Bushmeat hunting and consumption is a pervasive issue in African savannahs: insights from four protected areas in Malawi

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Abstract

The hunting and consumption of wild meat (bushmeat) is recognized as a key threat to the world's biodiversity and there are indications this threat may extend to much of the African continent. However, this problem is understudied in African savannah systems- particularly in southern Africa. Due to its illicit nature, little research on the drivers behind hunting and consumption exists, especially using methods appropriate to the topic's sensitivity. We explored the prevalence of hunting and consumption of wild meat in the low-income country of Malawi, by conducting 1562 interviews in communities neighbouring four different protected areas. We identified characteristics of households illegally hunting and consuming wild meat, using the unmatched count technique and socio-demographic variables in linear models. Consumption had a higher prevalence than hunting, reaching up to 39% of the population, while 4-19% of the population engaged in hunting. Consumption was more prevalent in poorer households, while hunting was more prevalent in wealthier households. Increased involvement in community projects initiated by protected areas did not always lead to reduced consumption or hunting, including at protected areas with substantial outside investment, indicating these projects need a clearer link to conservation outcomes. A preference for the taste of wild meat and for added diversity in diet were key drivers of consumption, whereas hunting was primarily motivated by the need for income. Our results highlight the disparity between drivers of hunting and consumption of wild meat and the pervasive nature of this threat, despite considerable investment into community projects and enforcement.

Keywords: wild meat, poaching, unmatched count technique, savanna, conservation, illegal wildlife trade

Introduction

Wild meat (or bushmeat) harvesting is recognized as a key threat to biodiversity in many parts of the world (Maxwell et al. 2016). The practice of harvesting non-domesticated terrestrial mammals, birds and reptiles for food (Nasi et al. 2008) has been found to cause species declines around the world, in forested (Fa et al. 2002) and savannah regions (Lindsey et al. 2013), affecting both common and rare species. Harvesting for human consumption is the largest threat to 98% of threatened megafauna (Ripple et al. 2019). Growing human populations, encroachment into wildlife areas, the increasing commercialization of trade, and technological advances of hunting weaponry are key factors in species declines worldwide (Benítez-López et al. 2017). The ecological consequences of widespread and unregulated hunting can be devastating, and can result in large areas being "emptied" of wildlife (Lindsey and Bento 2012) and the loss of critical ecological services such as seed dispersal (Wright et al. 2007). Additionally, the reliance of many communities on wild meat for protein means overhunting will negatively impact food security and livelihoods (Fa et al. 2003).

Protected areas (PAs) are coming under substantial human pressure (Jones et al. 2018). Specifically, wild meat poaching is considered the most frequent and severe threat to wildlife in PAs in Africa (Lindsey et al. 2017) and is exacerbated by a wide range of issues including: human encroachment; poor governance and corruption; food insecurity and poverty; chronic

underfunding and weak or poorly enforced laws; and the lack of frameworks to enable communities to benefit from wildlife (Lindsey et al. 2013). There is therefore a need to understanding drivers of hunting within a wide socio-economic context.

Studies of illegal hunting in Africa have traditionally focused on forest regions (Fa et al. 2002). Outside of forests, Tanzania has been a focal point (van Velden et al. 2018). However, wild meat hunting is thought to affect wildlife populations across Africa including savannahs, despite the comparative paucity of research in many areas (Lindsey et al. 2013). Encouragingly, the prospects for tackling illegal hunting in savannahs may be brighter than in forests. Firstly, many countries in southern and East Africa rely on substantial revenues from wildlife-tourism, meaning there are clear incentives for governments to tackle the issue. Secondly, savannahs are more productive than forests in terms of wildlife biomass (Robinson and Bennett 2004) meaning wildlife populations may be more resilient to harvests than in forest biomes. Savannahs can also support more livestock than forests (Robinson et al. 2014), and therefore provide people with alternative protein sources. Finally, controlling hunting in savannahs is both cheaper and more effective than in forests (Jachmann 2008a).

The lack of baseline information regarding the prevalence and drivers of hunting in savannah systems is exemplified in the southern African country of Malawi. Over the last few decades Malawi has suffered severe declines in the distribution and abundance of wildlife both outside of and within PAs (Munthali and Mkanda 2002), however little research has been conducted into the drivers behind these declines. In some PAs in Malawi this situation has recently improved due to growing local and international investments into conservation. For example, a recent change in legislation for wildlife infractions substantially increased punishments for hunting, selling or buying a game species (National Parks and Wildlife

(Amendment) Act 2017). Additionally, the international conservation non-governmental organization African Parks (AP) has recently taken over management of four PAs in Malawi in a public-private partnership with the Malawian government. This organization has invested substantially in both enforcement and community-based programmes at these PAs. However, strategies to foster wildlife recoveries and to tackle threats would be enhanced by an in-depth understanding of the extent, nature and drivers of illegal hunting. Further, Malawi acts as important case study for understanding wild meat hunting in sub-Saharan African countries such as Zambia and Mozambique, where similarly high levels of population growth (World Bank Group 2019) contribute towards natural resource use and more broadly, to understand this issue in the context of resource-poor low-income countries around the world.

In this paper we provide novel insights into the prevalence of wild meat hunting and consumption from four protected areas in Malawi, using specialized interview techniques designed for sensitive topics. We also explore socio-economic and demographic variables that influence these activities.

Methods

Study sites

Malawi is one of the world's poorest nations (World Bank Group 2016). Most of the population are smallholder farmers who face frequent food insecurity due to climatic factors such as droughts, and more than one third of the country is unable to meet calorie requirements (Ecker and Qaim 2011). There are currently 99 PAs in Malawi, making up 16.8% of the land area (World Bank Group 2017). Outside of protected areas, much of the landscape has been transformed into small-holder agricultural land. Severe under-funding of

the PA network has meant that many PAs have experienced drastic wildlife declines (Lindsey et al. 2018). However, the NGO African Parks (AP) has taken over management of four PAs (Majete in 2003, Liwonde and Nkhotakota in 2015, and Mangochi Forest Reserve in 2018), and invested substantially into enforcement and community programmes such as improving infrastructure and alternative livelihood projects (Online Resource 1).

We conducted this research at four national parks in Malawi namely Nyika National Park, Vwaza Marsh Wildlife Reserve, Nkhotakota Wildlife Reserve and Majete Wildlife Reserve between July and November of 2018 (Fig. 1; Table 1). Two of these parks are therefore government-run and funded, while two are managed and funded by AP.

Sampling strategy

We used a three-stage sampling design: first we selected zones around each PA, then villages within each zone and finally households within each village. Firstly, we selected either four or five predefined administrative zones in a non-random manner, such that the selected zones were scattered around the border of each PA so that one area was not preferred over another. Secondly, we selected villages within each zone. In Nkhotakota we randomly selected villages from a list of all villages within 5km of the PA. For the other three PAs we selected a number of "group village headmen" (GVH's) in each zone, who were able to provide us with a list of villages they administrated and from which we then randomly selected villages (Table 2).

