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ORIGINAL PAPER

Area prioritization and performance evaluation of the conservation area network for the Moroccan herpetofauna: a preliminary assessment

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Abstract The integration of spatial area prioritization algorithms and species distribution modelling has shown great promise in conservation planning in recent years. However, despite the fact that reptiles and amphibians have the highest threat status of all terrestrial vertebrates, these species are often under-represented in conservation planning. The Kingdom of Morocco possesses the richest and most varied herpetofauna in the Maghreb and the western Mediterranean, and is characterized by high species richness, endemism and number of European relict species. Despite the fact that Moroccan reptiles and amphibians have been the subject of numerous studies by a large number of international herpetologists since the beginning of the 20th century, few or none of these concerned their conservation. This study had three main objectives: (1) to identify those areas that harbour the highest species richness; (2) to evaluate the existing and proposed future 'important biological and ecological sites' (SIBES) conservation area network (CAN) with respect to their ability to protect the herpetofauna adequately; and (3) to identify priority areas into

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which the existing protected areas can be augmented. We used maximum-entropy species distribution modelling to run distribution models for 11 amphibian and 86 reptile species (27.6% endemics and 12.4% threatened) for which we had 2,170 single geographic records. A total of 97 models were used to create a richness map of the Moroccan herpetofauna and thereby detect both areas of high species richness and the distribution patterns of individual species. This map was subsequently used as a basis for performance evaluation of the CAN and area prioritization using the ConsNet conservation planning software initialized by "Rarity" first, while using representation targets of 5% and 10%. Additionally, the proposed future Moroccan CAN (SIBES) was evaluated in terms of its overlay and proximity with ConsNet solutions using visual interpretation and distance measurements in a GIS. Our results show that Moroccan herpetofauna is poorly protected under the existing and future CAN. Prioritization of areas shows that a major increase in conservation area is required to guarantee the persistence of individual herpetofauna species even with a global minimum representation target of only 10%. An increase of the existing CAN is especially needed along parts of the Atlantic coast, in the north-western Mediterranean region, on the north-eastern Moroccan coast, as well as in several areas in the Sahara, notably vast proportions of the Vallée du Haut and Bas Drâa.

Keywords Morocco · Conservation planning · Species distribution modelling · Maxent · ConsNet · Species richness

Introduction

The 'political' approach to selecting protected areas has traditionally been ad hoc or opportunistic and is primarily determined by economic and cultural factors (Margules 1989; Pressey 1994; Margules and Sarkar 2007). Despite the fact that many important natural areas have been given protective status based on these factors, they do not ensure regional conservation of biodiversity (Bakarr and Lockwood 2006; Meynard et al. 2009), which means that established protected areas therefore have to be complemented by reserves that incorporate the objectives of representativeness and persistence (see Margules and Pressy 2000; Margules and Sarkar 2007), alongside the three key concepts of complementarity, irreplaceability and vulnerability (Sarkar et al. 2006). In order to meet these objectives, it is important that conservation planning takes into account not only the location of reserves in relation to natural, physical and biological patterns, but also the design of these reserves, especially their shape, size, proximity and connectivity (Peres and Terborgh 1995; Shafer 1999; Margules and Pressey 2000; Haight and Snyder 2009).

Although species richness is known to be the most popular measure of conservation importance among field biologists, policy makers and the general public (Gaston 1996), the distribution patterns of individual species are equally important for conservation analyses (Margules and Pressey 2000), especially if these species are rare or have limited distributions within the study area (Margules and Sarkar 2007). It is often challenging to obtain a good representation of the distribution of individual species due to numerous factors such as landscape heterogeneity and the abundance, rarity and cryptic behaviour of these species (e.g. Gibbons et al. 1997). The use of distribution modelling algorithms has been shown to help overcome the Wallacean shortfall as it uses occurrence records alongside environmental variables to produce an index of habitat suitability for a species within a defined area (but see Cayuela et al. 2009). The integration of systematic area prioritization algorithms and species distribution modelling has shown great promise for achieving conservation goals in recent years (Sánchez-Cordero et al. 2005; Fuller et al. 2006; Sarkar et al. 2009), and has successfully been implemented using reptiles and amphibians (Pawar et al. 2007; Ochoa-Ochoa et al. 2009; Urbina-Cardona and Flores-Villela 2010). Systematic area prioritization aims to select conservation area networks (CANs) based on species distributions using algorithms that seek to maximize biodiversity representation in the smallest area of land possible (minimum area problem) whilst incorporating the concepts of complementarity, representativeness, persistence and other spatial criteria such as the size or compactness (economy) of each individual area (Margules et al. 2002; Margules and Sarkar 2007).

Reptiles and amphibians are important components of biodiversity, and amphibians are particularly valuable as bio-indicators (e.g. Hyne et al. 2009). These species are, however, often under-represented in conservation planning (Pawar et al. 2007; Urbina-Cardona 2008) despite having the highest threat status of all terrestrial vertebrates, with significantly more species at risk than either birds or mammals (Gascon et al. 2005; Cuttelod et al. 2008). The Kingdom of Morocco possesses the richest and most varied herpetofauna of the Maghreb and the western Mediterranean, which is characterized by high species richness (reptiles), endemism and European relict species (Bons and Geniez 1996). This is a direct effect of the Rif and Atlas Mountains, which divide the country into several biogeographic regions, thus resulting in a large number of climatic zones on a relatively small geographic area (Sobrino and Raissouni 2000) and the formation of several geographic barriers that allowed allopatric speciation (e.g. Brown et al. 2002; Fritz et al. 2005; Recuero et al. 2007). However, despite the fact that Moroccan reptiles and amphibians have been the subject of numerous studies by a large number of international herpetologists since the beginning of the 20th century (e.g. Boulenger 1891; Werner 1931; Hediger 1935; Aellen 1951; Pasteur and Bons 1959; Bons 1960, 1972, 1973; Mellado and Dakki 1988), few or none of these studies were directed at conservation (Bons and Geniez 1996). Phylogenetic analyses performed over the last decade have identified a multitude of evolutionary lineages in the Moroccan herpetofauna, several of which represent new (cryptic) species or species complexes (e.g. Harris et al. 2003; Perera et al. 2007; Carranza et al. 2008; Pinho et al. 2008; Fonseca et al. 2008, 2009). Furthermore, the large amounts of new distribution data presented have occasionally allowed certain species to be identified in new areas (e.g. Fahd et al. 2007; Harris et al. 2008). While Pleguezuelos et al. (2010) recently provided a regional red list of the herpetofauna from Morocco and the Western Sahara based on ranges displayed in Bons and Geniez (1996) and Geniez et al. (2004), evaluation of the performance of the CAN in respect to the herpetofauna is non-existant.

The Moroccan government established the SIBES (important biological and ecological sites) network in the framework of "The Study of Protected Areas of Morocco" (BCEOM-SECA, 1995) as an addition to the existing CAN (National Parks and Reserves). This study followed a clear approach on an ecosystem level but the designation of reserves was based solely on expert opinion. The SIBES network, which was divided into three priority levels and classified into continental wetlands, coastal wetlands and terrestrial sites, will eventually become part of the existing CAN, despite the fact that it is not known whether the existing and future CAN perform well in terms of protecting the biodiversity contained within it. More recently, Kark et al. (2009) included Moroccan herpetofauna (species richness) in their spatial prioritization study for the entire Mediterranean region. This study used IUCN distribution data and taxonomy but did not cover the entire Kingdom of Morocco. Moreover, these authors argued that refining the database on North Africa would be an important step towards a coordinated plan for the entire Mediterranean region.

In order to assess the CAN in respect to the diverse Moroccan herpetofauna on a more detailed scale, this study has three main objectives: (1) to identify those areas that harbour the highest species richness; (2) to evaluate the existing and future (SIBES) CANs with respect to their ability to protect the herpetofauna adequately; and (3) to identify priority areas into which the existing conservation areas can be augmented.

