CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Department of Animal Science and Food Processing

EVALUATION OF MANAGEMENT EFFECTIVENESS OF PROTECTED AREAS IN GHANA

Ph.D. DISSERTATION THESIS

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Evaluation of management effectiveness in protected areas of Ghana

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Objectives of thesis

Protected Areas (PAs) are cornerstones of biodiversity conservation, and of economic importance as they contribute to improving standards of living of communities surrounding them. However, PAs are subjectto pressures and threats, such as poaching, bush fires and land conversion due to farming or grazing around or within the PAs. In 2010 assessment of 8 protected areas was done using the Rapid Assessmentand Prioritisation of Protected Area Management (RAPPAM). The assessment revealed that appropriateresource allocation mechanism was a major issue that natural resource managers are facing as information needed to make decisions is inadequate. Consequently, management of natural resources is ineffective and inefficient. Since 2011 there have not been any record of assessing management
effectiveness of the remaining PAs.
The aim of the thesis will therefore be to determine the parameters which indicate the effectiveness ofthe protected areas and their management in Ghana.
Specific objectives: 1) Assess the long-term law enforcement monitoring operations, (2) Determinewhether local communities hold Local Ecological Knowledge, (3) Expand the understanding of local communities' knowledge and perceptions about mammal abundance and illegal activities in PAs, and (4) Carry out comprehensive PA management effectiveness assessments which included local communities and other relevant stakeholders.

Methodology

The dissertation will consist of;

1. Literature search of protected areas management

2. Methods of collecting data in the selected protected areas in Ghana, namely patrols' monitoring, rangers' and local communities interviews.

3. RAPPAM and METT methodology will be applied in five protected areas in Ghana

4. Data treatment will follow standard statistical procedures relevant to collected data.

The proposed extent of the thesis

80 pp.

Keywords

Biodiversity conservation, Effectiveness assessment, Nature protection, Protected areas, Management, West Africa.

Recommended information sources

Ervin J. 2003. Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) Methodology. WWF, Gland, Switzerland. Jachmann H, Nateg C, Balangtaa C, Debrah E, Damma F, Atta-Kusi E, Kipo A. 2011. Protected area performance and tourism in Ghana. South African Journal of Wildlife Research 41: 95-109.. Leverington F, Hockings M, Pavese M, Costa KL, Courrau J. 2008. Management Effectiveness Evaluation in Protected Areas- A Global study. Supplementary. Report No. 1: Overview of Approaches and Methodologies. The University of Queensland, Gatton, TNC,WWF, IUCN-WCPA.

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Leverington F, Lemos Costa K, Pavese H, Lisle A, Hockings M. 2010. A global analysis of protected area management effectiveness. Environmental Management 46: 685–698.

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DECLARATION

I, Jerry Owusu Afriyie, hereby declare that I have written this thesis entitled "Evaluation of Management Effectiveness of Protected Areas in Ghana" independently, except for chapters 3-6 where all the co-authors of the included articles were declared and all of them agreed that the articles will be published as a part of this thesis. Moreover, I declare that thesis includes original text and all sources used have been quoted and acknowledged employing the complete reference list in the chapter General references according to the citation rules of FTA. I state that the work has not been submitted for any other degree to this or any other university within and outside Czechia.

In Prague, January 24, 2022

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Ing. Jerry Owusu Afriyie

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ABSTRACT

Protected areas (PAs) usually contain irreplaceable and threatened biodiversity and are often considered one of the most important places to preserve for future generations. However, there is clear evidence that some PAs have disappeared or experienced large losses in surface area because of human activities, which in turn led to a significant decrease in habitat occupied by species. Effective PA conservation requires proper legal frameworks, sound governance, and the support of surrounding communities. This thesis aimed to provide valuable insights into the management effectiveness of PAs in Ghana. To achieve these, the current thesis seeked to: (1) Assess the long-term law enforcement monitoring operations, (2) Expand the understanding of local communities' knowledge and perceptions about mammal abundance and illegal activities in PAs, and to (3) Carry out comprehensive PA management effectiveness assessments. The results showed that the long-term law enforcement monitoring system was relatively effective enough to reduce illegal activities in PAs. However, in the years where rangers' performance was low, illegal activities increased and *vice versa*. This was mainly because of the differences in rangers' motivation through the provision of logistics. The long-term assessment of patrol-based monitoring data provides reliable information on illegal activities related to wildlife and enables stakeholders to design effective measures for biodiversity conservation. Furthermore, personal interviews with local communities revealed that they had considerable knowledge of the decline in mammal species abundance and illegal hunting trends. This knowledge of local communities was consistent with the ranger-based monitoring data collected over 12 years. Understanding the diverse knowledge of local people in an area may therefore significantly contribute to formulate conservation practices that focus on the relationship between knowledge, practices, and institutional context. It is therefore important to integrate local communities' knowledge into monitoring and management as it can be cost-effective, enhance community participation, and provide novel insights into sustainable resource use. Effective management of PAs requires that managers must often know the strengths and weaknesses of the management of these PAs. The results of this thesis showed that structured interviews using Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM), workshops, and site visits provided a clear picture of the management strengths and weaknesses of PAs in Ghana. The findings confirmed that the present systems do not effectively protect natural resources. The indices under the 'planning' element received the highest average scores in all three PAs, whereas lack of support from local communities, disputes of land tenure, inadequate funding, poor infrastructure, and poor research, evaluation, and monitoring received the lowest ones. To make PA management effective in delivering their objectives in biodiversity conservation in their full socio-ecological integrity and economic benefits requires highly motivated staff, adequate funding, and good park-community relations.

Keywords: Law Enforcement Rangers; Local Communities; Local Ecological Knowledge; Illegal Hunting Activities; Rapid Assessment and Prioritisation of Protected Area Management; Wildlife Conservation

CONTENTS

CHAPTER ONE

1. INTRODUCTION

Protected areas (PAs) represent the most vital conservation tool for protecting biodiversity and ecosystem services (Klein et al. 2007; Coad et al. 2008; Scharlemann et al. 2010) and proved to be one of the most successful approaches to prevent species loss and ecosystem degradation. Many of the unique natural areas of the Earth are protected areas, e.g., Yellowstone and Yosemite (USA), Galapagos Islands (Ecuador), Uluru Kata Tjuta (Australia), Serengeti (Tanzania), New Zealand Fiordland, Sagarmatha (Nepal), Iguazu (Argentina/Brazil), and China's panda reserves. They are the treasures of every nation and are often the basis for rural livelihoods and tourism industries. The importance of PAs, recognized by international community within Aichi Biodiversity Targetsas Strategic Goal C (CBD 2011), caused the growth of a global network of PAs covering about 22.5 million km^2 (16.64%) of land and inland water (UNEP-WCMC 2021).

Although PAs are the best option to reduce the loss of biodiversity, they are not invulnerable to biodiversity and habitat loss (Craigie et al. 2010; Laurance et al. 2012; Geldmann et al. 2013) or increases in human-induced pressures (Geldmann et al. 2014). There is also clear evidence that some PAs have disappeared or experienced large losses in surface area because ofhuman activities, which in turn led to a significant decrease in habitat occupied by species. For example, the lion population of West, Central, and East Africa declined by 50% in the last two decades and a 30% decrease in the numbers of African elephants in the last decade (Chardonnet 2019). Human activities in most of these areas have been primarily responsible for the declines in habitat, so it is important to improve the performance of PAs, which host many of these species. To effectively manage PAs, proper legal frameworks, sound governance, and effective management are required (Leverington et al. 2010; Watson et al. 2014).

One of critical management approaches is the law enforcement. Law enforcement in a PA is vital for ensuring the long-term conservation and sustainability of specific conservation targets (Craigie et al. 2010; Pfeifer et al. 2012; Tranquilli et al. 2012). In most cases, PAs with poor law enforcement often experience continuous biodiversity loss (Laurance et al. 2012). Law enforcement activities in African PAs are based on monitoring of animals and human presence, using both direct and indirect signs, made during regular law-enforcement patrols; such data may be used to analyze patterns and drivers of animal population decline, evaluate trophic interactions, and assess management effectiveness (Brashares et al. 2004; Jachmann 2008a, b). Moreover, in most African countries, the use of data management technologies (e.g., Management Information Systems [MIST], and Spatial Monitoring and Reporting Tool [SMART]) have made PA management more effective (Critchlow et al. 2017). Effective law enforcement in PAs also requires a complete understanding of the strength and weaknesses of the current enforcement system. The continuous presence of illegal activities in PAs implies that the benefits of these activities are perceived to bemore important than the deterrents. To improve enforcement, authorities must assess existing restrictions and identify where the weaknesses lie. However, one of the best ways to improve law enforcement is to increase the probability of detecting illegal activities, particularly identifying the people involved and penalizing them (Milner-Gulland & Leader Williams 1992). Law enforcementoperations allow PA managers to improve on their adaptive management systems. Therefore, managers must have adequate frontline law enforcement experience and authority to make decisions, as well as appropriate training in crucial management and administrative skills. Moreover, managers must communicate with patrol staff, providing them with regular feedback ontheir performance as well as on changing law enforcement priorities. Although law enforcement

monitoring patrols in most African countries including Ghana are by foot, the strategies need to be frequently looked at and must be dynamic if they are to effectively anticipate and respond to changing situations on the ground. In this regard, the ranger-based monitoring data must often be collected, examined, and reported to senior managers in a way that can effectively informoperational planning. Ranger-based data collection involves the collection of routine information,
i.e., illegal activities and mammal population, by rangers while they are on patrols in a PA (Gray & Kalpers 2005).

Another governance and management approach for effective PA management is the welfare and involvement of the local communities living in and around the PAs in PA management. Over the past decades, conservationists have been looking into making conservation of PAs responsive to the fast- changing society. In Africa, these changes include climate change, increase human populations leading to the changing socio-economic conditions, increase in natural resources demand, and industrialization. Previous research on the social and environmental effects of PAs reveals differences in their effectiveness at protecting nature and their impacts on local communities (Blomet al. 2010; Oldekop et al. 2016). Often, local communities are restricted from extracting natural resources that are vital for their livelihoods, and in many cases, they are removed from their lands with little or no consultation or adequate compensation (Chomba et al. 2015; Sheely 2015; Chechina et al. 2018). Furthermore, local communities often suffer human rights violations in the enforcement of PA rules and elite capture of benefits (Oldekop et al. 2016). These abuses tend to result in negative attitudes toward conservation strategies (Anthony 2007), threatening protection policies through conflicts between PA management and local communities, reducing the effectiveness of PAs for biodiversity conservation (Lane 2001).

The skills, knowledge, and resources that local communities may contribute to the management of PAs are increasingly recognized, in addition to equity concerns raised by the conservation society. Management approaches that involve local communities are known to ensure the long-term effectiveness of conservation. It is suggested by many studies that local communitieswho are actively involved in the PA decision-making process are more likely to adhere to long- term conservation policies (Fu et al. 2004; Pretty and Smith 2004; Gelcich et al. 2005). The way humans value, relate to, and perceive benefits and threats to ecosystems often affects the success of protecting and managing PAs (Palomo et al. 2014; Bennett 2016). For example, local communities' perception of their natural environment and PA management practices can affect thelegitimacy of conservation governance and social acceptance (Bennett 2016). In the midst of this, it is crucial to develop conservation strategies for PAs that are understood, legitimized and acceptedby local people based on their knowledge of natural processes and biocultural diversity (Mace 2014; Tengö et al. 2017). Many of these local people have considerable knowledge, beliefs, and practices about the local environment and their management that is usually derived from experienceor passed down over generations. By depending on such knowledge many local communities havebeen able to conserve biodiversity while supporting their livelihoods and dealing with uncertainty(Berkes 1999). Local Ecological Knowledge (LEK) generally refers to knowledge that is held by people about their local ecosystems and is usually derived from human-environment interactions (Raymond et al. 2010). Recent research suggests that assessing local communities' LEK is vital for exploring co-management options, adaptation alternatives, and incorporating knowledge processesinto future PA management policies (Palomo 2017). The incorporation of local communities' knowledge into PA policy and management decision processes is of importance in Africa and manydeveloping countries, where local communities still rely on PA resources for their subsistence. Local knowledge could play a vital role in their livelihoods as well as in maintaining their culture.However, it is usually not the case in these countries, and Ghana is not an exception. It is, therefore, necessary that studies focus on the LEK of communities bordering

PAs to gather more information to a more participative involvement of the community in the management of resources they dependon.

Many countries have utilized Protected Area Management Effectiveness (PAME) assessments in recent years to evaluate the strengths and weaknesses of PA management and guide improvement for the conservation of these areas (Leverington et al. 2010). The International Union for Conservation of Nature [IUCN] – the World Commission on Protected Areas (WCPA) has createda framework for evaluating management effectiveness which consists of specific evaluation methodologies to be designed within a consistent general approach (Hockings et al. 2006). In most instances, PAME assessments are carried out by PA managers, government, and donor institutionsincluding Non-Governmental Organizations [NGOs]. Most PAME tools are questionnaires that measure the management inputs, activities, and outputs linked with conservation strategies. These are done to assess management strengths, weaknesses, and possible needs (Mascia et al. 2014). The approach to assessing management strengths and weaknesses is usually qualitative and is, therefore, usually dependent on knowledge amongst PA stakeholders (Cook & Hockings 2011; Cook et al. 2014). The IUCN Management Effectiveness guidelines identify three main topics for evaluation:
(i) design issues relating to both individual sites and protected area systems; (ii) appropriateness of management systems and processes; and (iii) delivery of protected area objectives. Hence, the management effectiveness of PAs depends on proper planning, good decision-making, and good implementation of decisions.

Local communities are major stakeholders in PA governance and, therefore, are included in all the three main evaluation topics. This means that social concerns and capacities must be addressed during the design process as well as their involvement in the evaluation process. Similarly, when evaluating the "appropriateness" of management systems and processes, it is important to consider how PAs will deliver social benefits, including protecting cultural diversity and protecting the environment. Results of PAME assessments show consistent patterns of strengths and weaknesses around the world (Leverington et al. 2010). The performance of management has been reported as adequate in the areas of PA design, legal establishment, boundarydemarcation, resource inventory assessment, and objective-setting. On the other hand, performance has been weakest in activities relating to people as well as management planning, monitoring and evaluation, budget security, and law enforcement in most PAs especially, in Africa (Leverington et al. 2010). In many PAME assessments, participants involved so-called ‘experts’ (park managers, NGOs, etc.) without local people who are an integral part of PA stakeholders. As part of the initial steps to build good relationships between PAs and local communities, these local communities must form part of the assessment team. This can help bring together a range of vantage points and knowledge for both, aligning interests and innovative problem-solving.

Historically, many lands in Africa including Ghana were set aside based on protecting the natural resources within these areas. This led to forced evictions of the inhabitants and the neglect of the livelihoods of local communities which depended on the natural resources. During the early 1900s, lands put under permanent protection and management as forest and wildlife reserves were to maintain these natural areas for the protection of watershed, maintenance of micro-climate (Marfo 2009), and production of non-timber forest products for fringe communities. However, the creation of these reserves restricted community rights to resource use although the intention was to manage these PAs for the benefit of the land-owning communities (Marfo 2009). As a result, many local people operate secretly to access the PA resources. The implication here is that local communities have long been part of the reasons for the establishment of PAs. It is therefore imperative to understand that linking PAs (or conservation more generally) with the traditions and practices, livelihoods and needs of local communities while not losing focus of the goals of conservation.

In Ghana, 21 PAs are totalling 1,347,600 ha or 5.6% of the country. The protected area network

includes seven National Parks, 6 Resource Reserves, two Wildlife Sanctuaries, one Strict Nature Reserve, and five coastal wetlands (Figure 1). The national parks are Kyabobo, Mole, Kakum, Digya, Bia, Bui and Ankasa National Parks. The Resource Reserves are Shai-Hills, Gbele, and Kalakpa. The wildlife sanctuaries are Bomfobiri and Owabi. Kogyae is the only strict nature reserve. The Ramsar sites are Keta Lagoon Complex, Densu Delta, Songor, Muni Pomadzi, and Sakumo. The Wildlife Division of the Forestry Commission of Ghana is responsible for the protection and management of wildlife-protected areas. All wildlife both in and outside of PAs is backed by legislation. However, the lack of resources greatly limits the ability toimplement conservation legislation. Moreover, existing ecological, economic, and social conditions (Oldekop et al. 2016) make voluntary compliance with conservation legislation difficult,and that the protection of wildlife requires effective and often expensive enforcement mechanisms(Rowcliffe et al. 2004). The basis for all wildlife management decisions on law enforcement activities should include monthly assessments of staff deployment and performance, patrol effort, trends in the different types of illegal activity, and population trends of key wildlife species (Jachmann 2008a). However, the lack of voluntary compliance in these PAs is due to the neglect of the local communities in PA management (Hens 2006). Meanwhile, the current Forest and Wildlife Policy of Ghana included elements of local participation in the management of the PAs. For instance, the Wildlife Division in 1998 formed the Community Resource Management Areas (CREMA) and which promotes local communities' collaboration with PA management (Bempah et al. 2019). The underlying philosophy of the CREMA approach is that if natural resources are given "value" and communities are given the "authority" to "manage" then they will have the "incentive" to sustainably manage and conserve natural resources. However, CREMA in most PAs is inactive and in other areas non-existent. Hence, theacquisition of empirical and quantitative data from the PAs in Ghana is vital to provide a more reliable and generalized conclusive state of the art. Moreover, PA management requires constant and effective management to respond to multiple issues. Responding to these issues requires management to undertake many duties such as anti-poaching patrolling, community relations, species management, tourist services, research and monitoring, and restoration works. However, much is remained to be explored regarding law enforcement monitoring operations and communityrelations as these activities especially the former constitutes the biggest budget allocations in many PAs in Africa including Ghana (Jachmann 2008a, b).

1.1 Aims

Within this context, mentioned above, this thesis aimed to provide more valuable insights into the management effectiveness of PAs in Ghana. To achieve these the current thesis seeks to: (1) Assess the long-term law enforcement monitoring operations, (2) Determine whether local communities hold Local Ecological Knowledge, (3) Expand the understanding of local communities' knowledge and perceptions about mammal abundance and illegal activities in PAs, and (4) Carry out comprehensive PA management effectiveness assessments which included local communities and other relevant stakeholders.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Protected Area systems in Africa

Protected areas are the major means for the conservation of biodiversity and other natural or cultural heritage on Earth. This role for conserving biodiversity was formally recognised by 168 countries in 1992 in Article 8 of the Convention on Biological Diversity (CBD). In the 21st century,nearly all nations support the concept of PAs. These areas practically support all national and international conservation strategies where land, water or sea has been identified as vital and given special protection to maintain functioning natural ecosystems (Dudley 2008). There are over 8571PAs in Africa, and they cover around 14.18% of terrestrial and 17.06% of marine (UNEP-WCMC 2022). However, at the global or continental level, PA coverage is neither homogenous nor representative. Some areas, such as deserts, have been neglected, and others, more difficult to protect, are less represented, such as the highly populated territories on the coast. While the numberof protected areas keeps growing, biodiversity is slowly disappearing. Some of the reasons for thissituation include the fact that some PAs lack effectiveness as they haven't been set up properly, they lack funds, and they aren't well managed. Some areas known as "paper parks" are just a line on a map where nothing really happens. Another main reason has to do with PA networks and notwith the sites themselves. As many of the sites that face great challenges in terms of biodiversity conservation are not classified, these networks are often incomplete, so they are not representativeand are badly connected. For example, Benin only has two PAs in the north of the country, leavinga void that could benefit from some sort of protection. Finally, the governance of many of these areas can be questioned, especially the inability to get the support of local communities who are directly impacted by their existence.

The governance of PAs is vital in understanding the extent to which local people collaborate with PA management. Protected area governance refers to "who is accountable for a protected area's management, as defined by law, custom, or otherwise legitimate rights" (UNEP-WCMC 2004). Governance deals with extensive topics ranging from policy to practice, from behavioral issues to meaning, and from investments to impacts concerning PAs (UNEP-WCMC 2004). Generally, governance of PAs is categorized into government-managed (solely managed by government agencies); co-managed (management responsibility and authority shared among several actors); privately managed (exclusively in private hands), and community-managed (where local people manage PAs) (Borrini-Feyerabend et al. 2004). The state-managed PA governance types by their design exclude local people.

In Africa, current estimations indicates that there no records or reports on the governance types of over 27% of PAs (UNEP-WCMC 2022). However, the majority of those that have reported (44%) are under state governance, with a very small number of them being under shared, community, or private governance. The IUCN and CBD recognises the diversity of governance types in the national systems of PAs similarly to the six management categories of PAs rangingfrom strict nature reserves (Category Ia) to protected landscapes and seascapes (Category VI). Based on these the four broad governance types for PAs mentioned above have accepted and recognised represent a full spectrum of governance diversity in the system of PAs (Dudley 2008; CBD 2010; Borrini-Feyerabend et al. 2013; Belle et al. 2015).

Although governance and management are closely linked, they must always be separated. The reason is that while management concerns the activities to obtain certain objectives, including the activities and resources provided in the management plan, governance is focused on those who agreed on the management plan and all other issues involved. Governance is commonly discussed and increasingly assessed in two dimensions, governance diversity (or governance type) and governance quality (or good governance). Governance in all PAs must ensure legitimacy and good communication, focused direction, good performance, accountability, and fairness and rights of all stakeholders (Borrini-Feyerabend et al. 2013).

2.2 Protected Area systems in Ghana

Ghana has various ecosystems with relatively high degree of diversity of plant and animal species. The network of PAs represents as variety of ecosystems including the Guinean savannah woodland, dry and moist semi-deciduous forest types, dry and moist evergreen forest types, and many transitions between them (Figure 1). The diversity of PAs in Ghana protects different mammals, reptiles, amphibians, birds, vascular plants, and butterflies. Some of these PAs are part of the upper Guinean rain forest which is rich in biodiversity. The transboundary nature of other parks like Kyabobo makes it possible for buffalos and elephants to move between Ghana and Togo (Fazao-Malfakassa National Park). Ghana has about 3,725species of plants, 729 birds, 222 mammals, and 131 reptiles.

In Ghana, aside from the five coastal wetlands which are co-managed (government and local communities), all the terrestrial PAs are managed by the state. To encourage inclusiveness with local communities, IUCN initiated universal PA definitions centered on six management categories. These are Category IA (strict nature reserve), Category IB (wilderness area), Category II (national park), Category III (natural monument), Category IV (habitat/species management area), Category V (protected landscape/seascape), and Category VI (protected area with sustainable use of natural resources) (Dudley 2008). The main reason for this category was to allow a combination of various categories of PAs such that while some permit for a certain level of human activities, others would remain exclusive for the PA system to meet conservation, scientific, and socio-economic needs.

Although the IUCN PA management categories exist in Ghana, the management approach in all PAs puts a higher priority on ecological considerations than local community welfare. Meffe et al. (2002) referred to this approach as regulatory enforcement and regulation dictating decision-making. For example, in Digya National Park in Ghana there was a forced eviction of settlers by PA officials because their activities endangered the ecological integrity of the park is an outcome of such a state-controlled governance type (Ayivor et al. 2013). Managing PAs within the ecological and institutional context would result in local communities' opposition to the concept of PA establishment, negative attitudes, and eventually illegal behaviours towards resource extraction (Ayivor et al. 2020).

However, for all PAs in Ghana, successful conservation is mainly dependent on the active support of local people in the form of compliance with park rules (Mascia et al. 2014). Eventually, the failure to control illegal activities (Cifuentes et al. 2000) may substantially weaken the management effectiveness of PAs. Indeed, non-compliance with PA regulations is a major threat to the effectiveness of conservation policies in most parts of the world (Conteh et al. 2015; Solomon et al. 2015).

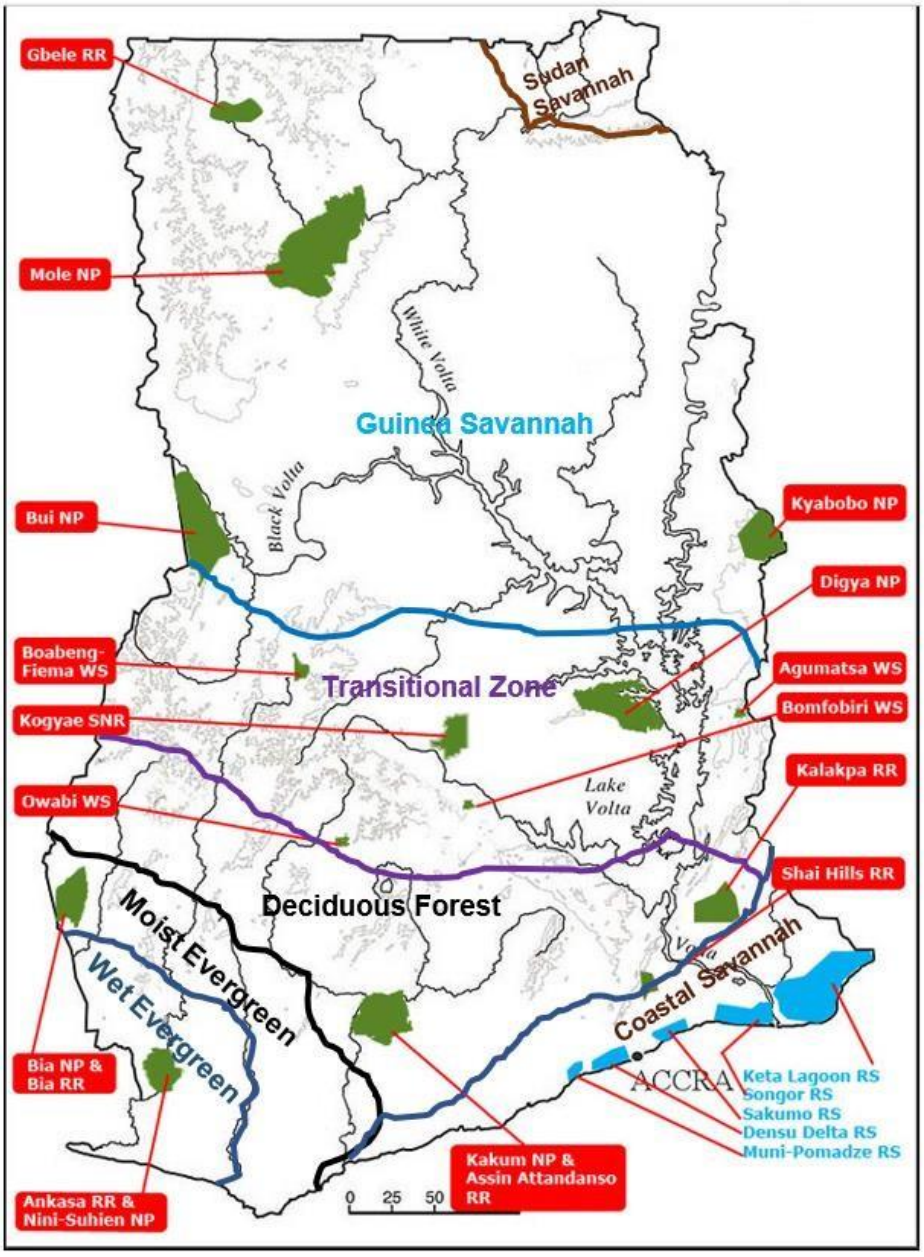

Figure 1. Wildlife protected areas in Ghana are indicated by green and names highlighted with red colors within the map. Ecological zones are distinguished by the different colours. Source: (Ghana Wildlife Division)

2.5 Law Enforcement monitoring system in Protected Areas

In effectively dealing with non-compliance in PAs, it is vital to implement measures that intensify the enforcement of conservation rules through, for example, more severely punishing violations. Law enforcement is an effective tool used by protected area managers to prevent illegal activity (Hilborn et al. 2006; Keane et al. 2008). In Africa, resources needed for the monitoring and protection of biodiversity are limited, and thus, underfunding reduces the management

effectiveness of PAs (Juffe-Bignoli et al. 2014; Plumptre et al. 2014; Watson et al. 2014). It is, therefore, vital that recognizing priority areas for intervention to minimise illegal activities is a key attempt for enhancing PA management. In many PAs, this is a difficult task because specific spatial information on illegal activity is mostly not available (Afriyie et al. 2021). Where available, analyses of law enforcement efforts that consider the spatial and temporal aspects of illegal activities (e.g., landscape features) can assist predictions of risk across landscapes, including unsampled areas (Critchlow et al. 2015, 2017; Plumptre et al. 2014). Additionally, such information can serve to investigate the spatial or temporal influence of different law enforcement strategies. For example, in Uganda, many PAs between 1997 and 2002 used the Management Information System (MIST) software developed by German Technical Cooperation (GTZ) and Ecological Software Solutions (ESS). This software has subsequently been used successfully in many PAs in Asia, Central, South, East and West Africa. MIST allows law enforcement data to be spatially mapped, to map where patrols had been, where illegal activities or sightings of key species had been made and to assess encounter rates of sightings per unit effort of patrol (Critchlow et al. 2015, 2017; Plumptre et al. 2014). The ability to assess the number of encounters of illegal activities per patrol day or per kilometer of ranger patrol made MIST unique among such tools that existed. Also, another tool developed for adaptive management of wildlife law enforcement is the Spatial Monitoring and Reporting Tool (SMART). The SMART approach covers three areas: software, capacity building and site-based protection standards. With a global need to improve PA management effectiveness, this system ensures that the available resources are provided to ensure conservation success (SMART 2018). SMART is used at more than 1,000 sites in over 70 countries to support conservation management activities, including biodiversity conservation, law enforcement, tourism and visitor management, natural resources use, intelligence, and performance and threat level assessments (SMART 2020). SMART assists users to monitor and evaluate conservation interventions to improve conservation management. The provision of quick access to proper data and analysis, SMART helps managers and frontline workers reduce pressures and threats to PAs (SMART 2020).

However, before the year 2000, only two PAs in Ghana, namely Mole and Kyabobo National Parks, where donor-funded projects were operating, had GIS-based systems used to visualise information collected on patrol to direct field operations. However, in the other PAs, management lacked a properly planned and executed law enforcement system and with most of them conducted on an ad-hoc basis. Meanwhile, by early 2008 in Ghana, performance and adaptive management systems were introduced in all terrestrial PAs (Jachmann 2008a, b). Adaptive management is a concept that integrates research into conservation strategies. Particularly, it involves: (1) dealing with uncertainty in the management system, (2) learning from management actions, and (3) achieving desired results. Adaptive management requires adhering to a stepwise process and fully implementing each step. A significant step is thorough monitoring and assessment of management interventions (Lancia et al. 1996; Salafsky et al. 2001).

In mid-2004, an inexpensive patrol-based monitoring system (Jachmann 2008a, b) wasinitiated in Ankasa and Kakum Conservation Areas, and Shai Hills and Kalakpa Resource Reserves. Early 2005, this system was created in Kogyae Strict Nature Reserve and Digya NationalPark. In early 2006, the system started in Bia Conservation Area, while Owabi and Bomfobiri Wildlife Sanctuaries, Gbele Resource Reserve, and Bui National Park had theirs in late 2007 and early 2008. Nevertheless, there is still no GIS-based systems in some PAs in Ghana. It is, therefore,imperative that top management of PAs in Ghana, NGOs and other relevant stakeholders ensure that all PAs have spatial monitoring systems.

2.5.1 Patrol operations and management

All studies on the law enforcement monitoring systems in Ghana focus on patrol staff performance, encounters of illegal activities, and encounters of mammals in the PAs (Jachmann 2008a, b; Jachmann 2011; Wiafe & Amoah 2012; Wiafe 2016; Wiafe 2018). All PAs use conventional law enforcement in the form of foot patrols that start from range camps and or the park's headquarters. Day patrols are carried out between morning and dusk, and night patrols between dusk and dawn. Meanwhile, long patrols are done for more than a day and combine daytime and night-time patrols. Ambush patrols remain in one location, often near a commonly used poaching trail, but most times as a response to a piece of intelligence information. Animal encounters are usually not collected on ambush patrols. Patrol routes are considered as transects with unfixed width used to collect information on indicators of illegal wildlife use and animal encounters. In all PAs standardized data sheets are used to record the numbers of staff on patrol; the exact duration; the distance travelled, quantity, and locations of illegal activity and animals encountered. Rangers draw patrol routes on a grip map where the location of each encounter is recorded. The head of rangers of a particular range uses the patrol routes for spatial planning to ensure that the whole range is covered at least once a month. In addition, Wiafe (2016) reported that rangers in the Kakum Conservation Area, Ghana hold monthly meetings to review collated patrol reports. During such meetings, based on the report and lessons learned from it, they adopt the necessary strategy towards subsequent patrols. For example, changes among the different types of patrols (day, night, and long) for the different range depends on the outcomes of the previous patrol report.

