



SPATIO-TEMPORAL ANALYSIS OF ILLEGAL ACTIVITIES FROM RANGER-COLLECTED DATA IN W NATIONAL PARK OF BENIN

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ABSTRACT

This study analyses the spatio-temporal trends of illegal activities in W Biosphere Reserve of Benin in order to provide guidance for planning the patrol system. We used ranger-collected data on illegal activities in the reserve from 2012 to 2015. Illegal grazing is the most common illegal activity observed in the reserve (1,137 incidents), followed by poaching (469 incidents), agricultural encroachment (285 incidents) and logging (69 incidents). The distribution of these activities in the reserve is highly dependent on zones and also varies between seasons. Generally, incidents of illegal activities were more frequent during the non-hunting season than the hunting season because of flooding, impassability of tracks and closing of plant cover which limit patrol activities during the non-hunting season. From these findings, managers of the W National Park can identify high human pressure zones where ranger patrol efforts should be enhanced. We propose the use of emerging technologies such as Unmanned Aerial Vehicles to better monitor these zones, especially during the non-hunting season when the reserve is practically inaccessible for rangers.

Key words: Protected area management, illegal grazing, poaching, agricultural encroachment, logging, high pressure zones, season, patrol system

INTRODUCTION

Global biodiversity is in decline (Butchart et al., 2010; Craigie et al., 2010) and drivers of this declines, such as, illegal resource extraction added to climate change effects, are increasing (Bennett et al., 2002; Mackenzie et al., 2012; Laurance et al., 2012; Critchlow et al., 2015).

In common with most protected areas in West Africa, the W Biosphere Reserve of Benin is impacted by illegal acts often by local populations surrounding the protected area (Tiomoko, 2014). Cohabitation of local communities in and around protected areas with wildlife is an ongoing problem faced by managers and communities that they find difficult to resolve (Niagate et al., 2005). In fact, these communities do not perceive the reserve as the managers and conservationists do, but as a source of resources needed to support their livelihoods (Allah-Demngar & Falmata, 2003). Significant biodiversity loss within protected areas is often the consequence of this illegal resources exploitation (Barnes, 2002; Bennett et al., 2002;

Jachmann, 2008; Critchlow et al., 2015; Stirnemann et al., 2018). The consequences of illegal activities within protected areas can be profound (Bennett et al., 2002; Niagate et al., 2005; Craigie et al., 2010; Becker et al., 2013; Lindsey et al., 2013) and range from ecological cascades due to loss of keystone species to total habitat loss due to land conversion (Green et al., 2013; Critchlow et al., 2015).

In Benin, 58 gazetted forests (category VI according to the IUCN Protected Area classification) and about 3,000 sacred groves, covering about 2.7 million hectares or nearly 22 per cent of the country, constitute the protected areas network (SPANB, 2011). Unfortunately, most of these areas have almost disappeared. Despite multiple efforts since the creation of the National Center of Wildlife Reserves Management (“Centre National de Gestion des Réserves de Faune-CENAGREF”) in 1996 to better manage the two national parks of Benin (Biosphere Reserves of W and Pendjari), they have continued to be degraded by substantial human pressure (Tiomoko, 2014).

W National Park is subject to poaching, illegal grazing, agricultural encroachment and illegal logging (PAPE, 2014). However, the spatio-temporal variation of illegal activities is poorly understood within most protected areas (Becker et al., 2013; Lindsey et al., 2013). Determining patterns of illegal activities would enable more effective patrol and potentially reduce the decline in biodiversity within protected areas (Critchlow et al., 2015).

Most studies do not consider the full range of illegal activities that occur within a protected area and assess either temporal or spatial variation alone (Mackenzie et al., 2012; Plumptre et al., 2014). Moreover, previous research on illegal resource-use mainly focused on single activities, such as hunting for bushmeat (Nuno et al., 2013; Watson et al., 2013), illegal logging (Green et al., 2013; Mackenzie & Hartter, 2013), or harvesting of rare or medicinal plants (Young et al., 2011). Single activity assessments do not provide a comprehensive understanding of combined impacts, while managers need to know the temporal and spatial magnitudes and dynamics of all classes of illegal activities if they are to make informed decisions on resource allocation (Critchlow et al., 2015).

