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What shapes the mammal species poaching in protected areas: biophysical or anthropogenic factors? A case study in Pendjari Biosphere Reserve

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Abstract

Understanding what shapes the mammal species poaching in protected areas is critical to developing targeted management strategies for reducing poaching. We collected the data for poaching incidents on the GPS coordinates from 2011 to 2017 to map poaching incidents in the Pendjari Biosphere Reserve. Poaching incidents were then related to environmental and anthropogenic variables using regression analyses. The study shows that poaching is more concentrated along the main river in the Pendjari National Park. Only nearest distance to the main river significantly predicted the location of high poaching incidents. These results could be used as the starting point by the park managers when planning the anti-poaching activities.

Keywords

Benin, GIS layers, Pendjari Biosphere Reserve, poaching incidents, wildlife

Introduction

The major driver of large mammal species population decreasing in Africa is poaching (Bouche et al. 2011; Maisels et al. 2013; Chase et al. 2016). A recent work on large mammal species population declines in Africa's protected areas (PAs) by Craigie et al.

(2010) has provided a first continent-wide assessment, warning on the decline between 1970 and 2005 of about 59% in population abundance of large mammal species, with a collapse of 85% when considering only western Africa. The authors have targeted the limitation in financial resources and personnel to protect the species as the major drivers increasing the poaching in many PAs despite the conservation role deserved (Thouless et al. 2008).

Some decades ago, an investigation on a continent-wide scale about elephant anti-poaching efficacy recommended a range of USD 50–200 per km^2 annually to protect them in their natural ranges in Africa (Jachmann and Billiouw 1997). Regarding the personnel, a minimum of one park ranger for every 24 km^2 of PAs is recommended if effective patrolling and policing is to be realised (Jachmann and Billiouw 1997). Again, several PAs including Pendjari in West Africa cannot meet this staffing level obligation and is, thus, unlikely to allocate more funds towards wildlife conservation (Lindsey et al. 2014; Tranquilli et al. 2014). Therefore, it is important to explore strategies that involve more efficient use of the limited available resources. By assessing what shapes the wildlife poaching in PAs, important insights about the characteristics of particular PAs where wildlife is more vulnerable to human-induced death can be generated, which can help guide effective deployment of anti-poaching patrols. Anti-poaching patrols in Western Africa PAs are challenging because of limited resources and the expansive area of the parks that limits the effectiveness of patrols by park rangers. It is in the interests of conservation to investigate some research questions such as: (i) what are the spatial patterns of large mammal species poaching in the Pendjari Biosphere Reserve (PBR); (ii) what mammal species are of concern and (iii) What are the relationships between observed patterns of poaching and anthropogenic, biophysical variables? Answering those questions will be useful to facilitate the development of effective and optimally targeted management strategies to reduce poaching in a critical poaching hotspot, such as in protected area landscape under the conditions of resource limitation.

Efforts to assess the drivers of large mammal species poaching in PAs have highlighted several factors. It shown that areas with extensive forest cover, with more challenging patrolling and enforcement than in open savannah, show, for example, a top level of poaching in elephant (Burn et al. 2011). Distance to water is targeted as the primary environmental factor influencing the density of large mammal species population in PAs (Redfern et al. 2003; Djagoun et al. 2014) and driving the poacher's interest on those sites.

This study aims to describe the most wildlife species poached between 2011 and 2017, together with the spatial distribution of large mammal species poaching incidents in the Pendjari's landscape and to identify the biophysical and human factors that determine the distribution of poaching incidents. We use an explicit spatial modelling approach to quantify the relative contribution of multiple potential factors described in literature as a priori to explain the poaching incidents. We hypothesised that poacher sites would be associated with: (1) water availability, (2) accessibility (roads and topography) and (3) proximity of human settlements and land uses.

Methods

Study site

The Pendjari Biosphere Reserve successively classified as a National Forest, a partial Wildlife Reserve of the Pendjari loop and a National Park, acquired the labels of Biosphere Reserve in 1986, RAMSAR site in 2007 and now considered as a UNESCO World Heritage Site. The PBR is in the Atakora Province, north-western Benin. It is situated at 10°30' to 11°30'N; 0°50' to 2°00'E (Fig. 1). It was declared as a Game Reserve in 1954 and upgraded to National Park in 1961. It is nowadays composed of a strictly-protected core area (the Pendjari National Park with 2,660 km^2) and three hunting zones in west and south sides (1,971 km^2). In the north and east parts, the River Pendjari forms a natural border of the PBR. Its northern boundary is also the country's border with Burkina Faso (Delvingt et al. 1989; MAB-UNESCO 1990). Climate is tropical, between late October and early April, there is a seven-month dry period. The PBR is located in the Sudanian zone with a single dry season from November until March and one wet season from April/May to October.

