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LETTER

Changes in wild meat hunting and use by rural communities during the COVID-19 socio-economic shock

Charles A. Emogor[1,2,3] | **Lauren Coad**[4,5] | **Ben Balmford**[6] | **Daniel J. Ingram**[7] | **Diane Detoeuf**[2] | **Robert J. Fletcher Jr.**[8] | **Inaoyom Imong**[2,3] | **Andrew Dunn**[2,3] | **Andrew Balmford**[1]

[1]Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge, UK
[2]Wildlife Conservation Society, New York, New York, USA
[3]Pangolin Protection Network, Calabar, Nigeria
[4]Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), Bogor, Indonesia
[5]Interdisciplinary Centre for Conservation Science, University of Oxford, Oxford, UK
[6]Land, Environment, Economics and Policy Institute, Economics Department, University of Exeter, Exeter, UK
[7]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, UK
[8]Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida, USA

Correspondence
Charles A. Emogor, Conservation Science Group, Zoology Department, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK. Email: emogorcharles@gmail.com

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Abstract

There is limited quantitative evidence of the effects of socio-economic shocks on biological resource use. Focusing on wild meat hunting, a substantial livelihood and food source in tropical regions, we evaluated the impacts of the shock from Nigeria's coronavirus disease (COVID-19) lockdown on species exploitation around a global biodiversity hotspot. Using a 3-year quantitative dataset collected during and after the lockdown (covering 1008 hunter-months) and matching by time of year, we found that successful hunting trip rates were more frequent during the lockdown, with a corresponding increase in the monthly number, mass, and value of animals caught. Moreover, hunters consumed a larger proportion of wild meat and sold less during lockdown, compared to non-lockdown periods. These results suggest that local communities relied on wild meat to supplement reduced food and income during the lockdown, buffering the COVID-19's socio-economic shock. Our findings also indicate that wild species may be especially vulnerable to increased hunting pressure during socio-economic shocks.

KEYWORDS

anti-poaching, biological resource use, COVID-19 pandemic, Cross River National Park, socio-economic shock, sustainable use, wild meat hunting

1 INTRODUCTION

The hunting of wild animals for food (i.e., wild meat) is one of the biggest threats to biodiversity globally (Abernethy et al., 2013; Schulze et al., 2018) while also providing food and income to many rural communities across the tropics and subtropics (Coad et al., 2019). Wild meat is an easily accessible resource with relatively low entry costs, compared to other livelihood activities (Schulte-Herbrüggen et al., 2013) and, therefore, can provide an important safety net for rural communities during socio-economic crises, civil conflicts, or other shocks characterized by reductions in livelihood opportunities and market access (UNDP, 2023). The economic importance of wild meat to rural communities is well known (Nielsen et al., 2017; Schulte-Herbrüggen et al., 2013), but there is limited quantitative evidence of its use during shocks, potentially because of their unpredictability and hence the lack of comparable data before, during, and afterward.

The 2019 coronavirus disease (COVID-19) triggered one of the greatest global shocks in modern human history (World Bank, 2022), with the disease linked to ~6.9 million human deaths worldwide (as of March 2023; JHU, 2023) and a global economic shrinkage by 3.5% in 2020 alone (World Bank, 2022). To curb the spread of the virus, many countries implemented national lockdowns to reduce transmission rates (Balmford et al., 2020; Hsiang et al., 2020).

McNamara et al. (2020) proposed that these lockdowns may have reduced urban demand for wild meat due to decreased spending power and increased costs for traders. Conversely, rural families, facing restricted livelihood options and increased urban–rural migration during the lockdown, may have increasingly relied on wild meat as a crucial source of food and income. Nonetheless, McNamara et al.'s hypotheses have yet to be quantitatively tested: Previous assessments of the impacts of the COVID-19 shock on wild meat extraction and use largely used qualitative interviews collected retrospectively and often focused on single species (Briceño-Méndez et al., 2021; Enns et al., 2023; Kamogne Tagne et al., 2022; Mendiratta et al., 2022; Vliet et al., 2022).

