Status of medium-sized ungulate populations in 2010, at the Nazinga Game Ranch, Burkina Faso (Western Africa)

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The present study consists of analyzing the raw data collected from the annual line-transect foot count of medium-sized ungulates, carried out at the Nazinga Game Ranch (NGR), Burkina Faso (Western Africa), in both 2001 and 2010. The annual census focused on the seven main medium-sized ungulates, namely (in alphabetical order), the Bushbuck (*Tragelaphus scriptus*), the Common Warthog (*Phacochoerus africanus*), the Defassa Waterbuck (*Kobus ellipsiprymnus*), the Grimm's Duiker (*Sylvicapra grimmia*), the Oribi (*Ourebia ourebi*), the Roan Antelope (*Hippotragus equinus*) and the Western Hartebeest (*Alcelaphus buselaphus*). The census also focused on illegal anthropogenic activities. The wildlife populations were quantitatively analyzed through an estimation of their absolute density *via* the distance sampling method and through their evolution over the last decade using two relative density indexes, namely the Kilometric Abundance Index (KAI) and a spatial distribution index. These indexes were also used to measure the evolution of illegal activities over the same period. Both the wildlife observations and the anthropogenic observations were mapped using the Kernel method. Following an increasing trend in their population between 2001 and 2010, both the Roan Antelope and the Western Hartebeest reached an estimated density of 4.7 individuals per km², while the Defassa Waterbuck reached 2.4 individuals per km². Following an inverse trend over the same period, the Bushbuck, the Grimm's Duiker and the Oribi reached an estimated density of 0.4 individuals per km². As for the Common Warthog, its estimated density of 2.5 individuals per km² seemed to remain unchanged during that decade. A comparison between wildlife observations and anthropogenic observations reveals a high decrease in animal densities in the north, east and west peripheral borders of the NGR and a flagrant extension of the proportion of the ranch being subjected to illegal activities (poaching, cattle herding, etc.).

Keywords. Wildlife, game reserves, ungulates, monitoring, illegal practices, Burkina Faso.

Le statut des populations d'ongulés de taille moyenne en 2010, Ranch de Gibier de Nazinga, Burkina Faso (Afrique de l'Ouest). La présente étude consiste en l'analyse des données brutes issues de l'inventaire pédestre annuel par transects en lignes des ongulés de taille moyenne, effectué au Ranch de Gibier de Nazinga en 2001 et en 2010. Le recensement s'est focalisé sur les sept principaux ongulés de taille moyenne, à savoir (dans l'ordre alphabétique), le bubale (*Alcelaphus buselaphus*), le céphalophe de Grimm (*Sylvicapra grimmia*), le cobe defassa (*Kobus ellipsiprymnus*), le guib harnaché (*Tragelaphus scriptus*), l'hippotrague (*Hippotragus equinus*), le phacochère (*Phacochoerus africanus*) et l'ourébi (*Ourebia ourebi*), ainsi que sur les activités anthropiques illégales. Les populations animales ont été analysées quantitativement par l'estimation de leur densité absolue *via* la méthode *distance sampling* et par l'évolution au cours de la dernière décennie de deux indices de densité relative, à savoir l'Indice Kilométrique d'Abondance (IKA) et un indice de distribution spatiale. Ces deux indices ont aussi été utilisés pour mesurer l'évolution des activités illégales sur la même période. Les observations fauniques et les activités anthropiques ont été spatialisées par la méthode de Kernel. À l'issue d'une augmentation de leur population sur la décennie, l'hippotrague et le bubale ont atteint une densité estimée à 4,7 individus par km², alors que celle du cobe defassa a atteint 2,4 individus par km². Au terme d'une tendance inverse, le guib harnaché, le céphalophe de Grimm et l'ourébi atteignent aujourd'hui une densité réduite estimée à 0,4 individus par km² pour la même période. Quant au phacochère, sa densité estimée à 2,5 individus par km² semble ne pas avoir changé sur la dernière décennie. La mise en parallèle des distributions fauniques et anthropiques a révélé une forte réduction des densités animales à la périphérie nord, est et sud et une extension inquiétante de la portion du ranch soumise aux activités illégales (braconnage, pâturage, etc.).

Mots-clés. Faune sauvage, réserve de gibier, ongulés, surveillance, pratique illégale, Burkina Faso.

1. INTRODUCTION

Within a context of the global erosion of wildlife in the whole of the Western African region, the Nazinga Game Ranch (NGR) in Burkina Faso constitutes a unique example of multi-valorization of its natural resources (Cornélis, 2007).

