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Chapter 25
Amphibians of Morocco, including Western Sahara: a status report

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Morocco has one of the highest rates (28.6%) of amphibian endemism among countries bordering the Mediterranean Sea and, while large areas of Morocco are crucial for conserving amphibian biodiversity, some areas are not afforded legal protection. We examine biodiversity, identify immediate anthropogenic threats, discuss critical habitat for the conservation of amphibian diversity and the role of currently protected areas in meeting conservation goals within Morocco, Western Sahara included. The study area harbours 14 amphibian species, eight of which are assigned to the categories of Endangered (*Pelobates varaldii*), Vulnerable (*Salamandra algira*, *Amietophrynus xeros*, and *Hoplobatrachus occipitalis*) or Near Threatened (*Pleurodeles waltl*, *Alytes maurus*, *Bufo spinosus,* and *Barbarophryne brongersmai*) using IUCN criteria at the regional level of the study area. Habitat loss and degradation due to conversion of land for agriculture, urbanization, or industry are major threats, but infrastructure for tourism, freshwater pollution by chemicals, introduction of non-native species to aquatic ecosystems (*Gambusia holbrooki*), pathogens (*Batrachochytrium dendrobatidis*), road-kills, and natural disasters (drought), are also rapidly increasing threats. In addition, consequences from global warming must also be considered. The present Conservation Area Network (CAN) does not include distributional ranges of some amphibian species, and a more complete CAN in Atlantic and desert areas is suggested. The northwestern Atlantic, Rif-Middle Atlas, Central Atlantic, and Tiris regions should be considered priorities for conservation because of amphibian endemism and/or the existence of isolated amphibian populations.

Key words: amphibian decline; conservation planning; Morocco; survival threats; Western Sahara.

Los anfibios de Marruecos, incluyendo Sáhara Occidental: Informe sobre su situación. Marruecos posee una de las tasas más elevadas de anfibios endémicos (28.6%) entre los países de la cuenca mediterránea y, a pesar de que extensas áreas de Marruecos son fundamentales para la conservación de la biodiversidad de anfibios, otras zonas no gozan de protección legal. En este estudio examinamos la biodiversidad, identificamos las amenazas antropogénicas más inmediatas y discutimos el hábitat crítico para la conservación de la diversidad de anfibios y el papel de las áreas actualmente protegidas en el cumplimiento de los objetivos de conservación en Marruecos, Sáhara Occidental incluido. El área de estudio alberga 14 especies de anfibios, ocho de las cuales se asignan a las categorías de En Peligro (*Pelobates varaldii*), Vulnerable (*Salamandra algira*, *Amietophrynus xeros* y *Hoplobatrachus occipitalis*) o Casi Amenazada (*Pleurodeles waltl*, *Alytes maurus*, *Bufo spinosus* y *Barbarophryne brongersmai*), utilizando criterios de la UICN a nivel regional en la zona de estudio. La pérdida de hábitat y la degradación debido a la conversión de terrenos para la agricultura, urbanismo o industria son las principales amenazas, pero las infraestructuras relacionadas con el turismo, la contaminación de agua dulce por productos químicos, la introducción de especies exóticas en los ecosistemas acuáticos (*Gambusia holbrooki*), la llegada de patógenos (*Batrachochytrium dendrobatidis*), los atropellos y los desastres naturales (sequía), también son amenazas en rápido aumento. Del mismo modo, también deben tenerse en cuenta las consecuencias del calentamiento global. La actual Red de Áreas de Conservación (CAN) no incluye ran-

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gos de distribución de algunas de las especies de anfibios, por lo que se sugiere una red de conservación más completa incluyendo zonas del Atlántico y el desierto. Las regiones del Atlántico Noroeste, Rif-Atlas Medio, Atlántico Centro y Tiris deben ser consideradas prioridades de conservación debido a los endemismos presentes y/o la existencia de poblaciones aisladas de anfibios.

Key words: amenazas para la supervivencia; declive de anfibios; Marruecos; planificación de conservación, Sáhara Occidental.

Morocco (including Western Sahara), with an area of 705 850 km^2, is biogeographically within the Maghreb. In the north, mild and wet winters alternate with long, hot and increasingly dry summers as one progresses southward and eastward. Annual rainfall averages 950 mm in the north (Tangier), 430 mm along the Atlantic Coast (Casablanca), and less than 100 mm in most of the Western Sahara. Four mountain ranges, the Rif (Jebel Tidighine, 2456 m), the Middle Atlas (Jebel Bou Naceur, 3356 m), the High Atlas (Jebel Toubkal, the highest peak in North Africa at 4167 m) and the Anti-Atlas (Jebel Siroua, 3304 m) traverse the country from north to south. The Sahara Desert begins south of the Anti-Atlas and High Atlas and extends east for more than 800 km and south for more than 1000 km to 21º N latitude.

Morocco probably has the most complete dataset regarding amphibian distribution and status across northern Africa, and BONS & GENIEZ (1996), SCHLEICH *et al.* (1996), MATEO *et al.* (2003), and GENIEZ *et al.* (2004) have been relied upon heavily for summaries of distribution and habitat preferences. While this manuscript was in review BEUKEMA *et al.* (2013) described a third subspecies within *Salamandra algira* (*S. a. splendens*) and provided natural history data separately for the three Moroccan subspecies; supplemental natural history data for other amphibian taxa are also provided throughout this paper.

Morocco has only 14 of Africa's 993 amphibian species (Table 1) (IUCN, 2009). One of these species, *Pelobates varaldii*, is endemic but three other species, *Discoglossus scovazzi*, *Alytes maurus,* and *Barbarophryne brongersmai*, may be considered quasi-endemic because most of their distributional area is within Morocco and only isolated populations are known from within Algeria. Morocco, therefore, has almost exclusive responsibility for global

Table 1: Moroccan amphibian species.

CAUDATA
Salamandridae
Pleurodeles waltl Michahelles, 1830
Salamandra algira Bedriaga, 1883
ANURA
Alytidae
Alytes maurus Pasteur and Bons, 1962
Discoglossus pictus Otth, 1837
Discoglossus scovazzi Camerano, 1878
Pelobatidae
Pelobates varaldii Pasteur and Bons, 1959
Hylidae
Hyla meridionalis Böttger, 1874
Bufonidae
Amietophrynus mauritanicus (Schlegel, 1841)
Amietophrynus xeros (Tandy, Tandy, Keith and Duff-Mackay, 1976)
Bufotes boulengeri Lataste, 1879
Barbarophryne brongersmai (Hoogmoed, 1972)
Bufo spinosus Daudin, 1803
Dicroglossidae
Hoplobatrachus occipitalis (Günther, 1858)
Ranidae
Pelophylax saharicus (Boulenger, 1913)

conservation of these four amphibians. Proximity to the Iberian Peninsula has provided Morocco with the greatest European influence on its amphibian fauna among all African countries; two species (*Pleurodeles waltl* and *Bufo spinosus*) and some genera (*Salamandra*, *Discoglossus*, *Alytes*, *Pelobates*, *Pelophylax*) are of European origin. Because of greater habitat diversity, higher rainfall, and lower rates of evaporation, amphibian species richness is highest in the north while large areas within the Sahara lack amphibians (BAHA EL DIN *et al.*, 2008).