This study analyses the spatio-temporal trends of illegal activities in W Biosphere Reserve of Benin based on ranger-collected data in order to provide guidance for the patrol system by: (i) describing the extent of illegal activities, (ii) identifying zones of high pressure for each class of illegal activity and (iii) evaluating their seasonal variation. We hypothesise that agricultural encroachment, illegal grazing and logging will be more concentrated at the edges of the reserve and that poaching incidents will be more prevalent far away from roads and park boundaries (Watson et al., 2013; PAPE, 2014; Critchlow et al., 2015). We also predict that illegal activities are likely to be less common in the reserve during the hunting season due to the presence of tourists and licensed hunters.

METHODS

Study area

The W Biosphere Reserve of Benin (WBR/Benin), commonly called W National Park (IUCN Management Category II) is located at the extreme northwest of the Republic of Benin about 670 km from Cotonou. It is one of the largest components of the W Regional Park Complex constituting the first Transboundary Biosphere Reserve in West Africa shared by three countries: Benin, Burkina Faso and Niger. The WBR/Benin covers an area of 780,480 ha (62.44 per cent) of the 1.25 million ha of land in the complex (ECOPAS, 2005). The WBR/Benin is a major national park in

West Africa around a meander of the River Niger shaped like a “W”. It is this river shape that gives the name W to the Reserve. Its official gazettal covers W National Park (563,280 ha), Djona Hunting Zone (115,200 ha) and the eastern part of the Hunting Zone of Atakora called the Hunting Zone of Mekrou (102,000 ha).

The WBR/Benin has about 200,000 people living within it and on its periphery, which frequently creates conflicts between park managers, herders and farmers.

In order to better identify high pressure areas of each illegal activity, we subdivided the WBR/Benin into seven zones with five zones in the core area of the W National Park (Park 1, Park 2, Park 3, Park 4 and Park 5) and the two Hunting Zones (HZ Djona and HZ Mekrou). This subdivision follows a regional track (from Alfakoara to Triple Point), one of the main tracks in the reserve that links Karimama and Founougo villages, and the administrative boundary between Karimama and Banikoara Township in the reserve (Figure 1).

Data collection

Our data set consisted of 1,960 position records from ranger patrols conducted between January 2012 and December 2015 within the WBR/Benin. During all patrol activities (by foot and vehicle), when sighting evidence of illegal activities rangers record on patrol cards all instances of illegal activity with their date, observations and position using the Global Positioning System (GPS). Using these patrol cards, illegal activity

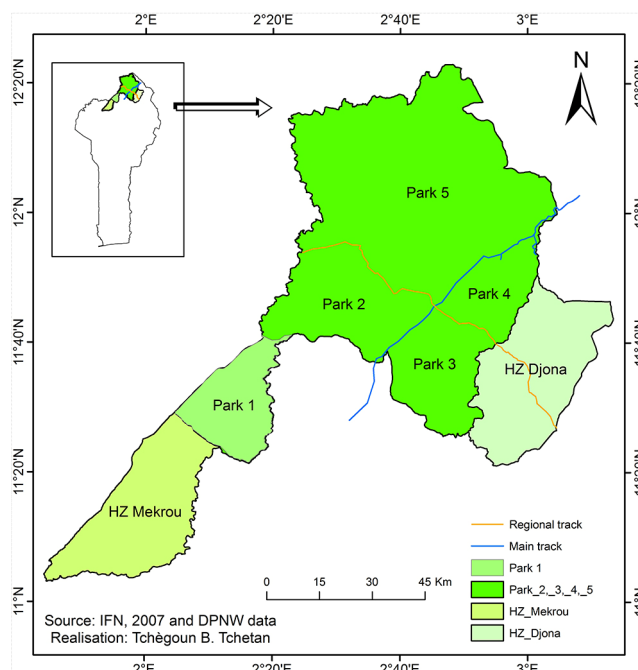


Figure 1. Map zoning of W Biosphere Reserve of Benin (WBR/Benin)

incidents are grouped together with their geographic coordinates and date of recording.