Since the foundation of the ranch in 1979, its aim has been to fulfill its original objective of being financially self-sufficient by integrating the local people into both the management structure and the sharing of ranch benefits (Portier et al., 2007). To this end, the main activities offered by the NGR are game viewing, sport hunting and game cropping for meat (Belemsobgo et al., 1998).

To facilitate the co-existence of these activities, the NGR undertakes ecological monitoring mainly based on an annual line-transect foot count of the main medium-sized ungulates. Originally designed to estimate the absolute abundance of the most common species of mammals using the distance sampling method, the sampling plan also facilitates the collection of data on illegal anthropogenic activities.

This study aims to analyze and to map the census data from 2010 at NGR for the seven main ungulates, classified (in alphabetical order) as the Bushbuck (*Tragelaphus scriptus* [Pallas, 1766]), the Common Warthog (*Phacochoerus africanus* [Gmelin, 1788]), the Defassa Waterbuck (*Kobus ellipsiprymnus* [Rüppell, 1833]), the Grimm's Duiker (*Sylvicapra grimmia* [Linnaeus, 1758]), the Oribi (*Ourebia ourebi* [Zimmermann, 1783]), the Roan Antelope (*Hippotragus equinus* [E. Geoffrey Saint-Hilaire, 1803]) and the Western Hartebeest (*Alcelaphus buselaphus* [Pallas, 1766]). The study also aims to map data provided by the census regarding anthropogenic activities. The choice of these species for this study was mainly based on the fact that they represent the most hunted – consequently the most economically important – species at the NGR. The chosen species were the ones for which we registered sufficient contacts in order to apply the distance sampling method (Buckland et al., 1993; Cornélis, 2007).

The distance sampling method (Buckland et al., 1993) was used to assess the population densities in both 2001 and 2010. Two relative density indexes, namely the Kilometric Abundance Index (KAI) and a spatial distribution index were used to observe the trends over the decade (from 2001 to 2010). These indexes were also used to measure the evolution of illegal activities over the same period. The data analysis was completed by the mapping of both the wildlife and the anthropogenic observations, *via* the Kernel method (Worton, 1999).

2. MATERIALS AND METHODS

2.1. Study area

Located in the south of Burkina Faso (near the Ghanaian border), the NGR covers an area of ca 970 km² (**Figure 1**). The ranch is situated between the latitudes of 11°00'N and 11°18'N, and the longitudes of 01°16'W and 01°43'W (Belemsobgo et al., 1998).

Falling within the tropical savannah of Köppen-Geiger (Kottek et al., 2006), the NGR had a mean annual temperature of 28 °C between 2000 and 2010 (MSP, 2010). In the same period the mean annual rainfalls ranged from about 730 to 1,230 mm (MSP, 2010). The climatograph for the NGR (MSP, 2010) shows a dry period beginning in November, lasting until April. The wettest months are July and August, and generally no rainfall is registered in December and January.

As part of the Sudanese regional centre of endemism (White, 1983), the NGR shows a high proportion (47.4%) of clear shrub savannah characterized by *Vitellaria paradoxa* C.F.Gaertn., *Terminalia* spp., *Acacia dudgeoni* Craib ex Holland, *Gardenia erubescens* Stapf & Hutch., and *Pteleopsis suberosa* Engl. & Diels, in which the dominating perennial herbaceous species are *Andropogon* spp. and *Schizachyrium sanguineum* (Retx.) Alston. (Dekker, 1985). The tree savannah with *Afzelia africana* Sm. ex Pers., *Anogeissus leiocarpa* (DC.) Guill. & Perr. and *Lannea acida* A.Rich. represents 25.4% of the total area (Dekker, 1985).

One principal watercourse, the Sissili River, and its two affluents, the Dawevele and the Nazinga Rivers, serve to drain temporarily the main watersheds of the NGR (Belemsobgo et al., 1998; Leclercq et al., 2007). With the aim of enhancing the fauna-carrying capacity of the ranch, 11 artificial dams have been built, most of them on the three rivers mentioned above (Leclercq et al., 2007). About 12 Burkinabe villages surround the NGR and are situated close to its boundaries (Vermeulen et al., 2007) (**Figure 1**).