The global conservation status of Moroccan amphibians has been assessed quite recently (Table 2; see also COX *et al.*, 2006) and while large areas of Morocco are crucial to conserving amphibian biodiversity (Table 3), many significant areas are not afforded legal protection (RONDININI *et al.*, 2006; DE POUS *et al.*, 2011). Threatened amphibian species and populations are found in southern desert and savannah, and in northern wetlands and mountains, but these habitat types are not always well-represented in the current Conservation Area Network (CAN, MINISTÈRE DE L'AGRICULTURE, 1994). Currently, no amphibian species is legally protected in Morocco.

Table 2: Red List status (IUCN categories) for amphibians of Morocco (PLEGUEZUELOS *et al.*, 2010). CR=Critically Endangered; EN=Endangered; VU=Vulnerable; NT=Near Threatened; LC=Low Concern; NSp=number of species; End=number of endemic species; for comparative purposes global data for the amphibians of the Mediterranean Basin are included (COX *et al.*, 2006).

	CR	EN	VU	NT	LC	NSp	End
Morocco, Anura		1	2	3	6	12	1
Morocco, Caudata			1	1		2	0
Morocco, Amphibia		1	3	4	6	14	1
Mediterranean, Amphibia	2	13	13	17	61	106	68

Table 3: Precipitation and attributes of the distributional ranges of amphibians in Morocco (including Western Sahara). See text for procedure.

Species	Range within Morocco (km²)	Percentage of global range within Morocco	Precipitation Minimum	Maximum	Mean
Alytes maurus	5 500	~95	700	> 2000	995.7
Amietophrynus mauritanicus	395 300	47.88	< 100	2000	466.1
Amietophrynus xeros	12 300	0.21			< 100
Barbarophryne brongersmai	95 100	~ 95	250	600	293.7
Bufo spinosus	183 200	1.16	500	> 2000	541.9
Bufotes boulengeri	438 600	22.44	250	> 2000	441.9
Discoglossus pictus	5 300	2.22	150	600	270.6
Discoglossus scovazzi	190 600	~ 95	350	2000	614.9
Hoplobatrachus occipitalis	525	0.01			< 100
Hyla meridionalis	240 900	31.67	300	2000	580.8
Pelobates varaldii	7 000	100	600	800	710.7
Pelophylax saharicus	398 300	28.21	< 100	2000	463.7
Pleurodeles waltl	60 500	14.11	500	2000	733.2
Salamandra algira	10 800	48.74	800	> 2000	943.9
All Species					441.8
Morocco					413.1

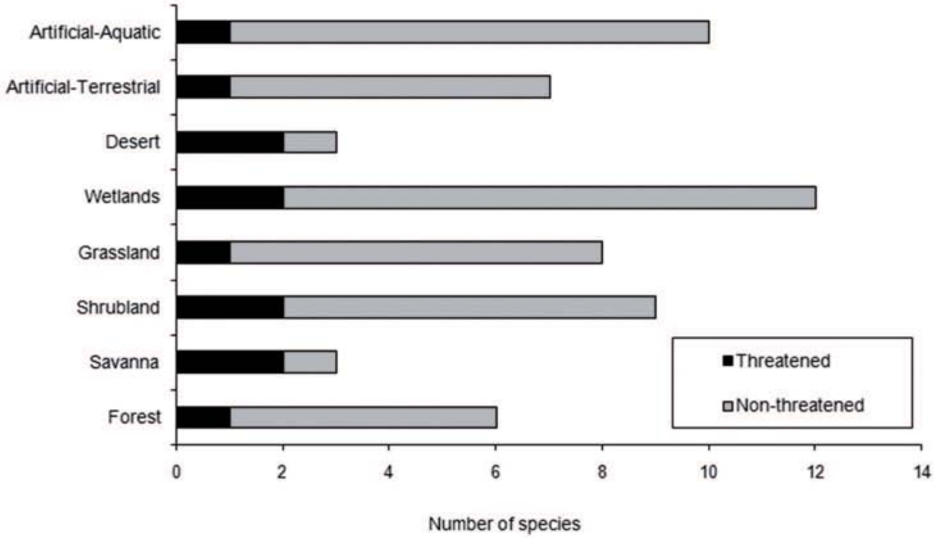

Figure 1: Major habitats utilized by amphibians at the regional level (from PLEGUEZUELOS *et al.*, 2010).

In the following pages amphibian biodiversity in Morocco is examined, the most important habitats (Fig. 1) and the role of protected areas are discussed, and immediate threats to this biodiversity are identified. It is hoped that this information will assist environmental and conservation planning in Morocco by identifying non-random threats to diversity in terms of species' associations or ecological preferences. In addition, this treatment provides important information on a group of terrestrial vertebrates under-represented in the CAN of most countries and frequently neglected in conservation policy (MILNER-GULLAND *et al.*, 2006).

IUCN RED LIST STATUS OF MOROCCAN AMPHIBIANS (2009)

Endangered

Pelobates varaldii: The Moroccan spadefoot toad (Fig. 2a), an endemic, is locally distributed within the northwestern coastal plain among cork oak and other forested habitat and in areas of uncultivated sandy soil next to temporary ponds; DE POUS *et al.* (2012) provided 134 georeferenced localities. Spawning sites are ephemeral ponds and dayas (Fig. 3a); modified habitats are avoided, and it is the most stenoecious Moroccan amphibian (BEUKEMA *et al.*, 2013). The northernmost locality is a small, forested area just south of the Tangier airport, easternmost localities are Khemisset and south of Ouezzane, and the southernmost locality is in the vicinity of Oualidia. Suitable areas for this species along most of the Moroccan Atlantic coastline, into the Souss Valley and southwards, and discontinuously along the Mediterranean coast east to the Algerian border, potentially do exist.

ESCORIZA & BEN HASSINE (2013) have reported a newly-discovered population of *Pelobates varaldii*, represented by a tadpole from one of 21 ponds surveyed in March 2013, in the Ben Slimane region. They suggest this population likely demonstrates the relictual nature currently found in a formerly continuous distribution through northern Morocco's Atlantic coastal plain.