Lastly, we selected 24 households within each village using a "random walk technique", where enumerators start at a central area and walk out in opposing directions, sampling every

second house within that area to minimize spatial autocorrelation. If a house was empty the enumerators proceeded onto the next available house. We pooled Nyika and Vwaza Marsh, such that the number of respondents for both PAs together totalled 500 because they are in such close proximity (<10km) and collaborate on programmes administration in some communities.

Interview process

Interviews were conducted in person by Malawian enumerators in English, ChiChewa or Tumbuka. Respondents had to be over 18 years of age and be residents of the village. Respondents could be anyone within the household meeting these criteria. We asked basic demographic and livelihood information about the respondent's household, involvement in PA-initiated community programmes and motivations for hunting and consuming bushmeat. We used the Basic Necessities Survey (BNS) approach to determine levels of household wealth. This approach measures deprivation via a consensual definition of poverty, based on what communities view as necessities to their households (Davies and Smith 1998). A basic necessity was defined as "things that everyone should have, and no one should go without". A list of such items was drawn up during discussions with key informants in Malawi and tested and refined in the piloting stage. Respondents were first asked to indicate which items on this general list they think were necessities, and then which items their household possessed. Only those items from the list that were considered to be necessities by more than 50% of the respondents were then used to calculate a maximum possible score for household wealth, these popular items being weighted according to the proportion of respondents who consider the item as a necessity (Online Resource table 2). A household's wealth was then

calculated as the sum of the weighted popular necessity items that they possessed and converted to a percentage of the maximum possible score.

Given hunting or buying wildlife meat is illegal in Malawi, it is challenging to accurately assess both its prevalence and drivers. For example, direct questioning of respondents may lead to dishonest or evasive answers and reduced data validity (Warner 1965). A range of methods have therefore been developed to facilitate more honest responses, such as the unmatched count technique (UCT), also known as a list experiment (Nuno et al. 2013). UCT can help counter-act the sensitivity of topics by providing anonymity in answers, and is appropriate if the activities are not too rare and a large sample size can be achieved (Hinsley et al. 2019). To find the prevalence of wild meat consumption and hunting we asked four different UCT questions at the end of the survey, two relating to hunting and two relating to consumption, both at the household level.

Respondents were assigned to either a control or a treatment group for each of the four questions by presenting two cards face down and asking the respondent to pick one. The treatment group's card consisted of four non-sensitive items and one sensitive item, while the control group's card consisted of just the non-sensitive items. Therefore, the difference in mean number of items chosen between the control and treatment groups indicates the prevalence of the sensitive activity. For the consumption questions the non-sensitive items were regular food items and the sensitive item was wild meat, while for the hunting questions the non-sensitive items were legal livelihood activities and the sensitive item was wild meat hunting (Online Resource table 3 &4). They were then asked to state *how many*, but not *which* items applied to the question. One of the questions about each activity related to the

post-harvest period (as the survey was completed during this period this was asked as "the past month", ranging from June-September depending on the PA) and one question related to the pre-harvest (or "lean season", ranging from November to March). These questions were presented in an alternating order i.e. one question about consumption, followed by one question about hunting. The questions were:

1. *Consumption 1*: How many of these foods did you and your household consume in the past month?
2. *Consumption 2:* How many of these foods did you and your household consume in lean season months, before harvest?
3. *Hunting 1:* How many of these income activities did you or anyone in your household do in the past month?
4. *Hunting 2:* How many of these income-generating activities did you or anyone in your household do in the lean season months, before harvest?

To ensure the UCT worked effectively we controlled for floor and ceiling effects, where anonymity is not possible due to the respondent answering negatively (floor effect) or positively (ceiling effect) to all items on the card (Blair and Imai 2012) by including one very common food item or activity and one very rare food item or activity. To ensure respondents understood the UCT process we used a training question of "How many of these animals cause problems to you?" with common crop pests on the card. To control for possible social desirability biases we placed sensitive questions towards the end of the questionnaire, conducted the interviews alone with the respondents, and used Malawian enumerators not affiliated with local institutions or protected areas and ensured complete anonymity to respondents. Additionally, for potentially sensitive direct questions regarding the motivations

for hunting or consuming bushmeat we asked the question by relating it to other peoples activities rather than their own e.g. “what are the reasons why some people hunt for wildlife meat?” (Fisher 1993). The survey was piloted on 14 respondents in the Nkhotakota area, which was not included in the final results.

Ethics statement

We received informed consent before each interview and ensured anonymity to respondents. As respondents have low literacy levels consent was obtained verbally. This research implemented the guidelines from the Australian National Statement on Ethical Conduct in Human Research (Ref 2018/350) and received a research permit from the Department of National Parks and Wildlife Malawi (Ref 10/2018).

Analysis

We analysed all data in R v. 3.5.1 (R Core Team 2018). For the UCT questions we used the specifically designed package “list” (Blair and Imai 2010). We first used the *ict.test* function to test for the presence of design effects, where the inclusion of the sensitive item changes the response to the non-sensitive items. No such design effects were found. We then performed logit models with binomial error structure to check for differences in basic socio-demographic variables between respondents in the control and treatment card groups for each UCT question, and found control and treatment respondents did not differ on the basis of almost all sociodemographic variables (Online Resource 5 &6).

To calculate the prevalence of each sensitive behaviour we used the *ict.reg*. function to find the difference-in-means estimate between the control and treatment groups. We next fitted

ordinary linear mixed models to the number of items selected from each UCT card. Models were created for each demographic variable, with card type (control or treatment) as an additional covariate, and village as a random effect. To account for temporal influences in the models exploring all PAs together, month was also included as a random term (PAs were sampled in different months: June in Nkhotakota, July in Vwaza Marsh, August in Nyika and September-October in Majete). Interactions between card type and each demographic variable were also included, where these interactions indicated differences in the number of behaviours reported for either the control or treatment card for each UCT question. Model assumptions for collinearity and heteroscedasticity were checked. We then selected, ranked and averaged the most parsimonious models using AICc (Corrected Akaike's Information Criterion), and investigated combinations of variables based on these top models, to arrive at a final top model. Only models with interactions alongside their constituent main effects were considered, and models were averaged if Δ AIC <4 (Burnham and Anderson 2002). When exploring differences between factor levels for a variable two requirements were needed for inference: firstly, a significant difference between control and treatment at that level, indicating a detectable level of wild meat consumption or hunting, and secondly, a significant difference between the treatment estimate for that level and the treatment estimate for another comparative level.

Results

We approached 1576 individuals, of which 7 refused and 7 were ineligible, leaving a total sample size of 1562 (non-response rate of <1%). We omitted questionnaires with missing data leaving 477 respondents from Majete, 300 from Nyika, 217 from Vwaza Marsh and 490 from Nkhotakota for a total sample of 1484. Significantly more females than males were interviewed (1013 females vs 549 males, $X^2 = 137.83$, df = 1, p=<0.001) due to females

mostly remaining at home during the day. The average household size was 4.83 ± SD 2.32 individuals and the mean age of respondents was 38.85 years ±16.07. Most respondents were Malawian (98%) and native to the district they were interviewed in (72% born in district, 28% born elsewhere), and had lived in the area for more than 20 years (57%). The majority of households ate three meals per day (53.3%), while 32.5%, 8.7% and 5.4% had two, one and four meals per day respectively (Online Resource 7 for more details on demographic variables).

