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Highlights

1. Protected area management plans should pay attention to the provision of food and income to adjacent human communities.

2. In our study bushmeat was the most important component of meals on nearly all study villages.

3. A quarter of households earned cash from hunting wildlife.

4. More bushmeat was consumed closer to the national park.

5. Income from bushmeat sales was greater closer to markets.

6. Wildlife is perceived as declining around all village groups.

Food and livelihoods in park-adjacent communities: The case of the Odzala Kokoua National Park

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ABSTRACT

Protected areas (PAs) in Central Africa provide unprecedented opportunities to maintain ecosystem integrity and safeguard the unique wildlife of one of the most biodiverse regions in the world. However, conflicts exist between wildlife protection, and the needs of human populations adjacent to PAs. Although the use of wildlife resources within PAs is nominally regulated, wildlife exploitation in the areas surrounding parks benefit human nutrition and livelihoods of adjacent populations. In 2013-2014, we interviewed 28% of all known households in 37 villages surrounding the Odzala Kokoua National Park (OKNP), Republic of Congo. We gathered information on bushmeat consumption, income, material assets, and hunter perception of the state of wildlife. We show that bushmeat species (mostly duikers, small monkeys and porcupine) were consumed in 38-48% of meals, and 20-30% of households earned cash from hunting wildlife in most villages; more than any other single source of revenue, except cocoa. Although it remains unknown whether the park was a reservoir for wildlife for areas around the studied villages, we showed that more bushmeat was consumed closer to OKNP. By contrast, income from bushmeat sales in villages closer to markets was greater, and as a corollary, market access and household wealth were positively correlated. Overall, total household income, income from bushmeat sales, travel time, and distance to the OKNP were good predictors of household wealth. Wildlife, although considered more abundant around villages closest to the park, was perceived as generally declining around all village groups. Our results highlight the possible importance of PAs and adjacent areas as reservoirs of wildlife and in maintaining wild meat resources used by the surrounding human populations.

Key words: Buffer zone, bushmeat hunting, Congo, human livelihoods, protected area, local communities.

1. Introduction

Carefully managed protected areas (PAs) remain the cornerstone for the conservation of dwindling natural resources (Coad et al., 2015). PAs also play a significant role in providing ecosystem services for adjacent human communities, by benefiting these directly, for example through the consumption of food produced or obtained in or around PAs (Taylor, 2009; Stolton and Dudley, 2010; Ferraro et al., 2011; Turner et al., 2012). Indirect benefits are manifold and include income and employment (Angelsen and Wunder, 2003). However, park-adjacent communities experience costs e.g. no entry into nearby PAs, and their lack of acceptance of these rules can influence support for PAs and subsequent conservation related behaviours (Acquah et al., 2017). If not properly managed and included in management plans, these communities can generate negative impacts on biodiversity, human livelihoods, and human well-being (Ghimire and Pimbert, 1997; West et al., 2006; McElwee, 2010; Barrett et al., 2011; Redpath et al., 2013).

Satisfying basic needs of people living near PAs puts enormous pressure on the environment. One of the key challenges facing such communities in tropical forest areas is how to meet the need for sufficient, safe and nutritious food without exhausting the resources available. Often park-adjacent peoples rely on wild meat as the main source of sustenance and even livelihoods. However, unsustainable hunting of wild animals even within PAs is the most commonly reported threat (Schulze et al., 2018), due to mounting human population pressures, technological advances and the emergence of a booming commercial wild meat trade. Overexploitation of wild meat has direct impacts on the survival of some targeted species, especially large mammals (Dirzo et al 2014, Ripple et al, 2016), and will

affect the availability of sufficient foods to meet the dietary needs of those peoples reliant on this resource. Ultimately, rural communities have the option of managing existing wild meat resources more sustainably, turning to alternatives (including the production of cash crops to generate income to buy food), or hunting wildlife to local extinction and then moving to other source areas.

In the Republic of Congo (ROC), tropical moist forests cover over 200,000 km^2 or around 66% of the country (Mayaux et al., 2013). Significant populations of species of high conservation concern (e.g. elephants, gorillas, chimpanzees, etc.) are found within the 200 PAs (11.7% of the country's area) as well as within unprotected forests. The latter include stretches of forest managed by logging companies that exploit the important economic timber resources are also found within the country's forests (Doumenge et al., 2015). Logging operations allow access to remote areas and encourage more people to settle within concessions in search of jobs, thus increasing hunting pressure for bushmeat (Clark et al., 2009; Poulsen et al., 2009, 2011; Nasi et al., 2012). Increased hunting pressure can be reduced or prevented through partnerships between timber companies and conservation organisations, which can be successful in promoting the sustainable management of wildlife resources within logging areas (Clark et al., 2009).

Understanding the role that PAs and logging concessions play in supplying wild meat to the adjacent communities is essential to resolve or even prevent conflict between policy-makers, local people, and managers (Oldekop et al., 2015). Ensuring that wild meat is sustainably managed in areas peripheral to PAs will positively contribute to the protection of biodiversity. To determine the level of

dependence on wild meat versus other foods and income sources it is crucial to obtain data from which to establish a causal connection between people's livelihoods and protected area management (Pullin et al., 2014). Foerster et al. (2011) contrasted resource use and livelihoods in communities less influenced by a newly established PA (i.e. further away from the park) and those closest to it. The influence of proximity to the PA was significant. However, similar investigations in which the use of resources and livelihoods in communities at different distances away from a PA are scarce. In this paper, we study the contribution that park resources (wild meat) and cultivation make to the livelihoods and well-being of communities located at different distances from the Odzala-Kokoua National Park (OKNP) and the Ngombé Forest Management Unit (NFMU), in the northern ROC. Thus, by comparing communities that traditionally rely on park resources with those that do not, we can develop future management strategies that balance human welfare and conservation of biodiversity. We employ a cross-sectional design (De Vaus, 2001) to examine how livelihoods and use of wildlife resources vary according to the distance to the park and markets as predictor variables (Salafsky and Wollenberg, 2000; Foerster et al., 2011). We test two main hypotheses: (1) greater market access increases income from bushmeat sales and agriculture (mainly cocoa in this region) and both are linked to higher household wealth, and (2) shorter distances to the park increase the volume of bushmeat consumed and sold, and hence household income.

Methods

2.1. Study area

The study area is located in northern Congo, Central Africa, 1.61361˚N, 16.05167˚E (Fig. 1). Human population density is around 0.8 inhabitants km^2

(unpublished data). The two main ethnic groups found in the area include several Bantu sub-ethnicities (70%) and indigenous Pygmies (30%). The two groups have co-existed for centuries. The main human settlement in the region is the town of Ouesso, with about 30,000 residents. It is rapidly growing because new roads connect it to Brazzaville and logging activities draw immigrants. There is also a logging town, Ngombé, as well as several villages.

The OKNP is a protected area officially proclaimed a national park in 1935, making it one of the oldest national parks in Africa. With 13,546 km^2 it is part of the TRIDOM Transfrontier Park, which extends from the Congo into Gabon and Cameroon (Kamdem-Toham et al., 2003). A secondary road from Ouesso to Sembé (hereafter the OS road) in the west borders the northern perimeter of the park. The Ouesso to Brazzaville road (N2) is found to the east of the park (Fig. 1).

The OKNP is situated within the catchment area of the Mambili River, which drains the area towards the south. The park is within the savanna-forest boundary of north-central Congo, allowing for a high biodiversity of flora and fauna, with species from forest and savanna. The area is densely wooded in the northwest; towards the south and east the forest becomes more open. In the south of the park an extensive forest-savanna mosaic is found, including gallery forests and dry and swamp savannas. Climate is typically equatorial with two dry and two wet seasons, 1,500 mm annual rainfall and a mean annual humidity of around 80%. Temperatures are moderately high (23-25°C), with a low annual temperature range of 1-2°C (Hecketsweiler et al., 1991).