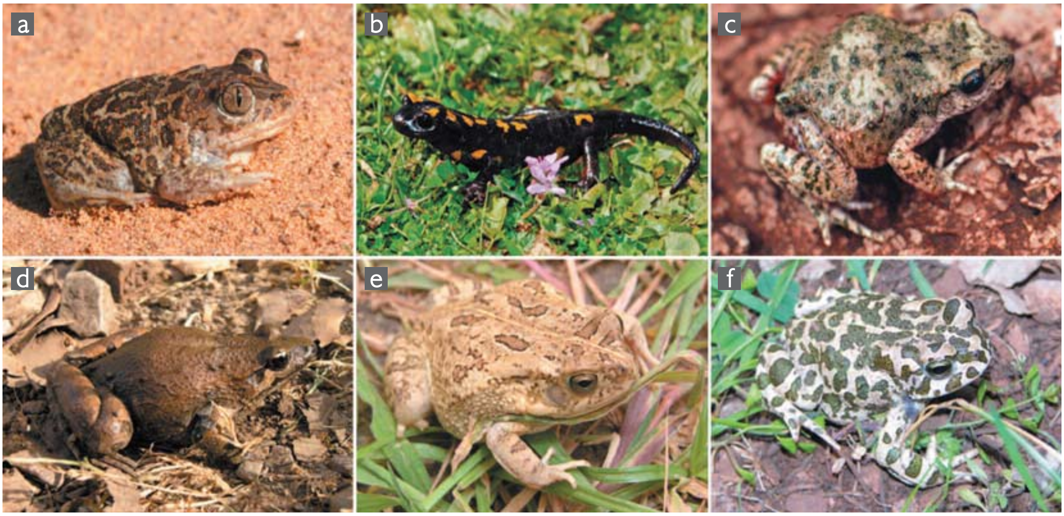

Figure 2: Portraits of some Moroccan amphibians: (a) *Pelobates varaldii* (Mamora cork oak forest). (b) *Salamandra algira* (Yebel Musa). (c) *Alytes maurus* (Chefchaouen). (d) *Discoglossus scovazzi* (Beni Snassene). (e) *Amietophrynus xeros* (Atar, Mauritania). (f) *Bufotes boulengeri* (Aïn Leuh). Photo credits: (a) P. de Pous, (b) S. Yubero, (c) S.D. Busack, (d) R. Reques and (e & f) J.M. Pleguezuelos.

Current major threats to survival derive from loss and degradation of habitat due to conversion of suitable land to pasture for, and water pollution by, livestock. Survival is contingent upon sandy soil, and industrial farming is expanding into coastal areas (DE POUS *et al.*, 2012). Populations are often restricted to temporal ponds where hydroperiods may not be sufficient for completion of larval development (developmental period is unstudied, but is dependent upon water depth, temperature, and availability of food; four to six months is likely). Tadpoles remaining in permanent bodies of water are disappearing because of introduced predatory fish (*Gambusia holbrooki*; see also SALVADOR, 1996 and STUART *et al.*, 2008) and sudden draining during the larval period. Additional discovery (November 2008, DE POUS *et al.*, 2012) of an indeterminate species of *Procambarus* (photographic documentation is suggestive of *P.* [*Ortmannicus*] *lophotus* rather than *P. clarkii* [*fide* John Cooper, North Carolina State Museum, *in litt.*, October 2010]) in a pond east of Larache (35.08122°N, 6.06908°W) signals an additional threat to this and other species. Invasive crayfish present an increasingly serious threat to aquatic organisms, including amphibian larvae, wherever they become established (COOPER & ARMSTRONG, 2007).

Batrachochytrium dendrobatidis, a globally distributed fungus responsible for chytridiomycosis and mass mortality among amphibians worldwide (HEATWOLE, 2013), has recently been reported from *P. varaldii* in Morocco. One of ten larvae sampled in April 2009, from ± 20.5 km SE Larache (35.038110°N, 6.029248°W) demonstrated a 0.4-genome equivalent infection intensity of this pathogen (EL MOUDEN *et al.*, 2011). This finding, while suggesting a low prevalence of infection, warrants additional investigation. Populations of


a
b
c
d
e
f
g
h

these amphibians are decreasing and there is urgent need for conservation and management; additional protected areas within its current range, coupled with management actions for conservation, are needed to mitigate continued population reduction.

The Evolutionary Distinct and Globally Endangered (EDGE) program at the Zoological Society of London (http://www.edgeofexistence.org/) recently listed *P. varaldii* at number 36 on their global amphibian top 100.

Vulnerable

Salamandra algira: The range of the North African fire salamander (Fig. 2b) is widely fragmented throughout northern, rather wet, mountain ranges in Morocco and Ceuta, Spain (Martínez *et al.*, 1997; Escoriza *et al.*, 2006; Bogaerts *et al.*, 2007; Escoriza & Comas, 2007; Beukema *et al.*, 2010, 2013). Recent morphological, genetic, and ecological studies suggest that there are different genotypes and phenotypes with parapatric distributions within Moroccan *Salamandra*, and further taxonomic study is warranted (Steinfartz *et al.*, 2000; Dubois & Raffaëlli, 2009; Beukema *et al.*, 2010, 2013). *Salamandra algira* populations occurring within the Rif and northern border of the Middle Atlas have been partitioned into two subspecies, *S. a. splendens* Beukema, de Pous, Donaire-Barroso, Bogaerts, Garcia-Porta, Escoriza, Arribas, El Mouden & Carranza 2013 and *S. a. tangitana* Donaire-Barroso & Bogaerts 2003. Some populations of *Salamandra* are ovoviviparous (Donaire-Barroso & Bogaerts, 2003a; Beukema *et al.*, 2013). Viviparous populations from the Tingitane Peninsula have also been proposed for species status (as *S. tingitana*; Dubois & Raffaëlli, 2009). The population in Beni Snassen is assigned to *S. algira spelaea*, which is more related to the Algerian populations. The species is locally common in the western and central Rif Mountains as well as in the Middle Atlas (Fahd *et al.*, 2006; Beukema *et al.*, 2010, 2013), in habitat associated with humid, montane areas of Atlas Cedar (*Cedrus atlantica*), Pyrenean Oak (*Quercus pyrenaica*), and mixed forest (*Abies*, *Cedrus*, *Pinus*, and *Quercus*) with an abundance of montane streams (Martínez-Medina, 2001) (Fig. 3b), and has been cited in caves (Aellen, 1951; Donaire Barroso & Bogaerts, 2001). *Salamandra algira* occurs between 100 and 2100 m above sea level.

Populations are threatened by habitat loss due to the agriculture of *Cannabis sativa* in the Rif, deforestation, alteration and channelization of water, overgrazing by livestock throughout its range and, locally, by road-kill (Taiqui, 1997; Taiqui & Martín-Cantarino, 1997). The pet trade, climatic change, and the chytrid fungus are emerging concerns (Bogaerts, 2007).

Figure 3: Habitats for some of Morocco's amphibian species. (a) Nufar pool, Kasr-el-Kebir; *P. varaldii*. (b) Stream, Talassemtane, Bab Taza; *S. algira*, *A. maurus*, and *B. spinosus*. (c) Temporary pond, Asilah. Breeding habitat, *P. waltl*. (d) Urban habitat, Chefchaouen, *S. algira*, *A. maurus*, *D. scovazzi*, and *P. saharicus*. (e) Spur of the Anti-Atlas, west of Agdz; *B. brongersmai*. (f) Lanasser pool, Rif Mountains, *H. meridionalis*, *A. mauritanicus*, and *P. saharicus*. (g) Fort Bou Cherif, *B. boulengeri*. (h) Dayet Sjri, Merzouga, Tafilalt, *A. mauritanicus*.

Photo credits: (a) D. Donaire, (b & f) R. Reques, (c & d) S.D. Busack, (e, g, & h) J.M. Pleguezuelos.

