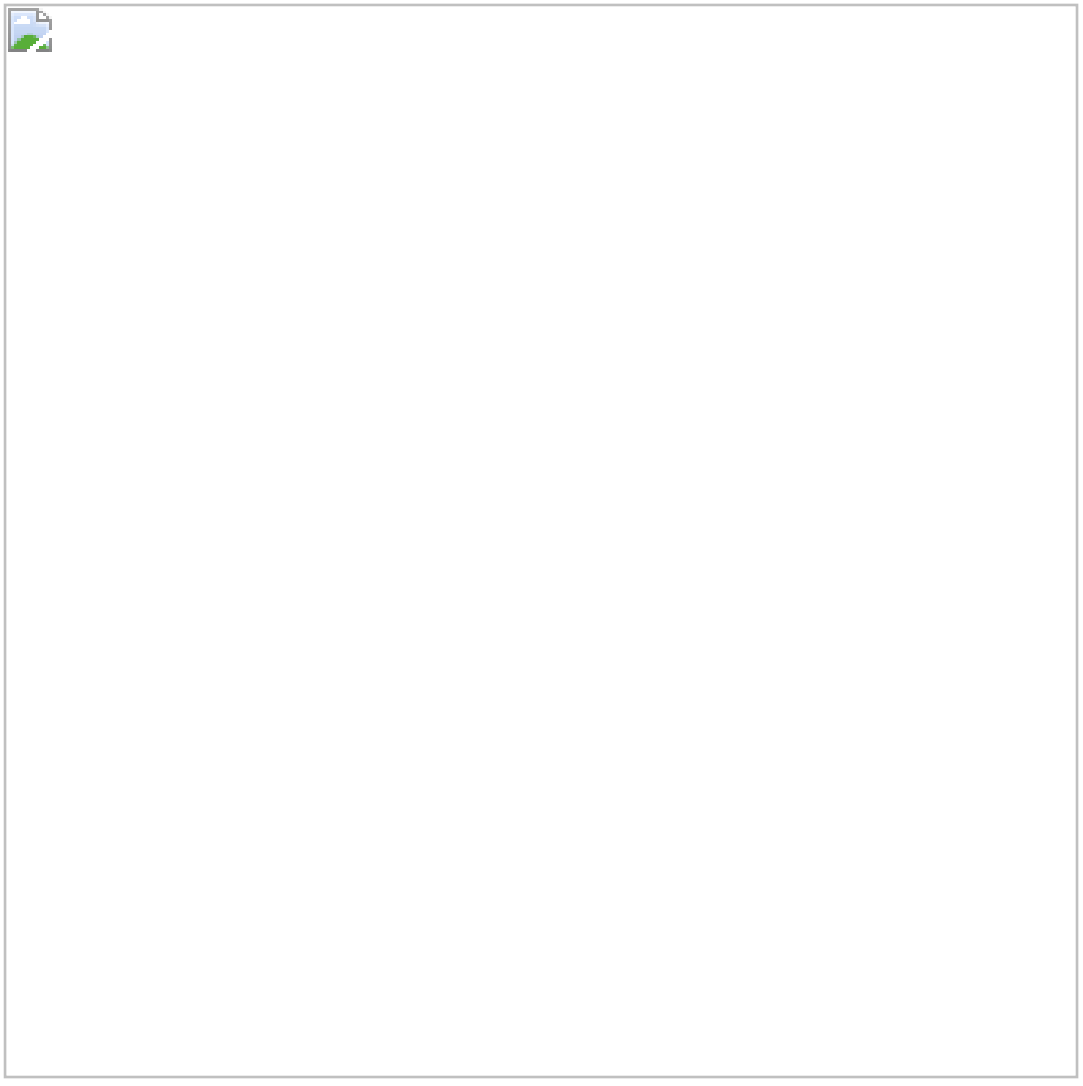

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Perceived Effects of Elephants (*Loxodonta africana* Cuvier) Presence and Impacts on Ecosystem Services Supply in the Pendjari Biosphere Reserve, West Africa

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Abstract

Information on how biotic factors influence delivery of ecosystem services (ES) in natural systems is important for holistic landscape management. In this study, we assessed the perceived effects of elephants' presence on ES supply in the Pendjari Biosphere Reserve in West Africa. A total of 112 respondents, including riparian communities and reserve officials, were interviewed. First, we used ranking techniques based on stakeholders' perceptions to evaluate differences in perceived importance of ES. Second, we assessed the perceived impact of elephants on ES supply from both direction and intensity perspective. Third, we assessed the economic importance of threatened ESs and elephants' damages related economic losses incurred by households. Twenty-seven ES were enumerated, 13 provisioning ES, 12 cultural ES, and two from the regulating and maintenance ES category. Provisioning ES were perceived as the most important although not significantly different from other categories. PES were also found to be most affected negatively by elephants' impacts. However, elephants' presence increased supply of cultural ES. The average cost of the losses due to elephants' negative impacts ranged from \$174.80 to \$586.05 per year and per victim household. These results were discussed in relation to management actions necessary to facilitate coexistence between elephant and local populations.

Keywords

biotic disturbances, ecosystem services, perceptions, economic valuation, protected areas

Introduction

Ecosystems provide various services that contribute to human well-being and development of local and national economies (Millenium Ecosystem Assessment, 2005; Schägner, Brander, Maes, & Hartje, 2013; The Economics of Ecosystems and Biodiversity, 2010). Because ecosystem services (ES) generate high economic, ecological, and social values for stakeholders at different scales (Grilli, Nikodinoska, Paletto, & De Meo, 2015; Mensah, Veldtman, Assogbadjo, et al., 2017), assessing ES importance and economic value is important for useful and sustainable management of both natural and human made systems (Grilli et al., 2015; Iniesta-Arandia, García-Llorente, Aguilera, Montes, & Martín-López, 2014; Mensah, Veldtman, Assogbadjo, et al., 2017; Palomo, Martín-López, Potschin, Haines-Young, & Montes, 2013).