Prevalence of hunting and consumption

The prevalence of wild meat hunting among respondents varied between 4 ± SE 3.7 and 19.1 ± 6.5 % (Fig. 2, a & b), with the highest hunting prevalence observed in Nyika in the pre-harvest season. Consumption (Fig. 2, c &d) had a higher prevalence than hunting, and wild meat consumption was highest in Vwaza Marsh pre-harvest, at 38.93 ± 9.9%.

There was seasonal variability in prevalence among PAs, particularly between Vwaza Marsh and Majete. For example, hunting was higher in Majete and Nkhotakota during the period post-harvest (June-October) compared to the period pre-harvest (November to March), while the opposite trend was observed in Vwaza Marsh. This trend was consistent over both hunting and consumption. Consumption in Nyika remained at nearly 20% across both pre-harvest and post-harvest periods. The estimate ± standard error did not overlap zero except for hunting in Nyika and Vwaza Marsh post-harvest and in Nkhotakota pre-harvest, and for consumption in Vwaza Marsh post-harvest. This overlap decreases our confidence in the direction of these particular estimates and could indicate when the behaviour in question was too rare to be estimated using UCT.

Socio-demographic variables relating to hunting and consumption

The top models for wild meat consumption and hunting are presented in Tables 3 &4. Basic Necessities Score (BNS) was an important factor in the consumption of wild meat (Table 3). We found wild meat was predominately eaten by poorer households (represented by the difference in control and treatment cards, Fig. 3b), and there was no difference between control and treatment for wealthier households, indicating less or no wild meat eaten. This relationship was found for consumption post-harvest in all PAs combined, in Majete and in Nyika, and for consumption pre-harvest in Nyika and Vwaza Marsh. Additionally, we found that households able to eat three meals per day were consuming more wild meat than those able to eat two meals per day ($t=-5.90$, $p<0.001$, $df=982$, Fig. 3a). This effect was observed for consumption post-harvest in all PAs combined and in Majete, and for consumption pre-harvest for Nyika. We also found wild meat consumption significantly increased ($z=2.543$, $p=0.011$) when households were involved in an increasing number of PA-community projects in Majete (Fig. 3c), but had the opposite effect in Nyika where involvement in more projects lowered consumption, although the difference between control and treatment groups was only marginally significant ($z=1.72$, $p=0.086$). Livestock ownership was only important for consumption post-harvest at Nyika national park, where households owning livestock ate significantly more wild meat than those without livestock ($t=-2.195$, $p=0.029$, $df=293$). Knowledge of village natural resource committees (VNRCs) had an important effect on consumption pre-harvest for Nyika, where households without any knowledge of VNRCs consumed significantly more wild meat than those that knew about the VNRCs ($t=3.151$, $p=0.002$, $df=302$), while the opposite effect was observed in Vwaza Marsh where households with knowledge of VNRCs consumed significantly more ($t=-2.894$, $p=0.004$, $df=220$). Marital status was important in Nyika pre-harvest, where households with widow/ers

consumed significantly more wild meat than single (unmarried) households (t=-2.12, p=0.035, df=290). Household size did not appear in the top models for consumption.

Different trends were observed for hunting (Table 4). Households eating one meal a day hunted more wild meat than those eating two and three meals a day (Fig. 3d). Basic Necessities Score was only present in two of the top models for hunting (hunting pre-harvest in all PAs combined and Majete), and both showed an opposite effect to consumption, where hunting was low in the poorest households but increased with wealth (Fig. 3e). Household size class was present in the top model for seven out of ten response variables, although its effect on hunting was not clear. Those with larger household sizes were involved in significantly more livelihood activities, but there was no difference between control and treatment groups indicating hunting did not explain this difference. Similar to consumption, households participating in more community projects were more likely to hunt in Majete in the pre-harvest model (t=3.53, p<0.001, df=469), however households participating in an increasing number of community projects in Vwaza Marsh were significantly less likely to hunt (Fig. 3f, z=2.102, p=0.036). The effect of gender for hunting pre-harvest in Nyika showed significantly higher levels of reported hunting in the household when the respondent was male than for female respondents (t=-2.60, p=0.01, df=294). Satisfaction and perception of community and households benefits from the PAs, amount of land owned, village residency and number of each particular livestock appeared in none of the top models.

Motivations for hunting and consumption of wild meat

When asked why people in their community eat wild meat 43% of respondents said they do not know. We therefore first present the percentage of each reason for consumption out all answers including "don't know", followed by the percentage of each reason excluding the "don't know" answers. Most respondents said taste was the main reason for consumption (23% of all answers, 32.9% of answers besides "don't know"), followed by it being cheaper than other options (17.7%, 25.2%) and to add diversity to diet (16.7%, 23.8%). No other options available (4.8%, 7.6%), easier to access than livestock (3%, 4.3%), cultural reasons (1.8%, 2.5%), consumption for status (0.3%, 0.4 %,) and wild meat being perceived as healthier than livestock (0.6%, 0.8%) were also mentioned. When asked why people in their communities hunted, 32.3% of respondents said they do not know. Of those that did give an answer, "for income" was the predominant reason (35.5% of all answers, 45.5% of answers besides "don't know"), followed closely by "for meat" (33.1%, 42.4%). Other reasons for hunting included cultural reasons (3%, 3.8%) and because respondents did not own any livestock (1.6%, 2%). All other reasons were mentioned in ≤ 1% of answers. There were differences between protected areas in the reasons given for eating and hunting wild meat (Fig. 4), especially relating to cultural and social reasons for hunting and eating meat.

Discussion

Our results reveal that wild meat hunting and consumption exists in Malawi at appreciable levels and depends strongly on the local context in which a PA is situated. Several factors were found to be consistently important drivers, including household poverty and food security, but these drivers did not have the same effect on hunting versus consumption of wild meat. Our findings are generally congruent with those from other savannah sites (van

Velden et al. 2018) however we show that hunting and consumption can remain a pervasive issue in PAs with substantial investment into enforcement and community programmes. Further this is the first paper to provide accurate estimates of prevalence of these activities in the southern African region.

Prevalence of hunting and consumption

The prevalence estimates for hunting of between 5-19% and higher consumption levels of 4-39% are in keeping with the literature in other savannah regions in Africa. For example Nuno et al. (2013) found 18% of households in the Serengeti hunt while Mfunda and Røskaft (2010) found that 10% hunt in this system. Also in the Serengeti, Ceppi et al. (2014) found 46% consume wild meat while Fischer et al. (2014) found that 17% of households do. Although the estimates provided in this study indicate hunting exists at considerable levels in Malawi, assessing sustainability requires both information on harvest levels as well as the effect of this offtake on specific species. (Milner-Gulland and Akçakaya 2001). Given the four PAs surveyed in Malawi are currently recovering from periods of low enforcement effort due to lack of funds and subsequent high poaching, it is likely these estimates were substantially higher in the past. Malawi acts as an important case study for many low-income countries in Africa (e.g. Mozambique, Zambia, Rwanda and Chad) where substantial recent international investment into conservation have been made (Baghai et al. 2018). It is however vital to gather baseline information on the prevalence of illegal activities from the outset, in order to measure progress and the overall effectiveness of investment.