2.2. Counting

A line-transect foot count (Buckland et al., 1993) was carried out in the second half of February 2010. This survey involved 13 census teams over seven days. One leader and two observers constituted a survey team. The team leader maintained the bearing along a transect through the use of a Global Positioning System (GPS). All observations of wildlife and anthropogenic activities were recorded and geo-referenced using the GPS. The leader and the two observers were in charge of spotting and counting observations. When a wild animal (or herd) was spotted, the angle of
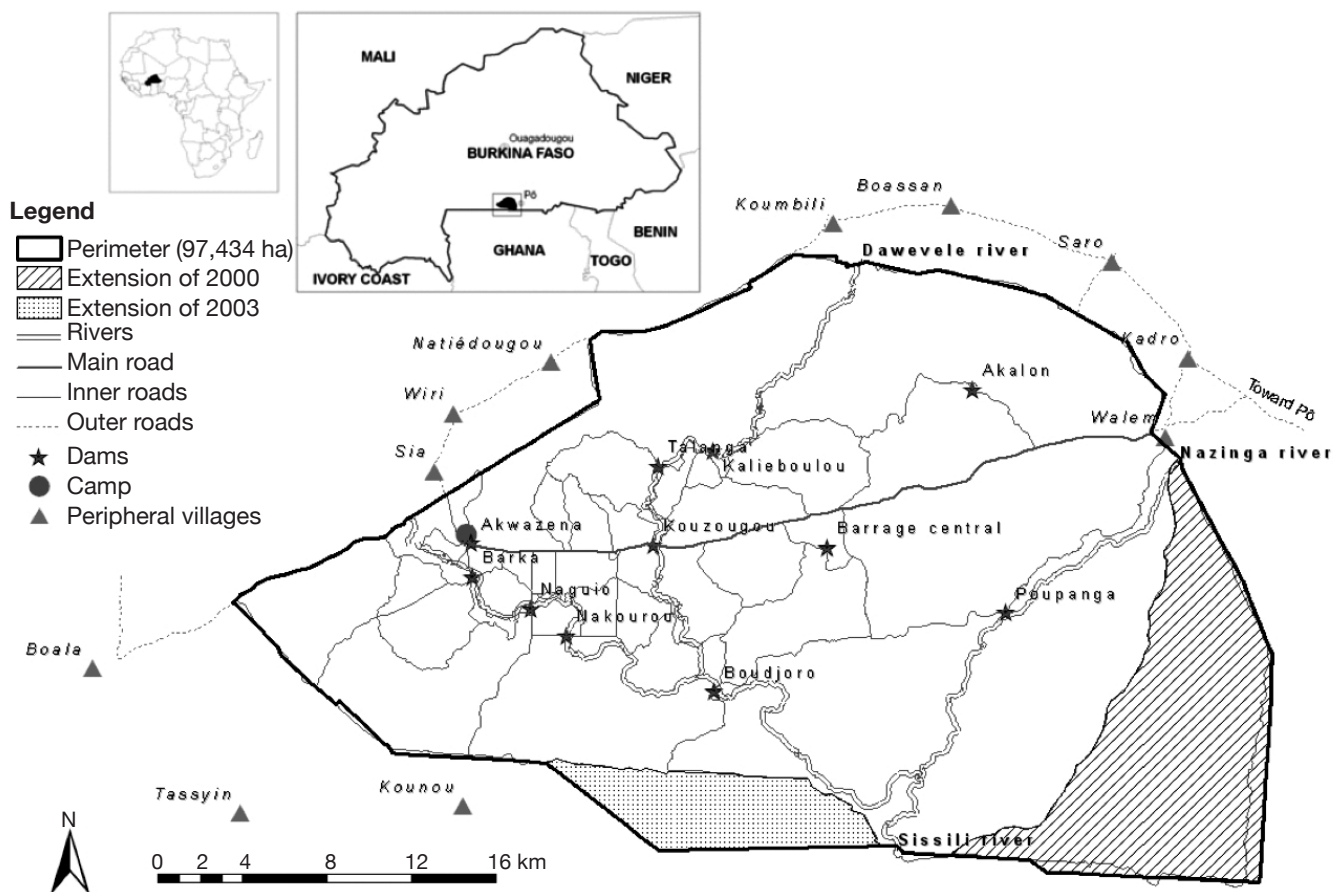
Figure 1. Location of Burkina Faso in Africa (inset 1), location of Nazinga Game Ranch (NGR) in Burkina Faso (inset 2) and general map of NGR — *Localisation du Burkina Faso en Afrique (encadré 1), localisation du Ranch de Gibier de Nazinga (RGN) au Burkina Faso (encadré 2) et carte générale du RGN.*

observation and the radial distance were measured, using respectively a compass (Suunto type) and a laser range-finder (Bushnell) (Portier, 2001). It is important to note that this counting methodology has followed more or less the same guidelines since 1984 (Portier, 2001). This obviously allows, with certain considerations, data comparisons over the years.