Near Threatened

Pleurodeles waltl: The Sharp-ribbed newt is distributed mainly throughout the coastal plain of northwestern Morocco (GARCÍA-PARIS *et al.*, 2004; BEUKEMA *et al.*, 2013) within a roughly triangular area connecting the Tingitane Peninsula, Souk Jemaa des Oulad Abbou, and Anosseur, but three recorded localities (Talamrhecht, Safi, Île d'Mogador) fall outside this area. In general, *P. waltl* inhabits ponds, lakes, ditches, and slow-moving streams with non-permanent water (Fig. 3c) and adjusts to habitat modified by cultivation (BEUKEMA *et al.*, 2013); populations are quite fragmented and are declining throughout the country (BEJA *et al.*, 2009).

This species is Near Threatened because of a general decline in population numbers (almost 30% over ten years) and widespread loss of habitat (BEJA *et al.*, 2009). Main threats to survival are agrochemical pollution and eutrophication caused by livestock, loss of aquatic habitat through drainage, and loss and fragmentation of terrestrial habitats (BAHA EL DIN *et al.*, 2008).

Alytes maurus: The Moroccan midwife toad (Fig. 2c) is often found in association with larvae-bearing populations of *S. algira* (DONAIRE-BARROSO *et al.*, 2006; BEUKEMA *et al.*, 2013). It has a discontinuous distribution throughout humid areas in montane-karst and forested areas (mainly *Q. pyrenaica*) close to water sources in the western and central Rif Mountains (Fig. 3b) between 200 and 2050 m above sea level (Jebel Tazekka) (see DE POUS *et al.*, 2013). Its distribution in the Middle Atlas is poorly known (LIBIS, 1985; DONAIRE-BARROSO *et al.*, 2006). A recent genetic analysis shows that *A. maurus* presents low levels of mtDNA variability with no clear geographical structuring (DE POUS *et al.*, 2013). Its current, fragmented range is likely a result of increasing temperatures throughout the Quaternary, as a fossil record likely attributable to *A. maurus* suggests a much wider historical distribution (BEUKEMA *et al.*, 2013; DE POUS *et al.*, 2013).

Populations in the Chefchaouen district are threatened by pollution due to human activity (Fig. 3d) and by introduction of the invasive Eastern mosquito fish (*Gambusia holbrooki*) (DONAIRE-BARROSO *et al.*, 2009a). In the Middle Atlas some breeding localities in the Jebel Bou Iblane region are within protected areas (site of bio-ecological interest, priority 1) but pressure from cattle grazing, deforestation, canalization of mountain-water, and soil erosion are increasing threats outside of protected areas (DONAIRE-BARROSO *et al.*, 2006). Additional threats to this species include the potential spread of recently detected chytrid fungus (EL MOUDEN *et al.*, 2011) as well as the effects of climatic change. Due to its reduced distribution (about 30 known localities in an area of less than 5000 km^2), the species has been listed as Near Threatened (DONAIRE-BARROSO *et al.*, 2009a).

Barbarophryne brongersmai: The genus *Barbarophryne* was recently published (BEUKEMA *et al.*, 2013) to reduce polyphyly within the "green toad group" by removing this species from the genera *Bufo*, *Bufotes*, or *Pseudepidalea* to which it has been variously assigned. Brongersma's toad is found from 5 m to 1000 m above sea level in suitable habitat south of Casablanca (HOOGMOED, 1972;

GENIEZ *et al.*, 2000; BEUKEMA *et al.*, 2013) where it inhabits semiarid areas of *Argania spinosa*, *Euphorbia*, grass-like vegetation, and ploughed fields. Temporary ponds where it breeds are generally located in rocky areas (Fig. 3e), and the species has been observed in artificial bodies of water (GARCÍA-MUÑOZ *et al.*, 2009). It is threatened by increased aridity and pollution and drainage of breeding habitat throughout much of its range. Although present in the Parc National de Souss-Massa, the species is probably in decline, and at a loss rate of almost 30% over ten years makes it close to qualifying for Vulnerable status (SALVADOR *et al.*, 2006).

Populations in the Souss Valley, Ifni, and Low Draa and Tekna regions, and those in northern Western Sahara, are being negatively affected by the proliferation of cisterns being built to water cattle. Toads, attracted by the humidity, fall into these underground cisterns and die when these watering structures dry up (GARCÍA-MUÑOZ *et al.*, 2009). One-meter-deep decantation chambers linked to these cisterns are frequently used by breeding toads and, while post-metamorphic toads can probably climb the vertical walls, adults are less likely to escape in this manner (L. García-Cardenete, personal communication).

Least Concern

Discoglossus scovazzi: The white-bellied painted frog (Fig. 2d) inhabits suitable habitat in Morocco and the Spanish territory of Ceuta at elevations from near sea level to 2650 m above sea level in the High Atlas Mountains (see Fig 9 in BEUKEMA *et al.*, 2013) (DUBOIS, 1982; MARTÍNEZ-MEDINA, 2001; ZANGARI *et al.*, 2006). Abundant in sub-humid and humid bioclimatic zones, but also in semiarid zones around Casablanca, this frog inhabits temporal and ephemeral ponds of fresh or slightly brackish water and montane streams (BEUKEMA *et al.*, 2013). Localized loss of breeding sites through agricultural development in inland areas and increasing salinity in lagoons are the main threats (SALVADOR *et al.*, 2009); it is presumed that the species can resist light modification of its habitat by deforestation. Chytrid fungus, *B. dendrobatidis*, recently has been reported from *D. scovazzi* at two localities in Tétouan Préfecture. One metamorphic individual sampled in November, 2006, from Agnane (near Tétouan at 35.535881°N, 5.386177°W) presented an infection intensity of 29.9 genome equivalents and one adult sampled in February, 2007, approximately 18.5 km SE Larache (35.043940°N, 6.046156°W) presented an infection intensity of 60.3 genome equivalents (EL MOUDEN *et al.*, 2011). Additional research regarding the actual extent of the distribution of this fungus is of paramount importance.

Discoglossus pictus: The western limit of distribution for the common painted frog is unclear. In Morocco apparently it is limited to a strip from the Cap des Trois Fourches Peninsula (Melilla included) to Morocco's northern border with Algeria and possibly extending westward beyond the Moulouya Basin (BEUKEMA *et al.*, 2013). It breeds in most types of still water, including temporal ponds, marshes, and brackish water. Habitat alteration, including changes in traditional land-use and urbanization (BOSCH *et al.*, 2009), is its principal threat.

Hyla meridionalis: Mediterranean treefrogs are widely distributed throughout the western Mediterranean (TEJEDO & REQUES, 2002); northern Mediterranean locations appear to have been colonized recently from Africa (RECUERO *et al.*, 2007; but see STÖCK *et al.*, 2012). Widespread in Morocco from coastal wetlands to montane habitats, it inhabits most areas adjacent to still or moving water (Fig. 3f); current gaps in its apparent range in many parts of northeastern Morocco and the Middle-Atlas and High Atlas are likely due to a lack of distributional research (BEUKEMA *et al.*, 2013). Loss of terrestrial and aquatic habitats is the major threat, but populations remain locally abundant. One of ten *H. meridionalis* larvae sampled in April, 2009, approximately 18.5 km SE Larache (Tétouan Préfecture; 35.043940°N, 6.046156°W) demonstrated a 395.9 genome equivalent infection intensity of the fungus *B. dendrobatidis* (EL MOUDEN *et al.*, 2011).