163 *2.2. Village selection*

164 Our study was conducted in villages located on the Ouesso-Sembé, Ouesso-
165 Liouesso, and Ouesso-Pikounda road axes (Fig. 1). Study villages were classified
166 into four comparison groups based primarily on their distance to Ouesso (one group
167 close, two distant groups and one quasi inaccessible), their proximity to OKNP, and
168 their most important economic activity; cocoa cultivation differentiates the two distant
169 groups (Table A1).

170

171 *2.3. Household data collection*

172 From July 2013 until June 2014 we gathered information from a total of 386
173 households (28% of the 1,382 known households), within 37 study villages in the
174 four village groups. Table A1 details main characteristics of the four village groups as
175 well as the number of villages and households sampled. Households were selected
176 at random within each study village where we conducted semi-structured
177 questionnaires with each household head (Table A2). Each questionnaire took
178 about 45 minutes to administer. They were applied by the principle investigator (PI),
179 a Master's student from Congo´s National School of Agricultural and Forestry
180 Sciences and a hired local guide. The PI trained the student and the guide. All three
181 interviewers conducted questionnaires in all villages in order to avoid biased results,
182 which might be introduced by subtle impacts of interview style on interviewees.

183

184 We documented household composition (number, age, and sex of all
185 household members), education, income, wealth and food consumption. To
186 determine the overall health status of all household members aged >1 year old, we
187 estimated the average of all household members' individual body mass index (BMI).

188 Individual household wealth was determined, first, by establishing an inventory of
189 cash reserves, household possessions and stocks of food items for own
190 consumption or sale. We then assigned monetary values to all possessions and food
191 items as declared by the respondents using current trading values in the local
192 currency, FCFA, as a baseline. The total estimated wealth was transformed into $US
193 using the exchange rate 1 $US = 500 FCFA. From these we partitioned the
194 distribution of wealth of all households into five quintiles, “poorest”, “poor”, “middle
195 income”, “rich”, and “richest”. Each Individual household was then assigned to its
196 corresponding category or wealth index relative to all surveyed households. A
197 household´s total income and its income from bushmeat was valued as absolute
198 estimates in $US. Analyses of income from specific items (including bushmeat and
199 cocoa, Table A3) considered absolute values and percentage of the total income (i.e.
200 relative bushmeat income). Community coherence was estimated by the community
201 trust index and the perception of wildlife abundance by the interviewee´s assessment
202 (Table A3).
203
204 *2.4. Statistical analyses*
205 The non-parametric Kruskal-Wallis test was used to examine whether the
206 samples come from village groups with equal medians. Boxplots were drawn to
207 visualize the distribution of data for the village groups. The alternative hypothesis is
208 that at least one pair of group villages has unequal medians. We quantified the
209 relationship between livelihood activities indices with the potential mediating
210 factors using the Spearman's rank correlation coefficient r_s and subsequently tested
211 for statistical significance. Because the same data set was used for several tests the
212 sequential Bonferroni correction (Holm, 1979), also known as the Holm-Bonferroni

correction, was applied and the corrected *p´*-values were report alongside the uncorrected *p*-values. The sequential Bonferroni correction is increasingly being rejected because it results in a low statistical power (Moran, 2003; Nakagawa, 2004). To account for this problem, we did not decide on significance when $p < \alpha = 0.05 < p´$. Significance applied for cases when $p < p´ < \alpha = 0.05$ and high significance for $p < p´ < \alpha = 0.01$. Because the regression analysis involving all pairwise comparisons of the selected variables would result in a large number of multiple tests, we made the *a priory* decision to apply statistical tests only to those pairwise correlations where the absolute value of r_s, $|r_s|$, was larger than 0.1. This is a reasonable trade-off between reducing statistical power by a larger number of multiple test and not further evaluating cases where low values of r_s indicate a low explanatory power whether the correlation is significant or not.

We evaluated the interactions between the potential mediating factors and their effect on relative income from bushmeat by using a linear mixed effect model as implemented in the lme4 package for R (Bates et al., 2014). We constructed a series of models aided by the correlation coefficients between relative income from bushmeat versus potential mediating factors and their significance, as calculated by r_s. Altogether five parameters were significantly correlated with relative income from bushmeat. As random effects the intercepts for village and village groups were used. P-values were estimated by likelihood ratio tests for the full model against the model without the specific fixed effect. All analyses were conducted using the R statistical environment (R Foundation for Statistical Computing, 2016).

238 ## 3. Results

239 ### *3.1. Characteristics and market access of surveyed villages*

240 Summary statistics of the socio-economic and livelihood variables across the
241 four village groups, as well as the results of the Kruskal-Wallis tests, are shown in
242 Table 1 (more details in Table A1). For the 37 villages sampled, we surveyed an
243 average (Mean ± SD) of 12.2 ± 6.6 (group 1), 8.7 ± 5.5 (group 2), 12.2 ± 5.0 (group
244 3) and 6.0 ± 2.9 (group 4) households per village.
245
246 Group 4 villages were the furthest settlements from OKNP (approx. 16 times
247 further away than group 1), about four times further than group 1 from Ouesso
248 market. Group 2 and group 3 villages were closest to OKNP and between three and
249 four times further away from Ouesso market than group 1. Travel times to Ouesso
250 corresponded with the actual distance by road from village groups 1 to 3 but was
251 significantly longer for group 4 villages due to their location away from main roads;
252 this difference was highly significant (Table 1).
253
254 ### *3.2. Households, income and expenditure*

255 Across all villages, household size varied between 3 and 5 persons. Median
256 and mean household size were highest for the two village groups closest to OKNP,
257 with differences being highly statistically significant. Age of respondents did not vary
258 significantly among villages, thus questionnaires were unbiased by age and, thus,
259 experience of the respondents.
260
261 Education levels were similar among all village groups but the most remote
262 village group (group 4) did not contain any person with a university education. Mean

household BMI was comparable between groups 1, 2 and 3, but slightly lower in group 4, though the differences were not statistically significant. The community trust index for all villages was low overall (median ≤ 2.3) with the exception of village group 4 which was highest (median 2.7); differences were significant.

All households in the four village groups relied heavily on wild food resources (ranging from 65% to 72% amongst village groups, Fig A1), followed by domestic products (22% to 35%), imported meat (less than 8%) and other sources (less than 5%). Only village group 4 did not consume imported meat or other resources, relying more on domestic products.