Annual mean precipitation is 1000 mm, with 60% falling between July and September (Sinsin et al. 2002).The mean annual temperature is 27 °C (Verschuren 1988). The mean daily temperatures for the period 1979 to 2010 peaked from March to

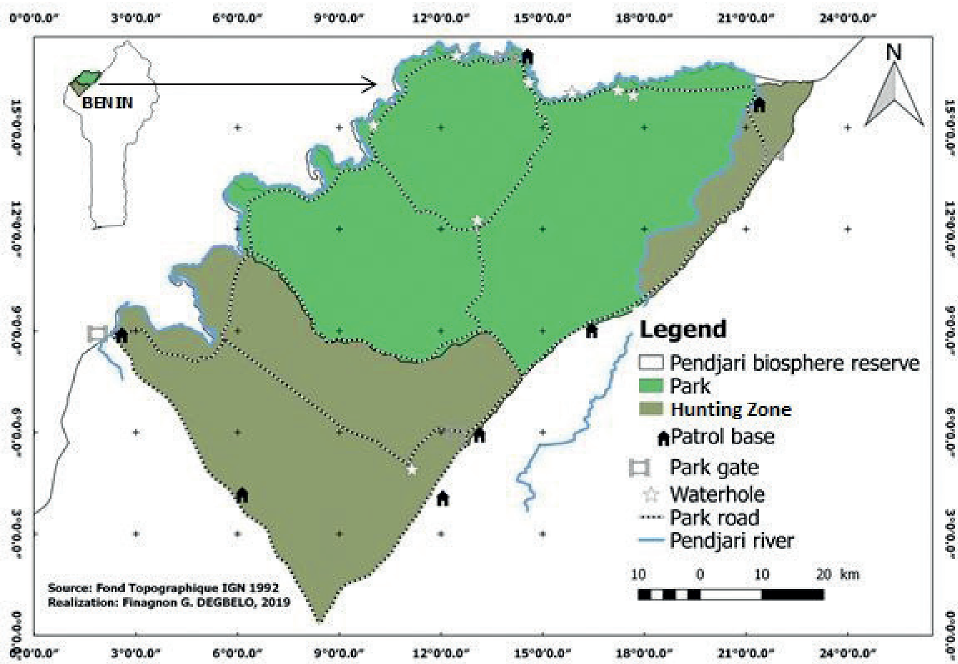

Figure 1. Map of Pendjari Biosphere Reserve.

April and reached a low value during November to January. Mean daily minimum and maximum temperatures were 19.2 °C and 30.9 °C for the cold month (December), 24 °C and 40 °C for the hottest month (March). The impact of the rainfall regime is very important because the rate of wildlife sighting through line transects is negatively correlated with the green cover in the top level in the rainy season (Strahler 1998). The rainy season allows the filling of many small and large waterholes in the centre of the National Park, namely Tiabiga, Fogou, Mondri, Diwouni, Yangouali and Bali. During the dry season, many waterholes attract a variety of animals, with large mammal species searching for water. The dominant vegetation type is savannah interspersed by some patches of dry forests with deciduous trees (Sokpon et al. 2001). Savannah vegetation is burnt every year for management to provide fresh pasture to herbivores that dominate the Reserve, provide visibility to wildlife tourists and hunters who visit mostly during the dry season and to avoid uncontrolled mid- or late dry season fires that are often started by poachers to camouflage illegal activities or that originate from surrounding villages.

Data collection

Mammal species poaching data from 2011 to 2017 was obtained from the PBR anti-poaching database, which has been developed over the years during routine daily patrols by rangers. The anti-poaching patrols are randomly distributed and the poaching incidents observed during these surveillance patrols are geo-referenced. Data on poached mammal species were then entered into an EXCEL spreadsheet. Each record had the following fields: X and Y coordinates (using Universal Transverse Mercator), date of registration and name of the place where the poaching incident occurred. A total of 279 poaching points were recorded by the guards for the period. Of these locations, 228 points fell inside the PBR. A total 303 mammal individuals were poached in the PBR from 2011 to 2017.

The locations of ranger patrol bases and park gates were obtained by visiting the sites and recording their locations using a Global Positioning System (GPS). The geographic coordinates of the Park boundaries, roads, rivers and waterholes were obtained from an ecological biomonitoring service (Fig. 2).