2.3. Sampling plan

Thirty-four parallel transects of south-north orientation have been systematically defined on the ranch area (Portier, 2001). The first transect was chosen randomly and the other lines were placed equidistantly at 1.4 km from the previous transect (Portier, 2001). The study area was divided into seven blocks in accordance with the main roads, and with the aim of being able to survey one block per day. This division provides areas of line-transect, which can be covered from early to late morning, just before the temperature gets too hot (Portier, 2001). The sampling effort traversed was 691,756 m.

2.4. Data analysis

Census data were analyzed according to the distance sampling method (Burnham et al., 1980; Buckland et al., 1993; Buckland et al., 2001) to provide the absolute density of the seven targeted species. The use of a distance sampling method using line-transects is based on the fact that the probability of detecting an animal decreases with the perpendicular distance to the transect (Buckland et al., 1993). In addition to the guidelines set by the original authors regarding model selection (Buckland et al., 1993; Thomas et al., 2002), we also followed the steps recommended by Jachmann (2001). Beyond the selection by a statistical test, such as the Akaike's Information Criterion or the likelihood ratio test, the Jachmann steps allow the user to find a model that provides results closer to the reality (Bouché, 2008a).

Wildlife observations and anthropogenic observations were mapped using the Kernel method. In this method, a density function analyzes the distribution and the measured quantity of the objects (wildlife or

anthropogenic observations) in order to produce a spatial representation of the densities on a continuing surface (Worton, 1999). For the wildlife observations, the calculation was made by taking into consideration not only the number of groups of the same species situated in the vicinity, but also the number of individuals per group (Worton, 1999; Cornélis, 2007). The two rasters were then compared by means of a correlation matrix (Dagnelie, 2006). This aims to provide more than the visual observations of the distribution by means of the interpretation of correlation coefficients.

The current absolute densities were compared to the 2001 results by means of a d-test (Bailey, 1995). This test allows us to determine whether two population estimates are statistically different, and is in fact based on the Student's t-test (Dagnelie, 2006). In addition, a comparison of the same two years was carried out using the KAI and a spatial index, named here as the mean Relative Density Index (mean RDI). In order to obtain the RDI, the distributions of the density frequencies computed *via* Kernel were divided into five classes of equal range with the maximum density of the period designated as the supremum (Cornélis, 2007). Density classes were then expressed in terms of a Relative Density Index increasing from 1 to 5 (Cornélis, 2007). Thus the mean Relative Density Index represents the relative importance of every class of density calculated by the Kernel method for a specific year (Cornélis, 2007).

3. RESULTS

3.1. Large mammal populations in 2010

A total of 313 contacts with wild animals were recorded. Of these, 247 contacts were with the seven targeted species. The Roan Antelope and the Western Hartebeest showed the highest estimated densities with respectively 4.81 (28.4 CV%) and 4.7 (24.8 CV%) individuals per km². The Common Warthog and the Defassa Waterbuck represented respectively approximately 2.47 (36.5 CV%) and 2.41 (32.6 CV%) individuals per km². The Bushbuck, the Grimm's Duiker and the Oribi represented respectively approximately 0.43 (35.3 CV%), 0.4 (43.5 CV%) and 0.4 (34 CV%) individuals per km² (**Table 1**).

3.2. Large mammals and anthropogenic activity distributions in 2010

The distribution of the seven main species (**Figure 2**) showed a core of high density (between ca 8.47 and 10.59 individuals per km²) located close to the Sissili River, east of the Boudjoro Dam and south of the Central Dam (**Figure 1**). Overall, most of the observations were

Table 1. Results of estimated number of individuals (N), estimated density (D individuals·km⁻²) and coefficient of variation in percentage (CV %) for the seven main species (par ordre alphabétique) — *Résultats du nombre estimé d'individus (N), de la densité estimée (D individus·km⁻²) et du coefficient de variation en pourcentage (CV %) pour les sept espèces principales (in alphabetical order).*

Species	N	D	CV %
Bushbuck	414	0.43	35.3
Common Warthog	2,411	2.47	36.5
Defassa Waterbuck	2,480	2.41	32.6
Grimm's Duiker	388	0.40	43.5
Oribi	392	0.40	34.0
Roan Antelope	4,685	4.81	28.4
Western Hartebeest	4,577	4.70	24.8

recorded south-west of the main road crossing straight through the ranch from the east (*i.e.* where the main entrance is situated in the village of Walem) to the west (*i.e.* at the Akwazena Dam, where the main camp is situated) (**Figure 1**).