2.5.2 Outcomes of Patrol operations

In a study carried out in nine PAs in Ghana, Jachmann (2008a) reported that after the introduction of the patrol-based monitoring system, patrol staff performance increased when compared tothe previous years. For example, in 2006, staff performance in Kogyae Strict Nature Reserve varied between 13.1 and 16.3 (compared to 2.7 and 3.8 in 2005) and in Ankasa between 10.7 and 14.8 (compared to 3.4 and 8.9 in 2005) effective patrol days/staff/month, a dramatic improvement. Staff performance in Kalakpa and Shai Hills only marginally improved, whereas that in Kakum steadily declined from 13.9 to 5.4 effective patrol days/officer/month at the end of 2006. Hence, following the assessment and the resultant response of PA managers, patrol performance improved by 59% in all the PAs they studied (Jachmann 2008a).

Meanwhile, most studies on law enforcement monitoring operations in Africa report a decline in illegal activities in PAs where patrols are relatively effective (Jachmann 2008a, b; Critchlow et al. 2015, 2017; Plumptre et al. 2014). This means that PAs that are monitored are more likely to protect wildlife than those that are not. For example, in the Port Gauthier and Dassioko Sud Forest Reserves in Cote d'Ivoire poaching and other illegal activities decreased immediately following the introduction of patrols in 2012 (Bi et al. 2019). Although there is a reported decline in illegal activities, some occur since bushmeat is still in higher demand and available on the market. However, effective patrolling of all PAs at a high frequency to prevent illegal activities is unlikely to be financially feasible especially in developing countries. Managers can, therefore, use spatial information on the distribution of threats to direct additional, or reallocate existing resources to mitigate illegal activity (Plumptre et al. 2014). Other options include advanced planning of patrol

routes using GIS to ensure wider coverage and to focus on high-risk zones, increasing the frequency of patrols, hiring additional rangers to cover more ground, and establishing temporary camps to spend more time patrolling in remote areas (Denninger-Snyder et al. 2019). Although law enforcement is a vital element of protected area management it is not the only solution; other approaches that focus on the drivers' illegal activities are also required (Denninger-Snyder et al. 2019). Rentsch and Damon (2013) indicated that enhanced enforcement may be the most effective means to reduce illegal hunting in the Serengeti Ecosystem by decreasing supply, increasing bushmeat prices, and promoting the consumption of alternative protein sources. To achieve the objectives of law enforcement, multiple approaches are needed, and interventions implemented with critical knowledge of their shortcomings.

2.5.3 The role of communities – Beyond Enforcement

The conservation community in the World has stressed the vital role of local communities in ensuring the effective management of protected areas. The continuous decline of biodiversity mainly through human activities, and the subsequent emphasis on improving law enforcement operations, has encouraged the conservation community to reemphasize the prospective role of communities in fighting wildlife crime, in an initiative called 'Beyond Enforcement' (Roe 2015). The Beyond Enforcement proposition is that enhancing law enforcement without the active support and engagement of local communities is inadequate to address the increased rate of illegal activities affecting most PAs in Africa. Furthermore, increasing law enforcement especially in an aggressive or militaristic manner without the cooperation of local communities is likely to antagonize these communities (Challender & MacMillan 2014). These will eventually negatively affect PA-community relations, reduce compliance to PA rules, and ultimately lead to increased illegal activities.

The other underlying principle of Beyond Enforcement is that even when enforcement is successful at a particular site, it may shift illegal activities to areas where there is weaker enforcement (Roe 2015). The motivation here is that local communities are poor or marginalized enough to put much effort to engage in illegal activities. As law enforcement cannot be always applied everywhere, and with the increased poverty in nearby communities, illegal activities will likely continue to move along the path of least resistance. In many PAs, for example, conservation policies prevent local people from deriving any economic benefit from protecting wildlife, thus removing a major incentive to protect and sustainably manage the wild species they live with. The resultant effect is finding lucrative land-use opportunities which may lead to biodiversity loss.

For effective law enforcement monitoring systems, there must be a need to develop collaborations with local communities. Local people are well placed to engage in illegal activities because they are closer to the PAs wildlife and their local knowledge. But for these same reasons they are also exclusively positioned to support and involve in law enforcement efforts. They can provide first lines of defense and can potentially serve as scouts, informants, and guides.

2.6 Local Ecological Knowledge

All over the world, indigenous peoples and local communities have the potential to acquire complex knowledge systems concerning the conservation and sustainable use of ecosystems. As

direct users of natural resources, local communities have for a long time been aware of the changes occurring in the resources they depend on for their livelihoods and, therefore, developed adaptive management responses.

Meanwhile, PA managers and conservationists have acknowledged that by disregarding local communities' in-depth ecological memory and detailed time-tested knowledge, the information base required for conservation interventions is diminished and the potential to make suitable decisions concerning biodiversity protection is also reduced. Conservationists over the last decades have recognised that including local knowledge in assessing and monitoring the status and trends of biodiversity in an area may potentially lead to effective and collaborative management of PAs (Davis & Ruddle 2010; Gomez-Baggethun et al. 2010). It helps motivate the local population to accept and participate in the enforcement of management regulations. The importance of local knowledge for conservation is increasingly highlighted in literature (e.g., Gadgil et al. 1993; Berkes & Turner 2006; Brook & McLachlan 2008; Gomez-Baggethun et al. 2010; Davis & Ruddle 2010; Díaz et al. 2015). This understanding is also reflected in international conventions, i.a. in Article 8(j) of the CBD, which requires all contracting parties to respect, preserve, maintain, and apply the knowledge, innovations, and practices of indigenous and local communities that are relevant for the conservation and sustainable use of biodiversity (UN 1992; CBD 2011).

Charnley et al. (2007) defined Local Ecological Knowledge (LEK) as knowledge, practices, and beliefs regarding ecological relationships that are gained through extensive personal observation of and interaction with local ecosystems and shared among local resource users. LEK is fixed in a context of values and social conventions, ethical principles, religious beliefs, ritual taboos, customs, innovations, and other cultural practices. It is part of a community's identity and forms the foundation of community livelihoods, connecting people to their land and its natural resources.

As stated by Thaman et al. (2013) LEK holders do not separate knowledge from practice as both, in interaction, are sources of innovation, learning, and new understandings. Different roles and functions such as ecosystem management, resource use, and biological monitoring or research, may be carried out by the same person demonstrating a holistic approach towards conservation. These local communities because of their direct use of natural resources can provide useful experience and information on the status and trends of biodiversity and ecosystem services. Moreover, LEK can provide site-specific observations that may give an accurate overview of the status of the population including their health, abundance, or composition (Thaman et al. 2013). For example, Braga-Pereira et al. (2021) compared the abundance of 91 wild species (among mammals, birds, and tortoises) obtained after sampling over 7 thousand km of line transects and performing 291 interviews on the LEK of local people in 17 areas across the Amazon. The results indicated a high similarity in abundance estimated between the two methods, which revealed the local knowledge as reliable as the standard scientific methods used. Additionally, the researchers found that LEK is more useful and accurate than the line transects when it comes to some specific species that are rarely observed on transects, such as nocturnal, cryptic, less abundant, or hunted species. Thus, LEK can contribute to (i) identify indicators to measure the current state of biodiversity, ecosystem services, and cultural well-being, (ii) establish thresholds to trigger different levels of management interventions to counter biodiversity decline, (iii) set targets for the rate of recovery, and (iv) fix stopping rules to terminate interventions and divert investments elsewhere (Thaman et al. 2013).

2.6.1 Integrating Local Ecological Knowledge into Protected Area Management

Steinmetz (2006) stated that the status of wildlife at a site is affected by a combination of historical and ongoing processes. Local people with a long history in an area will have insights into the spatial extent, intensity, duration, and range of variability of such processes. These details are important for site-specific conservation planning but are unavailable to protected-area staff and conservation biologists, who may be relative newcomers to an area. At the same time, however, local people do not necessarily perceive the positive or negative consequences of their land use or hunting practices for wildlife at the broader spatial scales of concern to biologists. Thus, local people and conservation biologists have much to learn from each other.

Meanwhile, there have been numerous arguments by different researchers about whether LEK should be integrated into PA management. Some believe that there should be a scientific verification of LEK before its application (Rerkasem et al. 2009), others emphasize the need to focus less on issues of 'correctness' but rather focus on what can be added to resource management when used together with standard scientific methods (Rist et al. 2010). Regardless of some studies indicating the inaccuracy of the information provided by LEK or their undesirable outcomes on biodiversity conservation when compared to scientific knowledge (Becker & Ghimire 2003; Silvano et al. 2005), most of them acknowledged the complementarity of both knowledge systems. These authors accentuate the potential benefits of combining them and that PA management measures may be improved if they integrate locally based information with empirical assessments obtained from scientific data.

Another school of thought that has criticized knowledge integration is that LEK may lose its authenticity when combined with scientific knowledge. Agrawal (2002) argues that by integrating LEK and scientific data, the unique contextual and applied characteristics of LEK will be stripped away. It will, therefore, increase existing inequalities, if LEK is misused and the benefits from its utilization are not equitably shared with the holders of that knowledge.

While knowledge integration is one of the main topics of LEK research, only a few examples are reported from practice (Charnley et al. 2007; Braga-Pereira et al. 2021). All in all, most PA managers continue to rely on scientific knowledge, often disregarding other means of knowing (Ellis 2010) or solely using LEK to strengthen their position of power. Accordingly, there persists a considerable lack of understanding on how the traditional and official conservation paradigms interact (Shen et al. 2012), that needs to be looked at for LEK to complement scientific knowledge in official conservation programs.

2.7 Management Effectiveness Assessment

Protected areas are established to achieve ecological and social benefits. However, their effectiveness depends on effective planning and implementation (Bennett & Dearden 2014; Klein et al. 2015), as well as the incorporation with other management interventions (Hilborn 2016). Management effectiveness relates to how well PAs are managed – mainly the extent to which management is effective at conserving values and achieving goals and objectives, such as protecting biodiversity (Hockings et al. 2006; Leverington et al. 2010)

There have been efforts to measure the effectiveness of management of PAs based on the management effectiveness evaluation framework provided by the IUCN-World Commission of Protected Areas (WCPA). The IUCN-WCPA have provided over 95 different tools used

consistently in more than 180 countries (Leverington et al. 2010; Coad et al. 2015) to design evaluation systems for PAs, with a framework including the design of systems and individual PAs (context and planning), appropriateness of management systems and processes (inputs and processes), and delivery of PA objectives (outputs and outcomes) (Figure 2). These evaluations have often been driven by pressures from governments and NGOs who fund management activities mainly to know the conservation outcomes associated with their investments in PA management. The evaluation results are usually used in more than one way. Information is used by managers to improve their performance (applied adaptive management), for reporting (accountability), and to improve planning in the future (project planning).

There are many benefits to assessing PA management effectiveness, but there are also challenges and limitations, and it is vital that assessments are carefully undertaken to prevent these risks (Hockings et al. 2006). To support the selection and application of methodologies, eight principles for good management effectiveness assessments have been developed (Hockings et al. 2015). Evaluations of management effectiveness of PAs should be: (1) Part of an effective management cycle, linked to defined values, objectives and policies and part of strategic planning, park planning and business and financial cycles; (2) Practical to implement with available resources, giving a good balance between measuring, reporting and managing; (3) Useful and relevant for improving protected area management, for yielding explanations and showing patterns and for improving communication, relationships and awareness; (4) Logical and systematic, working in a logical and accepted framework with a balanced approach; (5) Based on good indicators, which are holistic, balanced and useful; (6) Accurate - providing true, objective, consistent and up-to-date information; (7) Cooperative and participatory with good communication, teamwork and participation of protected area managers and stakeholders throughout all stages of the project wherever possible; and (8) Focused on positive and timely communication and application of results.

In Africa, different management effectiveness evaluation tools have been employed in assessing different types of PAs and for different purposes. For instance, assessments at site-level for specific PA (e.g., in Egypt), assessments at the broad ecosystem level (e.g., in African rainforest PAs or marine areas (the Western Indian Ocean Marine Protected Area Assessment), assessments of conservation potential conducted in the Central African Republic, or threat reduction assessment in Uganda (for more details see Leverington et al. 2008). In Ghana, assessing the performance of PAs has been carried out since 2009. Among the varieties of methodologies used worldwide, the World-Wide Fund for nature (WWF) Rapid Assessment Prioritization of Protected Area Management (RAPPAM; Ervin 2003), and the World Bank/WWF's Management Effectiveness Tracking Tool (METT) have been the only used management effectiveness evaluation tool. Because the RAPPAM and METT are the most used and has been applied in many PAs in the world and Ghana (Leverington et al. 2010), the discussion will focus on the outcomes of their useover the past years. The IUCN-PAPACO carried out management effectiveness evaluation using RAPPAM in eight PAs in Ghana, namely Ankasa, Bia, Kakum Conservation Areas, Bui, Mole, Kyabobo, National Parks: Bomfobiri Wildlife Sanctuary, and Shai Hills Resource Reserve. Also, two other studies have been carried out by Abukari and Mwalyosi (2018) at Mole National Park and Ayivor and Ntiamoa-Baidu (2015) in the Kogyae Strict Nature Reserve. However, both only used the "context" element in RAPPAM assessment. Except for IUCN-PAPACO where only parkauthorities were involved during the assessment process the rest involved both park authorities and other stakeholders.

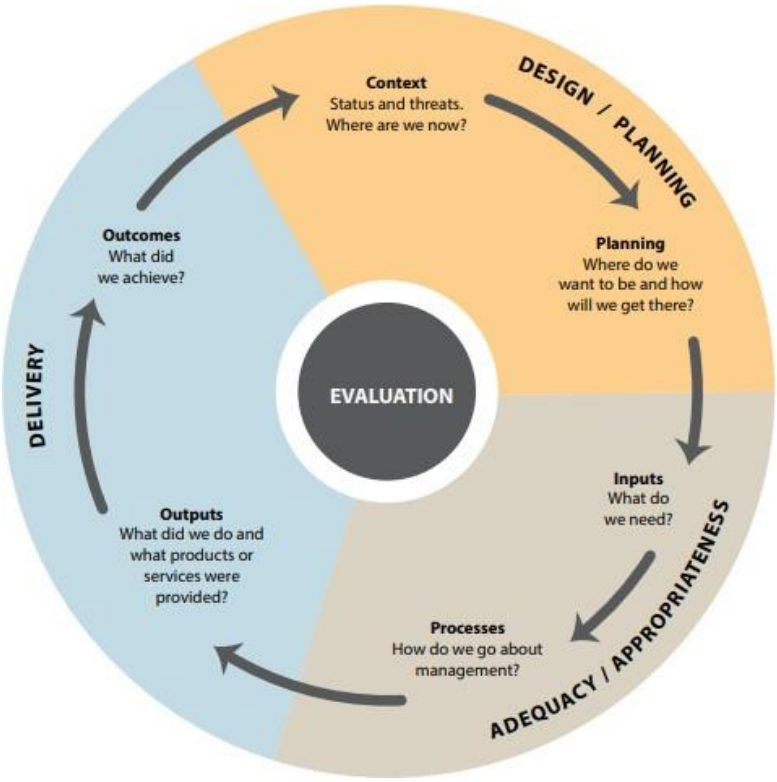

Figure 2. IUCN Framework for evaluating Protected Area Management Effectiveness (Source: Hockings et al. 2006).

2.7.1 Structure and Overview of the Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM)

The evaluation of the RAPPAM is drawn from the WCPA (Ervin 2003), however, an in-depth field assessment can be structured to answer site-specific questions e.g., management of biodiversity assets, training of staff, infrastructure, etc. The five steps of management and assessment cycle cover the; (1) Determining the scope of the assessment: This involves setting objectives of assessing the PA, people using the information and who will participate, time frame, follow up steps, and a host of other important assessment plans; (2) Assessing existing data of the PA: Preliminary assessment of both quantitative and qualitative data available at PA including aerial photos and satellite imagery, biodiversity reviews, needs assessments for training and capacity building, threat analyses, scientific and academic research, anthropological and sociological studies, internal programmes and field reports, external reports from independent agencies, legal and policy reviews, etc. These can be incorporated into the questionnaire; (3) Administering the questionnaire: This part involves the PA managers, administrators, and stakeholders (to obtain triangulated data) participating and discussing the questions and their interpretations, agreeing upon the answers, conducting the analyses, and recommend priorities and possible next steps ; (4) Analysis of the findings: The degree of each pressure and threat was calculated by multiplying its extent, impact, and permanence, using the numerical values. A degree of 1 to 3 was considered mild, 4 to 9 moderate, 12 to 24 high, and 27 to 64 severe. Scoring for the rest of RAPPAM

questionnaires use a numerical index using statements with four options: “yes” = 5, “mostly yes” = 3, “mostly no” =1, or “no” = 0. For example, in responding to the statement, ‘‘the park sustains a minimum viable population of key wildlife species’’, a “yes” answer would indicate that all, or nearly all, of the key species in the park, are well protected. A “mostly yes” answer could indicate that most of the key species are well protected, or, all the key species are well protected, but the respondent still has reservations about an unqualified “yes”. A “mostly no” answer could indicate that only a few key species are well protected, or that even if most key species are protected, their population is not viable. A “no” answer would indicate that none or almost none of the key species are securely protected nor exist in the park (Ervin 2003); (5) Identifying next steps and recommendations: As recommendations are site-specific, the general aims are to assess the findings and make constructive concrete plans. E.g., Identify critical knowledge and data gaps, and develop a focused research programme to fill those gaps, identifying which specific PA may require more in-depth assessments and site level monitoring (see Ervin 2003 for full details on RAPPAM).

2.7.2 Structure and Overview of the Management Effectiveness Tracking Tool (METT)

The METT is a simple rapid site assessment tool which provides a standard report of PAs in the world by tracking their progress overtime. However, it also encourages the addition of several questions to suit local conditions rather than the modification of the tool (see for e.g., METT in Thanda Private Game Reserve and Mduna Royal Reserve in South Africa). These questions are answered by managers of the PA without any additional research. However, a group of PA staff from the reserve, project staff or other agency staff and where possible additional external experts, local community leaders or others with knowledge and interest in the area and its management should be involved in answering the questions in the Tracking Tool. The overall outcome is to identify the needs and necessary actions to improve the effectiveness of PAs (Stolton et al. 2007). The METT is structured to cover all six elements of management (context, planning, inputs, process, outputs, and outcomes) by IUCN-WCPA Framework. The METT questionnaire consists of two major sections: (1) Data sheets is made of up of two parts. The first comprises of detailed information of the PA to be assessed; management objectives, administration, staffing and funding and the second part contributing to generic list of threats which PA can face; (2) Assessment form which provide 30 questions integrating all six components of the IUCN-WCPA. The 30 main questions derived from the assessment of PAs using METT with each question corresponding to a 4-point scale from 0 to 3. The four alternative answers for each question provide assessors the opportunity to make judgement as to the level of score. These four alternative answers include 1 = Mild, 2 = Moderate, 3 = High, 4 = Very high. However, where questions are not relevant to the PA, they are left out and adjusted accordingly. Scores are calculated as a percentage for each of thesix-elements of the IUCN-WCPA.

2.7.3 Application and outcomes of RAPPAM and METT assessments in Ghana

The results of the RAPPAM assessment carried out by IUCN-PAPACO in 2010 in Ghana revealed that the major pressures facing PAs were poaching, land conversion, and bush fires with the major threats being invasive species and land conversion. Other reported threats were illegal logging around the buffer zones of PAs, pollution of rivers and streams, road construction, and tourism

development. Ervin (2003) defined PA pressures as activities or events impacting the integrity of the PAs in the past five years. Threats also refer to those existing pressures which may persist in the next five years, and to the potential new ones which may occur should the condition remain the same (Ervin 2003). Meanwhile, the assessment carried out in Kogyae in 2015 revealed that some pressures also presented the greatest threats. For example, bushfires and adjacent land use were the most severe threats. In Mole National Park in 2018, both poverty in nearby communities and poaching were considered as the most severe pressures and threats during the evaluation process.

In all PAs assessed by IUCN-PAPACO (2010), the overall management effectiveness was lowest for Mole followed by Bomfobiri, and highest for Bia. This explains the high degree of pressure in Mole and Bomfobiri. Even though management is satisfactory in many aspects in Ankasa, land conversion is a major threat that needs immediate and effective conservation actions. Compared with other assessment elements, planning ranked as qualified strength in all PAs assessed. However, funding in all PAs was not sustainable in the long term, and as such,government budget allocation for the PAs should be increased to meet the conservation targets. Underfunding of PAs appears to be a systemic problem in other areas of the world; James and Green (2001) documented that PAs across Africa and Latin America are managed on less than US$150 per square kilometer (km^2), far less than the generally accepted US$250 per km^2 needed to adequately manage tropical parks.

It must be noted that most of the PAs assessed over the years did not involve other stakeholders such as representatives from the local communities and NGOs during the assessment process. Even though the wide-ranging consultation process of RAPPAM has not always been a feature of the implementation, their involvement in the assessment process will reflect the different opinions on management effectiveness and the social and governance outcomes in addition to the conservation outcomes. Upon the vital outcomes of the RAPPAM methodologies, limited attention was paid to the severity of some future threats such as the alarming rate of human population increase and increased poverty in nearby communities, and climate change in many of the PAs assessed. Therefore, future implementation of the RAPPAM must stand the tendency of modification to suit local conditions.The results of METT assessments carried out in Ghana is similar to the results from the RAPPAM assessments. However, it will be difficult to use the IUCN/PAPACO METT assessment in Kyabobo, Bomfobiri, Digya, Mole and Kakum as standard reference to track management progress overtime since they did not use any quantitative analysis. A more rigorous METT assessment and analysis must be carried out in these and other PAs to enable comparison of management strength and weakness overtime. The lack of repeated assessments of both methodologies in Ghana makes comparative analysis of management effectiveness of most PAs difficult. In countries such as South Africa, Madagascar, and Zambia, METT assessments, have been repeated in many sites and, in more recent years, have been completed annually or bi-annually in state-governed protected areas.

The management effectiveness evaluation in most African countries over the years revealed that management performance has been enough in the following fields: PA design, legal establishment, boundary demarcation, and objective setting. Conversely, performance has been weakest in activities related to people as well as management planning, monitoring, and evaluation, budget security, and infrastructure.

It must be stated clearly that METT is the most common methodology used at the site level and it is important to ensure that it is used in line with best practice (Stolton & Dudley 2016). A number of METT assessments are completed as part of donor requirements, and often contain no comments or ‘next steps’ which limits its usefulness. Nevertheless, a number of countries have adapted METT for use at the country level, particularly for state protected areas. RAPPAM is the

methodology most commonly used at the system-level and also has many advantages. The use of integrated methodologies that take into account management effectiveness as well as issues of governance and social equity could be helpful in ensuring that protected and conserved areas are assessed adequately across the different aspects of Aichi Target 11, so that improvements can be made for biodiversity and people.

CHAPTER THREE

3. EVALUATION OF LONG-TERM LAW ENFORCEMENT MONITORING IN A WEST AFRICAN PROTECTED AREA

Law enforcement rangers on patrols in Kogyae Strict Nature Reserve, Ghana. (Photo by Afriyie Jerry)

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Evaluation of long-term law enforcement monitoring in a West African protected area

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Abstract Law enforcement in protected areas is critical for ensuring long-term conservation and achieving conservation objectives. In 2004, patrol-based monitoring of law enforcement was implemented in protected areas in Ghana. Here, we evaluate long-term trends and changes in patrol staff performance, and illegal activities, in the Kogyae Strict Nature Reserve. The assessment was based on ranger patrol-based monitoring data collected during January 2006– August 2017. Along the patrol routes, patrol officers recorded all encounters with illegal activities associated with hunting and capturing or harming of animals. Across all years, staff performance was lowest in 2006 as staff learned the system but increased in 2007 and peaked in 2010, the latter as a result of motivation of the patrol staff. After 2011, staff performance decreased, mainly because of the retirement of some patrol staff and insufficient logistical support for successful patrolling. Snares were the most commonly recorded indicators of illegal activity. Because their use is silent, poachers using snares are less likely to be detected than poachers using other forms of hunting. Long-term assessment of patrol-based monitoring data provides reliable information on illegal activities related to wildlife, to enable stakeholders to design effective measures for biodiversity conservation. Our assessment indicates that patrol staff performance in Kogyae is, at least partly, dependent on governmental or external support and incentives, in particular the provision of equipment and transport facilities.

Keywords Ghana, illegal wildlife hunting, monitoring and assessment, patrol staff performance, West Africa, wildlife conservation

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Introduction

Illegal activities such as poaching, livestock grazing, and extraction of timber and non-timber forest products are the major threats to biodiversity in protected areas (Hilborn et al., 2006; Biggs et al., 2013). The conservation objectives of protected areas in West Africa mostly include the protection of animal populations against commercial or non-commercial subsistence harvesting and protection of ecosystems against the extraction of timber and other resources, to prevent habitat loss. Efforts are needed to achieve these objectives because of the increasing human population of West Africa (International Cooperation and Development, 2016) and, consequently, increasing socioeconomic pressures on land and resources. Management of protected areas therefore requires comprehensive approaches involving a clearly defined vision, mission and management plan, effective law enforcement, training programmes for staff, educational and awareness campaigns, and cooperation with local communities. Effective law enforcement in protected areas results in fewer illegal activities (Fischer et al., 2014; Moore et al., 2017) but, when not implemented, biodiversity may decline (Peres & Terborgh, 1995).

Assessing law enforcement effectiveness in protected areas in Africa relies mostly on ranger-collected monitoring data. The effectiveness of law enforcement depends on patrol strategies, determined by managers, and on the structure of enforcement incentives (Robinson & Lokina, 2012). The deterrence of illegal activities could, however, be low if detection rates are low and benefits outweigh penalties, and even lower if there is an ambiguous legal framework regarding land tenure (e.g., Abbot & Mace, 1999; Nolte, 2016).

Optimal ranger patrol strategies differ depending on the threat. Each threat may be targeted effectively based on the knowledge of past spatial and temporal patterns of illegal activities and an appropriate allocation of ranger patrols (Critchlow et al., 2015). Strategies targeting illegal activities based on predictions of their spatial distribution improve law enforcement efficiency even without any increase in ranger resources (Nyirenda & Chomba, 2012; Plumptre et al., 2014; Critchlow et al., 2017). Approaches using spatial planning tools make law enforcement more effective, yet are not applied in all protected areas, especially in West Africa. The main reasons seem to be inadequate training in the use of software and the lack of evaluation of outcomes from ranger patrols.

In Ghana, a ranger-based monitoring system was implemented by the Wildlife Division of the Forestry Commission in 2004. It focuses on patrols assigned to monitor illegal activities and mammal populations in protected areas. The system incorporated tools to assess staff performance and the effectiveness of field operations, to assist protected area managers in adopting appropriate law enforcement strategies to achieve conservation objectives (Jachmann, 2008a, b). This system was evaluated by several studies that identified internal (e.g., budget) and external (e.g., local population density, level of tourism) factors as key elements that may support or decrease the performance of protected areas (Jachmann, 2008a, b; Jachmann et al., 2011; Wiafe & Amoah, 2012; Wiafe, 2016). These studies focused on short-term data (2–4 years) collected shortly after the implementation of the system. The long-term dynamics of the system have not previously been examined.

The aim of our investigation was therefore to examine the long-term dynamics of the conventional ranger-based monitoring system in the Kogyae Strict Nature Reserve in Ghana and to provide an assessment of the incidences of poaching activities. Using data for January 2006–August 2017 on monthly patrol performance and poaching-related encounters, our objectives were to evaluate the temporal pattern of patrol staff performance and to examine what factors or events could have affected it. In addition, we investigated the temporal patterns of illegal activities in the

Reserve and aimed to identify whether the increasing human population around the Reserve affects the encounter rate of illegal activities.

Study area

The 386 km^2 Kogyae Strict Nature Reserve (Fig. 1) lies in the Afram Plains region of Ghana. It is a flat area with a mean altitude of 120 m, with some areas reaching 230 m. The higher areas are the watershed for a network of streams dominated by tributaries of the Afram and Sene rivers, mostof which dry up in the dry season (Hagan, 1998). The climate has dry (November–March) and wet (April–October) seasons, with a total annual rainfall of 1,200–1,300 mm. Kogyae lies between transitional woodland (semi-deciduous forest) and Guinea savannah woodland and open grasslands (Wildlife Department, 1994). A large ungulate community of conservation importance includes the buffalo *Syncerus caffer*, hartebeest *Alcelaphus buselaphus*, waterbuck *Kobus ellipsiprymnus*, Buffon's kob *Kobus kob*, bushbuck *Tragelaphus scriptus*, oribi *Ourebia ourebi*, red-flanked *Cephalophus rufilatus*, black *Cephalophus niger*, Maxwell's *Cephalophus maxwell*i and bay *Cephalophus dorsalis* duikers, red river hog *Potamochoerus porcus* and warthog *Phacochoerus africanus*. The Reserve also supports the baboon *Papio anubis*, patas *Erythrocebus patas*, green *Chlorocebus sabaeus*, mona *Cercopithecus mona* and spot-nosed *Cercopithecus petaurista* monkeys, and white-thighed colobus *Colobus vellerosus* (Wildlife Department, 1994).

The Kogyae Strict Nature Reserve is the extended former Kujani Forest Reserve, formerly managed by the Forestry Department. In 1971, the administration of the Reserve was handed to the Wildlife Division for strict protection under the Wildlife Reserve Regulations, LI 710. The Kujani Forest Reserve boundary extension was to obtain a viable ecological unit for the Kogyae Strict Nature Reserve (Oduro-Ofori et al., 2015). This became necessary because studies by the Wildlife Division indicated that, in the dry season, the animals in the Reserve depend on the rivers in unprotected areas for survival (Ayivor & Ntiamoa-Baidu, 2015). The extension also includes the communities of Asasebonso, Atakpame, Nyamekyere Dagomba, Birem, Yahayakura, Aberewanko and Konkomba. Additionally, Aframso, Birem, Chichibon, and Kyeiase lie along the border of the reserve (Ayivor & Ntiamoa-Baidu, 2015). Local communities comprise predominantly farmers, with up to 75% of the people in the area working in the agriculture sector (Ministry of Finance, 2015). Farming practices involve a slash and burn method of land clearing and cultivation of a variety of crops (yam, maize, paddy rice, groundnuts, cassava, cowpeas and vegetables). Fifteen and 10% of the population work in the industry and service sectors, respectively. The population in the district is increasing at a rate of 1.4% per year (Ministry of Finance, 2015).

The Kogyae Strict Nature Reserve is managed by a park manager, who is assisted by a law enforcement officer in charge of field operations. The patrol staff are employees of the Wildlife Division and are based only in Kogyae. The number of patrol staff varied from 31 to 44 during 2006–2017. The annual budget during 2006–2015 was GHC 6,000 (c. 1,130 USD); this was increased to GHC 40,000 (c. 7,460 USD) in 2016.

Kogyae has four management zones: the Protected, Special-use, Restoration and Development Zones. The Protected Zone is the largest, comprising 220 km^2 (57%). This is the most important and least disturbed Zone, fully dedicated to conservation. The 79 km^2 Special-use Zone (20%) is an area where some farming activities by local inhabitants are allowed, but not hunting or logging.