Many ecosystems, including protected areas, are reportedly been degraded, along with their ecological

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properties, processes, and functioning (Brodie, Post, Watson, & Berger, 2012; Ehrlich & Mooney, 1983; Schmitz, Post, Burns, & Johnston, 2003) and subsequent supply of services (De Groot et al., 2012; Ehrlich & Mooney, 1983; Ochoa & Urbina-Cardona, 2017). In turn, the loss of ES increasingly affects countries' economy (Pelicice, 2019). Protected areas are potential hotspots for multiple ecosystem functions and services (Chape, Harrison, Spalding, & Lysenko, 2005; Palomo, Martín-López, Zorrilla-Miras, García Del Am, & Montes, 2014). Their management should aim at maintaining healthy and resilient systems that can sustain delivery of a wide range of ES in the long term (Smith et al., 2017). However, in protected areas, multifunctionality and delivery of multiple ES are often underlooked in management plans (Jacobs, Burkhard, Van Daele, Staes, & Schneiders, 2015; Tallis & Polasky, 2009), and management strategies to increase one service often have negative impacts on other services (Smith et al., 2017). In addition, few management plans take into account occurrence of natural hazards (Smith et al., 2017) and ecosystem disservices (Shackleton et al., 2016). As a result, these systems lack risk mitigation plans, either for anthropogenic (climate change, fire, pollution, etc.) or environmental effects (e.g., overcapacity of charge of ecosystems with regard to large mammals' herbivores browsing).

Previous studies revealed that factors such as mammals' herbivory affect trees dynamic, ecosystem functioning, and services delivery (Asner & Levick, 2012; Brodie et al., 2012; Dublin, Sinclair, & McGlade, 1990; Field, 1971; Guldemond & van Aarde, 2008). However, studies on how biotic attributes influence the ecosystem capacity to supply different ES are still needed (Maseyk, Mackay, Possingham, Dominati, & Buckley, 2017; Smith et al., 2017). For example, there is less information on the effects of mammalian herbivores on diversity–ecosystem function relationships in established tree stands (Muiruri, Milligan, Morath, & Koricheva, 2015). Equally, it would be valuable to determine how current diversity loss due to natural and anthropogenic drivers simultaneously influences the supply of ES (Byrnes et al., 2014). Such information is crucial for long-term management strategies that promote biodiversity conservation (Mace, Norris, & Fitter, 2012; Smith et al., 2017) and sustainable ES supply (Palomo et al., 2013).

In West Africa, the Pendjari Biosphere is a nature reserve with a huge potential for ES supply. It is listed as a World Heritage Site. Several ecological studies were conducted in line with its potential for medicinal resources (Dossou-Yovo, Vodouhe, & Sinsin, 2014), biodiversity conservation, and plant dynamics (Atanasso et al., 2019; Azihou, Glèlè Kakaï, Bellefontaine, & Sinsin, 2013; Kiansi, 2011; Mensah et al., 2016; Vodouhê, Coulibaly, Adégbidi, & Sinsin, 2010). Recent studies also reported the potential damages caused by elephants in the Pendjari Biosphere reserve (Kassa et al., 2014; Salako et al., 2015). However, we lack information about its potential for ES supply. In this study, three hypotheses were explored on current ES supply in Pendjari Biosphere Reserve in Benin and related to (a) the ES supply and importance; (b) elephants presence and impacts on ES, as perceived by local stakeholders; and (c) economic importance of threatened ESs and elephants' damages related economic losses.

Analytical methods for testing such hypotheses require decades of monitoring natural ecosystems (Birkhofer et al., 2015; Martin, 2007). On the other hand, there is increasing interest in combining local knowledge and empirical evidence for in ES valuation surveys (Cowling et al., 2008; Palomo et al., 2014). Stakeholders' perception assessment of ES is useful to evaluate the current supply of ES as it is based on experiential knowledge on the distribution of landscape services and of nonmaterial benefits provided to humans (Fagerholm, Käyhkö, Ndumbaro, & Khamis, 2012). Participative ES assessment has further advantage to increase awareness of nature benefits, foster empowerment, and incorporate local knowledge into management decisions (Fagerholm et al., 2012; Mensah, Veldtman, Assogbadjo, et al., 2017; Palomo et al., 2014).

The aim of this study, therefore, was to understand how elephants' presence and damages, as perceived by local people, influence ES supply in the Pendjari Biosphere Reserve in Benin. The specific objectives were to (a) determine the importance value of ES categories, (b) assess the reserve manager's and local people's perception of elephants presence and impacts on ES, and (c) assess the economic importance of threatened ESs and elephants' damages related economic losses. For classification of ES, we adopted the Common International Classification for Ecosystem Services (CICES), proposed by the European Environment Agency (Haines-Young & Potschin, 2013).