Amietophrynus xeros: The desert toad (Fig. 2e) has been recorded from the extreme south of Western Sahara. The population found in temporal pools at Aouadi, a well close to Wadi Aïn Ascaf, is probably relictual and adversely impacted by regional drought; in areas near and within Adrar Atar (Mauritania) the species is always present around natural, temporal, small reservoirs. Listed as Least Concern at the global level, at the regional level of Morocco it could be considered Vulnerable (PLEGUEZUELOS *et al.*, 2010).

Bufotes boulengeri: Previously considered a member of the Palearctic green toad complex as *Bufo viridis*, this toad (Fig. 2f) has been recently reassigned independent species status based on mitochondrial DNA (see STÖCK *et al.*, 2006, 2008; BEUKEMA *et al.*, 2013). Inhabiting forested areas, shrubland, dry grassland, semi-desert, and desert at elevations from near sea level to 2670 m above sea level (Fig. 3g), Boulenger's toad is one of the most widespread amphibians in Morocco. The main threat facing the species appears to be loss of breeding habitat through drainage of wetlands, management of natural water sources, and water pollution (IUCN, 2006). In the southern belt of its Moroccan distribution *B. boulengeri* is the species most likely to die inside modern underground cisterns built for watering cattle (L. García-Cardenete, personal communication).

Bufo spinosus: The common toad is a European species with genetically distinct relictual populations in Morocco (GARCÍA-PORTA *et al.*, 2012). Isolated populations are found along Mediterranean mountains and in other mountains except the Anti-Atlas (FAHD *et al.*, 2006; BEUKEMA *et al.*, 2013). It inhabits very humid areas near permanent water, mostly in mountainous regions (Fig. 3b), and attains an elevation of 2750 m on Jebel Tinergouet in the High Atlas. Populations might be locally impacted by deforestation, water pollution, and draining of traditional breeding places (IUCN, 2006). While not threatened at the global level (AGASYAN *et al.*, 2009), at the regional level of Morocco it can be considered Near Threatened (PLEGUEZUELOS *et al.*, 2010).

Amietophrynus mauritanicus: The Mauritanian toad is a Maghrebian endemic with a wide distribution from the northern Sahara Desert to the Mediterranean coast, but its presence in Western Sahara is unconfirmed (Donaire-Barroso *et al.*, 2009b). It frequents nearly any water source (Figs. 3f, 3h), including temporary ponds used for crops or cattle at elevations from sea level to 2650 m above sea level in the High Atlas (Dubois, 1982). This may be the most abundant and widely distributed amphibian in Morocco and it currently does not require conservation action. Some populations, however, are affected by habitat loss and casualties due to motor vehicles (Fahd *et al.*, 2002) and, attracted by humidity, some individuals die inside underground cisterns in the southern limit of its Moroccan distribution (J.M. Pleguezuelos, personal observation).

Hoplobatrachus occipitalis: The groove-crowned bullfrog, widely distributed further south in Africa, recently has been found in Western Sahara. Known only from the south-western margin of Western Sahara (Gleïb Ladjir) it survives in temporary ponds of fresh water in regions with a Sahelian climate. The principal threat to Western Saharan populations is its dependence on water; at the regional level of Morocco it could be considered Vulnerable (Pleguezuelos *et al.*, 2010).

Pelophylax saharicus: Populations of the Saharan green frog are generally widespread in Morocco from sea level to 2670 m above sea level in the Middle Atlas but fragmented in the desert because of patchy availability of habitat (oases). Locally abundant where wetland habitat exists, *P. saharicus* is one of the most commonly recorded amphibians in Morocco. An aquatic species that inhabits irrigation ditches, ponds, springs, rivers, and temporary pools, and with high tolerance to alteration of its habitat (Figs. 3d, 3g), this species is presumed to have no major threats to survival. Survival, in fact, appears assisted in some regions by artificial ponds installed for agricultural purposes.

Ecological factors affecting distribution

Understanding environmental factors and ecological requirements for survival of amphibian populations is key to developing management strategies for conservation (Semlitsch & Rothermel, 2003). Amphibian species richness is influenced by latitude within Africa, with maximum values at the Equator and minimum values at northern and southern continental extremes (Rondinini *et al.*, 2006). Other factors accounting for African amphibian richness are the presence of suitable breeding places, rainfall, and terrestrial habitats used during non-breeding periods; below we review these factors within Morocco.

With the exception of the ovoviviparous *S. a. tingitana* in mountains north and west of Tétouan (Donaire Barroso & Bogaerts, 2001; Beukema *et al.*, 2010), the presence of every native species is contingent upon aquatic habitat for larval development. Mediterranean wetlands and other suitable breeding areas are highly temporal and unpredictable, and Morocco has suffered considerable degradation and loss of wetlands (Ramdani *et al.*, 2009); ecological monitoring of 24 wetlands and adjacent habitat (4529 ha) recorded a shrinkage in area of 25% from 1978 to 1999 (Morgan, 1982; Birks *et al.*, 2001; Ramdani *et al.*, 2001; Green *et al.*, 2002). Oligohaline ponds (along the Atlantic coast), montane lakes (in the

Middle Atlas) and temporal wetlands (both in Saharan and coastal areas), habitats considered most threatened, are precisely the habitats most important for amphibian reproduction. Degradation resulting from hydrological alteration (in Atlantic plains), siltation (in some eastern semiarid areas), pollution by cattle and domestic sources (mainly in Atlantic plains) via processes very similar to those which have occurred in southern Spain (GREEN *et al.*, 2002; REQUES, 2009) are common, yet only 10 of 47 wetlands with areas greater than two hectares surveyed between 1997 and 1999 by GREEN *et al.* (2002) have been provided legal protection.

Alteration or loss of pools, streams, and gullies suitable for amphibian reproduction frequently goes unnoticed because of the small size and temporal character of these areas (OERTLI *et al.*, 2005; REQUES, 2009) yet temporary wetlands with extended hydroperiods facilitate breeding success for most amphibians (PECHMANN *et al.*, 1989; ROWE & DUNSON, 1995; WEYRAUCH & GRUBB, 2004). Permanent wetland habitat is threatened by frequent introduction of non-native species (mainly fish) that feed upon amphibian eggs and tadpoles (STUART *et al.*, 2004), and desiccation of temporal pools results in loss of eggs and tadpoles (PECHMANN *et al.*, 1991) in amphibian populations in arid regions (SEMLITSCH *et al.*, 1996; BEJA & ALCAZAR, 2003). In general, all habitat modification reducing hydroperiod in breeding areas affects survival of amphibian populations.

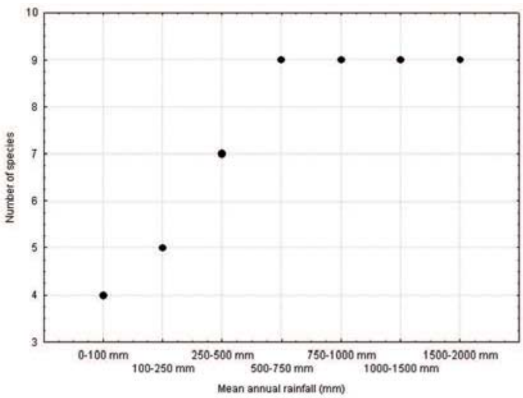

Figure 4: Amphibian species richness in relation to rainfall classes. See text for data collection protocol.