Differences between village groups in their monthly household income were highly significant; highest values were reported for groups 2 and 3, medium values for group 1 and lowest values for group 4. Income sources were highly diverse (Fig. A2), including bushmeat sales, farming, cocoa, fishing, small commerce, salaries, raphia wine, corn liquor, palm oil, gathering of NTFPs such as eru (*Gnetum africanum*), livestock, and other activities such as handicrafts. However, income was largest from the sale of bushmeat (ranging from 22% to 34% amongst village groups), farming (13% to 28%), and cocoa cultivation (10% to 49%). Absolute and relative incomes from bushmeat differed significantly between village groups (Fig. 2) with the highest absolute incomes from this source reported from group 3 (mean = $42, median = $0 and maximum = $480) and the lowest for group 4 (mean = $11, median = $0 and maximum = $190). The statistical comparison yielded, however, an undecided result. Income from cocoa was similarly distributed with highest values in

287 group 4 and lowest in group 4. In contrast to bushmeat the differences were highly
288 significant.
289
290 Total food expenditure was highly significantly different between village
291 groups and was lowest in group 4 (Table 1).
292
293 *3.3. Wealth*
294 According to our wealth index, around 60% of all rural households were
295 extremely poor, with less than 10% considered rich (Table 1). Highest proportions of
296 extremely poor and poor people were found in group 2 (21.17%) and in group 4
297 (28.33%). Rich households were less common in group 2 (9.68%) and group 3
298 (8.66%). There were no rich people in group 4. Across village groups, wealth was
299 highly skewed and significantly different (Table 1, Fig. 2). Relative income from
300 bushmeat was more highly skewed across village group than absolute income (Fig.
301 2). The smallest and largest percentages were in group 4 and 3 villages,
302 respectively.
303
304 *3.5. Relationships between bushmeat incomes and expenditures versus potential*
305 *mediating factors*
306 Correlations (r_s) between bushmeat and total incomes and expenditures relative
307 to potential mediating factors for all respondents are shown in Table 2.
308
309 Travel time to the market in Ouesso and distance to the OKNP were all
310 negatively correlated with expenditures and incomes. Total and relative incomes
311 from bushmeat versus travel time and distance, and the total income versus the

312 distance to the OKNP had relatively high r_s values, which were significant or highly
313 significant in all cases i.e. incomes and expenditures were highest for both
314 scenarios: nearer to the market and nearer to the OKNP. Bushmeat expenditure
315 contributed a large proportion of total consumption expenditure (r_s = 0.49) and was
316 highly significant. Bushmeat expenditure was also highly significantly correlated with
317 total income but to a smaller degree than total consumption expenditure (r_s = 0.18).
318 Income from cocoa was positively correlated with total income but negatively with the
319 relative income from bushmeat. Thus, the more cocoa sales the less the relative
320 income from bushmeat or vice versa. Wealth was significantly or highly significantly
321 correlated with all income and expenditure parameters (Fig. 3). Correlation was
322 negative only for absolute and relative bushmeat income, which indicates that
323 reliance on bushmeat income was associated with lower wealth. The data also
324 confirm that body mass indices were positively correlated with total income and
325 expenditures levels; whether total income and expenditure stemmed from bushmeat
326 or not had no effect. People reliant on bushmeat income, whether absolute or
327 relative to the total income, had higher trust in their communities than those that
328 depended less on bushmeat, reflecting a higher social coherence amongst
329 bushmeat hunters.
330
331 Linear mixed models for relative income from bushmeat were built using the
332 absolute values of the correlations r_s in Table 2 as guidelines. The null model based
333 of the mean jointly with intercepts for villages and villages groups as random effects
334 was significantly different from the model with wealth as a fixed effect (likelihood ratio
335 test: χ^2 = 21.35, df = 1, p<0.00001). The latter model was significantly different from
336 the model with wealth and travel time to the market as fixed effects (χ^2 = 8.12, df = 1,

337 p = 0.0043). The addition of the distance to the OKNP and cocoa sales were not
338 significant (χ^2 = 0.008, df = 1, p = 0.93 and χ^2 = 0.18, df = 1, p = 0.67, respectively).
339 The model with wealth, travel time and the community trust index as fixed effects
340 was significantly different to the model of wealth and travel time only (χ^2 = 16.12, df =
341 1, p = 0.00006). As the wealth and community trust indices might be interdependent,
342 we also evaluated the model of wealth, travel time and the community trust index
343 allowing for travel time x community trust interaction and compared with the model
344 without interaction. No significant interaction effects were observed (χ^2 = 0.39, df = 1,
345 p = 0.54). The final model produced fixed effects of 0.28 ± 0.083 for the intercept, -
346 0.02 ± 0.005 for the time to the market, -0.48 ± 0.127 for wealth and 0.11 ± 0.026 for
347 the community trust index, respectively.
348
349 **4. Discussion**
350 *4.1. Market access, household income and bushmeat sales*
351 The variations of household income and bushmeat sales can be explained by
352 the villages' accessibility to markets in Ouesso (i.e. travel time), and by the ability to
353 sell their products to passengers along the road that connects Ouesso to Brazzaville.
354 The sale of forest products is an important source of household income, and part of
355 an income diversification strategy (Shackleton et al., 2011).
356
357 Market access is critical in generating income from bushmeat, farming, and
358 cocoa. This is clearly demonstrated by the fact that Village group 4, the remotest
359 group of settlements (travel to Ouesso only along the Sangha River, since there are
360 no roads) relied on subsistence uses rather than market sales. Thus, poor market
361 access results in lower household incomes. In this group of villages, forest product

prices are lower than prices in the other three village groups where there are local weekly markets because of the easy access to Ouesso. Moreover, consumers travel regularly from Ouesso to buy rural products, particularly bushmeat, an important commodity sold by rural households (Bennett and Robinson, 2000). This possibility improves household incomes. The high income of group 3 from cocoa cultivation also emphasizes the importance of markets for household incomes. These villages are on the Cameroon border, and since the cocoa crisis in the early 1990s, traders from Cameroon buy cocoa in this area (Russell et al., 2011) but neglect plantations elsewhere in the Congo.

Group 3, with the highest average household income from cocoa cultivation has important implications for the discussion on alternative livelihoods and poaching. The assumption is often made that cocoa can be an important alternative income source that as a consequence will reduce the need for people to obtain cash and therefore reduces hunting pressure. However, these villages also have the highest average income from bushmeat ($41.8). This is because most cocoa plantation owners were older, whereas most young people (who neither own nor inherit cocoa plantations) were active in bushmeat hunting. Russell et al. (2011) argue that young people turn to illegal hunting activities in the absence of access to land. Another contributing factor is that group 3 is closer to the park, and although they are further from markets than other village groups the status of the road is better. Group 1 ($26.7 as income from bushmeat sales) is far from the park but near to Ouesso while group 2 ($30.5 as income from bushmeat sales), the group 1 is closest to Ouesso but further from the park.

4.2. Household daily food expenditure

Household expenditure on daily meals differed among village groups. The three groups with easy access to Ouesso spent more money in comparison to group 4, demonstrating that income is affected by market access. In village group 4, with no access to markets, people hunt more for subsistence rather than for trade, and each family tries to produce what they need (e.g. cassava, raphia wine, palm oil, maize). In rural areas, bushmeat consumption may be associated with people's preferences or their culture, but the scarcity of bushmeat can push consumers to change their preferences. In the largest towns in the country (i.e. Brazzaville and Pointe Noire), bushmeat is a luxury good consumed by rich people (Mbete et al., 2011). Although many people living in these cities originate from rural areas with bushmeat-eating habits, they cannot afford bushmeat and are forced to consume other sources of animal protein (Wilkie et al., 2005; Mbete et al., 2011). So rich people in cities diversify animal protein intake to include bushmeat, whereas poor people consume only the cheapest protein such as domestic meat (Auzel and Wilkie, 2000; Wilkie et al., 2005).