Methods

Study Area

The study was carried out in the Pendjari Biosphere Reserve located in the Sudanian zone in the north-west part of the Republic of Benin, West Africa (10°40′–11°28′N and 0°57′–2°10′E; Figure 1). It covers a total area of 4,661.4 km^2 and included the Pendjari National Park (PNP: 2,660.4 km^2), the Pendjari Hunting Zone (ZCP: 1,750 km^2), and the Konkombri Hunting Area (ZCK: 251 km^2) (Kiansi, 2011). Pendjari Biosphere Reserve was declared a Game Reserve in 1954, upgraded to a National Park in 1961, and became a Biosphere Reserve in 1986 (International Union for Conservation

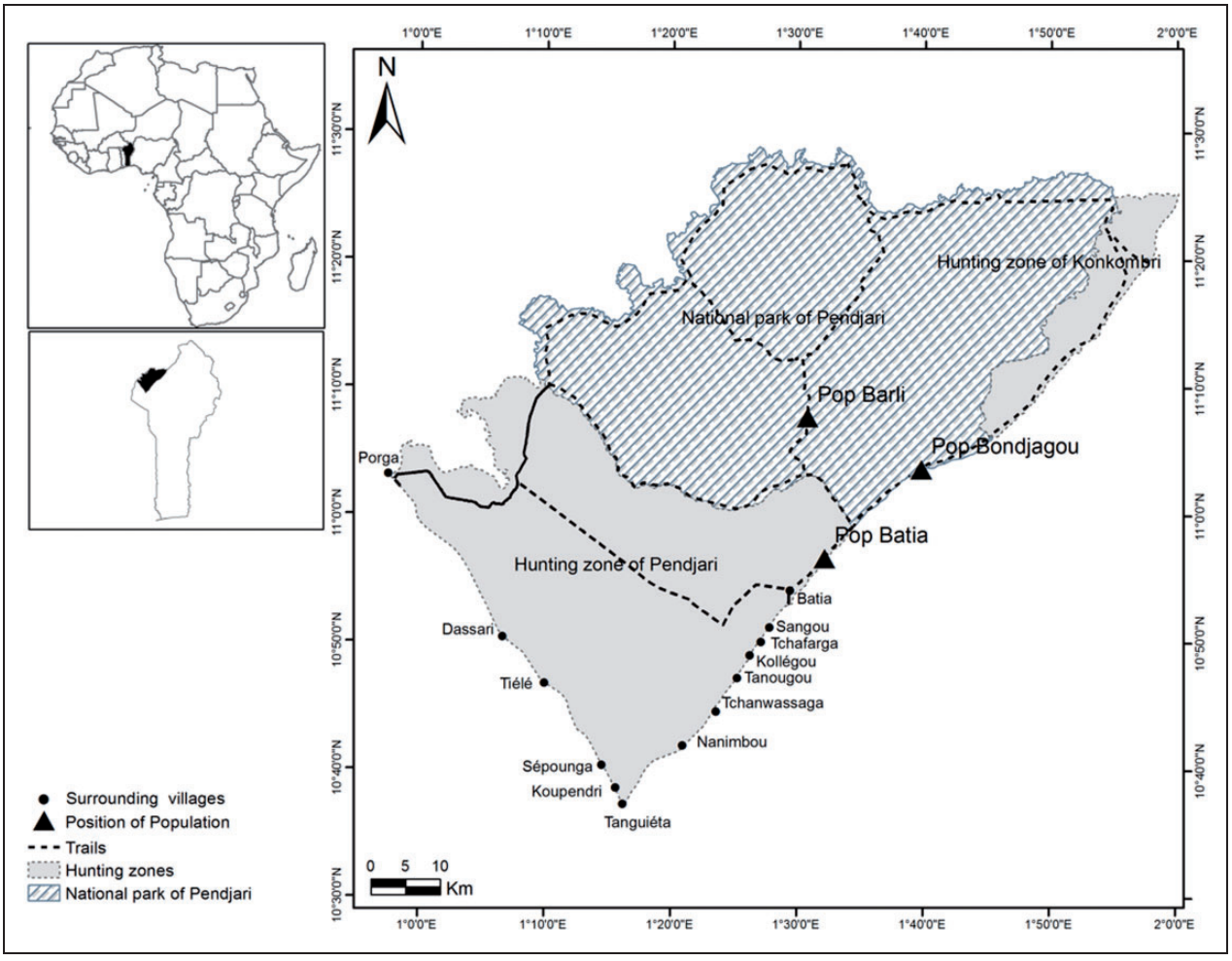

Figure 1. Maps showing the location of the Pendjari Biosphere Reserve and the surrounding villages where the survey was concucted.

of Nature, 2002). Recent studies in the Biosphere Reserve revealed that the elephant population increased from 826 individuals between 1985 and 1991 to 869 individuals between 2005 and 2010 (Bouché et al., 2011) and has reached a total of 1,719 in 2015 (Bouché, Frederick, & Kohi, 2015). This increase of elephant individuals number is related to the availability of suitable habitats and the recent efforts to reduce poaching in the Biosphere Reserve (Bouché et al., 2015). In addition, two subspecies of the African elephant (*Loxodonta africana*) have been identified in the Biopshere Reserve (Mondol, Moltke, Keigwin, Brown, Stephens, & Wasser, 2015): the forest elephants (*Loxodonta africana cyclotis*) and the hybrids (no scientific names proposed). Thus, the name *Loxodonta africana* (African elephant) was adopted to describe both the forest elephants and the hybrids in the study area.

The vegetation in the Pendjari Biosphere Reserve is dominated by the Sudanian regional centre of endemism plant species (White, 1983) with a mosaic of savannas ecosystems (grasslands, shrublands, and wooded savannas) interspersed with forest ecosystems (woodlands, gallery forests, riparian forests and dry forests) (Sokpon et al., 2001). Annual rainfall averages 900 to 1,000 mm, with a unimodal pattern (from May to November). Soils are mainly ferruginous.

In 2014, about 188,633 inhabitants are estimated to be living around the reserve (Recensement Général de la Population et de l'Habitation 4, 2015). The prime activity of these populations is subsistence and smallholder farming, which includes crops and staple foods such as yams, maize, sorghum, cowpea, groundnuts, and rice (Centre National de Gestion des Reserves et Faunes, 2005). The buffer zone is also used for cattle grazing and is prominent source of firewood for commercial and domestic use (Sinsin, Tehou, Daouda, & Saidou, 2002).