Following PAPE (2014), we defined four illegal activities classes (poaching, illegal grazing, logging and agricultural encroachment). Each incident recorded by the patrol teams was assigned to one of these classes of illegal activities. For example, incidents such as clearing new land for farming were grouped together as agricultural encroachment; while detection or arrest of poachers, animal carcasses with horns, tusks, etc. removed, poachers' camps and bicycle or motorbike tracks were classified as poaching; herders or their camps and herds of cattle were grouped as illegal grazing, and logging sites or logs were grouped as logging.

Geographic coordinates for each incident were used to identify the location in the reserve by zone. The recording dates were used to group incidents by year and season (the hunting season occurs from 15 December to 15 May and the non-hunting season from 16 May to 14 December). The hunting season roughly corresponds to the dry season and the non-hunting season to the rain season in northern Benin where WBR/Benin is located.

For the identification of the high pressure zones for each illegal activity, the analyses took into account four years' data (2012 to 2015), but for the evaluation of seasonal variation, the analyses only took into account three years' data (2013–2015) since the recording dates for the 2012 incidents were not available.

Statistical analysis

The constituted data matrix was subjected to statistical analysis using R (R Core Team, 2016) and QGIS. Descriptive statistics were used to compute and

describe the extent of illegal activities within the WBR/Benin.

To identify high pressure zones of illegal activities in the reserve, incidents were grouped by type of illegal activity in each zone to form the starting matrix. Fisher exact test was used to determine the relationship between activities and zones. A simple correspondence factor analysis was performed in R to determine the relationship between activities and zones. QGIS was also used to map each illegal activity distribution within the reserve.

To evaluate seasonal variation, illegal activities incidents were grouped by hunting season and non-hunting season in each year and with their geographic coordinates projected in QGIS to draw pressure maps for each season.

RESULTS

Extent of illegal activities within the WBR/Benin

Grazing was the most frequently reported illegal activity followed by poaching, agricultural encroachment and logging (Table 1). This pattern of occurrence was consistent across years ($\chi^2 = 89.104$; $p < 0.001$). More incidents were recorded in 2013 and 2014 (Table 1).

Spatial distribution of illegal activities within the WBR/Benin

The magnitude of illegal activities varies significantly across the zones ($\chi^2 = 894.56$; $p < 0.001$) (Table 1). Results of the correspondence analysis between illegal activities and zones indicated that the first two dimensions address 94.84 per cent of the variance (Figure 2).

Analysis of contributions and quality of representation as well as the projection of the activities and zones on

Table 1. Recorded incidences by illegal activity during each year and in each park zone

Illegal activities	Number of recorded incidences											
	Year					Location						
	2012	2013	2014	2015	Total	HZ Djona	HZ Mekrou	Park 1	Park 2	Park 3	Park 4	Park 5
Illegal grazing	202	405	335	195	1137	334	1	34	237	291	96	144
Poaching	67	118	186	98	469	102	8	40	107	96	28	88
Agricultural encroachment	30	110	96	49	285	46	4	0	116	102	0	17
Logging	1	51	5	12	69	3	35	5	0	26	0	0
Total	300	684	622	354	1960	485	48	79	460	515	124	249

the two factorial dimensions indicated that there is an affinity between logging and the HZ Mekrou on the one hand and between illegal grazing and HZ Djona on the other (Figure 2, dim 1). In addition, there is an affinity between agricultural encroachment and the Park 2 and Park 3 zones. Poaching and illegal grazing are close to the origin of the two axes and are surrounded by the HZ Djona, Park 1, Park 2, Park 3, Park 4 and Park 5 zones (Figure 2, dim 2).