Variation in drivers between hunting and consumption

The drivers behind wild meat hunting and consumption are complex and vary widely across studies and locations. Importantly, the drivers of hunting and consumption differ (Harrison et al. 2015), although many studies conflate them. Wild meat consumption was more prevalent in poorer households, but hunting appeared to be more prevalent in wealthier households. This may indicate that households are wealthier *due* to hunting, while consumption is generally related to food or income needs. Hunting may be a way for households to lift themselves out of poverty, by generating income for their household (45% of the reasons for hunting were "for income"). Also, wealthier households may have greater access to more effective or selective hunting methods (Damania et al. 2005). Wealthier rural households elsewhere in Africa have been found to harvest more wild meat (de Merode et al. 2004; Travers et al. 2019) and to be more likely to choose to continue to hunt wild meat when offered alternative incomes (Nielsen et al. 2013). Poverty is often seen as the key driver to hunt, however multidimensional, complex relationships are likely to exist (Travers et al. 2019). Hunting may have been underestimated in Nyika in the pre-harvest season, in which male respondents reported their households were engaged in hunting significantly more often than female respondents. This could potentially have introduced bias into the data as significantly more females than males were interviewed.

Consumption of wild meat in our study was mostly limited to households with Basic Necessity Scores below 60%, indicating that it is accessible to the poorest households. Consumption of wild meat has been found to increase among poorer households in rural areas (Brashares et al. 2011), and act as safety net during lean periods (de Merode et al. 2004). A key reason for eating wild meat was because it was cheaper than livestock meat, in keeping

with findings from other rural areas in Africa, and in contrast to the case in many urban areas where bushmeat is considered a luxury item (Brashares et al. 2011). Our study also found that widow/er households were more likely to consume wild meat than single unmarried households, indicating vulnerable households may need wild meat as a safety net (Mosberg and Eriksen 2015). Additionally, households consuming three meals a day were more likely to consume wild meat than those eating two meals a day, which suggests wild meat is a means to elevate household food security. However, given the high human densities around Malawi's PAs, it is likely that harvest could become so low as to cease to play any major role in food security, except as a safety net in lean conditions (Schulte-Herbrüggen et al. 2013).

Effect of seasonality and culture on hunting and consumption

Seasonality is known to play an important role in hunting and consumption of wild meat. The dry season is often associated with elevated hunting as wildlife becomes concentrated around water sources and is easier to locate (Holmern et al. 2007; Lindsey et al. 2011) and fires are frequently used as a tool to flush out animals (Fusari et al. 2006). We found hunting and consumption is relatively low in Majete and Nkhotakota in the pre-harvest wet season between November and March and greater in the dry season from June to October, but in Vwaza Marsh and Nyika this is reversed. An explanation for the different pattern between PAs could relate to seasonal differences in density of vegetation. Both Majete and Nkhotakota have denser woodland habitat than Nyika and Vwaza Marsh, which have areas of open grassy plains. Therefore, in Majete and Nkhotakota, hunting could become difficult during the rainy season due to declining visibility. In Nyika and Vwaza Marsh, hunting patterns may instead be linked to periods of declining human food security, as habitat is

accessible year-round. Seasonality could therefore be incorporated when designing cost-effective solutions to wild meat hunting. Each PA could adapt enforcement levels to such behaviour by emphasizing patrolling in higher risk seasons, especially in resource-poor PAs, as seasonal difference in hunting has been found to be important around the world (Jachmann 2008b; Lee et al. 2005).

Motivations behind hunting and eating wild meat are multi-facetted and are not only related to economic factors. Taste was a significant factor in consumption of wild meat as has been found elsewhere in Africa (Schenck et al. 2006). Cultural factors were found to be important for both hunting and consumption in Nyika and Vwaza Marsh, but not important in Majete or Nkhotakota. Tribal affiliation may contribute to this effect, as the ethnic groups found in Nyika and Vwaza Marsh are traditional hunting tribes, while those found in Majete and Nkhotakota areas are not. Working with traditional authorities at PAs where hunting is found to be culturally significant may therefore help to arrive at locally acceptable solutions, as such institutions are often unambiguously accepted by local society (Kideghesho 2009). At protected areas where diversity and taste are important, and where wild meat is perceived to be healthier, it may be more appropriate to work on solutions regarding livestock diversification and health.

It should be noted that 43% and 32% of respondents said they didn't know the reasons for eating or hunting bushmeat respectively. This may be due to a number of reasons. Firstly, in our UCT results, on average 14% of the respondents hunt and 21.5% consume bushmeat, and so a high proportion of the population may not be directly involved in these activities. Therefore respondents may have felt uncomfortable speculating on activities they do not

themselves engage in, as asking people to respond regarding the actions of others (indirect questioning) often results in subjects projecting their own beliefs and experiences (Fisher 1993). Secondly, due to the illegality of these activities, respondents may still have felt uncomfortable answering these questions, despite efforts to overcome social desirability biases (Krumpal 2013). We cannot be sure which of these options may have contributed towards the relatively high proportions of "don't know" answers, although we tend to believe the first to be true as 98% of respondents indicated that none of the questions made them uncomfortable in any way. Further, we believe that the distribution of reasons other than "don't know" is unlikely to change if more responses were able to be elicited, as none of the reasons given are suspected to be more sensitive than any of the others. Therefore we believe our findings regarding the prevalence of different motivations to be accurate. These findings again emphasise the need for specialised techniques such as UCT for asking sensitive questions (Nuno and St. John 2015) or using techniques such as self-administration of surveys (Tourangeau and Yan 2007).

Success of investment into community programmes

There is an increasing tendency for conservation NGOs and the private sector to engage in public-private-partnerships with wildlife authorities in the management of state-owned protected areas and recent work has assessed the pros and cons of different models (Baghai et al. 2018), both for species conservation and community development. Though the positive impact of African Park's efforts on wildlife populations is clear, hunting and consumption of wild meat from Majete (managed by AP since 2003) was found to be comparable to the other three PAs which have received substantially less investment (Nkhotakota only having been

managed by AP since 2015, and Nyika and Vwaza Marsh being run by the government of Malawi). Additionally, in Majete we found both consumption and hunting increased with the number of projects households participated in. This indicates that while the protection activities underway in Majete are adequate to foster wildlife recoveries, benefits received may not yet be at a scale that cessation of hunting and consumption of wild meat would be viable, especially given that communities around Majete were the poorest of all four PAs studied (Online Resource 7). Therefore, for community engagement projects to effectively change behaviour, they require a stronger link to the desired conservation outcome (Roe et al. 2015).