4.3. Wealth

People are poorest in the remote villages with few markets (group 4) and also in the villages nearer Ouesso (group 1) where forest products and wildlife, which constitute the main source of income, are severely depleted because of human pressure. Villages close to the park but further from Ouesso (groups 2 and 3) presumably benefit from wildlife dispersing out of the park where hunting is still productive, supporting a weekly bushmeat market. As noted, cocoa cultivation is a

411 major source of income contributing about 49% of income in group 3, but aside from
412 this localized group, cocoa farming is underdeveloped in the study area.
413
414 *4.5. General findings and conclusions*
415 Overall, we show that household income is negatively associated with
416 distance to the park, with household consumption expenditures, income from cocoa
417 sales, and wealth index, but is not related to travel time. These associations suggest
418 that people with better access to markets and the park tended to be richer because
419 of their income primarily from bushmeat sales, whereas those further away from the
420 park obtained less revenue from bushmeat and were overall poorer. Foerster et al.
421 (2011) report similar findings for Gabon, in which the authors suggest that because
422 richer hunting zones are found closer to the park, people in these localities are able
423 to hunt more and to sell. Greater access to wildlife also had an effect in permitting
424 beneficiaries to spend more money on bushmeat than poorer people, but also to sell
425 more bushmeat. However, wealthier people depended less on selling bushmeat, but
426 those who sold bushmeat were generally poor. Other studies suggest this (Scherl,
427 2004; Shackleton et al. 2011).
428
429 Dependence of rural peoples on forest resources is marked, as shown in our
430 study. Wildlife is an important source of both cash and food, similar to other locations
431 around the Congo basin (Wilkie and Carpenter, 1999; Wilkie et al., 2006; Van Vliet
432 and Nasi, 2008; Foerster et al., 2011) and in some African drylands (Von Richter and
433 Butynski, 1973). In our study, hunters are pushed to sell much of the bushmeat they
434 harvest for markets in Ouesso and even beyond (Brazzaville), where bushmeat is a
435 popular delicacy and usually sell at much higher prices. Such increase in commercial

436 hunting and trade to secondary towns and large cities in the country places
437 unprecedented pressures on wildlife populations in the region. This situation may be
438 reflected in the responses given by interviewed hunters who suggest that in all
439 villages, except those furthest away, wildlife is perceived to be decreasing. As shown
440 in other studies in the region (Noss, 1998; Muchaal and Gandjui, 1999; Poulsen et
441 al., 2009) current harvest rates around the OKNP could be much higher than
442 sustainable levels.
443
444 With growing human populations, urban areas, roads, and markets the
445 demand for bushmeat increasingly threatens its sustainability. More importantly, the
446 demand for bushmeat is growing in the absence of local regulations to protect
447 wildlife resources. Scarcity should drive up both the price and the production of
448 wildlife, but in the absence of clear property rights wildlife is exploited rather than
449 produced sustainably. Legally, wildlife is owned by the central government which is
450 unable to exert its “rights of exclusion” and the richest wildlife habitats are rarely
451 visited by most governmental agencies which in any case lack the human and
452 financial resources to effectively enforce laws even in even easy to reach areas
453 (Rowcliffe et al., 2004) - the government officials’ “authoritative reach exceeds their
454 implementational grasp” (Murphree, 2000:4). The result is a humanly constructed
455 stalemate and an economically incoherent wildlife economy, where local people
456 deplete the resource over which their livelihood depends, while the state lacks
457 strategies and the human and financial resources to enforce laws at the village level.
458 In public meetings, people regularly stated “wildlife is for the state” and asked “how
459 can we take care of something that doesn’t belong to us?” Thus, central control of
460 wildlife management disenfranchises local people, causing them to shirk any

461 responsibility for a resource that is “owned” by an outside entity. The seeming lack of
462 local conservation action despite the key contribution of wild resources to local
463 livelihoods is a paradox. The likely cause is weak local property rights (Schlager and
464 Ostrom, 1992; Hanna et al., 1996) and disempowerment of local people with respect
465 to their wildlife.
466
467 Given the high dependence of human livelihoods on forest resources in our
468 study area, as in other similar localities, the future of wildlife and PAs may lie in the
469 sustainable use of wild resources rather than non-use to strengthen the resilience of
470 the poor (Roe and Elliott, 2004; Sanderson and Redford, 2003). Livestock is not an
471 effective alternative activity to bushmeat hunting for forest dwellers in central Africa
472 (Russell et al., 2011) but, even if it were, the result of encouraging people to use
473 livestock rather than wildlife is simply for domestic species to replace wild ones. The
474 ecological reality is that forests (and drylands) often cannot produce more raw
475 commodities. In southern Africa, therefore, wildlife replaced livestock commodity
476 production once proprietorship was devolved to landholders, and because wildlife
477 could be converted into much higher values through trophy hunting and, in a few
478 places, through tourism. Reversing these trends may well require approaches like
479 those implemented in Namibia (NACSO, 2015).
480
481 Though this study does identify significant associations, its cross-sectional
482 rather than experimental design does not confirm causality (Bryman, 2008; Agresti
483 and Finlay, 2009). Therefore, further research is needed to investigate the
484 relationship among variables in terms of the causes and effects. In addition, we ask
485 what will motivate local people to take action to conserve wildlife. Despite this, our

results have generated a new hypothesis. Thus, the distance to the town did not provide strong clarification on rural livelihood activities' variation. However, the travel time from Ouesso to village that characterizes market access and offers a clearer explanation regarding the associations among variables (i.e. this is an effective predictor of livelihoods variation and-or association). Surrounding this study area, it is argued, "the impacts of conservation-related displacement need to be understood in the context of the other major land-use changes occurring in the region" (Curran et al., 2009, Ridell, 2013). The recognition of the starting point for interventions will facilitate the task when setting biodiversity conservation and poverty elimination goals (Adams et al., 2004). In other words, for the future evaluation of park management effects, these variables can be used to assess trends, comparing villages with the park effects to control villages (i.e. without the park effects). Child (2014) argues that we should establish a relationship between the economic value of the PAs and their benefit to local people, and then this can enable PAs to undertake conservation actions in their buffer zones.

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FIGURE LEGENDS

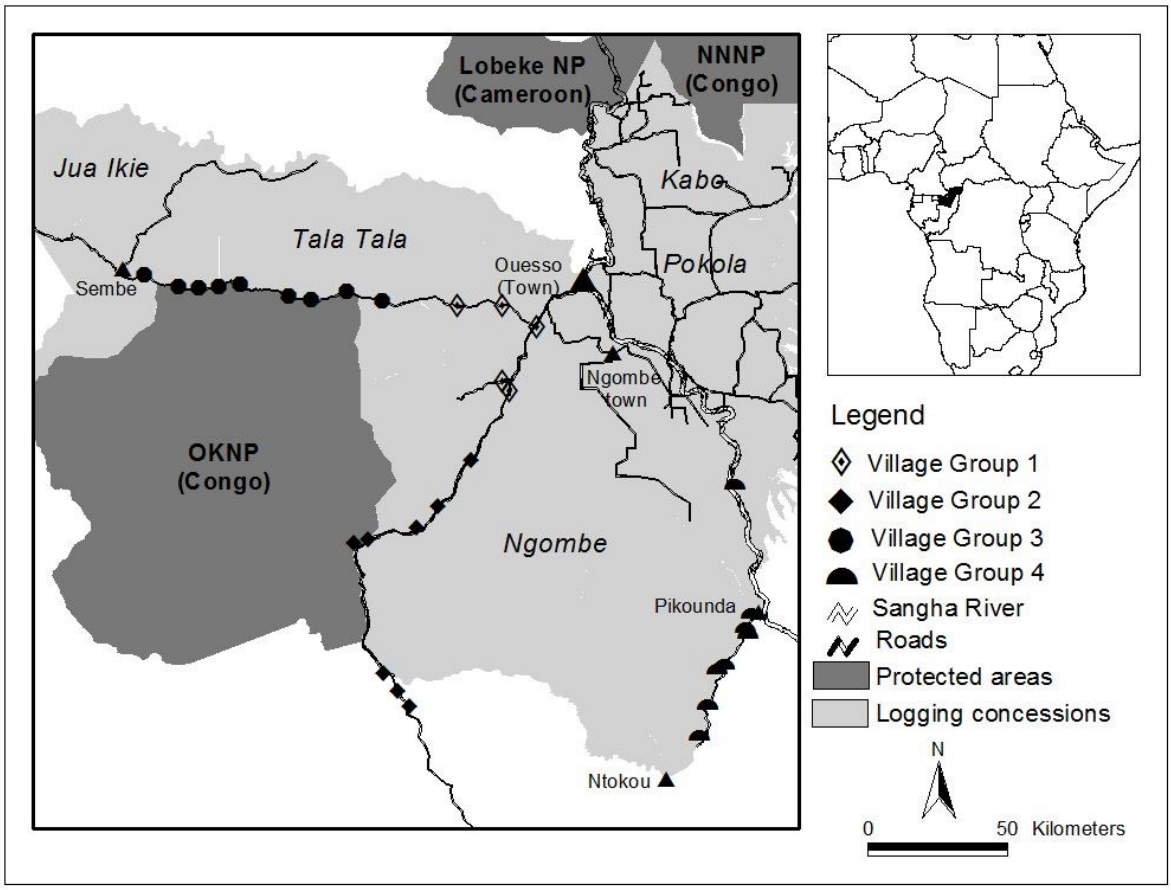
Figure 1. Location of the study area, villages and the Odzala Kokoua National Park OKNP (Northern Congo).

