Update of distribution, habitats, population size, and threat factors for the West African crocodile in Mauritania

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Abstract. The West African crocodile (Crocodylus suchus) is an emblematic species from the Sahara-Sahel with scarce knowledge on distribution and conservation status. This study updated the knowledge on distribution, occupied habitats, population size, and factors that threaten C. suchus and its habitats in Mauritania. Five field expeditions to Mauritania (2011-2016), allowed the detection of 26 new localities, increasing by 27% the current number of all known locations (adding up to $N = 96$). In most localities less than five individuals were observed, and in all visiting sites the number of observed individuals ranged from one to 23. Eleven threat factors were identified, being droughts and temperature extremes (100% localities affected) and water abstraction for domestic use and nomadic grazing (94%) the most frequent. These findings suggest that crocodiles are apparently vulnerable in Mauritania and that future local conservation strategies are needed to assure the continuity of its fragile populations and preserve their habitats.

Keywords: aquatic habitats, conservation, crocodile distribution, Crocodylus suchus, Sahara, Sahel, threat risk.

The West African crocodile (Crocodylus suchus) is an emblematic species that was widely distributed across the Sahara until the early 20th century (Brito et al., 2011a). Increased aridity since the Mid-Holocene (around 7000 years ago) combined with human persecutions led to local extinctions and the consequent range contraction and fragmentation (Brito et al., 2011a). Currently, C. suchus is distributed mostly across West Africa, from the north and west limits in Mauritania and Senegal, to the south and east limits in the Democratic Republic of the Congo and Uganda, respectively (Hekkala et al., 2011).

In Mauritania, the most comprehensive survey of crocodile populations assembled information for 78 localities, including 60 of confirmed presence, 10 of possible presence, five of unconfirmed status, and three of confirmed extinction (Brito et al., 2011a). New habitats and locations for crocodiles were discovered during that survey, but information remains incomplete for south-eastern Mauritania, particularly in the Afollé Mountain (see fig. 1). Several threats affecting crocodiles were previously identified, namely overexploitation by herdsmen, faecal contamination by domestic animals and water abstraction for domestic uses (see Tellería et al., 2008; Brito et al., 2011a), but the identified threats were coarsely scrutinised. Recently, Vale, Pimm and Brito (2015) conducted a quantitative assessment of threats associated to gueltas (mountain rock pools), but other important aquatic habitats (e.g. rivers and lowland floodplains) in Mauritania where the species exists remain unvaluated in terms of extinction risk factors. A quantitative assessment of the factors affecting crocodile populations and its habitats in Mauritania is still unavailable. Given that C. suchus is currently categorised as Not Evaluated by IUCN (IUCN, 2016), acquiring detailed information about its distribution, population status, and threat factors is crucial for updating its conservation status and to optimise future conservation planning.

Field expeditions to Mauritania since 2011 allowed the detection of new localities and the© Koninklijke Brill NV, Leiden, 2016.

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collection of further data on their threat risks. As such, this study: 1) updates the current distribution of *C. suchus* in Mauritania; 2) updates the knowledge about the habitats currently occupied by crocodiles; 3) updates estimates of crocodile population size at specific localities; and 4) quantifies the major threats for crocodile populations and the habitats in which they persist.

The study area encompasses the southern Mauritanian mountains of Tagant, Assaba and Afollé (fig. 1). Five field expeditions were developed between 2011 and 2016, during the periods after the rainy season (October to December in 2011, 2012 and 2014; January to February in 2014 and 2016), totalling 58 sampling days. A total of 52 localities (of which 10 were visited in two or more occasions) were sampled for the presence of crocodiles by at least 4 persons, with a total sampling effort of 1,363 man/hours and an average of 0.273 man/hours per locality. Crocodile sampling followed the procedures described in Brito et al. (2011a): 1) visual inspection of water from elevated points using binoculars; 2) search of crocodile marks in shorelines, including faeces, footprints, tracks or excavated burrows; 3) inspection of rock crevices for hidden crocodiles; 4) sampling of water and margins at night with lamps; and 5) inquiries to locals about the presence of crocodiles. The number of crocodiles present at each locality was quantified. Inquiries to local people were conducted for acquiring information concerning the annual water availability of the location (permanent or seasonal) and the period when the locality dries. The coordinates of sampled localities were gathered from a Global Positioning System (GPS). Localities were displayed in ArcGIS 10.1 on the WGS84 datum. Locality names used in this study are in accordance with the toponomies established in the topographic maps (1:200 000) from the French Institut Géographique National (IGN).