Methods

Study area

The study area comprised the Kingdom of Morocco (407,160 km^2 in the current analyses based on 1 × 1 km rasterization, see Fig. 1a) but excluded the Western Sahara due to its large geographical size and the lack of fine-scaled occurrence data. Morocco is situated on the African continent at the extreme north-western edge of the Mediterranean Basin conservation hotspot (sensu Myers et al. 2000), and is bordered to the west and north by the Atlantic Ocean and Mediterranean Sea, respectively. The southern and partially eastern boundaries are located in the Sahara desert. According to Franchimont and Saadaoui (2001), the country can be divided into three areas: the mountains (Rif and Atlas), the Atlantic plain and the semi-arid and arid regions of the south and east. Morocco has a number of terrestrial ecoregions including Mediterranean dry woodlands and steppe, Mediterranean woodlands and forests, Mediterranean acacia-argania dry woodlands and succulent thickets, as well as temperate coniferous forests, Mediterranean conifer and mixed forests, montane grasslands and shrublands, Mediterranean High Atlas juniper steppe, deserts and xeric shrublands and North Saharan steppe and woodlands (Burgess et al. 2004). Freshwater ecosystems include permanent and temporary Maghreb (Thieme 2005). Several ecosystems such as *Quercus suber*, *Argania spinosa* and *Abies pinsapo* forests have seen major decreases in the past and are still under severe threat by deforestation (e.g. Mikesell 1960; Ajbiloua et al. 2006; Esteban et al. 2010). Moreover, the Moroccan landscape is subject to land degradation, desertification and ecosystem degradation (Barbero et al. 1990; Messerli and Winiger 1992; Puigdefábregas and Mendizabal 1998; Parish and Funnell 1999; Sobrino and Raissouni 2000; McGregor et al. 2009). Morocco has a number of protected terrestrial areas that are divided under several designations; National Park (11), Biological Reserve (5), Nature Reserve (13), Reserve (4), Natural Park (2), Botanical Park (1) and Forest Sanctuary (1) (World Database of Protected Areas [WDPA] Consortium 2009 version). Additionally, there is a network with 153 SIBES that will be upgraded to protected areas in the future.

The herpetofauna of Morocco is characterized by high endemism (27.6%) and species richness (at least 98 species) and harbours centres of diversity for some reptile genera, such as *Acanthodactylus*, *Chalcides* and *Blanus*. Several species are threatened (9.7%) under IUCN Global Category and Criteria, while this percentage increases to 12.4% when applying Regional Category and Criteria (Pleguezuelos et al. 2010).

Sources of data

Occurrence data

Species occurrence records were collected in an exhaustive information search using both literature (Appendix 1) and personal field data, complemented by unpublished personal

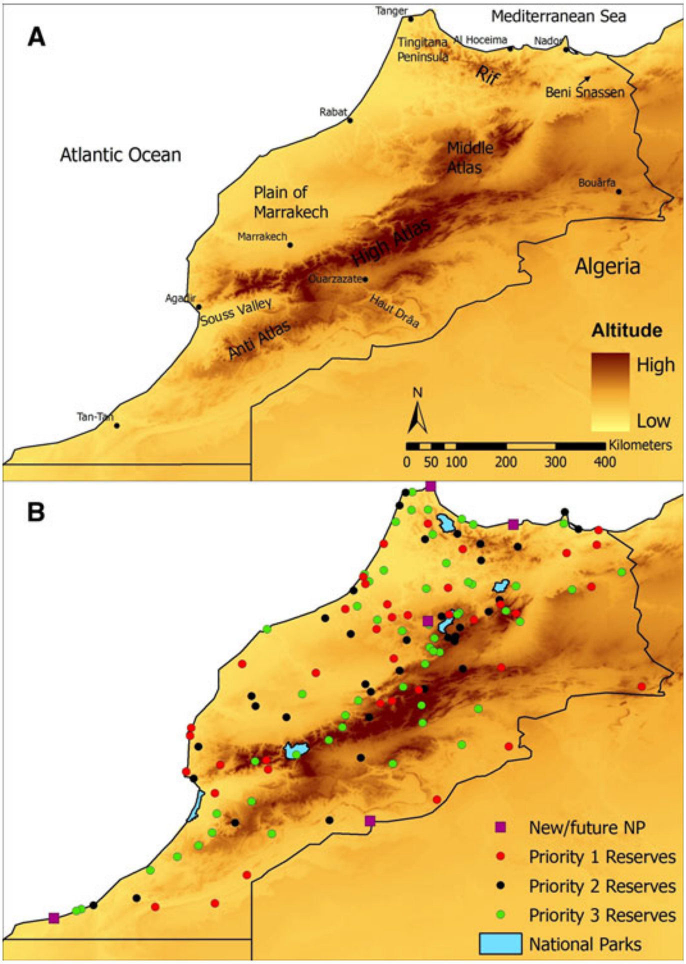

Fig. 1 Elevation map of Morocco showing (**a**) the main geographical features and cities treated in the text, and (**b**) the Moroccan CAN composed of present and future (SIBES) National Parks and different SIBES priority levels

field data provided by David Donaire-Barosso, Sergé Bogaerts and Salvador Carranza. Only literature sources and field data from 1980 onwards were used, except for some rare species with few occurrence records over time. Several species of doubtful occurrence in Morocco, or those characterized by only very few records were omitted from the analyses (*Tarentola annularis*, *T. hoggarensis*, *Trapelus tournevillei*, *Mesalina pasteuri*, *Acanthodactylus savignyi*, *Chalcides ebneri*, *Scincopus fasciatus*, *Eryx jaculus* and *Spalerosophis diadema*). All occurrence records obtained were converted in ArcGIS 9.2 to degrees-minutes-seconds and plotted into the UTM coordinate system ED50. The final database used in the study comprised 97 point files for Moroccan reptiles and amphibian species and subspecies, with a total of 2,170 occurrence records. Separate point files were constructed (see Appendix 2) for several highly genetically divergent lineages within a single species with an allopatric distribution (e.g. Brown et al. 2002; Fritz et al. 2005), following the principle of lineage-specific modelling (e.g. Arntzen and Alexandrino 2004; Tarkhnishvili et al. 2008; Beukema et al. 2010). Other species were grouped together due to reasons of taxonomic uncertainty or a lack of occurrence records (see Table 3).

Environmental parameters

Four types of environmental variables were used in this study: climatic variables, altitude, NDVI and geology (Appendix 3).

A total of 19 climatic variables were downloaded from the WorldClim database version 1.4 (http://www.worldclim.org/) to form the climatic dataset (Hijmans et al. 2005), and an altitude variable was obtained from the US Geological Survey (http://edc.usgs.gov). All variables were downloaded at a resolution of 1×1 km (30 arc seconds). Stepwise linear regression (backward) of the continuous variables was performed with SPSS 16 until the first variable reached a variance inflation factor (VIF) of less than 10 in order to exclude correlating variables (Belsley et al. 1980). The application of categorical variables was selected a priori for each species by expert judgment as models of heterogeneously distributed species could give biased results if the number of species localities does not cover all categories (e.g. Kadmon et al. 2004). A categorical normalized difference vegetation index (NDVI) was used to assess the influence of vegetation on the distribution of several species. The NDVI contains image data for each tenth day during the period from the 1st of April 1998 to the 1st of May 2008 (de Bie et al. 2008; Beukema et al. 2010). Unsupervised classification in ERDAS IMAGING with a maximum of 50 iterations and a convergence threshold of one was used for data reduction of the NDVI classes. Signature editor evaluation assessed by the minimum and average divergence of each class revealed an optimum of 75 vegetation classes for the study area. The superficial, categorical classified geology (35 classes within the study area) of North Africa was downloaded from http://www.northafrica.de/gis.htm (Persits et al. 2002).

Distribution modelling and model validation

Distribution modelling

Maximum entropy modelling (Maxent) of species' geographic distributions was used to predict the distribution of each species in combination with selected environmental parameters and occurrence records (Phillips et al. 2006, Maxent version 3.3.1). Maximum entropy is achieved by the constraint that the expected value of each variable must equal the mean value at the presence points (the empirical average) (Phillips et al. 2006). The model output displays the relative occurrence probability of a species within the grid cells of the study area. Maxent was used with default settings, configuring the algorithm to use 75% of the species records for training and 25% for testing the model. Ten replicates were run per species in order to gain an average prediction (i.e. ensemble forecasting, see Araújo and New 2007).

Model validation

All models were tested with receiver operating characteristics (ROC) curve plots, which plot the true-positive rate against the false-positive rate. The average area under the curve (AUC) of the ROC plot for ten models was taken as a measure of the overall fit for each model. Due to the fact that Maxent operates with presence records only, the AUC is calculated using pseudo-absences chosen at random from the study area (Phillips et al. 2006). The AUC is an index of habitat suitability ranging between 0.00 (highly unsuitable) and 1.00 (highly suitable) and displays the probability that a randomly chosen presence site will be ranked above a randomly chosen absence site (Phillips et al. 2006). Models with AUC values above 0.7–0.75 are considered potentially useful (Pearce and Ferrier 2000; Elith 2002).