Figure 2. Distribution of bushmeat related livelihood variables across the four village groups GP1 to GP4. Each box covers 50% of the respective data (i.e. first to third quartile). Bold lines indicate medians, whiskers indicate 1.5 the interquartile ranges and dots suspected outliers.

Figure 3. Association between potential mediating factors and incomes and expenditures from bushmeat. Those associations are shown which were significant or highly significant (Table 2).

693 Fig. 1

694



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697 Fig. 2

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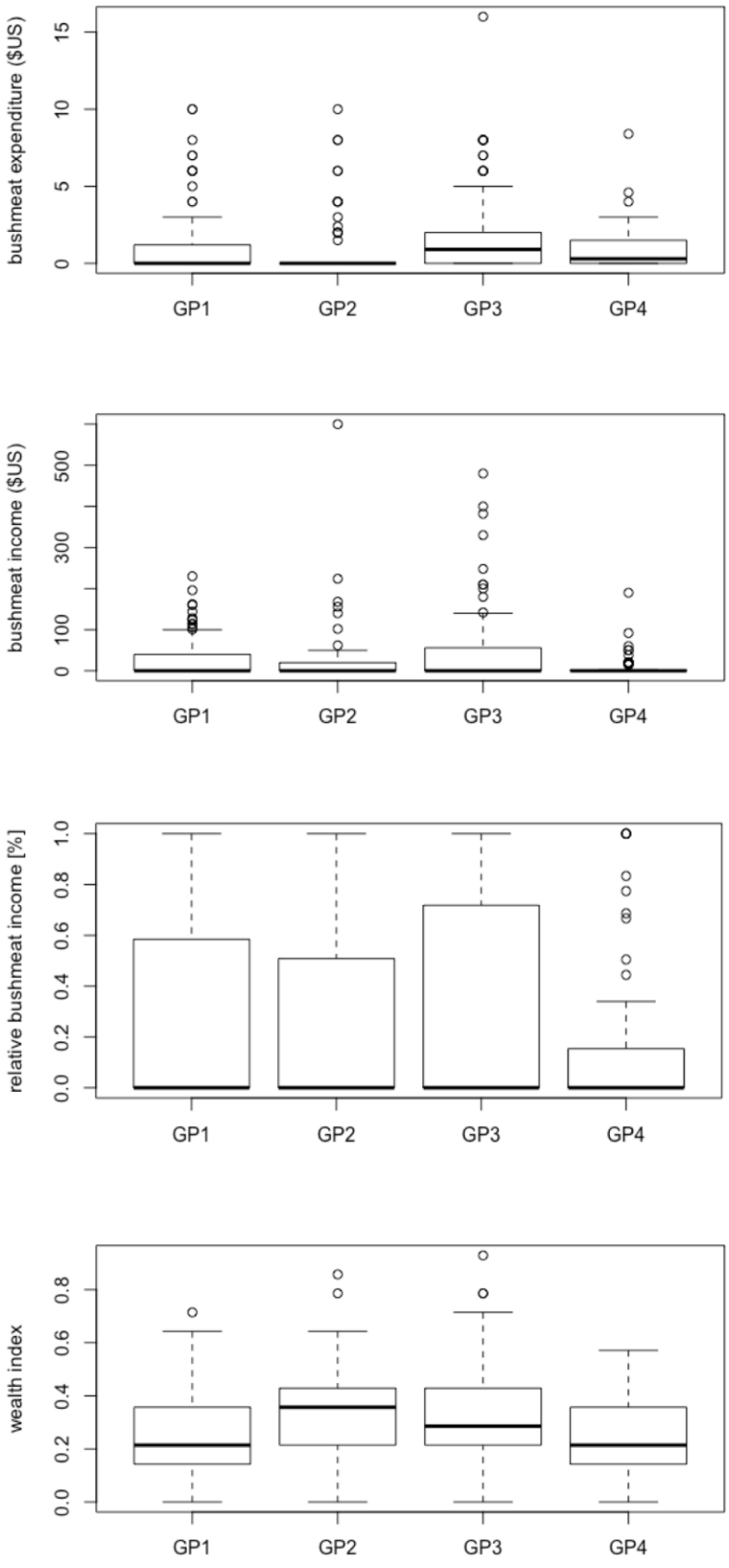
bushmeat expenditure ($US)
0
5
10
15
GP1
GP2
GP3
GP4
bushmeat income ($US)
0
100
300
500
GP1
GP2
GP3
GP4
relative bushmeat income [%]
0.0
0.2
0.4
0.6
0.8
1.0
GP1
GP2
GP3
GP4
wealth index
0.0
0.2
0.4
0.6
0.8
GP1
GP2
GP3
GP4