The status of crocodile populations at each locality was categorised as: 1) present, when crocodiles were observed during field expeditions or when faeces, footprints or burrows were found; and 2) possible, when locals reported the presence of crocodiles in apparently suitable habitats but no individuals or signs were observed. The type and number of threats associated to each locality were listed based on field assessments (see online supplementary table S1). Threat types followed the nomenclature of IUCN Threats Classification Scheme (Version 3.2; http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme). Chi-Square independency tests were performed in R 3.1.1 (*stats* package) to verify if the total number of threats affecting each locality was differently related with the type of habitat, mountain, or hydrographic sub-basin. A distance matrix was constructed in R (*stats*) based on the presence/absence of the threats in each locality. The matrix was used to perform a Multidimensional Scaling analyses (MDS) in R (*MASS* package) to verify if the localities affected by different type of threats were grouped according to

**Figure 1.** Study area and distribution data for *Crocodylus suchus*. New localities presented in this study (coded from 1 to 26) and previously published localities in which the crocodile status was updated (coded from 27 to 28) are represented in white triangles (possible presence of crocodiles) and in white circles (presence of crocodiles). Localities published in Brito et al. (2011a) are represented in black triangles (possible presence of crocodiles) and in black circles (presence of crocodiles). The names of the major mountains (black) and sub-basins (white) of the study area are written in bold. This figure is published in colour in the online version.
to habitats, mountains, or hydrographic sub-basins. Analyses were restricted to localities where population status was classified as “present” or “possible” and combined localities listed in Brito et al. (2011a) and this work (table S1). Localities listed in Brito et al. (2011a) where crocodile status was defined based only on bibliography or local inquiries were excluded, since the locality was not visited.

The field expeditions allowed the identification of 26 localities where the presence of crocodiles was confirmed for the first time (fig. 1; online supplementary table S2). In these localities, population status was categorised as present and possibly present in 17 and nine localities, respectively. These findings increased by 27% the total number of previously known localities of presence and possible presence in Mauritania \((n = 70)\), which now add up to 96 localities. The intensified sampling of the Afollé Mountain resulted in 14 new presence localities (82% of the new presence localities) and five localities where crocodiles were possibly present (56% of the new possible locations). The acquired information for the Afollé (total of 19 new localities) increased by 59% the number of known localities in this mountain. Although the cryptic behaviour of crocodiles may constrain their detectability (Brito et al., 2011a), the considerable increase of crocodile localities probably reflects the lack of sampling in the region. Future fieldwork should be focused in the Kolimbéné and Niôût hydrographic basins, where sampling efforts will probably allow discovering additional crocodile populations. However, the remoteness and the harsh conditions that characterise southern Mauritanian mountains, as well as the insecurity caused by the current regional conflicts (Larémont, 2011) constitute logistical challenges for local biodiversity surveys (Brito et al., 2014).

Of the 26 new localities where crocodiles were found to be present and possibly present, 14 were located in oueds (rivers), six in gueltas (mountain rock pools), three in tâmoûrts (seasonal floodplains at the foothills of mountains) and three in other habitats (table S1). Overall, gueltas and tâmoûrts still represent the most used habitats by crocodiles in Mauritania (Brito et al., 2011a), accounting with 36% and 23% of the total known crocodile localities \((N = 96)\), respectively. In fact, due to the associated suitable climatic conditions and longer periods of water availability, these habitats act as refugia for the persistence of crocodiles and other vertebrate species in the mountains of Mauritania (Trape, 2009; Vale, Pimm and Brito, 2015). Oueds also stand as important habitats for crocodiles, representing 22% of the total known crocodile localities. The seasonal lagoons that are formed within the riverbeds may sustain populations for a limited period of time after the rainy season. During the dry season crocodiles may find shelter between rock boulders or in excavated burrows in the muddy margins. Oueds are apparently crucial for crocodile dispersal between the mountain gueltas and the lowland tâmoûrts, and molecular data suggested that patterns of population structure are dependent on the geographical connectivity of hydrographic sub-basins (Velo-Antón et al., 2014).
Table 1. Threat code, threat definition and number and percentage of crocodile localities affected by each threat (according to the IUCN Threat Classification Scheme).