Poaching incidents locations, as well as locations of ranger patrol bases and park gates, have been projected on to the Pendjari Biosphere Reserve map. Then, with the ARCGIS 9.2 software, the biophysical variables, such as the closest distance to waterholes (NDis_Wh); the distance closest to the main river (NDis_Rv) and anthropogenic variables, such as the closest distance to the park gate (NDis_Pg); closest distance to the patrol base (NDis_PaB); distance closest to the park road (NDis_Pr) and the distance closest to the park boundary (NDis_Pb) were measured for each of the identified poaching sites.

The measured values of each of the variables, cited above, were used to model the distribution of poached species within the RBP.

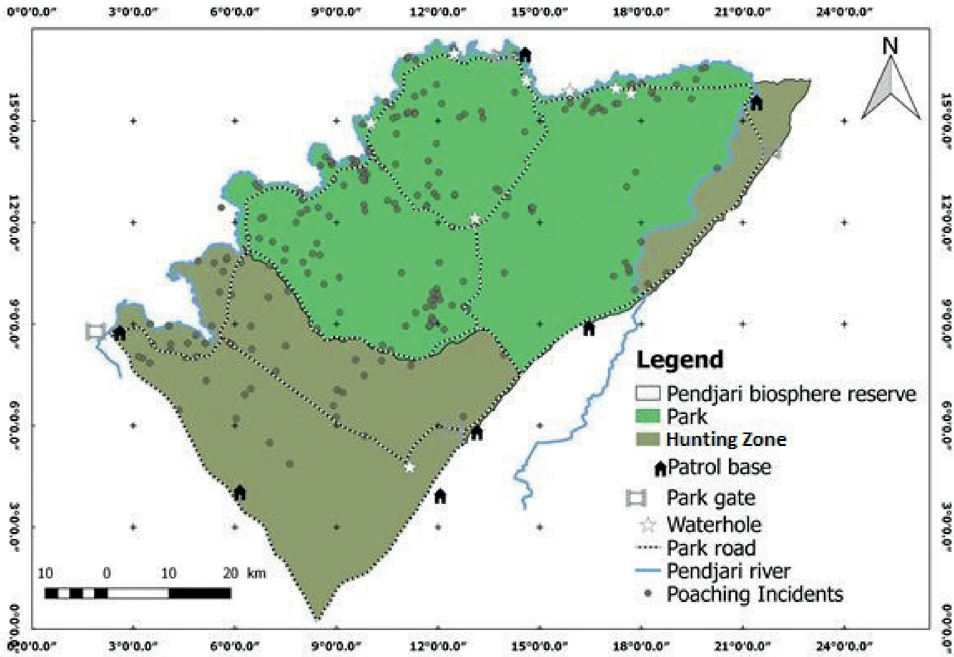

Figure 2. GIS layers generated showing locations of poaching incidents in Pendjari Biosphere Reserve.

Data analysis

Estimating the large game poached species according to the management zones

We performed all analyses in the statistical programme R v. 3.5.2 (R Core Team 2018). The percentage of most poached species in Pendjari Biosphere Reserve and the most threats to the wildlife were calculated and presented as bar plots. A Student's t-test was performed to assess the difference in the number of poached species per management zone.

Biophysical and human factors predicting the poaching areas

To assess multi-collinearity into the variables, variance inflation factors (VIF) were examined. This parameter estimates how much the variance of a coefficient is increased due to a linear relationship with other predictors (Barnier et al. 2019). A VIF value less than or equal to 4 indicates that there is no multi-collinearity between variables (Rakotomalala 2015). The package "car" (Fox et al. 2012) was used and applied on the linear model to calculate the variance inflation factors (VIF) with the live function. After analysis, we found for the variables that waterholes (VIF = 1.173), park_road (VIF = 1.074), main_river (VIF = 2.185), park_boundary (VIF = 2.110) are considered for the model because their VIF is less than 4. For the other two variables, namely park_gate (VIF = 8.741) and patrol_base (VIF = 9.049773), the VIFs were higher than 4, therefore are not used in the model. The model's odds ratios were calculated using "questionr" R package.

Spatial distribution pattern of poaching incidents around waterholes

We also estimated spatial distribution patterns of poaching sites in the PBR and around waterholes from 2011 to 2017. We used functions from the spatstat package to calculate K statistics to model Monte Carlo envelopes (999 simulations) to test the complete spatial randomness (CSR) hypothesis (Baddeley and Turner 2004) in R software (R Core Team 2018). Ripley's K distribution above the upper confidence interval indicates clustering, between confidence intervals indicates a random spatial pattern and below the lower confidence interval indicates a regularly distributed pattern.

