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Title: Lion and spotted hyaena abundance in Dinder National Park, Sudan

Running title: Lions and spotted hyaenas in Dinder

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Abstract

We conducted a call-up survey across a 3,000 km² area of Dinder National Park, Sudan, an important conservation area of East Sudanian savanna that has received little study. We had seven individual lion and eight individual hyaena responses to call-ups; using mean effective range and response rate from literature we find a density of 1.57 (SE 1.31-1.83) lions and 1.80 (SE 1.62-1.98) spotted hyaenas per 100km². Accounting for uncertainty in calibration, we estimate 30-82 lions and 36-89 spotted hyaenas in the 3,000 km² core area. The entire ecosystem is five times larger, but extrapolation is too speculative; peripheral areas are inaccessible by car and livestock incursions are frequent. We discuss the importance of securing the entire park, to maintain connectivity with lion range in Ethiopia, in the context of transboundary cooperation. This neglected area has a high potential for the conservation of biodiversity that is threatened across the Soudano-Sahelian belt.

Introduction

Little has been published internationally on Sudan's wildlife, even on the national flagship protected area; Dinder National Park (DNP). Scopus reports eleven papers with mention of DNP in title, keywords or abstract; only one is a recent wildlife study (Hashim & Mahgoub, 2008). DNP has lions (*Panthera leo*), but until recently these were undocumented.

The lion is listed by IUCN as a vulnerable species across its range (Bauer et al., 2016); the Spotted hyaena (*Crocuta crocuta*) is listed as a species of Least Concern. Even so, many Spotted hyaena populations have declined or have been extirpated, particularly those outside protected areas (Hofer & Mills, 1986; Bohm & Hoehner, 2015).

Lions and spotted hyaenas occupy a similar ecological niche and where they coexist they compete for prey and carrion (Hayward, 2006). The two species are often associated and can both be surveyed using call-ups (Ogutu & Dublin, 1998); no such surveys have ever been conducted in Sudan.

The only effectively protected lion population in Sudan occurs in DNP on the extreme eastern edge of the savanna of West and Central Africa. This study reports estimates of the lion and spotted hyaena populations in this park, based on a call-up carnivore survey in the northern core area of DNP.

Material and methods

DNP covers 10,291km²; it was established in 1935 following the London convention (1933) for the conservation of African fauna and flora (Dasmann, 1972), and has been Biosphere Reserve since 1979. We define a 3,000 km² area in the North of DNP as the core of DNP (Fig. 1); it includes the Dinder river and its tributary the Gelego that have their confluence at Gelego Camp main station for park staff and visitors. There are a few inselbergs on the boundary with Ethiopia, but the core area is entirely flat. The rivers feed wetlands with permanent water ponds, locally called 'maya', where wildlife concentrates.

The northern core area has a few rudimentary roads and is regularly patrolled by a wildlife police force of ~200 scouts, the southern part of DNP is inaccessible and receives far less conservation effort. DNP is contiguous with the 2,700km² Alataash National Park (ANP) which is contiguous with the 1,800km² Bejimiz National Park (BNP), both in Ethiopia. A recent list of mammal species is available in Bauer et al. (2018).

We played calls at twenty one locations, using the protocol of Ogutu and Dublin (1998) as adapted by Bauer (2007). We used an amplifier of 2x40W (Real Max SSB-80) and two speakers of 40W (Ahuja, SUH-40XT) to play sounds of feeding spotted hyaena and distress calls of buffalo (*Syncerus caffer*) and pig (*Sus domesticus*); these recordings are widely used by and exchanged between lion researchers. Each call-up was a cycle of three sessions of ten minutes of broadcast and ten minutes of silence, in which the recordings were alternated. After five minutes of broadcast, the speakers were rotated horizontally by 90 degrees to cover the area evenly with the call-ups. After each broadcast, the area around the car was scanned with a weak red light for eye reflections. The area was again scanned with a strong spotlight (>100 lumen) afterwards to assess the presence of lions or hyaenas. If a response was vocal, we counted the minimum number of individuals based on the number of voices heard simultaneously or from different directions.