<table>
<thead>
<tr>
<th>Code</th>
<th>Threats</th>
<th>N of localities (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1.2</td>
<td>Small-holder farming</td>
<td>23 (27)</td>
</tr>
<tr>
<td>2.3.1</td>
<td>Nomadic grazing</td>
<td>80 (94)</td>
</tr>
<tr>
<td>2.3.2</td>
<td>Small-holder grazing, ranching or farming</td>
<td>47 (55)</td>
</tr>
<tr>
<td>7.2.1</td>
<td>Abstraction of surface water (domestic use)</td>
<td>80 (94)</td>
</tr>
<tr>
<td>7.2.3</td>
<td>Abstraction of surface water (agricultural use)</td>
<td>38 (45)</td>
</tr>
<tr>
<td>9.1.3</td>
<td>Pollution: Type Unknown/Unrecorded (faecal contamination)¹</td>
<td>24 (28)</td>
</tr>
<tr>
<td>9.1.3</td>
<td>Pollution: Type Unknown/Unrecorded (detergents)²</td>
<td>10 (12)</td>
</tr>
<tr>
<td>9.3.3</td>
<td>Pollution: Herbicides and pesticides</td>
<td>23 (27)</td>
</tr>
<tr>
<td>10.3</td>
<td>Avalanches/landslides</td>
<td>18 (21)</td>
</tr>
<tr>
<td>11.2</td>
<td>Droughts</td>
<td>85 (100)</td>
</tr>
<tr>
<td>11.3</td>
<td>Temperature extremes</td>
<td>85 (100)</td>
</tr>
</tbody>
</table>

¹ Threat related with the faecal contamination of water by drinking cattle. The threat was classified as “Pollution: Type Unknown/Unrecorded” because it did not fit into any category of the IUCN Threat Classification Scheme.
² Threat related with the contamination of water by detergents used for domestic washing. The threat was classified as “Pollution: Type Unknown/Unrecorded” because it did not fit into any category of the IUCN Threat Classification Scheme.

A total of 56 crocodiles were counted in 11 of the new and updated locations (table S2). The majority of individuals was observed in the southern Afollé Mountains, where 39 individuals were counted among four localities (localities 17, 20, 21, 23). The southern regions of Mauritania are characterised by greater water availability and water flow (Campos, Sillero and Brito, 2012), which translates in wider availability of suitable habitats that might be able to sustain larger crocodile populations. In the remaining localities (N = 7), less than five individuals were counted, which corresponds to the pattern of general low population size previously reported for Mauritania (Brito et al., 2011a).

The analyses of threats for the localities listed in Brito et al. (2011a) and in this study (N = 85 localities) identified 11 threat factors that can directly affect crocodile populations and their habitats (table 1). Severe droughts and temperature extremes affected all localities while water abstraction for domestic use and nomadic grazing were also very common, which is in agreement with previous assessments focused on gueltas only (Vale, Pimm and Brito, 2015). The frequent climatic fluctuations and the consequent oscillations in inter-annual water availability characterise the arid and semi-arid regions of the Sahara-Sahel (Haas et al., 2009; Campos, Sillero and Brito, 2012). These regions are normally exposed to severe droughts and humid habitats become crucial for sustaining the local biodiversity as well as local human populations (Brito et al., 2014). Humid habitats are intensively explored by humans for domestic (e.g. abstraction of water for human and cattle consumption) and agricultural use, which can lead to other worrisome threats, such as excessive faecal contamination and water eutrophication (Tellería et al., 2008; Brito et al., 2011a). The Chi-Square tests revealed that the considered localities are threatened independently of the type of habitat (p = 0.03), mountain (p = 0.1) or sub-basin (p = 0.03). The MDS analyses showed that localities affected by different type of threats were not grouped according to habitats, mountains, or hydrographic sub-basins (see example in online supplementary fig. S1). These results indicate that the different humid habitats in which crocodile populations persist are similarly threatened and exploited by the local communities. Human activities (e.g. pastoralism) disturb crocodiles during daylight and over-exploitation of humid habitats may cause local shortage of water availability. Both factors affect physiological processes of crocodiles (e.g. feeding, growth and reproductive periods)
and further restrain the already limited annual active period of crocodiles (Brito et al., 2011a). Studies focused in the ecology and physiology of local crocodile populations are needed to evaluate possible stresses induced by the current habitat disturbances.

West African crocodiles are currently categorised as Not Evaluated by IUCN (IUCN, 2016). The threats identified in this study provide baseline data for the future assessment of C. suchus conservation status at both global and regional level (in Mauritania). Current predictions of climate change suggest precipitation decreases and a continuous warming in Africa, principally in flat desert environments (Loarie et al., 2009). Therefore, global warming represents a major threat for local crocodile populations and for other water-dependent species that share the same habitats (Vale, Pimm and Brito, 2015). Conservation strategies promoting the protection of water bodies and also their sustainable management and use by the local communities are needed, to assure the continuity of crocodile populations in the fragile, scarce and mostly seasonal humid habitats in which they persist.

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