Results

Estimating the large game poached species according to the management zones

Figure 3 shows that 14 ungulate species was regularly poached in the PBR. We notice a statistical difference in the poaching average of individuals across the difference zones (t = - 9.4525, P-value < 0.05) with a much more poaching activities in the Park. Only red flanked duiker (*Cephalophus rufilatus*) were poached exclusively in the Park. Amongst these species, *Loxodonta africana*, *Ourebia Ourebi*, *Papio anubis* and *Hippopotamus amphibious* were mostly poached in the Park, respectively in the proportion of 88%, 85%, 76% and 70%.

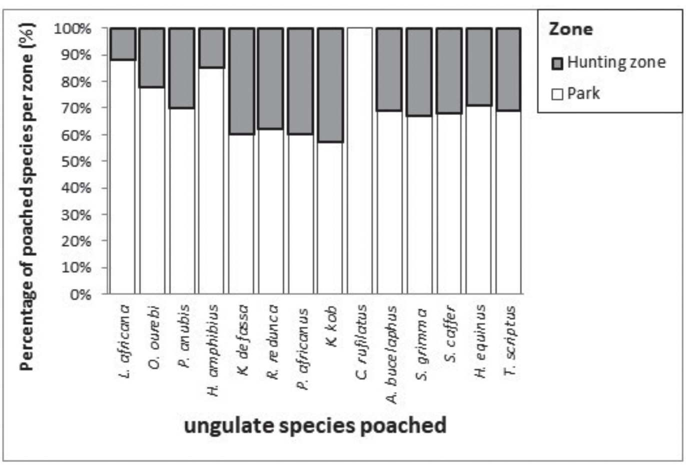

Figure 3. Hunted ungulate's species percentage per zone.

Biophysical and human factors predicting the poaching areas

Only the variable "nearest distance to the main river" (*p*-value = 0.041) contributed significantly in explaining the poaching incidents (Table 1). When the nearest distance to the main river increases by one kilometre, the probability of having a high poaching site increases by 0.8%. Other variables, such as nearest distance to the Patrol Base; nearest distance to the Waterholes; nearest distance to the Park Road, have not contributed to explain the poaching incidents.

Spatial distribution pattern of poaching incidents around waterholes

Figure 4 shows the Ripley's K-function analysis performed on the mammal species poaching site in the PBR. This showed significant random patterns up to 26 km and clusters beyond that distance (Fig. 4A). However clustered patterns of the mammal species poaching sites are revealed extensively in the PBR when considering the waterholes (Fig. 4B).

Discussion

Our study helped to assess the biophysical or anthropogenic factors predicting the mammal species poaching areas in the western African PAs using poaching data over

Table 1. Results of the generalised linear model between poaching incidents locations and predictors.

Parameters	Signs	Coef.	Odds ratio	Robust SE	Pr(> |z|)
(Intercept)	-	1.53945	0.19178	2.212365	0.68366
NDis_Wh	-	0.97483	0.92650	0.025397	0.29987
NDis_Rv	-	0.89485	0.79059	0.06097	0.0410*
NDis_Pr	-	0.98852	0.89355	0.026652	0.63059
NDis_PaB	+	1.01985	0.95631	0.037449	0.55261

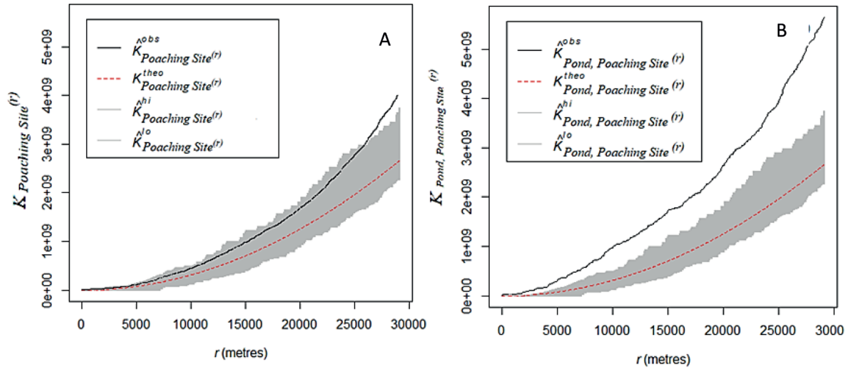

Figure 4. Ripley's K-function analysis performed on the mammal species poaching site in the PBR: **A** all poaching sites **B** poaching site vs. waterholes.

seven years (2011–2017). In total, we found 14 ungulate species to be mostly poached in the PBR with more poaching occurring in the Park. The study further highlighted the nearest distance to the river as the main driver of the poaching incidents in the PBR. Ripley's K-function analysis, performed on the mammal species poaching site in the PBR, showed significant random patterns up to 26 km and clusters beyond that. However clustered patterns of the mammal species poaching sites are found extensively in the PBR when considering the waterholes.