699 Fig. 3

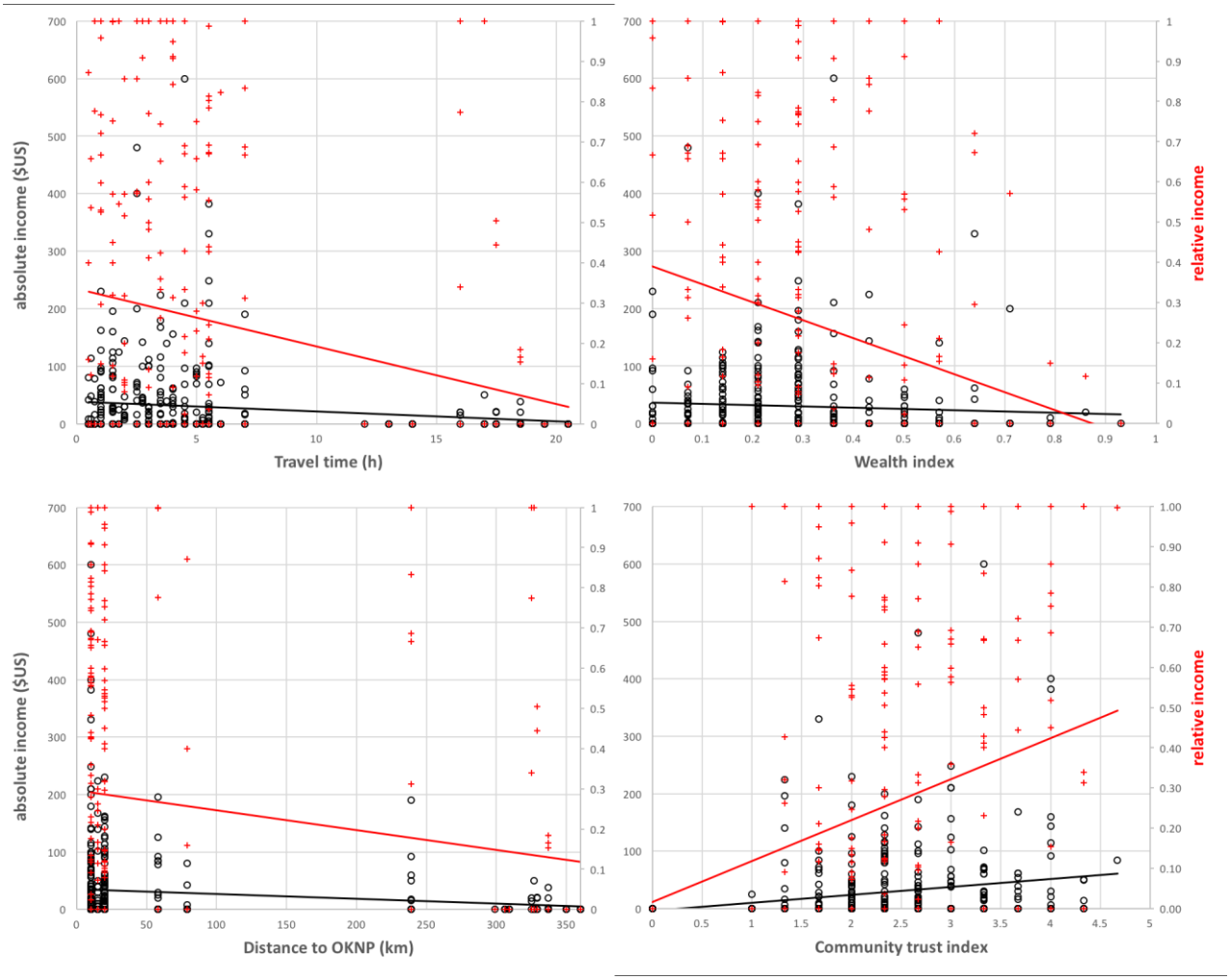
absolute income ($US)
relative income
Travel time (h)
Wealth index
Distance to OKNP (km)
Community trust index

Table 1. Socio-economic and livelihood variables across the four village groups surrounding the Odzala-Kokoua National Park. Shown are number of interviewed respondents *n*, mean μ, median Mdn and range, Kruskal-Wallis χ^2 and *p* (df = 3 in all cases) and adjusted *p´* for multiple testing by Holm-Bonferroni sequential correction. Means and medians are shown because of the skewed data distributions. Significance is indicated as * = $p < p´ < 0.05$, ** = $p < p´ < 0.01$ and "?" = $p < 0.05 < p´$. The descriptive distances were not statistically evaluated.

	group 1		group 2		group 3		group 4		Kruskal-Wallis test			
	n_{min}=133, n_{max}=136 11 villages		n_{min}=59, n_{max}=63 8 villages		n_{min}=115, n_{max}=127 9 villages		n_{min}= n_{max}=60 9 villages					
Parameter	μ | Mdn	range	μ | Mdn	range	μ | Mdn	range	μ | Mdn	range	χ^2	*p*	p´	∑
Survey villages and market access												
Distance to OKNP	30.4 | 20	20-79	14.5 | 15	10-20	10.0 | 10	10-10	316 | 328	239-360	-	-	-	-
Distance to Ouesso	53.1 | 48	25-85	176.8 |200	100-215	138.8 | 143	69-190	212.0 | 224	135-256	-	-	-	-
Travel time to Ouesso market	1.4 | 1	0.5-3	4.8 | 5	3.3-5.5	4.1 | 4	2.5-6	15.6 | 17.3	7-20	309	<.001	<.001	**
Household size	4.4 | 4	1-13	4.4 | 5	1-9	5.3 | 5	1-17	3.3 | 3	1-9	31.6	<.001	<.001	**
Respondent age	47.3 | 46	20-86	45.0 | 42	20-80	47.9 | 46.5	24-79	50.0 | 44	24-82	2.8	.417	.818	
Respondent education level	1.3 | 1	0-4	1.7 | 2	0-4	1.3 | 1	0-4	1.1 | 1	0-3	12.3	.006	.038	*
Respondent BMI	23.9 | 23.6	17.7-42.6	23.6 | 22	18-37.6	23.2 | 23.2	14.7-31	22.3 | 22.3	16.8-29.5	8.9	.031	.154	?
Community trust index	2.3 | 2.3	2-4.7	2.3 | 2	0-4	2.4 | 2.3	0-4	2.9 | 2.7	0-4.3	30.6	<.001	<.001	**
Household income, food consumption & wealth												
Total income $US	81.2 | 66	0-355	96.3 | 60	0-600	170.7 | 105	0-1170	55.0 | 33.3	0-320.8	38.2	<.001	<.001	**
Income from bushmeat $US	26.9 | 0	0-230	30.5 | 0	0-600	41.5 | 0	0-480	10.5 | 0	0-190	8.1	.045	.179	?
Income from cocoa $US	0.1 | 0	0-16.7	0 | 0	0-133	90.2 | 0	0-1320	4.7 | 0	0-35	90.4	<.001	<.001	**
Expenditure bushmeat $US	1.1 | 0	0-10	1.1 | 0	0-10	1.5 | 0.8	0-16	1.0 | 0.3	0-8.4	6.9	.076	.228	no
Expenditure consumption $US	3.9 | 2.4	0-10	4.5 | 4.1	0-13.7	2.9 | 2.4	0-0	2.3 | 2.2	0-7	27.7	<.001	<.001	**
Wealth index	0.3 | 0.2	0-0.7	0.3 | 0.4	0-0.9	0.3 | 0.3	0-0.9	0.2 | 0.3	0-0.6	17.4	.001	.004	**
Perception of abundance	3	0-4	3	0-4	3	0-4	3	0-4	2.9	.41	.818	

Table 2. Association between potential mediating factors and incomes and expenditures from bushmeat. Spearman´s rank correlation r_s, sample sizes *n* and outcomes from the test statistics are presented. Tests were only performed when r_s explains at least 10% of the observed variance. Observed *p* and the *p´*-values adjusted with the Holm-Bonferroni sequential correction approach are shown. Significance as in Table 1.

		Bushmeat consumption expenditure ($US)		Total consumption expenditure ($US)		Income from bushmeat ($US)		Total income ($US)		Relative income from bushmeat	
		n=386		n=383		n=386		n=386		n=359	
Potential mediating factors	n	r_s	p p´	r_s	p p´	r_s	p p´	r_s	p p´	r_s	p p´
Travel time to Quesso market	386	-0.03	-	-0.01	-	-0.15 *	0.004 0.022	-0.02	-	-0.17 **	<0.001 0.007
Distance to OKNP	386	-0.02	-	-0.09	- -	-0.13 *	0.011 0.033	-0.30 **	<0.001 <0.001	-0.12 *	0.018 0.037
Total consumption expenditure ($US)	383	0.49 **	<0.001 <0.001	N/A	N/A	0.09	-	0.18 **	<0.001 0.003	0.04	-
Income from cocoa sale ($US)	386	0.06	-	-0.08	-	-0.08	-	0.32 **	<0.001 <0.001	-0.17 **	<0.001 0.007
Wealth index	386	0.16 *	0.002 0.015	0.28 **	<0.001 <0.001	-0.13 *	0.008 0.032	0.21 **	<0.001 <0.001	-0.22 **	<0.001 <0.001
BMI	367	-0.06	-	0.11 *	0.018 0.037	-0.02	-	0.15 *	0.003 0.022	0.04	-
Community Trust Index	386	0.08	-	0.01	-	0.19 **	<0.001 0.002	0.08	-	0.17 **	<0.001 <0.001

710

711 **Supplementary Information**
712

713

Table A1. Summary of the four surveyed village groups surrounding the Odzala-Kokoua National Park northern Congo (Figure 1).