Here we investigate the impacts of the shock created by the COVID-19 pandemic on patterns of wild meat hunting and use in two rural communities around Nigeria's Cross River National Park (CRNP). Using quantitative data from 28 hunters collected during and after Nigeria's lockdown, and covering 1008 hunter-months, we compare the frequency of successful hunting trips—trips in which at least one animal was captured—and their outcomes (number, mass, value, and use of animals caught) during and after the lockdown. In line with McNamara et al.'s hypotheses, we expect that the frequency of successful trips and these outcomes will be higher during the lockdown compared to other periods. Further, given reported disruptions in protected area management during lockdown (Eklund et al., 2022; Singh et al., 2021), we also investigate changes during and after the lockdown in (a) ranger patrol efforts in CRNP and (b) hunting locations (i.e., within vs. outside the park). Our results provide quantitative evidence of the importance of wild meat to local communities and the vulnerability of wild animal populations during shocks, which can help to inform policies for withstanding future disruptions.

2 METHODS

2.1 Data collection

We tracked 33 male hunters (each recruited from a different household) around CRNP in south-east Nigeria for 3 years (April 1, 2020–March 31, 2023), but to ensure uniformity, we only used data from 28 hunters followed continuously. The communities (~10 km apart) border the Oban Division of CRNP, one of the largest remaining forest blocks in the Guinean Forest biodiversity hotspot (Myers et al., 2000; Figure 1). We recruited hunters through community hunter associations, focusing on formal hunters (those who primarily hunt with guns) as casual hunters (who mainly use snares to trap animals) were not members. After each hunting trip, we conducted structured interviews in English, which were administered by trained local field assistants.

The data collected included trip duration (in days), the number and species of animals captured, and, for each animal, its intended use (household consumption, gift, ceremonial use, or commercial purpose), mass, and price (for carcasses not intended for sale, we requested the likely price if sold). In cases where hunters had already slaughtered an animal, we recorded its mass and price per piece. Additionally, we inquired about any captures consumed during the trip; we had missing data for mass in such cases. We also recorded the location of capture as follows (a) plantation, (b) community forests, and (c) protected forests (i.e., CRNP). During the lockdown, we recorded only those trips on which animals were caught, and hence our analyses here focus on the frequency and outcomes of successful trips, restricting us from assessing variations across all hunts irrespective of the outcome. However, this limitation does not hinder us from testing McNamara et al.'s hypotheses. Note that all hunts within CRNP or that involved killing a protected species were illegal. The research ethics statement is provided in Appendix A in the Supporting Information.

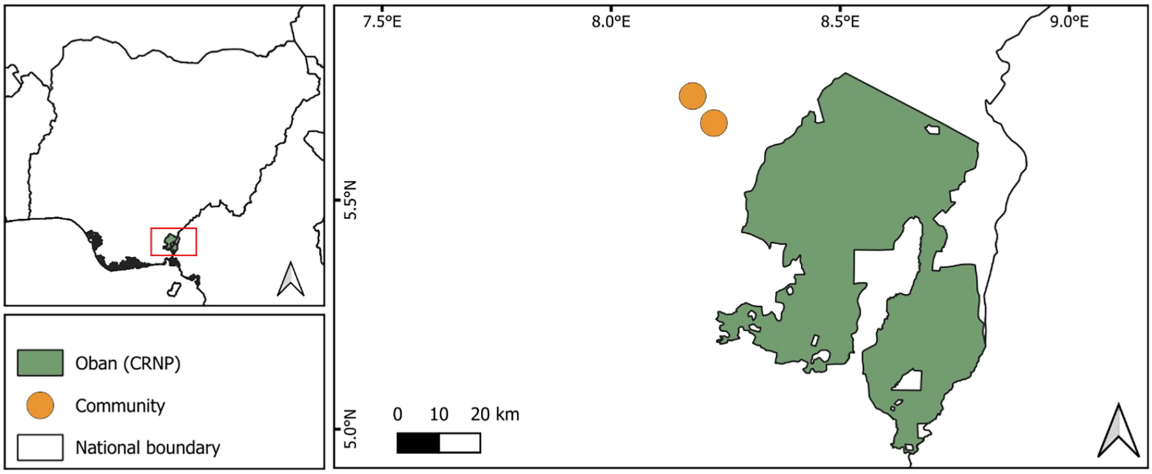

FIGURE 1 Approximate locations of the study communities around the Oban Division of Nigeria's Cross River National Park (CRNP). The red rectangle on the top left map shows the study location in Nigeria.

