Ways to understand and measure bushmeat hunting to improve targeting of conservation interventions: a case study of the GolaMA project, Liberia

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ABSTRACT

Over-hunting is a major driver of biodiversity loss and threatens people's food security and livelihoods worldwide. I describe a rural hunting system at a conservation project site in Gola, Liberia, and explore how social science tools can help conservationists understand and influence human behaviour.

In marketing, the technique of 'audience segmentation' is used to identify which specific group of people will be targeted by a campaign. I applied audience segmentation to differentiate hunters, identifying distinct hunter types that differed according to livelihood portfolios, hunting methods, citizenship (indigenous locals or non-locals) and previous experience of law enforcement. Results suggested that interventions should seek to target specific groups, for instance, programmes to support income from cocoa farming could be appropriate for local trappers with cocoa farms, but not for non-local gun-hunters who did not own plantations.

Measuring people's behaviour is challenging where activities are illegal and could be under-reported. I evaluated hunting and trading over a two-year period using the bean method, a technique designed to encourage truthful reporting by ensuring people's answers remain anonymous. Results indicated a decrease in bushmeat trading from 36% to 20% of households, but little change in hunting. Most respondents (>90%) gave direct answers that were consistent with bean method answers, suggesting questions were not sensitive despite conservation interventions aiming to reduce hunting. The technique was low-cost and straightforward to implement.

Harvest datasets are fundamental for understanding hunting systems but are susceptible to sampling and measurement biases. I compared catch-per-day from two methods, hunter recall interviews and village-based monitoring, revealing a two-fold difference in estimates. Results suggest non-random sampling of hunters' or hunting trips could be a major source of bias in harvest datasets. Conservation interventions can be improved by better targeting of interventions, supported by robust tools to measure resource-use behaviour.

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Chapters included as co-authored publications

This thesis includes four data chapters, three of which are included as jointly authored publications, and one of which is a slightly modified form of a jointly authored publication. Published chapters are included in the final published form. Page numbering follows the numbering of each respective journal.

Chapter 3. *This chapter is a replication of:*

Jones, S., Papworth, S., Keane, A., St John, F., Smith, E., Flomo, A., Nyamunue, Z., Vickery, J., 2019. Incentives and social relationships of hunters and traders in a Liberian bushmeat system. Biol. Conserv. 237, 338–347. https://doi.org/10.1016/j.biocon.2019.06.006

Chapter 4. *This chapter is a replication of:*

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Chapter 5. *This work is also published (with minor differences) as:*

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I made the principal contribution to all chapters, and lead on research conceptualisation and survey design, training and coordinating a team of data collectors, data entry and analysis, interpretation of results and writing. Co-authors contributions were:

S. Papworth, A. Keane, F St. John and J. Vickery provided support and advice across all aspects of the work in their capacity as my academic supervisors, and provided comments and editorial suggestions on manuscript drafts (all chapters).

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Summary of findings

This work provides the first detailed description of a tropical forest hunting system in rural Liberia and advances practical tools to support monitoring and targeting of conservation interventions. I conducted the research in Gola Forest, West Liberia, at the site of the GolaMA conservation project, a 5-year programme aiming to reduce over-hunting of forest wildlife. GolaMA was implemented by the Royal Society for the Protection of Birds and the Society for the Conservation of Nature of Liberia, in partnership with the Forestry Development Authority of Liberia, from 2014 to 2019. The project worked with two clans to establish legally recognised community-managed forests and supported the development of sustainable land-use plans which included hunting regulations. GolaMA also aimed to improve income from non-bushmeat sources, and provided livelihood support programmes such as agricultural training, introduction of bee-keeping, and a small loans scheme.

To understand bushmeat hunting and trading at the site, I conducted interviews with hunters (n=205), traders (n=50) and households (n=476 in 2017, n=523 in 2019) between July 2016 and July 2019. Respondents included participants and non-participants of GolaMA interventions. Bushmeat played a major role in local livelihoods: it provided income for up to 40% of households and was the principal or only income source for 74% of hunters and 78% of traders, many of whom were women. Perceived bushmeat incomes of US$120-260/month were high relative to other income sources, underscoring the challenge of designing effective livelihood-based interventions, particularly for vulnerable groups such as female traders. Hunters and traders were motivated to change their behaviour by different factors: traders were concerned with risks of bushmeat confiscation at roadblocks, while hunters cited time demands of agricultural activities as a principal constraint on hunting. The range of financial incentives, motivations and social influences suggested that livelihood-based approaches could be targeted strategically to maximise socio-economic and conservation impact.

I examined how interventions to reduce hunting could be effectively targeted by applying the marketing technique of audience segmentation to identify key groups within the population. Cluster analysis based on socio-demographic, livelihood and behavioural variables provided a way to distinguish distinct hunter types that differed in terms of livelihood portfolios, hunting methods, citizenship (indigenous locals or non-locals) and previous experience of law enforcement. The profiles of these groups suggested interventions could be targeted effectively. For instance, programmes to support income from cocoa farming could be appropriate for local trappers with cocoa farms, but not for a large group of non-local gun-hunters who did not own plantations.

Once interventions are designed and implemented, measuring patterns of behaviour is often challenging where activities are illegal and could be under-reported. I used the "bean method", which is designed to minimise misreporting of potentially sensitive behaviour by allowing respondents to answer straightforward questions without revealing their response to an interviewer. Answers are given by placing a coloured bean in a jar with a known number of beans in it, with the colour of bean denoting an answer (e.g. 'yes' or 'no'). Beans are counted after a survey-day to obtain group-level estimates. I assessed hunting and trading in households that did and did not participate in GolaMA, over a 2-year period. Bean method results agreed closely to when people were asked the same questions directly, for all groups. Results revealed a decrease in trading activity across project and non-project households from 36% to 20%, while hunting decreased only in one project group (38% to 28%). Alongside anecdotal reports, these results provided evidence that law enforcement at a roadblock had acted as an effective deterrent for some traders. The bean method was straightforward to implement and could be adapted to suit a wide range of conservation settings.

I examined sources of error in hunting catch data to evaluate how biases could influence monitoring outcomes or management decisions about who to target. Alternative methods to measure hunters' catch produced a twofold difference in estimates of catch per day. Continuous recording of catch by village-based assistants gave a mean estimate of 3.0 animals [2.4-3.6 95%CI] on an average length trip of 3.2 days, whereas asking hunters to recall their most recent catch gave an estimate of 7.3 animals [6.0-8.8] for a trip of the same length. The villages which appeared to have highest catch differed according to survey method. Several potential sources of bias were identified, including representation of long versus short hunting trips, and non-random sampling of hunters.

My work shows hunting-reduction interventions could be improved by focussing on who they aim to influence, social context for behaviour, and techniques to reliably measuring resource use. Future work at GolaMA should seek to identify behavioural responses to interventions and improve understanding of which mechanisms are effective for different types of people. In particular, there is a need to identify livelihood barriers for women and non-local hunters, as well as potential feedback processes between small loans schemes and bushmeat livelihoods. I suggest the technique of audience segmentation could be useful in a wide range of conservation settings to account for heterogeneity in people's behaviour and motivations. Similarly, the 'bean method' was a straightforward, low-cost monitoring tool that is practical in low-literacy settings, and could be useful in a variety of settings.