In summary, illegal grazing and poaching are concentrated in practically all zones of the W Biosphere Reserve except the HZ Mekrou. Agricultural encroachment is mainly concentrated in Park 2 and Park 3. The HZ Mekrou is a preferred zone for loggers where logging is frequently recorded (Figure 2).

Within WBR/Benin, the highest pressure zones are HZ Djona, Park 3, Park 2, Park 5 and Park 4, respectively (Figure 3). Poaching and illegal grazing are as concentrated in the central zones of the reserve as on its peripheries, except the HZ Mekrou (Figure 3-a, b). On the north-eastern peripheries of the HZ Djona and Park 5 and especially on the southern peripheries of Park 2 and Park 3, agricultural encroachment is the highest pressure (Figure 3-c). Logging is the only pressure threatening HZ Mekrou (Figure 3-d).

Seasonal variation of activities within the WBR/Benin

The Fisher exact test (Table 2) indicates a strongly significant relationship between illegal activities and the season regardless of the year (p-value <0.001).

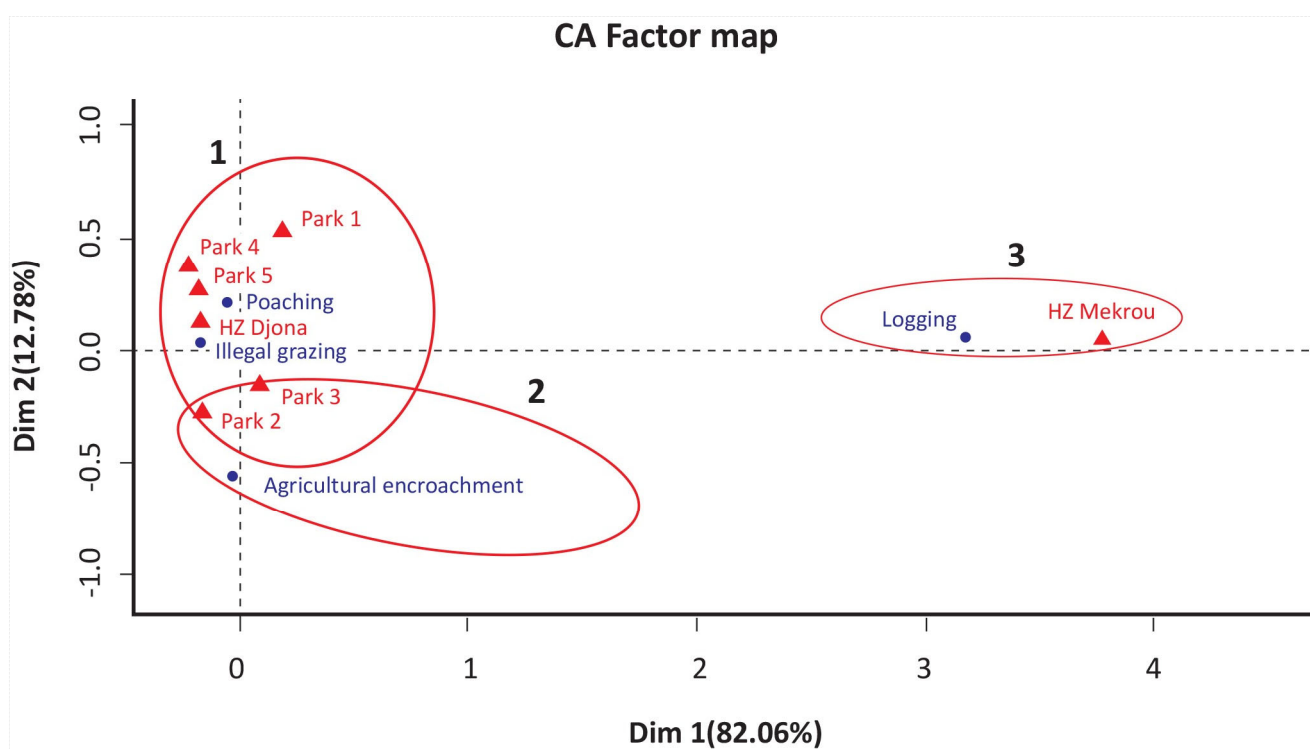


Figure 2. Positioning of illegal activities and zones on 2 mains factorial axes

Table 2. Recorded incidences by illegal activity during each season within WBR/Benin