Anthropogenic activities (**Figure 2**) were concentrated in the extreme south-east part of the NGR, exactly at the location of the extension added to the ranch in 2000 (**Figure 1**). Two other fronts of illegal activity are shown by the symbols; one is in the north area and the other one in the south-west area of the ranch. Furthermore we can observe a vacuum of illegal activities along the main road, which is the road at the NGR most frequented by tourists and hunters. Evidence of illegal activities was found mainly through the presence of cattle tracks (31.2%), human tracks (27.1%), and poaching paths (13.5%) (**Table 2**).

3.3. Correlation between wildlife and anthropogenic activity distributions in 2010

A comparison between the distributions of the wildlife observations and the anthropogenic observations gave a correlation factor of -0.1 in 2010 (**Figure 2**). This correlation factor indicates that the two distributions do not overlap but that the anthropogenic activities increasingly push centripetally the wildlife into their place of quietude. Furthermore this shows the negative impact of anthropogenic activities on the wildlife there.

4. DISCUSSION

4.1. Temporal comparison with 2001

Between 2001 and 2010, the comparison of the absolute densities showed an increasing trend for the Defassa

Legend

☐ Perimeter

Wildlife observations

✕ Roan Antelope
◊ Western Hartebeest
☐ Defassa Waterbuck
❀ Common Warthog
✦ Bushbuck
✧ Grimm's Duiker
✛ Oribi

Density of wildlife observations (individual·km²)

☐ 0-2.12
☐ 2.12-4.24
☐ 4.24-6.35
☐ 6.35-8.47
☐ 8.47-10.59

Anthropogenic observations

◯ Cattle track
◯ Man track
◦ Poaching path
◦ Other

Density of anthropogenic observations (contact·km²)

▦ 0-0.27
▦ 0.27-0.54
▦ 0.54-0.81
▦ 0.81-1.08
▦ 1.08-1.34
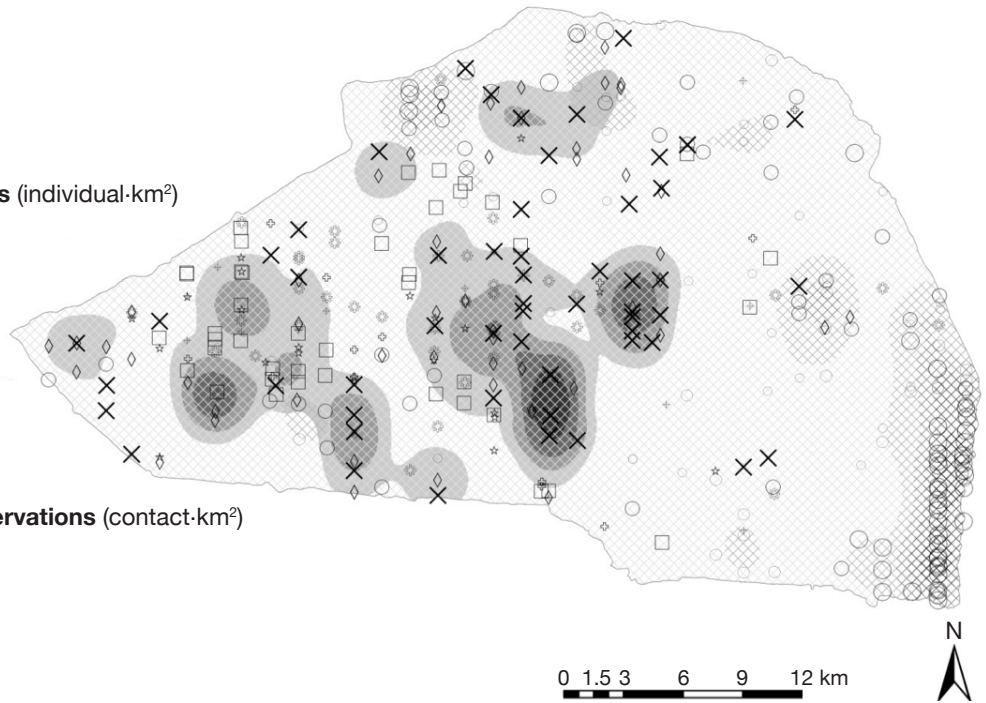
0 1.5 3 6 9 12 km