2.2 | Analysis

We first split our data into three periods: "lockdown" (March 30 to September 3, 2020; 5.2 months), "matched non-lockdown" (corresponding lockdown dates in 2021 and 2022, totaling 10.4 months; note these included minor restrictions on people's movements), and "other non-lockdown" (other days in 2020–2023, totaling 20.6 months; see Appendix B in the Supporting Information for more details). Next, we used a Chi-square test to compare (a) the species composition of the catch across periods (using data on 13 species as we dropped those with expected values per period <5) and (b) the location of captures across the periods (we combined captured in plantation with those in community forests and compared captures in the new "community forests" group with those in CRNP). We then examined how wild meat offtake and use varied with lockdown by fitting eight generalized linear mixed models to examine changes in hunting behavior and outcomes. The first four models examined variations in hunter behavior and hunting outcomes across our three periods, while the second set assessed the uses of the captured animals, providing insights into observed patterns in the earlier models. The response variables of the models were: (a) number of successful trips, (b) number of animals captured, (c) mass of wild meat harvested, (d) value of wild meat harvested, (e) mass of wild meat consumed in hunter's household (hereafter mass eaten), (f) mass of wild meat sold, (g) proportion of mass eaten, and (h) proportion of mass sold.

We summed the number of successful trips and animals captured per hunter for each period and calculated the mass and value of animals caught by multiplying each hunter's total number of animals per species in the relevant period by their median mass and median price (using period-specific values), respectively. We corrected the values of these response variables (models a–f) for differences in each period's duration by dividing them by their respective lengths in months. We fitted the models as a function of period (lockdown, matched non-lockdown, and other non-lockdown) and four hunter-level variables: (1) hunter's annual household income excluding hunting-related income ($\log_{10}$-transformed), (2) hunter's experience in years ($\log_{10}$-transformed; models a–d only), (3) their household's well-being index (WBI; L'Roe et al., 2023), and (4) their household size expressed in adult male equivalents (AMEs), which describes a household's energy needs by accounting for the sex, age, and physiology of its members relative to the average adult male's energy requirements (Weisell & Dop, 2012). The rationale for including each predictor and their derivation is set out in Appendix B in the Supporting Information. All hunter-level covariates were gathered in May 2022. Univariate plots of the response variables and predictors are in Figures S1–S8 presented in the order in which we described the models above. We used a Gaussian model to explore, using one data point per hunter for each period, the log-transformed number of successful trips and animals captured, mass and value of wild meat harvested, mass eaten, and mass sold (each expressed per hunter-month). Where only a part of an animal was eaten or sold, we used the median mass of the relevant part. To include zero values for the total mass of meat eaten or sold in a period, we added 0.0005 to all the records. We accounted for inflation in the value model—adjusting nominal prices in 2020–2022 to reflect current prices (i.e., real prices in 2023) using inflation rates based on Nigeria's consumer price index (Trading Economics, 2023; World Bank, 2023). For the models of proportions of mass eaten and sold, we used beta regression with a logit link function, transforming the response variables to meet the open interval assumption of the beta distribution (Smithson & Verkuilen, 2006). In all models, we examined collinearity among the predictors (using a variance inflation factor threshold of 3; Zuur et al., 2013) before and after fitting the model, standardized all continuous predictors, and used simulated residuals (Dunn & Smyth, 1996) to visually assess model fit (Figures S9–S16; see Equations S1–S8 presented in the order in which we described the models above; software and packages in the Supporting Information).