Sampling and Data Collection

Expert knowledge—for example, provided by reserve managers—is often used to gather information on the potential for ES supply (Cowling et al., 2008; Pereira

Table 1. Perceived Benefits of Five Important Ecosystem Services in the Pendjari Biosphere Reserve.

Ecosystem services	Benefits	Description	Type of damage
Shea nut	Shea butter	Fat extracted from *Vittelaria paradoxa* dried walnuts	break of trees and branches
Tamarind fruit	Tamarind balls	Traditional balls obtained from the Tamarind pulp	break of trees and branches
Balanites aegyptiaca seeds	*Balanites* oil	Vegetable oil extracted from *Balanites aegyptiaca* seeds	break of trees and branches
Parkia biglobosa seeds	*Parkia* mustard	Product obtained by processing the pods of the dry grains of tree	break of trees and branches
Detarium microcarpum fruits	*Detarium* powder	Dry powder obtained after rapping endocarp of dry seeds	break of trees and branches
Diverse hardwood trees and *Raphia sudanica* palm	Artwork	Animals handcrafts and key ring, chairs and tables made from *Raphia sudanica*	break of trees and branches

et al., 2005; Paletto, Giacovelli, Grilli, Balest, & De Meo, 2014; Palomo et al., 2013; Ricaurte et al., 2017; Sieber, 2006). Semistructured or focus group interviews are also often used (Bryan et al., 2010; Campagne, Roche, & Salles, 2018; Palomo et al., 2013; Ricaurte et al., 2017). Sample size is a key determinant that influences outputs from socioecological studies (Dagnelie, 1998). In case a limited number of individuals have knowledge on the subject, the sample size is often estimated by sampling as much as possible, a representative number (Gaoue & Ticktin, 2009; Palomo et al., 2013; Ricaurte et al., 2017). In this study, a preliminary stakeholder interview with the Biosphere Reserve managers and local authorities revealed six occupational groups of informants that have knowledge on ES and trends in their supply. The interviewees were identified following authorization of the Reserve managers and local authorities. In total, 112 informants (88% men and 12% women) were selected through nonproportional quota sampling (Cast et al., 2008; Raymond et al., 2009): Reserve administrators (10.8%), eco-rangers (9.9%), nontimber forest products (NTFP) processors (10.8%), tourism guides (14.3%), para-ecologists (13.4%) and local professional hunters (41.1%). The skew in the percentage of men versus woman interviewees was due to the professional categories in consideration; less women (as compared with men) generally work as eco-rangers, reserve administrators, tourism guides, para-ecologists and professional hunters. The focus on local people and Reserve managers that have long term experience in the Biosphere Reserve as informants was to make findings more relevant and accurate.

For the interview, a questionnaire was designed and administered to each respondent separately. The data collection took place from June to October 2017, with support from local guides. Each interviewee was presented with a list of the ES and related benefits derived from the Biosphere Reserve, and rated them from the most important to the least important. The trends in ES supply (decreased, increased, and constant) and the nature of the impacts (positive, negative impact, and not clear) of elephants on each ES as perceived by interviewees was recorded.

To assess the economic importance of threatened ESs, six products derived from ES were identified and recognized as of high economic importance for local people. They include shea butter (a butter from *Vitellaria paradoxa* fruit), tamarind ball (*Tamarindus indica* fruits' balls), Balanites oil (oil produced from *Balanites aegyptiaca* seed), Parkia mustard (*Parkia biglobosa* fruits' mustard), Detarium powder (*Detarium microcarpum* fruits' powder), and artwork (Table 1). According to interviewees, these ES benefits were affected by elephants' damages. We therefore collected from 12 Nontimber Forest Products processors, information on the amount of each Nontimber Forest Products transformed per year, the quantity of raw materials, the price of each ES benefits on the local market, the transport and workforce cost. To determine elephants' damages related economic losses, we collectedinformation on the amount of cropping systems affected, the expected yield, and the corresponding income from victim households. A total of 32 victim households were interviewed using semistructured interviews. The expected yield per hectare of each ES was determined, based on the area covered by the field crops being affected, as well as the average yield of the same crop provided by farmers whose field crops were not affected in the same locality and over the same period of elephants' damages.

Data Analysis

Social importance of ES has largely been assessed through stakeholders' perception (Grilli et al., 2015;

Iniesta-Arandia et al., 2014; Mensah, Veldtman, Assogbadjo, et al., 2017; Palomo et al., 2013; Ricaurte et al., 2017). Likert-type scale and scoring approach has been adopted by these authors to identify the most important ES delivered by ecosystem (Palomo et al., 2013; Ricaurte et al., 2017). Here, we used the scoring method (Martín-López et al., 2012), and assessed riparian communities and Reserve managers perceived importance of ES category by constructing a data matrix for ES scores given by the interviewees. An importance value index of the categories of ES was calculated afterward using the equation later (Equation 1, adapted from Ricaurte et al., 2017).

$$\mathrm{Iimp}_{\mathrm{ESc}} = \frac{\sum_{\mathrm{ES}i=1}^{n} \text{mean score ES}i}{n} \tag{1}$$

where $\mathrm{Iimp}_{\mathrm{ESc}}$ is index of importance of ES category (ESc), ESi is the ith ES of a given ES category and n is the number of ES cited per category. The ESc with the highest Iimp value was therefore considered as the most important (Mensah, Veldtman, Assogbadjo, et al., 2017). Due to the nature of the response variable (rank), we tested for significant differences in Iimp values among ES categories using the nonparametric Kruskal–Wallis test.