N

Figure 2. Distribution map of the wildlife observations (for the seven main species) and the anthropogenic observations in 2010; the borders of Nazinga Game Ranch are the ones from before 2003 — *Carte de distribution des observations de faune (pour les sept espèces principales) et des observations anthropiques en 2010 ; les frontières du Ranch de Gibier de Nazinga sont celles d'avant 2003.*

Table 2. Number of contacts and their proportions for anthropogenic activities in 2010 — *Nombre de contacts et proportions des activités anthropiques en 2010.*

Anthropogenic observation	Number of contacts	Proportion (%)
Bike tracks	8	4.7
Camp/ fire	16	9.4
Carcass	7	4.1
Cartridge-case	4	2.4
Cattle tracks	**53**	**31.2**
Cut tree	1	0.6
Honey extraction	2	1.2
Human	1	0.6
Human tracks	**46**	**27.1**
Livestock	2	1.2
Poaching path	**23**	**13.5**
Gunshot	5	2.9
Snare	1	0.6
Other	1	0.6
Total	**170**	**100.0**

The values in bold represent the three main categories of anthropogenic observations — *Les valeurs en gras représentent les trois catégories principales d'observations anthropiques.*

Waterbuck, the Roan Antelope and the Western Hartebeest (**Figure 3** and **Table 3**). Their multiplication factors were respectively 2.89, 1.79 and 7.08. For these species, both the evolution of the KAI and the mean RDI confirm that trend (**Table 3**).

A decreasing trend characterized the Bushbuck, the Grimm's Duiker and the Oribi (**Figure 3** and **Table 3**). Their multiplication factors were respectively 0.43, 0.64 and 0.57 (**Table 3**). Again, the trend is confirmed by the relative densities (**Table 3**).

For the Common Warthog, the d-test showed a non-significant difference between the absolute densities of 2001 and 2010 (**Table 3**). This result is confirmed by the evolution of both the KAI and the mean RDI, for which the factors were respectively 0.90 and 0.99, thus almost equal to 1 (**Table 3**).

The d-test showed that only the populations of the Bushbuck, the Defassa Waterbuck and the Western Hartebeest were significantly (p = 0.95) different between 2001 and 2010 (**Table 3**). The Oribi and the Roan Antelope populations over the decade were different for a p value equal to 0.90, the Grimm's Duiker with a p value of 0.80 and the Common Warthog with a p value of 0.70 (**Table 3**).

4.2. Comparison with other protected areas

A comparison with other protected areas elsewhere in Africa establishes the status and the potentiality of the NGR. In order to make this comparison as objective as possible, the areas chosen for comparison hosted similar habitats (Sudano-Sahelian region) and wildlife;
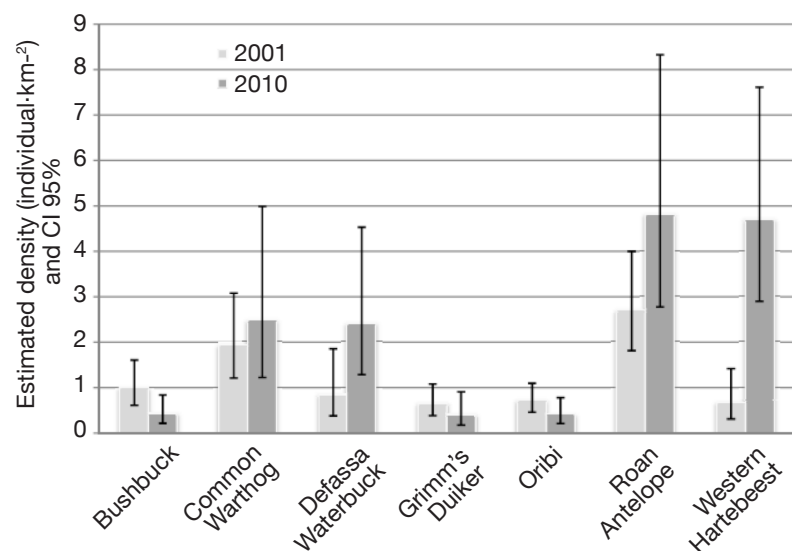
Table 3. Comparison between 2001 and 2010, characterized by the multiplication factor found by using the absolute density (*D*), the Kilometric Abundance Index (*KAI*) and the mean Relative Density Index (*Mean RDI*) for the 7 species (in alphabetical order) — *Comparaison entre 2001 et 2010 caractérisée par le facteur de multiplication en utilisant la densité absolue (*D*), l'Indice d'Abondance Kilométrique (*IKA*) et l'Indice de Densité Relative Moyen (*IDR Moyen*) pour les 7 espèces (par ordre alphabétique).*