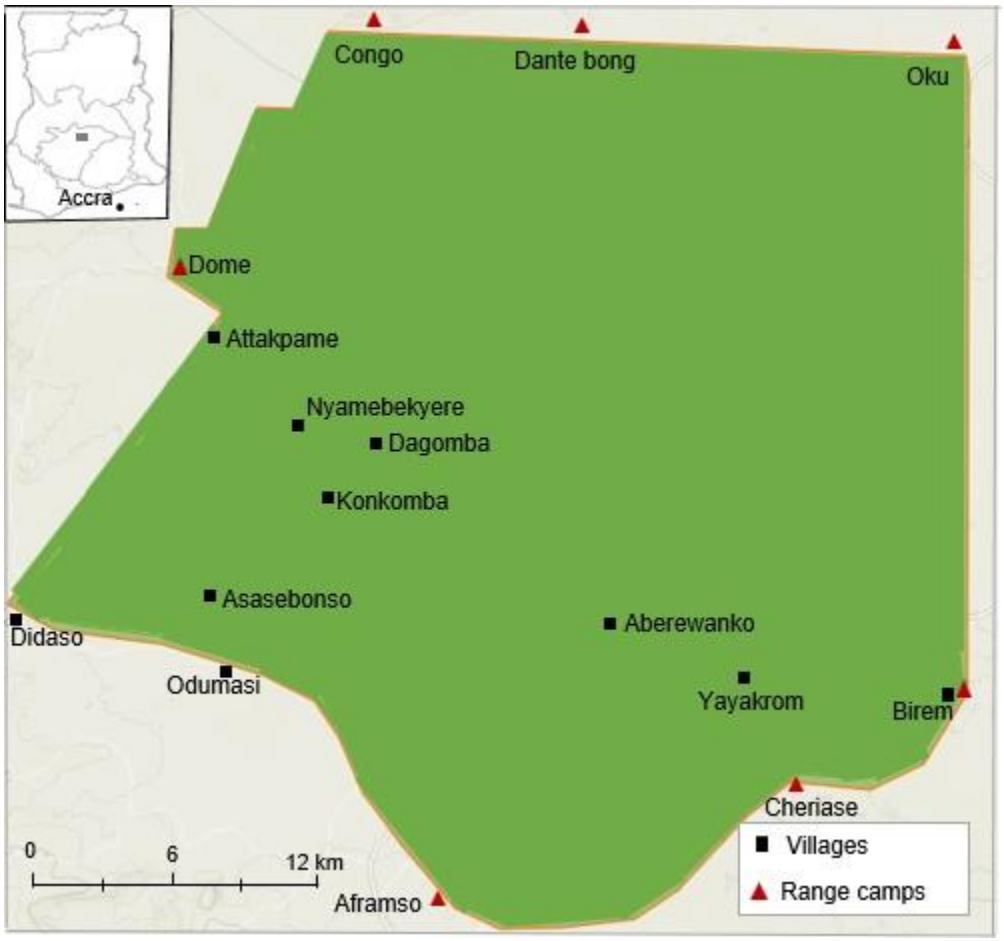

FIG. 1 Kogyae Strict Nature Reserve in Ghana, indicating the location of villages and rangers' camps (adapted from Ayivor & Ntiamoa-Baidu 2015).

The 86 km^2 Restoration Zone (22%) are those lands that have been degraded or significantly altered by farming, logging and charcoal making; they are leased to immigrants for settlement and farming. The management priorities in this Zone exclude all forms of destructive activities and the Zone is dedicated to the recovery of vegetation and wild animal populations. The 1 km^2 Development Zone (1%) has been set aside for staff accommodation, administration facilities, a research station and a centre for conservation education.

Methods

Patrol operations management

Kogyae uses conventional law enforcement in the form of foot patrols that operate from the headquarters and from camps established in each of seven communities at the periphery of the Reserve. A grid map is used for planning of patrol routes, to ensure that the entire Reserve is patrolled each month (described in detail by Jachmann, 2008a). A foot patrol comprises at least five rangers, led by the most senior of the group. Standardized forms are used to record data: the

number of staff on patrol, duration, total distance travelled, and types, number and locations of illegal activity encountered. Illegal activities recorded include poachers arrested, poachers observed, firearms confiscated, gunshots heard, poachers' camps found, animals found killed, snares recovered, and cartridges found.

Evaluation of patrol staff performance

In evaluating the performance of patrol staff, we used the monthly distance walked by all patrols and the effective patrol time, which is a measure of time spent in the field by a patrol team without including deployment time (sensu Bell, 1985, as applied by Jachmann, 2008a; Nyirenda & Chomba, 2012). To facilitate comparison of law enforcement performance across protected areas, two standardized measures of monthly patrolling effort were used: (1) effective patrol man-days calculated as the monthly effective patrol time divided by 8 hours (assigned time unit as standard for 1 patrol day), multiplied by the number of staff in the patrol group, and (2) effective patrol days calculated as the total effective patrol man-days for the month divided by the number of active staff on duty for the month.

We used catch per unit effort (Bell, 1985; Jachmann, 2008a) to measure the level of encounter rates with indicators of illegal activities per given period. Catch refers to the total number of monthly encounters with indicators of illegal activity, and the effort is the total number of effective patrol man-days per month.

A kilometric index of abundance, which is the ratio of the number of illegal activities encountered to distance walked by patrols per month, was used as a second measure of encounter rate. The kilometric index of abundance was multiplied by 100, to give the number of encounters per 100 km.

Data collection and analyses

We collected data on law enforcement operations from January 2006–August 2017, and we carried out field visits and informal interviews with the manager and patrol staff to gain insights into patrol operations. Locations of the illegal activities encountered were not available and therefore spatial aspects of law enforcement could not be evaluated. Total distance walked by patrols was only available for 2006–2014, when the GPS units were functioning. All data parameters recorded were examined with the Kolmogorov– Smirnov test and found to be normally distributed.

To examine any annual, monthly, or seasonal (wet vs dry) trends in patrol staff performance, general linear models were applied for each parameter separately as the dependent variable, with year, month and season as the independent predictors. In the case of significant differences, we used post hoc Tukey HSD tests to examine any further differences. Catch per unit effort and the kilometric index of abundance were highly correlated (Pearson's $r = 0.94$, P, < 0.001) and therefore only the catch per unit effort was used for further analyses. To examine differences in encounter rates with various types of illegal activities and their temporal trends, we used general linear models, with catch per unit effort as the dependent variable and year, month, illegal activity type, year × illegal activity type and month × illegal activity type interactions as the independent predictors. Post hoc Tukey HSD tests were used to examine any further differences among the levels of predictors if the general linear model was significant. To examine the effect of patrol staff performance and the number of inhabitants in the district surrounding Kogyae (which increased

annually during the years of monitoring) on encounter rate with illegal activities, we used simple linear regression. We used *STATISTICA 13* (TIBCO Software, Palo Alto, USA) to perform all statistical analyses.

Results

Patrol staff performance

The mean monthly distance walked by patrols in the Kogyae Strict Nature Reserve during 2006–2014 was 1,221 ± SE 47 km/month, with a minimum of 623 ± SE 0 km/month in 2012 to a maximum of 1,847 ± SE 64 km/month in 2010. Mean monthly effective patrol days were 17.5 ± SE 0.3 and mean monthly effective patrol man-days were 657 ± SE 14 during 2006–2017.

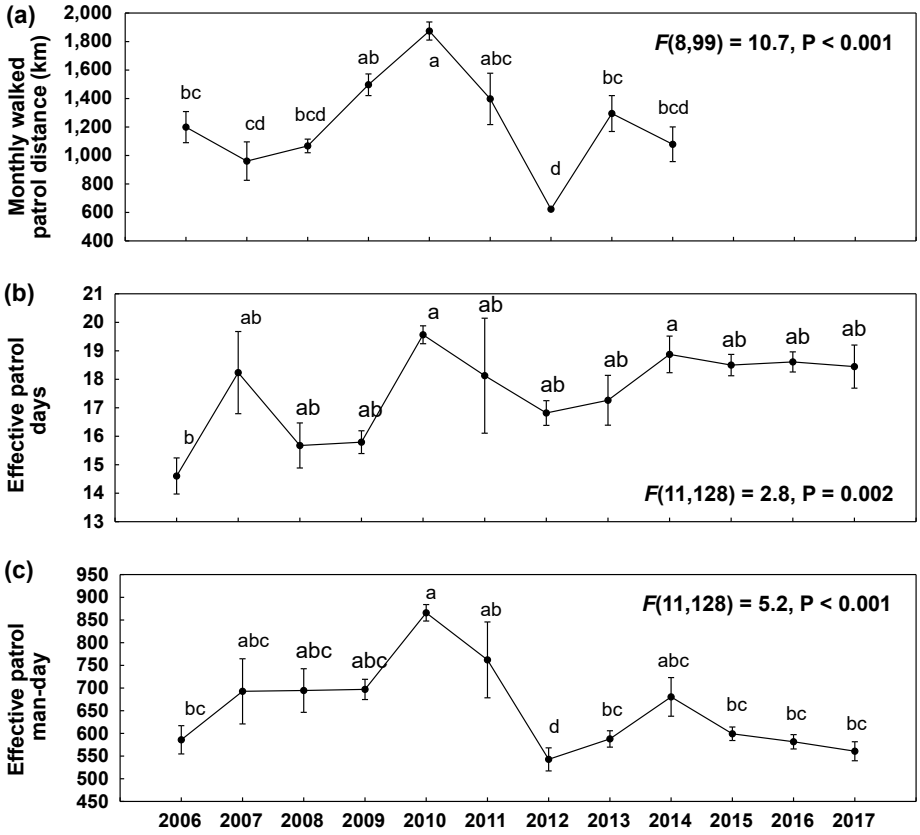

FIG. 2 Patrol staff performance in the Kogyae Strict Nature Reserve, Ghana (Fig. 2), during 2006–2017 measured as (a) mean monthly patrol distance walked, (b) mean monthly effective patrol days, and (c) mean monthly effective patrol man-days. Bars indicate SE. Different letters for years indicate significant differences at P = 0.05, detected with Tukey HSD post hoc tests.

The dynamics of patrol staff performance differed significantly among years but there was no obvious trend (Fig. 2). Performance in 2006 was similar to the levels measured after 2014 in all three parameters, with peaks in 2010 (Fig. 2).

Differences in the monthly distance walked by patrols (Fig. 3a) and effective patrol days (Fig. 3b) were not significant. Effective patrol man-days were, however, significantly different, with a peak in March and a low in October (Fig. 3c), and higher in the dry (686 ± SE 18 patrol man-days) than in the wet season (628 ± SE 21 patrol man-days Fig. 3c).

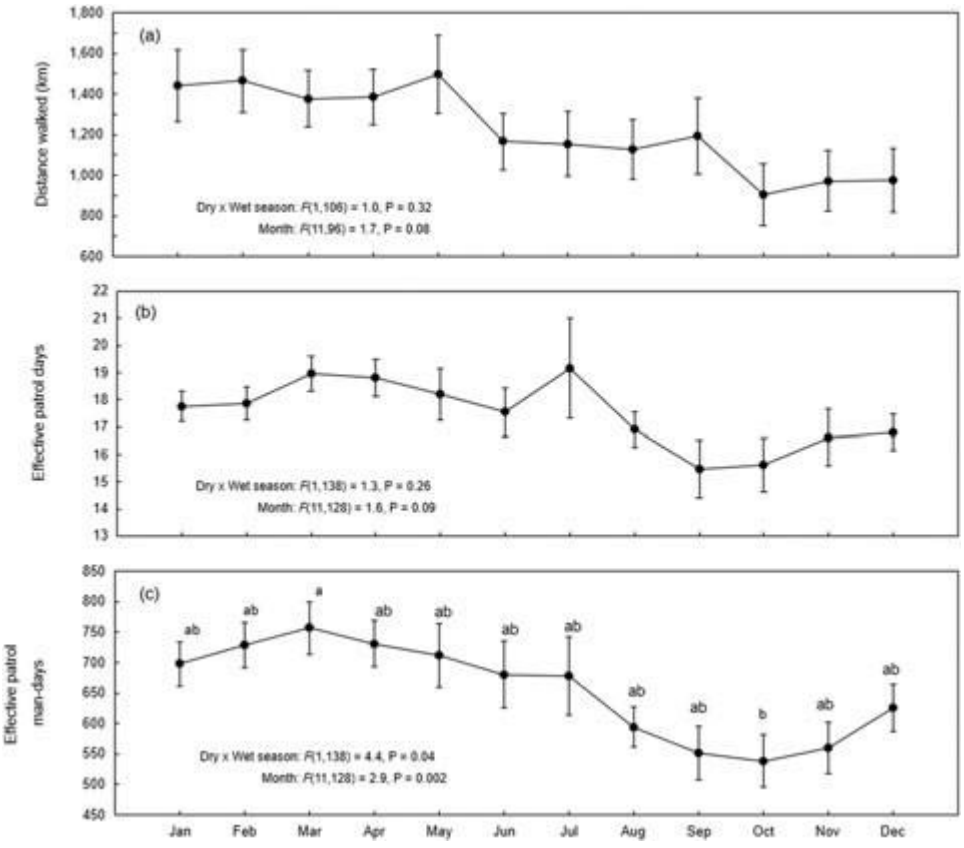

FIG. 3 Monthly patrol staff performance in the Kogyae Strict Nature Reserve, Ghana measured as (a) mean patrol distance walked, (b) mean effective patrol days, and (c) mean effective patrol man-days. Bars indicate SE. Different letters indicate significant differences at P = 0.05, detected with Tukey HSD post hoc tests. The dry season is November–March and the wet season April–October.

Illegal activities

There were differences in the mean encounter rates of illegal activities during 2006–2017 (F (6, 947) =52.5, P < 0.001). The highest encounter rate was with snares, followed by gunshots heard. The lowest indices were confiscated firearms and poachers arrested (Table 1).

There were annual increases in illegal activities encountered (comprising principally numbers of snares found, poachers observed, and gunshots heard) following the implementation of ranger-based monitoring in 2004, to a peak catch per unit effort in 2009 (×Fig. 4). Illegal activities then fell and remained relatively constant during 2012–2017. There was no significant variation in catch per unit effort of illegal activities between months (Fig. 5).

Encounter rates of illegal activities decreased with increased effective patrol days (r^2 = 0.05, P = 0.008). Similarly, the encounter rates with illegal activities showed a significantly negative relationship with the increasing number of inhabitants in the district where Kogyae Strict Nature Reserve is located (r^2 = 0.1, P < 0.001).

Discussion

Patrol staff performance

The performance of patrol staff in Kogyae was lowest in 2006, most likely because the patrol-based monitoring system was then in the early phase of its implementation. Analysis of staff performance in the first 2 years (2005-2006) after the implementation of the patrol-based monitoring system in nine protected areas in Ghana, Jachmann (2008a) revealed the performance of staff in Kogyae varied between 3.8–16.3 effective patrol days, relatively similar to that of Ankasa Conservation Area (3.4–14.8 effective patrol days). According to this study, patrol staff performance in Kogyae improved by c. 35% in 2007 (Fig. 2b), and was highest in 2010, primarily a result of motivation of rangers through external support from the Royal Netherlands Embassy in Accra in the form of food rations (J. Osei-Mensah, pers. comm. 2018). The findings and comparisons of Jachmann's analysis (2008a) aroused the interest of the management of the Ghanaian Wildlife Division in the patrol system, and motivations were offered across protected areas in Ghana (Jachmann, 2008a).

TABLE 1 Mean ± SE catch per unit effort and kilometric index of abundance of illegal activities encountered in the Kogyae Strict Nature Reserve during 2006–2017.

Illegal activity	Mean ± SE catch per unit effort[1]	Mean ± SE kilometric index of abundance ×100[2]
Poachers arrested	$0.0011^{a} \pm 0.0002$	0.063 ± 0.011
Poachers observed	$0.0037^{b} \pm 0.0005$	0.226 ± 0.033
Poachers' camps found	$0.0017^{ab} \pm 0.0002$	0.113 ± 0.012
Gunshots heard	$0.0080^{c} \pm 0.0007$	0.454 ± 0.049
Firearms confiscated	$0.0011^{a} \pm 0.0002$	0.057 ± 0.013
Snares found	$0.0113^{d} \pm 0.0013$	0.698 ± 0.088
Animals found killed	$0.0015^{ab} \pm 0.0002$	0.092 ± 0.014
Cartridges confiscated	$0.0025^{ab} \pm 0.0008$	0.171 ± 0.071

[1]Using Tukey HSD post hoc tests, mean values with difference letters indicate significant difference (at P = 0.05) among the encounters of illegal activities from 2006-2017.
[2]Number of observations per 100 km.

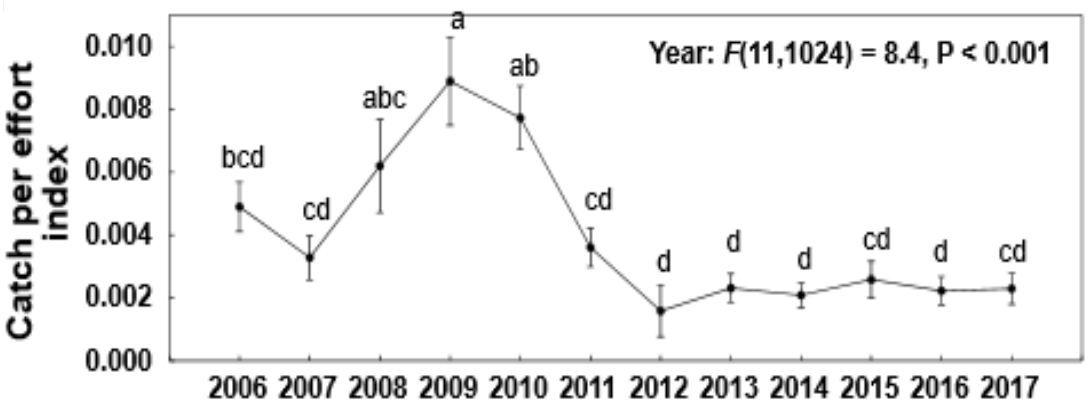

FIG. 4 Inter-annual trend trends of encounter rates (± SE) with illegal activities per monthly effective patrol man-days in the Kogyae Strict Nature Reserve during 2006–2017. Different letters for months indicate significant differences (P = 0.05) detected by Tukey (HSD) post hoc tests

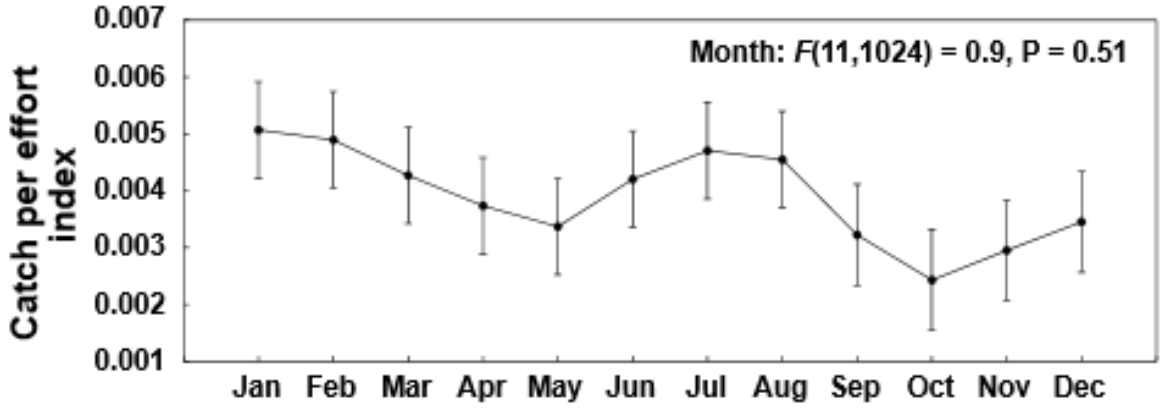

FIG. 5 Mean encounter rates (± SE) of illegal activities from January to December in the Kogyae Strict Nature Reserve (Fig. 1) across all years (2006–2017).

The reasons for the decline in staff performance after 2011 were threefold. Firstly, in 2011 and 2012 a number of the patrol staff retired, and there was a delay in the recruitment of new staff. Secondly, long patrols mostly accounted for the high performance of patrol staff, and for each such patrol, the Reserve vehicle transported patrol staff and equipment to the locations where patrols began. However, the vehicle was stolen in 2012, and thereafter patrol staff resorted to long patrols on foot, which is time- and energy-consuming, especially when moving between the base and the locations where patrols started and finished. Thirdly, the tents required for long patrols were damaged, and replacements were not provided. All these factors caused patrol staff to resort to day or night patrols only. Provision of equipment is particularly crucial given the dangerous nature of the work, with poachers sometimes resisting arrest violently, and in some cases injuring or even killing patrol staff (in Kyabobo National Park: Frimpong, 2013; in Mole National Park: Daily Graphic, 2018). Poachers have killed or assaulted patrol staff in Lobéké National Park, Cameroon

(Mathiesen, 2016), Maswa Game Reserve, Tanzania (BBC News, 2016), and Savé Valley Conservancy, Zimbabwe (Lindsey et al., 2011).

Unofficial reports suggest patrol staff performance decreases during the wet season in Ghana because the patrol staff tends to their farms during this season, to supplement their income (Wiafe & Amoah, 2012). However, we did not record any significant difference in the performance of staff between the dry and wet seasons, similar to the report by Wiafe & Amoah (2012) for the Kakum Conservation Area in Ghana. However, during the months of the peak wet season, patrol staff performance was slightly but not significantly lower compared to the dry season (Fig. 3). This was probably because of intensive rainfall, which makes movement and sightings difficult, and because there was no logistical support specific for rainy weather.

Changes in the encounters of illegal activities

In 2008 and 2009 patrol staff performance slightly decreased, though not significantly, in comparison with that of 2007 (Fig. 2), but an increase was observed in encounter rates with illegal activities (Fig. 4a). This could have been the result of patrol staff concentrating their operations in areas where there was a high probability of encountering illegal activity, especially in the Special-use zone. Although patrol staff effort was greatest in 2010 there was a lower encounter rate of illegal activities compared to the highest encounter rates in 2009. Poachers may have adjusted their behaviour (Montgomery & Blalock, 2010) or ceased to operate upon noticing the increase in regular patrols, decreasing the likelihood of illegal activities being detected. During 2011–2017, when patrol staff performance stabilized (Fig. 2), the detection of illegal activities remained low (Fig. 4). This could be attributed to patrol staff learning and gaining experience in adapting their patrol strategies to achieve patrol objectives, as suggested by the park manager (J. Osei-Mensah, pers. comm., 2018). Another possible explanation is that poachers changed their behaviour, leading to a decrease in the rate of detection by patrols even in high-risk areas (as reported by Abbot & Mace, 1999), and/or changed their poaching techniques.

The most frequently recorded illegal activity in Kogyae was the use of snares, as in other protected areas in Ghana (Wiafe, 2018) and elsewhere (Queen Elizabeth Conservation Area, Uganda: Critchlow et al., 2015; Serengeti National Park, Tanzania: Hurt & Ravn, 2000; Nyahongo et al., 2005; Holmern et al., 2007). As the use of snares is silent, poachers using them are less likely to be detected than poachers using firearms, and placing more snares maximizes the probability of hunting success. Animals found dead during patrols had mostly been caught in snares, similar to reports from other countries (e.g., Zambia: Becker et al., 2013), or died of infections from injuries suffered as a result of trying to escape from snares. The apparent preference for snares by poachers in Kogyae suggests that snaring may lead to a lower arrest rate because the time spent hunting is reduced (Table 1). This change in poaching method from firearms to snares was indicated by the changes in the encounter rates of poachers observed, which was notably high in 2008 and 2009 (Fig. 5). After 2009, a decline was observed in the direct encounters and in the numbers of poacher camps found in the Reserve, gunshots heard, and firearms confiscated. ‘Cartridges found’ was included as a new category of illegal activity in Kogyae in 2013 but was not frequently encountered by patrol teams.

The weak relationship between the encounters with illegal activities and the number of people in the district where Kogyae is located contrasts with the general findings of increasing pressures on ecosystems coupled with increasing population (e.g., Veldhuis et al., 2019). The weakness of this relationship in Kogyae might be a consequence of the implementation of regular and active

patrols specifically in the Reserve because many inhabitants of the local communities, upon noticing these patrols, avoided entry into the Reserve (J. Osei-Mensah, pers. comm., 2018). However, data on encounters of illegal activities are directly related to the killing of animals, whereas other human activities, such as conversion of habitat for agricultural purposes or grazing of livestock within the Reserve, were not covered in the ranger-based patrol monitoring system. Including these aspects as illegal activities could render the monitoring and evaluation both difficult and controversial as agricultural land use is part of the livelihoods of people inhabiting theSpecial-use Zone. Considering that the majority of the population is involved in agricultural production, the effects of these activities on wildlife and their habitats throughout the Reserve require further study.

Long-term assessment of law enforcement in protected areas provides stakeholders with information on patrol staff performance over time and on illegal activities related to wildlife. Our findings indicate that patrol staff performance in Kogyae Strict Nature Reserve was partly dependent on logistical support, such as the provision of GPS units, tents, motorbikes, bicycles, and other equipment. It means that patrol staff performance depends on the budget allocated by the government to protected areas or on external funding to support conservation. Improvements in provision of equipment would serve not only as an incentive for working in uncomfortable conditions but would also help rangers to feel their work is valued. To improve law enforcement and conservation in Kogyae, we also recommend training for rangers in the use of monitoring tools based on spatial information and the implementation of law enforcement allocation methods that allow prediction of illegal activities and targeting of conservation priorities. Spatial crime mapping approaches such as the Management Information SysTem (MIST, 2021) and the Spatial Monitoring and Reporting Tool (SMART, 2021) have proven to be effective in resource-limited settings (e.g., Critchlow et al., 2017), but this approach has not been used in Kogyae. These spatial-temporal approaches, which link the occupancy of large mammals to habitats and to human-related factors, would enable decision-makers to act more efficiently for successful conservation.

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Author contributions Conceptualization, design: JOA, MOA; data collection, analysis, interpretation: all authors; writing, revision: JOA, MOA, PH.

Conflicts of interest None.

Ethical standards Research approval and permits were granted by the Wildlife Division of the Forestry Commission of Ghana (permit number WD/A.30/VOL. 11/28). This research abided by the Oryx guidelines on ethical standards.

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CHAPTER FOUR

4. USE OF LOCAL ECOLOGICAL KNOWLEDGE TO DETECT DECLINES IN MAMMAL ABUNDANCE IN KOGYAE STRICT NATURE RESERVE, GHANA

Section of local community members in the Kogyae Strict Nature Reserve (Photo by Afriyie Jerry)

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Use of Local Ecological Knowledge to Detect Declines in Mammal Abundance in Kogyae Strict Nature Reserve, Ghana

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Abstract

The scarcity of environmental data means that other sources of information are needed to complement empirical evidence for conservation decisions. We, therefore, aimed to explore Local Ecological Knowledge (LEK) on mammal abundance and qualitative population trends through interviews from 331 local people in and around Kogyae Strict Nature Reserve, Ghana. The results show that 62% of the respondents perceived that mammal abundances had decreased, 31% perceived stability, and 8% perceived that mammal had increased between 2006 and 2017. The respondents attributed the decline to habitat degradation and illegal hunting. The knowledge of local people about mammal population trends is consistent with reported mammal encounters by law enforcement rangers. However, the length of residence, location of communities, and cardinal direction of communities influenced local peoples' knowledge of mammal abundance and population trends. Our results highlight the ability of LEK to provide reliable ecological information on animal abundance and qualitative population trends. Integrating LEK into monitoring and management is appealing because it can be cost-effective, enhance community participation, and provide novel insights into sustainable resource use.

Keywords Conservation ● Kogyae strict nature reserve ● Law enforcement ● Local ecological knowledge

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Introduction

The decrease in biodiversity is of prime concern to the international community (Dıaz et al. 2006; Cardinale et al. 2012). Research in African Protected Areas has indicated that habitat loss and degradation, illegal hunting, diseases, and drought caused a decline in mammal populations (Topp-Jørgensen et al. 2009; Craigie et al. 2010; Joppa et al. 2010; Okello and Kioko 2010; Scholte 2011). The knowledge of the distribution and abundance of species in protected areas is essential in ecology and conservation. These provide valuable information on the status of biodiversity (Collen et al. 2009) and allow management interventions to be developed and evaluated (Wintle et al. 2010; Jones et al. 2013). However, estimating the distribution and abundance of species is exceedingly time consuming and requires substantial funding and is sometimes impossible because of these and other factors.

Conducting rapid conventional research over large areas to ascertain the causes of wildlife population decrease may be difficult. Thus, Local Ecological Knowledge (LEK) can provide valuable insights for researchers, managers, and policymakers (Sillitoe 1998; Huntington 2000; Balram et al. 2004; Stave et al. 2007; Brook et al. 2006; Halme and Bodmer 2007). Local and indigenous ecological knowledge are continuous understandings, beliefs, and practices that human develop in relationship with their natural environment, developing with social and environmental changes (Berkes et al. 2000; von Glasenapp and Thornton 2011).

In many developing tropical countries, where species diversity is high and limited resources, scientific information on wild animal abundance and monitoring are scarce (Silvestre and Pauly 1997). The knowledge of local people in such settings may provide useful biological information for conservation efforts (Huntington 2000; Folke 2004). Using the knowledge of local people can provide information on the qualitative abundance of species (e.g., Leedy 1949; Zimmerer 1991; Vaughan et al. 2003; Moller et al. 2004; Gilchrist et al. 2005), qualitative population trends (Gandiwa 2012), and quantitative animal distribution and abundance (Lozano-Montes et al. 2008; Anadón et al. 2009). It is, therefore, important to rely on the knowledge of the local communities (Berkes and Folke 1998) to know the trends in wild animal populations. Incorporating LEK into protected area resource management (Moller et al. 2004) and monitoring will improve community involvement in conservation (Ban et al. 2009) and also provide different insights into sustainable resource use (Berkes and Folke 1998). The acquisition of LEK is dynamic and modified continuously thus, variations in LEK arise from differences in people's experience in the environment (Verweij et al. 2010). In addition, the process of identifying people to be included in LEK studies is inconsistent (Davis & Wagner 2003; Davis & Ruddle 2010; Hitomi and Loring 2018). For example, some studies suggest using stratified sampling for respondents' socio-demographic characteristics such as age, length of residence, educational level, and occupation (Bundy & Davis 2013; Cook et al. 2014). However, Hitomi and Loring (2018) also reported the need to include all these characteristics in the sample because they are important sources of knowledge. Many factors can influence how local people perceive their environment (Loring et al. 2014). For instance, local people's perceptions of animal abundance can vary among individuals of different ages or gender (Quinlan and Quinlan 2007; Gómez-Baggethun et al. 2010; Law et al. 2010). It is, therefore, imperative to seek knowledge from local people with different backgrounds, characteristics, and sectors to provide a complete overview of animal abundance and population trends than any single source.

In most ecological studies in Africa, emphasis on understanding local people's knowledge and perceptions focus on the conflicts between people and protected areas, such as strict restrictions to protected areas resource use and human-wildlife conflict (Hariohay and Røskaft 2015; Acquah

et al. 2017; Hariohaya et al. 2018). Therefore, it is essential from a scientific and conservationist perspective to understand local peoples' knowledge and perceptions to achieve conservation goals. An underlying assumption is that local people have in depth knowledge about their immediate environment and that this knowledge is relevant to science and conservation. For example, LEK gathered about the common eider duck (*Somateria mollissima sedentaria*) in Canada brought attention to a massive die-off that had gone unnoticed by the scientific community in the early 1990s (Gilchrist et al. 2005). Moreover, in using the LEK in remote villages in Myanmar, Platt et al. (2013, 2015) found evidence for numerous rare chelonian and reptile species, while also documenting new regional records.