We next evaluated the perceived impact of elephants' presence on ES supply. Specifically, we assessed the local perception of the level of impacts of elephants by computing for each ES category, the potential impact index (Equation 2, adapted from Ricaurte et al., 2017):

$$\mathrm{IPImp}_{\mathrm{ESc}} = \sum_{\mathrm{ES}=1}^{n} \frac{\text{Mean impact score on ES}i}{n} \tag{2}$$

where $\mathrm{IPImp}_{\mathrm{SEc}}$ is index of potential impact on ESc. The perceived impact was computed separately for positive and negative impacts of elephant damages. $\mathrm{IPImp}_{\mathrm{SEc}}$ is always positive, but we added negative signs to values for negative effect of each driver. The ESc with the high IPImp was considered as the most threatened. Kruskal–Wallis test was performed to compare among ES categories the perceived impact of elephants' damages. Following a previous approach in participatory assessment of trends in ES supply over time with regard to environmental drivers (Palomo et al., 2013), we also assessed the nature of the impacts (positive, negative impact, and not clear) of elephants on each ES, as well as the trends in ES supply (decreased, increased, and constant) as perceived by interviewees. For each ES, we computed the relative frequency of citation for each category of trend and nature of impacts. Then, the category of trends and the nature of the impacts which received the high score were used to characterize the trend and the nature of impacts of elephant on the targeted ES.

To assess the economic importance of threatened ESs, gross annual income and profits from shea butter, tamarind balls, Balanites oil, Parkia mustard, Detarium powder, and artwork were computed using the following equations (Bublot, 1965):

$$\begin{aligned}\text{Gross annual income} = {} & \text{Gross production} \\ & - \text{Cost of items paid from production}\end{aligned} \tag{3}$$

$$\begin{aligned}\text{Profit} = {} & \text{Gross annual income} \\ & - \text{estimated cost of nonpaid} \\ & \text{items used for production}\end{aligned} \tag{4}$$

Both gross annual income and profits were compared using an analysis of variance to determine which products mostly contribute to community well-being.

Finally, we estimated the economic losses due to elephants' negative impacts on crops and shea butter trees grown by farmers. For each crop, the annual size of farm negatively affected, the corresponding annual yield and income were computed for victim households over last 5 years. Analysis of variance and multiple comparison tests were performed to compare for each crop, the cultivated land sizes and corresponding yields to analyze the severity of damages per crop. The income losses per crop were compared using Kruskal–Wallis test as the data did not meet both normal distribution and homoscedasticity assumptions.

Results

Perceived Importance of ES in Pendjari Biosphere Reserve

Overall, the three ES categories (provisioning, regulating and maintenance, and cultural), as defined by the CICES, were recognized by local populations and reserve managers (Figure 2). There was no significant difference in the importance value among ES categories ($\chi^2 = 0.679$; $p = .712$; Figure 2). The mean importance values were 4.16 ± 0.96, 3.88 ± 1.36, and 3.54 ± 1.08, respectively, for provisioning, regulating and maintenance, and cultural ES. Provisioning ES category had the highest number of services (13), followed by cultural ES category (12) and regulating and maintenance ES category (Figure 2). Among the provisioning ES, edible fruits were the most important, followed by fish, firewood, and timber, while fodder was perceived as the least important (Figure 2(a)). Job was perceived as most important among cultural ES, followed by sport hunting, nature tourism, development projects facilities,