Species	Method			
	D	*d-test (p)*	*KAI*	*Mean RDI*
Bushbuck	0.43	0.95	0.73	0.99
Common Warthog	1.28	0.70	0.90	0.99
Defassa Waterbuck*	2.89	0.95	1.99	1.03
Grimm's Duiker	0.64	0.80	0.64	0.85
Oribi	0.57	0.90	0.32	0.73
Roan Antelope	1.79	0.90	1.62	1.77
Western Hartebeest	7.08	0.95	2.21	1.07

* between 2003 and 2010 — *entre 2003 et 2010.*

they were covered by surveys for the same species and analyzed using the same method (line-transects).

The selected protected areas were: in Benin, the Pendjari National Park (Sinsin et al., 2002); in Burkina Faso, the Singou Hunting Area (Crosmary, 2006) and the Konkombouri Hunting Area (Bouché, 2008b); in Cameroon, the Waza National Park (Scholte et al., 2007) and, in the Central African Republic (CAR), a cluster of five Community Hunting Zones (Bouché, 2009).

Despite the fact that the climatic conditions in the CAR are more favorable, our analysis showed that the total density is lower and all species, excluding the Bushbuck and the Grimm's Duiker, have a higher density at the NGR (**Table 4**). With about the same amount of rainfall as NGR, Konkombouri Hunting Area carries a higher total density than NGR for these seven species (**Table 4**). However the densities of Defassa Waterbuck and Western Hartebeest are both higher at the NGR (**Table 4**). The low densities of small mammals (Bushbuck, Grimm's Duiker and Oribi) at NGR, which are nearly similar to those of the CAR (Bushbuck and Oribi), reveal the high pressure on these

Figure 3. Comparison between 2001 and 2010 of the absolute density (individuals·km⁻²) for the seven main species (in alphabetical order) — *Comparaison des densités absolues (individus·km⁻²) entre 2001 et 2010 pour les sept espèces principales (par ordre alphabétique).*

Table 4. Comparison of the estimated density (D) and coefficient of variation in percentage (CV %) for the seven main species (in alphabetical order) between Nazinga Game Ranch and five other protected areas from the Sudano-Sahelian region — *Comparaison des densités estimées (D) et des coefficients de variations (CV %) pour les sept espèces principales (par ordre alphabétique) entre le Ranch de Nazinga et cinq autres zones protégées de la zone soudano-sahélienne.*

Area	Nazinga Game Ranch		Pendjari National Park		Konkombouri Hunting Area		Singou Hunting Area		Waza National Park		Five Community Hunting Areas	
Size	970 km²		2,660 km²		655 km²		1,800 km²		1,700 km²		4,913 km²	
Country	Burkina Faso		Benin		Burkina Faso		Burkina Faso		Cameroon		Central African Republic	
Study	This study		Sinsin et al., 2002		Bouché, 2008b		Crosmary, 2006		Scholte et al., 2007		Bouché, 2009	
Type and year of survey	Foot count, 2010		Foot count, 2000		Foot count, 2008		Vehicle count, 2006		Foot count, 2000		Foot count, 2009	
Rainfall·year[1]	950 mm		1,000 mm		900 mm		750-1,000 mm		650 mm		1,000-1,300 mm	
Species	D	CV%	D	CV%	D	CV%	D	CV%	D	CV%	D	CV%
Bushbuck	0.43	35.3	0.22	-	1.11	40.81	-	-	EXT	-	0.82	18.82
Common Warthog	2.47	36.5	0.66	-	2.44	40.07	0.64	26	-	-	2.18	15.71
Defassa Waterbuck	2.41	32.6	0.03	-	0.92	94.56	0.18	25	EXT	-	0.09	-
Grimm's Duiker	0.40	43.5	0.92	-	3.15	19.23	-	-	-	-	2.35	11.08
Oribi	0.40	34.0	0.67	-	8.14	15.71	1.72	13	-	-	0.27	33.97
Roan Antelope	4.81	28.4	0.77	-	8.14	32.15	0.24	20	0.29	-	0.51	40.48
Western Hartebeest	4.70	24.8	0.56	-	2.09	56.91	-	-	EXT	-	1.02	26.55
Total	**15.62**		**3.84**		**25.99**		**7.24**		**-**		**7.24**	