	Village group			
	1	2	3	4
Villages sampled (n)	11	8	9	9
Households sampled (n)	136	62	128	60
Average distance to OKNP (km)	30	14	10	316
Road access	On main north-south and east-west roads, good road conditions, high levels of traffic	On main north-south road, good road conditions, high levels of traffic	On main east-west road, good road conditions, high levels of traffic	No road access, access by boat only
Access to OKNP	Via both the main north-south and east-west roads	Via the main north-south roads, which straddles part of the eastern park border	Via the main east-west road, which straddles most of the northern park border	No access
Access to local bushmeat markets	Weekly market in some villages e.g. Liouesso and Attention	Weekly bushmeat market in some villages e.g. Mokouagonda and Moyoye	Weekly market in some villages e.g. Kokoua and Seka	No markets
Cacao cultivation	None	High	High	Low
Hunting pressure extended on OKNP	High	High	High	Low

Table A2. Heads of Households' Questionnaire

Village: Date: Investigator: Questionnaire #:

Name of household head (HH):

1. Demographic information

Please, how many individuals do you have in your household? :

Name	Relationship -HH	M-F	Age	Ethnicity	Education level	Weight	Height	Mid upper arm ⦸

2. Wealth assessment (basket of assets): Please, do you have these goods?

Items	# Unit	Cost per unit	Total Cost
Shotgun (i.e. for hunting)			
Wood bed			
Mattress			
Watch-Clock			
Stereo			
Radio			
DVD player			
Scooter			
Bicycle			
Livestock #			
Poultry #			
House_sheet metal roof			
Power Generator			
TV			
Other			

3. How important is wildlife for your household?

Very little: Little: Some: A lot of: Great deal:

3. Household consumption: Please fill out the following table regarding your expenditure for food in the last 48h

Products	Source					
	Wild		Domestic		Manufactured	
	Unit	Cost	Unit	Cost	Unit	Cost

4. Transitory income of household heads: What are the quantity and the values of your forest products and crops for both use and sale over past month or season?

Products	Quantity collected	Unity	Own use	Sold	Price per unit	Type of Market	Income

5. Importance of hunting in household income compared with other activities

Designation	1	2	3	4	5
Farming					
Cacao					
Fishing					
Hunting					
NTFPs (specify)					
Livestock					
Job					
Pensions					
Traditional practitioners					
Money from town					
Other (specify)					

6. Please, what are your hunting motivations

To increase household income: Traditional activity: Good product to sell: Other (specify):

7. Community trust: Please indicate whether you agree or disagree with the following statements

Items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Would you trust a neighbor to look after your house when you had to leave the village					
Would you trust a neighbor to look after your money					
Whether a machete left outside overnight would still be there in the morning					

8. Disease vulnerability

Please, in the past year, have any of you suffered from the following diseases?

Diarrhea: Kwashiorkor: Malaria: Other(specify):

9. Food security

How many times in the past five years has your family not been able to get enough food? Number of months without enough food?

20012: 2011: 2010: 2009: 2008: 2007:

Why:

10. Compared to 10 years ago, are your forest resources more or less abundant today and explain why?

Wild resources	Don't know (1)	No change (2)	Decrease (3)	Increase (4)
Wildlife				
Fish				
Caterpillar				
Irvingia sp				
Nkoko				
Other (specify)				

11. How far can we find the following wildlife species? Please specify how many walk time to find these species

Gorillas: Chimpanzees Small monkey: Brush-tailed porcupine:

Bleu duiker: Peter's duiker: Bush pig: Other (specify):

12. What major events have affected your livelihood in the past 5 years?

1: 2: 3:

What caused?

How did you respond?

13. What are the three biggest challenges to your livelihood that you are worried about and explain?

1: 2: 3:

14. Compared to 5 years ago, is your household more or less prosperous today and explain why?

More abundant Less prosperous No change Don' t know

15. Participation in community actions

Are you member of any associations in the village?

Yes: No:

Named them:

Social-Economic objective:

Do they interact with other villages?

A. Focus Group

Village: GPS X: Y: Distance to Ouesso:

Travel time: Distance to park: Population estimate:

1. What are your principle activities in the village? For men, for women?

2. What is the most important hindrance in community projects in your village? Why? How do you can overcome it?

3. What types of associations do you have in your community?

4. Do you any informal rules or regulations of access to your forest? If so, how strong are they comparing to formal?

5. What factor influence the most pressure on wildlife in your village?

6. Please sort your most important hunting motivations

Increase household Income: Traditional activity (culture): Bushmeat has high benefit:

7. What can we do to use wildlife for long term?

8. Can you report any poaching event in the village to village's authorities?

9. What do you know about wildlife?

Measures of control wildlife:

Benefits:

Trends (increase or decrease):

10. What are the consequences of wildlife extinction?

11. What actions should you take according to you?

12. Why are you not taking these actions?

849 **Table A3.** Human livelihood variables assessed through questionnaires.
850
851

Study variable	Measurements	Measurement units
Access to the main town Ouesso	Reported travel time village - Ouesso	minutes
Distance to Ouesso and OKNP	Distances from village according administrative records	km
Gender	Gender of household head	male / female
Age	Age of household head	years
Ethnicity	Self-assignment of ethnic group	Bantu, indigenous Pygmy groups
Level of the education	Level of the education of each household member	Index: no school (0), primary school (1), secondary school (2), high school (3), university (4)
Body mass index BMI	Weight and height of all household members aged 1 year or above	averaged BMI over all household members
Household size	all household members	n
Household food composition	Bushmeat, fish, domestic animals, vegetables from farm, vegetables from forest, imported protein, others	Composition of last main household meal in percent
Household expenditure for all food	Monetary value of all food items bought for last main household meal	Monetary value in the local currency FCFA, translated into $US using the exchange rate $US 1 = 500 FCFA
Household expenditure for bushmeat	As above but for bushmeat only	As above
Sources of income	Bushmeat trade, farming, cocoa, small commerce, salary, corn liquor, fishing, raffia wine, gathering, livestock, palm oil, handcrafts, and other items sold during the last season or this year	As above

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Study variable	Measurements	Measurement units
Household income from any sold food items	Estimated value of any food items sold during the last season or this year including	As above
Income from cocoa sale	As above for cocoa only	As above
Income from bushmeat sale	As above for bushmeat only	As above
Community Trust index	How are neighbours trusted to look after one´s house	Strongly mistrust (1), mistrust (2), neutral (3), trust (4), strongly trust (5)
Wildlife abundance perception	Perception of wildlife abundance	Index: don't know or not specified (0), no change (1), decrease (2), increase (3)
Household wealth	Sum of monetary value of itemized household possessions	Monetary value in the local currency FCFA, translated into $US using the exchange rate $US 1 = 500 FCFA
Household wealth index	Household wealth in relation to all other surveyed households	Partition of the distribution of wealth of all households into five quintiles, which were categorized as “poorest”, “poor”, “middle income”, “rich”, and “richest”. Each Individual household was then assigned to the adequate category,

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854 **Table A4.** Average prices of principal products sold surrounding Odzala-Kokoua
855 National Park OKNP (northern Congo). Prices in $US are converted from the local
856 currency FCFA (see Table A3).