The results about the most species poached confirm the work of many authors, notably, Van Schuylenbergh (2009) who affirms that poaching appears even more profitable in areas where animal species are protected, such as National Parks which fuel a profitable trade in trophies. The species poached in the Ebo Forest Reserve at Cameroon are dominated by ungulates (Fuashi et al. 2019). In addition, commercial animal poaching, such as for ungulates, occurs in the areas with greatest densities (Maingi et al. 2012). Our results also confirm those that are reported by the Wildlife Census (PAPE 2013), which revealed that, in the protected area, poaching is the most common form of human pressure. However, the pressure varies according to the zoning within the protected areas. Knowledge of the spatial distribution of poaching activities is very important for managers. It will allow them to bring together all the resources suited to the areas of concentration (Treves et al. 2011).

The poaching incidents mapping within Pendjari Biosphere Reserve shows that the high poaching areas are near to the main river and far from the park road, waterholes and patrol base. The high incidence of poaching along the river leads them to conduct repeated main patrols in the area. These results support previous research, such as Sibanda et al. (2016) research, who reported an increased activity of poachers near waterholes in the mid-Zambezi Valley, as did the Maingi et al. (2012) work on spatio-temporal models of elephant poaching in south-eastern Kenya which shows that hotspots of poaching were identified in areas with higher densities of waterholes, rivers and streams. The same information was reported in the "Emergency Action Plan Against Poaching (PAULAB)" by UEMOA (2014), which indicates that poaching occurs mainly along the main river. The proximity to water is the most important factor leading to poaching (Kuiper et al. 2020). This observation is explained because populations of wildlife species are mainly concentrated at the waterholes (Djagoun et al. 2014; Rich et al. 2019). Non-commercial animal poaching was associated with high-wetness areas and near rivers, possibly because there is a need for a certain amount of woody vegetation to conceal snares and create funnels for wildlife to move into the snare. Roads, waterholes and patrol bases play an important role in the fight against poaching. The history of wildlife conservation has shown that the presence of agents in living areas would reduce poaching. This study showed a negative relationship between the presence of patrol officers and illegal activities, as increasing the distance from living bases, roads and waterholes increases the likelihood of poaching. However, part of our results contradict the work of Sibanda et al. (2016) and Maingi et al. (2012) which also showed that poaching activities are observed close to roads. The proximity to major residential areas and roadways has a strong influence on poaching incidents

(Nieman et al. 2019). This statement is confirmed by Subedi and Subedi (2017) who showed that poaching incidents are located near the roads and also agree with us by specifying that these zones are located far from the bases of life. The claim that poaching areas are close to roads can be explained by the fact that, in the natural resource management scenario, roads facilitate the movement of people to previously-inaccessible areas. If the area is easier to reach, then the poacher can go to the area in a short time to poach (Toxopeus 1996; Subedi and Subedi 2017). The road infrastructures in these areas, therefore, facilitate poachers' access. However, in the context of the PBR, these roads could reduce the presence of poaching acts, but can allow the transport of game according to the fact that those roads are often used by rangers for patrols and, on the other hand, could be useful for the poacher to escape while patrols were not present in the area at the time of poaching. The poaching is concentrated in the main river because the rangers have not sufficient means to intensify the patrols in the area. Despite the efforts of the rangers, this plague continues to increase day by day.

Knowledge of the spatial distribution of poaching activities is very important for managers. It will allow them to bring together all the resources suited to the areas of concentration (Treves et al. 2011).

Our work has the particularity of having used spatial analysis methods to understand poacher's behaviour according to the biophysical or anthropogenic factors in the PAs. This study finding is important for ranger deployment and demonstrates the value of a full spatio-temporal analysis. This study could, therefore, form the basis for the formulation of future hypotheses which test the effect of poaching on the wildlife conservation in PAs. Future studies exploring similar hypotheses should include seasonality to understand the temporal patterns of poaching. This will allow better generalisations regarding the incidence of poaching according to the different seasons. Additionally, our findings represent a baseline for any further evaluation of the new management system put in place in PBR by the African Park Network since 2017.

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