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Atlas of the distribution of amphibians and reptiles in the Diawling National Park, Mauritania

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This study provides the first atlas of the distribution of amphibians and reptiles in the Diawling National Park (DNP), Mauritania. Unpublished fieldwork observations collected between 2010 and 2017 were combined with published records and museum data in a geographical information system to produce maps with the distribution of individual species and species richness. The taxonomic list includes 32 species, six amphibians and 26 reptiles, grouped in 17 families. Ten species are new records for the area. Species form distinct groups according to their distribution patterns and preliminary habitat selection trends: 1) species distributed in inland dunes, some extending their range to coastal dunes; 2) species distributed in inland dunes and floodplains; and 3) species associated with habitats that are permanently or seasonally flooded or that inhabit riparian forests. Three areas accumulating most of the species found are located in sand habitats of DNP and peripheral zones. Specific counts of *Crocodylus suchus* suggest strong seasonal fluctuations in population size inside DNP, which are likely a consequence of the human-mediated dynamics of water availability in the area.

Key words: Africa; biodiversity; GIS; protected area; wetlands.

West Africa contains various ecosystems, ranging from dry savannah to tropical forest, that are home to more than 2000 amphibian, bird and mammal species (Mallon *et al*., 2015). The globally significant biodiversity levels in the region have long been recognized, and protected areas have been established to preserve such biodiversity. In particular, wetland environments in coastal areas have been targeted for biodiversity conservation due to their outstanding importance to migratory birds (RAMPAO, 2015).

In Mauritania, the Diawling National Park (DNP) is an area of global importance for its diversity of water-birds, accumulat-

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ing almost 250 000 individuals during winter (SHINE *et al.*, 2001; PN DIAWLING, 2017). The area is a costal floodplain on very saline clay and silt with low sand relief in the lower delta of the Senegal River (Fig. 1). The DNP was created in 1991 by Mauritanian authorities as a response to the socio-economic and environmental degradations generated by the construction of the Diama dam in 1986, downstream of the river (BARRY & TAÏBI, 2011). The dam was built to block intrusion of salty water from the Atlantic Ocean, to facilitate perennial irrigation, and to improve water supply, but it altered the estuary hydrodynamics and two thirds of the park are now deprived from direct freshwater supply from the Senegal River (DIARRA, 1994; BA *et al.*, 2002). Consequently, the increased salinity levels in the floodplain caused the collapse of fishery resources and bird colonies, estuarine vegetation virtually disappeared, and the mangrove (*Avicennia germinans* and *Rhizophora racemosa*) was reduced to less than 10% of its 1960 extent (IUCN, 1989; BA *et al.*, 2002). At the same time, increased availability of freshwater in the main course of the Senegal River boosted the development of invasive vegetation (*Typha* sp.; IUCN, 2007). In 1994, the DNP and the western peripheral zone (Fig. 1) were categorised as Ramsar Wetland (DIARRA, 1994), which together with the Senegalese part of the delta, were declared as Transboundary Biosphere Reserve (TBR) of the Senegal River Delta in 2005. Restoring ecosystems and floodplain hydrodynamics have been subject of intense research and management, and, as from 1994, management of flood releases were used to partially rehabilitate the floodplain and to create an artificial estuary (HAMERLYNCK & CAZOTTES, 1998; HAMERLYNCK *et al.*, 1999, 2005; BA *et al.*, 2002; DUVAIL & HAMERLYNCK, 2003; DEGEORGES & REILLY, 2006; BARRY & TAÏBI, 2011). The simulation of the pre-dam hydrodynamics partially allowed restoring ecosystem functions, with positive impacts on biodiversity and traditional human activities (HAMERLYNCK *et al.*, 2005; HAMERLYNCK & DUVAIL, 2009; LY & ZEIN, 2009).

Contrarily to birds and mammals, knowledge on the amphibian and reptile species of DNP is very limited. Until the late 1980s, 11 amphibians or reptiles were known broadly from south-western Mauritania (LE BERRE, 1989). This number was increased to 19 species with the inventories made during the project *Biodiversité du Littoral Mauritanien,* which included two localities close to DNP (ARVY & TIJANE, 1997; INEICH, 1997). Posterior works targeting the distribution of amphibians and reptiles at country-level (BRITO, 2003; NICKEL, 2003; PADIAL, 2006; BRITO *et al.*, 2008) or of particular species (CROCHET *et al.*, 2003; PADIAL, 2003; BRITO *et al.*, 2012; VALE *et al.*, 2014) have set the taxonomic list of DNP in two amphibians and 20 reptiles. However, data on species distribution at local scale and on areas concentrating most species are largely unavailable, which hampers conservation planning of biodiversity. Furthermore, there is evidence of regional ecosystem changes through time (initial degradation followed by restoration) modifying population dynamics of, at least, aquatic reptiles. For instance, West-African crocodiles (*Crocodylus suchus*) were regionally abun-

dant, but after the closure of Diama dam in 1986 they were considered as locally extinct (IUCN, 1989; HAMERLYNCK *et al*., 1999). In 2010, the species was rediscovered in the area (BRITO *et al*., 2012), but quantitative data on population size or trends are lacking.

The major aims of this work are: 1) to provide an updated taxonomic list of the amphibians and reptiles present in the DNP; 2) to map their distributions; and 3) to identify areas concentrating species richness. In addition, the study aims at providing preliminary data on local population size and trends of crocodiles. The present work, together with the inventories made in the Banc d'Arguin National Park (Sow *et al*., 2014a,b), fulfil a previous knowledge gap in the distribution of amphibians and reptiles in protected areas of coastal Mauritania.