Richness mapping

In order to combine all models for richness mapping, each logistic map displaying an index of habitat suitability was converted into binary format. Following the assumption that ten percent of the records were either wrongly identified or georeferenced (Raes et al. 2009), we used the average ten percentile threshold obtained by ensemble forecasting to convert maps, meaning, the 10% of data with the lowest predicted probabilities fall into the 'absence' region of the thresholded model, and 'presence' regions include the 90% of distribution records with the highest model values (Marske et al. 2009). All binary maps were superimposed to produce a richness map of the Moroccan herpetofauna. In order to identify regions of discrepancy (Graham and Hijmans 2006; Costa et al. 2010), the predictive richness map and the observed richness of Bons and Geniez (1996) were also visually compared.

ConsNet

ConsNet input data

The algorithm "Maxent to ResNet" (Fuller 2008) was used to convert the 97 species binary presence–absence maps into ConsNet input data. Data for the protected areas of Morocco were obtained from the WDPA Consortium (2009 version). Although several conservation areas have been elevated from SIBES to national park (NP) status in recent years (Jbel Moussa NP, Iriqui NP, Lagune de Khnifiss, Al Hoceima NP and Haut Atlas Oriental NP), these parks have not yet been gazetted (e.g. Birdlife International 2009) or incorporated into the WDPA database. These NPs were therefore excluded from the analyses in this study. Individual surface pixels of the available parks within the 1 × 1 km grid of Morocco were extracted and formatted into the permanently included cells ($n = 2{,}883$) file for ConsNet. Landcover data for Morocco was downloaded from www.landcover.org (last accessed 22 November 2009) and reclassified to only represent the populated areas of the country. Individual surface pixel values of the populated areas (cities) within the 1 × 1 km grid of Morocco were extracted and formatted into the permanently excluded cells ($n = 354$) file for ConsNet using the "Maxent to ResNet" algorithm.

ConsNet

The ConsNet conservation planning program was implemented to evaluate the performance of the existing CAN and area prioritization. As the current objective is to determine the smallest set of cells such that each species meets its representation target, ConsNet tries to minimize the area of selected land that is sufficient to contain and protect a specified representation level of biodiversity resources whilst simultaneously optimizing a variety of costs and spatial criteria such as size, compactness, replication, connectivity and alignment (for a more detailed explanation of ConsNet see Ciarleglio et al. 2008, 2009, 2010). For performance evaluation of the existing CAN, ConsNet runs were initialized with the RF4 adjacency algorithm (Ciarleglio et al. 2008, 2009, 2010), meaning that those cells that contain the rarest species which have not met the representation target are chosen first, and in the event of a tie, cells are chosen based on complementarity. Rarity-based initialization was chosen because it is known to result in more effective area selection (Pawar et al., 2007) than species richness-based initialization (Garson et al. 2002). ConsNet runs for the area prioritization were also initialized with the RF4 adjacency algorithm, although the existing CAN was permanently included in all solutions for this analysis. This procedure identifies areas into which the existing protected network can be expanded (Pawar et al. 2007). Expanding the existing network is preferred in this case because creating a completely new CAN is logistically and politically unfeasible (Pawar et al. 2007). In addition, Margules and Sarkar (2007) have argued that analyses of the extent to which existing conservation areas contribute to regional biodiversity goals might provide options for future rationalization.

Representation targets of 5% and 10% of the total expected occurrence of all species were used for both evaluations. These representation targets were used because a preliminary study on the existing and future (SIBES) CAN revealed that a higher setting was politically unfeasible due to the major increases in area that would be needed with these higher targets. All ConsNet runs were initialized with the minimum area problem (Intransitive Shape Objective, ITS) objective to seek a minimal cardinality solution and to improve the shape (compactness) of the solutions. ConsNet was run with the standard neighbourhood selection strategy for 1.000.000 iterations (Ciarleglio et al. 2008, 2009, 2010). The solutions generated were then improved by applying a basic selection strategy (using large neighbourhoods only), as recommended by Ciarleglio et al. (2008, 2009, 2010).

SIBES reserve network

Data on SIBES reserves (reserves, sensu Williams et al. 2005) were collected from, and compared with, Franchimont and Saadaoui (2001), Madbouhi and Falaki (2003), Madbouhi (2006), and the Morocco 118/119 Assessment Team (2008). The locations of these reserves (Fig. 1b) were georeferenced in ArcGIS 9.2 to pointfiles as data for the perimeter of SIBES reserves is not yet available. SIBES reserves at each priority level and class were then visually analysed in ArcGIS by means of overlay and proximity (distance) with the 5% and 10% ConsNet solutions initialized on rarity with the existing CAN permanently included.

Results

Species distribution modelling performance and richness mapping

A total of seven climatic variables (mean diurnal range, isothermality, mean temperature of wettest quarter, mean temperature of driest quarter, precipitation of wettest month, precipitation seasonality, and precipitation of warmest quarter) and one altitude variable were included in Maxent. The performance values of the 97 Maxent models resulted in an average testing AUC of 0.845 ± 0.020 (range 0.339–0.999). Seventeen models had an

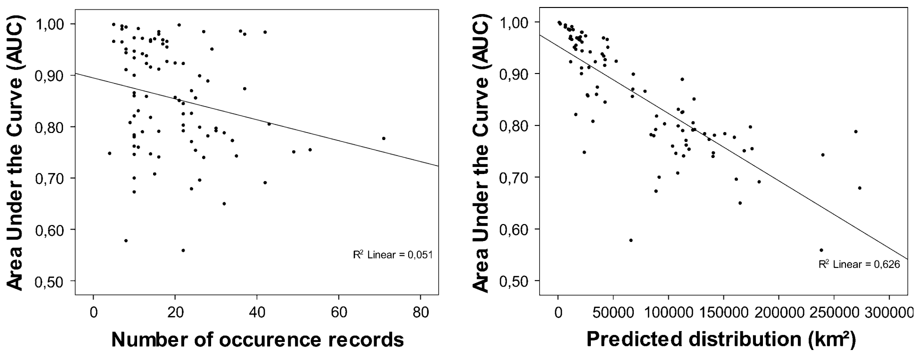

Fig. 2 The maximum area under the curve (AUC) versus the predicted distribution in km^2 and the number of coordinates used for Maxent modelling. Each point represents a species. Three species (*Bufo mauritanicus, Chamaeleo chamaeleon,* and *Pelophylax saharicus*) with a very large distribution and low AUC values were excluded from the analyses

AUC lower than 0.75, with ten of these having an AUC lower than 0.7 (Appendix 2). Narrowly distributed species had higher AUC values than widely distributed species and a very weak ($r^2 = 0.051$) negative and non-significant relationship between the number of occurrence records and the AUC was recovered (Fig. 2). ConsNet solutions initialized on the basis of rarity with adjacency resulted in large 'connected' reserves with low edge/area ratios. The total number of clusters ranged from 29 to 43 (5–10% target) for the performance evaluation of the existing CAN, and from 30 to 36 (5–10% target) for the area prioritization. Species richness appears to be highest in four disjunct areas (Fig. 3): (1) the northernmost Tingitana peninsula, including the Atlantic lowlands and the western Rif Mountains; (2) the eastern Mediterranean coastline, including the Beni Snassen Mountains, the Gourougou Massif near Nador and the upper Moulouya Basin; (3) the Atlantic coastal area, including the area north of Agadir, the Souss valley and southwards to the border with the Western Sahara, including the Valée du Bas Drâa; and (4) the Middle Atlas region. Moderate to locally high richness is achieved along the Middle Atlas and High Atlas Mountains and the Sahara desert. Areas with relatively low species richness include the semi-desert plain of Marrakech and the semi-deserts east of the High Atlas between Aïn Benimathar in the north, Bouârfa in the south, and the Algerian border in the east. The Anti Atlas Mountains are also identified as having low species richness.