Unfortunately, few studies have directly analyzed animal species abundances and trends using LEK (e.g., Nyhus et al. 2003; Moller et al. 2009; Anadón et al. 2010; Ceríaco et al. 2011; Maynou et al. 2011; Gandiwa 2012). We, therefore, examined the LEK held by local community members living in and around the Kogyae Strict Nature Reserve, Ghana, concerning wild mammal species abundance and population trends. Our objectives were to, (1) determine local people's knowledge and perception of mammal abundance and population trends (sighting frequency and trend assessments) (2) determine the reasons and or explanations for perceived mammal abundance and population trends (3) establish the factors associated with LEK on mammal abundance and population trends. We then evaluated the information obtained from LEK by comparing it with mammal observation data derived from law enforcement rangers between 2006 and 2017. In particular, we explored the ability of LEK to detect population trends and, thus, it's potential as a tool in monitoring programs.

Material and Methods

Study Area

The Kogyae Strict Nature Reserve (7°08'N to 7°21'N, 0° 59'W to 1°14'W; Fig. 1) is located in the Afram Plains region of Ghana and covers an area of 386 km2. It is a flat area with an average altitude of 120 m a.s.l., with several higher areas reaching up to 215 and 230 m a.s.l. These areas serve as the watershed for a network of streams dominated by tributaries of the Afram and Sene rivers, most of which cease to flow above ground in the dry season (Hagan 1998). The climate is the dry (from November to March) and wet (from May to October) season, with annual rainfall ranging between 1200 and 1300 mm. Kogyae lies in the transitional zone between the transitional woodland (semi-deciduous forest) and the Guinea savannah woodland and open grasslands of Ghana (Wildlife Department 1994). The reserve supports primate, ungulates, and bird species. As Kogyae is unfenced, animals move freely in and out of the park boundaries to the adjacent communal areas.

In 1952, the colonial Gold Coast government gazetted the site as the Kujani Bush Forest Reserve under the administration of the Forestry Department. However, in 1971, the reserve was designated as a Strict Nature Reserve under the Wildlife Reservation Regulations L.I. 710 of 1971 under the then Game and Wildlife Department by expanding the Kujani Bush Forest Reserve boundaries southwards (Oduro-Ofori et al. 2015). The expansion was to obtain a viable ecological unit for the Kogyae Strict Nature Reserve. Studies conducted by the Wildlife Division indicated that in the dry season, animals from the park depended on the rivers in the unprotected areas for survival (Ayivor and Ntiamoa-Baidu 2015). The expansion also included some communities,

namely, Asasebonso, Atakpame, Nyamekyere Dagomba, Birem, Yahayakura, Aberewanko, and Konkomba. Additionally, Aframso, Birem, Chichibon, and Kyeiase are now on the immediate border of the reserve (Ayivor and Ntiamoa-Baidu 2015; Fig. 1). Local communities are predominantly farmers, with up to 75% of the people in the area working in the agriculture sector (Ministry of Finance 2015). Farming practices involve a slash and burn method of land clearing and cultivation of a variety of crops, e.g., yam (*Dioscorea spp*), maize (*Zea mays*), paddy rice (*Oryza sativa*), groundnuts (*Arachis hypogaea*), cassava (*Manihot esculenta*), cowpeas (*Vigna unguiculate*), and vegetables. Approximately 15% and 10% of the population work in the industry and service sectors, respectively, and have a growth rate of 1.4% per year (Ministry of Finance 2015).

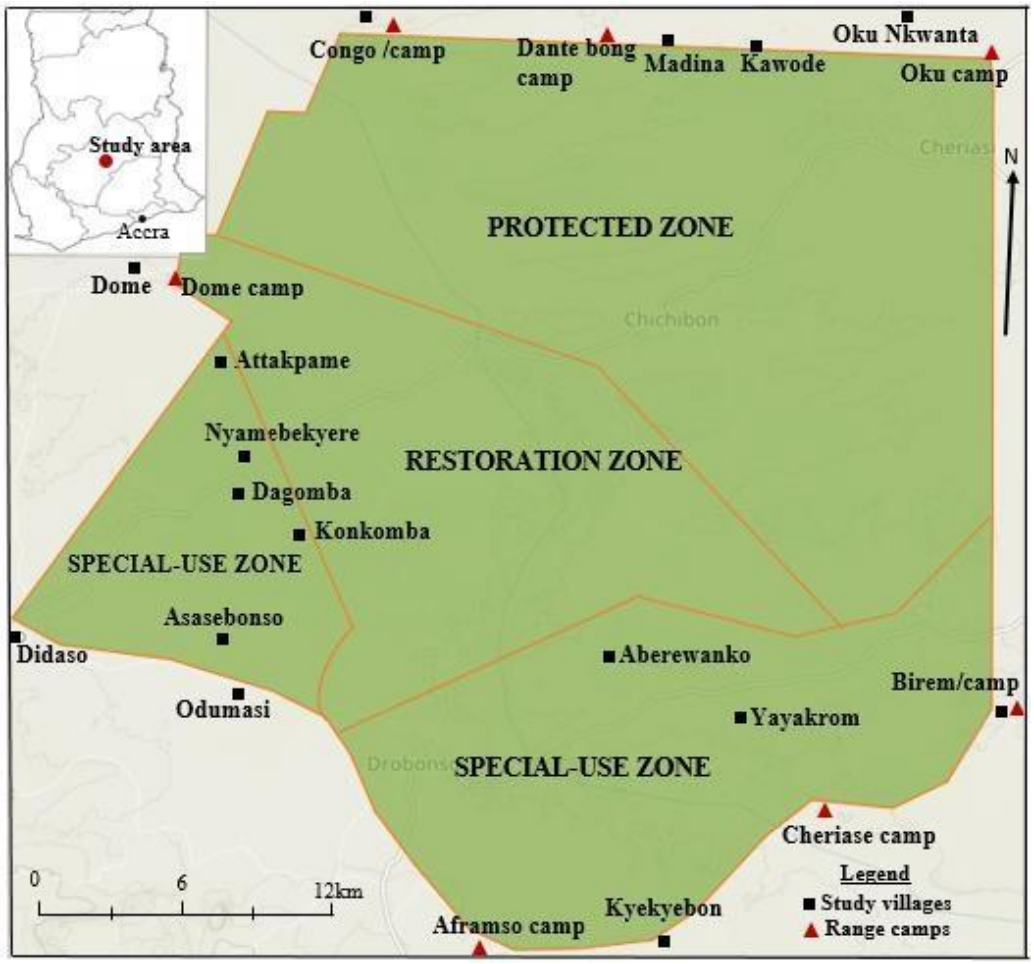

Fig 1 Map of Kogyae Strict Nature Reserve showing the location of study communities and Range camps.

Kogyae is divided into four management zones: The Protected Zone, Special-use Zone, Restoration Zone, and Development Zone. The Protected Zone is the largest in Kogyae; it constitutes 220 km^2 and represents 57% of the protected area. This area of the reserve represents the most important and least disturbed habitat and is fully dedicated to conservation. Human settlements activities such as farming,

logging, and charcoal production have severely degraded the restoration zone. It constitutes 86 km^2, representing thus 22% of Kogyae. The Special-use Zone is an area where some farming activities of local inhabitants are allowed but no hunting and timber logging. It has a size of 79 km^2 and represents 20% of the protected area. The Development Zone has been set aside for staff accommodation, administration facilities (headquarters), the mini-research station, and a center for conservation education. It constitutes 1 km^2, i.e., 1% of the reserve area.

Data Collection

To answer our research questions, we made use of unique household survey data collected from local communities residing in and around Kogyae. The questionnaire survey formed part of a broad study on the knowledge, attitudes, and perception of local communities towards wildlife and protected areas. We collected data in August and September 2018, which consisted of face-to-face interviews. We selected all villages located in Kogyae (Asasebonso, Atakpame, Nyamekyere, Dagomba, Yahayakura, Aberewanko, and Konkomba). We also randomly selected 12 communities/ villages out of the 18 located ≤ 5 km outside Kogyae (Berem, Odumasi, Didaso, Aframso, Cheriase, Dome, Madina, Oku Nkwanta, Congo Nkwanta, Madina, Kyekyebon, and Kawode; Fig. 1). For good coverage, we visually divided each community into four quadrants and opportunistically (conveniently) selected household head or an adult family member of ≥18 years based on presence/ absence in each household. In this study, we used the terms "local community" and "local people" as synonyms, when referring to the people living in small villages (i.e., clusters of houses) in the rural area of the visited villages.

The total population size of selected communities was ~6500 (Ghana Statistical service 2014). We set our confidence level at 95% and precision (margin of error) at 5% by using the sample size calculator Raosoft (http://www.ra osoft.com/samplesize.html) and obtained a sample of 363. The number of respondents in each community in Kogyae ranged from 15 to 30. Of the 363 respondents, 32 (19 women and 13 men) withdrew from the interview. These were removed from the analysis, producing a final sample size of 331 households. We began all our interviews in the form of informal conversation with the respondents, to gain their trust first, and then we ask about their knowledge of local wildlife. We explained that all interviews were anonymous and confidential and that they would not be at any risk in answering the questions. We used a semi-structured interview questionnaire consisting of closed and open-ended questions (Hariohaya et al. 2018). We constructed the questions to gather information on the socioeconomic and demographic characteristics, local knowledge and perceptions of the sighting frequency, and the trend assessment of mammals. In the sighting frequency assessment, respondents were asked to indicate whether they see wild mammals "every day", ''once in 14 days", ''once in 30 days", ''once in 1–3 months", ''once in 3–6 months", and ''once in a year". Also, respondents were asked to indicate whether the mammal population was increasing, decreasing, or remained the same (see Supplementary Material for questionnaires). We obtained the list of all mammal species from the Wildlife Division Office in Kogyae. Where respondents could not recall the local or common name for a particular species, we showed them their pictures for easy identification. We obtained most of the pictures from Law enforcement rangers and a few from the internet. The questionnaires were translated from English to Twi by the authors of this article, and four undergraduate students hired and trained to assist in the data collection. We pre-tested the questionnaires by interviewing five

persons each in Dagomba and Birem community in early August 2018 to ensure that questions were clear. All interviews lasted between 30 and 65 min.

We thoroughly explained the purpose of the research to the respondents and their willingness to participate enquired (Kothari 2004) after appropriate permission from village heads. In all the 18 villages, the research team also had more informal discussions with the village heads/leaders about the contents of the questionnaires to gain additional qualitative information that could support the questionnaire data. We used tape recorders to record all the discussions with the full consent of the respondents.

Patrol Operations Management

Kogyae uses conventional law enforcement in the form of foot patrols that frequently range out from the headquarters and seven camps established in seven communities at the peripheries of Kogyae. Day patrols are done between dawn and dusk, night patrols between dusk and dawn, while long patrols have a minimum duration of 24 h, and combine daytime and night-time patrols. Ambush patrols remain in one particular location, often near a frequently used poaching trail, but sometimes as a response to intelligence information. On ambush patrols, the rangers do not record wildlife encounters. A grid map used indicate patrol routes and the location of each encounter. Patrol routes are transects with unfixed width where the ranger in charge of a particular range used them for spatial planning, thereby ensuring that the entire range was covered at least once a month (Jachmann 2008). Because patrol movements should be unpredictable by nature, rangers were trained to randomize patrol movements as much as possible, first to optimize the impact of law enforcement, and second to enable statistical inference from monitoring data. Rangers record the number of staff on patrol, the exact duration, the total distance traveled, types, quantity, and locations of illegal activity, and the species and number of mammals encountered on standardized forms. All encounters with mammals of a similar size or larger than Maxwell's duiker (*C. maxwelli*) was recorded (5–10 kg). Mammals encountered by the patrol team included 12 ungulates and six primate species from 2006 to 2017 (Table 2). We divided ungulates into large (seven species) and small (five species) for our analysis. To compare the collected LEK on mammal population trends, data on law enforcement patrols, which occurred during 2006–2017, were extracted from monthly reports of patrol missions conducted by the rangers of the Kogyae Strict Nature Reserve.

Data Analysis

For multiple responses on an open-response question, we presented data as the percentage of the respondents giving each response and may sum to over 100%. We used Mann-Whitney Test to analyze whether responses on the frequency of sighting mammals and trend assessments differed among the location of communities (inside and outside). We also used the Kruskal–Wallis H test to analyze whether responses on the frequency of sighting mammals and trend assessments differed among respondents from the different cardinal directions of the park (North, West, East, and South). We coded respondents' responses on the frequency of sighting mammals as: "everyday", 1, "once in 14 days", 2, "once in 30 days", 3, "once in 1–3 months", 4, "once in 3–6 months", 5, and "once a year", 6. For the trend assessment, we represented "increase" as 3, "same" as 2, and "decrease" as 1. To determine the relationship between respondents' socio-demographic characteristics and their knowledge and perceptions of mammal frequency and trend assessments,

we used the ordinal logistic regression model. The independent variables used in the model were gender, age, length of residence (Bragagnolo et al. 2016; Sobral et al. 2017), location, and cardinal direction of communities. We conducted all statistical analyses using SPSS version 25 (Chicago, USA). We considered all statistical tests significant at $p \leq 0.05$.

We used catch per unit effort index (C/E) (Bell 1985; Jachmann 2008) to measure the level of encounter rates with mammals per given period. Catch refers to the total number of monthly encounters with mammals, and the Effort is the total number of effective patrol man-days per month. For each patrol, independent of its duration, the number of patrol hours was divided by eight, and multiplied by patrol size to give effective patrol man-days (effective patrol man-days = ((duration of patrol (hours)/8) × patrol size (no. staff)). To examine the encounter rates with mammals, we first tested the differences in encounter rates with the individual species under the three groups of mammals (large ungulates, small ungulates, and primates) by the Generalized Linear Models using the catch per unit effort index as tested dependent variable, and year, and species, as independent predictors. To determine the relationship among the trends in encounters of individual species over the years we used Pearson correlation using STATISTICA package 13.4 (TIBCO Software Inc., USA).

Results

Socio-economic and Demographic Characteristics of Respondents

Of the 331 respondents, 52.9% (n = 175) were males and 47.1% (n = 156) females (Table 1). The mean age of respondents was 45.3 ± 12.7 (± indicate standard deviation, SD). One hundred (n = 30%) of the respondents had not received formal education, 32% (n = 107) had primary education, 2% (n = 87) had received junior secondary education. Twenty-five (8%) of the respondents had attained a senior secondary certificate while 4% (n = 12) had received tertiary education. Almost half of the respondents (49%) were farmers, 15% were charcoal producers/ sellers, and 10% involved in the livestock business. The mean number of years of residence of respondents in the communities were 17.2 ± 10.94 (±SD) Over half (54%) of the respondents lived outside Kogyae, while 46% (n = 153) lived inside the park. Of the total respondents, 20% (n = 67) lived in communities in the northern part of the park, 38% (n = 127) lived in the west, 10% (n = 32) lived in the east while 32% (n = 105) lived in the southern part of the park.

Knowledge and Perceptions of Mammal Sighting Frequency and Trend Assessments

About 10% (n = 35) of the respondents reported that they sighted wild mammals daily, 28% (n = 91) reported sighting wild animals once in every 2 weeks, 25% (n = 82) reported sighting wild mammals at least once within a month, 28% (n = 94) reported sighting wild mammals once between 1 and 3 months, 89% (n = 28) reported sighting wild mammals once between 3 and 6 months, and only one person reported sighting wild mammals once a year in their villages and/or communities. However, the frequency of sighting wild mammals differed among communities inside and outside the park (U = 11027; p = 0.002). Also, the knowledge of respondents on the frequency of sighting mammals differed among respondents who lived in the Northern, Western, Eastern, and Southern parts of the park (K–W test: H (3) = 87,993; $p < 0.001$). About two-thirds (n = 204) of the

respondents perceived that mammal abundances had decreased; slightly less than a third (n =102) perceived that mammal abundances and population trends were stable, and the remainder (n = 21) perceived that mammal abundances had increased between 2006 and 2017 in Kogyae. There was also a significant difference in the knowledge of local people about mammal abundance among those living inside and outside the park (U = 9974; $p < 0.001$). Further, we recorded significant differences among respondents living in the four cardinal directions of the park (K-W test: H (3) = 64,272; $p < 0.001$). Mammals perceived to have decreased included buffalo, red-flanked duiker, waterbuck, red river hog, black duiker, warthog, Oribi, Bay duiker, Mona monkey, Green monkey (Table 2).

Table 1 Socio demographic characteristics of respondents

Categories	Frequency	Percentage
Gender		
Male	175	53
Female	156	47
Age		
18–25	15	5
26–35	67	20
36–45	86	26
46–55	94	28
56 and above	69	21
Education		
No education	100	30
Primary education	107	32
Junior secondary	87	26
Senior Secondary	25	8
Tertiary	12	4
Occupation		
Farming	162	49
Livestock keeping	33	10
Charcoal production/selling	50	15
Hunting	28	8
Employment/business	40	12
Unemployed	18	5
Length of residence		
1–5	39	12
6–10	66	20
> 10	226	68
Location of community		
Inside	153	46
Outside	178	54
Cardinal direction of community		
North	67	20
West	127	38
East	32	10
South	105	32

Table 2 Comparing local community knowledge and perceptions of mammal trends and encounter data from law enforcement officials in the Kogyae Strict Nature Reserve

Mammal group	Scientific Names	Number of respondents	Percentage (%)	Perceived status	Status from Rangers law enforcement data
Large ungulates					
Buffalo	*Syncerus caffer*	318	96	Decreasing	Decreasing
Warthog	*Phacochoerus africanus*	294	89	Decreasing	Decreasing
Red river hog	*Potamochoerus porcus*	196	59	Decreasing	Decreasing
Waterbuck	*Kobus ellipsiprymnus*	173	52	Decreasing	Decreasing
Kobs	*Kobus kob*	177	54	Increasing	Decreasing
Bushbuck	*Tragelaphus scriptus*	136	41	Increasing	Decreasing
Hartebeest	Alcelaphus buselaphus	-	-	Not identified	Locally rare
Small ungulates					
Red-flanked duiker	*Cephalophus rufilatus*	308	93	Decreasing	Decreasing
Black duiker	*Cephalophus niger*	302	91	Decreasing	Decreasing
Bay duiker	*Cephalophus dorsalis*	116	35	Decreasing	Decreasing
Oribi	*Ourebia ourebi*	230	70	Decreasing	Decreasing
Maxwell's duiker	*Philantomba maxwellii*	92	28	Increasing	Decreasing
Primates					
Spot nose monkey		-	-	Not identified	Locally rare
Mona monkey	*Cercopithecus mona*	203	61	Decreasing	Relatively stable
Green monkey	*Chlorocebuss abaeus*	216	65	Decreasing	Decreasing
Black-white-colobus	*Colobus polykomos*	-	-	Not identified	Locally rare
Baboon	*Papio anubis*	255	77	Increasing	Decreasing
Patas monkey	*Erythrocebus patas*	201	61	Increasing	Increasing

Total percentage exceeds 100 because the respondents were allowed to give multiple answers

Reasons for the Perceived Status of Mammal Abundance and Population Trends

Respondents (R) referred to various reasons why mammal abundance and population decreased or increased. They highlighted the reasons for the decrease to include habitat degradation, illegal hunting, lack of available watering points, and diseases; for example, R143 described the effects of illegal hunting on some mammals because ‘the numbers of ‘’Adowa” (most duikers) have reduced due to illegal hunting. R018 expressed how ‘burning of the land for farms every year has

destroyed the habitat leading to the reduced numbers of most animals (mammals) in the park'. R057 also reported that because of 'the lack of watering points in the park, I see so many animals gathered at one river mostly at dawn for water, so I think hunters target animals in these areas. This was reiterated to us by other respondents (20 of them) who stated that most animals died in the past especially, during the dry season when there is a prolonged drought. Further, R103 indicated that 'at first we used to see some animals lying dead in the reserve or sometimes close to our community without any sign of being caught by a trap (snare) or other forms of hunting activities and I believe they died of diseases'.

Conversely, baboon, patas monkey, kobs, bushbuck, and Maxwell's duiker were perceived to have increased in abundance, attributed to improved law enforcement and less disease occurrence. For example, R238 stated that 'I know that improved work by park staff (law enforcement rangers) have made most of us afraid to enter especially that area (protected zone) otherwise, eh? I will be arrested, and nobody will help me'.

Table 3 Socio-economic and demographic factors associated with the frequency of sighting mammals in the Kogyae Strict Nature Reserve

Predictors	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval		
						Lower Bound	Odds	Upper Bound
[Gender= Male]	−0.028	0.205	0.019	1	0.890	−0.430	0.972	0.373
[Gender= Female]	0[a]			0			1	
[Age = 18–25]	1.042	0.541	3.709	1	0.061	−0.018	2.834	2.102
[Age = 26–35]	0.233	0.315	0.544	1	0.461	−0.386	1.262	0.851
[Age = 36–45]	0.438	0.300	2.129	1	0.145	−0.150	1.550	1.026
[Age = 45–55]	0.505	0.292	2.989	1	0.084	−0.068	1.658	1.078
[Age = > 55]	0[a]			0			1	
[Length of residence = 1–5]	−0.018	0.327	0.003	1	0.957	−0.659	0.982	0.624
[Length of residence = 6–10]	−0.159	0.267	0.355	1	0.551	−0.683	0.853	0.365
Length of residence = > 10]	0[a]			0			1	
[Location of community = Inside]	−0.995	0.298	11.134	1	**0.001**	−1.580	0.370	−0.411
[Location of community = Outside]	0[a]			0			1	
[Cardinal direction = North]	−3.488	0.371	88.324	1	**0.000**	−4.215	0.031	−2.760
[Cardinal direction = West]	0.271	0.276	0.967	1	0.325	−0.270	1.312	0.812
[Cardinal direction = East]	−2.151	0.413	27.141	1	**0.000**	−2.960	0.116	−1.341
[Cardinal direction = South]	0[a]			0			1	

[a] Set to zero because this parameter is redundant

Factors Associated with Local Community Knowledge and Perceptions of Sighting Frequency and Trend Assessments of Mammals

The location and cardinal direction of communities were factors that significantly explained respondents' variation of the knowledge and perception of mammal abundance and population trends (Tables 3 and 4). The location and cardinal direction of the communities significantly influenced the frequency of mammal sightings. The full model containing all predictors was

statistically significant (χ^2 =124.1, df= 11, p < 0.001) indicating that the model gives better predictions than using the marginal probabilities for the outcome categories. The Goodness-of-fit test also indicated our data is consistent with the fitted model (Pearson χ^2 =395.7, df= 499, p=1.00; Deviance χ^2=336.4, df=499, p=1.000). The Nagelkerke's R^2 explains 33% of the variation between the location and cardinal direction of communities and the frequency of sighting mammals (Table 3).

Table 4 Socio-economic and demographic factors associated with Local Ecological Knowledge (LEK) of mammal abundance and population trends in the Kogyae Strict Nature Reserve

Predictors	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval		
						Lower Bound	Odds	Upper Bound
[Gender = Male]	0.206	0.249	0.684	1	0.408	−0.282	1.228	0.693
[Gender = Female]	0[a]			0			1	
[Age = 18–25]	−0.230	0.646	0.127	1	0.722	−1.496	0.795	1.036
[Age = 26–35]	0.099	0.381	0.068	1	0.794	−0.648	1.105	0.847
[Age = 36–45]	−0.034	0.359	0.009	1	0.925	−0.738	0.967	0.670
[Age = 45–55]	−0.115	0.360	0.101	1	0.750	−0.819	0.892	0.590
[Age = > 55]	0[a]			0			1	
[Length of residence = 1–5]	0.317	0.376	0.708	1	0.400	−0.421	1.373	1.054
[Length of residence = 6–10]	0.142	0.330	0.185	1	0.667	−0.505	1.153	0.790
Length of residence = > 10]	0[a]			0			1	
[Location of community = Inside]	0.030	0.377	0.006	1	0.936	−0.709	1.031	0.769
[Location of community = Outside]	0[a]			0			1	
[Cardinal direction = North]	2.000	0.375	28.449	1	**0.000**	1.265	7.386	2.734
[Cardinal direction = West]	−0.277	0.358	0.601	1	0.438	−0.979	0.758	0.424
[Cardinal direction = East]	1.657	0.450	13.529	1	**0.000**	0.774	5.243	2.540
[Cardinal direction = South]	0[a]			0			1	

[a] Set to zero because this parameter is redundant

Only the cardinal direction of communities significantly influenced the respondents' perception of the increase, decrease, and stability of wild mammals. The model with all predictors was significant (χ^2 = 66.7, df = 11, p < 0.001), which indicates the accuracy of the model when we add our explanatory variables. The Goodness-of-fit test also indicated the model is a good fit to the data (Pearson χ^2 = 177.4, df = 193, p = 0.80; Deviance χ^2 = 170.7, df = 193, p = 0.9). Nagelkerke's R^2 indicates that the model explained only 23% of the variation in the outcome. The highest predictors were respondents from communities located in the northern and eastern parts of the park with an odds ratio of 7.4 and 5.2, respectively (Table 4).

Encounter Rates of Mammals Recorded by Law Enforcement Rangers

The encounter rates of mammals recorded between 2006 to 2017 varied, with primates the most frequently observed, followed by large ungulates and small ungulates (Figs. 2– 4). There were negative correlations among the encounters with all large ungulates across all years indicating a decline in their encounters (Fig. 2a–e). Although there were also negative correlations among the encounters of small ungulates across all years, the encounter with Maxwell's duiker was highest and bay duiker the lowest (Fig. 3c, b). Except for baboons and Mona monkey, there were negative correlations with the encounters among all the other primates in Kogyae. However, black-and-white colobus was the least encountered across all years (Fig. 4e, f).

Compared to the mammal abundance and population trends identified by local people in this study, the majority of respondents' (73%) perceptions of small and large ungulates and primates were similar to the recorded trends in the law enforcement data. However, the local peoples' inability to identify species such as black-and-white-colobus, spot nose monkey, and hartebeest maybe because these species are locally extinct (Table 2).

Discussion

The long-term knowledge accumulated by local people can provide valuable insights for sustainable management. Our study represents one of the few conservation research investigations to use LEK for informing assessments of mammal population trends in a protected area. The use of LEK has provided additional and confirmative information on mammal abundance and reasons for mammal population trends, which are all important to consider for effective conservation.

Comparing the Local Ecological Knowledge of the Sighting Frequency and Trend Assessments of Mammals and the Encounter Data from Law Enforcement Operations

Of most mammal species identified by rangers and respondents, their population had decreased in the Kogyae Strict Nature Reserve from 2006 to 2017. Infrequent sighting of wild mammals in the study area was the key indicator of local perceptions of mammal abundance and population trends. The decline was most pronounced among others for buffalo, red-flanked duiker, black duiker, warthog, and oribi. The respondents attributed the decline to habitat degradation, illegal hunting, lack of available watering points, and diseases. Duikers are, however, hunted intensively, often excessively, and are principal items in the bushmeat trade (Bobo et al. 2015). The perceived decrease and lowest encounter rates for buffalos and waterbuck indicate simultaneously and probably confounding effects. These species are large, living in herds and inhabiting more open savannah areas rather than thickets and forests, which taken together make them suitable and favored species for poachers. Moreover, the activities of human settlers in the Special-Use Zone and the Restoration zone in Kogyae have destroyed about 40% of forest cover. The activities range from farming, logging, charcoal production, hunting, and setting of bush fires (Ayivor and Ntiamoa-Baidu 2015). Many of the respondents who live inside the park engage in one or more of these activities. Interestingly, the local peoples' knowledge and perception of species population decrease suggest that they have to some extent similar views on the population trends of mammal species in the study area and beyond. For example, declines in mammal abundance attributed to habitat degradation are consistent with studies in the Abdoulaye Fauna Reserve in Togo (Djiwa

2008) and several other countries in Africa. The conversion of protected area land for oil palm, rubber, and cocoa production led to a decline of primates and other species (Woods 2003; Gonédélé et al. 2012).

Several findings, however, were noteworthy, such as no encounters of black-and-white-colobus, hartebeest, and spot nose monkey after 2006, 2010, and 2012, respectively, indicating that these species may be considered locally rare. This also explains local people's inability to mention these species as present in the reserve.

Meanwhile, improved law enforcement explained by local people to increase the mammal population is similar to other findings (Kablan et al. 2019), which reported that, the encounters of primates and duikers increased in areas with high patrolling efforts. Although local communities are not part of the day-to-day management of the park, the results of our study show that their knowledge and perception of mammal population trends are consistent with wild mammal encounters reported by law enforcement officers between 2006 to 2017 (see Figs. 2–4). This indicates that LEK and other scientific methods may provide similar approximations of determining wild mammal population trends (Moller et al. 2004).

Factors Associated with Local Communities Knowledge and Perception of Mammal Sighting Frequency and Trend Assessment

Knowledge of species abundances and population trends was quite variable among local people in this present study. Factors that influence the variability in the LEK include only landscape variables (location of communities and cardinal direction of communities). The landscape variables that significantly influenced people's LEK was mainly due to the human settlement activities inside the park and also the zonation of the park. Due to the increased activities in the Special-use and Restoration zones, most animals have moved away from these areas to the northern part of the reserve (Fig. 1). This area is the Protected zone with little or no human presence and active law enforcement. Hence, local communities located around the northern borders of Kogyae are more likely to sight mammals. Earlier studies by Danquah and Owusu (2015) on buffalos' distribution in Kogyae revealed that buffalos were observed only in the Protected Zone, and no observations recorded in the Special-use Zone and other zones. Moreover, in the Bakossi National Park in Cameroon, high numbers of mammals such as Blue duiker (*Cephalophus moticola*), Red duiker (*C. dorsalis*), Bushbuck, Black-fronted duiker (*C. nigrifrons*), Mona monkey, and Chimpanzee were found in the northern and southern part of the park related to less agriculture encroachment and hunting, and availability of food and shelter (Fonkwo et al. 2011). It is for this reason why we expanded our sample to cover almost every part of the reserve.

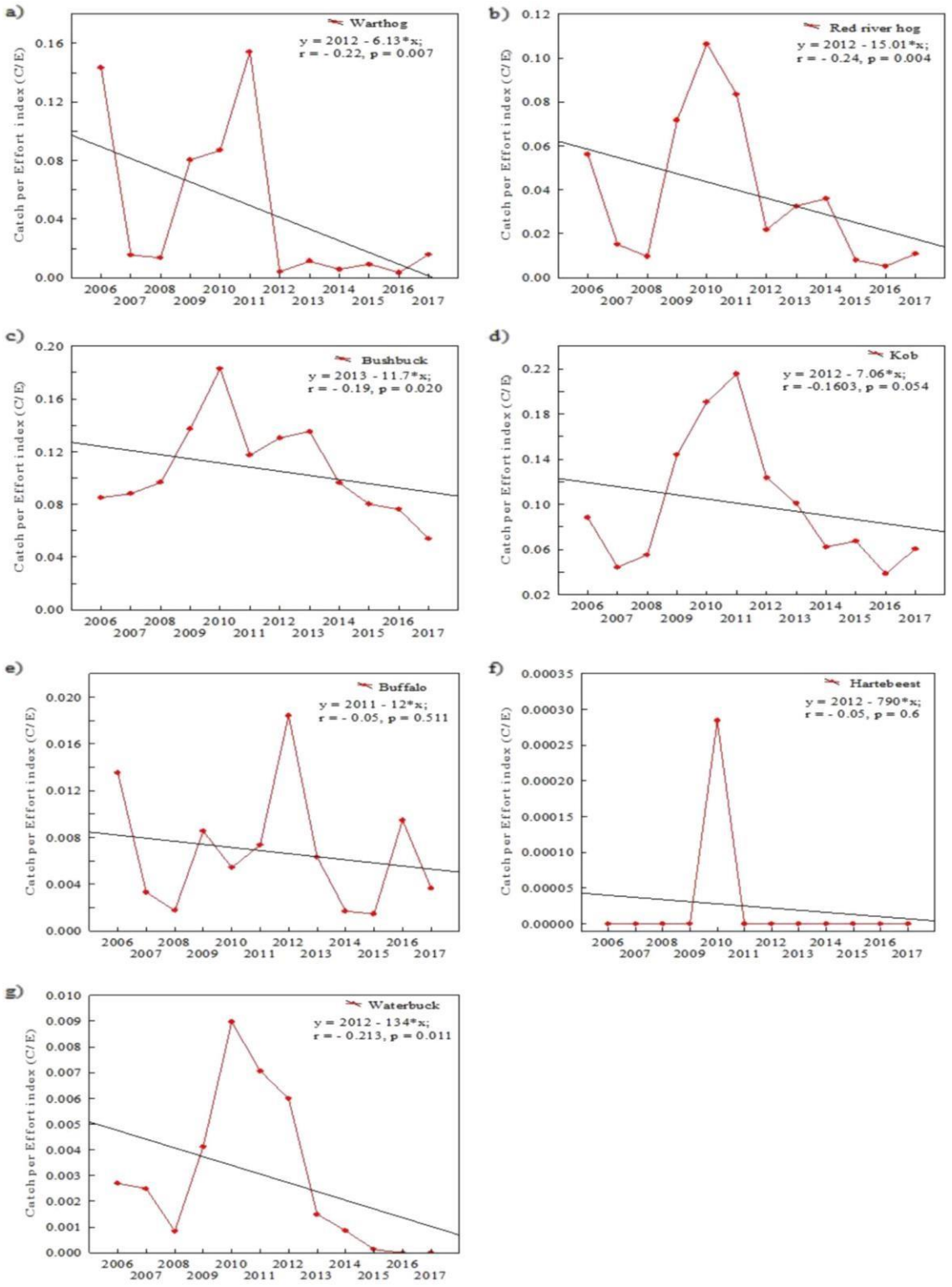

Fig. 2 Trends of encounters with large mammals' groups (a) Warthog (b) Red-river hog (c) Bushbuck (d) Kob (e) Buffalo, (f) Hartebeest, and (g) Waterbuck in the Kogyae Strict Nature Reserve in Ghana. Trend encounters were based on law enforcement patrol operations.