MATERIALS AND METHODS

Study area

The study area (latitudes 16°02.39′ to 16°36.40′ N and longitudes 16°14.30′ to 16° 31.10′ W) covers the DPN (200 km^2) and the peripheral costal area (546 km^2), and it is located along the coastal Atlantic region of southern Mauritania, West Africa (Fig. 1). The area is mostly flat (maximum altitude 9 m) and climate is arid and hot, with minimum and maximum annual precipitation and annual average temperature ranging between 168 and 276 mm and 24.7 and 26.3 °C, respectively (HIJMANS *et al*., 2005). About 73% of the study area is covered by multiple water / wetland habitat types and the terrestrial habitats (27% of the area) include coastal dunes, inland dunes, and inland islands. Coastal dunes (36.7 km^2; 5% of the area) are typically composed of loose white sand and are covered by sparse grasslands and shrublands, while inland dunes (156.7 km^2; 21%) are typically composed of compact yellow sand and are covered by sparse *Acacia* trees (*A. tortilis*, *A. senegal*), *Euphorbia balsamifera*, and *Balanites aegyptiaca* (the latter two especially in coastal areas, where they forms woodlands), with a herbaceous cover of *Cenchrus biflorus*, *Chloris prieurii* and *Schoenefeldia gracilis* (SHINE *et al*., 2001). There are several small islands in the extreme southern areas (7.8 km^2; 1%) surrounded by brackish water, where relict mangrove stands are found, which testify past humid conditions in the region (GASSE, 2000).

Fieldwork and data analysis

Fieldwork was performed during a total of 26 days, distributed in eight visits between 2010 and 2017 (Fig. 1). Sampling sites were selected in order to cover the environmental variability of terrestrial habitats of the study area, as well as particular topographic features, such as the Chott Boul wetland. Visual encounter surveys by foot were performed on average by 3.8 persons (range 3 to 6 persons) for no longer than 1 hour (sampling effort ranging from 0.02 to 1.01 persons / hour / day). Night sampling was performed opportunistically around camping sites. *Ad hoc* observations (road-kills and live specimens) collected by the authors and National Park staff were also recorded. Captured specimens were photographed, a tissue sample was collected, and the geographic coordinates of the locality were recorded with a global positioning system (GPS).

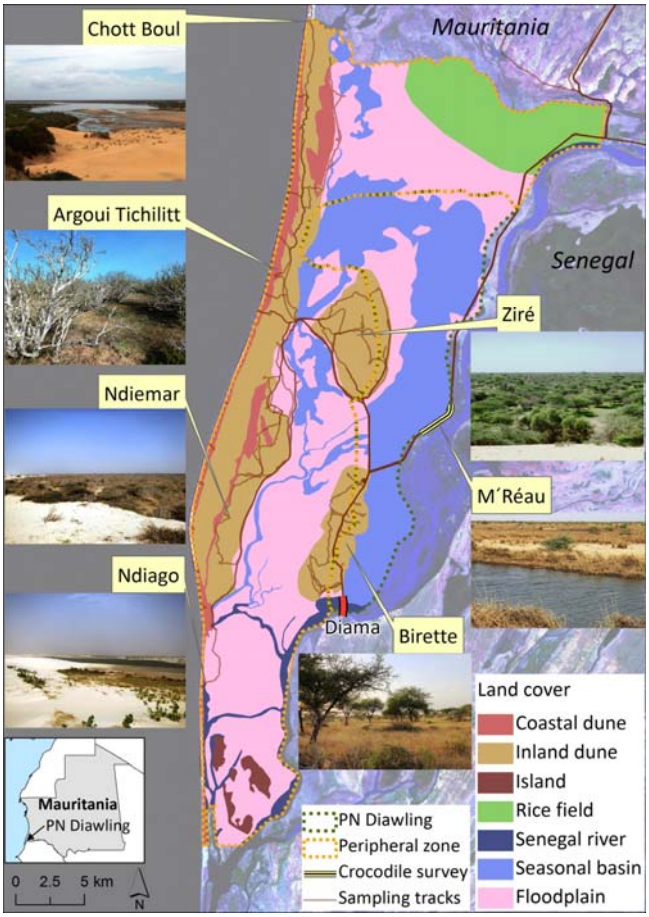

Figure 1: Limits of the Diawling National Park and the peripheral zone, tracks of sampling routes (between 2010-2017), land-cover categories, and localities mentioned in text. For a correct visualization of the figure, readers are referred to the online, coloured version.

A georeferenced database of fieldwork observations was created and complemented with published data (ARVY & TIJANE, 1997; INEICH, 1997; BRITO, 2003; CROCHET *et al.*, 2003; NICKEL, 2003; PADIAL, 2003, 2006; BRITO *et al.*, 2008, 2012; VALE *et al.*, 2014; OBSERVATION INTERNATIONAL, 2017). Geographic coordinates of bibliographic references were collected from topographical maps of Mauritania (Institut Géographique National; scale 1:200 000). Specimens from the study area available at the collection of the *Muséum national d'Histoire naturelle* of Paris (INEICH, 1997) were also included in the database.

The distributions of individual species and species richness were projected on the coordinate system WGS 1984 UTM Zone 28N, using the geographical information system ArcGIS 10.0 (ESRI, Redlands, California, USA). Species maps represent fieldwork and published observations over 2 x 2 km UTM grid cells (232 cells in total) and the species richness map represents number of species observed over 5 x 5 km UTM grid cells (51 cells in total). Observations of species with more than eight recorded localities were intersected with land-cover categories, extracted from Google Earth, to quantify preliminary patterns of habitat

Table 1: Taxonomic list of amphibians and reptiles present in the Diawling National Park and peripheral area. Number of observations (N obs), number of 2 x 2 km UTM squares with detected presence of each species (N 2km), percentage of area occupied (%), and percentage of observations in the most frequent land-cover categories (comprising altogether 88% of the study area).

