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- *Article structure* : Introduction, materials and methods, results, discussion, conclusion, acknowledgements (when appropriate), references.

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GUYOT B., TOBAR M. & VINCENT J. C. 1988. Essai de détermination de la couleur verte du café en système modèle. *In* : XIII colloque scientifique international sur le café. Montreux, Suisse, 28 juin-3 juillet 1987. Paris, France, ASIC, pp. 143-147.

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## HUMAN-WILDLIFE CONFLICTS AND MITIGATION MEASURES IN PENDJARI BIOSPHERE RESERVE, NORTHERN BENIN

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### ABSTRACT

Human-wildlife conflicts are any interactions between human and wildlife with a negative impact for both parties. Understanding these conflicts is necessary to guaranty a better coexistence between human and wildlife and an improvement of wildlife conservation. The current research aims at assessing human-wildlife conflicts and analyzing the management measures developed by local communities around Pendjari Biosphere Reserve in Benin. Data were collected in January and February 2017 through a questionnaire survey of 245 respondents from different socio-professional background. Three main types of conflicts were observed around the Reserve: crop raiding, livestock predation and destruction of fishing materials. The most destroyed crops were maize (15 %), cotton (15 %) and millet (14 %), and sorghum (29 %) and baboon was the most important crop raiding species (61 % of depredation cases). Regarding livestock, pig (25 %) and sheep/goat (23.1 %) were the most attacked animals while hyena was the most important predator reported (40.6 % of attacks). Fishing nets and hoop nets were destroyed by crocodile (72.2 %) and hippopotamus (27.8 %). To reduce these damages, farmers used several measures such as guarding (82%), scarecrows (64.5 %), and fires on the outskirts of the fields (67.3 %). Herders mostly used livestock guarding (12.7 %) and fires or torchlight lit in the enclosures during the night (8.6 %). These measures were not efficient to prevent or avoid the damages but they did reduce them. They must be reinforced to reduce the impact of the damages on the agricultural production, the main source of income of local communities.

**Keywords:** human-wildlife coexistence, damage, predation, conflicts mitigation, West Africa.

## CONFLITS HOMME-FAUNE ET MESURES DE RÉDUCTION AUTOUR DE LA RÉSERVE DE BIOSPHERE DE LA PENDJARI, NORD BÉNIN

### RÉSUMÉ

Les conflits homme-faune sont toutes les formes d'interaction entre les humains et la faune sauvage ayant des impacts négatifs sur l'une ou l'autre des parties. Comprendre ces conflits est nécessaire pour garantir une meilleure coexistence entre l'homme et la faune et ainsi une meilleure conservation de la biodiversité animale. La présente étude se propose d'évaluer les conflits hommes-faune et analyser les mesures de gestion de ces conflits autour de la Réserve de Biosphère de la Pendjari. Les données ont été collectées à l'aide de questionnaires en Janvier et Février 2017 sur un échantillon aléatoire de 245 personnes de différentes catégories socio-professionnelles. Trois formes de conflits ont été observées autour de la Réserve. La destruction de cultures, surtout par les babouins (61 %), concerne le maïs (15 %), le coton (15 %), et le mil (14 %). La prédation du bétail affecte les porcins (25 %) et les ovins/caprins (23,1 %) et est principalement l'œuvre de la hyène (40,6 %). La destruction des filets de pêche est causée par les crocodiles (72,2 %) et les hippopotames (27,8 %). Pour réduire les dégâts, les agriculteurs utilisent principalement la surveillance des champs (82 % de nos enquêtés), les épouvantails (64,5 %) et les feux aux abords des champs (67,3 %). Quant aux éleveurs, ils gardent le bétail (12,7 %) ou allument des feux dans les enclos la

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nuit (8,6 %). Ces mesures ne préviennent pas de façon significative les dégâts mais réduisent leur ampleur. Elles doivent être renforcées et accompagnées pour plus d'efficacité.