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Chapter 1. Introduction

The hunting of animals for consumption is considered one of the most significant threats to tropical forest wildlife (Milner-Gulland et al., 2002; Nasi et al., 2008; Ripple et al., 2016) and contributes substantially to rural diets throughout much of the tropics (De Merode et al., 2004; Fa et al., 2003; Rushton et al., 2005). The term 'bushmeat' (or wildmeat), refers to wild animals hunted for consumption and encompasses a huge diversity of species (Cawthorn and Hoffman, 2015). Bushmeat is traded commercially in local, national and international markets, with extraction estimates of 4.9 and 5 million tonnes / year for Neotropical and Central African regions respectively (Fa et al., 2002). Unsustainable levels of hunting have resulted in elevated extinction risks and local defaunation (Fa and Brown, 2009; Ripple et al., 2016), with potential food security consequences for human populations (Cawthorn and Hoffman, 2015) as well as wider ecological impacts (Abernethy et al., 2013; Peres et al., 2016). As such, hunting is considered by many to be an issue of both social and ecological concern and efforts to address it increasingly seek to integrate development goals with conservation aims (Lindsey et al., 2015; Salafsky and Wollenberg, 2000).

A wide range of interventions aim to reduce unsustainable use of tropical forest resources, encompassing the establishment of protected areas (Tranquilli et al., 2014), educational campaigns (Barker et al., 2013; Jenks et al., 2010; Rakotomamonjy et al., 2015), sustainable livelihood promotion (Wicander and Coad, 2018) and financial mechanisms such as conservation payments (Niesten et al., 2010). A widely applied governance framework is community-based natural resource management (Nelson et al., 2007; Nielsen and Meilby, 2015; Pailler et al., 2015), whereby some rights to manage and determine the rules of forest resource use are devolved to the resource users (Brooks et al., 2013). Under this framework, incentives for sustainable management can vary depending on the motivations and opportunity costs for communities of conserving rather than over-exploiting the resource (Souto et al., 2014). Given that over-exploitation can be a financially attractive option (Sayer et al., 2017) community-based management is typically coupled with mechanisms to provide additional incentives or restrictions. These come in a variety of forms that vary in how directly they are linked to conservation outcomes, with examples including co-management with government or non-government bodies (Pailler et al., 2015), payments for specified conservation outcomes (Ingram et al., 2014), financial or development benefits based on adherence to conservation agreements (Niesten et al., 2010), or more general livelihood

approaches such as promotion of alternative income sources (Wright et al., 2016). Deciding which of these tools to adopt is complex and challenging (Pullin et al., 2004) and the most appropriate intervention design might depend on site-specific differences in cultural values, socio-economic factors and historical context (Enuoh and Bisong, 2014; Sterling et al., 2017; Walters et al., 2015). For many conservation approaches, the evidence base remains insufficient to effectively guide decisions (Brooks et al., 2013; Burivalova et al., 2019a; Roe et al., 2014). There is a clear need for a more strategic, evidence-driven approach to guide and inform decisions about which types of interventions to implement at a site.

Like most conservation problems, the threats to wildlife from over-hunting can only be addressed by changing people's behaviour (Schultz, 2011). However, many conservationists lack the appropriate understanding, training and skills to do this sensitively and effectively (Robinson et al., 2019; Selinske et al., 2018). A key underlying issue is that interventions are often developed to achieve ecological outcomes and fail to consider the processes that motivate people to act the way they do (St John et al., 2010). Ignorance of the social and cognitive complexities surrounding behavioural decisions can lead to interventions which are at best ineffective (Baynes et al., 2015) and at worse, have unintended consequences (Larrosa et al., 2016). As such, there is a need to advance conservation tools that describe hunting systems from the perspective of resource users, and intervention designs need to be grounded in an understanding of who they aim to influence (Agrawal and Gibson, 1999; Veríssimo, 2013).

In this thesis I explore how a focus on the human behaviour aspects of resource use could help conservationists to: (1) understand social-ecological systems and underlying drivers of resource use; (2) develop more effective behaviour change interventions and; (3) monitor outcomes to assess the impacts of interventions. For each of these processes I consider how techniques and insight from the social sciences could be usefully applied to conservation practices, within the context and constraints of a rural hunting system.

Understanding social-ecological systems from the perspective of resource-users

Conservationists need to understand hunting systems from the perspectives of resource-users in order to design tools that can effectively influence behaviour. To achieve this, researchers and practitioners are increasingly adopting theoretical frameworks and methodologies developed in the psychological and social sciences (Bennett et al., 2016b; Moon and Blackman, 2014; Saunders et al., 2006). Decision-making theories, such as the theory of planned behaviour (Ajzen, 1996), bring to light factors that can underpin behavioural choices, such as attitudes, personal and social norms, and perceived intrinsic or extrinsic barriers. The integration of these frameworks into conservation work

has proven useful to identify determinants of behaviours (e.g. Fairbrass et al., 2016; Gurney et al., 2016) and in supporting the design of behaviour change programmes (Martinez et al., 2013; Mastrangelo et al., 2014; Steinmetz et al., 2014), and could contribute to better models of social ecological systems (Schlüter et al., 2017). Cultural values and their social context can be particularly relevant for understanding wildlife use (Etiendem et al., 2011). For instance, taboos against hunting or consuming particular species can affect patterns of exploitation and abundance (Heinicke et al., 2019a), and may change through time due to sociodemographic trends (Jones et al., 2008). Understanding patterns of information flow across social networks can help ensure conservation messages are delivered effectively (Baird and Gray, 2014; de Lange et al., 2019), while social factors such as trust are integral to cooperative, sustainable management of open-access resources (Bouma et al., 2017; Smith et al., 2019; Stern and Baird, 2015). At the level of individuals, variation in cognitive and psychological factors might influence how people respond to different interventions, for instance, attitudes towards risk can affect livelihood decisions (Charness and Gneezy, 2010), while intrinsic motivations can affect the success of payment schemes in promoting a particular behaviour (Nilsson, 2015; Rode et al., 2015).

Previous case-studies of hunting systems have demonstrated that an understanding of socio-cultural context can generate valuable insights into underlying drivers of resource use and potential pathways for sustainable management (e.g. Coad et al., 2013; Kumpel, 2006; Van Vliet et al., 2015). For instance, wildlife consumption patterns can be driven by economic factors, such as the price of other protein sources (Brashares et al., 2004), but also by taste preferences (Mbete et al., 2011), cultural associations with status or wealth (Chausson et al., 2019), perceived health benefits (Chausson et al., 2019), spiritual belief systems (Etiendem et al., 2011; Jenkins et al., 2011), or food-sharing practices that maintain social ties (Van Vliet et al., 2015). Resource use behaviour is affected by political, economic or ecological pressures (Coad et al., 2013; Gill et al., 2012; Yasuoka et al., 2015), and changes through time can be underpinned by shifts in values and attitudes which have long-term consequences for local governance systems (Kaye-Zwiebel and King, 2014). Behavioural perspectives help show that while motivations for hunting are often commercial (e.g. Bachmann et al., 2019; Nielsen and Meilby, 2015), the relationship between hunting and poverty is far from straightforward, and factors such as availability of suitable employment may be more important than material wealth (Travers et al., 2019). It is evident that most hunting systems encompass a diversity of actors who are likely to vary in terms of behaviours, attitudes, values, socio-economic circumstances and experiences (e.g. Coad et al., 2010; Kümpel et al., 2009; Lindsey et al., 2015; Rist et al., 2010). However, conservation approaches tend to treat resource users as a homogenous group, and interventions are often aimed at an “average” person rather than being targeted towards

those with the greatest conservation impacts (Agrawal and Gibson, 1999; Olmedo et al., 2017; Spiteri and Nepal, 2006).