Rural products	Village Groups				Ouesso
	1	2	3	4	
Red duikers ($-Kg)	1.30	1.30	1.30	0.70	3.30
Blue duikers ($-Kg)	1.60	1.60	1.60	1.20	2.40
Small monkeys ($-Kg)	1.30	1.30	1.30	1.00	2.00
Porcupine ($-Kg)	2.00	2.00	20	1.30	4.00
Raffia wine ($-liter)	0.30	--	0.30	0.10	0.60
Palm oil ($liter)	1.00	1.00	1.00	0.50	2.00
Gnetum africanum ($-Unit)	0.40	0.40	0.20	0.10	1.00
Local chicken ($-unit)	4.00	4.00	4.00	2.00	8.00
Corn ($-3 ears of corn)	0.60	0.60	0.60	0.10	0.60

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859 **Table A5.** Potential explanation of associations between assessed livelihoods.

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	Possible associations among variables	Direction of significant association	Explanation
1	Market access and bushmeat income	-	It is harder to sell bushmeat to distant markets. As market accessibility declines (i.e. travel times increase), bushmeat becomes more difficult to transport and sell, or transport costs exceed the price in the market
2	Market access and community wealth	+	Communities with access to markets are wealthier. People successfully use markets to increase their household wealth
3	Distance to park and expenditure, income, wealth	-	The further from the park people are, the poorer they are, because there are fewer forest products (and village group 4 is both far from the park and far from markets)
4	Distance to the park and bushmeat sales	-	Local people far away from the park have less wildlife resources to hunt and sell
5	HH expenditure and bushmeat purchases	+	Wealthier people choose to spend money on bushmeat, and-or poor people have no money to spend on bushmeat. Richer households buy more bushmeat
6	Household expenditure and bushmeat sales	+	The more wealthy people are, the less they depend on selling bushmeat, or people who depend mainly on selling bushmeat remain poor
7	HH expenditure and HH income-community wealth	+	Richer households spend more money
8	Cocoa sales and household income, wealth	+	Cocoa production is a key component of household income in some villages (group 3) in the region and allows people to purchase more goods
9	Bushmeat sales and wealth index	-	This is opposite to 5 and 6 because results show a very low negative correlation between wealth index and income from bushmeat sales. This means richer people sell less bushmeat.

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863 Figure A1. Main food sources

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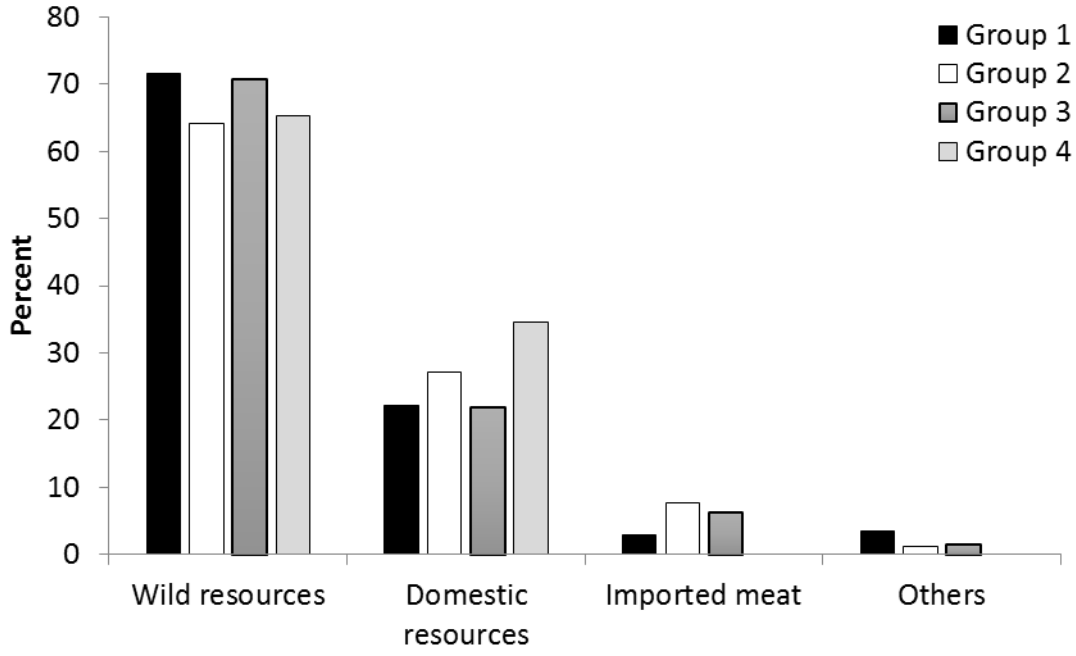

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868 Figure A2. Income sources
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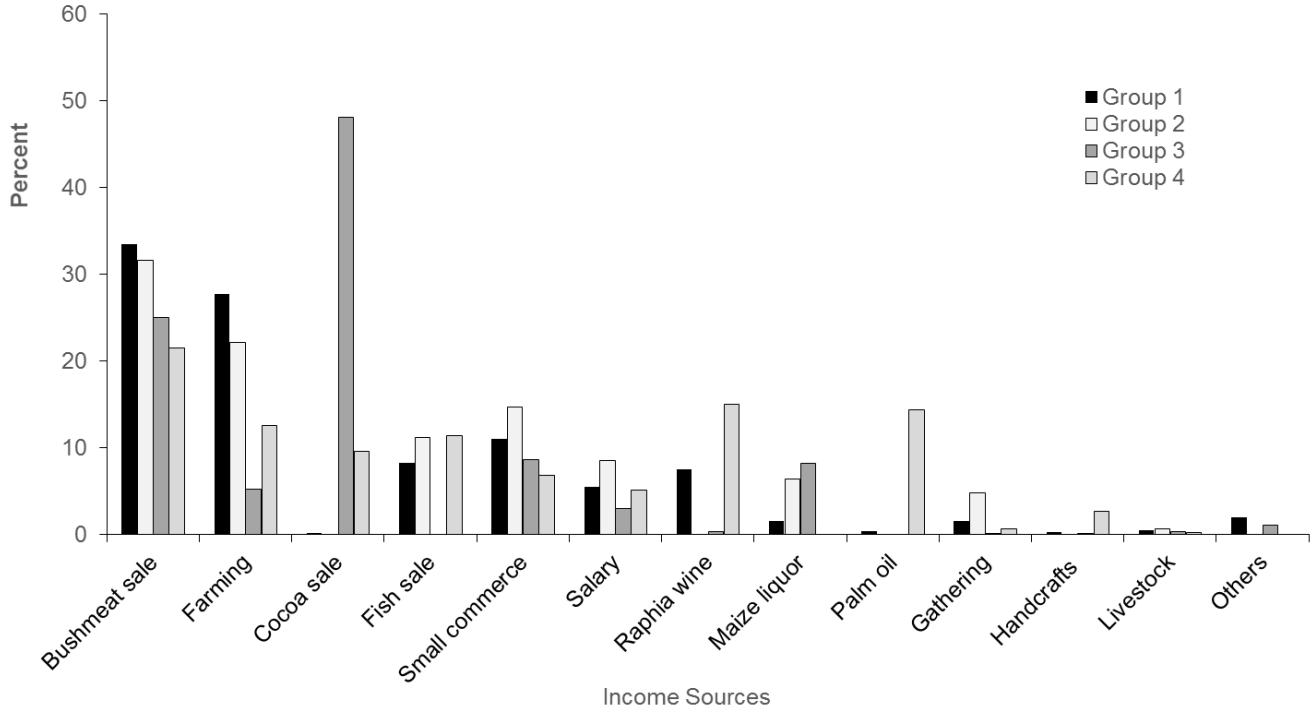

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