**Mots clés :** coexistence homme-faune, dégâts, prédation, réduction des conflits, Afrique de l'Ouest.

## INTRODUCTION

Human-wildlife conflicts is a global concern and a critical threat to the existence of several endangered species such as lion, crocodile, leopard, bear, elephant, as well as to human beings (Lamarque *et al.*, 2009 ; Bhattacharjee & Parthasarathy, 2013). These conflicts are among the factors that threatened the most wildlife species throughout the world. Human-wildlife conflicts occur when the needs of wildlife overlap those of human populations. Conflicts are more intense in areas where both human populations and wildlife live and share ecosystem services, mainly around protected areas. The implications of conflicts are manifold, ranging from psychological manifestations, such as fear, to fatal attacks (Bhattacharjee & Parthasarathy, 2013 ; Jhamvar-Shingote & Schuett, 2013). Since 1990, human-wildlife conflicts get an increasing interest from scientists (Marchand, 2016) in an interdisciplinary approach (Dickman, 2010).

In Africa, several studies have been carried out on human-wildlife conflicts. Despite smaller species such as insects and birds cause more damages, more attention are paid to large mammals and crocodiles (Lamarque *et al.*, 2009). Wildlife damages are mainly towards crops and livestock. In many areas, people are injured or killed by wildlife (Packer *et al.*, 2005 ; Lamarque *et al.*, 2009 ; Dunham *et al.*, 2010). These conflicts that can be very costly to communities (Mkonyi *et al.*, 2017) jeopardize peoples' livelihoods. People in retaliation kill wildlife, endangering several wildlife species (Swanepoel *et al.*, 2015). Various forms of human-wildlife conflicts are observed in West Africa (Lamarque *et al.*, 2009 ; Sogbohossou *et al.*, 2013). Like in other parts of Africa and the word, emphasis was placed on large herbivores and carnivores. Studies investigated aspects such as characteristics of conflicts, people perceptions, mitigation measures... (Lamarque *et al.*, 2009 ; Bauer *et al.*, 2010 ; Sogbohossou *et al.*, 2011 ; Sogbohossou *et al.*, 2013 ; González *et al.*, 2017). However there are very few publications on the subject in the region compared to other parts of Africa. Considering the importance of human-wildlife conflicts for wildlife and humans, it is important to monitor closely these conflicts in order to better manage them. In Pendjari Biosphere reserve, West Africa, Sogbohossou *et al.* (2011) showed that the predation of the domestic livestock by the wildlife is a reality around Pendjari Biosphere Reserve in Benin. The main predators were lion, hyena and baboon and they

attacked large and small stock. Regarding crop raiding, maize, sorghum, millet and cotton were the most destroyed crops by elephants and baboons (Kiki, 2012). These studies focused on conflicts' characteristics without highlighting measures developed by local communities to manage these conflicts. In order to guaranty a bright future for the coexistence between wildlife and people, it is important to evaluate regularly the importance of conflicts and the effectiveness of conflicts mitigation methods used.

The current research aims at assessing human-wildlife conflicts and analyzing the management measures developed by actors involved in human-wildlife conflicts around Pendjari Biosphere Reserve. This information is necessary to develop more efficient mitigation measures in order to sustainably preserve wildlife species and human populations' livelihoods.

## MATERIALS AND METHODS

### *Study Area*

The study was carried out around Pendjari Biosphere Reserve in north-west Benin (Figure1). The Reserve is part of a complex of four adjoining protected areas W, Arly, Pendjari and Oti-Mandouri (WAPO) in four adjacent countries (Benin, Burkina Faso, Niger and Togo). Pendjari Biosphere Reserve was established in 1954, upgraded to National Park status in 1961 and to a UNESCO Man and Biosphere Reserve in 1986. It comprises Pendjari National Park (2.660 km<sup>2</sup>), Pendjari and Konkombri Hunting Zones (1.600 km<sup>2</sup> and 251 km<sup>2</sup>, respectively) and a buffer zone with controlled land-use access for local people (340 km<sup>2</sup>).