Performance evaluation of the existing and future CAN

Performance evaluation solutions show a reasonable to good overlap with the existing CAN at the 5% and 10% representation targets (Fig. 4 a–b). However, the species-specific representation deficit in the existing CAN (Appendix 2) shows that only 11 of the 97 species (11.3%) have at least 5% representation in the existing conservation areas. Surprisingly, 60.8% of the 97 species have a representation lower than 1%. The maximum representation for any species is 8.37% (for *Salamandra algira algira*). Note, however, that data on the perimeter of Jbel Moussa NP, Iriqui NP, Lagune de Khnifiss, Al Hoceima NP and HAO NP were not available. These areas were therefore excluded from the analyses,

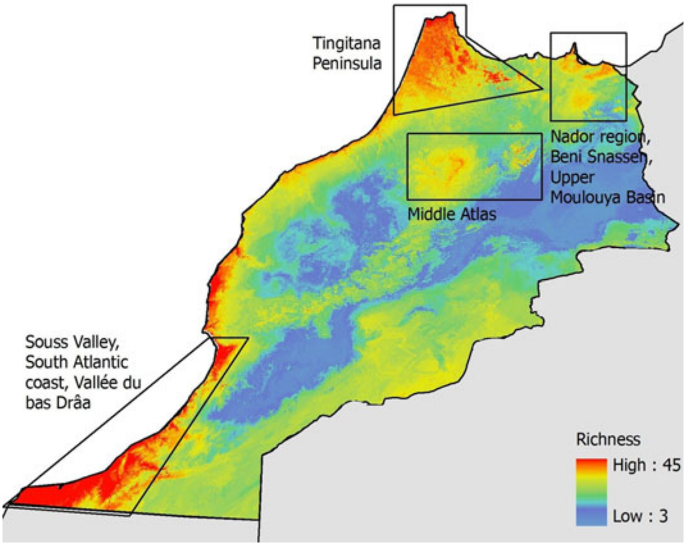

Fig. 3 Richness overview of the Moroccan herpetofauna. *Warmer colours* indicate higher richness. High richness areas are indicated in the figure with polygons. (Color figure online)

which is likely to mean that the species-specific representation percentages given here are slightly lower than the actual percentages.

Evaluation of the existing CAN shows that a large increase in area is needed for both representation targets. This increase ranges from 3.92% (15.961 km^2) to 8.61% (35.057 km^2) of the existing CAN. These projected areas have an overlap ranging from 8.23% to up to 29.85% with the existing CAN (Table 1).

An increase in projected area per target is especially clear along the Atlantic coast, the Mediterranean extreme north-western region, the north-eastern Moroccan coast, including the Beni Snassen Mountains, and several areas in the Sahara, notably the Vallée du Haut Drâa (Fig. 4a–b).

The 45 priority 1 reserves of the SIBES network (6,537.87 km^2 and 1.61% of total land surface) show a reasonable overlap with the area prioritization for both representation targets (13.3% with a 5% target and 22.2% with a 10% target). The priority 1 terrestrial reserves, however, show a rather poor overlap, with a minimum of 4% (5% target) and a maximum of 12% (10% target). The 48 priority 2 reserves (2,412.35 km^2 and 0.59% of total land surface) show a low overlap with both representation targets (6.3% with a 5% target and 16.7% with a 10% target) Finally, the 60 priority 3 reserves (716.63 km^2 and 0.18% of total land surface) show a low overlap of 13.3% for both representation targets. (See Table 2 and Appendix 4).

Area prioritization

The area prioritization solutions suggest that a slightly larger increase in area is needed than suggested by the existing CAN performance evaluation. This increase ranges from 3.98% (16.205 km^2) to 8.67% (35.301 km^2) of the existing CAN (Table 1).

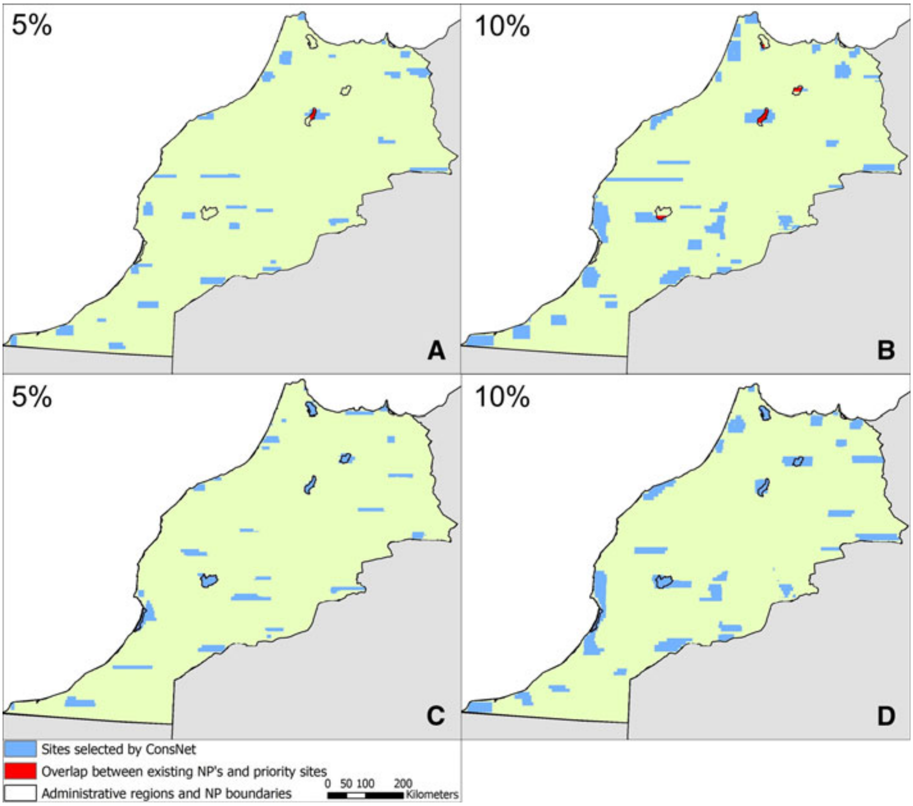

Fig. 4 **a–b** Performance evaluation of the existing CAN (initialized by rarity) obtained by ConsNet analyses for 5% and 10% representation targets. Overlap areas with the existing CAN are indicated with *red colour*. The selected area (*blue*) increases per target. **c–d** Prioritization of the Moroccan CAN (initialized by rarity with the existing CAN permanently included in each solution) obtained by ConsNet analyses for the 5% and 10% representation targets. The selected area (*blue*) increases per target. See Table 1 for a numerical summary of these results. (Color figure online)

Table 1 Results of the performance evaluation of the Moroccan existing protected area network and area prioritization using ConsNet with 87 species. All areas are in km^2

Algorithm initialization	Taxon representation target (%)	Area selected (% of total area)	Change from the existing protected area network (%)	Intersection between the existing protected area network and prioritized areas (%)
Performance evaluation	5	19,088 (4.69)	3.92	8.23
	10	38,176 (9.38)	8.61	29.85
Area prioritization	5	19,339 (4.75)	3.98	100
	10	38,427 (9.44)	8.67	100

The increase in projected area per target is, in general, similar to that obtained when evaluating the conservation areas in terms of the increase in projected Atlantic coastal areas, along the Vallée du Haut Drâa, the northeast of the country, general Algerian border areas in the Sahara and the north-western Mediterranean region (Fig. 4c–d).