To check that any long-run declines in animal populations do not drive the patterns we observed in our main analyses, we ran another mixed-effects model to infer temporal trends in animal availability, using mass harvested per trip (restricted to each hunter's last lockdown and first post-lockdown trips) as the response variable. Here we hypothesize that decreased mass per trip following the lockdown suggests that potential lower offtake rates post-lockdown were driven by diminished prey availability, possibly due to overhunting in lockdown. We used the following as predictor variables: period (lockdown and other non-lockdown), trip duration in days (accounting for effort), and the hunter-level covariates in previous models (Figures S17–S18 and Equation S9). Finally, we analyzed CRNP ranger patrol data provided by the Wildlife Conservation Society to compare patrol efforts (see units of analysis below) during the lockdown and matched days in 2019 (matched pre-lockdown) and 2021 (matched post-lockdown). Using Kruskal–Wallis tests and Dunn's post hoc, we examined variations in the monthly median (a) patrol frequency, (b) rangers per patrol, (c) distance covered, and (d) active patrol time (duration) across these periods (five data points per period; see additional information in Appendix B in the Supporting Information). We did not include the ranger data as a predictor in models a–h because the patrols occurred within the park, whereas most hunting trips took place in community forests.

3 | RESULTS

The 28 hunters made 1398 successful hunting trips (433 during lockdown, 340 in matched non-lockdown, and 625 in other non-lockdown; period length adjustments = 83, 33, and 31, respectively). Together, they captured 2369 animals of 39 different species (five birds, five reptiles, and 29 mammals) with a combined estimated mass of 13,870 kg and a value of ₦17,941,000 ($23,921 at $1 = ₦750). The adjusted monthly capture rate summed across our sampled hunters was 130, 53, and 56 animals in lockdown, matched non-lockdown, and other non-lockdown periods, respectively. Note here and afterward, "rate" refers to monthly offtake within successful trips only. Approximately 85% of all captures occurred in community forests, while the remaining captures occurred in the park. Hunters consumed 8% of the total mass, selling 91% (with gifting and ceremonial use together accounting for 1%).

The proportional composition of the catch across species differed significantly between periods ($\chi^2 = 106.81$, $df = 24$, $p < 0.001$). Of the 13 species used in the test, African brush-tailed porcupine (*Atherurus africanus*), African palm civet (*Nandinia binotata*), blue duiker (*Philantomba monticola*), greater cane rat (*Thryonomys swinderianus*), sitatunga (*Tragelaphus scriptus*), mona monkey (*Cercopithecus mona*), sitatunga (*T. spekii gratus*), and white-bellied pangolin (*Phataginus tricuspis*) were caught disproportionately more in lockdown than non-lockdown periods (Figure S19; see species monthly capture rate per period in Figure S20). We also found that the number of animals captured in CRNP and community forests differed significantly across the periods ($\chi^2 = 493.4$, $df = 2$, $p < 0.001$). There were more captures in CRNP during lockdown than expected based on the distribution of captures across all periods (observed count: 284, expected count: 108), with 42% occurring there during lockdown, compared with 0% during matched non-lockdown. Nonetheless, the observed count in community forests (388) during lockdown was higher than the expected count there (284; Figure S21).

We found a higher number of successful trips per month in COVID-19 lockdown than in matched non-lockdown ($\beta = -1.08$, $SE = 0.11$, $p < 0.001$) or other non-lockdown periods ($\beta = -1.05$, $SE = 0.11$, $p < 0.001$; Figure 2a; overall model $r^2 = 0.79$; full details in Table S1). There was no significant difference in the average number of successful trips conducted between the two non-lockdown periods, and the number did not significantly vary with hunter experience or the income, WBI, or AME of their households. These patterns were similar in the model exploring the number of animals caught: hunter's monthly capture rates were higher in lockdown than in matched non-lockdown and other non-lockdown periods ($\beta = -1.06$, $SE = 0.12$, $p < 0.001$ and $\beta = -0.94$, $SE = 0.12$, $p < 0.001$, respectively; Figure 2b; overall model $r^2 = 0.76$; Table S2), with no significant difference in capture rates between the two non-lockdown periods or across hunter-level predictors.