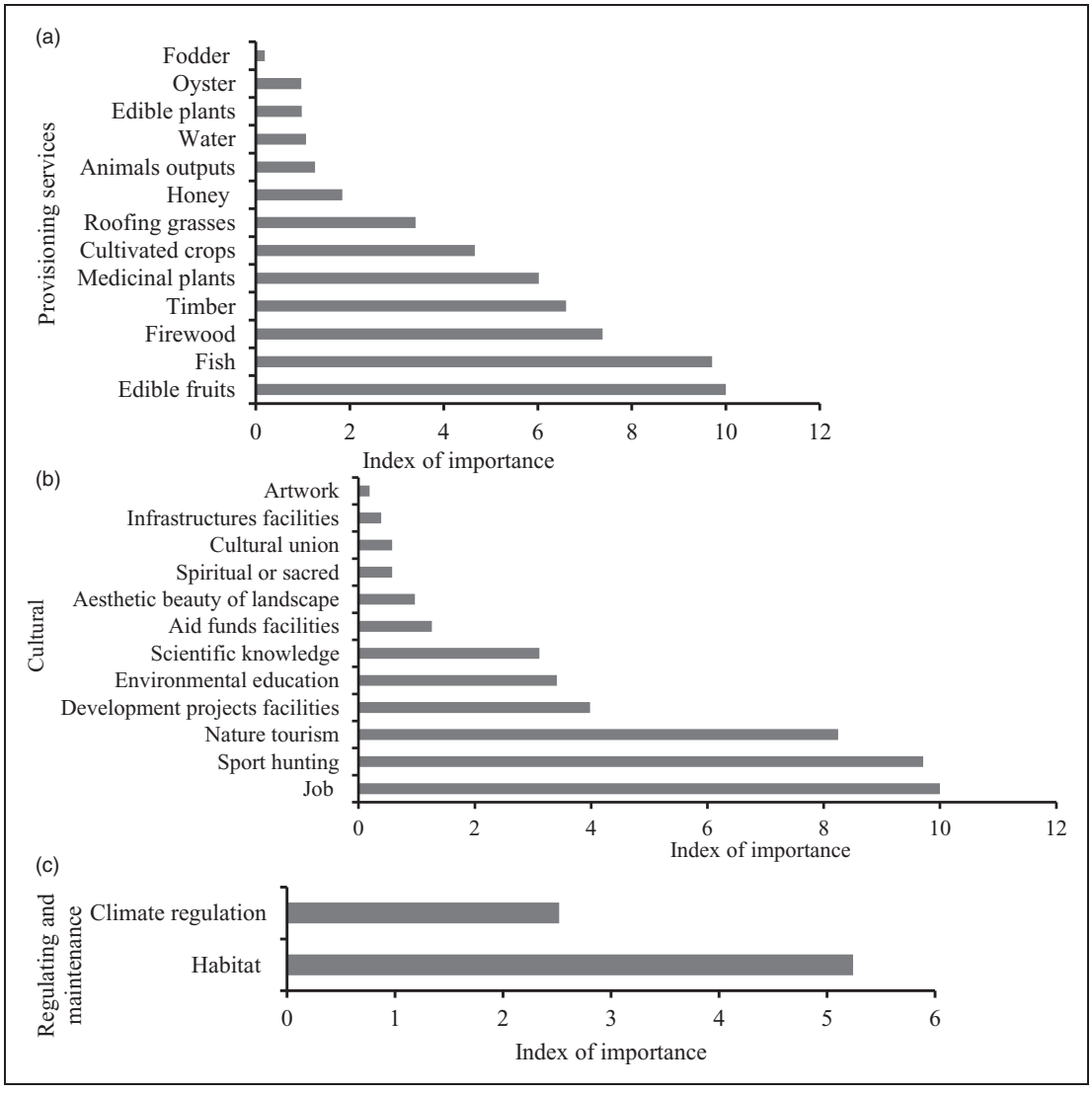

Figure 2. Perceived importance of ecosystem services of Pendjari Biosphere Reserve. The Common International Classification for Ecosystem Services (CICES) was adopted for categorization of ES ($\chi^2 = 0.679$; $p = .712$).

while artwork was considered as the least important globally (Figure 2(b)). For the regulating and maintenance ES category, habitat was perceived as more important than climate regulation (Figure 2(c)).

Perceived Impact of Elephants on ES

All participants reported increased elephants' pressure over last three decades. The perceived potential impacts of elephants on each ES category are summarized in Figure 3. For absolute value of the indices, there were significant differences of elephant's impacts among the three ES categories ($\chi^2 = 0.482$, $p < .05$; Figure 3). The highest and positive elephant's impact was observed for cultural services (66.11), followed by negative impact on

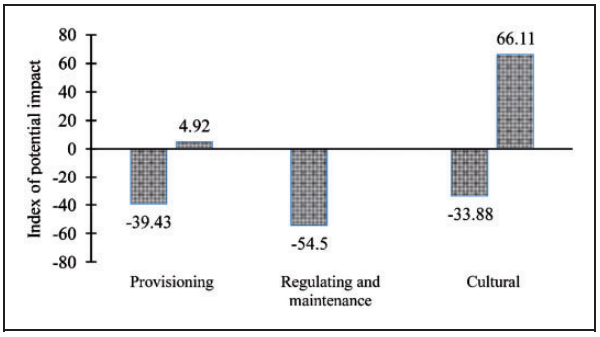

Figure 3. Perceived impact of elephants on ES categories in Pendjari Biosphere Reserve; Provisioning = Provisioning ES, Regulating and maintenance = Regulating and maintenance ES and Cultural = Cultural ES ($\chi^2 = 0.482$, $p < .05$).

regulating and maintenance (54.5), and provisioning ES (39.43).

While analyzing the direction of elephants' impacts on specific ES, we found negative effects on the supply of regulating and maintenance, and provisioning ESs except for supply of firewood, roofing grasses, and fodder (Table 2). Analysis of current supply trends revealed that edible fruits, fish, timber, animals' outputs, as well as regulating and maintenance ES are decreasing in the Pendjari Biosphere Reserve (Table 2).

For cultural ESs, elephants' presence influenced positively nature tourism, environmental education, scientific knowledge, artwork, spiritual or sacred, and cultural union but negatively affected aesthetic beauty of landscape.

Table 2. Nature of the Effects of Elephants' Impacts on Ecosystem Services in the Pendjari Biosphere Reserve.

Ecosystem services	Elephants' impacts	Trends
Provisioning		
Edible fruits	–	↓↓
Fish	–	↓↓
Medicinal plants	–	→
Cultivated crops	–	→
Firewood	+	→
Timber	–	↓↓
Honey	–	→
Water	*	→
Roofing grasses	+	→
Animals outputs	*	↓↓
Fodder	+	→
Edible plants	–	→
Oyster	*	→
Regulating and maintenance		
Habitat	–	→
Climate regulation	–	↓↓
Cultural		
Nature tourism	+	↑↑
Development projects facilities	*	↑↑
Sport hunting	*	↑↑
Environmental education	+	↑↑
Aid funds facilities	*	↑↑
Scientific knowledge	+	↑↑
Aesthetic beauty of landscape	–	↑↑
Spiritual or sacred	+	↑↑
Cultural union	+	↑↑
Artwork	+	↑↑
Job	*	↑↑
Infrastructures facilities	*	↑↑

Note. + = positive impact; – = negative impact of the driver; * = not clear; red arrow = decrease of ES supply; gray arrow = no change in ES supply; green arrow = increasing supply of ES; ES = ecosystem services.