Annual rainfall influences distribution and abundance (BORKIN, 1999) and in Morocco annual average rainfall is approximately 400 mm for most of the country, increasing to between 1500 mm and 2000 mm in northern mountains and decreasing to about 50 mm in the Sahara. Data on rainfall were obtained from GLOBCOVER (2008; full resolution mode, spatial resolution of 300 m), amphibian distributional data were obtained from the Global Amphibian Assessment (IUCN, 2006) and both datasets were entered into ArcGIS 9.2® (ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE, 2006) to obtain precipitation ranges and means for distributional areas of the 14 species in Morocco. As the boundaries between *D. pictus* and *D. scovazzi* are currently not clear (see Fig. 9 in BEUKEMA *et al.* 2013), we deal with this uncertainty by considering all populations of painted frogs from Cap des Trois Fourches Peninsula east to Algeria (including the Beni Snassen) as *D. pictus*. Most species are distributed throughout northern and western Morocco in localities where annual precipitation ranges between 400 mm and 1000 mm. Only two species, *H. occipitalis* and *A. xeros* in the extreme south, are found in localities with an annual rainfall of less than 150 mm. Together with *A. mauritanicus*, *B. boulengeri*, *B. brongersmai,* and *P. saharicus,* these species represent the only Moroccan species inhabiting the desert. At the opposite extreme, *S. algira* and *A. maurus* inhabit areas with an annual precipitation greater than 600 mm (DONAIRE-BARROSO & BOGAERTS, 2003b) (Table 3, Fig. 4).

With the exception of *P. saharicus* and most populations of *P. waltl*, Moroccan amphibians can be considered terrestrial, and that is significant for conservation. Little is known about microhabitat use by most Moroccan amphibians (but see EL HAMOUMI *et al.*, 2007; DE POUS *et al.*, 2012; BEUKEMA *et al.*, 2013) and any analysis must be performed within the framework of major habitats. Landscape ecology can highlight relationships among species and landscapes, follow shifts in relationships through time, and monitor the influence of anthropogenic changes in the landscape (NAUGLE *et al.*, 2005). Data on the distributional area of major habitat types within the range of each species were obtained from GLOBCOVER (2008; see above), and the frequency of habitat use for each amphibian species analyzed by correspondence analysis (STATSOFT, 2001), which allowed assessment of relationships between landscape variables and amphibian species (PÉREZ-LÓPEZ, 2005) (Fig. 5). *Hoplobatrachus occipitalis* and *A. xeros*, associated with barren areas typical of desert regions, were again identified as isolated from the remaining species. At the opposite extreme were *A. maurus* and *S. algira*, both of which occur in forested or shrubland areas of northern Morocco. Other associations of conservation interest were those of *P. varaldii* with *P. waltl*, and of *D. scovazzi* and/or *D. pictus* with *H. meridionalis*. Anurans of the genera *Bufo*, *Bufotes*, *Barbarophryne*, and *Pelophylax* utilized the landscape in an eclectic manner.

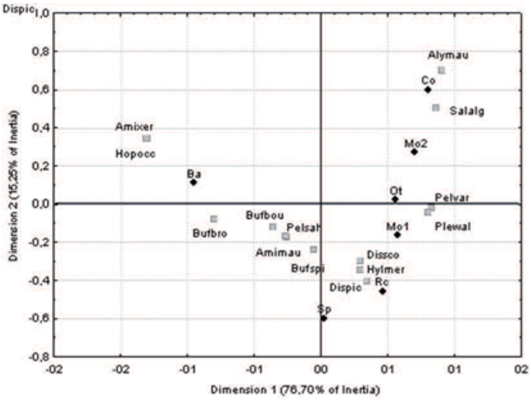

Figure 5: Correspondence between amphibian distribution and habitat type. Rc = Rainfed croplands; Ba =Bare areas; Mo1 = Mosaic cropland, 50-70% vegetation/20-50% grassland-shrubland-forest; Mo2 = Mosaic vegetation, 50-70% grassland-shrubland-forest/20-50% cropland; Co: Closed to open, >15% broadleaved or needle-leaved evergreen or deciduous, <5m shrubland; Sp = Sparse, <15% vegetation; Ot= Other. Data from GlobCover dataset (GLOBCOVER, 2008). Alymau = *Alytes maurus*; Amimau = *Amietophrynus mauritanicus*; Amixe = *Amietophrynus xeros*; Barbro = *Barbarophryne brongersmai*; Bufspi = *Bufo spinosus*; Bufbou = *Bufotes boulengeri*; Dispic = *Discoglossus pictus*; Dissco = *Discoglossus scovazzi*; Hopocc = *Hoplobatrachus occipitalis*; Hylmer = *Hyla meridionalis*; Pelvar = *Pelobates varaldii*; Pelsah = *Pelophylax saharicus*; Plewal = *Pleurodeles waltl*; Salalg = *Salamandra algira*.

PROSPECTS FOR CONSERVATION

Synthesis of Threats to Amphibian Assemblages

Survival problems faced by Moroccan amphibians can be attributed to environmental change of anthropogenic origin (IUCN, 2009); habitat loss is the major threat (Fig. 6). The negative effect of human replacement of natural habitats with agricultural, urban, or industrial sites involves loss both of suitable habitat for breeding and of connectivity

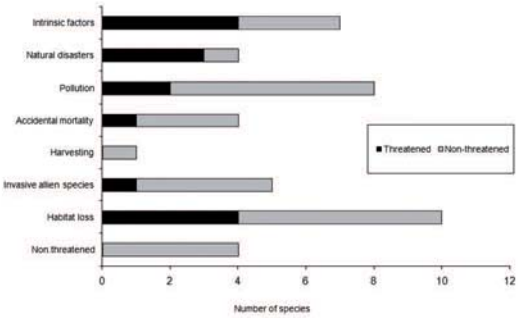

Figure 6: Major threats to Moroccan amphibians (from PLEGUEZUELOS *et al.*, 2010).

between patches of suitable habitat (LAURANCE, 2001; STUART *et al.*, 2008); the last is an increasing threat in Morocco, because of the spreading network of paved roads. These threats are particularly harmful to species with restricted distributions or ecological requirements, such as *S. algira*, *P. varaldii,* and *A. maurus*. Some species, however, do benefit from anthropogenic change; deforestation increases open habitat that may be rapidly colonized by generalist species such as *A. mauritanicus* and *H. meridionalis*. Anurans also adapt well to agricultural landscapes if habitat change is not extreme; new and modified habitats can provide artificial, but suitable, breeding habitat in the form of irrigation ponds for *P. saharicus* and *A. mauritanicus* (STUART *et al.*, 2004). Currently only four amphibian species, *A. mauritanicus*, *B. boulengeri*, *P. saharicus* and, to a lesser extent, *H. meridionalis* (because of overall resilience) exhibit relatively high tolerance to human-induced change to the landscape (deforestation and agriculture in particular).