Illegal activities	Number of recorded incidences						All data	
	2013		2014		2015		HS	NHS
	HS	NHS	HS	NHS	HS	NHS	HS	NHS
Illegal grazing	44	361	107	228	43	152	194	741
Poaching	38	80	83	103	49	49	170	232
Agricultural encroachment	38	72	47	49	38	11	123	132
Logging	2	49	0	5	2	10	4	64
Probability (p-value)	< 0.001		< 0.001		< 0.001		< 0.001	

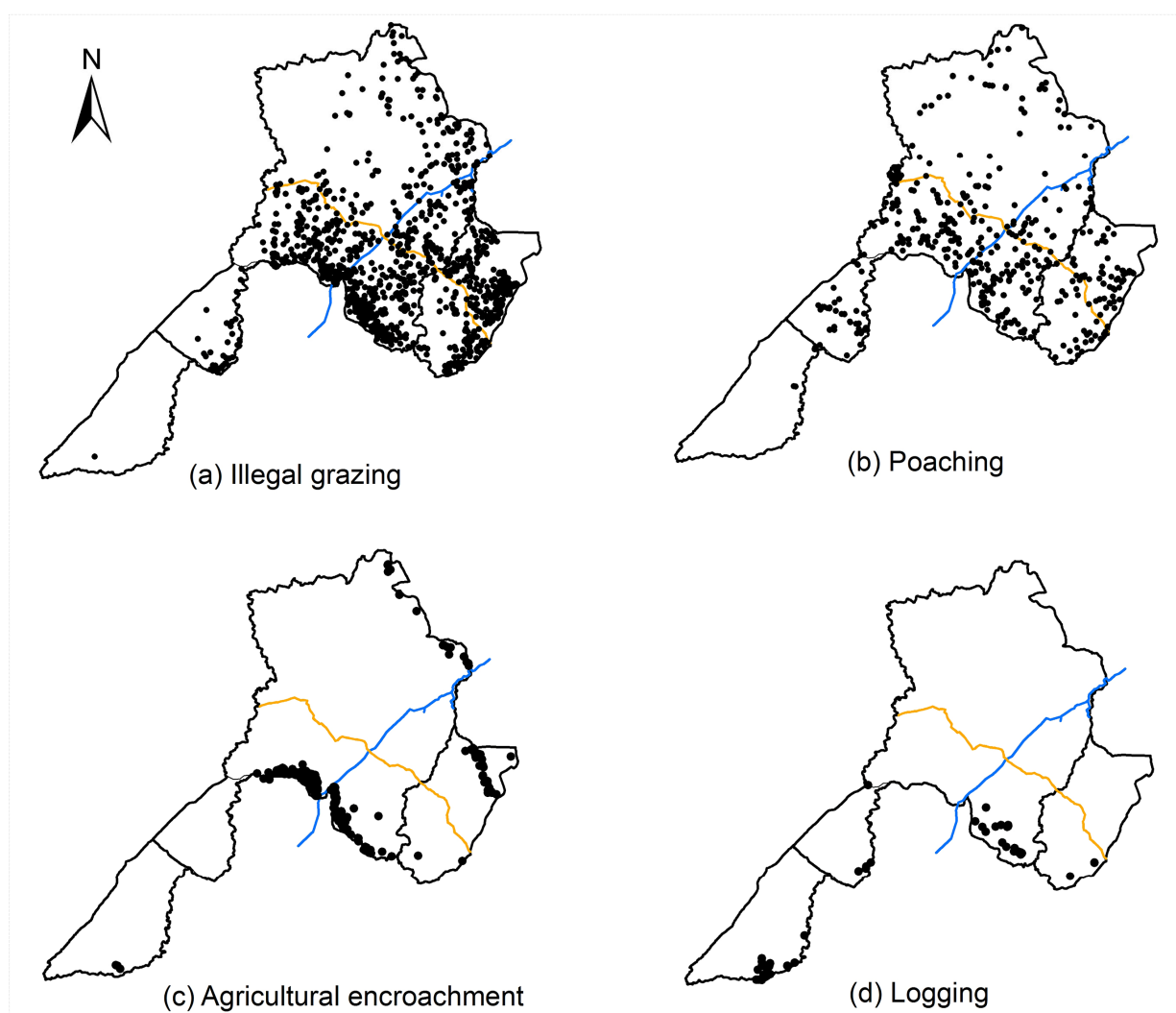


Figure 3. Spatial distribution of illegal activities incidents within the WBR/Benin

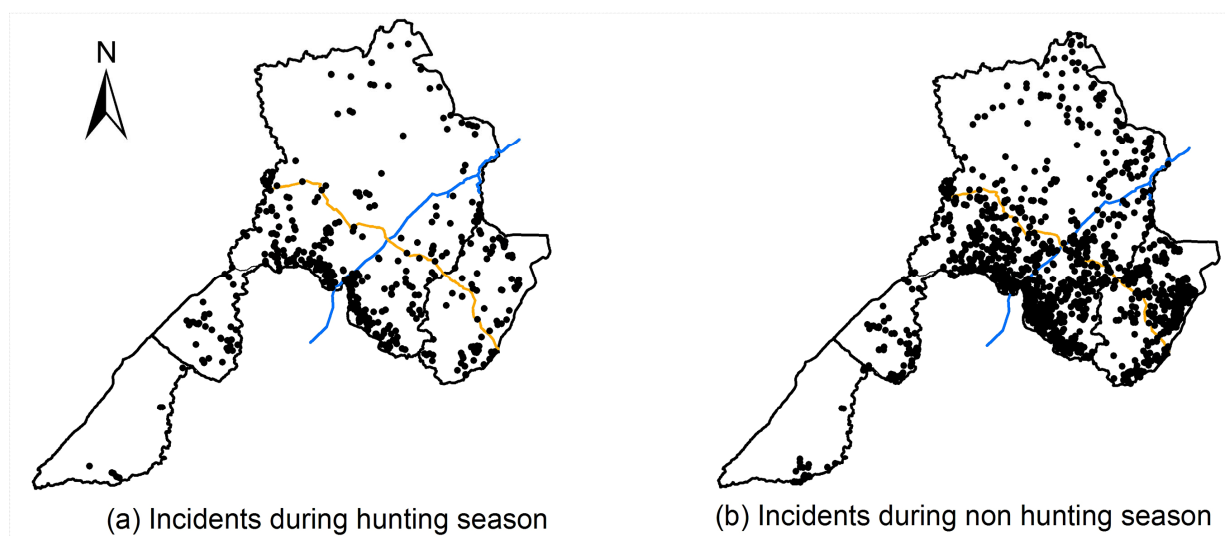


Figure 4. Season variation of illegal activities incidents within the WBR/Benin



Lion (*Panthera leo*) in the reserve © Gerard N. Gouwakinnou

Whatever the year and the type of illegal activity, the incidents are less common during the hunting season than non-hunting season (Figure 4).

DISCUSSION

Extent of illegal activities within the WBR/Benin

In the past, the W Biosphere Reserve of Benin was subject to an increase in illegal wildlife trafficking and increased poaching (PAPE, 2014). From our results, the problems of illegal grazing and poaching within WBR/Benin are still critical. In fact, illegal grazing remained the most common problem within the reserve followed by poaching and agricultural encroachment. Logging was not a major problem and was confined to one part of the reserve. Illegal activities were more common in 2013 and 2014 which may be the result of the reduced presence of rangers in the reserve during these years due to technical and financial difficulties with staff management according to the W Park Manager (pers comm. Grégoire Djijsounou).