Improving intervention designs: targeting specific groups of people

Techniques developed in the world of marketing could help conservationists influence behaviour more effectively (Salazar et al., 2019; Wright et al., 2015). Indeed, the value of marketing tools as a means to promote changes in behaviour has long been recognised by those working in fields such as public health, giving rise to the discipline of 'social marketing' (Kotler and Lee, 2008). Social marketing campaigns are developed from a strong grounding in behavioural theory, using an iterative approach of testing, implementing, monitoring and adapting interventions based on their effectiveness (Mckenzie-Mohr, 2000). Fundamental to this process is defining specifically who the campaign seeks to influence and using their perspectives and motivations as the basis for intervention design (Mckenzie-Mohr, 2000). Social marketing has been successfully used in public health (Gordon et al., 2006; Hastings, 2007) and to address environmental issues (Hargreaves, 2011; Peattie and Peattie, 2009) but has been applied less frequently to biodiversity conservation (Veríssimo, 2019). Exceptional examples are the Pride campaigns of the RARE Centre for Behaviour and the Environment, which have been using social marketing to address conservation issues worldwide for the past 30 years (Green et al., 2019; Jenks et al., 2010; Salazar et al., 2019). For instance, Salazar et al. (2019) describe how a Pride campaign promoting messages about conservation of a parrot species, *Amazona barbadensis,* contributed to its population increase, improving people's awareness and compliance with regulations, and shifting social norms. Several authors have made compelling arguments that social marketing principles could be better integrated into conservation practice. For example, marketing techniques might improve campaigns using flagship species to garner support for conservation (Verissimo et al., 2011), efforts to reduce human-wildlife conflict (Veríssimo et al., 2019), demand-reduction campaigns to address illegal wildlife trade (Greenfield and Veríssimo, 2019), and the way conservation messages are communicated (Kidd et al., 2019).

An important insight from social marketing is that behaviour change interventions might be improved if they are targeted toward specific groups within society (Kidd et al., 2019; Verissimo et al., 2011), a view which is supported by observations of hunting systems (e.g. Coad et al., 2013). Reviews of conservation campaigns suggest that conservationists often fall short of standard marketing practice when it comes to defining who they intend to influence (Greenfield and Veríssimo, 2019; Kidd et al., 2019). Conservation programmes may be designed without identifying a target group (Olmedo et al., 2017) or doing so in vague terms (Agrawal and Gibson, 1999; Spiteri

and Nepal, 2006), whereas marketers devote substantial attention and resources into defining who a campaign is aimed at (e.g. Schmid et al., 2008). This tendency in conservation to adopt a "one-size-fits-all" approach is part of a wider problem of failing to strategically plan behaviour-change interventions (Schultz, 2011). For instance, in campaigns to reduce rhino horn demand, target groups were broadly defined, such as encompassing 'the general public', and differed between organisations (Olmedo et al., 2017). Campaigns also lacked a clear purpose, for instance, whether the intention was to "raise awareness" or "reduce demand" (Olmedo et al., 2017). Moving towards standard practices which place humans and their behaviour at the core of intervention design, and using this to target specific groups, could be an effective way forward for biodiversity conservation (Salazar et al., 2019).

A promising tool for targeting behavioural interventions is the marketing technique of "audience segmentation". In marketing, the term audience segmentation describes the process of differentiating a general population according to peoples' characteristics, such as behavioural, demographic or socio-economic profiles. The aim is to identify groups that are expected to be internally homogenous in their response to behaviour change interventions, but which differ from one another in terms of the interventions that are most effective (Schmid et al., 2008). Identifying and profiling these clusters can enable the design of behaviour change tools that are optimal for specific groups (Schmid et al., 2008). The factors used to identify groups is paramount, and marketers may incorporate a large range of socio-demographic variables, as well as psychological traits, such as risk attitudes and personality, which can mediate decision-making (Barber et al., 2012). While psychological profiles of resource-users may be hard to obtain in many conservation settings, attributes such as livelihoods, demography, economic status and harvesting behaviour might offer a practical basis to define target groups. Hunters can differ substantially in terms of their impacts on wildlife (Kümpel et al., 2009), their financial and non-financial motivations (Carvalho et al., 2014; Chang et al., 2019) and the barriers they face for adopting new livelihood strategies (Wicander and Coad, 2018). The technique of audience segmentation might be a useful approach to better understand the full range of behavioural, sociodemographic and livelihood profiles at a site, and develop behaviour change mechanisms which effectively target different groups.

Monitoring behaviour and resource use

To effectively influence behaviour, targeting needs to be coupled with an understanding of which interventions work best for which types of people. However, evidence that interventions have been successful in influencing resource use behaviour is often of poor quality and provides a mixed

picture (Brooks et al., 2013; Burivalova et al., 2019a; Hajjar et al., 2016; Ingram et al., 2014). Consequently, more robust studies are needed to build an evidence base that can guide decision-making (Burivalova et al., 2019b). While a growing body of work shows positive impacts of protected area management and law-enforcement as a conservation tool (Coad et al., 2015; Ferraro and Hanauer, 2015), the general effectiveness of community-based management for achieving either conservation or social development aims remains unclear (Bank and Sills, 2014; Baynes et al., 2015; Galvin et al., 2018; Keane et al., 2019; Roe et al., 2014; Terborgh and Peres, 2017; Travers et al., 2015). Empirical support for livelihood-based approaches is particularly sparse (Brooks et al., 2013; Roe et al., 2014) and the processes by which livelihood interventions are intended to operate are often poorly thought-through (Spiteri and Nepal, 2006; Wright et al., 2016). One problem is that community-based management often aims to achieve multiple outcomes, and these may be hard to measure accurately (Burivalova et al., 2019a; Cook and Hockings, 2011; Hajjar et al., 2016).

In many cases, interview-based surveys can represent a practical and cost-effective means to monitor behaviour. However, reported behaviour is susceptible to social desirability bias, where people may avoid sharing information that is incriminating or presents them unfavourably, or exaggerate reporting of socially accepted acts (Krumpal, 2013). Therefore it can be particularly challenging to measure activities that are illegal or illicit, due to inaccurate or non-reporting by those unwilling to share potentially incriminating information (Gavin et al., 2010; Krumpal, 2013). Ways to minimise social desirability bias include specialised survey methods that encourage truthful responses by ensuring researchers cannot directly link behaviour to individuals (Nuno and St. John, 2015). These have provided higher prevalence estimates of non-compliance with conservation rules where the issue is sensitive (Conteh et al., 2014; Fairbrass et al., 2016; Razafimanahaka et al., 2012; St John et al., 2012) but can come at a cost of statistical efficiency (Hinsley et al., 2019) and some perform poorly with small sample sizes or for behaviours with low prevalence (Hinsley et al., 2019; St John et al., 2018). Well known techniques which have been used to reveal patterns of illegal hunting include the unmatched count technique (Hinsley et al., 2019) and randomised response technique (Razafimanahaka et al., 2012). The former involves asking respondents to indicate how many items on a list they have participated in, with half of the sample being shown a list that includes the sensitive behaviour. This approach was used by Harrison et al., (2015) to investigate socio-economic patterns of illegal resource use in Uganda, and by Nuno et al (2013) to identify spatial and socio-economic patterns of poaching in Tanzania. The randomised response technique uses a randomising device, such as dice, to mask respondents' true answers. For example, respondents could be instructed to answer a sensitive question with the word "yes" if they roll a 1, "no" if they roll a 6, and otherwise to answer either yes or no truthfully. Interviewers do not see the

dice roll but can analyse results based on the known probabilities of the randomising device. This technique has been applied in several studies to understand drivers and patterns of wildlife hunting and consumption (Chang et al., 2019; Razafimanahaka et al., 2012; Solomon et al., 2007; St John et al., 2012).

Specialised techniques can have drawbacks which may make them inappropriate if a behaviour is not highly sensitive, where financial or time constraints are limiting, or if managers lack statistical expertise (Danielsen et al., 2014; Hinsley et al., 2019). A pragmatic solution may be a technique developed by Lau et al. (2011), which uses a straightforward voting system to help gauge social desirability bias. Known as the "bean method", respondents are asked to give their answer by placing a coloured bean in a jar which already has a number of beans. The colour of the bean denotes whether the answer is yes or no, and interviewers only count the beans at the end of each day, to give group level prevalence estimates. Differences between direct answers and those given through the bean method indicate under- or over- reporting which is presumed to be attributable to sensitivity of the question. This technique could be a useful monitoring tool in community-based resource management, being relatively simple, and potentially less costly or demanding to implement and interpret than other specialised approaches. However, the bean method has yet to be applied in site-based conservation settings.