Our models of the mass and value of animals caught corroborated these findings. In the mass model, hunters harvested more wild meat per month during lockdown compared to the matched non-lockdown ($\beta = -1.05$, $SE = 0.13$, $p < 0.001$) and other non-lockdown periods ($\beta = -0.98$, $SE = 0.13$, $p < 0.001$; Figure 2c; overall model $r^2 = 0.73$; Table S3). The value model showed that each hunter's total value of wild meat harvested monthly was

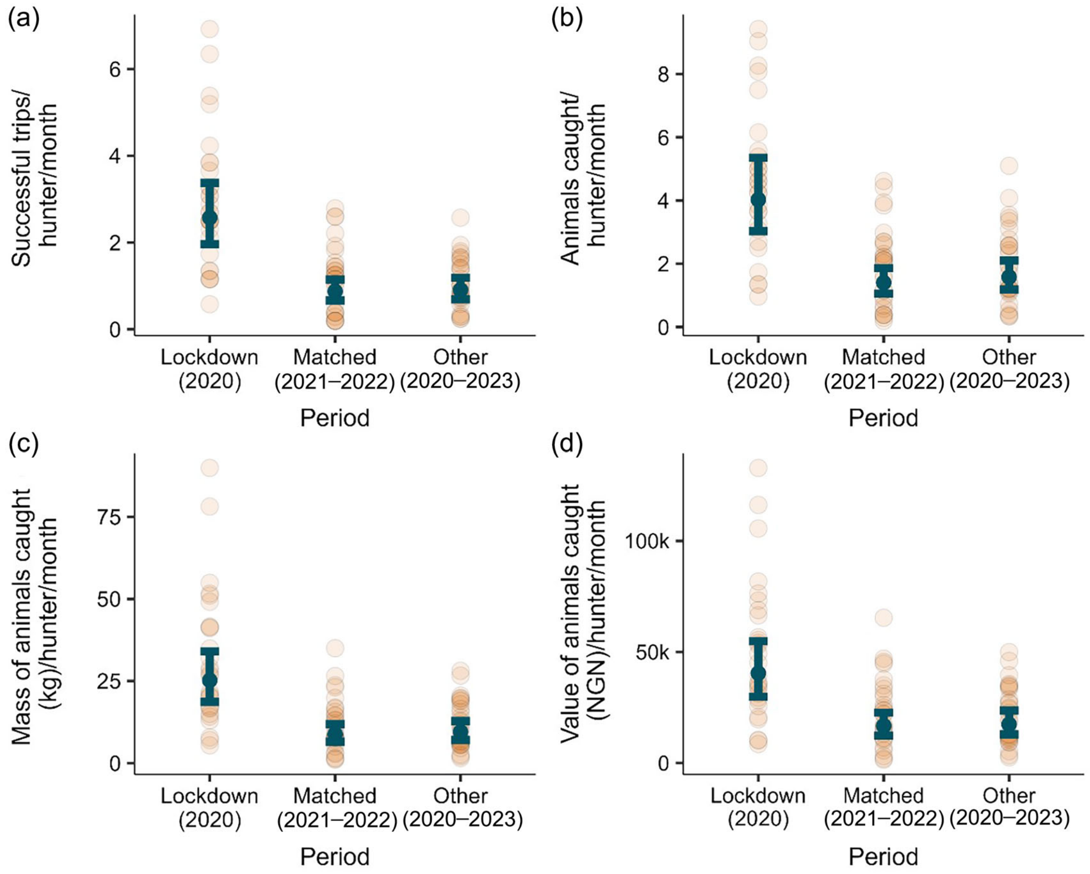

FIGURE 2 The monthly number of successful hunting trips and number, mass, and value of animals caught were higher during the coronavirus disease (COVID-19) lockdown than in matched non-lockdown and other non-lockdown (a–d, respectively). There were no differences between matched and other (a–d). Green points show marginal predictions (error bars = 95% confidence intervals) taken from models, with other covariates held constant: (a) annual household income, (b) hunting experience, (c) household's well-being index (WBI), and (d) household size (expressed in adult male equivalents [AME]). Pale brown circles show observed data for each period for 28 hunters in two communities adjacent to Nigeria's CRNP (April 2020–March 2023).

higher during lockdown than in matched non-lockdown ($\beta = -0.88$, $SE = 014$, $p < 0.001$) and other non-lockdown periods ($\beta = -0.84$, $SE = 0.14$, $p = < 0.001$, Figure 2d; overall model $r^2 = 0.67$; Table S4). The two non-lockdown periods did not differ in either of these models, and no hunter-level covariates were statistically associated with the response variables.