The Reserve is bordered to the north and west by the Pendjari River and to the east by the Atacora mountain range. In this Sudanian ecosystem the climate is characterized by one dry season from October to May and one wet season with a total annual rainfall of 800–1,000 mm. The vegetation is a mixture of open grass and tree savannahs interspersed with dry and gallery forests. These habitats harbour a variety of wildlife species (Delvingt *et al.*, 1989). The density of lion in the Reserve is estimated to be between 0.67 (Di Silvestre, 2002) and 1.5 lions per 100 km<sup>2</sup> (Sogbohossou, 2009) and the spotted hyena occurs at a minimum density of 1.5 per 100 km<sup>2</sup> (Sogbohossou, 2009). Cheetah, which almost disappeared, seem to be recovering, although numbers remain low, and there is no estimate of leopard abundance.

The Reserve is bordered by two main roads, Tanguiéta-Porga and Tanguiéta-Batia, along which there are 24 villages (Figure 1). In addition to native farmers, most villages are also inhabited by Fulani (with one to eight camps

in each village), who are pastoralists. During the dry season, migrating herds of cattle led by Fulani herdsmen from neighboring countries reside within or close to the border of the Park in search of water and fodder.

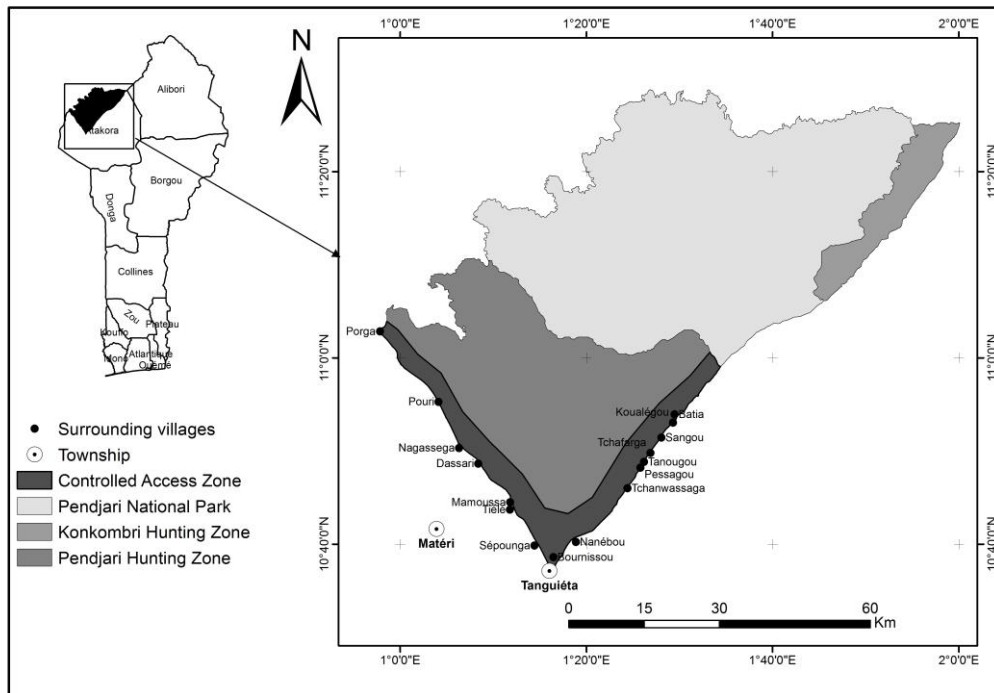


Figure 1. Pendjari Biosphere Reserve and the main surrounding villages

*Data collection and analysis*

Data on human–wildlife conflict management measures were collected between January and February 2017. A total of 21 out of the 24 villages surrounding Pendjari Biosphere Reserve were surveyed. The managers of the protected area and the farmers, breeders and fishermen from the local communities were questioned. Questions were related to human-wildlife conflict manifestations including livestock predation and crop raiding, conflicts mitigation and mitigation measures’ effectiveness.