Assessing the quality of data that describes hunting behaviour

In hunting systems, information about hunters' catch and effort is central to understanding patterns of hunter behaviour (Sirén et al., 2013), economic motivations (Golden et al., 2014), ecological impacts (Bobo et al., 2015) and for evaluating conservation success. Harvest data may help managers identify appropriate target groups, and design interventions that effectively address threats to wildlife (Borgerson, 2016). Furthermore, metrics based on catch per unit effort or prey composition can provide low-cost monitoring tools in community-based management (Marrocoli et al., 2019; Yasuoka et al., 2015), and reveal patterns at large spatial or temporal scales (Ávila et al., 2017; Ingram et al., 2015). However, catch per unit effort has several well-documented limitations as a monitoring tool (Keane et al., 2011; Maunder et al., 2006; Rist et al., 2008). For instance, relationships between catch, effort and prey populations may be complex, and effort is difficult to define appropriately (Dobson et al., 2019; Rist et al., 2008). More generally, survey methods to collect catch data are susceptible to several sources of bias which need to be quantified to interpret patterns appropriately. Data quality may suffer from non-representative sampling (St John et al., 2014), inaccurate reporting, error in recalling past events (Golden et al., 2013; Jones et al., 2008), or variation in how questions are interpreted. Survey design details, such as the timeframes being

examined (Golden et al., 2013; Jenkins et al., 2011; Jones et al., 2008) or the point along the market chain that observations are made (Crookes et al., 2005), can also affect results. Sources of bias are likely to change through time due to shifts in hunting practices, ecological patterns, social trends and political contexts (Coad et al., 2013; Gill et al., 2012). It is therefore important to evaluate how different methods and sampling approaches can affect the type of information that is likely to be reported, and the consequences this could have for results used to guide management decisions.

Overall aims and structure

There is a need to improve the impact of conservation interventions which aim to influence resource-use and to develop cost-effective monitoring tools that measure behaviour from the perspective of human decision-making (Crookes et al., 2005; Sommerville et al., 2010). Effective approaches are likely to be based on a good understanding of the social context for behaviours, a clear definition who is to be targeted so that intervention design can be informed by target group profiles, and robust monitoring of behavioural outcomes. This thesis explores these topics and aims to advance practical tools for conservation, using a case-study of a hunting system in rural Liberia.

Chapter 2 Provides an overall background and description of the study site.

Chapter 3 Aims to describe the structure of the bushmeat trading system from a social, economic and livelihood perspective. I apply a mixed methods approach to describe sales and consumption of bushmeat, the role of bushmeat income to livelihoods, financial motivations to hunt or trade, perceived disincentives for hunting and trading and inter-personal relationships between hunters and traders.

Chapter 4 Aims to evaluate "audience segmentation" as a tool for designing hunting reduction interventions that are more effectively targeted toward specific types of resource users. I compare alternative approaches to identify potential target groups: a cluster analysis which incorporates information about livelihoods and hunting behaviour; and a simplistic approach that considers only hunting offtake as a basis for defining target groups. I apply these segmentation approaches to hunters and households and explore how effectively they differentiate groups with distinct profiles that could be targeted with behaviour-change interventions.

Chapter 5 Aims to develop an appropriate monitoring tool for assessing change in hunting behaviour. I apply a specialised questioning technique, the "bean method", designed to minimise the problem of social desirability bias which can affect the quality of behaviour data. I use the bean method alongside direct questions to assess change in prevalence of bushmeat hunting and trading following implementation of conservation interventions.

Chapter 6 Aims to evaluate potential extent of bias in harvest data introduced by differences between data collection methods. I compare estimates of catch per day from two survey methods: face to face interviews in which hunters report their catch from the most recent hunting trip; and continuous monitoring of a subset of hunters by village-based assistants.

Chapter 7 Provides a discussion of the findings. I discuss implications of my results for conservation management at the study site and offer some recommendations for managers going forward. I then discuss how the tools and approaches evaluated in my work could be contribute to conservation practices more generally.

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Chapter 2. Background to the study site and the GolaMA project

This study was carried out in the Gola Forest, West Liberia, at the site of an EU-funded conservation project titled "Securing Liberian forest connectivity through community forest management and innovative financing mechanisms", or GolaMA, which stands for "Gola Management Agreement". This project, which was implemented by the Royal Society for the Protection of Birds and the Society for Conservation of Nature of Liberia, aimed to achieve biodiversity conservation by establishing community-based forest management over approximately 400km² of lowland forest. A principal focus of GolaMA was reduction of bushmeat hunting to sustainable levels, as high levels of hunting pressure were seen to be a major threat to wildlife populations. Prior to conducting the doctoral research presented here, I worked for the GolaMA project as a field-based researcher and had been living in the study site for approximately 18 months. In the following chapter, I provide a brief background into bushmeat hunting and conservation interventions in Liberia, then I describe the study site in terms of livelihoods, resource management and threats of hunting to wildlife. I finish with an overview of the survey design and data collection methods.

Hunting and wildlife conservation in Liberia

Bushmeat is consumed across Liberia (Junker et al., 2015b; Ordaz-Németh et al., 2017) and commercial trade of dried bushmeat can provide a profitable source of income (Greengrass, 2016; Hoyt, 2004), playing a potentially large role in the country's economy (Hoyt, 2004). Animals are killed by hunters using snares or shotguns and the carcasses then may be consumed or sold locally, or dried and transported to urban markets, often by a trader who buys bushmeat from several hunters. In larger towns and cities, market sellers and restaurateurs may buy bushmeat to prepare and sell to consumers (Bakarr et al., 2009). Bushmeat is an important natural resource for rural populations in low-income settings (Fa et al., 2003). Liberia ranks 176 out of 189 countries according to the Human Development Index (UNDP, 2019); in 2013 almost two thirds of the population lived in multidimensional poverty, and about 50% were considered to live in severe poverty (UNDP, 2019). Hunting can therefore be an important livelihood option where few alternatives are available, particularly since it does not need large investments of capital (cable for snares can be bought cheaply and shotguns can be purchased for US$60, *pers obs*), and skills can be learnt relatively easily.

A wide range of species are hunted for bushmeat in Liberia, encompassing most medium to large-bodied mammals, reptiles and birds (Junker et al., 2015a; Ordaz-Németh et al., 2017). Among the most commonly hunted groups are forest ungulates, such as duikers, and primates. However, the list of bushmeat species also includes pangolins, bats, snakes, forest crocodiles, hornbills, vultures,

leopards, elephants and rodents, such as porcupines and squirrels (Buij et al., 2015; Covey and McGraw, 2014; Greengrass, 2016). Many species hunted in Liberia are endemic to the Guinean Forests of West Africa biodiversity hotspot (Mittermeier, 2004) and globally threatened with extinction. This forest habitat, which once extended from Sierra Leone to Togo, has rapidly declined in recent decades (Junker et al., 2012) with Liberia retaining about half the remaining forest habitat (Junker et al., 2015a). Consequently, the country supports globally significant populations of forest wildlife, for instance, among the only remaining viable populations of Western chimpanzee (*Pan troglodytes verus*) (Heinicke et al., 2019b) and pygmy hippopotamus (*Choeropsis liberiensis*) (Mallon *et al.* 2011). The remaining forest cover in Liberia occurs largely within two major forest blocks: the largest is situated in the South-East of the country, extending to the border with Ivory coast; while a second area in the North-West extends from the Sierra Leonean border towards Guinea. The Gola forest, where this study was conducted, constitutes a large portion of this latter forest area.