Class	Family	Species	N obs	N 2 km	%	Land-cover categories			
						Coastal dunes	Inland dunes	Seasonal basin	Floodplains
Amphibia	Bufonidae	*Sclerophrys pentoni* (Anderson, 1893)	1	1	0.4	-	100.0	-	-
		Sclerophrys regularis (Reuss, 1833)	7	2	0.9	-	100.0	-	-
		Sclerophrys xeros (M. Tandy, J. Tandy, Keith, and Duff-MacKay, 1976)	19	7	3.0	-	87.5	-	12.5
	Dicroglossidae	*Hoplobatrachus occipitalis* (Günther, 1858)	9	7	3.0	-	77.8	11.1	11.1
	Ptychadenidae	*Ptychadena schillukorum* (Werner, 1908)	1	1	0.4	-	100.0	-	-
	Pyxicephalidae	*Tomopterna milletihorsini* (Angel, 1922)	1	1	0.4	-	100.0	-	-
Reptilia	Agamidae	*Agama agama* (Linnaeus, 1758)	1	1	0.4	-	100.0	-	-
		Agama boueti Chabanaud, 1917	60	36	15.5	10.0	86.0	-	4.0
	Chamaeleonidae	*Chamaeleo africanus* Laurenti, 1768	2	2	0.9	-	50.0	-	-
	Gekkonidae	*Hemidactylus angulatus* Hallowell, 1854	33	18	7.8	8.7	82.6	4.3	4.3
		Stenodactylus petrii Anderson, 1896	19	3	1.3	-	100.0	-	-
		Stenodactylus sthenodactylus (Lichtenstein, 1823)	11	2	0.9	-	100.0	-	-
	Phyllodactylidae	*Tarentola senegambiae* Joger, 1984	42	21	9.1	9.1	87.9	-	3.0
	Lacertidae	*Acanthodactylus boskianus* (Daudin, 1802)	48	22	9.5	10.0	73.3	-	16.7
		Acanthodactylus dumerilii (Daudin, 1802)	66	22	9.5	42.3	57.7	-	-
		Latastia longicaudata (Reuss, 1834)	8	8	3.4	12.5	87.5	-	-
		Mesalina pasteuri (Bons, 1960)	5	4	1.7	75.0	25.0	-	-
	Scincidae	*Chalcides sphenopsiformis* (A.H.A. Duméril, 1856)	5	5	2.2	-	100.0	-	-
		Scincus albifasciatus Boulenger, 1890	1	1	0.4	-	100.0	-	-
		Trachylepis perrotetii (A.M.C. Duméril & Bibron, 1839)	18	15	6.5	12.5	87.5	-	-
	Varanidae	*Varanus exanthematicus* (Bosc, 1792)	28	16	6.9	-	95.5	4.5	-
		Varanus niloticus (Linnaeus, 1766)	30	20	8.6	3.7	33.3	22.2	29.6
	Pythonidae	*Python sebae* (Gmelin, 1789)	5	5	2.2	-	40.0	40.0	-
	Colubridae	*Dasypeltis sahelensis* Trape & Mané, 2006	2	2	0.9	-	50.0	-	50.0
		Lytorhynchus diadema (A.M.C. Duméril, Bibron & A.H.A. Duméril, 1854)	1	1	0.4	-	100.0	-	-
		Psammophis cf. rukwae Broadley, 1966	17	11	4.7	16.7	58.3	-	16.7
		Psammophis schokari (Forskal, 1775)	9	6	2.6	-	66.7	16.7	16.7
	Lamprophiidae	*Boaedon fuliginosus* (Boie, 1827)	4	3	1.3	-	66.7	-	33.3
		Ramphiophis oxyrhynchus (Reinhardt, 1843)	1	1	0.4	-	-	-	-
	Elapidae	*Naja nigricollis* Reinhardt, 1843	2	1	0.4	-	100.0	-	-
	Crocodylidae	*Crocodylus suchus* Geoffroy Saint-Hilaire, 1807	67	10	4.3	-	-	27.8	72.2
	Testudinidae	*Centrochelys sulcata* (Miller, 1779)	2	2	0.9	-	50.0	-	-

selection.

One transect of 3163 m of length in the M'Réau area (Fig. 1) was established specifically for counting *C. suchus*. Surveys were made from the international road delimiting the eastern border of the study area. Surveys were made only to the western side of the road, dominated by a seasonal basin with sparse vegetation cover, because the eastern side corresponds to the main Senegal river and is fully covered by the invasive *Typha* sp.. Surveys were performed in November 2012, November 2014, August 2015, January 2016, and April 2017. All surveys were standardised and followed baseline methodology for crocodile counting previously used in Mauritania (BRITO *et al.*, 2011; CAMPOS *et al.*, 2016): an observer installed over the rooftop of a four-wheel drive vehicle moving along the transect line, holding a high-power lamp, counted the number of pairs of eyes (from yellowish to goldish) that reflected the light emitted by the lamp within a distance of up to 100 m. Surveys started at around 23:00 h and lasted about 15 min (average vehicle speed 12.7 km / h), which allows the direct comparison of the total number of crocodiles observed in each survey.