In each household or camp we interviewed the head and when he was absent his elder son or wife. A total of 245 interviewees participated to the study. Data were analyzed using SPSS v.16. Descriptive statistics were used to describe the different types of conflicts.  $\chi^2$  tests were used to compare depredation characteristics. We used for each crop mean yield and prices

communicated by the Beninese Office of Food Security (Office National de Sécurité Alimentaire, ONASA) on December 2016 to evaluate the economic impact of human-wildlife conflicts. Those prices were converted from XOF to US dollar using the USD value of September, 1<sup>st</sup> 2017 (1USD = 550 XOF) ([www.mataf.net/fr/conversion/monnaie-USD-XOF](http://www.mataf.net/fr/conversion/monnaie-USD-XOF)). To verify the effectiveness of the management measures, we asked interviewees to rank them according to their effectiveness. Kendall's test was used to test the concordance of ranking. Results from statistical analysis were considered to be significant when  $p < 0.5$ .

## RESULTS

Three main types of conflicts were observed around Pendjari Biosphere Reserve : crops depredation, livestock predation and fishing materials destruction.

### *Human-wildlife conflicts characteristics*

#### *Crop raiding species*

Farming was the main activity of the populations in the villages surveyed. The mean farm size per household was 5.03 ha (SE = 0.22 ; n = 205). There was an average of 6 agricultural workers by household (SE = 0.48 ; n = 170). Maize (15 %), cotton (15 %) and millet (14 %) were the most destroyed crops (Figure 2) by baboon (61 %), warthog (16 %) and elephant (13 %). Damages of hippopotamus on rice were less observed around the Reserve (Figure 3). Wildlife species seemed not to be specialized in some crops ( $\chi^2 = 56.8$  ;  $p = 0.99$  ;  $df = 90$ ).

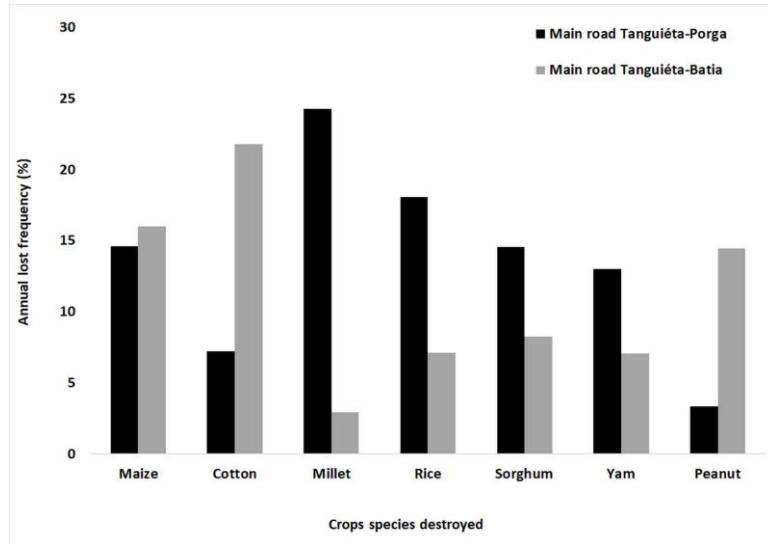


Figure 2. Proportions of crop raiding by wildlife along Tanguiéta-Porga and Tanguiéta-Batia main roads

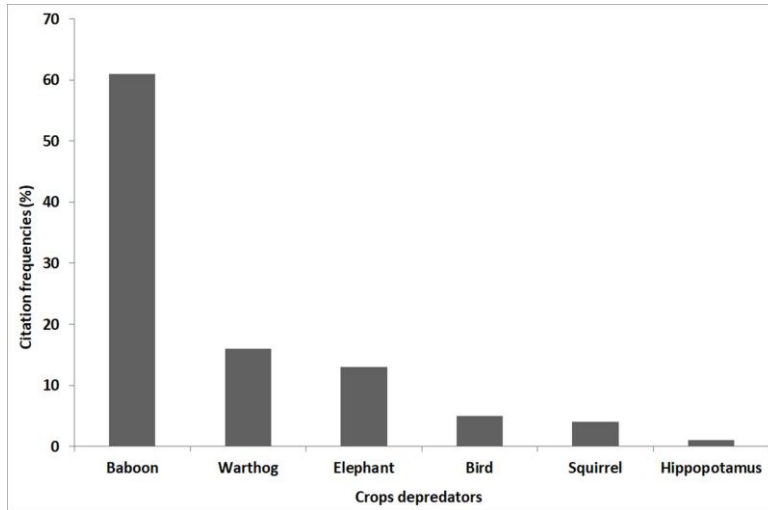


Figure 3. Frequency of attacks by crop raiding species around Pendjari Biosphere Reserve