Importantly however, wildlife populations in Majete have recovered under the public-private partnerships instituted with AP (Baghai et al. 2018). This could mean that even though the percentage of respondents who are hunting and consuming wild meat may be similar to government-run PAs, the percentage of animals poached out of the total population will be much lower. This means that the overall impact of hunting on wildlife populations in Majete could be significantly lower than in Vwaza Marsh and Nyika, both of which currently have depleted wildlife densities. Also, reduced hunting effort could yield higher returns of meat here than in parks where wildlife populations are depleted. Finally, improved community relations with PA authorities and the investment into infrastructure and sustainable livelihoods may have far-reaching benefits (Adams and Hutton 2007), beyond what can be measured using a single estimate of prevalence of an illegal activity. Wildlife may only be able to substantially contribute to food security in the long term if communities are provided with opportunities to benefit via employment or stakes in wildlife-based industries. Consequently, the derivation of benefits via killing animals for meat is unlikely to yield

robust food security benefits in the long term, because it frequently results in wildlife populations being depleted to the point where sustainable harvests are not possible.

Recommendations and future research

Although multiple drivers were identified in this study, the lack of consistency across sites and between hunting and consumption highlights the need for a nuanced approach to interventions, tailored to these differences in drivers and motivations between hunters and consumers. For example, poorer households could be targeted for interventions relating to consumption (such as alternative protein projects), while middle to wealthier households could be targeted for interventions relating to hunting (such as alternative livelihood projects). Two approaches specifically may be applicable: livestock donation projects have been found to theoretically reduce hunting (Nielsen et al. 2013), and micro-credit schemes to start businesses have been found to potentially reduce poaching in Tanzania (Kaaya and Chapman 2017), although numerous other programme models are possible (Lindsey et al. 2012). These types of programmes however require substantial investment and ongoing monitoring, and may be associated with other ecological challenges (Herrero et al. 2009).

A number of key assumptions must be validated before such projects can be successfully implemented. Firstly, there is an assumption that alternative proteins or livelihoods would lead to participants substituting their current protein choices or activities with the newly provided project. However, many respondents may see these projects rather as additions to hunting or consuming bushmeat. This assumption may often be false, as consumers may still

choose to eat bushmeat for taste or diversity reasons, and livelihood activity projects may leave time to complete the activity and still hunt (Wicander and Coad 2014). Secondly, additional conditionality to participation is likely required so that project participation has a strong link back to enforcement, as has been found for other types of conservation projects e.g. REDD (Blom et al. 2010). Thirdly, community engagement models that reduce poverty may increase purchasing power and thus demand for bushmeat. Therefore it is also necessary to decide on key goals such as whether to aim for maintaining populations of important species while minimising net welfare losses to communities or whether to maximise net welfare gains to communities (Crookes and Milner-Gulland 2006). Decisions regarding the trade-offs between social, ecological and conservation goals are crucial, as our research makes apparent that simply providing community-based projects will not necessarily lead to better outcomes for reducing bushmeat hunting and consumption even if it may meet other goals.

Our results also emphasize the need for temporal replication of studies of prevalence and drivers, to understand the effect of community programmes over the longer term, given the suspected seasonal and multi-year temporal variation. Therefore, future research can use these results as a baseline to measure the progress of enforcement and community-based programmes. We also encourage further research to try to overcome non-response biases in questions relating to the motivations behind bushmeat hunting or consumption, potentially by using a mixed method approach of indirect questioning techniques such as UCT and ethnographic research. Further research is also required to understand how the estimated prevalence relate to biomass harvested from PAs, and what species are particularly targeted. With this study we provide the first baseline prevalences of wild meat hunting and

consumption in a low-income southern African country, and emphasize that this issue is pervasive, even with substantial investments into protected areas.

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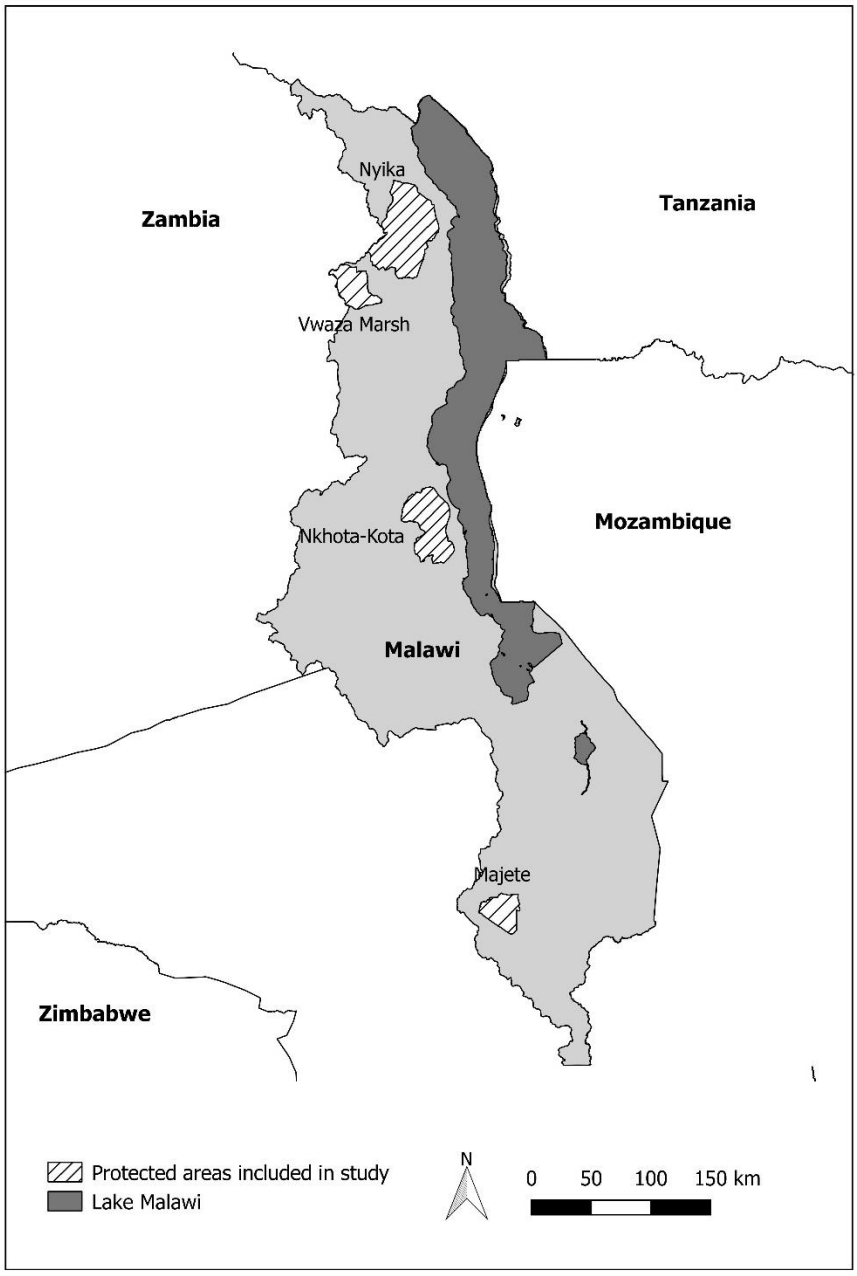
Figure Captions

Fig. 1: Map of study sites in context of Malawi and neighboring countries

Fig. 2: Estimated percentage prevalence (±SE) of (a) hunting in the past month (post-harvest, June to October depending on park), (b) hunting pre-harvest (November-March), (c) consumption in the past month (post-harvest, June to October depending on park) and (d) consumption pre-harvest (November-March) for protected areas in Malawi. The estimates for all parks combined together are represented in grey. Estimates are the difference in means between control and treatment UCT cards. The grey line indicates when standard error bars overlapped zero. Consumption was not estimated for Nkhotakota.