Table 2 Number and surface areas of the SIBES reserve network per priority level and class

		Priority 1	Priority 2	Priority 3	Total
Terrestrial	Number	25	21	33	79
	Surface area (km^2)	5,802.5	1,495.77	637.33	7,935.60
Continental wetlands	Number	11	14	17	42
	Surface area (km^2)	225.10	72.5	78.5	376.10
Coastal wetlands	Number	9	13	10	32
	Surface area (km^2)	510.27	844.08	0.8	1,355.15
Total	Number	45	48	60	153
	Surface area (km^2)	6,537.87	2,412.35	71,663	9,666.85
	Total area (%)	1.61	0.59	0.18	2.38

Discussion

Maxent model performance and implementation

With a resulting average AUC of 0.845 ± 0.020, which is above the 0.7–0.75 target value, Maxent was implemented ‘moderately’ successful (Swets 1988). This can be explained by three shortcomings. It is well known that the use of coarse scale variables in distribution modelling can lead to inappropriate reserve location selection (e.g. Seo et al. 2009), therefore we chose a spatial scale of 1 × 1 km, which probably also has a positive effect on model performance in comparison with coarser resolutions (Hernandez et al. 2006; Pawar et al. 2007; Kaliontzopoulou et al. 2008). Secondly, the use of pseudo-absences can influence AUC values. While it is known that models based on random pseudo-absences have the lowest fit when compared to models with true absences (e.g. Wisz and Guisan 2009), the gathering of true absences is often highly time- and material consuming (Kéry 2002). Gathering true absences within the scale of the current project was not considered feasible. Finally, AUC values tend to be higher for the prediction of ecologically specialized or rare species when compared to the prediction of generalist species, relative to the study area described by the environmental data (e.g. Luoto et al. 2005; Elith et al. 2006; Hernandez et al. 2006; Jiménez-Valverde and Lobo 2007). As the current study area is very large and is characterised by a high variation of climatic regions, it could be expected that narrowly distributed species within the study area will achieve a high AUC score due to comparison with the many absence sites (Elith et al. 2006). Indeed, in agreement with previous studies, most narrowly distributed species achieve both high to very high average AUC values (Fig. 2) and present a very good fit as regards their true distribution data (Bons and Geniez 1996). As a result of the upper stated shortcomings, the use of AUC values as indicators of model performance is the subject of ongoing debate (e.g. Lobo et al. 2008) but is still widely used because other model improvement methods have only been developed very recently (Warren and Seifert 2010; Phillips and Elith 2010). Since these methods have not been used widely and require substantial methodological and theoretical immersion that is currently beyond the ‘applied’ scope of this paper, AUC was used despite the acknowledgeable shortcomings of this method.

Although the current average number of occurrence records per species is relatively low (22.37 ± 24.58), especially when compared to several previous studies (Elith et al. 2006; Hernandez et al. 2006; Pineda and Lobo 2009, but see Pawar et al. 2007), a very weak and non significant negative relationship between the number of occurrence records and the AUC was recovered (Fig. 2). This might suggest that a larger number of occurrence records does not necessarily guarantee higher predictive accuracy, as is often concluded (e.g. Kadmon et al. 2003; Hernandez et al. 2006; Wisz et al. 2008) but occasionally refuted (Elith et al. 2006). However, this is by no means conclusive as Maxent is known to achieve high predictive accuracy with few occurrence records and is relatively insensitive to low sample sizes when compared to other algorithms (e.g. Hernandez et al. 2006; Pearson et al. 2007; Wisz et al. 2008; Costa et al. 2010).

Despite several overviews (e.g. Liu et al. 2005; Jiménez-Valverde and Lobo 2007; Pineda and Lobo 2009), there is still no consensus on the "best" threshold method to be implemented when converting probability maps into binary format. Although a recent method proposed by Pineda and Lobo (2009) appears promising, the current choice for species-specific thresholds was based on expert knowledge of Moroccan herpetofaunal distribution. The ten percentile threshold was likewise chosen because of its widespread use (e.g. Urbina-Cardona and Loyola 2008; Brito et al. 2009; Raes et al. 2009) and the possible error of some of the occurrence records used to model the species' distributions (Raes et al. 2009).

Although an increasing number of studies have used probabilistic distribution data in conservation planning in recent years (e.g. Pawar et al. 2007; Sarkar et al. 2009), we used binary distribution data as this allowed us to identify regions of discrepancy (Graham and Hijmans 2006; Costa et al. 2010) by means of comparison with Bons and Geniez (1996) and our in-depth knowledge of Moroccan herpetofauna. However, the development and improvement of conservation planning software that can interpret probabilistic expectations (e.g. Ciarleglio et al. 2009, 2010) shows great promise and should be considered for any future conservation planning studies in Morocco.

Richness mapping

The predicted richness is largely in agreement with the richness map compiled from actual observations displayed by Bons and Geniez (1996). Indeed, both the semi-desert plain of Marrakech and the semi-deserts east of the High Atlas harbour low species richness, in agreement with our predictive map. There are, however, several differences between the predictive and actual observations. In the current analyses the Anti Atlas Mountains are characterized by relative low to very low species richness, which differs from the observations of Bons and Geniez (1996). This might be attributable to a combination of unique climatic circumstances within the mountains with respect to the rest of Morocco and a relatively low number of species occurrence records from this region incorporated in the species models. Likewise, predictive species richness in the Sahara desert is moderate to high, whereas Bons and Geniez (1996) show relatively low numbers of actual observations from this area due both to the remoteness and deficiency of roads in the area and the nocturnal or cryptic behaviour displayed by several species (Schleich et al. 1996). Hence, the use of predictive species distribution modelling proved very useful in this area.

The northernmost Tingitana peninsula is characterized by high species richness due both to the heterogeneous landscape of the Rif Mountains and Atlantic lowlands. Further eastwards, recurring areas of high richness along the coast from Al Hoceima to the Algerian border can again be explained by the heterogeneous landscape but also the occurrence of several narrowly distributed species in this area such as *Chalcides mauritanicus*, *C. parallelus* and *Macroprotodon abubakeri* (Fahd et al. 2005). Southern-lying areas of relatively high richness continue through the Middle Atlas and High Atlas

Mountains towards Agadir, mostly due to the number of (largely) endemic species within these mountains, such as both *Quedenfeldtia* species, *Chalcides montanus* and *C. lanzai*, *Atlantolacerta andreanszkyi,* and *Vipera monticola* (Bons and Geniez 1996). The high richness along the Atlantic coastline southwards of Agadir is explained by southwards increasing numbers of reptile species confined to desert areas (Geniez et al. 2004). The Atlantic coastal area around Essaouira (north of Agadir) is characterized by possible overprediction of several more southern occurring reptile species, since the High Atlas mountains, which reach the Atlantic coast near Agadir, seem to have functioned as a barrier for most of these species (albeit not for all; e.g. *Bufo brongersmai*, *Naja haje*). We therefore identify this area as a 'potential' distribution for these species and the actual species richness in this area might be lower. The Sahara desert all along the Algerian border in the south is characterized by moderate species richness due to the absence of most northern-occurring species and the presence of many desert-dwelling reptile taxa.

Performance evaluation of the existing and future CAN

The only known comprehensive area prioritization study for Morocco is the SIBES network (Appendix 4). Although the SIBES network was designed following a clear ecosystem level approach, the designation of sites for prioritization was based solely on expert judgement, thus meaning that this planning approach is not standardized or repeatable (Margules and Sarkar 2007). The absence of an algorithmic approach without clear representation targets also means that the complementarity that each area contributes to the full complement of biodiversity features, in this case ecosystems, cannot be measured. It is therefore not known what percentage of each ecosystem is protected under the future (SIBES) CAN. A network of conservation areas that represents the range of different environmental combinations in a region might be a sensible strategy for prioritizing areas (Margules and Sarkar 2007). However, this method has several limitations as relationships between environmental classes and the distribution patterns of taxa can be unclear and difficult to quantify (Pressey 1992). Furthermore, some species may require a combination of environmental variables not recognized by a classification (Pressey 1992). It is therefore not remarkable that the results of the current study show some clear differences from those of Franchimont and Saadaoui (2001) and the Morocco 118/119 Assessment Team (2008) (see Appendix 4).

The SIBES network represents a misleading overlap with the area prioritization solutions when looking at priority levels only. Coastal and continental wetlands are reasonably covered under the 10% representation target, whereas terrestrial sites are poorly covered under both presentation targets. Consequently, reptile and amphibian species that mainly live inland are not well protected under the future conservation area (SIBES) network.

Area prioritization

Despite the fact that many previous studies used sets of species covering entire taxa (e.g. all birds, mammals) as estimator surrogates for biodiversity (Margules and Sarkar 2007), most studies that have analyzed the performance of such taxonomic surrogate sets report pessimistic results (e.g. Prendergast et al. 1993; Dobson et al. 1997; Lund and Rahbek 2002; Kati et al. 2004; Sarkar et al. 2005). The results of this study should therefore not be taken as an area prioritization study for overall biodiversity in the region.

Based on a lower overall species richness for amphibians compared to other Mediterranean EU countries, due to drier habitats and lower primary vegetation production and the fact that endemic North African reptiles and amphibians are relatively widespread where conservation costs are lower, Kark et al. (2009) selected very few priority areas in Morocco and North Africa. As this study used coarse-scaled (10 × 10 km) distribution data based on current Linnean shortfall IUCN taxonomy and only included the part of Morocco that belongs to the Mediterranean biome, we argue that the study by Kark et al. (2009) should be seen as a step forward towards a Euro-Mediterranean inter-country collaboration instead of a comprehensive area prioritization study for Morocco and the entire North African region.