Other recent threats include loss of suitable coastal habitat due to increasing development for tourism (affecting mainly *P. varaldii* along the Atlantic and *Discoglossus* species along the Mediterranean), and spread of other developments that modify natural water sources. Since construction of the Ouarzazate reservoir on the Oued Drâa, regular flooding ceased and oases that formerly provided suitable breeding places for *A. mauritanicus*, *B. brongersmai*, *H. meridionalis*, and *B. boulengeri* disappeared. Due to the high number of species affected, four of them threatened, intrinsic factors of the species should be considered the second major threat to Moroccan amphibians (Fig. 6). Restricted distributional area and low population density place Moroccan populations of *S. algira*, *P. waltl*, *A. maurus*, *P. varaldii*, *A. xeros*, *B. spinosus,* and *H. occipitalis*, all species with reduced dispersal capacity, in very sensitive situations.

Amphibians cannot escape natural effects resulting from climatic change (PARMESAN *et al.*, 1999; CAREY & ALEXANDER, 2003) as changes in temperature and humidity affect physiology and phenology of the reproductive process (WALTHER *et al.*, 2002; ROOT *et al.*, 2003; READING, 2007) in addition to promoting loss and fragmentation of habitat (TEWKSBURY *et al.*, 2008). Earlier estimates that at least four Endangered species and 13 Vulnerable species within Africa, most inhabiting the northern half of the continent, would be affected by climatic change (IPCC, 2007) have been reinforced by MARTÍNEZ-FREIRÍA *et al.* (2013) who predict a reduction in suitable area for 50% of Moroccan reptilian species in the future, suggesting a serious potential threat to amphibians as well. Natural disasters like the current drought affecting Western Sahara (BENASSI, 2008) could hamper survival of *A. xeros* and *H. occipitalis*, species living in desert habitats at the southern extreme of Western Sahara.

Batrachochytrium dendrobatidis, the globally distributed fungus responsible for chytridiomycosis and mass mortality among amphibians worldwide (HEATWOLE, 2013), has recently been reported in populations of *P. varaldii*, *D. scovazzi*, and *H. meridionalis* from Tétouan Préfecture. While opportunistically sampling 51 sites on the Gharb plain and in the Rif and Middle Atlas mountains between 2005 and 2009, EL MOUDEN *et al.* (2011) examined 203 amphibian specimens for presence of chytrid fungus. Three sites (6%; all north of latitude 35.038°N) proved positive for chytrid fungus. While sample sizes for individuals determined to carry the fungus were low (one *P. varaldii* tadpole of 10 sampled, one adult *H. meridionalis* of four sampled, and two *D. scovazzi* [a metamorph and an adult] from each of two sites; see IUCN Red List Status, above) and infection rates cannot be accurately determined from the data obtained, the presence of this fungus in northern Morocco introduces another serious threat to the survival of native amphibians.

When ranked by number of species affected by each major threat to Moroccan amphibians, pollution placed third (Fig. 6). Chemical pollution of freshwater has been recognized as a serious global threat to amphibian populations (BRIDGES & SEMLITSCH, 2000; SPARLING *et al.*, 2000) but while there are data concerning the effect of some pesticides on the Northern Bald Ibis (*Geronticus eremita*; ARMESTO *et al.*, 2006) in Morocco, data are lacking on the effect of pesticides upon amphibians. Pollutants in favourable breeding habitat in Morocco are generally nitrogenous derivatives from agricultural fertilizer, but urban and cattle waste also contribute. Although the relationship between pollutant level and amphibian richness is generally negative (BOONE & BRIDGES, 2003), different species do respond differently (BRIDGES & SEMLITSCH, 2000). Low pollution levels can increase trophic resources (BOONE & JAMES, 2005), and the relative abundance of some generalist species (*P. saharicus*, *A. mauritanicus,* and *H. meridionalis*) residing on the outskirts of urban areas, such as Chefchaouen, Ifrane, Goulimine, and Ouarzazate (FAHD *et al.*, 2006, 2007) may be artificially high because of pollution. Species such as *S. algira*, however, cannot tolerate this kind of pollution (DONAIRE-BARROSO & BOGAERTS, 2003a).

Non-native species in aquatic ecosystems can pose serious threats to native amphibian populations (MOUSLIH, 1987; KATS & FERRER, 2003; KIESECKER, 2003). Mosquito fish (*G. holbrooki*), for example, are known to be detrimental to amphibian breeding success (SEGEV *et al.*, 2009) and recent introductions of mosquito fish into numerous montane springs may compromise populations of *A. maurus* and other species (DONAIRE-BARROSO & BOGAERTS, 2003b; BEUKEMA *et al.*, 2013). Discovery of New World crayfish *Procambarus* cf *lophotus* (DE POUS *et al.*, 2012) suggests impending threats to aquatic amphibians in this area as well. “Once established, no methods exist by which a non-indigenous crayfish can be exterminated without unacceptable harm to native crayfishes and other organisms” (LODGE *et al.*, 2000).

Road-kills may cause local extirpation of populations when traffic levels in proximity to breeding areas are high (DODD & SMITH, 2003; HOULAHAN *et al.*, 2006). There are no data on such an impact on Moroccan amphibians, but the threat from traffic is presumed to be increasing because the number of roads and vehicles continues to increase.

An increasing threat to amphibian assemblages in arid areas of the south (Souss Valley, Ifni, Low Draa, Tekna) is the building of more and more reinforced concrete cisterns by shepherds. These deep, underground and covered structures with one or two uncovered decantation chambers positioned at the bottom of lightly sloping valleys accumulate humidity and attract amphibians. Individuals fall into decantation chambers or cisterns, both of which serve as death-traps (e.g. GARCÍA-MUÑOZ *et al.*, 2009). Although some *B. brongersmai* may breed in decantation chambers, others are subjected to predation or to dehydration as these structures become empty (L. García-Cardenete, personal communication). This increasing threat could rapidly deplete Saharan populations of *A. mauritanicus*, *B. brongersmai* and, particularly, *B. boulengeri*, in regions where they currently are scarce because of arid conditions. This hazard can be corrected easily by installation of evacuation slides.

Priority Areas

The Mediterranean Basin is considered a global hotspot for amphibian diversity and endemism (STUART *et al.*, 2008). Biogeographically, this eco-region includes four mountain chains and the northern half of the Moroccan lowlands and, as with other Mediterranean areas, Moroccan habitats are highly degraded and scarcely protected (BROOKS *et al.* 2004; WILSON *et al.*, 2007; DE POUS *et al.*, 2011). Gap analysis of diversity and distribution of amphibians, mammals, and protected areas in Africa illustrated the convenience of broadening protected areas around the western Rif, western Middle Atlas, and some localities along the Atlantic coast (RONDININI *et al.*, 2005, 2006).

Figure 7: Priority areas (shaded) for amphibian conservation (see text).

Protection of places of interest, with amphibians acting as umbrella species, would conserve other vertebrates as well (RONDININI & BOITANI, 2006). Using models for 11 amphibian and 86 reptilian species, DE POUS *et al.* (2011) defined priority areas into which the existing protected areas could be extended.