Fig. 3: Differences in number of items selected (CI) from control and treatment UCT cards, indicating levels of a) wild meat consumption post-harvest for all PAs combined, according to meals eaten per day; b) wild meat consumption post-harvest for Nyika national park, according to Basic Necessity Score (BNS), expressed as a percent from poorest to richest households; c) wild meat consumption pre-harvest for Majete wildlife reserve, according to number of community projects respondents were involved in; d) Hunting post-harvest for Vwaza Marsh wildlife reserve according to meals eaten per day; e) hunting post-harvest for all PAs combined, according to Basic Necessity Score (BNS) of respondent 5; f) hunting post-harvest for Vwaza Marsh wildlife reserve, according to number of community projects respondents were involved in. Estimates are predicted from the relevant top models (Tables 3 & 4).

Fig. 4: Reasons given by respondents for a) eating and b) hunting wild meat at each of the four Malawian protected areas, represented as proportions of answers given at each PA, apart from answering "don't know" (43% and 32.3% of respondents answered "don't know" for eating and hunting bushmeat respectively). The total count of a reason is shown at top of bars.



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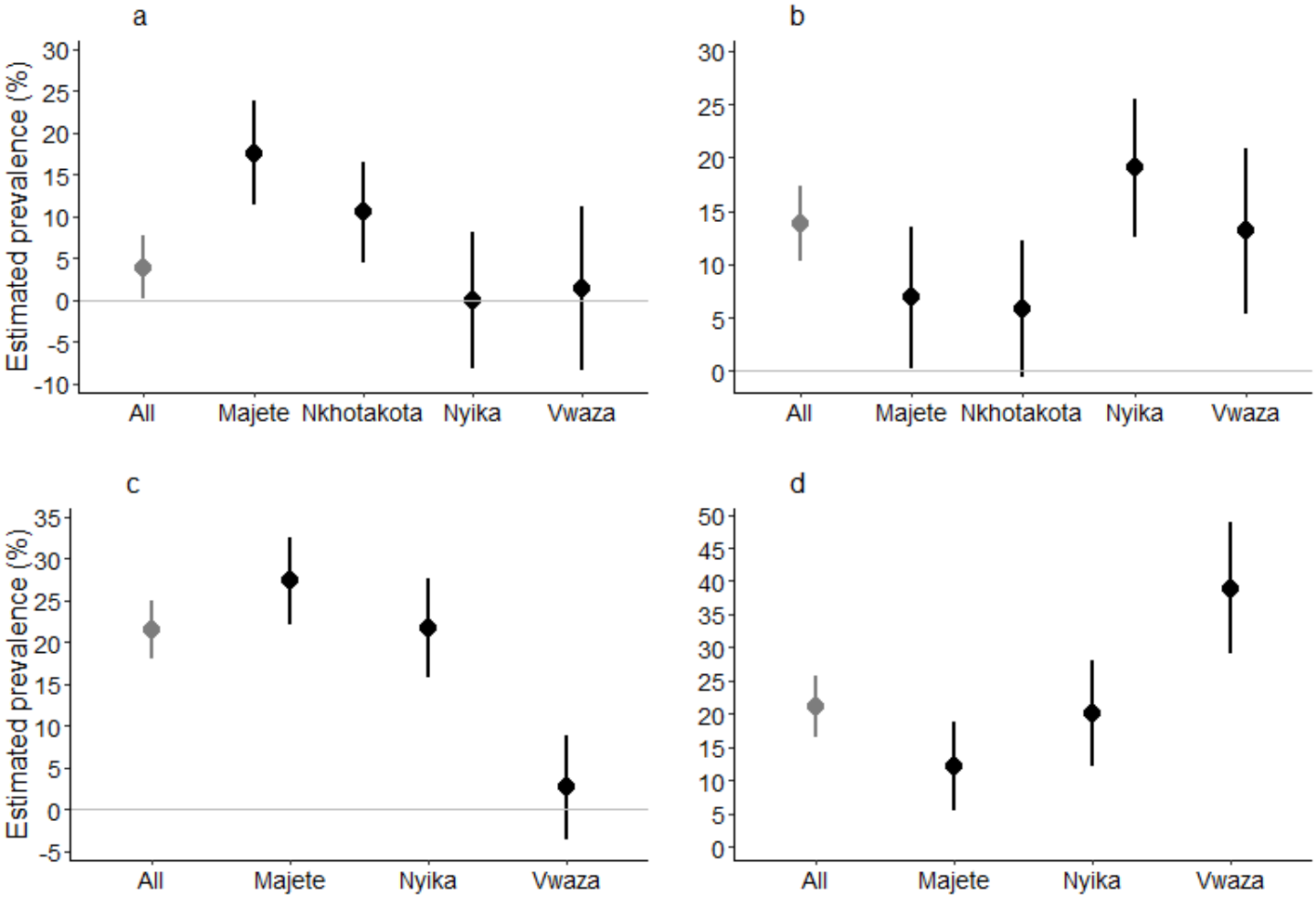