*Livestock predation*

The small stock (sheep, goat and pig) husbandry was the second important activity of the populations around Pendjari Biosphere Reserve. Livestock represented savings for both local farmers and Fulani: the sale of small stock used to provide cash income to compensate for food shortages or to cover other expenses. Most important livestock predators were spotted hyena (40.6 %), lion (9 %) and baboon (3 %) (Figure 4).

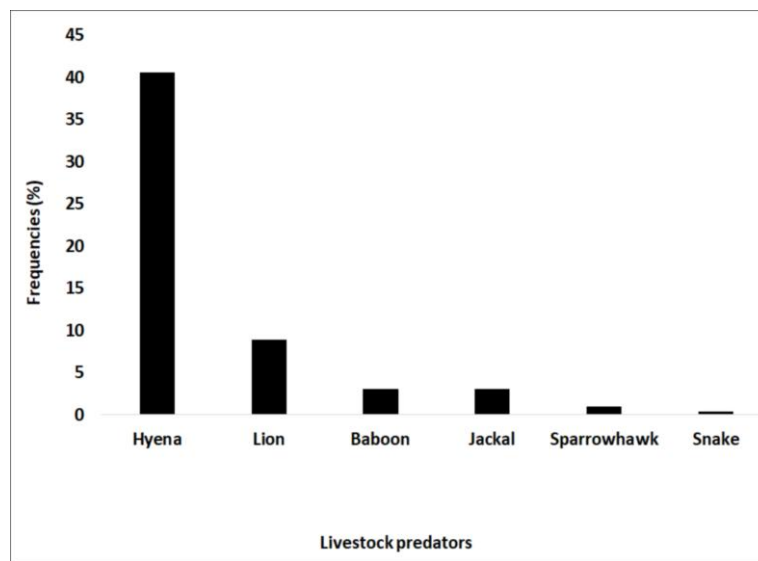


Figure 4. Livestock predators around Pendjari Biosphere Reserve

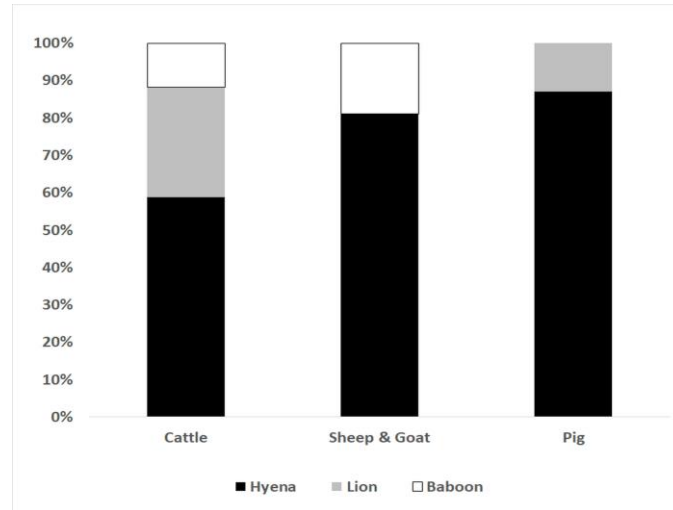


Figure 5. Importance of livestock predation by different predators' species

There was a significant relation between livestock species attacked and large carnivores species ( $\chi^2 = 56.36$  ;  $p < 0.001$  ;  $df = 27$ ). Lion attacked mainly cattle whereas baboon specialised in sheep, goat and pig (Figure 5).

#### *Fishing materials destruction*

Fishing was the third activity, after agriculture and livestock breeding, occupying 8.6 % of respondents. Local materials like fishing nets and hoop nets were used. Those materials were sometimes (4.2 %) destroyed by crocodiles (72.2 %) and hippopotamus (27.8 %).