RESULTS

The published and fieldwork data comprised 525 records (487 unpublished observations and 38 published observations) from six amphibian and 26 reptile species, grouped in four and 13 families, respectively (Table 1). Detailed distributions are presented in Figs. 2-7. In relation to the previously published data, 10 new species were detected in the study area: 1) four amphibians, i.e. *Hoplobatrachus occipitalis*, *Ptychadena schillukorum*, *Sclerophrys xeros*, and *Tomopterna milletihorsini* (Fig. 2); 2) three reptiles mostly associated with inland dunes of Birrete, i.e. *Agama agama*, *Boaedon fuliginosus*, and *Naja nigricollis* (Figs. 3 and 5); and 3) three reptiles associated with coastal dunes, i.e. *Lytorhynchus diadema*, *Mesalina pasteuri*, and *Scincus albifasciatus* (Figs. 4-6). On the contrary, the snakes *Dasypeltis sahelensis* and *Ramphiophis oxyrhynchus*, and the turtle *Centrochelys sulcata* that were known from less than two localities in the area (ARVY & TIJANE, 1997) were not observed during our field surveys.

General patterns of habitat selection were observed among the amphibians and reptiles in the study area (Table 1): 1) species mostly related to the coastal and inland dunes (Birrete and Ziré), such as *Agama boueti*, *Hemidactylus angulatus*, *Tarentola senegambiae*, *Trachylepis perrotetii*, and *Varanus exanthematicus*, or restricted to the coastal dunes, such as *Acanthodactylus dumerilii*, *Latastia longicaudata*, and *M. pasteuri*; 2) species mostly related to inland dunes and floodplains, such as *Acanthodactylus boskianus*, *H. occipitalis*, and *S. xeros*; and 3) species associated with habitats that are permanently or seasonally flooded, such as *C. suchus*, *Python sebae*, and *Varanus niloticus*, or that inhabit the riparian forests, such as *Psammophis* cf. *rukwae* (following KELLY *et al.*, 2008).

The distribution of observed species richness exhibits spatial asymmetries, and three areas accumulating more than 10 species can be identified: 1) the area south of Chott Boul; 2) Ziré and Argoui Tichilitt dunes; and 3) Birette dune, especially its north-eastern area (Fig. 8). These areas are

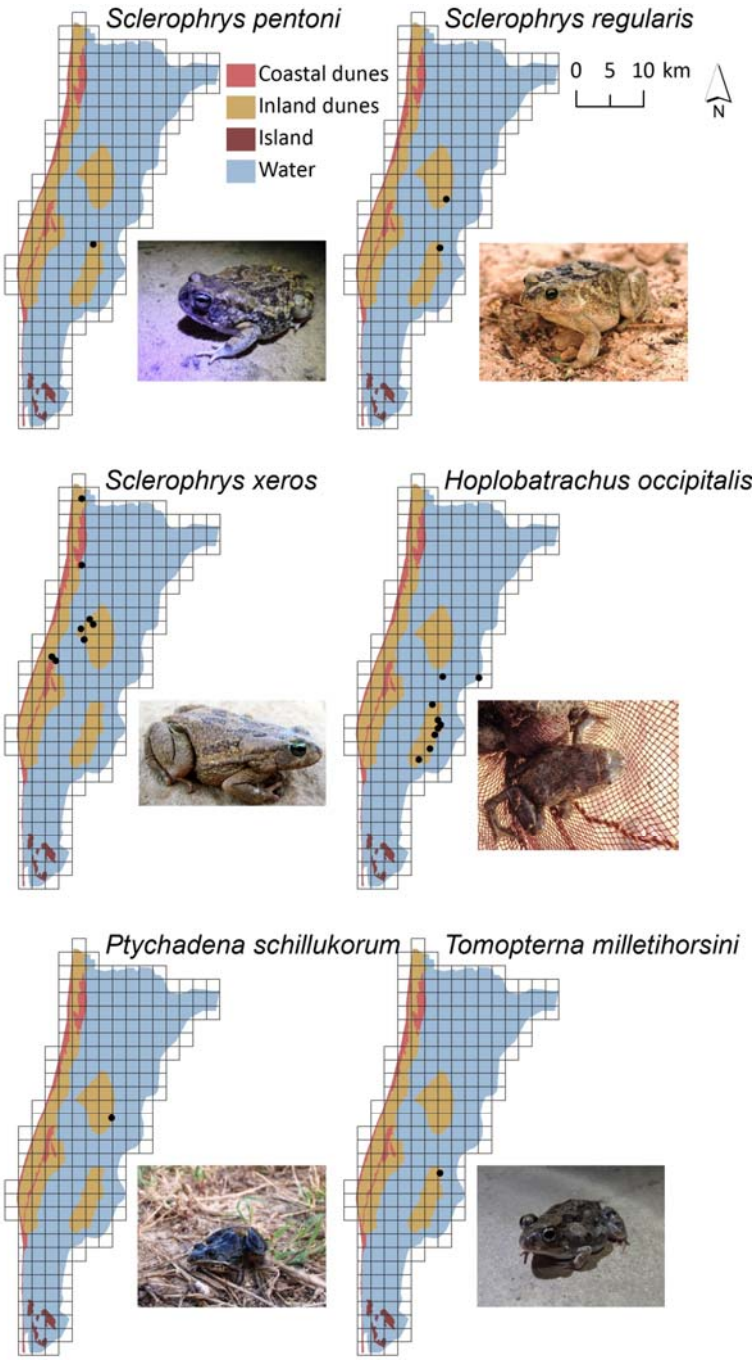

Figure 2: Distribution of *Sclerophrys pentoni*, *S. regularis*, *S. xeros* (specimen from Assaba region), *Hoplobatrachus occipitalis*, *Ptychadena schillukorum*, *Tomopterna milletihorsini*, and non-flooded land-cover categories in the Diawling National Park and the peripheral zone at a 2 x 2 km UTM scale.