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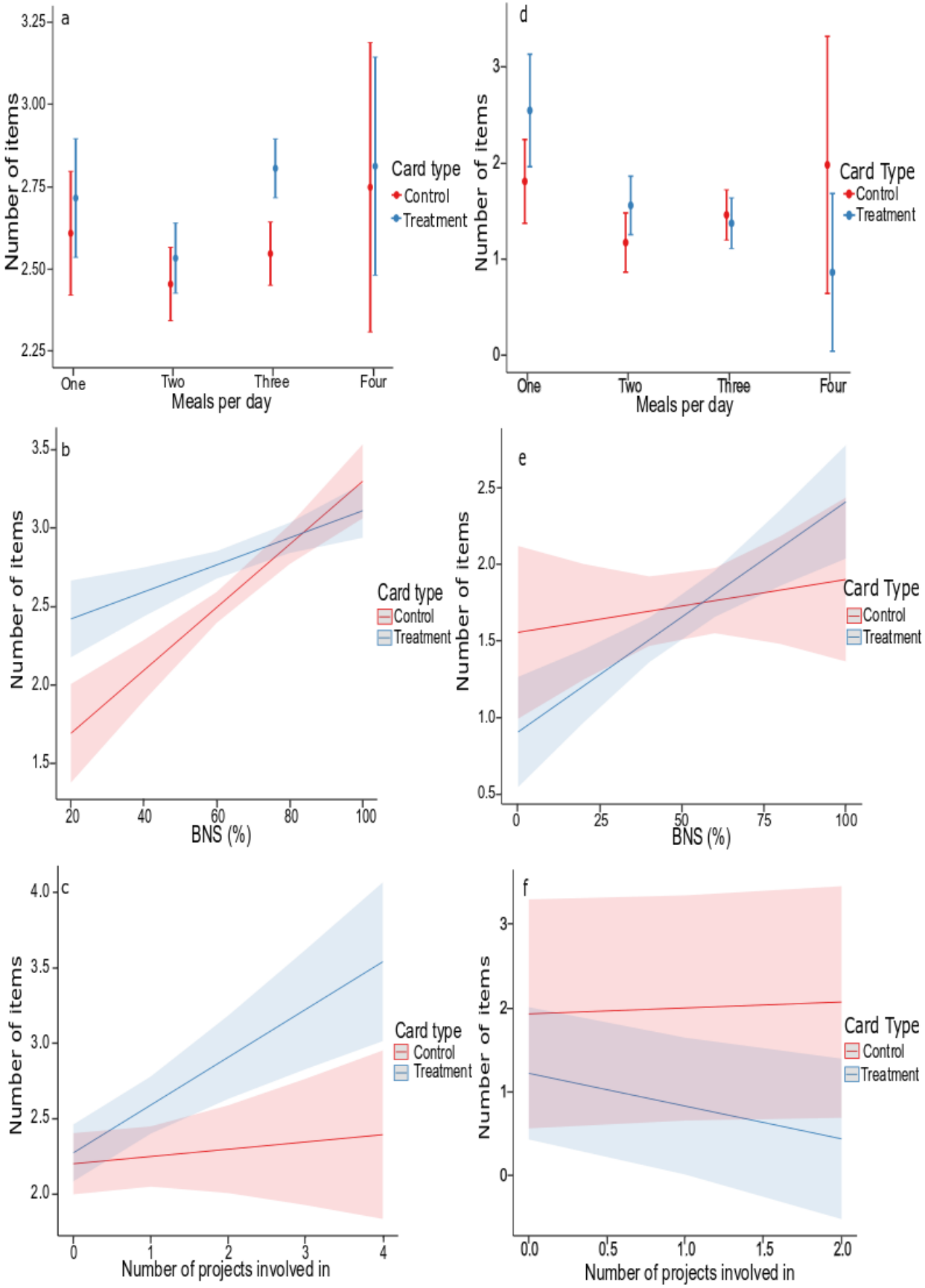

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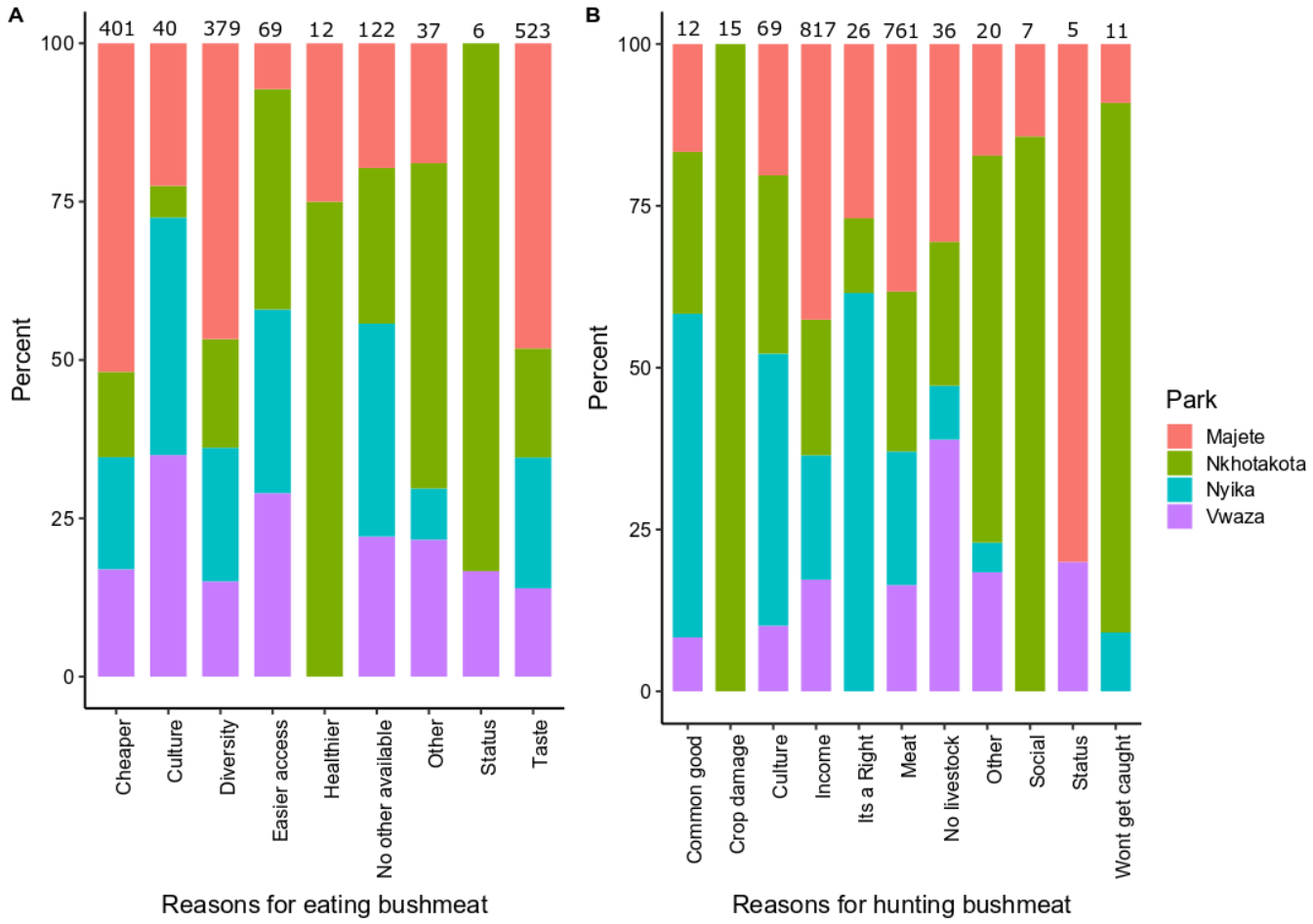

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Tables

Table 1: characteristics of the four Malawian protected areas of interest

	Nyika National Park	Vwaza Marsh Wildlife Reserve	Nkhotakota Wildlife Reserve	Majete Wildlife Reserve
Regional characteristics	North: optimum agricultural conditions and lowest human population density (63 persons/km^2)	North: optimum agricultural conditions and lowest human population density (63 persons/km^2)	Central: moderate agricultural conditions, high population density (154 persons/km^2)	South: volatile agricultural conditions, high population density (185 persons/km^2)
Subjective Park Status	Established: well developed tourism and management, limited infrastructure	Limited: limited tourism, developing management and partnerships, limited infrastructure	Imminent: rebuilding from a collapsed state, limited infrastructure	Established: well developed tourism and management, good infrastructure
Ethnicity of local communities	Ngoni, Poka, Tumbuka	Ngoni, Poka, Tumbuka	Chewa, Yao	Chewa, Mang'anja
Habitat	Mountainous Miombo woodland *(Caesalpinioideae* family) and montane grassland	Lowland Miombo woodland, seasonally inundated grasslands	Miombo woodland	Miombo and Mopane (*Colophospermum mopane)* woodland
Fencing status	Majority unfenced	Majority unfenced	Fencing currently being completed	Completely fenced
Management organization	DNPW (Malawi Government)	DNPW (Malawi Government)	African Parks NGO partnership	African Parks NGO partnership

Table 2: Sample selection for each protected area of interest indicating the number of zones, Group village headmen (GVH) units, villages and households.