#### *Economic impact and temporal distribution of human-wildlife conflicts*

The economic impact of human-wildlife conflicts was evaluated considering annual crops destroyed per farmer and livestock species attacked per breeder around Pendjari Biosphere Reserve. Farmers can lose from 42,264 XOF (US\$ 76.8) in millet farm to 163,674 XOF (US\$ 297.6) in maize farm. The mean annual loss per breeder is 18,000 XOF (US\$ 32.7) for cattle and 96,000 XOF (US\$ 174.5) for small stock.

The three types of conflicts were observed at different periods of the year. The figure 6 presents damages frequencies per month.

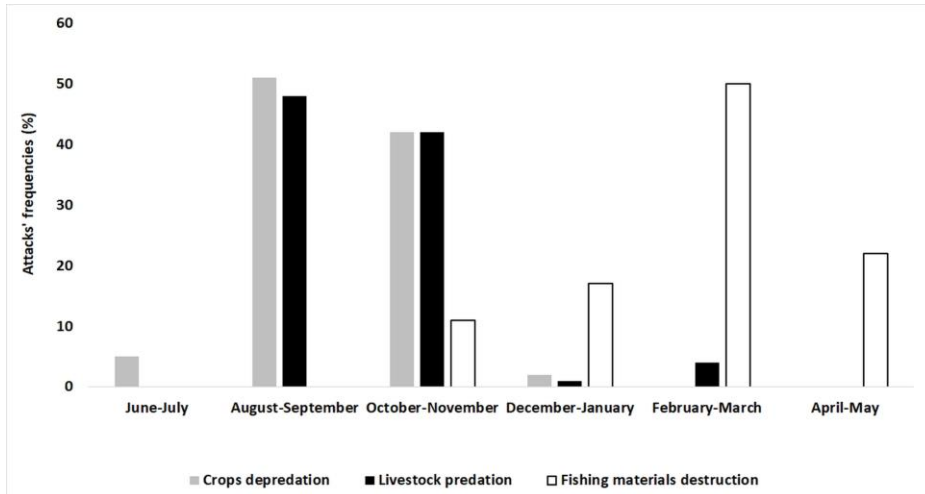


Figure 6. Evolution of the different types of conflicts during a year

Crop raiding occurred mainly during seedling and harvest periods from June to December. Predation of small stock generally occurred at night during the rainy season from August to October. At this time, because of farming activities, animals were kept in enclosures usually made of clay, or tied to trees. By contrast, cattle predation occurred during the dry season from January to March. Regarding the damages on fishing equipment, they occurred only during dry season from October to April.

#### *Human-wildlife conflict mitigation measures*

Different measures were used by local communities to mitigate conflicts with wildlife (Table 1). Farmers used mainly guarding, fires around the fields and scarecrows while herders used the livestock' guarding and fires or torchlights during the night.

Table 1. Human-wildlife conflicts management measures around the Reserve

Victims	Measures	Wildlife species targeted	Frequencies of use by communities (%)
Farmers	Guarding	Baboon, bird	82.0
	Fires	Warthog, elephant	67.3
	Scarecrows	Baboon, bird	64.5
	Steel sheets	Hippopotamus, elephant	26.1
	Trap	Baboon, squirrel, bird	6.1
	Guarding dogs	Baboon, squirrel	4.9
	Hunting	Baboon, squirrel, bird	4.5
	Fence	Baboon, squirrel	2.9
	Pepper	Elephant	2.0
	Nut of <i>Parkia biglobossa</i>	Squirrel	1.2
Livestock Breeders	Livestock guarding	Hyena, lions, baboon	12.7
	Torchlight in enclosures	Hyena, lion	8.6
	Building of enclosures	Jackal, sparrowhawk, snakes	5.0
Reserve headers	Compensation	-----	3.3

The most effective measures according to local communities were guarding and fires (Table 2). Mitigation measures had significantly different impacts on conflicts ( $\chi^2=25.9$  ;  $p<0.001$  ;  $df= 6$ ). However, they were not so effective to prevent farms and livestock from damages ( $\chi^2= 77.57$  ;  $p = 0.704$  ;  $df = 85$ ). They were used mainly to reduce the impact of the depredation.