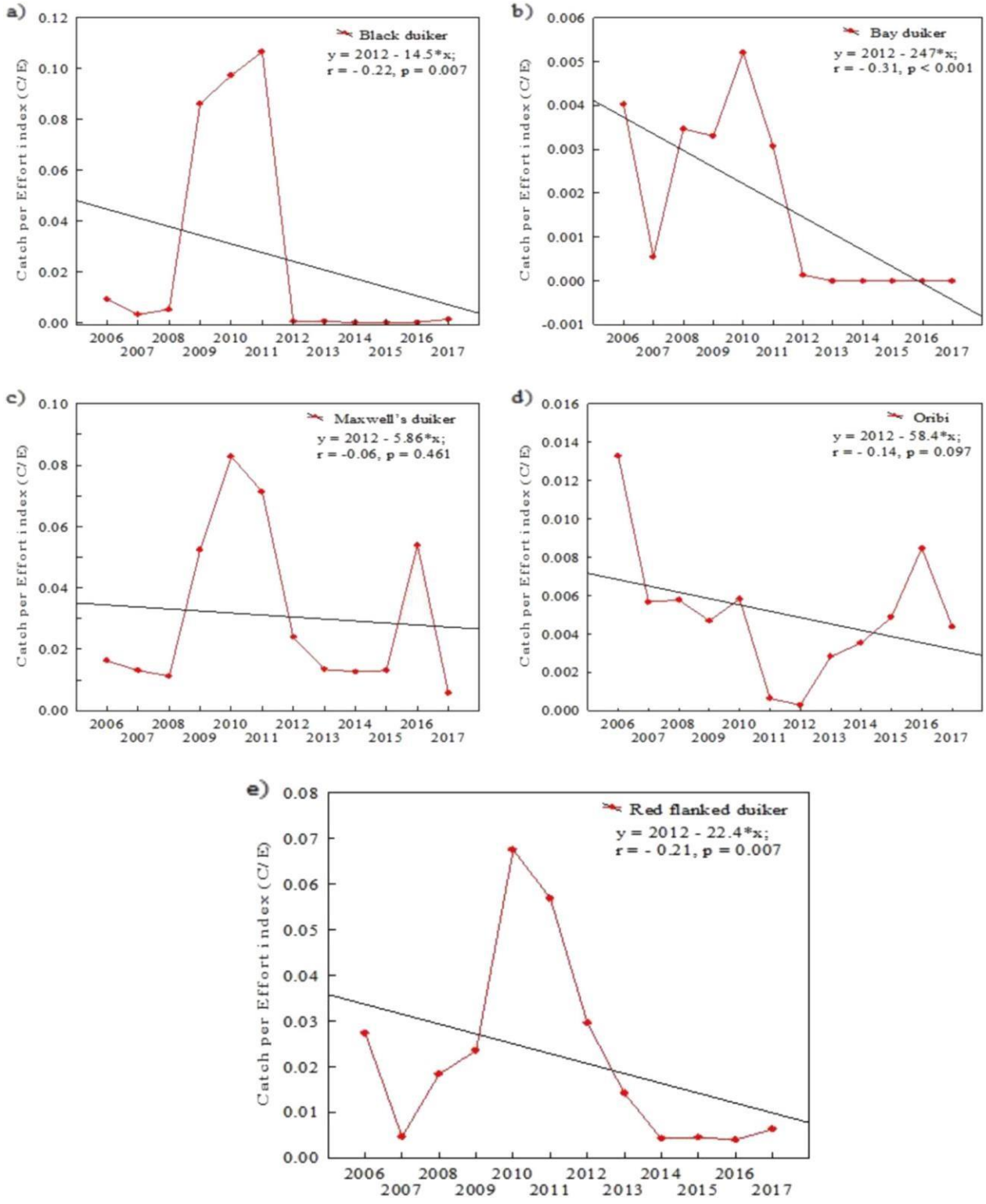

Fig. 3 Trends of encounters with large mammals' groups (a) Black duiker (b) Bay duiker (c) Maxwell's duiker (d) Oribi, and (e) Red-flanked duiker in the Kogyae Strict Nature Reserve in Ghana. Trend encounters were based on law enforcement patrol operations.

The reliability of local knowledge on animal abundance depends strongly on the characteristics of the target animals. For this reason, we selected mammals because most of them are easy to recognize and also commonly hunted for bushmeat. Hence knowledge of mammals is engrained in the local culture (Brashares et al. 2004). In addition, some local people may be unwilling to share their knowledge of species abundance due to their hunting or economic interest (Grant and Berkes 2007). We overcame this by the use of our initial informal conservation and in-depth interviews (Huntington 2000) and also the assurance of confidentiality.

Nevertheless, interviews provided information about the causes of change in mammal abundance, especially habitat degradation, and illegal hunting mainly from human settlements. This study highlights the ability of LEK to serve as a reliable tool for monitoring mid to long-term population trends.

Integrating LEK into Protected Area Management

For effective participation of local communities in protected area management, the Wildlife Division of Ghana has established Community Resource Management Areas (CREMA) in many protected areas. The main aim of CREMA is to ensure sustainable use of natural resources and improved the livelihoods of local communities. CREMA-owning communities are trained on wildlife monitoring and rehabilitation of degraded vegetation. More sustainable local production systems are adopted and both financial and technical assistance given to community members to boost their livelihood activities (Bosu 2014; Murray et al. 2018). Moreover, other NGO's such as OKO Forests (http://www.okoforests.com) have taken measures to reduce the dependence of local communities in and around Kogyae by creating a robust environment for small-scale farmers to improve average annual incomes by supporting improved farming practices and crop yields. Establishment of CREMA and these NGO's in Kogyae Strict Nature Reserve will serve as a basis for successful knowledge integration through understanding the communication and operating styles of the people that hold LEK, and establishing a foundation of trust to work from (Charnley et al. 2007), Furthermore, the identification of incentives and mutual benefits from knowledge sharing and a genuine willingness to share power (Young et al. 2016) would be enhanced for effective protected area management.

The numerous studies that exist in other protected areas in Ghana (Jachmann 2008; Ayivor et al. 2013; Kyerematen et al. 2014; Abukari and Mwalyosi 2018a, 2018b) and the very few in Kogyae (Ayivor and Ntiamoa-Baidu 2015) emphasize the value of LEK as an information source for conservation science, policy, and management. While acknowledging incorporating LEK into management decisions and actions are means of involving and empowering local communities in the protected area management, information from the LEK about most mammal decline will provide the basis for effective management actions especially in the Protected Zone of Kogyae.

Conclusions

Interviews with local people showed that they have considerable knowledge of mammal species' abundances and population trends. The LEK, when compared to law enforcement reports on encounters of mammals, confirmed that the majority of the species are declining related to human settlement activities in the park.

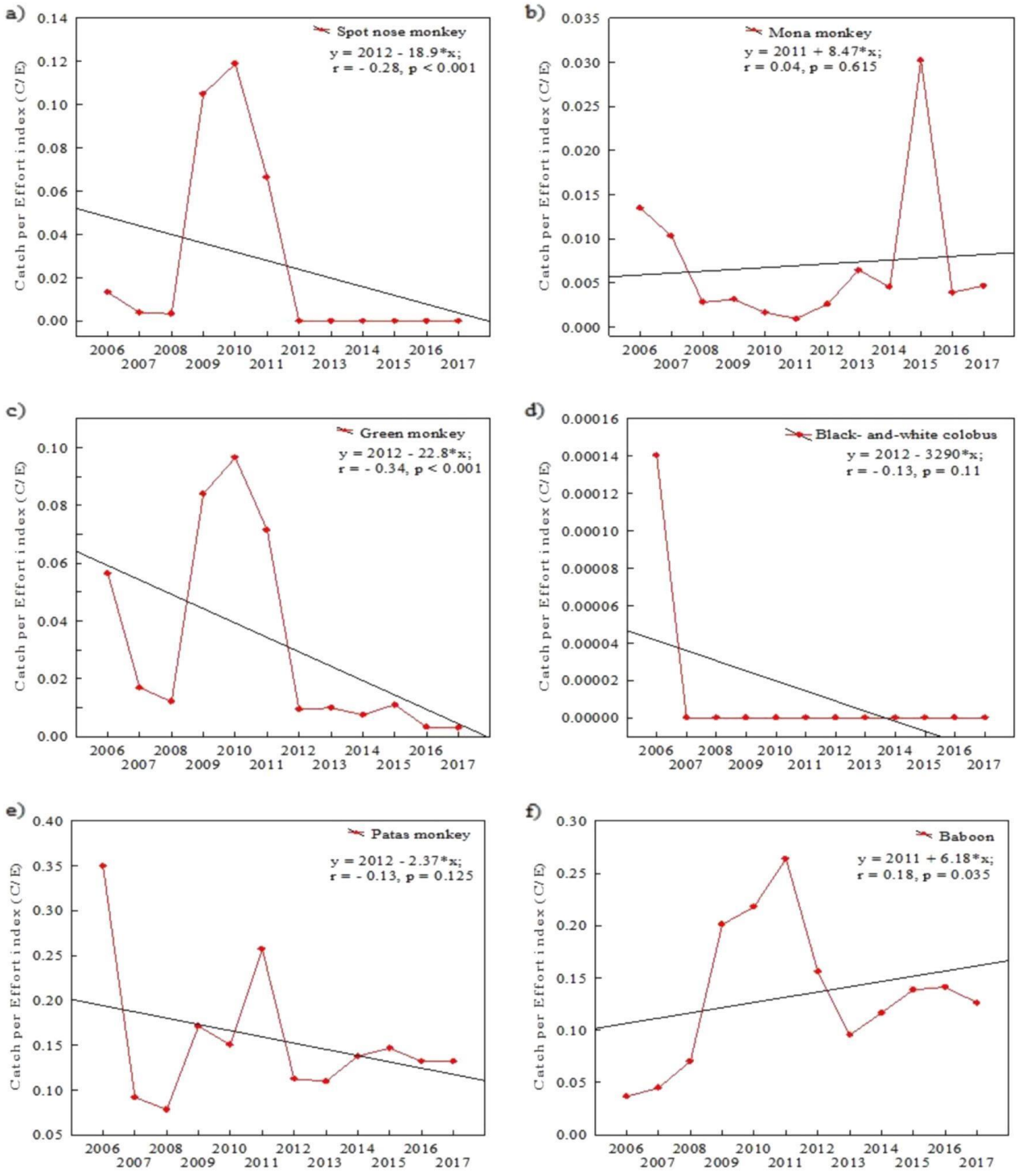

Fig. 4 Trends of encounters with large mammals' groups (a) Spot nose monkey (b) Mona monkey (c) Green monkey (d) Black-and-white colobus, (e) Patas monkey, and (f) Baboon in the Kogyae Strict Nature Reserve in Ghana. Trend encounters were based on law enforcement patrol operations.

Based on this evidence, we conclude that LEK can be an accurate and integrative tool to obtain information about wild animal species. However, the location and cardinal direction of communities influenced the knowledge of local people on mammal abundance and population trends. Although, logically, these predictors evaluated should display a localized influence, generalizing these results can lead to erroneous conclusions if applied without taking the characteristics of each place into account. We assert that understanding the diverse knowledge of local people in an area is important to formulate conservation practices that focus on the relationship between knowledge, practices, and institutional context. Our findings provide a strong argument for the conservation of LEK using local strategies that consider all these possible variations and influence.

The knowledge of local people about the declining mammal abundance and population trend suggests a potential for synergy with more effective participative management initiatives. We, therefore, advocate increased use of local knowledge to design new studies or seek adaptive management strategies that are acceptable for local peoples and other stakeholders.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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CHAPTER FIVE

5. EXPLORING THE KNOWLEDGE AND PERCEPTIONS OF LOCAL COMMUNITIES ON ILLEGAL HUNTING: LONG-TERM TRENDS IN A WEST AFRICAN PROTECTED AREA

Sections of the local community members in the Kogyae Strict Nature Reserve (Photo by Afriyie Jerry)

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Article

Exploring the Knowledge and Perceptions of Local Communities on Illegal Hunting: Long-Term Trends in a West African Protected Area

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Abstract: Local communities in rural areas are dependent on hunting for their livelihoods and rely on their knowledge to understand wildlife ecology. Their knowledge and perceptions may be vital for forming effective and sustainable management plans related to wildlife conservation. We aimed to examine perceptions of local people living inside (n = 153 households) and outside (n = 178 households) the Kogyae Strict Nature Reserve (KSNR, Ghana) regarding bushmeat prevalence and long-term trends in illegal hunting, and to explore people's knowledge about hunting tools, species, and reasons to hunt illegally. Perceptions of bushmeat sightings and illegal hunting trends were influenced by living inside or outside the protected area, gender, and residence time. Residents living inside the reserve perceived bushmeat and hunting as frequently present in their environment mainly due to frequent sightings of bushmeat and other wildlife products, while people living adjacent to the KSNR were more knowledgeable about the decrease in illegal hunting trends, probably because of awareness about penalties and biodiversity conservation. Furthermore, the perceptions of most residents about the decrease in hunting over time were validated by long-term KSNR law enforcement data. The perception in local communities that snares were the commonest form of hunting equipment used was also consistent with the ranger-based monitoring data. The need for money, bushmeat, unemployment, and retaliatory killings were the main drivers for illegal hunting. Our findings indicated that local people's knowledge can have a valid relevance in protected area management and may assist in developing effective conservation strategies and in overall improvement of local socio-ecological systems.

Keywords: bushmeat; conservation strategies; human–wildlife conflict; illegal hunting; law enforcement; protected area management; socio-economic survey; wildlife conservation

1. Introduction

In most African countries, hunting and trading of bushmeat is a significant component of rural and even national economies [1]. Bushmeat contributes significantly to food security and is often a vital source of protein for rural people [2,3] while causing a severe threat to wildlife populations [4,5].

The increase in the human population and easy access to markets has escalated the demand for bushmeat. These factors are also associated with the increased use of guns in-stead of traditional methods such as bows, arrows, and pitfalls [6,7]. Strict protection and law enforcement patrols within and around protected areas are fundamental for successful biodiversity conservation and protected area management [8]. Intensifying the patrol efforts in protected areas ensures a decrease in illegal hunting activities [9]. Meanwhile, the economic benefits from the sale of bushmeat and other wildlife products remain higher than the costs associated with the probability of arrest and punitive fines [10]. Further-more, hunting activities intensify with increased human population density inside or ad-jacent to protected areas [11,12] and decline with increasing distance of human settlements from protected area boundaries [13]. The trends in hunting activities are also associated with the benefits local communities gain from wildlife conservation projects, i.e., if local communities are involved in protected area management and economically or otherwise gain from this, it creates a win–win situation whereby wildlife is conserved and at the same time community welfare is improved [14].

Fundamental drivers for illegal hunting by people living in rural areas in proximity to protected areas are associated with limited opportunities for formal employment, lead-ing to high levels of unemployment and poverty [10,15]. Besides basic livelihood needs, hunting is driven by people's values and a sense of ownership regarding the use of wild-life resources [16], and therefore individual attitudes, behaviour, and decision-making are critical motivators [17]. However, values, experience, and knowledge influence individual attitudes [18,19]. The knowledge of local people about their environment is acquired through their interactions and relationship with it, i.e., the resource management practices that local people use and their related social institutions and worldviews, which may have been passed down over generations [20].

Local people's socio-economic and cultural backgrounds are diverse, and people's livelihoods rely on their knowledge of local wildlife ecology [21]. Social aspects of conservation studies therefore tend to be site- and ecosystem-specific, despite the existence of some cross-culturally consistent patterns, such as level of education and gender [22,23]. Socio-ecological research on illegal hunting activities has mainly focused on moist forest ecosystems in Africa [24,25], while specific studies on the knowledge and perceptions of local communities regarding illegal hunting activities in other West African ecosystems are still rare.

Understanding why people poach and trade bushmeat, and their socio-economic contexts and resulting perceptions, is essential for developing strategies for designing ap-propriate ways to manage wildlife and reduce illegal hunting activities [16,26]. In addition, conservation strategies for PAs which are understood, legitimized, and accepted by local people contribute to building positive relationships between the parks and local people and are beneficial to overall conservation success [27].

In this study, we aimed to expand the understanding of local communities' knowledge and perceptions of illegal hunting in the Kogyae Strict Nature Reserve (KSNR) in Ghana. The KSNR is composed of a unique ecological unit with undisturbed habitats (the strictly protected zone, at 57% of the total area) and other zones, including a special-use zone where some farming and other human settlement activities are allowed (20%). This protected area setting offers an opportunity to

explore variations between the perceptions of local people connected directly with the protected area by living inside it and those of local people living in the adjacent area, i.e., outside the protected area. Our objectives were therefore: (1) to examine the knowledge and perceptions of residents living inside and adjacent to the KSNR on the prevalence of bushmeat and long-term trends in illegal hunting activities, together with reasons for their perceptions; (2) to examine whether these perceptions vary according to people's socio-demographic characteristics, such as age group, gender, place of residence, length of residence, level of education, and occupation; (3) to explore the hunting equipment used, the species hunted, and the rea-sons for local people to huntin the KSNR. To provide comparability, we complemented the knowledge and perceptions of localpeople about illegal hunting trends with long-term ranger-based monitoring data (Appendix B).

2. Materials and Methods

2.1. Study Area

The KSNR (map reference 7°08′ N to 7°21′ N, 0°59′ W to 1°14′ W; Figure 1) is in the Afram Plains region of Ghana and covers an area of 386 km2. The Park is flat with an average altitude of 120 m a.s.l. The area serves as a watershed for a network of streams dominated by tributaries of the Afram and Sene rivers, most of which dry up in the dry season. The climate has dry (from November to March) and wet (from May to October) seasons, with annual rainfall ranging between 1200 and 1300 mm. The KSNR lies in the transitional zone between the transitional woodland (semi-deciduous forest) and the Guinea savannah woodland and open grasslands of Ghana. The reserve supports primates, ungulates, and bird species. As KSNR is unfenced, animals move in and out of the park to the adjacent communal areas.

The KSNR is the extended version of the former Kujani Forest Reserve, managed un-der the Forestry Department of Ghana at that time. In 1971, the Wildlife Division took over the administration of the reserve for strict protection under the Wildlife Reserve Regulations LI 710. The extension of the Kujani Forest Reserve boundaries was to obtain a viable ecological unit for the KSNR [28]. Studies conducted by the Wildlife Division indicated that in the dry season, animals from the park depended on the rivers in the unprotected areas for survival [29]. The extension also included some communities, namely, Asasebonso, Atakpame, Nyamekyere Dagomba, Birem, Yahayakura, Aberewanko, and Konkomba. Additionally, Aframso, Birem, Kyekyebon, and Kyeiase are now on the immediate border of the reserve. The local communities are predominantly farmers, with up to 75% of the people working in the agriculture sector. Farmingpractices involve a slash-and-burn method of land preparation and the cultivation of a variety of crops, e.g., yams, maize, paddy rice, groundnuts, cassava, cowpeas, and vegetables. Around 15% and 10% of the population work in the industry and service sectors, respectively, with a growth rate of 1.4% per year [30]. In Ghana, the Wildlife Conservation Regulations 1971 (LI 685) allow the provision of hunting licenses for the hunting of certain species at specified times in the year. However, because of KSNR's status as a strict nature reserve, no hunting is allowed there.

KSNR has four management zones: The Protected, Special-use, Restoration, and Development Zones. The Protected Zone is the largest in the KSNR; it covers 220 km2 and represents 57% of the protected area. However, this area represents the most important and least disturbed habitat and is fully dedicated to conservation. Human activities such as farming, logging, and charcoal

production have severely degraded the Restoration Zone. It covers 86 km2, representing 22% of the KSNR. The Special-use Zone is an area where some farming activities are allowed for local inhabitants but no hunting or timber logging. It has a size of 79 km2 and represents 20% of the KSNR. The Development Zone has been set aside for staff accommodation, administration facilities (headquarters), the mini research station, and a centre for conservation education. This constitutes 1 km2 (1%) of the reserve area.

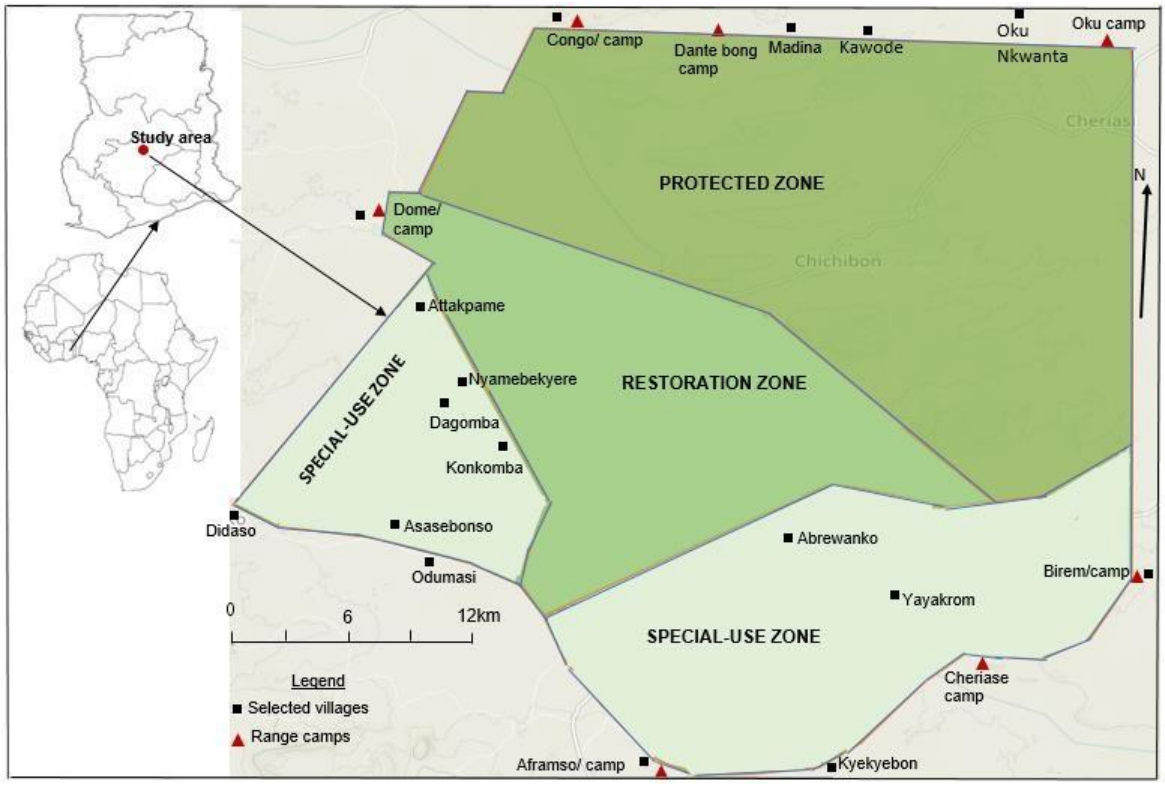

Figure 1. Map of Kogyae Strict Nature Reserve showing the locations of study communities and rangers' camps.

2.2. Data Collection

We conducted a household survey from August to September 2018 in local communities residing in and around the KSNR to collect data on their knowledge and perceptions regarding wildlife hunting and the KSNR protected area. The research was approved by the Wildlife Division of Ghana, the authority for the KSNR, and by the local communities' chiefs.

We selected all communities inside the KSNR (Asasebonso, Atakpame, Nyamekyere Dagomba, Yahayakura, Aberewanko, and Konkomba). Additionally, we randomly selected 12 communities out of the 18 located ≤ 5 km outside the KSNR (Berem, Odumasi, Didaso, Aframso, Cheriase, Dome, Madina, Oku Nkwanta, Congo Nkwanta, Madina, Kyekyebon, and Kawode; see Figure 1). For good coverage, we visually divided each community into four and randomly selected a household head or an adult family member ≥ 18 years old based on those who were present in each household, until the required sample size was reached. Therefore, each household had an

equal chance of been selected for the study. We randomly selected respondents who were ≥ 18 years old because local knowledge may be acquired through long-term observations, experiences, and interactions between humans and local ecosystems. Moreover, this knowledge may be handed down through generations; hence, no single person or social group holds the entire body of knowledge [31]. We set our confidence level at 95% and precision (margin of error) at 5% by using the sample-size calculator Raosoft (http://www.raosoft.com/samplesize.html accessed on 4th February 2020). The total population size of the selected communities was approximately 6500 [32]. The number of respondents in each village/community in the KSNR ranged from 20–45, with a total of 363 respondents. Of these, 32 (19 women and 13 men) withdrew from the interview. These were removed from the analysis, producing a sample size of 331 households and a response rate of 91%. We used semi-structured interview questionnaires involving closed and open-ended questions. Our questionnaires were based on a previous survey of perceptions of illegal hunting in southeastern Zimbabwe [33]. We constructed the questions to gather information on the socio-economic and demographic characteristics of respondents and their knowledge and perceptions of illegal hunting practices in the KSNR between 2006 and 2017.

Data collected included information on the frequency of sighting bushmeat and other wild animal products, perceptions of illegal hunting trends, hunting equipment, animal species hunted, and reasons for hunting (see Appendix A for questionnaires). Respondents indicated how frequently they saw bushmeat and other wild animal products, i.e., "every day", "once in 14 days", "once in 30 days", "once in 1–3 months", "once in 3–12 months", and "never seen it". Further, we asked respondents to rate the prevalence and trends of illegal hunting activities on a 5-point Likert scale ranging from "decrease greatly" (1) to "increase greatly" (5).

The questionnaires were translated from English to Twi by the first two authors of this article, and four undergraduate students were hired and trained to assist in the data collection. We pre-tested the questionnaires by interviewing five persons each in two communities outside our study zone in early August 2018, to assess the clarity of the questions. All interviews lasted between 30 and 70 min. We thoroughly explained the purpose of the research to the respondents and obtained their consent to participate [34] after appropriate permission was obtained from the village heads. We explained that all interviews were anonymous and confidential and that they would not be at any risk in answering the questions. In all 18 villages, the research team also had more informal discussions with the village heads/leaders about the contents of the questionnaire, to gain additional qualitative information that could support the questionnaire data. We used tape recorders to record all the discussions with the full consent of the respondents.

To avoid or minimize a social bias towards questions targeting the topic of illegal activities (see, e.g., [35,36]) or a common method bias, e.g., [37], we implemented diverse methodological approaches during the interviews, such as decreasing the respondent's concerns about admitting to or sharing views on illegal hunting activities by emphasizing the anonymity, importance, and scientific character of the survey, and by adjusting the survey environment, i.e., ensuring bystanders were not present, e.g., [38]. To validate the information obtained from the local communities, we used the ranger-based monitoring data presented in the discussion section. The information from the ranger-based monitoring data was obtained from previous research [9] between 2006 and 2017 and complemented by information from the year 2018.

2.3. Data Analyses

To illustrate the open-ended questions, respondents' quotes are presented verbatim unless otherwise stated. To protect the identity of the respondents we used unique identifier codes for each respondent, with each respondent code indicating the sequence of the interviews (e.g., a respondent who was our 16th interviewee was given a unique code of R016).

All percentages were calculated based on the total number of respondents in the sampled communities. However, for multiple responses on an open-response question, we presented the data as the percentage of the respondents giving each response, and these may sum to over 100%.

To determine the differences in the knowledge and perception of commonly used hunting equipment between communities inside and outside the park, we also used the chi-square (χ^2) test. To determine the relationship between the socio-demographic characteristics of respondents and their perception of the prevalence and trends in illegal hunting activities, we used an ordinal logistic regression model. The independent variables included in the model were gender, education, occupation, and location of the communities (inside vs. outside) as factors, and age and length of residence as covariates [39]. We per-formed a post hoc test to test for a potential common method bias in our interviews, specifically Harman's single-factor test [37]. We used SPSS version 27 (SPSS, Inc, Chicago, IL, USA) for all statistical analyses, with the level of significance set at $p \leq 0.05$.

3. Results

Forty-six percent (n = 153) and 54% (n = 178) of respondents lived inside and outside the park, respectively. In total, 60% were males (n = 198), while 40% were females (n = 133). However, the gender balance was almost the same for respondents living outside the park as for residents inside the park (Table 1). Half of the respondents were married (n = 165), and most were above the age of 36 years. The education of respondents was low; 36% had no education, while 27% had only primary education. Half of the respondents were farmers (n =166), and very few of them were unemployed (n = 15). The average household size consisted of two adults and three to five children. Most respondents, 68.6% (n = 227), had lived in the area for ≥ 11 years. Table 1 provides details of the respondents' socio-demographic information.

3.1. Perceptions about Prevalence and Long-Term Trends in Illegal Hunting Activities

More respondents living inside the park reported sighting bushmeat and other wild-life products frequently than those outside, over the years (Figure 2). Twenty-three percent (n = 35) and 7% (n = 11) of respondents living inside and outside the park, respectively, reported sighting bushmeat and other wildlife products every day. Similarly, the majority of respondents (n = 64, 19%) who perceived an increase in illegal hunting activities over the years lived inside the park with only a few (n = 20, 6%) of those living outside the park reporting an increase (Figure 3). However, of the total number of respondents who perceived a decrease in illegal hunting activities, the majority (n = 139, 42%) were residents living outside the park, while 16% (n = 53) lived inside the park. In addition, 36 (11%) and 19 (6%) respondents living inside and outside the park, respectively, reported no change in illegal hunting activities over the years.

The reasons given for a perceived increase in illegal hunting (Figure 4a) were: (i) the high influx of migrants leading to human population increase; (ii) retaliatory killings related to crop damage

Table 1 Socio-demographic characteristics of respondents living inside and outside the KSNR.