Sample size information	**Protected area**			
	Nkhotakota	**Nyika**	**Vwaza Marsh**	**Majete**
Number of zones around PA	12	18	12	4
Number of zones selected	5	5	5	4
Number of GVHs selected	N/A	5	5	11
Number of villages selected from each GVH	N/A	2-3	2	2
Number of villages selected	22	13	10	22
Number of households interviewed	**504**	**309**	**231**	**518**
		540		

Table 3: Effect of socio-demographic variables on estimated prevalence of wild meat consumption, both post-harvest (June-October) and pre-harvest (November-March) for Malawian protected areas, as the coefficients (S.E) for each variable*.

UCT Question	Protected area	Card type	Meals per day			Park employment	BNS score	Livestock ownership	Market access				Knowledge of VNRCs	Born in district	Gender	Tribe		Marital status			# projects known about	# projects involved in
			One	Two	Three				Very easy	Quite easy	Quite difficult	Very difficult				Ngoni	Tumbuka	Married	Single	Widow/er		
	All PAs	0.47 (0.35)	-0.03 (0.33)	-0.07 (0.31)	0.12 (0.31)	0.59 (0.41)	-0.05 (0.00)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Consumption post-harvest	Majete	0.21 (0.61)	0.20 (0.54)	0.04 (0.51)	0.28 (0.51)	0.51 (0.47)	-0.01 (0.00)	NA	NA	NA	NA	NA	NA	0.55 (0.22)	-0.21 (0.11)	NA	NA	NA	NA	NA	NA	NA
	Nyika	0.89 (0.35)	NA	NA	NA	NA	-0.01 (0.01)	-0.02 (0.15)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vwaza Marsh	-1.00 (0.49)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.01 (0.14)	NA	NA	1.12 (0.38)	1.18 (0.33)	NA	NA	NA	NA	NA
	All PAs	0.07 (0.47)	-0.10 (0.43)	0.19 (0.40)	0.19 (0.40)	NA	0.00 (0.00)	NA	-0.63 (0.77)	-0.12 (1.7)	-0.07 (0.12)	-0.16 (0.13)	NA	NA	NA	NA	NA	NA	NA	NA	0.04 (0.03)	NA
Consumption pre harvest	Majete	0.07 (0.14)	NA	NA	NA	NA	NA	NA	-0.07 (1.02)	-0.35 (0.33)	-0.07 (0.16)	-0.11 (0.19)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.27 (0.11)
	Nyika	0.33 (0.91)	0.20 (0.83)	0.25 (0.79)	0.36 (0.77)	NA	-0.01 (0.01)	NA	NA	NA	NA	NA	-0.30 (0.16)	NA	NA	0.65 (0.91)	1.24 (0.77)	-0.53 (0.29)	-0.57 (0.40)	0.025 (0.46)	NA	-0.33 (0.19)
	Vwaza Marsh	0.69 (0.48)	NA	NA	NA	NA	-0.01 (0.01)	NA	NA	NA	NA	NA	0.26 (0.18)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Reference level		control	4 meals per day			Not employed by park	Intercept	No livestock	Neither difficult nor easy				Don't know VNRC	Not born in district	Female	Ndali tribe		Divorced			Intercept	Intercept

*Variables that were not included in the top averaged model (from all models with ΔAIC<4) are indicated with "NA". All estimates represent the interaction between that variable and card type (control/treatment). Highly significant variables ($p<0.05$) indicated by dark grey shading and moderately significant ($p<0.1$) by light grey shading.

Table 4: Effect of socio-demographic variables on estimated prevalence of wild meat hunting, both post-harvest (June-October) and pre-harvest (November-March) for Malawian protected areas, shown as the coefficients (S.E) for each variable [a]

UCT Question	Protected area	Card type	Household size class	Meals per day: One	Meals per day: Two	Meals per day: Three	Park employment	BNS score	Livestock ownership	Market access: Very easy	Market access: Quite easy	Market access: Quite difficult	Market access: Very difficult	Knowledge of VNRCs	Born in district	Gender	Age	Number projects involved in
Hunting post-harvest	All PAs	0.07 (0.10)	0.05 (0.07)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.0002 (0.02)	NA
	Majete	0.21 (0.16)	0.18 (0.12)	NA	NA	NA	NA	NA	-0.10 (0.13)	-1.31 (0.92)	-0.15 (0.29)	-0.15 (0.15)	-0.08 (0.17)	NA	NA	NA	NA	
	Nyika	0.08 (0.22)	-0.04 (0.15)	-0.05 (0.43)	NA	-0.34 (0.20)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.31 (0.17)	NA	NA
	Vwaza Marsh	-0.90 (0.80)	0.31 (0.20)	1.63 (0.86)	1.15 (0.81)	0.80 (0.81)	NA	NA	NA	NA	NA	NA	NA	-0.05 (0.20)	NA	NA	NA	-0.46 (0.22)
	Nkhotakota	-0.03 (0.20)	NA	0.14 (0.23)	0.30 (0.19)	0.42 (0.19)	0.41 (0.29)	NA	NA	NA	NA	NA	NA	-0.10 (0.12)	-0.15 (0.12)	NA	NA	NA
Hunting pre-harvest	All PAs	-0.11 (0.37)	-0.02 (0.07)	0.018 (0.20)	0.024 (0.18)	-0.03 (0.17)	NA	0.01 (0.00)	0.05 (0.09)	-0.01 (0.48)	-0.10 (0.15)	-0.10 (0.10)	-0.06 (0.11)	NA	NA	NA	NA	NA
	Majete [b]	-0.82 (0.34)	NA	NA	NA	NA	NA	0.011 (0.006)	0.12 (0.16)	NA	NA	NA	NA	NA	NA	NA	NA	0.37 (0.11)
	Nyika	0.11 (0.27)	0.03 (0.14)	-0.07 (0.73)	-0.09 (0.69)	0.00 (0.67)	NA	NA	NA	0.53 (0.68)	-0.13 (0.26)	0.11 (0.21)	-0.09 (0.24)	NA	NA	0.19 (0.14)	NA	NA
	Vwaza Marsh	0.40 (0.57)	0.00 (0.15)	-1.07 (0.65)	-1.00 (0.63)	-1.15 (0.62)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Nkhotakota	-0.12 (0.16)	NA	0.46 (0.23)	0.08 (0.19)	0.05 (0.19)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Reference level		Control	Household < median	Four meals per day			Not employed by park	Intercept	No livestock	Neither difficult nor easy				No knowledge	Not born in district	Female	Intercept	Intercept

[a] Variables that were not included in the top averaged model (from all models with Δ AIC<4) are indicated with an "NA". All variables represent the interaction between that variable and card type (control or treatment). Highly significant variables ($p<0.05$) are indicated by dark grey shading and moderately significant ($p<0.1$) by light grey shading, representing differences in number of behaviours between control and treatment cards.

[b] Majete modelled without random terms