The high rate of illegal grazing in the WBR/Benin is particularly due to its Transboundary Reserve status

which results in grazing pressure not only from Benin but also from Niger and Burkina Faso transhumants. Illegal grazing is one of the main problems for the sustainable management of WBR/Benin. It currently creates conflicts between herders and farmers, wildlife and cattle (carnivore attacks on cattle), and uncontrolled fire in the reserve (herders use fire to stimulate vegetation regrowth for their cattle).

However, though illegal grazing is the most commonly detected illegal activity in WBR/Benin, its impact on the ecological integrity of the reserve may be less than the other threats as, according to Bennett et al. (2002), the two main threats to wildlife across the world are habitat loss (agricultural encroachment and illegal logging) and poaching.

Our results show poaching as a major threat commonly detected in WBR/Benin. The problem of poaching in protected areas has been widely documented and discussed (Bennett et al., 2002; Becker et al., 2013; Lindsey et al., 2013; Nuno et al., 2013; Stirnemann et al., 2018). According to Stirnemann et al. (2018), poaching for consumption and trade of wildlife

constitute the key causes of biodiversity loss. It is therefore urgent that park managers take seriously the problem of poaching on this reserve and empower rangers by better equipping them.

Moreover, even though agricultural encroachment and logging incidents are lower in WBR/Benin, they constitute major threats. According to Tranquilli et al. (2014), agriculture and logging are the most common indirect threats to wildlife and most prevalent in West Africa protected areas. In fact, the patrol cards used to construct our data matrix show that tens or even hundreds of hectares and logs from taller trees of forest have been destroyed by agricultural encroachment and logging, respectively. The impacts of these activities on ecosystems can be profound and range from ecological cascades to total habitat loss due to extraction of keystone species (logging) and land conversion (agricultural encroachment), respectively (Green et al., 2013; Mackenzie & Hartter, 2013; Critchlow et al., 2015). In WBR/Benin, the problem of logging is more



New clearing for land conversion © Tchégoun B. Tchetan

worrying because in the past, this activity did not occur according to the W Park Managers. Two species commonly encountered in the area that are subject to illegal logging are Senegal rosewood (*Pterocarpus erinaceus*) and African mahogany (*Azalia africana*). These species are amongst the most endangered species in Benin.

Spatial distribution of illegal activities within the WBR/Benin

The distribution of illegal activities was highly spatially variable. Illegal grazing and poaching occur across WBR/Benin except in the Hunting Zone of Mekrou. The co-occurrence of these two threats may be because the majority of transhumants within the reserve both bring their grazing animals with them and also poach for food and commercial purposes.

Illegal logging is concentrated in the Hunting Zone of Mekrou. The presence of the Mekrou River in this zone provides optimal ecological conditions for growth of gallery forests which contain larger trees. This accords with the results of Mackenzie et al. (2012), and Mackenzie & Hartter (2013), who showed that illegal logging was more common where there are taller trees on the peripheries of protected areas.

Rapid population growth in Benin, which has been increasing at nearly 3 per cent annually (INSAE, 2013), has added to land shortage prompting farmers to clear new land including encroaching on protected areas. The WBR/Benin has not escaped this pressure. Indeed, its peripheral zones are experiencing strong agricultural pressure leading to degradation and fragmentation. The north-eastern peripheries of the HZ Djona and Park 5 and especially the southern peripheries of the Park 2 and Park 3 zones are particularly affected, because they



Bush meat on bicycle © Gerard N. Gouwakinnou

are closer to human habitation. Similar results were found by Mackenzie & Hartter (2013) and Plumptre et al. (2014), with illegal activities like agriculture being more common near the boundaries of protected areas.

Seasonal variation of activities within the WBR/Benin

Within WBR/Benin, illegal activities vary from season to season. In general, the results confirm our basic hypothesis that illegal activities are less observed during the hunting season than the non-hunting season, whatever the activity class, year or zone considered. This is likely to be because tourists' presence during the hunting season constitutes a deterrence to illegal activities in the reserve. During the non-hunting season (rain season), patrol activities are lower within the reserve because of the inaccessibility of some zones to rangers due to flooding and dense vegetation.