Categories	Inside		Outside		Total	
	Frequency	**Percent (%)**	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**
Gender						
Male	103	67	95	53	198	60
Female	50	33	83	47	133	40
Age (years)						
18–25	7	4	10	5	17	5
26–35	33	22	33	18	66	20
36–45	31	20	49	28	80	24
46–55	47	31	49	28	96	29
56 and above	35	23	37	21	72	22
Marital status						
Single	37	24	61	34	98	30
Married	81	53	84	47	165	50
Divorced	35	23	33	19	68	20
Education						
No education	63	41	55	31	118	36
Primary education	33	22	58	33	91	28
Junior secondary	34	22	51	29	85	25
Senior Secondary	15	10	10	5	25	8
Tertiary	8	5	4	2	12	3
Occupation						
Farming	72	47	94	53	166	50
Livestock keeping	18	12	17	9	35	10
Charcoal production/selling	27	18	23	13	50	15
Hunting	11	7	14	8	25	7
Employment/business	17	11	23	13	40	13
Unemployed	8	5	7	4	15	5
Household size						
0	22	14	53	30	75	23
1–2	32	21	50	28	82	25
3–5	60	39	67	38	127	38
6 and above	39	26	8	4	47	14
Length of residence (years)						
1–5	13	9	25	14	38	12
6–10	45	29	21	12	66	20
11 and above	95	62	132	74	227	69

One respondent said that:

> *"So many people (migrants) have moved into the park and surrounding villages in search of fertile lands to farm and better living conditions. Together with the indigenes have increased human population which has put too much pressure on the park including illegal hunting activities".*

On the other hand, the main reasons given for a perceived decrease in illegal hunting activities (Figure 4b) included: (i) illegal hunters fear arrest and imprisonment by the authorities; (ii) illegal hunters fear injury or being killed by law enforcement rangers; (iii) wildlife conservation awareness creation. Specifically, respondent R016 reported that:

"I have my family to take care of and so I will not risk going hunting and get arrested".

In addition, respondent R054 said:

"If I get arrested now by hunting … who will bail me? Nobody. My family is poor and we have no connections (no friends at the judiciary or the top-level) to ask for help".

Other respondents such as R032, R115, R207, and R294 were of a similar view:

"I (we) hear that conditions in the prisons (Ghana prisons) are bad, so why will I (we) go hunting and get imprisoned just for common meat or money? I (we) will rather starve than go hunting".

Similarly, respondents R005, R009, R81, R93, R213, and R306 expressed their anxiety about encountering law enforcement rangers during hunting:

"I (we) may encounter them and exchange fire (especially when using firearms) and you may be injured or killed".

Further, R101 confirmed that:

"In truth, I was nearly killed when I went hunting some time ago. I gave a warning shot to scare the rangers away, but I was shot at, and I had to run away to escape death and or arrest. I promised myself that I will never go hunting again and will also not advise anyone to do so".

Respondents also highlighted that wildlife conservation awareness was one of the reasons for the declining trend in illegal hunting activities. For example, R157 described how law enforcement rangers and other park authorities continue to educate them on wildlife conservation:

"Anytime they come here and speak to us about the importance of conserving the animals in the park".

Respondent R321 also confirmed that:

"At first, I thought hunting was our right and a source of food/income, but after continuous awareness creation, I now know about the importance of wildlife conservation".

3.2. Effects of Socio-Demographic Factors on the Perception of Local Communities about Illegal Hunting Activities

The model testing the effects of socio-demographic factors on the frequency of sighting bushmeat and other wild animal products, indicated the significant improvement of the model relative to the baseline null model (likelihood ratio $\chi^2 = 119$, df = 13, $p < 0.001$), while a goodness-of-fit test indicated that the model was not good (Pearson $\chi^2 = 1313$, df = 1172, $p = 0.002$). A possible reason for this was that among the six predictors, only gender and the location of the communities significantly predicted the frequency of sighting bushmeat and other wildlife products. The odds ratio indicated that local community members living inside the park were 2.6 times more likely to see bushmeat and other wildlife products than those living outside. Furthermore, men were 0.1 times less likely to see bushmeat and other wildlife products than women (Table 2). Nagelkerke's R^2 explained 31% of the variation between genders, the location of communities, and the frequency of sighting bushmeat and other wildlife products.

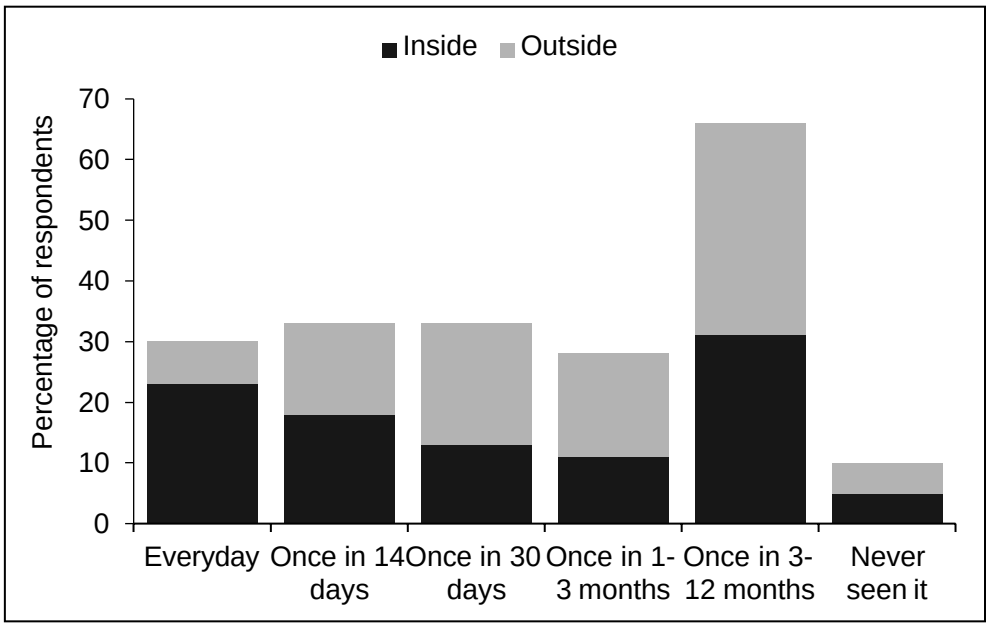

Figure 2. Perception of respondents about the frequency of sighting bushmeat/wildlife products. The total number of respondents living inside and outside the park was 153 and 178, respectively.

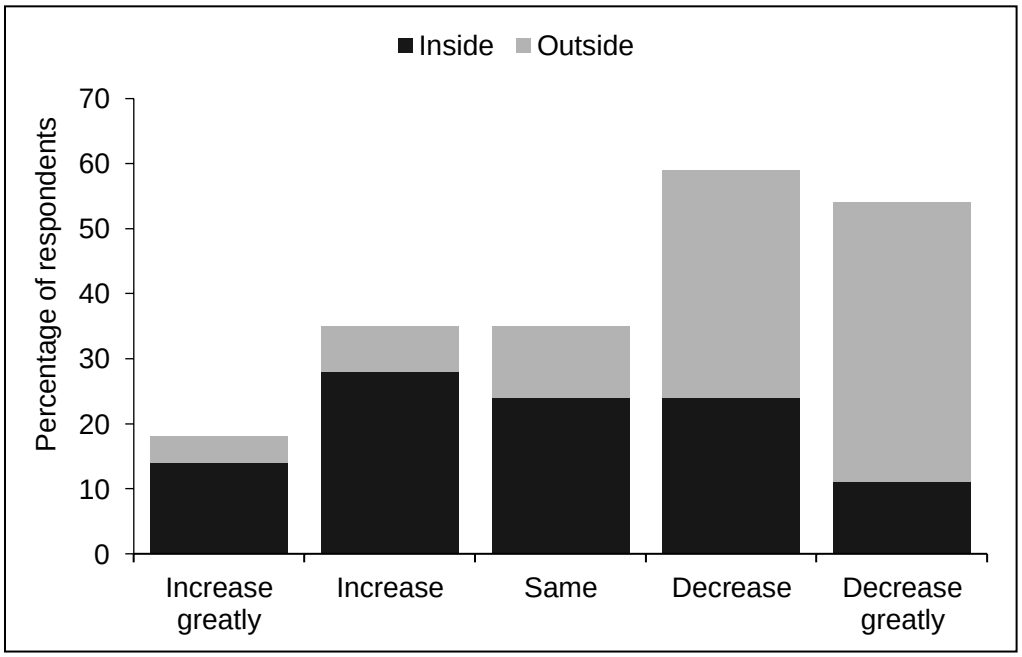

Figure 3. The perceived trends of illegal hunting activities between 2006 and 2017. The total number of respondents living inside and outside the park was 153 and 178, respectively.

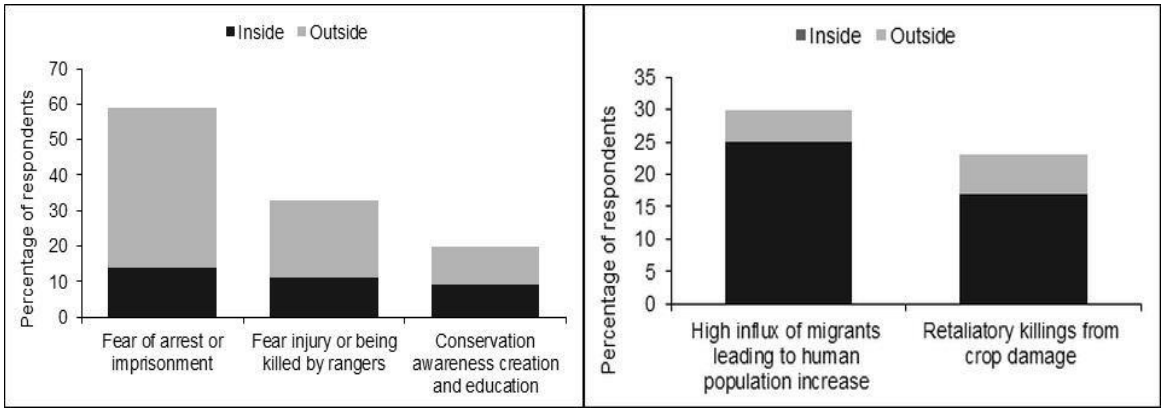

Figure 4. Reasons for the perceived (a) increasing and (b) decreasing trends in illegal hunting activities in Kogyae Strict Nature Reserve from 2006 to 2017. The total number of respondents living inside and outside the park was 153 and 178, respectively.

The model testing the effects of socio-demographic factors on perceptions and knowledge of the trends in illegal hunting activities indicated a significantly good fit in both tests, for the model fitting relative to the null model (likelihood ratio $\chi^2 = 118$, df = 13, $p < 0.001$) and the goodness-of-fit test (Pearson $\chi^2 = 917$, df = 935, $p = 0.65$). The location of the communities, length of residence, and gender significantly predicted the respondents' perception and knowledge of the trends in illegal hunting activities (Table 3). The odds ratio indicated that respondents who lived outside the park were 7 times more likely to perceive decreasing trends in illegal hunting activities. Residents who had lived longer in the area were 0.7 times more likely to perceive decreasing trends in illegal hunting activities than short- to medium-term residents, and men were 0.3 times more likely to perceive decreasing trends in illegal hunting activities than females. Nagelkerke's R^2 indicated that the model explained 32% of the variation in the results.

Harman's single-factor test showed 12% of the variance in extraction sums of squared loadings and did not confirm any common method bias in our interviews, as > 50% of the variance is considered as an indicator of common method bias.

3.3. Hunting Equipment, Hunted Animal Species, and Reasons for Hunting

There was no significant difference between respondents living inside and outside the park regarding their perception of the equipment and methods used for hunting ($\chi^2 = 4.1$, df = 3, $p = 0.3$). Most of the respondents reported that snares ($n = 231$, 70%) and firearms ($n = 73$, 22%) were the most common forms of hunting equipment and methods used in the area (Table 4). These were mostly used to hunt grasscutters ($n = 143$, 43%), bushbucks ($n = 64$, 19%), duikers ($n = 46$, 14%), kobs ($n = 37$, 11%), buffalo ($n = 19$, 6%), pangolins ($n = 13$, 4%), and patas monkeys ($n = 9$, 3%).

The respondents highlighted various reasons why local communities hunt illegally: (i) trading of bushmeat to raise money ($n = 237$, 72%); (ii) bushmeat for domestic consumption ($n = 182$, 55%); (iii) hunting for traditional reasons ($n = 98$, 30%); (iii) unemployment ($n = 74$, 22%); (iv) to minimize crop damage ($n = 71$, 21%).

Table 2 Effects of local communities' socio-demographic factors on the frequency of sighting bushmeat and other wildlife products in KSNR.

Variables	Estimate	Std. Error	Wald	df	Sig.	95% Co	
						Lower Bound	C
Age (years)	−0.070	0.087	0.637	1	0.425	−0.241	
Length of residence (years)	−0.216	0.149	2.092	1	0.148	−0.509	
Gender							
Male	−2.162	0.237	83.409	1	0.000	−2.626	
Female	0 [a]			0			
Education							
No formal	0.682	0.570	1.434	1	0.231	−0.434	
Primary	0.733	0.580	1.601	1	0.206	−0.403	
Junior secondary	0.693	0.582	1.420	1	0.233	−0.447	
Senior secondary	0.575	0.661	0.756	1	0.385	−0.721	
Tertiary	0 [a]			0		.	
Occupation							
Farming	−1.406	0.519	7.345	1	0.077	−2.422	
Livestock keeping	−1.226	0.586	4.375	1	0.066	−2.375	
Charcoal production/selling	−0.648	0.564	1.323	1	0.250	−1.753	
Hunting	−0.693	0.624	1.236	1	0.266	−1.916	
Business/ formal employment	−1.604	0.584	7.553	1	0.086	−2.749	
Unemployed	0 [a]			0		.	
Location of community							
Inside	0.975	0.215	20.643	1	0.000	0.555	
Outside	0 [a]	.	.	0	.		

[a] Set to zero because this parameter is redundant.

Table 3 Effects of local communities' socio-demographic factors on the knowledge and perceptions of the trends in illegal hunting activitiesin KSNR.

Variables	Estimate	Std. Error	Wald	df	Sig.	9 Lower Boun
Age (years)	0.047	0.088	0.292	1	0.589	−0.125
Length of residence (years)	−0.335	0.150	5.002	1	0.025	−0.629
Gender						
Male	−1.039	0.220	22.396	1	0.000	−1.470
Female	0 [a]	.	.	0	.	
Education						
No formal	−0.730	0.555	1.731	1	0.188	−1.817
Primary	−0.534	0.564	0.895	1	0.344	−1.640
Junior secondary	−1.118	0.570	3.847	1	0.060	−2.235
Senior secondary	−0.626	0.647	0.936	1	0.333	−1.894
Tertiary	0 [a]	.	.	0	.	
Occupation						
Farming	−0.218	0.501	0.190	1	0.663	−1.200
Livestock keeping	0.444	0.571	0.606	1	0.436	−0.674
Charcoal production/selling	0.027	0.549	0.002	1	0.960	−1.049
Hunting	−0.433	0.624	0.483	1	0.487	−1.656
Business/ formal employment	−0.566	0.570	0.986	1	0.321	−1.684
Unemployed	0 [a]			0		
Location of community						
Inside	1.984	0.231	73.793	1	0.000	1.531
Outside	0 [a]			0		

[a] Set to zero because this parameter is redundant.

For example, respondent R188 mentioned that:

> *"Most of the hunters I know go hunting because of money from the sale of bushmeat. Some of them and families may sleep without food if they do not get a catch and or a buyer".*

Respondent R003 also explained that:

> *"The money he (they) get from the sale of bushmeat is better than selling your farm produce such as yam, cassava, and plantain. It is a good business but risky".*

Other respondents such as R233 mentioned the fact that hunters hunt for consumption:

> "*My husband used to set traps in the park, but he only brings his catch for us to eat. We can eat this catch for more than a week".*

Respondent R167 also reported that:

> *"Bushmeat is delicious than the livestock and poultry we eat here. I know that most of the hunters hunt especially grasscutter for domestic consumption".*

Further, respondents explained that hunting occurs because people believe it is their right to hunt. R300 reported that:

> "*This land (park) belongs to us. We are custodians of the land and, as such, we must have full access to everything within it".*

Other respondents also explained hunting occurs because those involved in it do not have jobs. R325 said that:

> *"My brother was a hunter because he had no job nor a land to farm on so, he chose hunting for survival".*

Similarly, some respondents explained that they hunt because of retaliation for crop damage by some animals in the park. For example, R260 explained that:

> *"I (we) set traps in our farms to kill animals that damage our food crops especially … hmm … that animal, "adwee" (patas monkey)".*

Table 4. Local communities' knowledge of hunting equipment and methods used in Kogyae Strict Nature Reserve.

Hunting Equipment/Method	Location of Community		Statistics		
	Inside (%)	Outside (%)	χ^2	df	*p*
Snares	115 (75)	116 (65)	4.1	3	0.3
Firearms	27 (18)	46 (26)			
Bushfires	7 (4)	11(6)			
Hunting with dogs	4 (3)	5 (3)			

4. Discussion

4.1. Perceptions about Prevalence and Long-Term Trends in Illegal Hunting Activities

Wildlife hunting is inevitably associated with the lives of local people, and bushmeat, wildlife products, and associated activities, i.e., hunting, were frequently present in local communities, despite the fact that there were some differences among particular groups of people.

The strongest factor influencing peoples' perceptions of bushmeat sightings and il-legal hunting was living inside or outside the protected area. The residents living inside rely more for

their livelihoods on bushmeat and wildlife products than the residents living outside, which may explain why their sightings of bushmeat were shifted towards daily or more frequent sightings, while the outside residents reported these sightings less frequently, i.e., with longer periods between sightings, especially between 3 and 12 months. Another possible reason for fewer sightings of bushmeat by those outside the protected area is that all the rangers' camps are located along the boundaries and in the villages adjacent to the KSNR. Outside villages are therefore rangers' bases and areas around them are starting points for law enforcement patrols, thus they are heavily patrolled by default. This substantially decreases the probability of occurrence of poaching-related events [40]. However, the communities inside the park may implicitly engage in increased bushmeat consumption and trade, and bushmeat may be more accessible, i.e., prices may be lower [41,42].

Living inside or outside the protected areas also strongly influenced the local com-munities' perceptions of long-term trends in illegal hunting activities. People living inside the KSNR reported trends that may be due to their more frequent use of bushmeat and other wildlife products. Additionally, residents living inside mentioned two specific rea-sons for the perceived increase, i.e., an influx of new incomers to their villages, thereby creating higher pressure on natural resources, specifically hunting, and a higher incidence of retaliatory killings, since living inside the park also leads to a higher frequency of crop damage by wildlife than living outside the park. The people living outside the KSNR mostly reported a decreasing trend in illegal hunting over time which corresponded to the long-term records of illegal hunting activities in the park recorded by the ranger-based monitoring system (Appendix B). Their perception, therefore, reflected the long-term effects of KSNR law enforcement and therefore additionally confirmed that local people's knowledge can have a valid relevance to protected area management, e.g., [21]. We may also infer that effective law enforcement, by creating awareness of the consequences of breaking established rules, and positively oriented biodiversity conservation awareness campaigns in local communities result in deterring illegal hunting activities. Finally, we cannot rule out the possibility that the decline in illegal hunting activities in the park has been due to animal population decline caused by the destruction of habitat from intensive human activities such as farming and logging [29].

Gender was the next important factor explaining differences in perceptions regarding bushmeat and illegal hunting, which are both associated with the division of labour in households. Females sighted bushmeat and other wildlife products more frequently than men, in agreement with other studies in Africa reporting that the daily activities of women are more focused on agricultural production and livelihood chores, including going to the market [43–45]. Thus, women have considerable knowledge of their environment, and hence their involvement in the wildlife monitoring process should be increasingly encouraged, since women are vital stakeholders in conservation [45]. On the other hand, al-most 68% of respondents who reported a decline in illegal hunting activities were males, as only men are involved in hunting, and hence they are more likely to assess trends in il-legal hunting activities accurately. Protected area managers must acknowledge that even small communities are not homogenous entities. Understanding gender differences in so-cio-ecological systems is fundamental to the proper planning and implementation of conservation activities.

We found that local people who had lived in the area for more than ten years were more knowledgeable about the trends in illegal hunting activities over the years than short-term residents. Short-term residents had come to the KSNR area as recent migrants, and they may not experience any strong attachment to the protected area, while long-term residents feel a certain ownership of the site, valuing local wildlife and natural environments [46,47]. Although interventions to combat illegal hunting activities need a range of components, the knowledge and perceptions of local

communities are a complex yet vital feature. Protected area managers should therefore acknowledge all factors and implement an understanding of overall differences in groups of people and their perceptions of nature in proper planning and engagement in conservation activities, as a part of a holistic approach [48].

4.2. Hunting Equipment, Hunted Animal Species, and Reasons for Hunting

The local communities reported that the most common hunting method used was snaring; this was consistent with the KSNR ranger-based monitoring data [9] and is known to be widespread in other protected areas in Ghana [49] and elsewhere, e.g., the Queen Elizabeth Conservation Area, Uganda [50] or the Serengeti National Park, Tanzania [51]. The reason clearly lies in the fact that this technique is quiet, time-efficient, and less risky compared to the use of noisy firearms, and placing more snares maximizes the probability of hunting success. In addition to snares, firearms are used. Dogs are also used by hunters, specifically to bring wildlife to bay or to chase animals into holes, where they are killed with shotguns or cutlasses [52]. Furthermore, informal discussions revealed that hunters use fire to force animals out of their hideouts, particularly grasscutters (*Thryonomys swinderianu*), which is the most hunted species in the KSNR. Bush fires are considered to be the highest threat to conservation in the KSNR [29], though they are associated not only with hunting but also strongly with illegal livestock grazing, because herdsmen intentionally burn dried grass during the dry season to induce the early sprouting of fresh grass for their cattle. Bush fires can also result from the careless handling of fires by palm wine tappers, local gin distillers, farmers, and cigarette smokers.

Illegal hunters and consumers preferred a range of animal species, notably grasscutters, bushbucks, duikers, and kobs. These targeted and preferred species, especially grasscutters, follow the pattern recorded in other parts of Ghana and West Africa, while buffalo (Syncerus caffer), pangolins (*Smutsia temminckii*), and baboons (*Papio anubis*) were amongst the least-targeted species, similarly to previous reports [53,54].

Drivers for the hunting of wildlife in the KSNR were similar to those in other regions of the world, specifically economic, nutritional, cultural, and recreational requirements [16,55]. The reasons given for illegal hunting in the present study suggest that the main drivers for bushmeat hunting include the need for money, need for food, unemployment, and retaliatory killing as a response to crop damage without compensation measures from the park management. These findings support previous research recognizing that the poverty of residents [56], inadequate livelihood sources [57,58], and a lack of alternative livelihoods [59] influence local people's decision to participate in risky illegal activities. Therefore, addressing the socio-economic livelihood needs and challenges of communities [60,61] through the provision of alternative income streams, employment, and integrated conservation and development projects is vital in ensuring effective protected area management. Recent studies suggest that when communities benefit from protected areas, they are more likely and willing to protect the park and reduce engagement in illegal activities [36,62].

4.3. Integrating Local Community Knowledge into Protected Area Management

The present study highlighted that local communities are knowledgeable about eco-logical processes and, more importantly, are familiar with the prevalence and trends of il-legal hunting activities, which can provide valuable information for the management of the protected area. Information on the types of equipment used in hunting (some not captured by the ranger-based monitoring data) and motivations for hunting provide a clearer understanding for protected area managers and governments to underpin better conservation strategies. Conservationists, however, do not usually integrate local knowledge, which is often qualitative, in a non-standard format, and different from their own [63], despite the fact that local communities' knowledge has been effective and efficient in monitoring the hunting of vulnerable tropical forest species at large scales. For instance, Parry and Peres [64] found through interviews with local people that hunting led to the depletion of threatened species from large areas of their putative ranges, even in the 1.6 million km² Brazilian State of Amazonas, where primary forests are still intact. As protected area management evolves, current perceptions about local communities' knowledge and the role of these communities in conservation need to change. Local communities' knowledge may not only fill scientific knowledge gaps but may also contribute to higher success in protected area management by making local resource users feel important and included in the process. Carmack and Macdonald [65] argued that where the focus and the scale of inquiry are the same, collaborative research should regard scientific and local communities' knowledge as equal. The integration of local communities' knowledge into protected area policy and management decision processes is of im-portance in Africa and many developing countries, where many local communities still rely on PA resources for their subsistence. Local community knowledge could be a vital stronghold for their livelihoods as well as for the survival of their culture.

5. Conclusions

Understanding the knowledge and perceptions of local people about protected areas and the activities within them represents a vital source of information for conservation managers [21,66], and a tool for improving relationships between communities and protected area management [67].

When considering complex ecological systems, it is uncommon to have a study with objective data on human behaviour. In this study, the combination of different data sources improved its internal and external validity, especially with regard to sensitive items. Local communities' knowledge and perceptions of trends in illegal hunting activities were inconsonant with the long-term ranger-based monitoring data. Perceptions of bushmeat sightings and illegal hunting trends were influenced by living inside or outside the protected area, gender, and residence time. Residents living inside perceived bushmeat and hunting as frequently present in their environment, while people living adjacent to the KSNR were more knowledgeable about decreasing bushmeat and illegal hunting trends.

Furthermore, the local communities perceived that snares were the most common hunting equipment used, and this was consistent with the ranger-based monitoring data. The reasons given for hunting illegally included the need for money, bushmeat, unemployment, and retaliatory killings This information should provide a good basis for developing measures that diversify sources of income for local communities, and these measures are likely to result in a reduction in illegal hunting. Effective responses will re-quire relating illegal wildlife hunting to development rather than solely to conservation. Similarly, acknowledging the diversity of local communities in their perceptions within their social, economic, cultural, and environmental backgrounds is the way to target effective educational programmes and environmental awareness campaigns to enhance

community knowledge and people's involvement in wildlife conservation. Such initiatives should provide opportunities for people to become involved in wildlife conservation as peer educators and should empower local communities in actions aimed at protecting biodiversity.

Our findings indicate that recognition of local communities' knowledge and perceptions by protected area authorities may substantially assist in developing effective conservation strategies and overall improvement of the local socio-ecological systems.

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Appendix A

Interview questionnaire on understanding local communities' knowledge and perception about illegal hunting activities.

Introduction

Thank you so much for meeting me. I appreciate your time. This should take about half an hour to an hour. Would you mind if I audio record this meeting so that I can make sure that I don't miss anything important that you tell me? Despite being taped, I would like to assure you that the transcribed notes will contain no information that would link you to specific statements. The information from our discussion today will be anonymous. Do you have any questions or concerns so far?. Okay great! Let's get started:

Date:……
Time:……
Interview reference number: ……
Village name:…
Village location: ☐ Inside ☐ Outside

1. Basic information
1.1 Name (optional): …

1.2 Gender: ☐Male ☐Female

1.3 Age: ☐ 18–25 ☐ 26–35 ☐ 36–45 ☐ 46–55 ☐ >55

1.4 Marital status: ☐Single ☐Married

1.5 Education: ☐No formal ☐Primary ☐Junior Secondary ☐ Senior Secondary ☐ Tertiary

1.6 Occupation: ☐ Farming ☐ Livestock keeping ☐ Charcoal production/selling ☐ Hunting ☐Employment/business ☐ Unemployed

1.7 Household size: ☐ 1–2 ☐ 3–5 ☐ >5

1.8 Length of residence: ☐ 1–5 ☐ 6–10 ☐ >10

2.1 How often do you see bushmeat and other wildlife products in your village?
☐ Every day ☐ Once in 14 days ☐ Once in 30 days ☐ Once in 1–3 months
☐ Once in 3–12 months ☐ Never seen it.

2.2 In your opinion what are the trends in illegal hunting activities over the past 18 years?
☐ Increase greatly ☐ Increase ☐ Same ☐ Decrease ☐ Decrease greatly

2.3 What are the reasons for the given trend in illegal hunting activities in the area?

2.4 What are the common illegal hunting equipment used in the area?

2.5 May you list the wild animal species that are mostly hunted illegally in the area?

2.6 In your opinion what are the main reasons why people engage in illegal hunting activities in the area?

Conclusion

Thank you for the time and information that you have shared with me today! This has been a very interesting meeting and your opinions will be valuable. Once again, I would like to remind you that any comments of yours will be anonymous.

Appendix B

Table A1. Actual trends in prevalence and distribution of illegal hunting activities in KSNR (2006–2018).

Illegal Hunting Activities	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total Incidents	%	Avg/yr	Incident/ km^2
Poachers arrested	6	11	9	9	11	11	10	7	6	12	12	3	3	110	4	8.5	0.3
Poachers observed	28	10	32	126	65	45	2	25	5	2	15	5	1	361	13.1	27.8	1
Poacher's camps found	28	12	16	38	33	12	1	4	13	6	2	2	2	169	6.1	13	0.5
Gunshots heard	80	76	69	98	153	67	12	16	47	59	38	33	26	774	28	59.5	2.1
Firearms confiscated	5	5	5	5	32	6	8	9	5	10	7	4	2	103	3.7	7.9	0.3
Snares found	70	68	194	218	217	41	47	53	34	39	61	44	9	1095	39.6	84.2	3
Animals found killed	10	6	7	29	57	19	2	5	6	4	6	1	1	153	5.5	11.8	0.02
Total	227	188	332	523	568	201	82	119	116	132	141	92	44	2765	100		

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CHAPTER SIX

6. ASSESSING THE MANAGEMENT EFFECTIVENESS OF THREE PROTECTED AREAS IN GHANA

Interactions with the protected area manager and local communities (Photo by Asare Michael)

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Article

Assessing the Management Effectiveness of Three Protected Areas in Ghana

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Abstract

Assessments of management effectiveness of protected areas offer vital information about threats and management issues at the protected area. However, these assessments are frequently conducted mainly at the internal management level, without input from the local communities that implicitly influence the resources of the protected areas. The aim of this study was to assess the effectiveness of three protected areas in Ghana—Kogyae Strict Nature Reserve, Gbele Resource Reserve, and Kalakpa Resource Reserve—using the Rapid Assessment and Prioritisation of Protected Areas Management assessment tool. The study included workshops with park managers and representatives from local communities, district assemblies, and the Environmental Protection Agency. Poaching, settlements, agricultural encroachment, poverty in nearby communities, and bush fires were identified as common pressures to all the assessed protected areas. The degree of these pressures was influenced by little or no funding, poor community relations, lack of staff and research, and natural resource inventories in the protected areas. Our study highlights the priority of remedial actions that are urgently needed to preserve the protected area resources.

Keywords: biodiversity conservation, bushfire, logging, poaching, settlement, stakeholders, wildlife management

Introduction

Protected areas (PAs) are key sites where conscious efforts are made for the preservation of wildlife and the sustainability of ecosystems (Craigie et al. 2010; Stolton et al. 2015; Lindsey et al. 2017). However, the state of biodiversity is deteriorating globally, compromised by anthropogenic threats that have increased in recent decades (Pereira et al. 2012). The effectiveness of wildlife protection varies greatly across PAs, ranging from effective to almost entirely ineffective with poor or a complete lack of any protective measures (Craigie et al. 2010; Leverington et al. 2010).

Currently, many West African countries are affected by the same kinds of land-use development, i.e., urbanization and agricultural production, that in the past destroyed the original forest cover of many parts of Europe, the United States of America, and large areas of East Asia (International Cooperation and Development 2016). However, societal dynamics in the twenty-first century are connected with the numerous conservation issues facing PAs. Protected area managers are confronted with relentless increasing pressure to cope with these changes.

Assessments of PA management effectiveness offer valuable information about the threats and other management issues that PAs face (Schulze et al. 2017). These assessments create opportunities for all stakeholders, especially policymakers, to improve their conservation strategies, reallocate budget expenditures, and develop strategic responses to the most prevalent threats and management weaknesses (Leverington et al. 2010; Watson et al. 2014). There is, therefore, a call for the periodic assessment of PAs in terms of their management effectiveness, as reported by many authors (e.g., Ervin 2003a; Goodman 2003; Kurdoğlu and Çokçaliskan 2011; Kolahi et al. 2013). In Ghana, the International Union for Conservation of Nature (IUCN/PACO 2010) assessed the management effectiveness of many PAs from the perspective of government authorities, with little or no inclusion of the views and knowledge of local communities, non-governmental organisations, district assemblies, the Environmental Protection Agency (EPA), and other relevant local stakeholders.

However, the local communities are directly dependent upon the natural resources and land-use decisions of these areas for their basic needs and livelihoods. Planning and implementing systems for managing PAs that exclude local communities and other stakeholders have resulted in various conflicts and frustrations, including dislocation, violence, poaching, and poverty among indigenous communities (Amaja et al. 2016; Frank 2016). Involving local communities and other stakeholders in the process can contribute to the effectiveness of PA management since people's perceptions and attitudes towards PAs are influenced by their involvement in the PA management activities and decision-making (Ramakrishnan 2007). It is therefore vital that local communities and other stakeholders be included in PA management effectiveness assessments to bring together a range of vantage points and knowledge for both, aligning interests and innovative problem-solving.