Table 2. Ranking of the measures according to their level of damage reduction

Measures	Mean rank
Guarding	1.04
Fires	2.43
Guarding dogs	3.40
Scarecrows	3.42
Steel sheets	4.73
Trap	6.15
df	6
$\chi^2$	1.22
Probability	0.000

## DISCUSSION

In general, data from interviews may be subject to bias. It would have been better to monitor conflicts daily. Declared predation rates may be negatively or positively biased (Rasmussen, 1999). Nevertheless, information have been collected from affected communities, what could provide reliable data on human-wildlife conflicts (Anthony *et al.*, 2010). We believe we reduced the potential bias by focusing on the previous year to limit omissions and by explaining carefully to interviewees the goal of the study so that they did not have any expectations and then distort supplied information.

### *Environmental and socio-ecological patterns of the conflicts*

Our results indicated that wildlife attacks were against crops, livestock and fishing equipment in Pendjari Biosphere Reserve. Crop raiding is the most important form of human-wildlife conflicts (Naughton-Treves, 1998). However, fishing equipment destruction, which was rarely reported in Pendjari has been an important problem elsewhere (Marchand, 2016). Like in Cameroon (Weladji & Tchamba, 2003), baboon, warthog, elephant and birds were the most important crop depredators. Elephant which is usually the most important threat to crops (Parker *et al.*, 2007) was not the first raider around Pendjari. This can be explained by the fact that villages are separated from the protected area by a buffer zone and the density of most wildlife is very low close to villages. One exception is baboon which can also be found on the mountain bordering villages in the eastern part of the reserve and hills found in the western side villages. The most destroyed crops were the most common in the area. We noticed that damages occurred most during sowing and harvest periods. If damages during sowing could be repaired by another sowing, damages during the harvest period are unrecoverable. Crop raiding and especially damages on cereals affects then wellbeing of neighboring communities (Barua *et al.*, 2013).

Regarding livestock predation around Pendjari Biosphere Reserve, hyena was the most important predator responsible of about 40 % of predation case followed by lion (9 %). The importance of hyena in livestock predation varies considerably across Africa. In Maasai Mara National Reserve, Kenya, hyena was the dominant livestock predator (Kolowski & Holekamp, 2006) like in Pendjari. Elsewhere lion is a more important depredator than hyena. In Tsavo National Park in Kenya for example, hyena was responsible for less than 10 % of livestock' attacks against 86 % for lion (Patterson *et al.*, 2004).

Lion was also a more important predator than hyena in commercial ranches of northern Kenya (Ogada *et al.*, 2003) and in the Gokwe Communal Area in Zimbabwe (Butler, 2000). The difference in the rates of livestock predation and predator species' importance from one region to another can be explained by local environmental conditions such as the abundance of natural prey (Stoddart *et al.*, 2001 ; Polisar *et al.*, 2003), rainfall (Patterson *et al.*, 2004 ; Woodroffe & Frank, 2005) and predator's prey preference. Socio-ecological factors including livestock husbandry practices (Stahl *et al.*, 2001 ; Madhusudan, 2003 ; Ogada *et al.*, 2003), characteristics of attacked farms, villages, and livestock enclosures (Mech *et al.*, 2000 ; Ogada *et al.*, 2003) are also important. The difference between lion and hyena predation characteristics around Pendjari Biosphere Reserve could be explained by the density, prey preferences of the carnivores and husbandry techniques. Hyena is more abundant than lion in Pendjari reserve (Sogbohossou, 2009), what could explain why it is the most important predator. On the other side, lion, which prefers large prey in protected areas, generally preyed on cattle. In contrast, hyena and baboon both attacked small stock (Kissui & Packer, 2004 ; Patterson *et al.*, 2004 ; Kolowski & Holekamp, 2006). Although cattle were relatively infrequently preyed, the cost of this perceived predation is greater than other livestock species due to the higher market price of cattle (Rust & Marker, 2013). In general, conflicts are more observed in rainy season when it is most difficult for predators to hunt for natural prey and crops are growing and then are attractive as easy food for herbivores.