Degradation and loss of forest habitats continues to pose a threat to Liberia's biodiversity, due to commercial and non-commercial activities such as logging, conversion to palm oil plantations, mining and small-holder agriculture. To counter such threats, conservation strategy in Liberia has focussed on the establishment and management of protected areas, alongside laws to regulate hunting. Liberia currently has 10 protected areas, covering about 4% of the country (UNEP-WCMC & IUCN, 2020) which vary in terms of the resources available for active management. Hunting of wildlife is prohibited within protected areas and enforcement is enacted by forest rangers during patrols or through confiscation of bushmeat at road-blocks near park boundaries. However, resources for law enforcement varies between protected areas and all protected areas are under-staffed (*pers obs*). Despite this, sites that receive external support and funding, such as Sapo National Park, are able to enact regular ranger patrols, although for many sites law enforcement remains a challenge (*pers obs*). Interventions to support livelihoods of forest edge communities, and involvement of local people in forest protection roles, such as 'Eco-guards' (WCF, 2014), are increasingly being used as key tools for protected area management in Liberia. Unfortunately, despite significant progress in recent years, protected areas remain vastly under-resourced and illegal activities such as hunting and mining remain a widespread issue and source of conflict (e.g. Greengrass, 2016).

Beyond protected area boundaries, Liberia's laws prohibit harming or selling protected species anywhere in the country (National Wildlife Conservation and Protected Area Management Law, 2016). Species that are protected include: all those listed as globally threatened according to the IUCN redlist (www.iucnredlist.org); species with restrictions on international trade under CITES

(www.cites.org), as well as all diurnal primates. Technically, all hunting requires a license under Liberian law. However, a licensing system is yet to be put in place, so this is not enforceable. Bushmeat from illegally killed species may be confiscated during transport to urban markets, typically at road-blocks situated along major roads. While progress is being made, bushmeat hunting and trade of protected and non-protected species remains widespread and openly practiced across the country. For instance, protected species are often sold openly in markets or roadsides and few people in rural areas are aware of protected species laws (*pers. obs;* GolaMA, unpublished).

Governance and Community-based Forest Management

To adequately address both the conservation and livelihood consequences of over-hunting, changes to natural resource use need to take place outside protected area boundaries (Junker et al., 2015a). In Liberia, community-based forest management could be an appropriate way to achieve this. The Community Forest Rights Law (2009) provides a mechanism by which communities can establish use-rights over a demarcated 'community forest' which can be governed according to land-use management plans that are approved by the central government. Communities can choose between commercial or conservation-oriented management approaches, and the government ratifies management plans on a five-yearly basis. There is growing interest in the potential role of community forests for conservation (A. Gardner *pers. comm.*), with the GolaMA project representing one of the first case-studies for establishment of community forests as a tool for both landscape conservation and socio-economic development.

The community-based management framework reflects the wider governance system in Liberia whereby customary laws and governance institutions sit alongside those of a central government (Tokpa & Yengbeh, 2012). Liberia is divided into 15 counties, then into districts, which are governed by District Commissioners and District Superintendents that are appointed by the president. Each district encompasses several customary jurisdictions called 'clans', with two or more clans coming together to form a 'chiefdom'. These are traditionally governed by locally elected Clan Chiefs and Paramount Chiefs, respectively. Thus, a district will contain more than one chiefdom and several clans. Any settlement (i.e. a town, village or encampment) will fall within the jurisdiction of a clan, and local affairs are managed by a 'town chief' (sometimes also a 'general town chief') (Tokpa & Yengbeh, 2012). Major local disputes are traditionally settled in a clan headquarters, while issues concerning more than one clan are addressed at the chiefdom headquarters. Status as the headquarters is assigned to settlements based on their historical significance, for example, the original sites established by the ancestors of the present-day occupants of the land. Other settlements have a locally recognised hierarchy based on their history of establishment, such that

recently established settlements are referred to as being 'under' an older one. Although customary authorities are not appointed by government, their positions are legally recognised and they receive government salaries.

There are 16 ethnolinguistic groups, or 'tribes', in Liberia, which traditionally were spread across several chiefdoms. In the present day, people from several different tribes can be found living within a chiefdom. Tribes are not linked to specific political structures but remain important socio-cultural groups. For example, people from tribes that do not 'belong' to a given chiefdom generally do not wield local political power. Where migration has resulted in a large diaspora, immigrants may elect a representative from their own tribe to negotiate on their behalf with the local leadership. Historic tensions between tribes can affect present day social conflicts and resource use governance. For instance, in the study site immigrant hunters from a particular tribe were considered to be causing social disturbance and over-harvesting wildlife. This resulted in a decision by the local clan leaders to forcibly drive them off the land, which was done by a group of armed citizens (R. Kpoto, *pers. comm*).

Local governance of natural resources under the community-based management framework is implemented at the level of clans, such that a clan may establish a community forest, which will be managed via a locally appointed 'Community Forest Management Body'. By-laws to govern access and rights to forest resources will be created by the management body, as part of a land-use management plan. The central government's Forestry Development Authority (FDA) are involved throughout the application process, validating the proposed boundaries and management plans. After five years the FDA must ratify that management plans have been followed, and new management plans must be approved after 15 years.

Previous bushmeat research in Liberia

Despite the importance of Liberia's wildlife resources from both a conservation and human welfare perspective (Junker et al., 2015a; Ordaz-Németh et al., 2017), there have been relatively few studies of hunting and bushmeat consumption in the country. This may be partly due to the political and social upheaval caused by a sustained period of civil conflict from 1989 until 2003. Before the war, a small-scale study indicated that most (97%) households in Monrovia consumed bushmeat (Anstey, 1991), and later work reported at least 35 species were hunted for commercial sale, with ungulates being the most common group (Hoyt, 2004). Current levels of exploitation are likely to be unsustainable: for instance a market survey at the Liberia-Ivory Coast border estimated volumes of trade that likely exceeded sustainable yield thresholds for primates, which represented over a third

(37%) of the animals sold (Covey and McGraw, 2014). A study at commercial hunting camps around Sapo National Park documented intense hunting pressure on many threatened species, and estimated that professional hunters could earn upwards of $1000 / month (Greengrass, 2016). A nationwide study conducted in 2012 using interviews and transect surveys, showed that hunting remains a widespread activity that has likely contributed to local extirpation of larger fauna (Junker et al., 2015a; Tweh et al., 2015). More recently, a nationwide consumption survey showed bushmeat remains a key component of rural and urban diets, although consumption decreased slightly during the Ebola outbreak in 2014-15, particularly among poorer households (Ordaz-Németh et al., 2017).

Livelihoods and socio-economic background of the study site

The research I describe in this thesis took place in Kongba district, which has one of the lowest population densities in Liberia (LISGIS, 2008) and remains relatively inaccessible due to poor transport and communication infrastructure (Bulte et al., 2012). Vehicle roads linking the study site to Monrovia were introduced in the 1980's as a consequence of commercial logging operations. Prior to this, aircraft were used to access areas which contained rich diamond deposits (Z. Nyamunue *pers. comm.*). As is typical across rural Liberia, subsistence agriculture is at the centre of local livelihoods, and uses swidden systems that are common to much of West Africa (Ellis, 1998).

Diamond-mining and to a lesser extent, gold-mining, resulted in the establishment of some present-day settlements in the study site, and small-scale mining continues to be a locally important activity which influences socio-demographic patterns (Bulte et al., 2012; Hilson and Van Bockstael, 2011). For instance, miners employ seasonal labourers as diggers, many of whom are temporary migrants from Sierra Leone, resulting in a male-biased gender ratio and relatively high ethnic diversity (Table 1; taken from GolaMA, unpublished). Cash revenues from mining activities, and the need for miners to buy food for their labourers (Hilson and Van Bockstael, 2011), means that small-scale business enterprises selling food, alcohol and other goods can be relatively viable, in contrast to villages without mining (*pers obs*). Some present-day settlements in the study site came about from commercial selective logging operations, which were carried out across much of the district but ceased in the early 1990's due to the civil conflict (A Flomo, *pers. comm.*). During the conflict many villages were abandoned or occupied by fighters, and remote areas in the forest were temporarily inhabited by people who had been displaced (Corriveau-Bourque, 2010; Hilson and Van Bockstael, 2011). Precious minerals mined from the study area were notoriously involved in funding rebel groups and fuelled conflict across both sides of the border, but are now valuable income sources for those with few alternative livelihood options (Hilson and Van Bockstael, 2011).