Economic Value and Monetary Losses of ES Benefits Threatened by Elephants

The results of analysis of variance on gross annual income and profit made from production and sale of the six benefits (shea butter, tamarind balls, Balanites oil, Parkia mustard, Detarium powder, and artwork) revealed significant difference (F value = 2.081, $p < .005$) (Table 3). Artwork provided the highest profit per year (on average \$2,497.11/year), followed by shea butter (\$158.56/year), Balanites oil (\$75.03/year), and Parkia mustard (\$60.50/year) (Table 3). Tamarind balls and Detarium powder provided the lowest gross annual income and profit.

Most affected crops per victim household were rice (1,866.66 kg/ha/year), maize (1,587.75 kg/ha/year), yam (1,600 kg/ha/year), cotton (1,000 kg/ha/year), and sorghum (705.71 kg/ha/year) (Table 3). Shea nuts are also affected up to an average of 491.66 kg of loss per hectare and per year. The average cost of losses varied between \$174.80 and \$586.05 per year and per victim household, respectively, for yam and sorghum (Table 4).

Discussion

The Pendjari Biosphere Reserve provides important ES to local population and international tourists and research industry. These include provisioning ES (13), regulating and maintenance ES (02), and cultural ES (12) (Haines-Young & Potschin, 2013; Millenium Ecosystem Assessment, 2005), following CICES classification (Haines-Young & Potschin, 2013).

Perceived importance values were 4.16 ± 0.96, 3.88 ± 1.36, and 3.54 ± 1.08, respectively, for provisioning, regulating and maintenance, and cultural ES, indicating that the three categories were perceived as almost important by participants. Indeed, interviewees were mainly local people and reserve managers' representatives with long experience on use and management of ES provided by the reserve. Thus, their perception on ES is indicative

Table 3. Gross Annual Income and Profit of Benefits From the Most Important Ecosystem Services Threatened for Riparian.

	Gross annual income (\$)		Profit (\$)	
ES benefits	Mean	CV (%)	Mean	CV (%)
Artwork	2,675.47	28.28	2,497.11	28.28
Shea butter	163.91	129.54	158.56	128.53
Balanites oil	76.36	100.32	75.03	100.20
Tamarind balls	53.51	60.09	53.21	60.67
Parkia mustard	61.09	150.19	60.50	149.36
Detarium powder	29.43	81.42	22.30	84.85
Probability	0.010	—	0.009	—

Note. CV = coefficient of variation.

Table 4. Annual Losses of Crops Per Household Due Elephants' Damages.

	Cultivated area (ha/year)		Yield (kg/ha/year)		loss ($)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Cotton	1.60[ab]	68.64	1,000[bc]	68.643	463.75	85.36
Yam	1.16[ab]	184.78	1,600[ab]	184.775	174.80	61.39
Shea	2.00[a]	0.00	491.66[d]	22.93	279.44	22.42
Corn	1.57[ab]	119.66	1,587.75[ab]	119.65	354.00	127.58
Rice	0.25[b]	58.77	1,866.66[a]	32.73	175.39	22.93
Sorghum	1.54[ab]	104.84	705.71[c]	63.51	586.05	116.43
Probability	0.039	–	0.000	–	0.144	–

Note. CV = coefficient of variation. Mean in each column with same letters are not significantly different.

of the potential of the Biosphere Reserve for ES supply. Contrary to previous studies that revealed that provisioning and regulating and maintenance ES are the most important in natural stands (Gallo & Rodriguez, 2010; Mwakaje, 2009; Ricaurte et al., 2017), riparian people and reserve managers' representatives of Pendjari Biosphere Reserve indicated that local communities benefit from each ES category and differences may be among individual ES. Further analyses indicated that edible fruits were the most important, followed by fishes, firewood, timber, medicinal plants, and cultivated crops. Consistently, participants indicated that wild edible fruits contribute to human diet and household income. For example, seeds from fruits of the *Balanites aegyptiaca* are processed by local people to make oil for domestic and commercial purposes. Freshwaters are located in the Biosphere Reserve, and therefore are also protected from overexploitation, according to interviewees. However, every 2 years, local people are granted permission to fish in some surrounding ponds to supplement their diet.

Among cultural ES, job facilities were perceived as the most important, followed by sport hunting, nature tourism. The Biosphere Reserve provides considerable job opportunities. Most of the rangers, local guides, and reserve managers are drawn from locally available workforce. On annual basis, venison and other products from sport hunting, as well as 30% of nature tourism gross incomes are distributed among neighboring villages. Artwork was not perceived as important probably because it is a specific income generating activity for craftsmen, and local people not involved in the woodwork would probably underestimate its contribution to household income. Woodworking has been shown to be a source of income, employment and rural development (Lähtinen, 2007), and the discussion with craftsmen revealed that artwork is a high-income generating activity.

There are components in the ecosystems that sometimes limit the benefits and provide disservices to humans (Campagne et al., 2018; Kareiva, Watts, McDonald, & Boucher, 2007; Lyytimäki, Petersen, Normander, & Bezák, 2008). This study revealed that elephants' presence in the Pendjari Biosphere Reserve provides both ES and disservices for local and international communities. Elephants damages often turn woody habitats into herbaceous savannas (Dublin et al., 1990; Guldemond & van Aarde, 2008; Waithaka, 1993), affecting the ecosystem integrity and capacity to provide services (Ehrlich & Mooney, 1983). Elephants were reported to affect negatively the supply of regulating and maintenance services and most provisioning services. The indices of perceived potential negative impact of elephants' damages were 39.43, 54.5, and 33.88, respectively, for provisioning, regulating and maintenance, and cultural ES (Figure 3). While according to informants, habitat destruction due to elephants browsing has led to erosion of several areas within and outside the reserve, it should also be taken into account that tree fall and breakage caused by elephants make timber and firewood available for local people, fodder for livestock, roofing grasses for traditional house construction especially in the areas they have access to. On the other hand, elephants' presence was perceived to enhance supply of 6 cultural ES out of the 12 that were enumerated (perceived positive impact equal to 66.11). According to interviewees, elephant presence and increase in the Biosphere Reserve have contributed to grow business around activities such as nature tourism, environmental education, scientific knowledge, artwork, spiritual services, and cultural union. The role of elephants and other big fauna in the nature tourism has been documented in recent studies. Wildlife tourism is a key component for local and national economies in developing countries (Arbieu, Grünewalda, Martín-López, Schleuninga, & Böhning-Gaesea, 2017; Balmford et al., 2015; Naidoo et al., 2011). African protected areas harbor a unique diversity of large mammal species that attract millions of local and international tourists each year (Arbieu et al., 2017; Balmford et al., 2015; Lindsey, Alexander, Mills, Romanach, & Woodroffe, 2007). For local people and Reserve managers, elephants and lions are key species of attraction for

