near the locality Z11. For details on localities, see Table S1. Photos: authors.

Nador and several ponds over the mouth of the Moulouya River.

Bufoles boulengeri occupies a vast area in northern Africa. It is one of the most common and widely distributed amphibians species of Morocco (GARCÍA-MUÑOZ *et al.*, 2010). In the Oriental Region, it has been recorded in large numbers at several localities (BONS & GENIEZ, 1996) across different habitats, ranging from more or less brackish coastal marshes to dams and artificial ponds. It is also found in urban and agricultural landscapes (localities M3, M4, M5, M19, M20, M21 and Z9, Table S1). According to the IUCN criteria, *B. boulengeri* is classified as of Least Concern (MARTÍNEZ-SOLANO *et al.*, 2008). Over the Oriental Region, we have detected several conservation problems for this species, like intense road traffic during the wet season, loss of breeding sites because of drainage of wetlands, and desiccation or contamination of

water bodies (Fig. 5). Furthermore, the use of wetlands as landfills, the high environmental pressure of livestock, and the discharge of wastewater from nearby residential areas to wetlands, constitute severe threats to the habitats of this species.

Discoglossus pictus is distributed over both insular (Sicily, Malta, Gozo, and some islands close to Tunisia) and continental regions, where it is spread throughout northwestern Africa. African populations range from the Moulouya River Basin to Tunisia (BEN HASSINE & NOUIRA, 2012). Its presence in Morocco is restricted to the Oriental Region (VENCES *et al.*, 2014), mostly at the east of the Moulouya Basin (localities M18, M19, M20, M21, M22, Z9, Z10, Z12, O3, O4, O5, O7, O8, O9, O10, O11, O12, O13, O14, O15, O16, O17, N1, N2, N3, N4, N5, N6, N8, N9, N10 and N11, Table S1). Some of these localities present different climatic conditions, ranging from

the semi-arid landscapes of the Moulouya Valley and Marchica Lagoon to the sub-humid climate in the upper areas of the Beni Snassen. *Discoglossus pictus* is considered as of Least Concern according to the IUCN criteria. It is an abundant species that occurs in wetlands of the Oriental Region; in arid zones, it is linked to the existence of mostly permanent waters (springs and troughs). We found that the water cisterns could represent a local threat for some populations because they work as traps for adults and juveniles. At locality O6, dozens of adult and metamorphic individuals were found dead together with hundreds of tadpoles during the dry season.

Discoglossus scovazzi is a Moroccan endemism that has been considered traditionally as a subspecies of *D. pictus* (e.g. LANZA *et al.*, 1986). However, despite its parapatric distribution in Morocco, *D. scovazzi* and *D. pictus* are not sister species (PABIJAN *et al.*, 2012). The western areas of the Moulouya River Basin represent a secondary contact zone between both species (VENCES *et al.*, 2014). Within the study area, we have found this species in the Middle Atlas and eastern Rif (localities N23 and N24, Table S1), at locations close to streams. Listed as of Least Concern according to the IUCN criteria, their major threats found in the Moulouya River Basin are related to water overexploitation and pollution from the discharges of untreated domestic wastewater to natural wetlands (Fig. 5).

Pelophylax saharicus is a common amphibian species in Morocco, occupying several bioclimatic levels. In the southern region of Morocco, its distribution range is

very fragmented, formed by isolated populations that occur close to water bodies (mostly permanent) (e.g. Laâyoune and surroundings) (BONS & GENIEZ, 1996). It is one of the most widespread amphibians in the study area. It was found in almost all water bodies, from streams and large rivers to temporary ponds and lagoons, being also frequent in artificial water pools (localities M1, M2, M3, M4, M5, M6, M7, M8, M9, M10, M11, M12, M13, M14, M15, M16, M17, M18, M19, M20, M21, M22, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8, Z9, Z10, Z11, Z12, O1, O2, O3, O4, O5, O6, O7, O8, O9, O10, O11, O12, O13, O14, O15, O16, O17, N1, N2, N3, N4, N5, N6, N7, N8, N9, N10, N11, N12, N13, N14, N15, F1, F2, F3, F4, F5, F6, F7, F8 and F9, Table S1). According to the IUCN criteria, *P. saharicus* is cataloged as of Least Concern (DONAIRE-BARROSO *et al.*, 2008). In spite of its abundance, populations from the Oriental Region have been severely affected by habitat degradation and destruction, which are mainly linked to the urban expansion (such as in Nador), as well as by wetland desiccation, overexploitation and pollution from domestic and industrial effluents (Fig. 5).

Hyla meridionalis is distributed over the western Mediterranean. In Morocco, it is widespread throughout the northern region (BONS & GENIEZ, 1996; BARNSTEIN *et al.*, 2010). It can be found in trees, shrubs, fruit trees and pastures, usually near freshwater habitats during the breeding season. We recorded this species at five localities in Berkane area where it had not been recorded previously (localities M20, M21, M22, O4 and O12, Table S1). Some adult

males were found calling on fruit trees during daytime at Beni Snassen, while at the Lower Moulouya adults were found over the waterside vegetation (e.g. *Typha latifolia*). An individual was found dead at Pont Hassan II. *Hyla meridionalis* is listed as of Least Concern by the IUCN because it presents a wide distribution, can occur at different habitat types, and presumably has high population densities (DONAIRE-BARROSO *et al.*, 2009c). In the study area, we have observed habitat loss because of agricultural intensification (especially in the river bank of the localities O4 and O12), infrastructure development (near the SIBE of Moulouya, locality O7) and pollution of aquatic habitats. The introduction and expansion of *Gambusia* (Fig. 4) over most part of the Lower Moulouya represents an additional local threat.

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