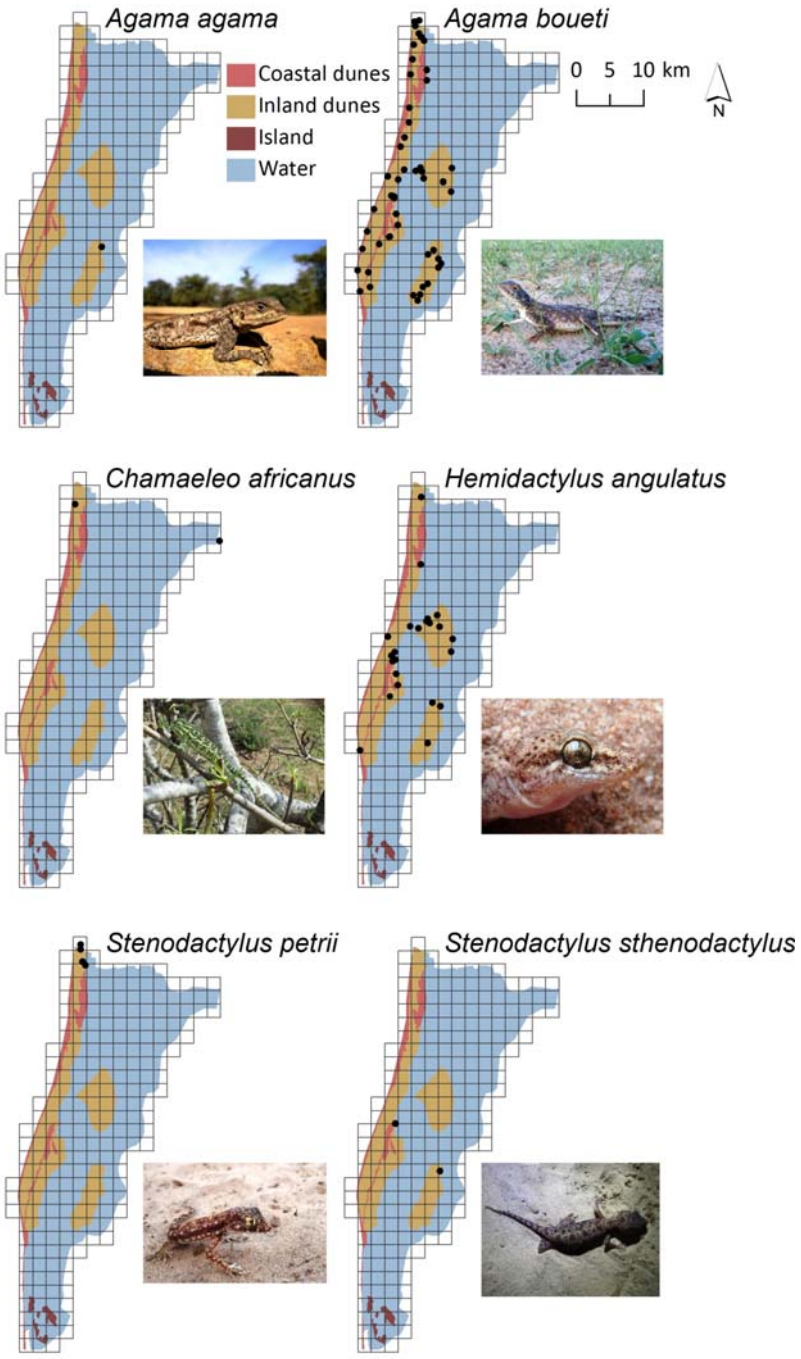

Figure 3: Distribution of *Agama agama*, *A. boueti*, *Chamaeleo africanus*, *Hemidactylus angulatus*, *Stenodactylus petrii*, *S. sthenodactylus*, and non-flooded land-cover categories in the Diawling National Park and the peripheral zone at a 2 x 2 km UTM scale.