tourists during their visit to the Biosphere Reserve. These perceptions align with studies that showed that elephants are among the most desired of African wildlife species for tourist viewing (Di Minin, Fraser, Slotow, & MacMillan, 2013; Lindsey et al., 2007; Naidoo, Fisher, Manica, & Balmford, 2016). Participants further mentioned that elephants' presence in specific place is sign of great spiritual importance of that place. This belief aligns with previous studies that showed presence of elephants in a given region is associated with power and royalty and used as clan totems and names (Twine & Magome, 2007).

The results of the economic value of benefits from threatened ES and losses due to elephants' damages showed that benefits from ES contribute significantly to the well-being of populations. Artwork, shea butter, tamarind balls, Balanites oil, Parkia mustard, and Detarium powder were found to be important sources of income for local populations. There were significant differences in the gross annual income among ES benefits. Artworks provided the highest profit per year to local population, followed by shea butter, Balanites oil, and Parkia mustard. These results indicate the financial contribution of benefits from ESs to the communities' household income (Assogbadjo et al., 2012; Boffa, 1999; Sinare & Gordon, 2015). These products are often used for domestic purpose (health care and foods) but are also marketable commodities that generate income for pupils tuitions fees and other local businesses. However, increased density of elephants negatively affects some of these benefits. Our results showed that the average cost of losses due to impact of elephants, varied between \$174.80 and \$586.05 per year per victim household, respectively, for yam and sorghum. However, the contribution of the Biosphere Reserve to local development through job creation, local trade, cultural union, and sharing of revenue from tourism (30% of total tourism income) for improvement of facilities in the villages under direction of eco-development committee's administration makes it possible for local people to sustain elephants' damages, due to trade-offs between gains and losses. The contribution of protected areas to socio-economic development of surrounding communities has been addressed in other countries. For example, Sinha, Qureshi, Uniyal, and Sen (2012) found out that wildlife tourism contributed considerably to enhanced communities livelihoods in Kanha tiger Reserve in India. Given the current state of elephants' damages in the Pendjari Biosphere Reserve, further management policies must be taken to better manage elephants impacts on communities' livelihoods.

Implications for Conservation

As part of efforts to preserve diversity and sustainable supply of ES in the Biosphere Reserves while promoting local economic development of surrounding communities, this study assessed the perceived importance, economic value, and elephants' effects on supply of a wide range of ESs in the Pendjari Biosphere Reserve in West Africa. Twenty-seven ESs are perceived by local people and Reserve managers as the most important. Differences were, however, observed within each category of ES. Most of provisioning and regulating/maintenance ES are negatively affected by elephants' disturbances. However, elephants' presence in the Biosphere Reserve is positively correlated with supply of most cultural ESs. Artwork was perceived as least important by interviewees, although few craftsmen involved in the woodwork indicated that it contributes substantially to the annual income. Apart from artwork, other benefits such shea butter, Balanites oil and Parkia mustard are used for domestic purpose (health care, and foods), and as marketable commodities that generate income for local businesses.

The outputs of this study are relevant for management actions that sustain the supply of ES and facilitate coexistence between elephant and local populations. Due to the spatial context (proximity with agricultural fields) leading to increased negative elephants' impacts, we suggest that remote or distant farms that are often exposed to elephant activities be protected or fenced with metallic barriers. However, because fencing agricultural fields that are too close to protected areas can be viewed as controversial practices in management of wildlife and human coexistence (Vanak, Thaker, & Slotow, 2010; Pekor et al., 2019), we suggest promotion of beekeeping and chili production activities on these farms. Keeping bees has been proven effective against crops raiding by elephants in Kenya (King, Lawrence, Douglas-Hamilton, & Vollrath, 2016). Honey bee hives can be, for example, placed close to the farms. Similarly, important bee plants can also be planted to attract and maintain honey bees (Mensah, Veldtman, & Seifert, 2017). The beekeeping activities will not only provide income to local people through honey production but also contribute to sustain pollinator diversity in the surrounding environments, thereby promoting delivery of pollination services to farms and fruit fields and trees. Another suggested action includes local production of chili pepper in the margin fields surrounding the Biosphere Reserve, not only for commercialization but also for coping with increasing presence of elephant populations in crops fields (Chang'a et al., 2016).

Finally, participative conservation should be promoted, and local communities taken into account in the sharing of the benefits and economic returns from touristic activities in the Reserve. Sharing of the economic returns will contribute not only to promote elephant conservation but also to offset the cost of managing negative interactions between elephants and riparian

communities, for example, by supporting the fencing of vulnerable farming areas. We also recommend that future studies investigate climate change and elephants' disturbances effects on the ES hotspots in the Biosphere Reserve, as well as the conservation status of the wild edible tree species in the reserve.

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