The model exploring variation in the mass of wild meat eaten per month showed that hunters consumed more wild meat in their homes in lockdown, compared to matched non-lockdown ($\beta = -2.79$, $SE = 0.43$, $p < 0.001$) and non-matched non-lockdown periods ($\beta = -1.63$, $SE = 0.43$, $p = < 0.001$; Figure 3a; overall model $r^2 = 0.56$; Table S5). Unlike in other models, the mass eaten during matched non-lockdown was lower than in other non-lockdown periods but only weakly ($\beta = 1.16$, $SE = 0.44$, $p = 0.03$). The model of the mass of wild meat sold per month revealed similar patterns: More mass was sold during lockdown than in matched non-lockdown ($\beta = -0.97$, $SE = 0.15$, $p < 0.001$) and other non-lockdown ($\beta = -0.91$, $SE = 0.15$, $p < 0.001$; Figure 3b; overall model $r^2 = 0.70$; Table S6), with no difference between the two non-lockdown periods. Wild meat trade during the lockdown happened within each community but did not involve wider trading because markets were shut (S. Agbor, personal communication; August 24, 2023). None of the hunter-level covariates in either model showed a significant association with the response variables.

Our models on the proportions of wild meat mass eaten and sold revealed opposite patterns. The model of the proportion of wild meat eaten showed an increase in household consumption during the lockdown relative to matched non-lockdown ($\beta = -0.89$, $SE = 0.14$, $p < 0.001$) and other non-lockdown periods ($\beta = -0.59$, $SE = 0.13$, $p < 0.001$; Figure 3c; overall model $r^2 = 0.62$; Table S7). The model of the proportion of meat sold revealed that, on average, hunters sold a smaller proportion of the wild meat they caught during the lockdown, compared with the other