CONCLUSION

W Biosphere Reserve of Benin is under heavy human pressure, including illegal grazing, poaching, agricultural encroachment and logging. The consequences of these activities on ecosystems are well established from habitat loss to declines in wildlife populations.

To control agricultural encroachment, patrol and surveillance efforts should be focused on the north-eastern peripheries of the HZ Djona and Park 5 and especially the southern peripheries of the Park 2 and Park 3 zones. To prevent logging, efforts should be focused on the Hunting Zone of Mekrou. Illegal grazing and poaching are the most widespread activities in the reserve and need to be patrolled more frequently in almost all zones.

This information is very important to ranger deployment and demonstrates the value of a full spatio-temporal analysis of illegal activities. However, because spatial and temporal changes in illegal activities occurred, regular patrols throughout the protected area, even in zones of low occurrence, are also required.

We recommend to W National Park managers to develop new technologies including the use of Unmanned Aerial Vehicles to better monitor the zones at greatest risk for each class of illegal activity, especially those that are virtually inaccessible to rangers in order to potentially reduce pressure during the rainy-season (non-hunting season).

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RESUMEN

Este estudio analiza las tendencias espacio-temporales de las actividades ilegales en la Reserva de la Biosfera de la Región W de Benín con el fin de proporcionar orientación para la planificación del sistema de vigilancia. Utilizamos datos recopilados por los guardabosques sobre las actividades ilegales en la reserva desde 2012 hasta 2015. El pastoreo ilegal es la actividad ilegal más común observada en la reserva (1137 incidentes), seguida de la caza furtiva (469 incidentes), la invasión agrícola (285 incidentes) y la tala (69 incidentes). La distribución de estas actividades en la reserva depende en gran medida de las zonas y también varía según las estaciones. En general, los incidentes de actividades ilegales fueron más frecuentes durante la temporada de veda que durante la temporada de caza debido a las inundaciones, la inaccesibilidad de los caminos y el cierre de la cubierta vegetal que limitan las actividades de patrullaje durante la temporada de prohibición de la caza. Con base en estos resultados, los administradores del Parque Nacional de la Región W pueden identificar zonas de alta presión humana donde es necesario intensificar los esfuerzos de vigilancia de los guardabosques. Proponemos el uso de nuevas tecnologías, tales como los vehículos aéreos no tripulados, para un mejor monitoreo de estas zonas, especialmente durante la temporada de veda cuando la reserva es prácticamente inaccesible para los guardabosques.

RÉSUMÉ

Cette étude s'est intéressée à l'analyse de la variation spatio-temporelle des pressions anthropiques dans la Réserve de Biosphère W du Bénin afin de mieux orienter le système de surveillance. Nous avons utilisé les données de patrouille collectées par les éco-gardes sur les activités illicites de 2012 à 2015 dans la réserve. Le pâturage est l'activité illicite la plus observée dans la réserve (1137 incidences). Il est suivi du braconnage (469 incidences), de l'empiètement agricole (285 incidences) et de l'exploitation forestière (69 incidences). La distribution de ces activités dans la réserve est fortement dépendante des zones et varie également d'une saison à une autre. De façon générale, les résultats ont montré que les incidences d'activités illicites sont plus observées en saison non-cynégétique qu'en saison cynégétique. Cette situation est due à l'inondation du parc, la difficulté d'accès aux pistes et la densité de la végétation qui limitent les activités de patrouille en cette saison. A travers cette recherche, les gestionnaires du Parc du W seront désormais conscients des zones à fortes pressions anthropiques où les efforts de surveillance des éco-gardes devraient être redoublés et intensifiés. Nous recommandons l'utilisation de nouvelles technologies comme les drones pour mieux surveiller ces zones, en particulier pendant la saison non-cynégétique lorsque la réserve est pratiquement inaccessible aux éco-gardes.