Prioritization of areas reveals that a major increase in area is needed to achieve a better representation for reptiles and amphibians. For example, to achieve a representation of 10% for all 97 species, the area covered by the existing conservation areas would need to increase with 1,225.35% (to 38,427 km^2 from the current total of 3,136 km^2). This seems unfeasibly high despite the fact that a representation target of 10% lies towards the lower end of the range reported for solutions globally (Kelley et al. 2002; Wilson et al. 2005; Pawar et al. 2007). Moreover, Soulé and Sanjayan (1998) argue that global targets such as 10% and 12% might be too small for the persistence of many species. The maximum representation target (10%) chosen for this study might therefore not per se guarantee the persistence of species over time, but was mainly chosen for political expediency as the future CANs best solution (with all SIBES priority levels and National Parks included), with a size of 9,666.85 km^2, does not even comes close to the 5% target (19,339 km^2) of this study.

Conclusions and recommendations

The Moroccan herpetofauna is poorly protected under the existing (NP) and future (SIBES) CAN. Evaluation of the existing CAN reveals that a major increase in conservation areas is needed to guarantee the persistence of individual herpetofauna species even under a global minimum representation target of 10%. Expansion of the existing CAN is especially needed along many parts of the Atlantic coast, the Mediterranean extreme north-western region, the north-eastern Moroccan coast and inland areas and several areas in the Sahara, notably vast proportions of the Vallée du Haut and Bas Drâa.

Urbina-Cardona and Flores-Villela (2010) showed that CANs for Mexican mammals had very little coincidence with those required to preserve herpetofauna. Hence, future comparative studies should be directed at incorporating additional taxonomic groups (e.g. birds, mammals) and probabilistic distribution data combined with expert judgement to develop an integrative network of conservation reserves for Morocco. Likewise, the implementation of new conservation planning techniques (e.g. Gordon et al. 2009; Becker et al. 2010; Carroll et al. 2010; Edwards et al. 2010; Orestes Cerdaira et al. 2010; Urbina-Cardona and Flores-Villela 2010) should guarantee the persistence of biodiversity in the Kingdom of Morocco over time.

Moreover, the prioritized and high richness areas identified in this study could be useful in focusing field expeditions searching for new herpetofauna species and distribution records.

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Appendix 1

Literature sources that were used to gather species occurrence records used for species distribution modelling.

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Appendix 2

See Table 3.

Table 3 Amphibian and reptile species used in the Moroccan herpetofauna conservation assessment, with the number of point localities used for Maxent modelling, AUC values, regional red list status (following Pleguezuelos et al. 2010), predicted distribution, predicted distribution in the existing protected area network and percent of protected habitat in the existing protected area network given for each species

Taxon	Number of point localities	AUC	Current IUCN status	Predicted distribution (km^2)	Predicted distribution in protected areas (km^2)	Protected habitat (%)
Salamandra algira tingitana	21	0.998	VU	1,550	0	0
Salamandra algira algira	36	0.986	VU	9,402	787	8.37
Pleurodeles waltl	16	0.980	NT	21,329	52	0.24

Table 3 continued

Taxon	Number of point localities	AUC	Current IUCN status	Predicted distribution (km^2)	Predicted distribution in protected areas (km^2)	Protected habitat (%)
Alytes maurus	42	0.984	NT	10,439	727	6.96
Discoglossus scovazzi + *D. pictus*	30	0.792	LC + NE	88,405	2,509	2.84
Pelobates varaldii	27	0.985	EN	13,748	0	0
Bufo bufo	24	0.826	NT	113,011	2,592	2.29
Bufo boulengeri	53	0.755	LC	175,706	2,050	1.17
Amietophrynus mauritanicus	153	0.596	LC	253,110	2,760	1.09
Bufo brongersmai	43	0.805	NT	122,258	261	0.21
Hyla meridionalis	71	0.777	LC	159,639	2,834	1.78
Pelophylax saharicus	187	0.584	LC	252,136	2,719	1.08
Testudo graeca	30	0.797	LC	174,157	1,684	0.97
Emys orbicularis occidentalis	22	0.923	VU	33,705	1,266	3.76
Mauremys leprosa leprosa	28	0.889	LC	112,523	979	0.87
Mauremys leprosa saharicus	12	0.790	LC	112,842	261	0.23
Tarentola mauritanica	32	0.650	LC	164,907	1,486	0.9
Tarentola boehmei	14	0.818	LC	89,248	2	0
Tarentola deserti	14	0.969	LC	16,899	0	0
Tarentola chazaliae	12	0.972	LC	11,412	216	1.89
Hemidactylus turcicus	7	0.990	LC	6,589	41	0.62
Quedenfeldtia trachyblepharus	7	0.965	NT	19,803	931	4.7
Quedenfeldtia moerens	10	0.934	LC	41,397	987	2.38
Ptyodactylus oudrii	27	0.740	LC	140,346	35	0.02
Stenodactylus mauritanicus	16	0.741	LC	113,691	0	0
Stenodactylus petrii	10	0.973	LC	24,958	0	0
Saurodactylus brosseti	24	0.870	LC	67,764	261	0.39
Saurodactylus mauritanicus	10	0.947	LC	16,141	0	0
Saurodactylus fasciatus	10	0.900	NT	21,206	85	0.4
Tropiocolotes algericus	10	0.700	LC	91,582	0	0

Table 3 continued

Taxon	Number of point localities	AUC	Current IUCN status	Predicted distribution (km^2)	Predicted distribution in protected areas (km^2)	Protected habitat (%)
Chamaeleo chamaeleon	9	0.339	LC	381,759	2,599	0.68
Agama impalearis North of Great Atlas	28	0.782	LC	84,206	1,629	1.93
Agama impalearis South of Great Atlas	22	0.559	LC	238,460	294	0.12
Trapelus mutabilis	10	0.781	LC	141,622	0	0
Uromastyx nigriventris	10	0.784	LC	151,026	0	0
Varanus griseus	10	0.673	LC	88,733	0	0
Timon tangitanus + *T. pater*	37	0.874	LC + NE	35,594	2,182	6.13
Atlantolacerta andreanszkyi	11	0.991	NT	12,462	775	6.22
Scelarcis perspicillata	10	0.860	LC	34,849	1,971	5.66
Podarcis "vaucheri"	18	0.927	LC	42,646	2,131	5
Psammodromus algirus	26	0.799	LC	108,776	1,860	1.71
Psammodromus blanci	8	0.911	NT	21,270	0	0
Psammodromus microdactylus	20	0.857	EN	27,054	1,285	4.75
Ophisops occidentalis	8	0.951	LC	14,741	0	0
Mesalina olivieri	15	0.708	LC	108,423	261	0.24
Mesalina simoni	9	0.808	LC	31,599	108	0.34
Mesalina guttulata	14	0.747	LC	140,644	0	0
Mesalina rubropunctata	14	0.966	LC	44,523	0	0
Acanthodactylus erythrurus complex	34	0.773	LC	136,783	2,729	2
Acanthodactylus maculatus + *A. busacki*	11	0.760	LC + LC	103,758	261	0.25
Acanthodactylus boskianus	25	0.856	LC	67,326	49	0.07
Acanthodactylus dumerili	8	0.944	LC	21,745	0	0
Acanthodactylus longipes	5	0.966	NT	12,433	0	0
Acanthodactylus aureus	16	0.985	LC	10,917	192	1.76
Chalcides ocellatus ocellatus	24	0.771	LC	115,877	0	0
Chalcides ocellatus subtypicus incl. *C. o. tiligugu*	37	0.980	LC	21,730	47	0.22
Chalcides manueli	13	0.923	VU	11,437	113	0.99
Chalcides colosi	14	0.968	LC	10,980	648	5.9
Chalcides lanzai + *C. montanus*	17	0.961	NT + NT	21,678	1,525	7.03