Commercial bushmeat hunting in the study site dates back to pre-war mining and logging operations and some present-day settlements originated as commercial hunters' camps (Z. Nyamumue, *pers. comm.*). In a pattern typical of tropical forests worldwide (Edwards et al., 2019), these extractive industries generated opportunities for hunters as company employees created a local demand for meat, and transport links to larger urban markets were improved. The years following the end of the war in 2003 saw an influx of immigrants, many coming from more densely populated counties in Liberia (Corriveau-Bourque, 2010). For many affected by the conflict, particularly ex-combatants, activities such as hunting and pitsawyering were among the few available livelihood options (A. Flomo *pers. comm.*). Settlements in the study site which did not originate from logging, mining or hunting activities, are located on historic sites which have been occupied by subsistence farmers for several generations.

Table 1. Socio-demographic summary of the two clans participating in the GolaMA project and in the present research, taken from GolaMA socio-economic survey conducted in 2015-16 (GolaMA, unpublished). Note the male-biased gender ratio and relatively high ethnic and tribal diversity in Clan 2.

	Clan 1	Clan 2
Number of households	230	219
Number of men (over 16 years)	306	355
Number of women (over 16 years)	291	234
Number of children (16 years and under)	495	442
Literacy of adult women	15%	35%
Literacy of adult men	46%	54%
% adults educated at senior high-school level*	6%	12%
% of population who are Christian	26%	48%
% of population who are Muslim	74%	52%
% of population from Liberia	88%	87%
% of population from Sierra Leone	11%	11%
Number of tribes represented	16	19
Three most populous tribes (% population)	Gola (70%) Mende (13%) Gio (5%)	Mandingo (18%) Kissi (18%) Gola (16%)

* this corresponds to having completed at least 9 years in formal education

A socio-economic baseline survey was conducted by GolaMA in 2015-16, across all households from the two clans that participated in this conservation project. These households were all also included in the present study, along with households from additional non-project villages (see below for details). The GolaMA baseline survey showed that for most people, agricultural activities represent the most significant occupation in terms of time spent and income generated, with rice-farming being the major time demand for around 40% of adults (Table 2; GolaMA, unpublished). The survey results also reveal slight differences between the two neighbouring clans that participated in the project (Fig. 1), in terms of natural resources, livelihood patterns and demographic history (GolaMA, unpublished). For instance, small-scale mining was a principal occupation for about 25% of adult men in clan 2, but for fewer than 1% in clan 1. Small business enterprises may represent a more prominent occupation in clan 2 particularly among women, 42% of whom cited it as the most significant income generating activity (GolaMA, unpublished). In clan 1 both men and women were predominantly occupied with agriculture; and plantation crops such as cocoa, coffee and oil palm were more important than in clan 2. These differences reflect the greater prominence of diamond mining in clan 2 and may be linked to the fact that clan 1 is situated further from Monrovia with poorer transport links to the capital. However, for clan 1, bush paths into Sierra Leone facilitate cross-border trade, providing routes for selling cocoa, coffee and palm oil (*pers. obs*).

Local dependence on bushmeat for food and income was reported to be high among villages in the GolaMA project area: hunting contributed to the livelihoods of about 12% of adult males: 9% of men in clan 2 (n=355) and 15% of men in clan 1 (n=306; only one woman reported hunting) (GolaMA, unpublished). As elsewhere in Liberia, hunting activities generally formed part of diverse livelihood strategies and was typically accompanied by other activities such as subsistence agriculture, seasonal farm labour or mining. Overall, 96% of households (n=450) had consumed animal protein in the previous three days, 84% had consumed fish and 50% had consumed bushmeat (clan 2 = 48% of households, n=220, clan 1 = 44%, n=230; GolaMA, unpublished). Besides bushmeat, other meats consumed were locally raised chickens and goats, as well as chicken feet and canned processed meat imported from urban centres. Fish was mainly locally caught, but dried fish imported from the coast was also consumed in some villages (GolaMA, unpublished).

The GolaMA survey also assessed poverty using the Progress out of Poverty Index (developed by the Grameen Bank for Sierra Leone; www.progressoutofpoverty.org; 2003). This provides a household score from 0 to 100, based on factors such as house structure, assets, education and income sources which are linked to likelihood of being within poverty brackets defined by more complex metrics. The results showed an average poverty rate in clan 2 of 50% of households (n=220) likely to fall

below the Millenium Development Goal US$1.25/day at 2005 purchase power parity line, and 66% of clan 1 households (GolaMA, unpublished). As elsewhere in Liberia, rates of adult literacy were low, particularly among women, with less than half of adults unable to read or write and only a third of women (Table 1; GolaMA unpublished)

Conservation management across the Gola landscape

The Gola Forest landscape represents one of the largest remaining tracts in Guinean Forests of West Africa biodiversity hotspot, and provides more or less contiguous forest cover from Eastern Sierra Leone through to North-West Liberia (Christie et al., 2007; Myers et al., 2000). Ecologically, the forest supports a rich diversity of lowland forest wildlife, including globally significant populations of endangered species, such as the Pygmy Hippopotamus (*Choeropsis liberiensis,* Hillers, 2013), Western Chimpanzee (*Pan troglodytes verus;* Tweh et al., 2015) and Forest Elephants (ELRECO, 2019). Previous conservation research in the region includes ecological and social studies linked to the two large protected areas which lie across the Liberia-Sierra Leone border (Fig. 1): the Gola Rainforest National Park (GRNP), in Sierra Leone and the Gola Forest National Park in Liberia (e.g. Hillers et al., 2017; Lindsell et al., 2011; Lindsell and Klop, 2013; Voors et al., 2011). Surveys within these protected areas have shown that hunting occurs throughout the forest, both in Sierra Leone and Liberia (Hillers, 2013; Jones et al., 2017; Blasi-Foglietti, 2020).

The GRNP covers 690 Km² to the West of the study site in Sierra Leone. The area was first designated as a Forest Reserve for timber extraction in the 1920s, then formally became a National Park in 2010. Its management for conservation has been supported by the Royal Society for the Protection of Birds in partnership with the government of Sierra Leone, since 1990 and the protected area now employs approximately 150 staff. GRNP is actively managed through law enforcement patrols, carried out regularly by 50 rangers, as well as community social development programmes, livelihood support work and environmental education campaigns. Several management interventions are linked to the Parks' carbon accreditation under a Reducing Emissions from Deforestation and Forest Degradation plus (REDD+) scheme and aim to ensure positive social and ecological impacts across 122 villages within a 'leakage belt' around the park boundary (RSPB, 2015; see Fig. 1). The leakage belt is a 4 Km zone around the protected area, in which forest quality and cover is maintained under the REDD+ scheme, to ensure that harmful activities are not merely displaced from the park into the neighbouring forest. Key interventions include direct payments to landowning families and paramount chiefs (Voors et al., 2011), livelihood support projects to promote sustainable land-use, saving and lending schemes, scholarship programmes and a community development fund for chiefdoms around the park edge (RSPB, 2015). Other work

includes environmental education and a 'species champion' programme (Hillers et al., 2017). Livelihood support programmes focus on agricultural training, and there is an extensive programme to improve incomes from 'forest-friendly' cocoa.