Compared to 2010 (Bauer *et al.*, 2010), livestock predation costs seem to have decreased in Pendjari. Indeed the costs for livestock owners were between US\$ 77-207.2 for this study against US\$ 196-350 several years ago. The difference could be a consequence of the different mitigations methods promoted by the Local Communities Association and Non-Governmental Organizations and the awareness of local populations. However these losses remain quite important for poor rural communities who rely on their harvest and livestock for food and income and are unable to afford expensive methods to protect their stock and farms (Stephens *et al.*, 2001 ; Dickman, 2005).

#### *Effectiveness and vulnerability of mitigation measures*

Mitigation measures used by populations around Pendjari Biosphere Reserve were non-lethal. This is quite positive as local populations did not seem to think about retaliatory killing as a way to reduce predation, at contrary to other parts of Africa where wildlife pay a heavy tribute to conflicts (Nowell &

Jackson, 1996 ; Balme, 2009). As already highlighted by Sogbohossou (2011) and Sogbohossou *et al.* (2011), local communities around Pendjari have a rather positive attitude towards the protected area that they considered as their heritage and a source of jobs and revenue through tourism.

Guarding, the most widely used method in Pendjari Biosphere Reserve is the oldest and the most effective human-wildlife conflicts management measure (Nyhus, 2016). However the costs of labor and the need for constant vigilance are the key drawbacks of this approach (Kiki, 2012). This method can be effective both against crop raiders and livestock depredators. Its efficiency is limited against nocturnal depredators as it is difficult to guard farms during the night. Fire, used to dissuade nocturnal predators, is not a sustainable measure because fire made with fallen branches could not stay for long time to dissuade animals (Conover, 2002 ; Linnell *et al.*, 2012).

The use of guarding dogs, noted around Pendjari, is also observed against cheetah in Namibia (Marker *et al.*, 2005) and in elsewhere in Europe (Shivik, 2006), Australia (Vanak *et al.*, 2014). This method has mixed outcomes. While Woodroffe *et al.* (2007) and Ogada *et al.* (2003) found that dogs can deter somehow predators days and nights, Kolowski & Holekamp (2006) noticed they were not efficient against nocturnal livestock predation by hyenas and lions. In Pendjari, Sogbohossou *et al.* (2011) found that dogs were not as efficient as they can be killed by predators. A combination of methods appears as the best alternative to reduce efficiently human-wildlife conflicts.

It is also important that local communities receive more benefits from wildlife. Blackburn *et al.* (2016) found that lion can survive outside protected areas if communities receive benefits from wildlife. In Pendjari, as pointed out by Sogbohossou *et al.* (2011), this could contribute to improve human-wildlife coexistence in the area.

There is a method which aims more at helping people to cope with conflicts than mitigating conflicts: compensation. Rarely used in Pendjari, this method contributes to offset the costs of carnivore damage (Wagner *et al.*, 1997). Although compensation is described as inefficient, ineffective, expensive and unfeasible (Nyhus *et al.*, 2005 ; Dickman *et al.*, 2011; MacLennan *et al.*, 2009), well organized, it could create a win-win situation by redistributing costs and benefits between local, national and global levels (Dickman *et al.*, 2011). It could be funded sustainably around Pendjari with benefits received by the Local Communities Association.

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## CONCLUSION

Human-wildlife conflicts, like in many protected areas, are effective in Pendjari Biosphere Reserve, northern Benin. Depredation of millet, maize and sorghum by baboon and predation of cattle, sheep, goat and pig by hyena and lion are the two main forms of conflicts identified around Pendjari. Local communities, compare to their poverty level, paid a heavy tribute to wildlife. To cope with these damages, local communities developed several measures such as guarding, fires and scarecrows. Unfortunately, most of these measures were not effective to prevent fields from damage and about the quarter of local populations' production is destroyed every year. The coexistence with wildlife is costly for local communities. Considering the importance of losses, it appears important to reinforce mitigation measures, develop more income-generating activities from wildlife and create a dynamic compensation plan in order to relieve local communities around Pendjari Biosphere Reserve.

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