Table 3 continued

Taxon	Number of point localities	AUC	Current IUCN status	Predicted distribution (km^2)	Predicted distribution in protected areas (km^2)	Protected habitat (%)
Chalcides pseudostriatus	26	0.899	NT	68,196	1,205	1.77
Chalcides minutus	29	0.951	VU	45,072	808	1.79
Chalcides mauritanicus	7	0.996	EN	2,000	0	0
Chalcides parallelus	5	0.999	EN	1,103	0	0
Chalcides polylepis	25	0.754	LC	118,611	374	0.32
Chalcides mionecton	12	0.942	LC	29,091	261	0.9
Chalcides sphenopsiformis	8	0.994	LC	6,652	152	2.29
Chalcides boulengeri	20	0.924	LC	52,654	0	0
Scincus albifasciatus	15	0.971	LC	20,231	0	0
Eumeces algeriensis	22	0.825	LC	112,215	347	0.31
Hyalosaurus koellikeri	22	0.803	LC	96,481	2,410	2.5
Blanus tingitanus	10	0.821	LC	16,122	767	4.76
Blanus mettetali	22	0.792	LC	123,773	1,185	0.96
Trogonophis wiegmanni wiegmanni	13	0.938	LC	39,976	161	0.4
Trogonophis wiegmanni elegans	21	0.851	LC	123,193	2,306	1.87
Myriopholis macrorhynchus	11	0.831	LC	108,891	0	0
Hemorrhois hippocrepis	26	0.696	LC	161,382	2,001	1.24
Hemorrhois algirus	22	0.845	LC	42,581	24	0.06
Spalerosophis dolichospilus	10	0.784	LC	132,739	0	0
Coronella girondica amaliae	14	0.916	LC	42,275	2,148	5.08
Macroprotodon abubakeri, *M. brevis* and *M. cucullatus*	32	0.788	DD NT LC	269,681	2,816	1.04
Telescopus tripolitanus	8	0.578	DD	66,067	0	0
Lytorhynchus diadema	10	0.762	LC	116,029	0	0
Boaedon fuliginosus	16	0.912	VU	27,931	261	0.93
Dasypeltris sahalensis	10	0.866	VU	78,788	261	0.33
Natrix natrix	17	0.969	NT	41,167	1,981	4.81
Natrix maura	49	0.751	LC	168,587	2,011	1.19
Malpolon monspessulanus + *M. insignitus*	35	0.743	LC + NE	239,863	2,847	1.19
Scutophis moilensis	10	0.780	LC	86,728	0	0
Psammophis schokari	24	0.679	LC	273,254	977	0.36
Naja haje	16	0.791	Not evaluated	122,045	261	0.21
Vipera latastei	17	0.969	NT	18,624	940	5.05
Vipera monticola	18	0.955	NT	16,230	1,006	6.2

Table 3 continued

Taxon	Number of point localities	AUC	Current IUCN status	Predicted distribution (km^2)	Predicted distribution in protected areas (km^2)	Protected habitat (%)
Daboia mauritanica	42	0.691	NT	182,134	1,217	0.67
Cerastes cerastes	10	0.746	LC	106,668	0	0
Cerastes vipera	18	0.966	LC	18,955	0	0
Bitis arietans	13	0.859	VU	26,481	187	0.71
Echis leucogaster	4	0.748	VU	23,792	0	0

Appendix 3

See Table 4.

Table 4 Metadata table with all the environmental variables used in this study

Ecogeographical parameters	Period	Source
Annual mean temperature 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Mean diurnal range: mean of monthly (max temp – min temp) 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Isothermality: (P2/P7) × 100 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Temperature seasonality (sd × 100) 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Max temperature of warmest month 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Min temperature of coldest month 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Temperature annual range (P5–P6) 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Mean temperature of wettest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Mean temperature of driest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Mean temperature of warmest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Mean temperature of coldest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Annual precipitation 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation of wettest month 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation of driest month 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation seasonality (coefficient of variation) 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation of wettest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation of driest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation of warmest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
Precipitation of coldest quarter 1 × 1 km	1950–2000	BioClim (Hijmans et al. 2005)
NDVI 1 × 1 km	1998–2008	ITC Enschede (de Bie et al. 2008)
Geology	2002	Persits et al. (2002)
Altitude	2005	USGS
Landcover 1 × 1 km	1981–1994	Hansen et al. (2000)

Appendix 4

See Table 5.

Table 5 The SIBES reserves used for evaluation in this study with priority level, location and size given per reserve. For the SIBES performance analyses overlay and proximity with the ConsNet rarity with the existing protected area network permanently included was made for each representation target (5% and 10%). SIBES reserves that fall within a solution are indicated with an X, whereas figures stand for distance (km) from the edge of the nearest ConsNet solution

Name	Code	Priority	Latitude (N)	Longitude (W)	Size (hectares)	5%	10%
Continental wetlands (42)							
Lac de Tislite	H34	1	32 12 00	05 38 00	250		
Aguelmam-Afennourir	H21	1	33 17 00	05 16 00	600	X	X
Oued Tizguit	H17	1	33 34 00	05 05 00	800	X	X
Dayet Er-Roumi	H9	1	33 45 00	06 12 00	150		
Dwiyate	H10	1	34 03 00	05 06 00	200		
Barrage Mohammed V	H2	1	34 41 00	02 57 00	6500	7.2	7.2
Barrage Al Massira	H29	1	32 30 00	07 30 00	14000		
Daya Mamora	H6	1	34 07 00	06 36 00	????		
Oued El Bared	H12	1	33 57 00	04 00 00	10	X	
Assif n'Ouarzane	H37	1	31 10 00	07 57 00	????	X	X
Assif n' Aït Mizane	H38	1	31 03/31 13	07 54/07 57	????	3.2	X
Aguelmane Sidi Ali	H25	2	33 05 00	04 59 00	500		
Barrage Mansour Ad Dahbi	H42	2	30 58 00	06 41 00	5000		6.1
Oued Lakhdar	H35	2	31 42 00	06 32 00	10		
Sebkha Zima	H30	2	32 05 00	08 40 00	300		
Lac d'Isli	H33	2	32 13 00	05 32 00	400		
Barrage El Maleh	H8	2	33 30 00	07 20 00	900		
Source de Tit Zill	H20	2	33 20 00	04 53 00	10		
Aïn Bou Adel	H3	2	34 33 00	04 30 00	10		
Aguelmane N'Tifounassine	H22	2	33 09 00	05 06 00	50	9.3	9.4
Guelta Tamda	H13	2	33 50 13	04 04 00	????		
Lac d'Ifni	H39	2	31 02 00	07 53 00	35	X	X
Daya Tamezguidat	H43	2	31 06 00	04 03 00	????	6.4	
Gorges d'A'azzi	H19	2	33 29 00	04 37 00	????		
Wad Zegzel amout	H1	2	34 48/34 52	02 21/02 24	????		X
Barrage Idriss premier	H11	3	34 07 00	04 40 00	4000		4.8
Dayet Iffer	H14	3	33 36 00	04 54 00	20	6.5	6.5
Dayet Ifrah	H18	3	33 34 00	04 56 00	250	3.4	3.4
Plan d'eau Zerrouka I	H16	3	33 33 00	05 05 00	10		X
Plan d'eau Amghass	H23	3	33 23 00	05 27 00	10		7.0
Aguelmam Ouiouane	H24	3	33 08 00	05 21 00	30		
Aguelmane Abekhane	H28	3	32 40 00	05 31 00	40		
Aguelmane Azigza	H26	3	32 58 00	05 26 00	600		
Aguelmane Mi'Ammi	H27	3	32 54 00	05 22 00	60		
Merja Bokka	H4	3	34 22 00	06 16 00	10	5.1	5.1