Immediately south of the study site is Liberia's Gola Forest National Park which covers about 790 km² and joins the GRNP to form a transboundary 'peace park'. The Gola Forest National Park was formally gazetted in 2016. However, active conservation work in the area dates from 2009, when the governments of Liberia and Sierra Leone formally agreed the establishment of the peace park (Hillers, 2013). From 2009 to 2013, ecological surveys, livelihood support projects and environmental awareness-raising activities were carried out by the Royal Society for the Protection of Birds and the Society for the Conservation of Nature of Liberia through the project 'Across the River—a Transboundary Peace Park for Sierra Leone and Liberia' (Hillers, 2013). Twenty-five Liberian park rangers were trained during the transboundary project and deployed at a park headquarters. From about 2012 rangers conducted irregular law enforcement patrols in the proposed protected area, and confiscated bushmeat at a road-block being transported to Monrovia. This roadblock is situated on the only vehicle road from the study site to Monrovia, and bushmeat is confiscated regardless of whether it was killed within the protected area, in accordance with regulations prohibiting commercial transportation of more than five carcasses per vehicle. Both patrolling effort and vehicle inspections increased substantially during the present study following the park's gazettement (in 2016) and subsequent boundary demarcation in 2017 (*pers. obs.*).

The transboundary project implemented livelihood support activities intended to reduce pressure on forest resources, principally a swamp-rice farming programme and livestock-rearing, which involved some of the participants in the present study (Hillers, 2013). Livestock rearing of goats was explicitly intended to provide an alternative to bushmeat both in terms of income and as a protein source. However, anecdotal evidence suggested the approach achieved limited success, as very few participants continued to rear livestock after the project end (*pers obs*). Apparent reasons for this included that the livestock were reported to cause nuisance by eating crops, or that they became sick. Some commentators added that people weren't 'serious' to pursue this livelihood, or didn't 'believe' in livestock raising, suggesting that people preferred to invest time and money in activities for which the risks and returns were already known and familiar. Nevertheless, a few individuals that were fully engaged in the activity were able to generate and sustain profits (*pers. obs*).

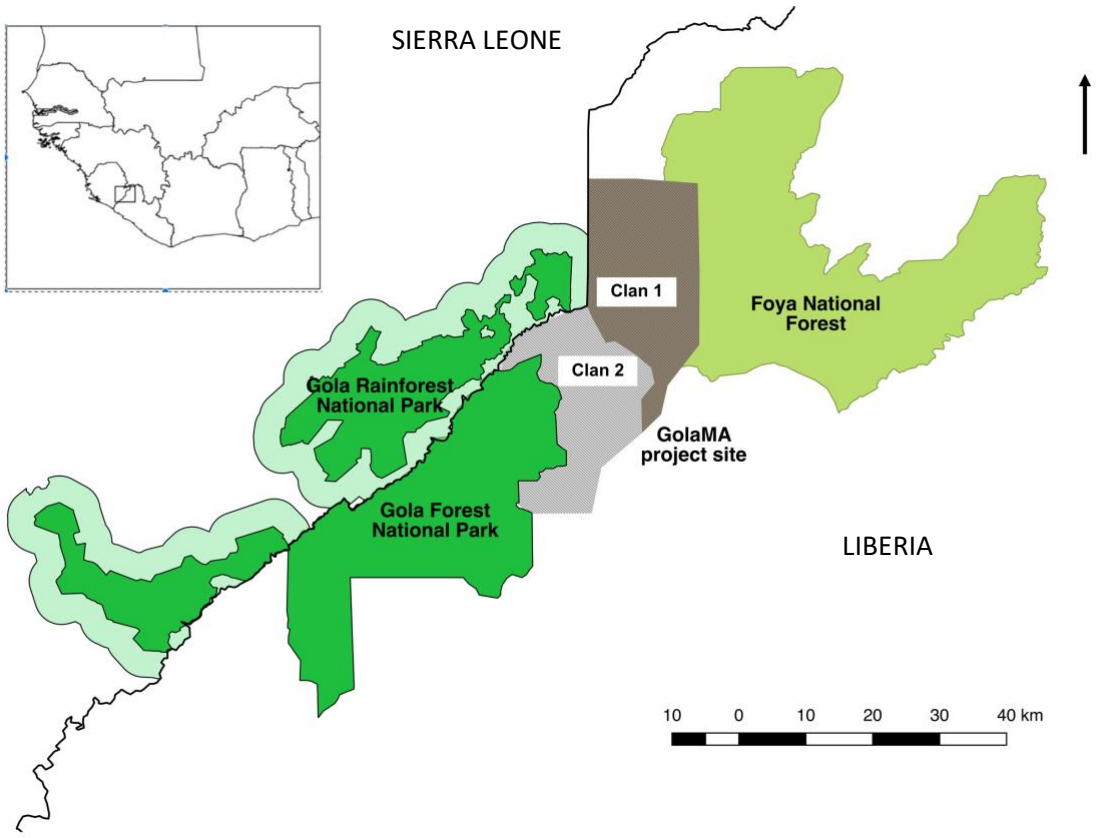

Figure 1. Map showing the GolaMA project site and adjacent protected areas: the Gola Rainforest National Park (GRNP) in Sierra Leone and the Gola Forest National Park in Liberia. The 4Km buffer ('leakage belt') around the GRNP boundary is shown in paler green, indicating the area in which livelihood support work is implemented. Inset shows the location of the study site in West Africa.

Surveys conducted under the transboundary project around the proposed Gola Forest National Park in 2012, revealed communities to be highly dependent on bushmeat and other forest resources for livelihoods (Bulte et al., 2012). Results from 27 forest edge villages (10 of which are included in the present study) showed that many forest-edge villages were extremely remote and lacked access to infrastructure such as roads and healthcare. There was a large number of very small, often temporary, settlements, linked to small-scale mining activities. Lasting socio-demographic effects of civil conflicts in Liberia and Sierra Leone were apparent in the weakening of traditional governance structures, particularly the 'stranger-father' system which traditionally demands that non-locals must seek a local sponsor to access land or extract resources such as wildlife (Corriveau-Bourque, 2010). The authors also noted high levels of suspicion and mistrust towards conservation and protected area management (Bulte et al., 2012).

Table 2 Livelihood activities of adults within the two clans participating in the GolaMA project, adapted from the 2015-16 GolaMA baseline socio-economic survey (GolaMA, *unpublished*). Values are % of adults (over 16 years) for whom the activity was reported as the most or second-most important occupation in terms of time or income.

		Number of individuals interviewed	Number of house-holds	Most important occupation in terms of time	Second most important occupation in terms of time	Most important occupation in terms of income	Second most important occupation in terms of income
Clan 1	Men	306	212	**Rice farmer (53%)** Plantation crops (10%) Mining broker (9%) *[No answer 2%]*	**Rice farmer (23%)** Plantation crops (13%) Garden (10%) *[No answer 25%]*	**Rice farmer (28%)** Plantation crops (23%) Mining broker (11%) *[No answer 5%]*	**Rice farmer (28%)** Garden (11%) Plantation crops (7%) *[No answer 29%]*
	Women	291	210	**Rice farmer (51%)** Garden (22%) Business / trade (17%) *[No answer 2%]*	**Rice farmer (26%)** Garden (24%) Business / trade (13%) *[No answer 30%]*	**Garden (30%)** Rice farmer (29%) Business / trade (25%) *[No answer 9%]*	**Rice farmer (34%)** Garden (14%) Business / trade (8%) *[No answer 41%]*
Clan 2	Men	355	205	**Rice farmer (27%)** Mining digger (24%) Student (9%) *[No answer 1%]*	**Rice farmer (18%)** Garden (13%) Business / trade (9%) *[No answer 36%]*	**Mining digger (25%)** Rice farmer (14%) Business / trade (10%) *[No answer 10%]*	**Rice farmer (22%)** Garden (9%) Business / trade (8%) *[No answer 43%]*
	Women	234	167	**Business / trade (33%)** Rice farmer (31%) Garden (15%) *[No answer 1%]*	**Garden (21%)** Rice farmer (18%) Business / trade (18%) *[No answer 33%]*	**Business / trade (42%)** Garden (23%) Rice farmer (15%) *[No answer 11%]*	**Rice farmer (24%)** Garden (15%) Business / trade (11%) *[No answer 47%]*
Both clans	Men	661	417	**Rice farmer (39%)** Mining digger (13%) Other trade (7%) *[No answer 2%]*	**Rice farmer (20%)** Garden (11%) Plantation crops (7%) *[No answer 31%]*	**Rice farmer (21%)** Mining digger (14%) Plantation crops (12%) *[No answer 8%]*	**Rice farmer (25%)** Garden (10%) Business / trade (6%) *[No answer 37%]*
	Women	525	377	**Rice farmer (42%)** Business / trade (24%) Garden (19%) *[No answer 2%]*	**Garden (23%)** Rice farmer (23%) Business / trade (15%) *[No answer 31%]*	**Business / trade (32%)** Garden (26%) Rice farmer (23%) *[No answer 10%]*	**Rice farmer (29%)** Garden (14%) Business / trade (9%) *[No answer 44%]*