Amphibians occur in most major habitats in Morocco, and threatened species are notably present in wetlands as expected, but also in shrublands, savannahs, and deserts (Fig. 1). Threatened Moroccan amphibians have very restricted ranges, but ranges of the most threatened species include portions of the ranges of most other remaining species. Well-designed conservation area networks (CAN) will include most threatened species and much of Morocco's amphibian species richness (Fig. 7; see also DE POUS *et al.*, 2011). In northern Morocco, for example, protection of the entire range of *A. maurus* will protect eight additional species; DE POUS *et al.* (2011) showed that only about 7% of the distribution of *A. maurus* falls inside protected areas (e.g. National and Natural Parks of Jebel Bou Hachem, Bou Iblane, Talassemtane, Koudiat Tidighine, Al

Jabha Tazekka), although remaining populations are in areas so rugged that alteration is not imminent (Donaire-Barroso & Bogaerts, 2003b). In western Morocco, protection of the range of *P. varaldii* would include partial ranges of six additional species. This CAN would not include *B. brongersmai*, *A. xeros*, or *H. occipitalis*; conservation of the latter two species requires management action in the southern extreme of Western Sahara, areas currently suffering extreme drought and political problems.

Expansion of areas under protection would benefit *A. maurus* and other species of concern in Morocco, e.g. *S. algira* and *B. spinosus*. Because *P. varaldii* has not been confirmed within limits of the Merja Zerga Biological Reservation recently, it apparently does not occur in any protected area (de Pous *et al.*, 2011, 2012). The Mamora cork oak forest and surrounding area is the only locality where it is still common, and here it is highly threatened by overgrazing, logging, exotic tree plantations, and industrial development. Reduction of these negative effects and avoidance of further fragmentation (de Pous *et al.*, 2012) is essential, while establishing protected areas within this part of the range is urgent. Such action would also benefit *P. waltl*, *D. scovazzi*, *H. meridionalis*, *B. boulengeri*, *A. mauritanicus*, and *P. saharicus*.

The CAN in Morocco does not currently include all amphibian species, and a more complete network including remaining species is advisable (de Pous *et al.*, 2011). Some threat-

Table 4: Characteristics of regions having priority for amphibian conservation. For approximate regional areas, currently-protected areas, and percentages of major habitats within regions, see Globcover (2008) and text for details. Cost.A.R. = Coastal Atlantic Region; R.A.M.R. = Rif-Middle Atlas Mountain Region; Cent.A.R. = Central Atlantic Region; T.R. = Tiris Region.

	Cost.A.R.	R.A.M.R.	Cent.A.R.	T.R.
Approximate regional area (km^2)	5782	15 608	15 416	> 211 576
Currently-Protected areas	Merja Zerga, Sidi Boughaba	Talassantane, Tazekka	Souss-Massa	None
Rainfed cropland	15.8	6.9	13.1	0
Mosaic cropland (50-70%) / other vegetation (grassland / shrubland / forest) (20-50%)	36.3	24.0	16.0	0
Mosaic vegetation (grassland / shrubland / forest) (50-70%) / cropland (20-50%)	25.7	23.0	26.2	0
Closed broadleafed deciduous forest (> 40% of the area with trees > 5m in height)	0.7	6.0	0	0
Mosaic forest or shrubland (50-70%) / grassland (20-50%)	4.4	10.6	8.4	0
Closed to open (> 15%) (broad-leafed or needle-leafed, evergreen or deciduous) / shrubland (< 5 m)	11.7	19.3	4.6	0
Sparse (< 15% cover) vegetation	2.4	4.3	20.7	100
Bare areas	0.6	2.2	9.4	0

ened species are found in desert and savannah but neither habitat type is well represented in the current CAN. Areas of high priority for protection are those in which historical ecological processes continue to function and in which climatic changes forecasted for the future may be mitigated (PARRISH *et al.*, 2003; LOVEJOY, 2006; DE POUS *et al.*, 2011). It is proposed here that the northwestern Atlantic, Rif-Middle Atlas, central Atlantic, and Tiris regions be considered as priorities for amphibian conservation (Fig. 7; see also RONDININI *et al.*, 2005, 2006; CARVALHO *et al.*, 2011; DE POUS *et al.*, 2011). Currently protected areas in the first three regions should be enlarged (Table 4) and protection should be established for the Tiris region. Each of these regions contains habitat meeting ecological requirements (GLOBCOVER, 2008; see above) for the survival of Moroccan amphibians (Table 4).

NEW ECOLOGICAL STAGES AFFECTING MOROCCAN AMPHIBIANS

Morocco will achieve significant human population increase and economic amelioration in the near future (AFRICAN DEVELOPMENT BANK, 2012), both of which likely will have negative effects on natural ecosystems. Predicting how these changes will affect the amphibian fauna is difficult. One cannot rely upon modelling because time-series data for these effects on amphibian populations are not available, and one can only hypothesize future relationships between environmental change and amphibian populations. Knowledge of the ability of Moroccan amphibians to adapt to, and survive, human-induced environmental change is also lacking; some degraded habitats, abandoned quarries, or deforested areas for example, may become suitable habitat for some amphibian species.

Besides foreseeable change in land use and pollutant levels, consequences from climatic change must also be considered. The Intergovernmental Panel on Climate Change (IPCC) predicts Morocco will be severely affected by an increase in temperature and a decrease in rainfall in the near future (HULME *et al.*, 2001; IPCC, 2007; KLAUSMEYER & SHAW, 2009; LOARIE *et al.*, 2009; MARTÍNEZ-FREIRÍA *et al.*, 2013). A 15% decrease in average annual rainfall has been recorded in Morocco during the past 30 years, with periods of drought increasing in duration and intensity (BENASSI, 2008). Following this scenario, Mediterranean wetlands will face altered hydroperiods, and wetlands currently permanent will become seasonal while wetlands currently temporal will disappear (REQUES, 2005; IPCC, 2007). Shortening of the hydroperiod would affect species like *P. varaldii*, a threatened species with a relatively long larval period. It would also have negative consequences for other species through population and community effects (SCHNEIDER, 1997; MOREY, 1998). Scarcity of freshwater would hardly affect availability of water for humans (IPCC, 2007); competition for available water will increase between humans and amphibians and the loser in this competition will always be the non-humans.

Many aspects of the biology and ecology of Moroccan amphibians remain unknown (BEUKEMA *et al.*, 2013); to foresee climatic and anthropogenic effects of global change upon amphibians it is necessary to understand the natural history and tolerance of each species to environmental change. Amphibian decline occurring on the southern Iberian Peninsula because of increasing aridity (unpublished data) is probably very similar to that occurring in Morocco. Effective measures in Spain included restoring habitat in important breeding areas and creating new breeding areas (Beebee, 1996; Semlitsch & Rothermel, 2003; Reques & Tejedo, 2008). The most suitable breeding places for amphibians in Mediterranean regions are temporal, spatially heterogeneous, and with extended hydroperiods (Beja & Alcazar, 2003; Tews *et al.*, 2004). Species-specific conservation effort is needed in several cases, such as in the temporary coastal breeding ponds of *P. varaldii* and for some marginal, isolated, and scarce populations of *S. algira* and *A. maurus* (de Pous *et al.*, 2012, Beukema *et al.*, 2013).

Amphibians have survived dramatic episodes of climatic change for millions of years. Their future now depends upon humans. If measures are not undertaken to minimize the impact of humans and the harsh effect of climatic change on amphibians, some species will not survive, particularly those in countries with large arid areas like Morocco.

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