Values in bold represent the highest density for each species amongst the areas — *les valeurs en gras représentent les densités maximales des espèces entre les zones*; "-": value not available — *valeur non disponible*; EXT: means that the species are extinct — *les espèces sont éteintes.*

animals probably caused by poaching. The Singou Hunting Area also showed lower densities than NGR for the Common Warthog, the Defassa Waterbuck, the Oribi and the Roan Antelope (only species studied) (**Table 4**). The Pendjari National Park presented higher densities than NGR for Grimm's Duiker and Oribi, but all the other species in the Pendjari National Park were found in lower densities (**Table 4**).

East (1999) estimated the Roan Antelope population of Burkina Faso at more than 7,370 individuals. This shows the importance of NGR in the preservation of this species, which was estimated at 2,483 in 2001 and 4,685 in 2010 (**Table 1** and **Figure 3**). The populations of Roan Antelope in Pendjari National Park, Singou Hunting Area, Waza National Park and the cluster of CAR's Community Hunting Areas were respectively as low as 0.77, 0.24, 0.29 and 0.51 individuals per km² (**Table 4**), while Konkombouri Hunting Area and NGR showed densities of 8.14 and 4.81 individuals per km² (**Table 4**).

4.3. Environmental and human factors explaining ungulate trends

The increase in the large species (Roan Antelope, Western Hartebeest and Defassa Waterbuck) populations between 2001 and 2010 can be explained by several factors.

Contrary to many other protected areas in West Africa, NGR shelters a homogenous and permanent water-point network, which favors an increase in

antelope populations (Leclercq et al., 2007). This point has been decisive, especially for the survival of water dependent species like Defassa Waterbuck, affected by the drought periods and hydric deficit that have hit Sudano-Sahelian Africa since the early 1970s (Scholte et al., 2007).

Roan Antelope and Western Hartebeest are quite shy and very alert antelopes, making them fairly resistant to poaching (Estes, 1991).

Carcasses of large species killed by poachers are difficult to hide and to transport (Bouché et al., 2004). These carcasses must be processed and smoked in the field, which requires time and discretion by the poachers. Their illegal activities are disturbed by game viewing tourists, safari hunting and anti-poaching activities at least in the western half of the ranch area. Waterbuck meat is one of the less appreciated African game meats because of its strong odor (Spinage, 1982; Kingdon, 1997), making it a less targeted species by poachers. Poachers prefer to target smaller species, which are easier to hide and to process, such as Bushbuck, Duikers (Grimm's Duiker and Red-flanked Duiker *Cephalophus rufilatus*), Oribi and Common Warthog. In contrast with Bushbuck, Oribi and Duikers, the Common Warthog is a prolific species (Kingdon, 1997), with its numbers seemingly stable since 2001, suggesting that their illegal mortality is compensated by their births.

Despite the increase in large species populations, large mammals are restricted to the western half of the ranch area (**Figure 2**). This suggests that despite the water availability in the eastern half during the dry season, wildlife do not find this area sufficiently quiet. Consequently the current large mammal densities could be larger if the eastern half of the ranch were properly managed.

In the 1980s, NGR's management practices and that of other areas in West Africa, showed that if appropriate water availability, law enforcement, burning management and community based wildlife management are met, wildlife densities can reach a far higher level than those currently found at the NGR (Portier et al., 2007; Bouché, 2008b). NGR shelters the highest Defassa Waterbuck and Western Hartebeest density of West Africa and one of the highest for Roan Antelope. This could be explained by the fact that for several decades, management infrastructure (water-points) has been present as well as the absence of large predators in Nazinga (Bouché, 2008b). Defassa Waterbuck and Western Hartebeest are known to be among the favorite prey of lions (Schaller, 1972; Spinage, 1982; Estes, 1991; Breuer, 2005).

These results suggest that several NGR wildlife populations are far from reaching their respective carrying capacities. Illegal activities threaten the eastern part of the ranch, causing the depletion of

wildlife in this area. Concrete field measures including strong law enforcement, sharing ranch benefits and decision-making in consultation with communities, road network and water-point maintenance, are urgently required to favor an increase in wildlife densities at the level known in the 1980s (Portier et al., 2007).

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