The study, therefore, aims to adopt a more open approach to the assessment of the effectiveness of PA management and seeks to link this assessment not only with PA staff but also with district assemblies, the EPA, and representatives from the local communities in three PAs in different ecoregions in Ghana: The Kalakpa Resource Reserve (Kalakpa), Gbele Resource Reserve (Gbele), and Kogyae Strict Nature Reserve (Kogyae). According to our knowledge, no comprehensive assessments have been done in these PAs as of conducting/publishing the study.

The study was designed to provide an opportunity for local communities and other stakeholders to be involved in policymaking, PA management decisions, and also as a guidance to decision-makers on the management problems and priorities of the three PAs. We, therefore,

present a detailed assessment of the management effectiveness of these PAs and ask the following questions:

a. How do the park authorities, local communities, and other stakeholders perceive pressures and threats in these PAs?
b. How have pressures and threats affected these PAs?
c. What are the strengths and weaknesses of the current PA management?

Materials and Methods

Study areas

Kalakpa, Gbele, and Kogyae are three of the 13 PAs under the management of the Wildlife Division of Ghana. Table 1 gives a summary of the size, elevation, annual rainfall, geographic coordinates, and operational budget for 2018 in the three study areas.

Kalakpa is approximately 100 km northeast of Accra and 20 km south of Ho, the capital of the Volta Region (Figure 1). The natural attributes of the reserves—a lush terrain, good opportunities for wildlife viewing, and proximity to Ghana's capital city—provide an excellent potential for ecotourism. The vegetation of Kalakpa is dry forest, and short grassland savannah, and some commonly found plants include *Cussonia arborea, Daniellia oliveri, Entada abyssinica, Ficus platyphylla, Pterocarpus erinaceus, Vitellaria paradoxa,* and *Afzelia africana*. Mammals regularly encountered in the reserves include African buffalo *Syncerus caffer*, Kob *Kobus kob*, Waterbuck *Kobus ellipsiprymnus*, Oribi *Ourebia ourebi*, and Patas monkey *Erythrocebus patas.*

Gbele is approximately 700 km north of Accra, the capital of Ghana, and located in the Sissala East, Sissala West, and Daffiama-Bussie-Issa political districts of the Upper West region (Figure 1). The vegetation is a woody savannah dominated by *Burkea africana*, *V. paradoxa, Parkia biglobosa, Terminalia spp., P. erinaceus*, and grasses such as *Hyparrhenia spp*. and *Pennisetum spp*. The most common mammals are Olive baboon Papio anubis, Patas monkey, King colobus *Colobus polykomos*, Roan antelope *Hippotragus equinus*, Bushbuck *Tragelaphus scriptus*, Waterbuck, Oribi, and Common warthog *Phacochoerus africanus*.

Kogyae is in the transitional semi-deciduous forest zone of the Ashanti region of Ghana and underlain by the Voltaian geological system (Figure 1). Mammal species of conservation importance in Kogyae include buffalo, Kob, Waterbuck, Bushbuck, Oribi, Maxwell's duiker *Cephalophus maxwelli,* and Bay duiker *Cephalophus dorsalis*. The reserve also supports many primate species, including the Putty-nosed monkey *Cercopithecus nictitans*, King colobus, baboon, and Patas monkey (Wildlife Department 1994). The management of Kogyae is into four zones, namely, the Protected Zone, the Special-Use Zone, the Restoration Zone, and the Development Zone. The Protected Zone is the largest in Kogyae, constituting 220 sq. km and representing 57% of Kogyae. This area of the reserve represents the most important and least disturbed habitat. The Special-Use Zone constitutes 79 sq. km and represents 20% of Kogyae. The Development and Restoration Zones are 1 sq. km and 86 sq. km, representing 1% and 22% of the PA, respectively.

Data collection

We organised separate workshops of 12 to 15 participants to elicit detailed information on the conservation issues and management effectiveness in the three PAs involving park managers,

local community representatives, and representatives from the district assemblies and EPA of Ghana.

In Kogyae, 15 participants were involved in the assessment process, which included the park manager, one representative each from the communities located inside the reserve (Asasebonso, Atakpame, Nyamekyere Dagomba, Birem, Yahayakura, Aberewanko, and Konkomba) and a representative from the political district of Kogyae (Sekyere Central District Assembly). The management effectiveness assessment in Gbele involved the park manager, one representative each from Gbele, Dasima, Duvie, Timie, Sentie, Jijen, Samambaw, and Jolinyiri communities. Additionally, representatives from Sissala East Municipality, Daffiama-Bussie-Issa, and Sissala West political districts, and the EPA, were also actively involved in the assessment process. All local community representatives in the three PAs assessed were selected by local chiefs/leaders of the respective communities. We conducted separate interviews with all park managers in all the PAs. These interviews were followed up by field visits to each PA to verify and further probe the opinions of the stakeholders on conservation issues. We carried out all consultations and interviews from August to October 2018.

Table 1. Description of studied protected areas.

Protected area	Size (km^2)	GPS Coordinates	Elevation (m a.s.l.)	Annual rainfall (mm)	Vegetation type	Operational budget (US$/$km^2$ /year 2018)
Gbele Resource Reserve	565	10° 22' N to 10° 44' N 2° 03' W to 2° 12' W	260–300	950–1050	Guinea savannah	43.34
Kogyae Strict Nature Reserve	386	7° 08'N to 7° 21'N 0° 59'W to 1° 14'W	120–230	1200–1300	Transitional woodland	7.41
Kalakpa Resource Reserve	320	06º 19′ N, 06º 28′ N 00º 18′ E, 00º 30′ E	60–400	1200–1300	Dry forest and short grassland savannah	10.7

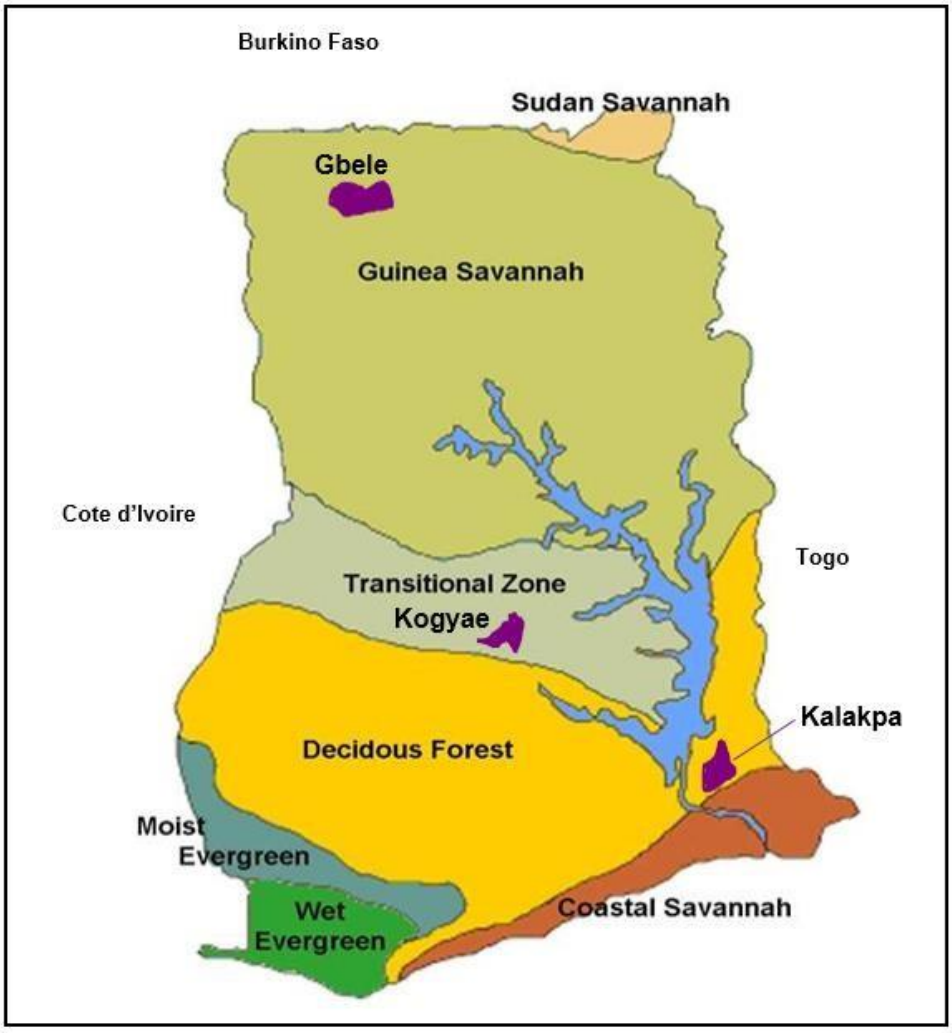

Figure 1 Map showing the location of the three protected areas and the vegetation zones of Ghana (according to Mensah Owusu 2017).

A checklist of questions for the workshop and interviews was adopted and modified from the Rapid Assessment and Prioritisation of Protected Areas Management (RAPPAM) assessment tool (Ervin 2003b; see supplementary material for the RAPPAM questionnaires used in this study). We started each workshop with an overview of the purpose of the assessment, an introduction to the RAPPAM methodology, and an outline of the procedures that to be followed in completing the questionnaire. We projected each question onto an overhead projector screen and explained each question to all participants in each PA (Goodman 2003).

Additionally, we read each question out in English and translated into local languages in each of the PAs, i.e., Twi for participants in Kogyae, Ewe for those in Kalakpa, and Sissali, Dagaare and Twi for the participants in Gbele. Local translators were hired and trained in facilitation to ensure that participants who spoke Ewe, Sissali, and Dagaare were able to understand and freely express their views. The first two authors translated questions from English to Twi. Once there is a complete understanding of all participants, we scored the question, and the attempted next question.

Each workshop lasted for a day and took five to six hours to complete. We used tape-recorder to capture all of the details of the discussion with the full consent of the participants.

Data analysis

We assessed the identified pressures and threats using three indicators (extent, impact, and permanence) as specified in the RAPPAM questionnaire. The 'extent' is the range of the activity's impact on the PA. For instance, the extent of poaching would be measured relative to the possible occurrence of the species population. The 'extent' could be localised, scattered, wide-spread, or throughout. The 'impact' is the degree, either directly or indirectly, to which the pressure affects overall PA resources. The 'impact' could be mild, moderate, high, or severe. The 'permanence' (persistence) is the length of time needed for the affected PA resource to recover with or without human intervention and could be short-term, medium-term, long-term, or permanent. Each identified pressure took a score on each of the indicators (extent, impact, and permanence) on a scale of 1 to 4, where 1 represents the lowest score, and 4represents the highest score. We obtained the degree of each pressure by multiplying the scores of that pressure on the extent, impact, and permanence. In applying the scale values from 1 to 4 on the three indicators, the lowest possible degree is 1, and the highest possible degree is 64. The degree serves as the overall impact of a given pressure/threat on the PA. By way of classification, a degree from 1 to 3 is considered mild, 4 to 9 is moderate, 12 to 24 is high, and 27 to 64 is severe (Ervin 2003b).

To determine the strength and weaknesses (management effectiveness) of the PAs, i.e., planning, inputs, processes, and outputs, we used a numerical index using statements with four options: *yes* = 5, *mostly yes* = 3, *mostly no* = 1, or *no* = 0. A score of 5 does not necessarily mean that there is no problem, and a score of 0 does not indicate a total failure (Ervin 2003b). The average scores were calculated as a percentage of the maximum possible score and compared with global average values (Leverington et al. 2010; Kolahi et al. 2013).

Results

Pressures and threats and their effects on the PAs

Based on our results from the workshops, settlements, bush fires, agricultural encroachment, poaching, and poverty in nearby communities were pressures and threats common to all the three PAs; they were perceived, however, to have a varying degree of severity, the score ranging from 9 to 96 (Figure 2). In Kalakpa, participants perceived settlements as the extreme pressure and threat (63), followed by logging (54) and charcoal production (45). However, human settlements in Kalakpa are considered illegal by the Wildlife Authorities and the government. Other pressures and threats mentioned by participants during the workshop in Kalakpa were agricultural encroachment (35), grazing (35), and bush fires (30). Meanwhile, in Kogyae, participants perceived bush fires as the most extreme pressure and threat (scored 96), agriculture encroachment, and population increase (both at 54). Settlements (34) and poverty in nearby communities (30) were

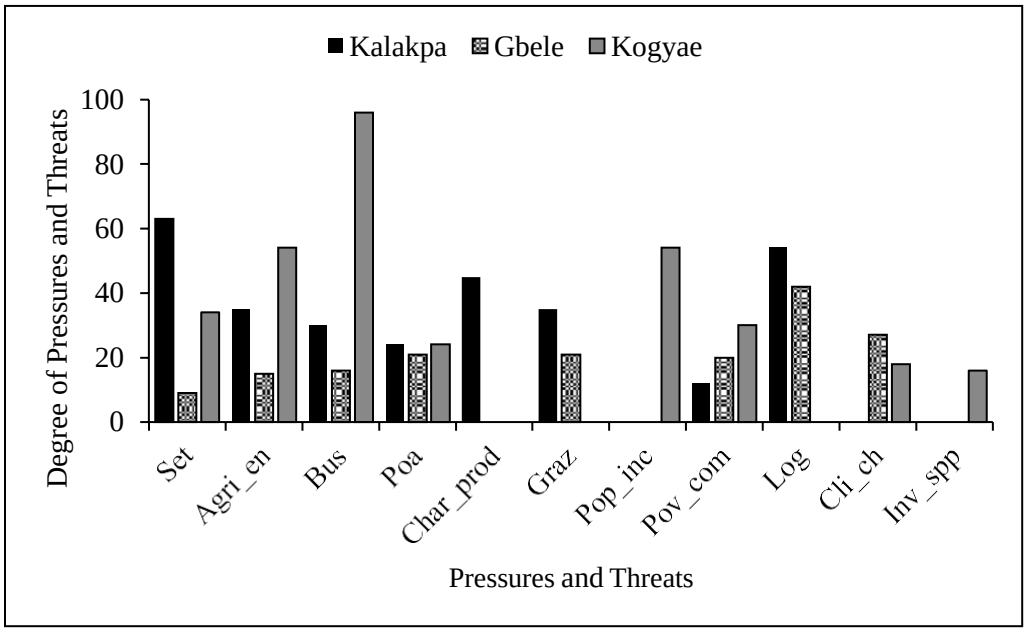

Figure 2 Assessment of the degree of severity of pressures and threats by participants in Kalakpa Resource Reserve, Gbele Resource Reserve, and Kogyae Strict Nature Reserve severity of the pressures and threats. Abbreviations: Set, Settlements; Agri_en, Agricultural encroachment; Bus, Bushfires; Poa, Poaching; Char_prod, Charcoal production; Graz, Grazing; Pop_inc, Population increase; Pov_com, Poverty in nearby communities; Log, Logging; Cli_ch, Climate change; Inv_spp, Invasive species.

also perceived as pressures and threats in Kogyae. Participants revealed that bushfire is an annual activity that threatens the ecological stability of Kogyae. The most extreme pressures and threats in Gbele were logging (42), climate change (27), and poaching, and grazing (both at 21). Others mentioned by participants were poverty in nearby communities (20), bush fires (16), and agriculture encroachment (15). Although participants considered settlements as pressure and threat in Gbele and Kogyae, these settlements were legally established, and in Kogyae, they are designated as the Special-use Zone. Participants in all the workshops agreed that settlements increased the direct pressures and threats facing the PAs, including bush fires, poaching, agriculture encroachment, grazing, and charcoal production. All the PAs were faced with habitat loss/fragmentation, wildlife population decline, the spread of invasive species, and increased drought. Table 2 gives a summary of the pressures and threats in all the PAs, their implications for management, and solutions based on responses from participants and field visits.

Management effectiveness (strength and weaknesses) of PAs

The management effectiveness assessment, including planning, inputs, processes, and outputs of the three PAs, had the overall average scores (in %) as follows: Kalakpa (46), Gbele (55), and Kogyae (50). The scores for Kalakpa and Kogyae were lower than the overall global average of management effectiveness score for PAs of 54%, indicating deficiencies in their management. However, the overall average for Gbele (55%) was higher than the global average score (54%), indicating effective management practices (Figure 3).

Based on the performance of the various management elements, Gbele and Kogyae scored the highest in terms of the "planning'' element and Kalakpa scoring the lowest (Figure 3). The score for Kogyae in the 'planning' was the highest among its scores in all the other elements. Meanwhile, the management effectiveness score for Kalakpa was lowest in all the assessed elements, except for the 'output' element where Kogyae scored the least. The scoring for Gbele was also highest in the input, processes,

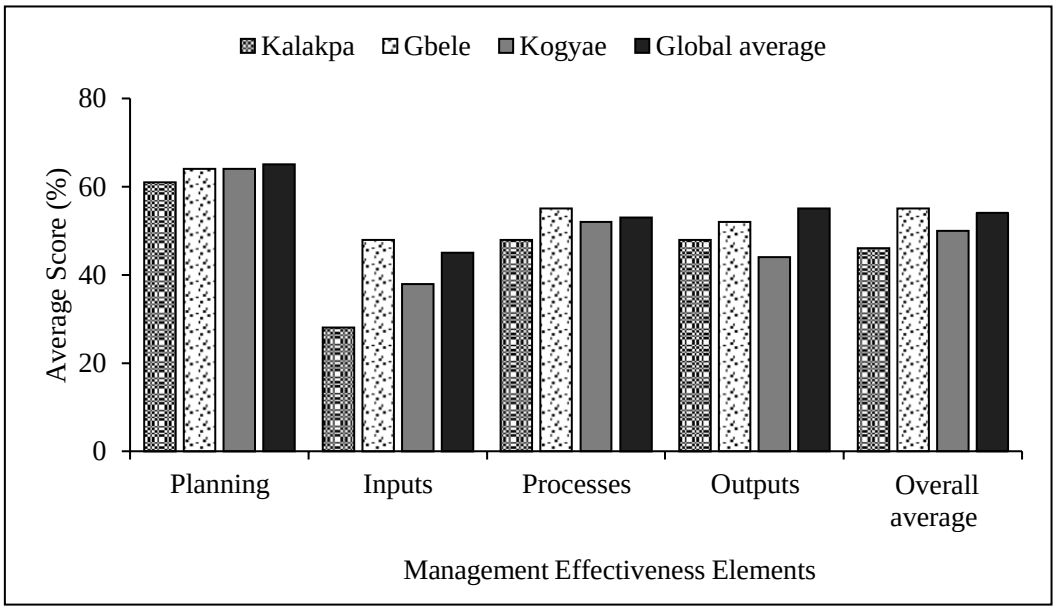

Figure 3 Assessment of the management effectiveness of Kalakpa Resource Reserve, Gbele Resource Reserve, and Kogyae Strict Nature Reserve by participants based on RAPPAM and compared with global averages.

and output elements. However, within the various elements, the participants perceived some weaknesses in the management of these protected areas (Table 3). Under the planning element, the lack of local support, disputes of land tenure, and lack of funds for critical law enforcement were common weaknesses in the three PAs assessed. These were perceived to have led to the increased pressures and threats and the lack of support for conservation from the local communities. Similarly, all the three PAs had lower scores in inadequate staff, poor employment conditions, and poor infrastructure under the 'input' element.

Under the 'process' element, Kalakpa and Kogyae scored the lowest in terms of a "recent and comprehensive management plan." The implication is that the management of the PAs had no mechanism to apply the PA policies. Another area of poor performance was in research, monitoring, and evaluation. Except for Kogyae, the other two PAs had low scores in all the items under "research, monitoring, and evaluation."

The 'output' element of the assessment shows the effects of management actions, the achievement of goals, and management of the pressures and threats achieved by the authorities of the PAs over the past two years. To an extent, the score in this element reflects the evaluation results of the others previously mentioned.

Comments of participants

During the workshops, we collected comments from the stakeholders concerning the capacity and the positions by the management authorities, and the different perspectives of pressures and threats, and their implications and also management solutions in the three PAs (Tables 2 and 3).

The majority of the participants in all the three PAs supported and recognised the importance of the assessment. However, the local community representatives who formed the majority of participants in all the PAs were concerned about the lack of involvement of local communities in the PA decision-making process and management. Although the PA authorities acknowledged this concern, they also argued that local communities must support wildlife conservation by reducing activities that hamper conservation efforts. The PA authorities, especially in Gbele, assured the local communities of their involvement in the decision-making process since measures were in place to establish Community Resource Management Areas (CREMA) and Protected Area Management Advisory Board (PAMAB). The CREMA and PAMAB support participatory management of the PAs and are successful in other PAs in Ghana (IUCN/PACO 2010).

Table 2 Stakeholders perception of pressures and Threats, their causes, implications and possible solutions in Kalakpa Resource Reserve,Kogyae Strict Nature Reserve, and Gbele Resource Reserve.

Pressures and Threats	Kalakpa	Kogyae	Gbele	Causes	Implications	I
Settlements	✓	✓	✓	Land tenure issues	Increase in direct pressures	I c i p a
Agricultural encroachment	✓	✓	✓	Settlements in the PAs; Population Increase; Poverty	Habitat loss/degradation/fragmentation; Wildlife population decline	S a r s
Bushfires	✓	✓	✓	Settlement activities (slash and burn agriculture, hunting, smoking)	Habitat loss/degradation/fragmentation; Wildlife population decline; invasive species	S e a i
Poaching	✓	✓	✓	High demand for protein; Subsistence needs; Economic gains; Ineffective law enforcement	A decline in Wildlife population	S a a a
Charcoal production	✓	-	-	Settlements in the reserves; Lack of employment	Habitat loss/degradation/fragmentation	C c a
Grazing	✓	-	✓	Settlements	Habitat loss/degradation/fragmentation	I p p f

Table 2 continued

Pressures and Threats	Kalakpa	Kogyae	Gbele	Causes	Implications
Poverty in nearby communities	✓	✓	✓	Poor national economic policies and governance	Increase direct pressures on protec area resources
Population increase	-	✓	-	Migration; No proper population control measures	Increase in direct pressures on protected area resources
Logging	✓	-	✓	Settlements; High economic gains; Corruption between perpetrators and wildlife officials	Habitat loss/degradation
Climate change	-	✓	✓	Human activities through emission	Increased drought; Desertification
Invasive species	-	✓	-	Continuous bushfires	The spread of *Chromolaena odorata* which prevents natural tree regeneration

Note: ✓ indicates existing pressure/threat in the PA
- Non-identified pressure/threat in the PA

Discussion

Pressures, threats, and their effects on the PAs

Settlements

Human settlements in the three PAs contributed to most of the pressures and threats. Due to the dangers from settlement activities, the Wildlife Division, in collaboration with its donor partners, started constructing a new resettlement site in Gbele, approximately 4 km outside the reserve boundary, for the relocation of the inhabitants of the Gbele community. However, in Kalakpa, there is currently no established process from the government to relocate the inhabitants. Since policy prohibits the Government of Ghana from providing services to these illegal residents, there are no facilities inside the reserve, i.e., no schools, electricity, health facilities, piped water, or boreholes. The lack of such basic amenities further deepens residents' poverty, resulting in their direct dependence on the park's resources. However, human settlements usually cause the degradation of park health and ecosystem services, as reported for instance in Khojir National Park in Iran (Kolahi et al. 2013) or in Côte d'Ivoire where the Marahoué National Park, Mont Péko National Park, and Monogaga Forest Reserve contain over 10,000 inhabitants each, resulting in increased poaching and forest degradation (Bitty et al. 2015). On the other hand, the absence of land tenure conflicts in PAs was positively associated with reduced deforestation (Nolte et al. 2013). Therefore, PAs cannot be managed effectively and fulfil their objectives without solving human settlement issues, either by resettling the inhabitants outside or finding a new strategy for co-existing.

Agricultural encroachment

Agricultural encroachment was the most prevalent either on the borders or inside the PAs. Some of Ghana's forest reserves were destroyed by agricultural encroachment following settlement by immigrant farmers, namely, in the Bia-Tawya and Sukusuku Forest Reserves (Danquah 2015). These forests were intended to be buffers around the Bia Conservation Area, established to protect the rare primates and other wildlife. The conversion of PAs into crop-production lands, such as oil palm, rubber, and cocoa farms, were responsible for the decline in wildlife; see, for instance, the reduction of Côte d'Ivoire's primate population (Woods 2003; Gonédélé et al. 2012). To reduce the encroachment of agriculture in PAs, authorities must ensure the intensification of agriculture outside PAs through the provision of fertilisers, irrigation facilities, credit facilities, improve market access, develop high-yield crops, and adopt genetically modified crops.

Poaching

Poaching is one of the causes of wildlife population decline in the world (Newmark 2008).

Table 3. Stakeholders' perception of management weaknesses, their implications and possible solutions.

Management Effectiveness	Management weaknesses			Implications
	Kalakpa	**Kogyae**	**Gbele**	
Planning	Lack of support from local communities	Lack of support from local communities	Lack of support from local communities	Increase PA pressures and threats; Lack of support for PA conservation
	Disputes of land tenure	Disputes of land tenure	Disputes of land tenure	Increase encroachment; Lack of support for PA conservation; Increased conflicts between PA authorities and Local communities
	Lack of funds for law enforcement	Lack of funds for law enforcement	Lack of funds for law enforcement	Increase in poaching and other human activities
	Adjacent land use	Adjacent land use; Poor PA zoning system	Poor PA layout	Increase encroachment
	Unresolved conflicts with local communities	-	-	Lack of support for successful conservation
Inputs	Inadequate PA staff	Inadequate PA staff	Inadequate PA staff	Ineffective law enforcement
	Poor employment conditions; Poor training of staff	Poor employment conditions	Poor employment conditions	The low motivation of PA staff

Table 3 continued

Management Effectiveness	Management weaknesses			Implications
	Kalakpa	**Kogyae**	**Gbele**	
Inputs	Inadequate means of communication between field staff and office staff	Lack of ecological and socioeconomic data	Inadequate means of communication between field staff and office staff	No knowledge of the changes in vegetation cover and wildlife population for proper management actions; No knowledge of socio-economic information of local communities; Lack of collaboration between field and office staff
	Poor Infrastructure	Poor infrastructure; Inadequate systems for data analyses	Poor infrastructure	Low motivation of staff; Lack of scientific information and technology for effective PA
	Inadequate funding	Inadequate funding	Inadequate funding in the next 5 years	Poor PA management operations
Processes	Outdated Management plan	Outdated Management plan		No mechanism to apply PA legislation and policy; lack of continuity
	Poor Research, Evaluation, and Monitoring	No comprehensive inventory of natural/cultural resources	Poor Research, Evaluation, and Monitoring	No knowledge of the status of PA resources and factors affecting conservation efforts
		Lack of participation of local communities in decision making		Lack of support for PA conservation
		No regular access to scientific data to PA staff		Lack of knowledge on the current trends in PA management

Table 3 continued

Management Effectiveness	Management weaknesses			Implications
	Kalakpa	**Kogyae**	**Gbele**	
Outputs	Poor site restoration measures	No site restoration measures	Poor visitors and tourist management	Continued habitat loss; Loss of revenue from tourism
	Poor visitors and tourist; Poor staff training and development management	Poor infrastructure development	Poor staff training and development	Loss of revenue through few visitors and tourists; Low staff motivation; Lack of skills for effective PA management
		No management planning and inventorying		No knowledge of the status of PA resources
	Lack of research and monitoring outputs	Lack of research and monitoring outputs	Lack of research and monitoring outputs	Poor knowledge of the status of the PA and factors affecting its conservation

However, in Kogyae, there is stability in poaching since 2012 in comparison to high rates in previous years (Afriyie et al. 2020), whereas in Gbele, it has drastically reduced (Wildlife Division 2017). This is mainly because of the high interest in and market value in the trade of Kosso Pterocarpus erinaceus. Poaching in Kalakpa is relatively low because of the movement of most animals away from areas close to human settlements and towards the northern part of the reserve, where there is little or no human presence, and there is active law enforcement. More efficient ranger patrols will deter poaching-related threats and may lead to the arrest of poachers. Additionally, community-based conservation (Steinmetz et al. 2014), and or alternative livelihood projects (Wright et al. 2016) are also important in reducing poaching because they involve the local community in the conservation of PAs through various means. In areas with high levels of poverty, such as Ghana, these approaches could be instrumental because they provide local communities with an alternative source of livelihood (Milder et al. 2010).

Bush fires

In transitional and savanna ecosystems, fires are known to important stress factors and are more intense and frequent inside than outside the PAs (Caillault 2011). Officials in Kogyae blamed the origin of the bush fires on the activities of residents in the Special-use Zone, but the local community representatives alleged that the fires usually started from the Protected Zone, which is accessible exclusively to officials of the Wildlife Division. Though the lack of communication and collaboration between the Wildlife Division authorities and local communities caused the recrimination, it also reveals the differing opinions of various stakeholders and their openness during the assessment processes. It is, therefore, important to provide opportunities for the participants to comment on the role and position of the PA management authorities before classifying the pressures and the threats for PAs by reflecting on the area's situation and providing direct feedback to site management (Lu et al. 2012).

In Gbele, bush fires caused the degradation of parts of the reserve, revealed by a time series map between 1990, 2000, and 2010 (Wildlife Division 2017). Bush fires sweep through these reserves from inside and surrounding areas. However, human activities cause bush fires, e.g., from livestock herdsmen who intentionally burn dried grass in the dry season to induce the early sprouting of fresh grass for forage. Moreover, poachers also start fires to force animals out of their hideouts, and also by palm wine tappers, local gin distillers, farmers, and cigarette smokers (Ayivor and Ntiamoa-Baidu 2015). These activities are highly destructive but deeply ingrained in the local culture in all of the assessed PAs.

Logging

Although regulations and laws prohibit logging in all PAs and wildlife reserves in Ghana, the illegal logging of rosewood in Gbele and Kalakpa has recently emerged. The rapidly increasing demand for rosewood in China, the top market, and consumer of rosewood, has led to increased and illegal exploitation in these reserves (Treanor 2015). The United Nations Office of Drugs and Crime (UNODC) in 2016 reported that rosewoods seized accounted, at 35%, for the highest proportion of all wildlife confiscated from 2005 to 2014 (UNODC 2016).

Concerns about the exploitation of rosewood in the fragile savannah and transitional ecosystems led to the imposition of two export bans in Ghana (Dumenu and Bandoh 2016). The

latest ban in 2014 is still in place. In Kalakpa, there was evidence of rosewood harvesting through the numerous rosewood stumps, among others, found during field visits. However, the local community representatives accused some field staff working with Kalakpa have granted individuals and wood companies' access to the reserve to fell rosewood. Elsewhere in Ghana, Saibu (2016) reported that the invasion of local people's farms and Mole National Park by loggers for the extraction of rosewood is also active despite the ban. Exploitation in the face of an active ban reflects the current situation in many range countries in West Africa. Benin, Burkina Faso, Cote d'Ivoire, Mali, Nigeria, and Sierra Leone have long-standing bans on harvesting and export of rosewood, yet China Customs reports significant imports of rosewood logs from these countries (Gueye 2015; EIA, 2017). Though there have been efforts to arrest and prosecute illegal loggers (Luri 2017), the current development raises concerns about the impact of the rate and level of exploitation on the conservation of these PAs, with the current management resources being inadequate to prevent this situation. Protected area managers must, therefore, ensure strict law enforcement, and engage local community members as 'watchdogs' in monitoring the exploitation of rosewood.