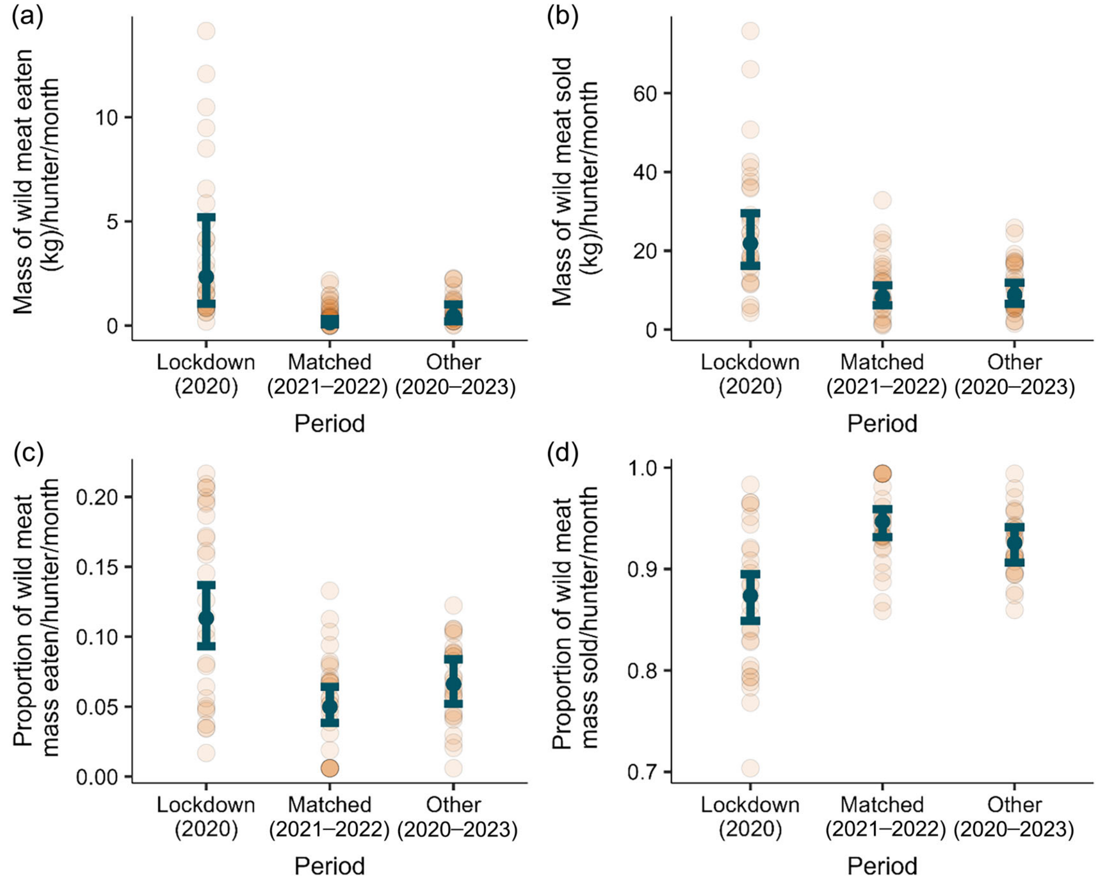

FIGURE 3 The mass of wild meat eaten within hunter households and the mass sold were higher during the COVID-19 lockdown than matched non-lockdown and other non-lockdown (a and b, respectively). In proportional terms, hunters ate more of the mass of animals they caught in their homes and sold less during the lockdown, compared to matched and other (c and d, respectively). Only in (b) was there a difference between matched and other non-lockdown periods. Green points show marginal predictions (error bars = 95% confidence intervals) taken from models, with other covariates held constant: (a) annual household income, (b) household's WBI, and (c) household size (expressed in AME). Pale brown circles show observed data for each period for 28 hunters in two communities adjacent to Nigeria's CRNP (April 2020–March 2023).

two periods ($\beta = 0.95$, $SE = 0.15$, $p < 0.001$ and $\beta = 0.59$, $SE = 0.14$, $p < 0.001$ respectively; Figure 3d; overall model $r^2 = 0.75$; Table S8). Neither proportion model showed differences in the non-lockdown periods, and no hunter-level covariates were significantly associated with the response variables.

The model of mass per trip indicated no significant difference in the mass (kg) harvested by each hunter on the last trip during lockdown and the first trip after lockdown, suggesting consistent prey stock throughout the study (Table S9). Finally, Kruskal–Wallis tests revealed that ranger patrol duration and the number of rangers per patrol were comparable across periods (lockdown, matched pre-lockdown [2019] and matched post-lockdown [2021]; $\chi^2 = 4.69$, $df = 2$, $p = 0.10$ and $\chi^2 = 4.91$, $df = 2$, $p = 0.09$, respectively). However, we found differences in patrol frequency and distance covered ($\chi^2 = 9.10$, $df = 2$, $p = 0.01$ and $\chi^2 = 9.53$, $df = 2$, $p = 0.009$, respectively), with higher rates after the lockdown, compared to other periods, which both had comparable frequency and distance covered (Table S10).

4 | DISCUSSION

We quantitatively investigated how wild meat hunting and use varied during the coronavirus pandemic in southeast Nigeria and found that the lockdown, implemented to curtail the spread of the virus, was associated with increased rates of successful hunting trips, higher hunting offtakes (number, mass, and value of animals caught), and greater wild meat consumption by rural hunters' households. These findings support McNamara et al.'s (2020) hypotheses of elevated hunting and use of wild meat in rural areas during the pandemic. Our results suggest that increased household demand for meat probably intensified hunting efforts, underscoring the importance of wild meat as a safety net during socio-economic shocks. Turning to our results on protected area management, we found that patrol activities in CRNP remained consistent before and during lockdown (increased funding for patrols 2020–2021 explains the elevated efforts post lockdown; I. Imong, personal observation). This finding suggests sustained park management activities in CRNP during lockdown, which differs from other areas, including Madagascar, where elevated forest fires correlated with reduced management activities during lockdown (Eklund et al., 2022).