Table 5 continued

Name	Code	Priority	Latitude (N)	Longitude (W)	Size (hectares)	5%	10%
Dayet Aoua	H15	3	33 39 00	05 02 00	300	X	X
Oued Fouarate	H5	3	34 10 00	06 32 00	400	8.5	8.5
Cascades d'Oufoud	H32	3	32 00 00	06 44 00	100		
Sahb Al Majnoun	H31	3	32 07 00	07 45 00	2000		
Source Tizi-n-Test	H41	3	34 09 00	04 44 00	10		
Assif N'Tifnoute	H40	3	31 01 00	07 51 00	10	X	X
Assi Rerhaya	H36	3	3108/31 21	07 55/07 59	????	X	X
Coastal wetlands (32)							
Archipel Essaouira	L26	1	31 30 00	09 48 00	27		
Dunes d'Essaouira	L25	1	31 22 00	09 48 00	11000		9.8
Embouchure Moulouya	L1	1	35 06 00	02 22 00	2700		X
Embouchure du Tamri	L27	1	30 43 00	09 51 00	900	7.0	7.9
Merja Zerga	L16	1	34 51 00	06 16 00	7000	X	X
Sidi Bou Ghaba	L18	1	34 15 00	6 39 00	800	6.4	9.1
Sidi Moussa Oualidia	L24	1	32 40 00	8 50 00	6000		
Foum Assaka	L30	1	29 07 00	10 25 00	19000		
Marais de Larache	L12	1	35 07 00	06 00 00	3600		X
Ilots de Bou Regreg	L20	2	34 00 00	06 49 00	5		
Cap des 3 Fourches	L3	2	35 26 00	02 59 00	8000	9.4	
Cap Ghir	L28	2	30 35 00	09 43 00	4000	5.1	4.9
Falaise de Sidi Moussa	L19	2	34 07 00	06 45 00	300		
Embouchure Oued Drâa	L32	2	28 25 00	10 45 00	40000		X
Ilot de Skhirat	L31	2	33 53 00	07 04 00	3		
Jorf Lasfar	L23	2	33 10 00	08 38 00	300		5.7
Oued Cheibeka	L33	2	28 17 00	11 32 00	3500		X
Oued Tahadart	L11	2	35 34 00	06 00 00	14000		
Sebkha Bou Areg	L2	2	35 10 00	02 45 00	14000		
Merja Halloufa	L15	2	34 58 00	06 15 00	300		X
Merja Oulad Skhar	L13	2	35 04 00	06 13 00	1.5		5.1
Merja Bargha	L14	2	35 02 00	06 13 00	????		6.1
Baie de Haouzia	L22	3	33 18 00	08 24 00	10	X	X
Cap Spartel	L10	3	35 47 00	05 45 00	10		9.7
Cirque d'El Jebha	L5	3	35 12 00	04 39 00	10		
Cote Rhomara	L6	3	35 20 00	04 50 00	10		
Oued Amma Fatma	L34	3	28 13 00	11 46 00	10		3.3
Oued El Ouar	L35	3	28 12 00	11 52 00	10		7.8
Plage Blanche	L31	3	28 55 00	10 30 00	10		
Sansouire du Sebou	L17	3	34 18 00	06 37 00	10	X	3.6
Koudiet Taifour	L7	3	35 41 00	05 15 00	????	5.2	
Lagune de Smir	L8	3	35 44 00	05 20 00	????	X	
Terrestrial sites (79)							
Ademine	58	1	30 19 00	09 20 00	3500	X	8.3

Table 5 continued

Name	Code	Priority	Latitude (N)	Longitude (W)	Size (hectares)	5%	10%
Aghbar	54	1	30 55 00	08 24 00	6500		
Ain Asmama	56	1	30 50 00	09 14 00	22000		
Ait Oumribet	75	1	28 50 00	08 45 00	71000		3.4
Aqqa Wabzaza	50	1	31 57 00	06 20 00	3000		
Beni Snassene	14	1	34 50 00	02 24 00	6750		X
Beni Zemmour	41	1	32 46 00	06 05 00	10500		
Bou Iblane I	20a	1	33 45 00	04 09 00	12000		
Bou Naceur	21	1	33 35 00	03 52 00	14000		
Bou Riah-Beddouz	38	1	33 18 00	06 24 00	4000		
El Harcha	35	1	33 31 00	06 07 00	3700		
Jbel Bouhachem	5	1	35 13 00	05 28 00	8000		
Jbel Krouz	69	1	32 15 09	01 35 05	60000		X
Jbel Lalla Outka	10	1	34 45 00	04 50 00	4000		
Jbel Tichoukt	23	1	33 28 00	04 38 00	12500		
Kharrouba	36	1	33 33 00	05 50 00	6300		
Lalla Chafia	16	1	34 04 00	02 30 00	26000		X
Mamora	31	1	34 07 00	06 36 00	5000		
Merzouga	70	1	31 10 00	04 00 00	22700		
Msseyed	77	1	28 15 00	10 25 00	175000		8.5
Oued Cherrat	33	1	33 40 00	06 58 00	11300		
Oued Mird	72	1	30 12 00	05 18 00	60000		
Oued Tighzer	76	1	28 19 00	09 20 00	21000		
Tafingoult	59	1	30 45 00	08 22 00	3000		
Tamga	49	1	31 59 37	06 06 57	8500		
Aghbalou N'Arbi	26	2	33 10 00	04 58 00	14000		
Azrou Akechar	12	2	34 48 00	03 50 00	2000		
Bou Iblane 2	20b	2	33 50 00	04 10 00	2500		
Brikcha	6	2	34 56 00	05 31 00	670		
Deroua	42	2	32 18 00	06 36 00	700	X	
El Aderj	19	2	33 37 00	04 22 00	6000		
Jaaba	25	2	33 32 00	05 13 00	1800	5.0	X
Jbel Amsittene	57	2	31 10 00	09 38 00	3500		X
Jbel Ayachi	46	2	32 35 00	04 50 00	20000		
Jbel Kest	62	2	29 47 00	08 58 00	13000		
Jbel Taghioult	45	2	32 36 00	04 08 00	10000		
Jbel Tazerkount	29	2	32 10 00	06 30 00	15000		
Jbel Tizirane	8	2	35 02 00	04 56 00	1100	9.0	7.1
Khatouat	39	2	33 13 00	06 52 00	5000		
Koudiat Tidighine	9	2	34 51 00	04 31 00	4000		
Marais de la Palmeraie Marrakech	43	2	31 42 00	08 02 00	250	X	6.6
M'Sabih Talaa	44	2	31 54 00	08 35 47	1987	9.3	X
Oasis de Tissint	73	2	29 50 00	07 15 00	31000		8.4

Table 5 continued

Name	Code	Priority	Latitude (N)	Longitude (W)	Size (hectares)	5%	10%
Ouardane	40	2	33 06 00	05 51 00	3000		
Perdicaris	1	2	35 47 00	05 52 00	70		
Tizi-n-Ait Ouirra	28	2	32 33 00	05 59 00	14000		
Ait Er Kha	64	3	29 22 00	09 38 00	4000		X
Anezi	63	3	29 36 00	09 23 00	10		
Assads	60	3	30 10 00	08 40 00	10		
Ben Karrich	2	3	35 28 00	05 28 00	22100		
Bou Tferda	48	3	32 15 00	05 55 00	10		
Bou Timezguida	65	3	29 10 00	10 01 00	10		9.0
Bouzemmour	20c	3	33 38 00	04 03 00	10		
Chekhar	15	3	34 20 06	01 57 14	10000		
Dar Lahoussine	61	3	29 57 00	09 18 00	1000		
El Kheng	68	3	31 51 00	04 33 00	4000		
Grotte d'Akhyam	47	3	31 55 00	05 35 00	10		
Imaoun	74	3	29 35 00	08 18 00	10		
Imi-N-Ifri	51	3	31 44 00	06 58 00	10		
Jbel Amergou	11	3	34 30 00	05 08 00	10		
Jbel Gourougou	13	3	35 13 00	03 00 00	10	X	X
Jbel Haabib	3	3	35 28 00	05 46 00	5000		
Jbel Ouarirt	18	3	34 05 00	03 52 00	10	X	X
Jbel Sarghro	66	3	30 51 23	06 06 28	10		
Jbel Zerhoun	30	3	34 02 00	05 30 00	2000		
Khemis Es Sahel	4	3	35 15 00	06 03 00	1000		
Oued Korifla	32	3	33 43 00	06 45 00	2000		
Lalla Mimouna	17	3	34 01 00	02 51 00	800		
Ment	37	3	33 16 00	05 56 00	10		
Msissi	71	3	31 12 00	04 51 00	10		
Oued Todra	67	3	31 36 00	05 34 00	10		
Outat El Haj	22	3	33 26 00	03 48 00	10000		
Sidi Meskour	52	3	31 31 00	07 01 00	10		
Souk El Had	7	3	35 01 00	05 23 00	343		
Takeltount	24	3	33 36 00	04 54 00	10	6.6	6.5
Talarhine	27	3	32 53 00	05 15 00	300		
Tichka	55	3	30 54 00	08 36 00	10		
Tsili	34	3	33 28 00	06 23 00	1000		
Vallee de Telouat	53	3	31 17 00	07 16 00	10		

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