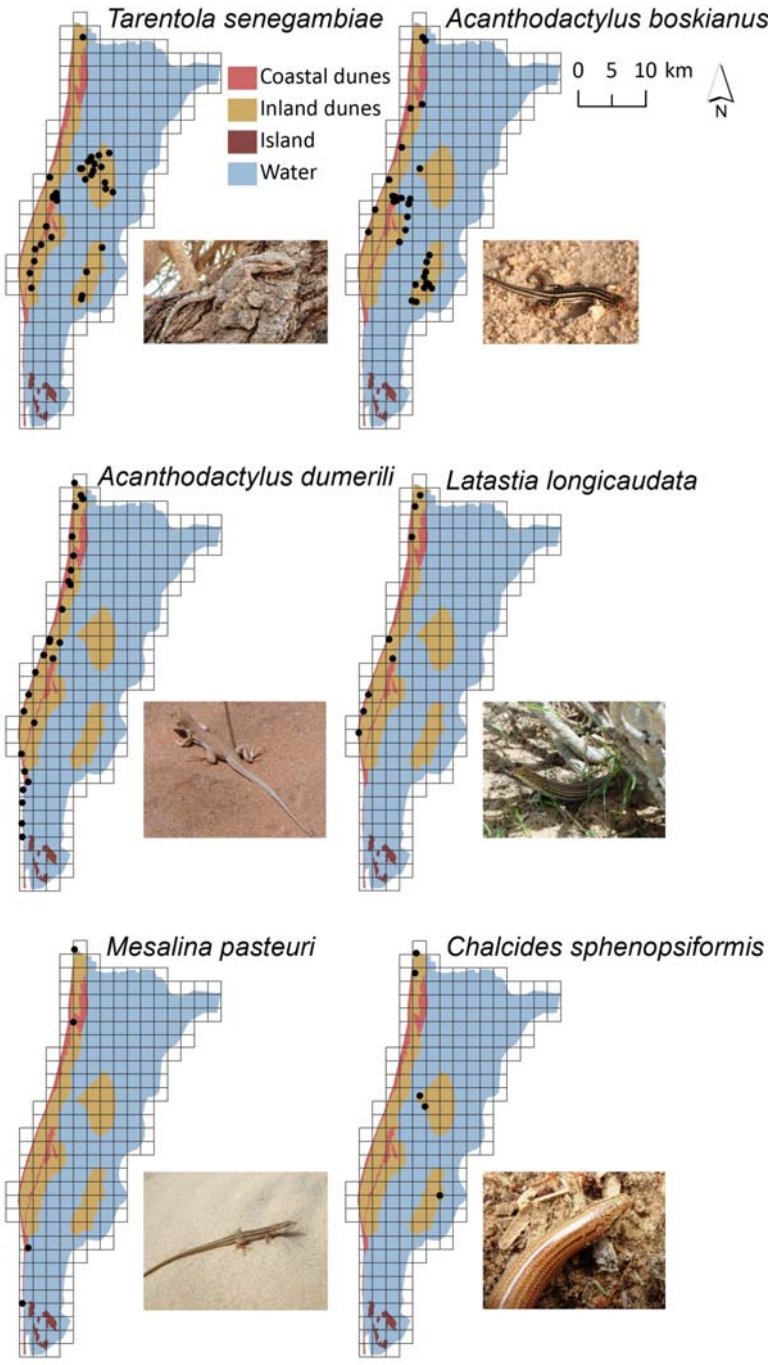

Figure 4: Distribution of *Tarentola senegambiae*, *Acanthodactylus boskianus*, *A. dumerili*, *Latastia longicaudata*, *Mesalina pasteuri*, *Chalcides sphenopsiformis*, and non-flooded land-cover categories in the Diawling National Park and the peripheral zone at a 2 x 2 km UTM scale.

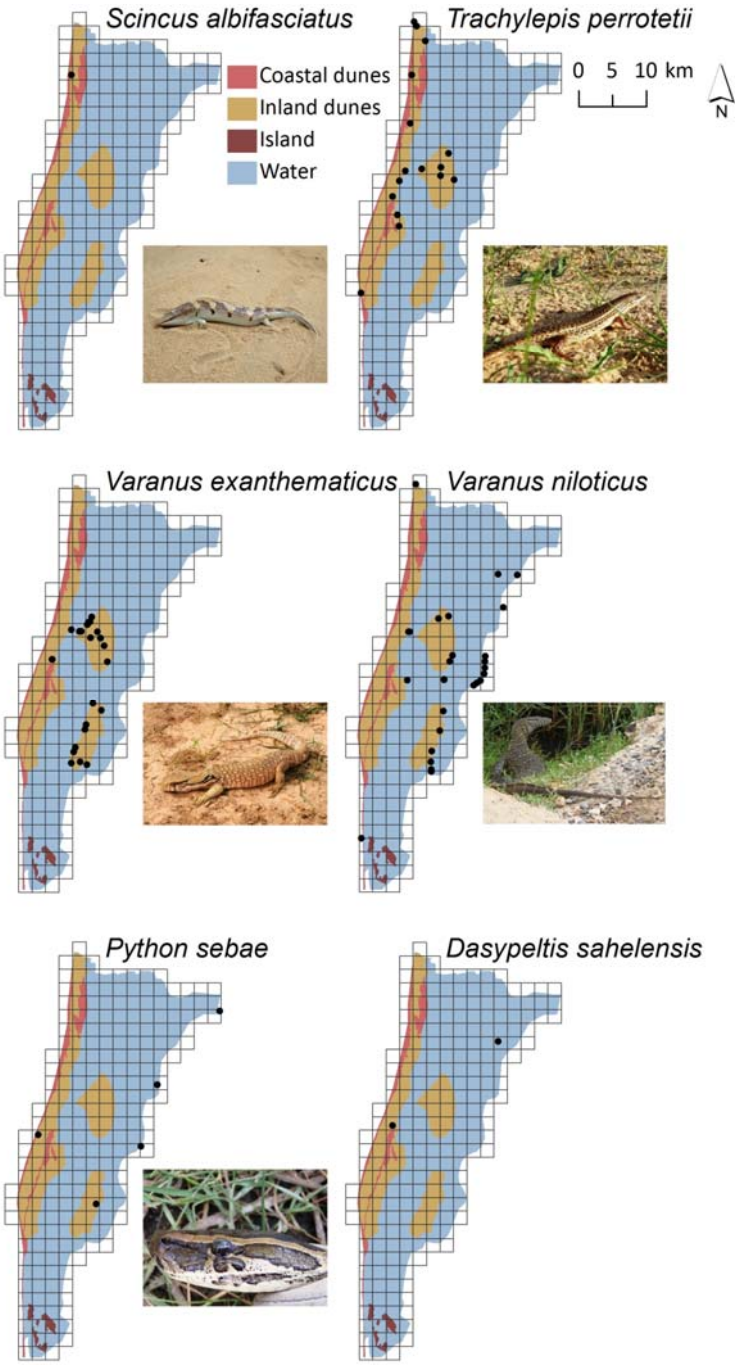

Figure 5: Distribution of *Scincus albifasciatus*, *Trachylepis perrotetii*, *Varanus exanthematicus*, *V. niloticus*, *Python sebae*, *Dasypeltis sahelensis* (no picture available), and non-flooded land-cover categories in the Diawling National Park and the peripheral zone at a 2 x 2 km UTM scale.