Grazing

Livestock grazing causes severe habitat degradation and has multiple effects on wild herbivore distributions (Maxwell et al. 2016). In Kalakpa, approximately 90% of households engage in several livelihood activities, such as farming and livestock rearing, that are the most destructive to Kalakpa's natural environment (pers. obs). The cattle population in the reserve is estimated to be at least 7000 heads (Akunnor Samuel, pers. comm.) and resulted in overgrazing in many areas. In Gbele, grazing only occurs in the reserve when communities experience a shortage of pasture and water sources in village lands, especially during dry seasons. Kideghesho et al. (2012) and Mwakatobe et al. (2013) reported similar situations in Serengeti National Park in Tanzania. Moreover, livestock grazing is widespread in tropical regions (de Haan et al. 1997), including inside PAs (Naughton-Treves et al. 2006), where often, livestock are left to range freely to feed on the native vegetation (Stern et al. 2002). In some cases, livestock owners' clear natural areas favour the growth of native or introduced pastures that are beneficial for livestock which changes the forest structure and also affects the diversity of wildlife (Piana and Marsdenm 2014). The wildlife authorities must, therefore, provide measures such as pasture and livestock management to reduce the negative impact of grazing on the PAs.

Charcoal production

Following the comments from participants, charcoal production is a means of earning money when other preferred options are no longer viable or sufficiently productive. Local communities in Kalakpa produce charcoal to generate additional income because of large family size (Sunderlin et al. 2005). Charcoal production, together with wood harvesting, clearly results in a decrease of natural habitats, as reported, for instance, in the Mekrou Forest Reserve in Benin (Bouko et al. 2016) and the Fina Wildlife Reserve in Mali (Diallo et al. 2011). Given that charcoal production has severe impacts on biodiversity we suggest that protected area management planning should systematically include mechanisms to detect, understand, and mitigate or adapt to livelihood change to minimize its potential negative effects.

Poverty in nearby communities

Poverty in nearby communities in the assessed PAs reflects what pertains worldwide (Scherl et al. 2004). While the poverty rate in Ghana has decreased from 85.4% in 1998 to 56.9% by 2016, poverty persists in many rural areas (Ghana Statistical Service; GSS 2016). Contrary to earlier studies by the IUCN/PACO (2010) in nine PAs in Ghana, poverty in nearby communities were not considered to be a pressure or threat to the PAs. However, since the economic conditions of most communities in and around PAs in Ghana are similar, the exclusion of such pressure or threat is attributed to the lack of involvement of other stakeholders during the assessment process of these areas. It must be stated that reducing or eradicating poverty in the nearby communities is not within the jurisdiction of PA authorities and may only be effectively managed by national-level policy reforms and resources. It is possible that involving only PA managers during the assessment, as was the case in the IUCN/PACO assessment (IUCN/PACO 2010), may not give accurate results since they may consider only pressures and threats whose impacts can be prevented, mitigated or reversed through management intervention. It is therefore imperative that wider consultation including local communities and other stakeholders should be considered in management effectiveness assessments.

Population increase

The high influx of migrant populations over the past decades and an increase in the indigenous population caused the rise in the population of settlements in Kogyae and surrounding communities. Population data indicates that between 1960 and 2010, the population of fringe communities increased by 600% on average (GSS 1984, 2014). High populations in and around PAs result in increased demand for food and fuelwood, which is evident in the high degree of severity of agricultural encroachment in Kogyae and may lead to a significant decline in the wildlife population (Metzger et al. 2010). As the human population grows around PAs, collisions between these areas and people struggling to find land on which to survive will continue. Governments and policymakers must link the development of urban areas with rural areas by providing diversified sources of income, and also investing in rural economies. Moreover, connecting existing PAs through corridors (Anderson and Jenkins 2006) and creating future PAs in places where they can be most effective are much needed.

Invasive species

The spread of main invasive species in Kogyae, Chromolaena odorata, is attributed to forest gaps created by frequent bush fires. Ch. odorata has affected many PAs in Africa, such as Hluhluwe-Imfolozi National Park in Kwazulu-Natal, South Africa, where Ch. Odorata has covered almost half of the park (IUCN/PAPACO 2013). In Cameroon, Ch. odorata displaced native species in the Zingiberaceae family, the main food source for the endangered Western lowland gorilla Gorilla gorilla gorilla (Van der Hoeven and Prins 2007). Invasive species, in general, pose a significant threat to PAs worldwide (Foxcroft et al. 2013a) but are rarely recognised as a threat in Africa, except in South Africa (Foxcroft et al. 2013b). The lack of information on the severity of the invasions indicates the failure of the management of PAs to address the issue effectively.

Climate change

The changing climate has had adverse effects on Kogyae and Gbele and in many parts of Ghana (Environmental Protection Agency, EPA 2011). Severe droughts caused by the change in climate in Kogyae led to animals foraging outside the reserve and making them susceptible to poaching (Jachmann 2008). However, the park management has taken steps to build many artificial watering points in the reserve to curb the problem. The savannah zone of Ghana—where Gbele is located—is considered more vulnerable to the effects of climate change, as this area has only one rainy season compared to the two rainy seasons in the transitional and the forest zones (Asante and Amuakuah-Mensah 2015). Over the years, the temperatures in all the ecological zones of Ghana are rising, while rainfall levels have generally reduced and patterns increasingly becoming erratic (EPA 2011). Ghana has therefore developed a National Climate Change Adaptation Strategy, which aims to enhance Ghana's current and future development to climate change impacts by strengthening the country's adaptive capacity and building the resilience of the society and ecosystems.

Management effectiveness

The assessment of management effectiveness reveals the system-wide strengths and weaknesses of PAs. Compared to other assessment elements, planning ranked as a qualified strength across all three PAs. The protection and conservation of biodiversity were the primary objectives of management in all PAs. Management plans and policies were consistent with those objectives, and PA employees were generally familiar with these objectives. Moreover, the PAs were legally secure, and their settings were consistent with their objectives. However, the lower score of 'planning' under the theme 'site design and planning' for Kalakpa relates to the 35+ years of illegal settlements in the park, increasing the pressures and threats in the park.

Additionally, the lack of local community support in conservation and disputes of land tenure was deficient in all the three PAs. Developing and improving the relationship between the PA authorities and local communities is vital to achieving the PA's conservation goals. Participatory management is, therefore, paramount in the management of the PAs (Kolahi et al. 2013). Collaborative management will protect local communities' rights and interests and focus on a management body that represents all stakeholders equitably. Generally, the planning element in the RAPPAM methodology has received the highest score in most PAs assessed around the world, including for instance those in Russia (Tyrlyshkin et al. 2003), China (Diqiang et al. 2003), and Turkey (Kurdoğlu and Çokçaliskan 2011).

In terms of inputs, the highest scores for Gbele were as a result of external funding from the Sustainable Land and Water Management Project (SLWMP) sponsored by the World Bank and Global Environmental Facility, which began in 2011 and ends in 2020. Kalakpa, which had the lowest management input scores, has insufficient funds, and consequently, extremely inadequate staff facilities and equipment and poor visitor facilities. The primary sources of funds for PAs in Ghana are the Government funds, the internally generated funds from the Forestry Commission of Ghana, and the contributions by the donor agencies/governments. Insufficient funding often creates a shortfall that is extremely difficult to overcome, even when PAs have well-trained and highly motivated staff. According to officials of the Wildlife Division, PAs have approximately 55-60% of the staff needed for effective management. Lack of staff, funding, inadequate facilities, and

equipment are some of the causes of poor management in PAs at a global level (Leverington et al. 2010; Lu et al. 2012; Kolahi et al. 2013; López-Rodrígueza and Rosado 2017).

The lack of a management plan for Kogyae and Kalakpa suggests that these two PAs lack the support of a specific and workable plan. Without management plans in PAs, it will be difficult for the management of PAs to know the progress of management actions leading to difficulties in the allocation of resources by governments and other funding agencies (Kolahi et al. 2013). In all three PAs, there is inadequate research, long-term and regular evaluation, and monitoring of biodiversity. Consequently, there is a lack of knowledge of the proper ecosystem, the state of the biodiversity, key species, and ecological relationships that when applied in management decision-making, would make conservation more effective (Niesenbaum, 2019). Unfortunately, few PAs in the worldhave comprehensive research, monitoring, and evaluation programmes (Lockwood et al. 2012; Kolahi et al. 2013; López-Rodríguez and Rosado 2017). Hence, research and monitoring are frequently reported as the weakest output of PAs' management effectiveness assessments (e.g., Liet al. 2003).

Inputs of local communities and other stakeholders

We emphasise the participation of local communities in the assessment process. Our approach is mostly different from numerous RAPPAM assessments, in which, primarily the people from management authorities and sometimes from non-governmental organisations are involved. In this study, we allowed local communities and other stakeholders to voice their opinions and to be involved more in the discussions. Open discussions helped the gathering of comments of different stakeholders and to clarify and communicate the present condition of the PAs with the stakeholders, who usually lacked the means to receive relevant, comprehensive, and accurate information. Moreover, the open discussion generated diverse opinions among stakeholders to avoid restrictions in the assessment process or depend only on experts' opinions (Stoll-Kleemann 2010; Cook and Hockings 2011).

Conclusion

Applying the RAPPAM methodology, this study conducted the first extensive and explicit management effectiveness assessment in PAs in Ghana. Although this wide-ranging consultation process of the RAPPAM methodology has not always been a feature of the implementation, this study involved representatives of local communities, district assemblies, and the Environmental Protection Agency, which reflected the different perspectives, especially in terms of the pressures and threats. The extensive consultations increased the participation of stakeholders, helped to collect and share comprehensive information, and increased data quality, which created more responses to the inquiries concerning PA assessments. The studied PAs face intense external pressures and threats from human activities deeply influenced by the macro-economic and social environments of Ghana. Well-resourced management can effectively deal with threats by setting priorities, developing situation analyses, and designing and executing strategic and monitoring plans. However, the effects of pressures and threats deepen with the lack of support from local communities, inadequate funding, and management resources in these PAs.

Our findings lead us to suggest the following priorities for government and management decisions: a) create or speed up measures for collaborative PA management; b) increase funding and also plan for long-term financial sustainability for PAs by extending the time frame of interventions; c) improve research and monitoring systems that facilitate adaptive management.

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The authors declare no conflict of interest.

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Supplementary Material

Checklist of RAPPAM questionnaires used in this study

Context

Pressures and Threats (as identified by participants during the workshop)

Planning

Management Objectives

• The protected areas objectives provide for the protection and maintenance of biodiversity.
• Specific biodiversity-related objectives are clearly stated in the management plan.
• Protected areas employees and administrators understand the protected area objectives, practices, policies and regulation.
• Management policies and plans are consistent with the protected area objectives.
• Local communities support the overall objectives of the protected areas.

Legal Security

• Both protected areas have long-term legally binding protection
• There are no unsettled disputes regarding land tenure or use rights or on the existence of passage rights, etc.
• Boundary demarcation is adequate to meet the protected areas objectives
• Staff and financial resources are adequate to conduct critical law enforcement activities within the protected areas.
• Conflicts with the local communities are resolved fairly and effectively.

Site Design and Planning

• The sitting of the protected areas is consistent with the protected areas objectives.
• The layout and configuration of the protected areas under study optimizes the conservation of biodiversity.
• The protected areas zoning system is adequate to achieve the protected areas objectives.
• The land use in the surrounding area enables effective protected area management.
• The protected area is linked to another area of conserved or protected land.

Inputs

Staffing

• The number of staff is sufficient to manage the protected area effectively
• Staff members have adequate skills to conduct critical protected area management activities.
• Training and development opportunities are appropriate to the needs of the staff.
• Staff performance and progress on targets are reviewed periodically.
• Staff employment conditions such as salaries, and work environment are sufficient to retain high-quality staff.

Communication and Information

• There are adequate means of communication between rangers and office staff.
• Existing ecological and socio-economic data are adequate for management planning.
• There are adequate means of collecting new data.

• There are adequate systems for processing and analyzing data.
• There is effective communication with local communities

Infrastructure
• Transportation infrastructure is adequate to perform critical protected area management activities.
• Field equipment is adequate to perform critical protected area management activities.
• Staff facilities are adequate to perform critical protected area management activities.
• Maintenance and care of equipment is adequate to ensure long-term use.
• Visitor facilities are appropriate to the level of visitor use.

Finances
• Funding in the past 5 years has been adequate to conduct critical protected area management activities.
• Funding for the next 3 years is adequate to conduct critical protected area management activities.
• Financial management practices enable efficient and effective protected area management.
•The allocation of expenditures is appropriate to protected area priorities and objectives.
• The long-term financial outlook for the protected areas is stable.

Management Processes
Management Planning
• There is a comprehensive, relatively recent written management plan.
• There is a comprehensive inventory of natural and cultural resources as well as detailed maps of the protected areas.
• There is an analysis of, and strategy for addressing the protected areas threats and pressures.
• A detailed work plan (annual for example) identifies specific targets for achieving the protected areas management objectives.
• The results of research and monitoring are routinely incorporated into planning.

Management decision making
• There is clear internal organization.
• Management decision making is transparent.
• Protected areas staff regularly collaborate with partners, local communities, and other organizations.
• Local communities participate in decisions that affect them.
• There is effective communication among all levels of protected area staff and administration.

Research, Evaluation and Monitoring
• The impacts of legal and illegal uses of the protected areas are accurately monitored and recorded.
• Research on key ecological issues is consistent with the needs of the protected areas.
• Research on key social issues is consistent with the needs of the protected areas.
• Protected area staff members have regular access to recent scientific research and advice.
• Critical research and monitoring needs are identified and prioritized.

Outputs
• Threat prevention, detection. and law enforcement.
• Site restoration and mitigation efforts.
• Wildlife or habitat management.

- Community outreach and education efforts.
- Visitor and tourist management.
- Infrastructure development.
- Management planning and inventorying.
- Staff monitoring, supervision, and evaluation.
- Staff training and development.
- Research and monitoring output

CHAPTER SEVEN

7. SYNTHESIS

Protected areas (PAs) have become the bedrock of conservation in many parts of the World. Effective management of PAs is needed to reduce human pressure and sustain biodiversity (Watson et al. 2014). Additionally, there is an increasing attention on the role of PAs in cooperation and support of local communities mainly to achieve conservation outcomes across the biological and socio-economic strata. Effective management of PAs is about management interventions that achieve the overall objectives of the PA and includes defining and allocating tasks, responsibilities, and accountabilities regarding capacity, resources, enforcement, and decisions. However, many of the set targets for PAs are difficult to achieve especially in developing countries like Ghana. Studies on management approaches that involve local communities are scarce in Ghana (Dewu & Røskaft 2018; Abukari & Mwalyosi 2020). Moreover, even with the top-down governance style that includes strict enforcement, few studies have analysed the impact of law enforcement efforts in PAs in Ghana, especially in the long term. In this thesis, the focus was on how effective protected area management is including the law enforcement monitoring system and local communities' knowledge about ecological processes.

The results of the study showed that the law enforcement monitoring system was effective enough in observing and reducing illegal activities in the PA. However, in assessing the long-term law enforcement monitoring data, it was revealed that in the years where rangers' performance was low, illegal activities increased and *vice versa*. The meaning here is that regular law enforcement operations indirectly communicate to illegal activists that the PAs and their wildlife are valued and are beingwatched. Furthermore, the study revealed that law enforcement can be highly effective and can lead to a sustained decline in illegal activities. However, without a clear understanding and supportof the factors contributing to these activities, as well as the structures needed to deal with them, it will be difficult to improve conservation in the PAs (Nutakor et al. 2011). For example, the lack of logistic supply for rangers in the study led to a decline in patrol performance which contributed to an increase in illegal activities. Furthermore, law enforcement tools such as SMART and MIST were not used in the study area. Although these tools have been used in certain PAs in Ghana (e.g., Mole and Kyabobo National Parks), its effectiveness in ensuring proper adaptive management approaches should guide Wildlife authorities to provide such tools in all PAs. The importance of these tools was reflected in the increased staff performance and reduced illegal activities in both PAs since its inception in 2004 (Jachmann 2008a).

A difficult work environment for wildlife rangers causes occupational stress with implications for work enjoyment and performance as similarly reported among rangers in Uganda (Moreto 2016). Also, in many areas, rangers often report the lack of basic equipment for patrols which makes their work difficult and sometimes impossible to fulfil (Spira et al. 2019). In a global surveyof 7100 rangers, a little over half of them felt that they had inadequate basic equipment to carry outtheir duties (Belecky et al. 2019). For effective PA management and biodiversity conservation the welfare of rangers and their basic resource and training needs must be properly addressed.

Although law enforcement is a vital component of PA management it is not the only solution; complementary strategies that focus on the drivers of resource extraction are also required. These mainly involve the cooperation of local communities in PA management. Successful PA management depends on the collaboration, involvement, and support of local communities (Barkin & Bouchez 2002; de Beer & Marais 2005; Andrade & Rhodes 2012). Local communities adjacent to PAs are perceived as playing a vital role in achieving conservation targets and sustainability

goals, due to their continuous interactions, through resource uses and knowledge of surrounding environments (Schelhas et al. 2002). For this reason, the study further looked at local communities' knowledge of the animal population and illegal hunting activities in PAs.

To effectively respond to erratic global changes to biodiversity, PA managers must be provided with updated and accurate information about ecological processes. Usually, scientific data are used to estimate the population size, ecology, and threats to species and their habitats. Processing of data and rigorous scientific interpretations take time and outputs are laggingwhat happens at site, sometimes five years and more. However, the knowledge of local communities has been acknowledged by conservationists as extremely rich but often ignored information on the dynamics of the environment, biodiversity, and local conditions. LEK is developed through continuing relations with the natural environment, producing a rich understanding of the surrounding ecology. Numerous research recognises the significant adaptivecapacity of LEK and the ability for local people to understand changing social and environmentalconditions (e.g., Díaz et al. 2015; Braga-Pereira et al. 2021).

In this thesis, it was revealed that most of the local communities had adequate knowledge of the status of mammal numbers in a PA. To validate local people's knowledge of mammal abundance, their information was compared with the law enforcement monitoring data collected over 12 years (2006-2018). In most cases, local communities' knowledge of the abundance of a particular species was complemented by the range-based monitoring data. Where local communities were unable to identify certain species, it meant that these species were generally locally rare as revealed in the ranger-based monitoring data. For example, local communities' inability to identify hartebeest as present in the Kogyae Strict Nature Reserve was confirmed by the range-based monitoring system where it was only encountered by rangers in 2006. There have been no encounters of hartebeest since then indicating local communities' knowledge of the dynamics of their natural environment.

Furthermore, the thesis revealed a greater knowledge of local communities about illegal hunting activities in protected areas. Most studies on LEK focused on biodiversity conservation and monitoring of species and ecosystems (e.g., La Torre-Cuadros & Arnillas-Merino 2012; Sutherland et al. 2014, Tengö et al. 2014; Johnson et al. 2015). However, studies on the in-depth knowledge of local communities about illegal hunting activities are scanty all over the world. Local communities' knowledge of the decrease in illegal hunting activities over the years was also consistent with the ranger-based monitoring data. Their knowledge of illegal hunting trends was based on the frequency of sightings of bushmeat and other wildlife products over the years. Moreover, local communities' accuracy in reporting the most common equipment (snares) used for hunting further reveals the importance of LEK in PA management. This enforces the importance of the connection between ecological and social issues. Acknowledging their in-depth knowledge will strengthen collaboration and encourage a more unified conservation effort among all the relevant stakeholders.

In researching illegal behaviours, different methodological approaches must be adopted to reduce social bias. In this study, confidentiality and manipulation of the survey environment were adopted. For example, bystanders during the interviews were reduced in most cases. It must be mentioned that the knowledge from local communities is independent and depends exclusively on their choice. Given this, LEK can be acquired even when there is a lack of financial resources or restrictions on external research. For example, the restrictions of movement during the current COVID-19 pandemic, where many PAs were closed to external researchers, did not provide PA managers with current information on ecological processes. However, such information may only be acquired from the knowledge of the local people.

Effective management of PA requires that managers must often know the strength and weaknesses of the management of these PAs. As such regular assessment of the effectiveness of PA management is always necessary. In this thesis, the focus was on assessing the management effectiveness of three protected areas in Ghana using the RAPPAM tool. This study revealed that PA establishment indicators (gazettal, design, and adequacy of legislation) scored relatively well, implying that the fundamentals of PA systems are in place. However, inadequate resourcing, lack of communication and community relations, the lack of research, long-term and regular evaluation, and monitoring among others contributed to the poor performance of PA management. Many PAs around the world still lack basic requirements to operate effectively. It is, therefore, vital that increased financial and logistical support for PAs, especially developing countries, will enhance management capacity. The poor communication and community relations in any PA system resultin negative attitudes towards it. Negative attitudes contribute to the increase of illegal behaviours towards PAs by local communities. PA managers must ensure a good relationship between the PA management and local communities. The lack of research, evaluation, and monitoring in PAs result in the provision of poor information to PA managers for proper management decisions. It is also for these reasons LEK is always advocated in PA management. PA managers rely on LEK especially in times when there are difficulties in acquiring scientific data.

It must be stated that previous research has found that PA managers have enough experience and knowledge to assess key management issues accurately (Cook et al. 2014), but such findings might not provide the realities of management performance of PAs. The reasons here are that managers may deliberately overestimate management performance, to ensure continuedfunding, especially since many of the donor agencies require protected area management effectiveness assessment results as a funding requirement (Craigie et al. 2010; Coad et al. 2015). Involving other stakeholders during the assessment process allows the evidence base to be built, promotes transparency in the process, and gives the stakeholders' sense of ownership of the outcome and the PA itself.

The relationship between PAs and local people is somehow complex with the attitudes of local people varying from positive to negative (Dudley & Stolton 2018). Many reports provide evidence that PA management are unable to deal social issues (Tessema et al. 2010; Garekae et al.2015; Rohini et al. 2018). The access to PA resources has caused negative attitudes to these PAsby human right groups and most social scientists (Dudley & Stolton 2018). The rights of local communities have not been unnoticed especially, since the 2003 World Parks Congress. There has been increasing concern to the rights of local communities; the use of more collective approaches;use of different governance and benefit-sharing systems. However, there are still differences between words and actions concerning encouraging collaborative management. Particularly, continuous conflicts with local people are troubling and counterproductive. However, in most cases local people wish for sustainable use of resources which may be similar to conservation interests. These conflicts if not addressed in comprehensive way will affect both conservation and sustainable development. PA managers andgovernments must recognise, document, and encourage different governance types in protected areasystems, address gaps in governance quality through training, assessment, and provision of improved capacity-building materials. Moreover, they must develop and undertake the assessmentof social costs and benefits of PA management as a as a major part of management and should outlined in the Management Plan. They must alsoensure increase the role local people in management decisions and the day-to-day management of PAs (Dudley & Stolton 2018).

On the other hand, regardless of the increasing biodiversity loss in PAs, many PA managers and rangers receive no special training, commonly being supported from the government's chest or deciding to manage land in their care for conservation purposes with little external support. Even

when training is available, it often does not address vital issues – social conditions, poverty reduction, climate change and management of ecosystem services – that the PAs are expected to provide. Rangers are often undervalued, under-resourced and poorly paid, despite doing an increasingly difficult and dangerous job. If they come from local communities, they have often received insufficient education to advance far in their organisation, however well they perform (Spira et al 2019). PA management must have access to extensive and site/system specific skills, techniques of collaborative management and monitoring technologies. Promoting professionalism, building committed staff, and raising perceptions of the importance of PA management are key elements in ensuring suitable management. It is also vital to encourage proper training and equipping of PA managers, staff, and rangers, which meets agreed management and competency standards. Expanding alternatives for training provision including online options is also vital in current PA management systems. Almost all PAs in especially, developing countries remain underfunded and in most of these states, staff struggle without proper transport, old equipment, poor living conditions, low wages, and low budgets (Moreto 2016). However, it is of major concern that the amount of money provided by donor agencies to these developing countries in recent times is of serious concern due to poor government oversight and corruption (Taccon & Williams 2020). Financial support often fails to keep pace with the growth of the PA estate, meaning that new PAs are just paper packs' but few or no resources for implementation. Potential funds, such as the REDD+ mechanism, have so far failed to deliver on the scale required, and conservation organisations have been slow to understand, develop and advocate the types of new funding mechanisms. Understanding the reasons behind this and coming up with new and practical suggestions for reducing the deficit, are key priorities, which demands new skills and new partners. New advances and mechanisms are underway, particularly for privately managed PAs, but more needs to be done to learn from successful examples. For example, introducing a worldwide task force with a team of independent and concerned experts from the finance sector to investigate the funding needs for PAs, along with existing and potential funding mechanisms, and to provide solutions to these problems.

CHAPTER EIGHT

8. GENERAL CONCLUSIONS

The establishment and management of PAs continue to be the primary means for biodiversity conservation which involves investing resources by institutions and other stakeholders (Watson et al. 2014). However, many of these sites have been subjected to intense human pressure leading to declines in biodiversity (Scholte 2011, Craigie et al. 2015). Effective collaboration with local communities and a robust law enforcement monitoring system among others are known to improve the management of these areas. The current thesis investigated the PA law enforcement monitoring system, local communities' knowledge, and views about ecological processes, and assessing the management performance of PAs in Ghana.

In this thesis, the fluctuations in the law enforcement staff performance were proved mainly due to the inadequate logistic supply. Low patrol staff performance led to a decline in encounters with illegal activities. Although rangers work in harsh conditions especially under poorly resourced equipment, they constitute an important component of an effectively managed PA. Improvements in the provision of logistic supply would not only serve as an incentive for working in uncomfortable conditions but would also help rangers to feel their work is valued.

Interviews with local communities revealed that they had considerable knowledge of mammal species abundance and illegal hunting trends. The knowledge of local communities was consistent with the ranger-based monitoring data. Understanding the diverse knowledge of local people in an area is important to formulate conservation practices that focus on the relationship between knowledge, practices, and institutional context. The findings of this thesis provide a strong argument for the conservation of local ecological knowledge using local strategies that consider all these possible variations and influences. The in-depth knowledge of local people about the declining mammal abundance and illegal hunting trends suggests a potential for synergy with more effective participative management initiatives. Therefore, it is advocated that increased use of local knowledge to design new studies or seek adaptive management strategies that are acceptable for local peoples and other stakeholders.

The results of this thesis showed that structured interviews (using RAPPAM), workshops, and site visits provided a clear picture of the management strengths and weaknesses of PAs in Ghana. The findings confirmed that the present systems do not effectively protect natural resources. The indices under the 'planning' element received the highest average scores in all three PAs, whereas lack of support from local communities, disputes of land tenure, inadequate funding, poor infrastructure, and poor research, evaluation, and monitoring received the lowest ones. The studied PAs face intense external pressures and threats from human activities deeply influenced by the macro-economic and social environments of Ghana.

To conclude, our findings propose that PAs management effectiveness lies in a well-resourced management on site that can effectively deal with threats by setting priorities, developing situation analyses, and designing and executing strategic and monitoring plans. Another key lies in accepting local people and their knowledge, specifically in formulating conservation practices that focus on the relationship between knowledge, practices, and institutional context which will build in the PA social-ecological integrity. And when those aspects are in place and additionally the governments provide to national conservation authorities a technical and financial support, then PAs and the nature conservation have the potential in bringing their full ecological, social and economic benefits.

CHAPTER NINE

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CHAPTER TEN

10. CURRICULUM VITAE

Name: Ing. Jerry Owusu Afriyie
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Nationality: Ghanaian
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EDUCATION AND QUALIFICATION

2017– to date Ph.D. Tropical Agrobiology and Bioresource Management- Czech University of life Sciences Prague.

- Topic: Evaluation of Management Effectiveness of Protected Areas in Ghana

2015–2017 Msc Engineering ecology (Nature Conservation)- Czech University of life Sciences Prague

- Study emphasis: focused on communities and populations of plants, invertebrates, and vertebrates and their use in terms of bioindication, biodiagnostics, and ecological monitoring
- Master's thesis: Effectiveness of monitoring in Wildlife Protected Areas: A case study in Kogyae Strict Nature Reserve, Ghana.
- Supervisor: prof. Ing. Jaroslav Cerveny

2008–2011 Bsc Natural Resource Management, Kwame Nkrumah University of Science and technology, Kumasi-Ghana.

- Study emphasis: Forest Management, Wildlife and Range management, and the use of Remote Sensing & GIS in Natural Resource Management.
- Bachelor thesis: Distribution of Buffaloes (*Syncerus caffer*) in the Kogyae Strict Nature Reserve.

2003–2006 Diploma in Natural Resource Management, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana (Formerly School of Forestry).

- Study emphasis: Acquisition of practical knowledge in forest ecology, management, and renewable natural resource management.
- Diploma thesis: Survey of Agroforestry practices in Wenchi District.

RESEARCH INTEREST

- Protected Area Management
- Wildlife Conservation
- Ecosystem Management and Conservation
- Soil Science

PUBLICATIONS

Afriyie OJ, Asare MO, Hejcmanová P. 2021. Exploring the knowledge and perception of local communities on illegal hunting: long-term trends in a West African protected area. Forest **12**: 1454. https://doi:10.3390/f12111454

Asare MO, **Afriyie OJ,** Hejcman M, Jungová MK. 2021. Can wood ashes of commonly planted tree species in Ghana be applied as fertilizers? Waste and Biomass Volarization. https://doi.org/10.1007/s12649-021-01588-7

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Afriyie OJ, Asare MO, Osei-Mensah J, Hejcmanova P. Long-term performance and potential of an adaptive management system for effective law enforcement in African protected areas. In: Owusu J. A., Asare, M. O., Hejcmanová, P., (Eds): Evaluated of long-term law enforcement monitoring in a West African Protected area. Oryx- *Book of abstract*, Kostelecké Inspirování (November 2018).

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species in the tropics. In: Asare M. O., Owusu J. A., Hejcman, M., Jungová, M., K., (Eds.). Can wood ashes of commonly planted tree species in Ghana be applied as fertilizers? Waste and Biomass Volarization

Afriyie OJ, Asare MO, Hejcmanova P. (Eds) Can we make it together? Local communities' and rangers' perceptions on protected areas management in Ghana. Book of abstract, Global Biodiversity Conservation Conference (Prague 2021), pp. 30.

PAPERS IN OTHER SCIENTIFIC JOURNALS

Asare MO, **Afriyie OJ,** Hejcman M. 2019. What constitutes Archaeo-anthrosols? Review on the effects of ancient anthropogenic activities on the chemical signatures of archaeological soils. African Journal of Soil Science.

Danquah E, **Afriyie OJ.** 2015. Distribution of Buffaloes in Kogyae Strict Nature Reserve, Ghana. Applied Research Journal **1**: 20-26.

SUBMITTED MANUSCRIPTS

Afriyie OJ, Asare MO, Hejcmanová P. Economic benefits are not the sole determinants of local peoples' support of protected areas in West Africa. Ecosphere.

Asare MO, Apoh W, **Afriyie OJ,** Hejcman M. Human: the custodian of the soil – Reconfiguring the impact of past human activities in Northern Ghana by physicochemical analyses of soil. ` European Journal of Soil Science.

INTERNSHIP

August–September 2021	Faculty of Renewable Natural Resources. Department of Wildlife and Range Management, Kwame Nkrumah University of Life Sciences, Kumasi-Ghana

CONFERENCE, PRESENTATIONS, AND WORKSHOPS

- Global Biodiversity Conservation Conference 2021, Prague- Czech Republic
- Kostelecké inspirování 2019, Czech Republic
- Kostelecké inspirování 2018, Czech Republic
- ELLS Scientific Student Conference 2018, Wageningen, The Netherlands
- Workshop on Community Forest Management Project (CFMP), 2009 and 2010, Kumasi-Ghana
- Conference on Wildfire Management Project, 2013, Kumasi-Ghana

PROFESSIONAL EXPERIENCE

2011–2015 Assistant to District Manager, Offinso-Ghana.

- Assist in wildfire educational campaign
- Assist in law enforcement monitoring operations
- Plantation activities
- Assist in Forest Management operations

2007–2008 Assistant Forest Manager, John Bitar & Co. Ltd, Sefwi-Wiawso-Ghana

- Supervise enumeration of trees in forest reserves
- Preparation of stock summary for trees in forest reserves
- Preparation of stock map for trees in forest reserves

2010–2011 Intern, Water Resources Commission, Ghana.

- Assisting in inspection for a drilling license
- Assist in Dam safety license
- Educational campaign on water use

LANGUAGES

English, Twi

REFEREES

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