We propose that four factors would have contributed to higher hunter-offtake rates in lockdown. First, market closures presumably reduced the supply of domesticated meat to villages, leading to greater reliance on wild meat. Second, food requirements in rural households probably increased due to elevated urban–rural migration (Kamogne Tagne et al., 2022). In line with both these suggestions, we found that hunters consumed a larger proportion of wild meat and sold less in lockdown. Third, the economic shock of the lockdown probably reduced labor opportunities for hunters, lowering the opportunity cost of hunting. Fourth, the apparent increase in hunting in the park during lockdown, where animals are conceivably more abundant (Novaro et al., 2000), may have facilitated the elevated offtake rates that we observed then. Although ranger activities in CRNP remained consistent during the lockdown, it is conceivable that hunters' perception, rather than the reality, of reduced site-based law enforcement during lockdown contributed to increased hunting activities within the park.

Our study has three main limitations. The first is the possibility of social desirability bias arising from self-reporting (Kormos & Gifford, 2014). However, hunters had no incentive to inflate reports to our observers, as this would mean admitting to violating government guidelines. Second, we focused exclusively on formal hunters because casual hunters were more diffused and hence harder to follow. However, we estimated that, on average, casual hunters account for 40% of the total offtake in the landscape (Appendix B in the Supporting Information and Table S11). Last, the absence of pre-lockdown data could mean that the observed post-lockdown declines in hunting arose from long-term temporal changes in hunter behavior or wild animal availability, potentially exacerbated by overhunting in lockdown. Nevertheless, the absence of a difference in mass harvested on each hunter's last trip in lockdown and the first trip after lockdown contradicts the notion of changes in prey availability.

Our work has several conservation implications. First, given our finding that local communities consumed a higher proportion of the wild meat they caught during the COVID-19 lockdown, we suggest that in future health, climatic, socio-political, or economic crises, policy interventions that disrupt everyday socio-economic activities should consider the likely impacts on food insecurity of rural communities, especially those without access to hunting areas. Such impacts could be mitigated by providing local communities with alternative protein sources. Similarly, given the dependence on wild meat, restrictive interventions, such as blanket bans on hunting and consuming wild meat, could be counterproductive (Tylianakis et al., 2021). Second, the increased offtake rates during lockdown have likely further reduced the sustainability of hunting, especially for already vulnerable groups such as pangolins and primates. Therefore, social policies, especially those made during socio-economic shocks, should consider and mitigate potential effects on biodiversity (McCleery et al., 2020). Third, the resilience of local communities and of wildlife populations are interlinked. In the medium term, both rely on reducing hunting pressure during normal conditions (e.g., by promoting sustainable hunting practices and investing in site-based law enforcement in protected areas). Thus, without progress in reducing hunting pressures during less disrupted times, it is probable that future shocks will result in even greater economic and ecological impacts. Last, community-centered conservation interventions should anticipate shock-triggered changes that could disrupt otherwise successful efforts.

AUTHOR CONTRIBUTIONS

Charles A. Emogor: Conceptualization; methodology; investigation; formal analysis; writing—original draft; funding acquisition. **Lauren Coad**: Conceptualization; methodology; writing—original draft; supervision. **Ben Balmford**: Conceptualization; methodology; writing—review and editing. **Daniel J. Ingram**: Methodology; writing—review and editing. **Diane Detoeuf**: Investigation; writing—review and editing. **Robert Fletcher Jr.**: Conceptualization; methodolog; writing—review and editing. **Inaoyom Imong**: Resources; writing—original draft. **Andrew Dunn**: Resources; writing—original draft. **Andrew Balmford**: Conceptualization; methodology; writing—original draft; funding acquisition; supervision.

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CONFLICT OF INTEREST STATEMENT

Charles A. Emogor is a conservation fellow at the Wildlife Conservation Society (WCS), and Diane Detoeuf, Inaoyom Imong, and Andrew Dunn are employees of the organization; WCS provided ranger patrol data for this study.

DATA AVAILABILITY STATEMENT

The data supporting this study's findings are not publicly available due to privacy and ethical restrictions but are available from the corresponding author upon reasonable request.

ORCID

Charles A. Emogor https://orcid.org/0000-0002-9589-2931

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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