Call-ups were from 19:00 to 24:00h, starting at the end of a road and then working back to the center, doing call-ups at every 6 km (straight line distance; (Figure 1). We shifted locations by up to 500m when vegetation was very dense, but all call-up locations are spaced by at least 6 km. There was no rain throughout the study period, wind speed and luminosity were not specifically recorded. Since large carnivore densities are low across all sahelian ecosystems (Bauer et al., 2010), double counting was unlikely. The risk of double counting between stations in one night is low; the area is rarely visited and habituation to cars is minimal, we consider it unlikely that individuals exposed to one call-up would follow the car and be double counted. We used all the available roads, one road per night; the current road network does not allow for more call-ups.

Due to logistic and ecological constraints, local calibration of the call-ups was not possible. Since we had similar ecological conditions we used Bauer's (2007) assumptions; an effective range of 3km in all directions and a response rate of 75% (\pm SD) for both species. We only used sounds that

have also been used by other researchers, to increase the plausibility of these assumptions. We did not test audible range since it is not related to effective range, we note that weather conditions, relief and vegetation density were rather constant throughout the study, with no exceptional sound barriers. Furthermore, we generated a plausible range of the population size using the extreme values for the response rate found in the literature (50-100%; Ogutu and Dublin, 1998; Mills et al., 2001; Ferreira and Funston, 2010; Cozzi et al., 2013; Ferreira and Funston, 2016).

Results and Discussion

During the twenty one call-ups, eight hyaenas (± 0.80) and seven lions (± 1.5) responded; the hyaenas were seen, lions were not seen but were heard roaring in direct response to the calls at a short distance (we speculate $< 500\text{m}$). Lions are unlikely to approach cars, probably due to limited exposure to traffic; we counted lions based vocal responses. This is not unprecedented (Bauer, 2007), but it is unusual and it presents a caveat to comparability with other call—up surveys: probability of response detection may vary between visible and audible responses. Assuming an effective range of 3km, call-ups covered an area of $21 \times \pi \times 3^2 = 594 \text{ km}^2$. Assuming a response rate of 0.75, this gives a density of 1.57 (SE 1.31-1.83) lions and 1.80 (SE 1.62-1.98) spotted hyaenas per 100km^2 . Accounting for uncertainty in calibration by taking the extreme values of response rates (50%+SD - 100%-SD), minimum and maximum population estimates are 30-82 lions and 36-89 spotted hyaenas in the $3,000 \text{ km}^2$ core area. Note that our call-ups covered 20% of the core area, a sampling level recommended by Ogutu & Dublin (1998). While response rates are site specific and vary between species, values are within the same range for both species so we used that range for both lions and spotted hyaenas. While local calibration of effective range and response rates, and habituation to cars to get visual responses, would improve precision, our estimates are the best possible results for this part of DNP under current working conditions. The entire ecosystem is almost 5 times larger all of it can be considered lion and spotted hyaena range, we caution against further extrapolation because of the abovementioned methodological caveats and because parts of the area are dryland and/or are less effectively protected and are likely to have lower wildlife densities.

The lion density is similar to the densities found in a similar ecosystem in Cameroon (Bauer et al., 2015) and within the range of values reported across West and Central Africa (Bauer et al., 2008). Spotted hyaena density was only slightly higher than lion density, often it is double or more (e.g. Henschel et al., 2012; Bauer et al., 2015). We do not have an explanation for the relatively low density of spotted hyaenas.

Within the core area, lions responded around Gelego camp and along the Dinder river, which is well protected and where ungulate prey densities are high (pers. obs.). Further away, prey densities were patchy but locally high, especially around permanent surface water (mayas). However, no lions were observed in the periphery where we did observe spotted hyaenas but also several herds of trespassing livestock. Possibly, livestock herders illegally present in DNP tolerate most wildlife, but not lions. The presence of nomadic herdsman of Felata and Umbararu ethnicity is a well-known challenge to regional conservation efforts (wardens of DNP and ANP, pers. comm.).

Bertola et al. (2011) suggested that the distribution of the West and Central African lion subspecies (*Panthera leo leo*) extends into Sudan. This subspecies is suspected to be declining in CAR and South Sudan (Bauer et al. 2018); other countries only have a combined population size of <1000 so the Sudan population is of regional conservation importance. Viability of the lion and other species in DNP is boosted by connectivity with ANP and BNP in Ethiopia, and we recommend extending effective protection across the ecosystem and to ensure connectivity across the Transboundary zone.

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Figure 1: Map of Dinder ecosystem, showing the core area and the locations of the calling stations in red circles (GERD = Great Ethiopian Renaissance Dam).