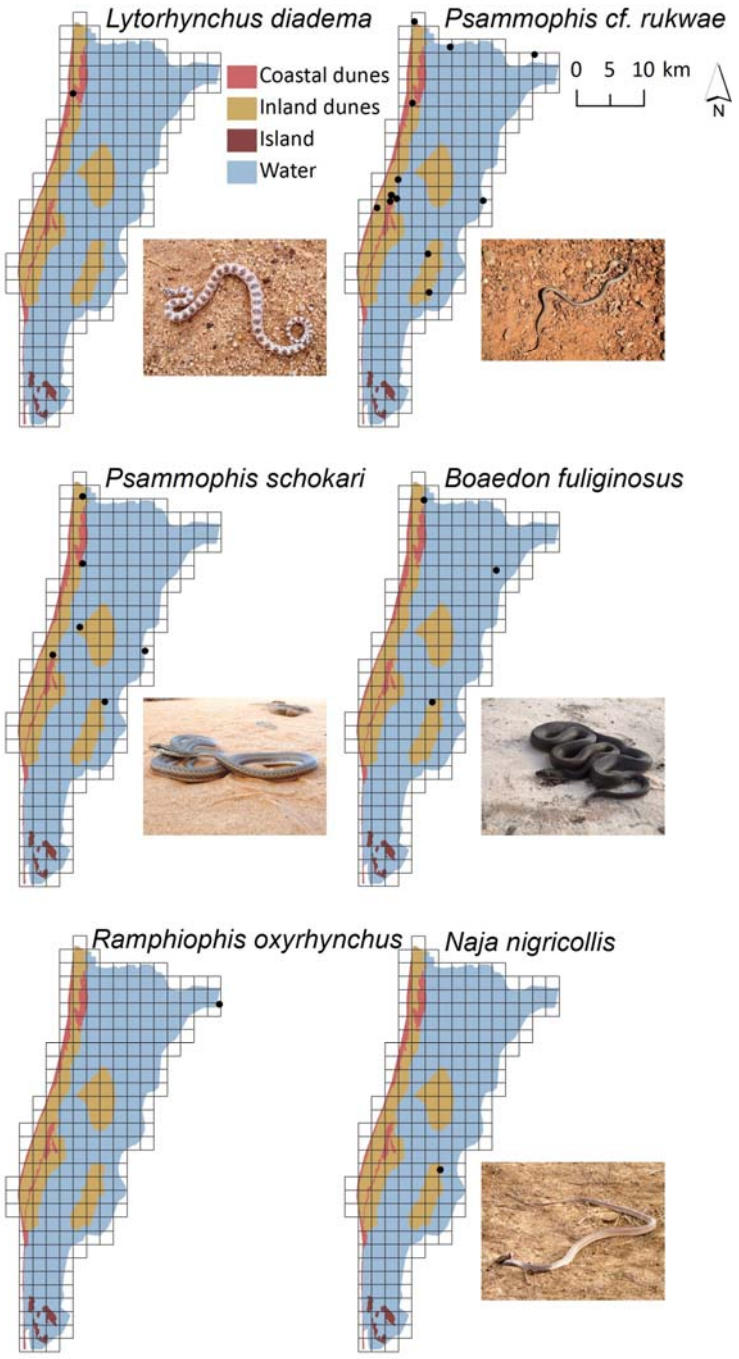

Figure 6: Distribution of *Lytorhynchus diadema* (specimen from Dakhlet-Nouadhibou region), *Psammophis* cf. *rukwae* (specimen from Gorgol region), *P. schokari* (specimen from Adrar region), *Boaedon fuliginosus*, *Ramphiophis oxyrhynchus* (no picture available), *Naja nigricollis*, and non-flooded land-cover categories in the Diawling National Park and the peripheral zone at a 2 x 2 km UTM scale.

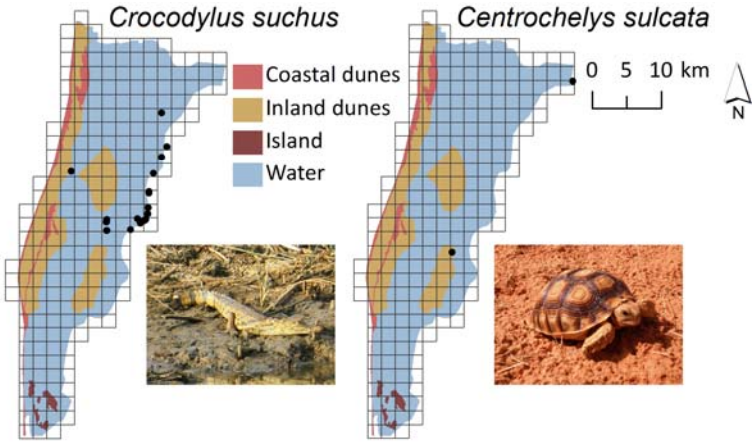

Figure 7: Distribution of *Crocodylus suchus*, *Centrochelys sulcata* (specimen from Hodh El Gharbi region), and non-flooded land-cover categories in the Diawling National Park and the peripheral zone at a 2 x 2 km UTM scale.

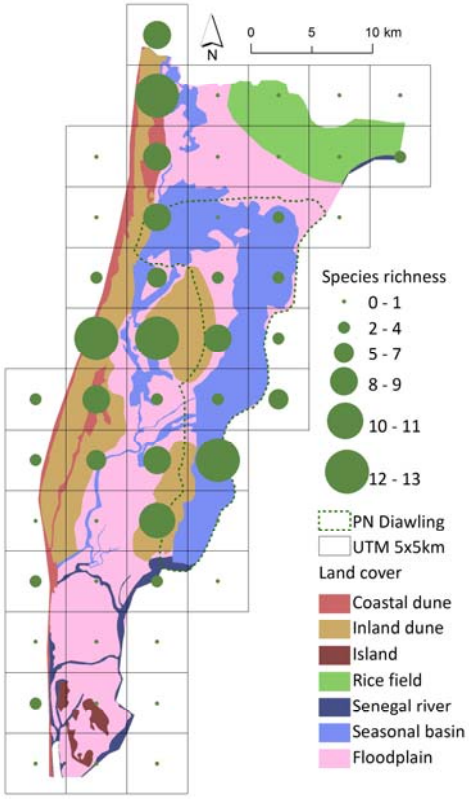

Figure 8: Distribution of amphibian and reptile species richness and land-cover categories in the Diawling National Park and the peripheral zone at a 5 x 5 km UTM scale. For a correct visualization of the figure, readers are referred to the online, coloured version.

located in the transition zones from seasonally flooded land-cover categories to coastal / inland dunes, and thus accumulate species that are mostly found in each of the land-cover categories. For example, the Ziré-Argoui Tichilitt dunes gather species typical of costal dunes (*A. dumerilii*, *L. longicaudata*), of inland dunes (*S. xeros*, *V. exanthematicus*), or of both types of dunes (*A. boueti*, *Chalcides sphenopsiformis*, *H. angulatus*, *Psammophis schokari*, *T. senegambiae*, *T. perrotetii*), and flooded habitats (*C. suchus*, *V. niloticus*).

The numbers of crocodiles observed (including juveniles and adults) were: 38 individuals in 2012, 68 individuals in 2014, two individuals in 2015, 40 individuals in 2016, and 47 individuals in 2017.

Discussion

Ten new species were detected for the first time in the study area. These include the amphibians *P. schillukorum*, that was recently described for Mauritania (Sánchez-Vialas *et al.*, 2017), and *T. milletihorsini*, which replaces the former designation of *T. cryptotis* given to West-African populations (Ohler & Frétey, 2008; Zimkus & Larson,

2011). Our observations of *L. diadema* and *M. pasteuri* along coastal dunes expand their known range southwards and constitute the extreme south-western limits of their ranges (TRAPE & MANÉ, 2006; TRAPE *et al*., 2012). On the contrary, the turtle *C. sulcata* and the snakes *D. sahelensis* and *R. oxyrhynchus*, that had been previously reported for the study area (ARVY & TIJANE, 1997; INEICH, 1997; NICKEL, 2003), were not detected, which might be related to seasonal activity cycles, low detectability and / or low abundance. Furthermore, the snakes *Malpolon moilensis* and *Bitis arietans* were not observed but are known from surrounding areas to the north and to the south, respectively, of the study area (TRAPE & MANÉ, 2006). Further sampling is needed to determine the potential presence of these taxa in the region.

Nine species, including three amphibians and six reptiles, were observed in less than two localities. The low detectability of *Chamaeleo africanus*, *L. diadema*, and *S. albifasciatus* may have hampered the additional detection of these species along inland / coastal dunes. On the contrary, the amphibians *P. schillukorum*, *Sclerophrys pentoni*, and *T. milletihorsini* may be locally rare due to the salinity levels of most floodplains. Further sampling is needed to understand if they are locally rare, exhibit low detectability, and / or were not recorded because sampling occurred during periods of low activity.

The richest areas in amphibians and reptiles were observed in sand habitats of DNP and its peripheral zone. Such observation stresses the importance of the peripheral zone of this relatively small national park for local biodiversity conservation, as observed in other areas (e.g. LUJA *et al*., 2017). The peripheral zone is included in the Ramsar Wetland and in the Transboundary Biosphere Reserve (TBR) of the Senegal River Delta, which should contribute to framing local biodiversity conservation planning.

While the absolute number of crocodiles observed in M'Réau transect increased from a few individuals recorded in 2010 up to a maximum of 68 individuals, the most striking pattern was the extreme fluctuation in crocodile counts (decreasing from 68 individuals in autumn 2014 to just two individuals in summer 2015). These extreme fluctuations are probably associated with the dynamics of water availability in the DNP; after the controlled flooding of the basins (after mid-August), the number of observed crocodiles was the highest recorded. In winter, when water levels start to decrease, there were fewer observations (40 and 47 individuals in January and April, respectively). During the dry season, the floodplain is mostly dry and crocodiles are forced to find shelter (digging caves in the muddy river banks) and / or to move to the adjacent Senegal River watercourse. There have been occasional observations by local fishermen of crocodiles crossing the dam that runs alongside the park to reach the Senegal River. The road built over this dam has a considerable amount of vehicle traffic (it is presently the single overland access to Senegal). In the M'Réau sector of the dam, one adult crocodile was found road-killed, besides two *P. sebae* and four *V. niloticus*. There is a project to asphalt the current road, which will have negative ecological and tourist impacts, since the dike is the

best site for bird watching (IUCN, 2007). In 2017, DNP installed warning signs in the M'Réau sector about the presence of crocodiles and the sensitivity of the region to road traffic. The construction of an international large bridge between Mauritania and Senegal in Rosso (about 50 km to the east of DNP) would help minimising the negative impacts of local traffic in the Park and its biodiversity.

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