Species conservation in the study site

The forest in and around the study site supports a full diversity of lowland forest species found in the upper Guinea forest biome (Lindsell *et al.* 2011, Tweh *et al.* 2015), and as such, hunting is a concern for populations of several endangered species. These include the Pygmy Hippopotamus (*Choeropsis liberiensis*) and Jentink's duiker (*Cephalophus jentinkii*), both classified as endangered, and the zebra duiker (*C. zebra*) and forest elephant (*Loxodonta cyclotis*) which are listed by the IUCN as vulnerable. There are eight species of diurnal primate found in the study site, all of which are hunted and many of which have rapidly declining global populations. These include the critically endangered Western Chimpanzee (*Pan troglodytes verus*), four endangered monkey species and two that are vulnerable. Comparisons of primate densities between the study site and Gola Rainforest National Park, show the latter has higher densities of threatened monkeys, notably Western red colobus (*Piliocolobus badius*) and Diana monkey (*Cercopithecus diana*) (Blasi-Foglietti, 2020). As the areas are adjacent with similar habitats but differing levels of hunting pressure, this discrepancy likely points to the impacts of hunting (Blasi-Foglietti, 2020). Other threatened species that are vulnerable to hunting include three pangolin species, as well as the critically endangered slender-snouted dwarf crocodile (*Mecistops cataphractus*).

In this study, I focus on hunting for bushmeat, which constitutes the vast majority of hunting activity within the study site. However, markets for other animal products can lead to targeting of particular high value species. Notably, pangolins have recently been exposed to increasingly targeted persecution at the study site, due to the influence of international pangolin scale traffickers (*pers. obs*). Products such as leopards' teeth, crocodile skin, and chimpanzee body parts are also reported to fetch high prices locally (*pers obs*). Elephants are targeted for ivory, but unlike other species, elephants are not likely to be killed opportunistically, but rather only by specialised elephant hunters due to fire-power and skills required. Additionally, due to the high value of ivory, there is more rigorous law enforcement with respect to elephants, evidenced by the recent prosecution in 2019 of an elephant hunter (africanelephantjournal.com).

All of the above-mentioned species are formally protected under Liberian law. However, many hunters in the study site are unaware of the protected status of species (GolaMA, unpublished), with the likely exception of forest elephants, and hunting methods such as snares are often largely indiscriminate. As such, there is no evidence that hunters' prey selection is substantially influenced by whether or not a species is protected. There are also several bushmeat species that are not currently endangered and are not listed as nationally protected. These include species that have relatively widespread distributions, such as the Maxwell's duiker (*Philantomba maxwelli*), as well as

species that are tolerant (or even pests) of agricultural habitats such as the greater cane rat (*Thryonomys swinderianus*) and bushbuck (*Tragelaphus scriptus*). In the study site, it was prohibited to transport over five carcasses in a single vehicle, and confiscation at checkpoints was the only form of enforcement of hunting laws that applied to hunters operating outside protected area boundaries. As such, hunters could expect the same penalties whether or not species were formally protected, with the exception of ivory confiscation, reducing incentives to avoid killing protected animals.

The GolaMA project

The GolaMA project was Funded by the European Union, under the full title "Ensuring Liberian forest connectivity through community-based management and innovative financing mechanisms", and it ran from December 2013 to December 2019. GolaMA stands for 'Gola Management Agreement' and is a word in the Lorma language meaning 'unity'. The project was implemented by the Royal Society for the Protection of Birds and the Society for the Conservation of Nature of Liberia, building on relationships that had been established with communities during previous work under the project, 'Across the River – a transboundary peace park for Liberia and Sierra Leone'. The GolaMA project aimed to secure conservation of forest area that connects with the northern sectors of protected areas in Liberia and Sierra Leone (Fig 1), using a framework of community-based natural resource management. Due to the outbreak of Ebola virus in the region, field activities were delayed from the project start until March 2015.

The GolaMA project worked with 16 villages belonging to two clans, in Kongba district, encompassing approximately 430 households. Activities focussed on supporting each of the two participating clans to establish 'community forests', under Liberia's Community Forest Rights Law (2009). These community forests would be managed based on conservation land use plans approved by the government's Forestry Development Authority, and revised every five years. The final agreement of community forest management plans took place after the completion of this study, in November 2019. This saw each clan create hunting regulations which will be implemented by community 'eco-guards' (GolaMA end of project report, in prep).

In addition to the goal of sustainable forest resource management, GolaMA aimed to contribute positively to local livelihoods and socio-economic development. The project implemented several types of livelihood support programmes from 2015 to 2019, which included the introduction of bee-keeping, agricultural training programmes, a small loans scheme, and adult literacy classes. Agricultural support included a programme to develop swamp farming techniques for crops such as

rice, a programme to improve yields from cocoa through farmer training schemes and provision of high yielding cocoa seed, and support for farmer collectives through the provision of seeds for crops such as peanuts and beans. The small loans scheme offered local residents (organised into loan groups) access to credit for which interest was partly paid through contributing time or labour to conservation action such as conducting environmental education campaigns. Members of loan groups were not required to specify the purposes for which loans would be used, but loan groups signed a memorandum of understanding that none of their members would use loans for activities relating to hunting or trading wildlife. Livelihood support programmes were typically implemented gradually, with 'trial' phases during which the activity was carried out on a small-scale to identify any issues before full-scale implementation began (Fig 2). The project also sought to improve incomes from small-scale mining, the environmental impacts of which are considered limited at the GolaMA site and held discussions with local miners around interventions such as provision of equipment for local mining groups alongside improvements to mining methods intended limit ecological degradation from digging of mining pits. Participation in all the above programmes was accompanied by formal agreements to refrain from hunting or trading of bushmeat.

Methods

Rationale for the survey design

Data collection for this study was designed with the dual aim of exploring research questions outlined in Chapter 1 and supporting implementation of the GolaMA project. Thus, survey methodology aimed to achieve the following:

1) develop understanding of the bushmeat system from the perspectives of hunters and traders: with a focus on the livelihood role of bushmeat hunting and trading and peoples' incentives or disincentives.
2) develop understanding of which species were affected by hunting and approximate levels of harvest.
3) gain insights into who was engaged in hunting and trading, their livelihood profiles and variability in levels of resource use to help identify the target group(s) for project interventions.
4) evaluate the prevalence of hunting and trading among households at the start and end of the project.
5) develop tools that might be suitable for post-project monitoring of hunting and trading by community forest management bodies.

Additional key considerations were minimisation of survey costs such as travel to remote villages and the risks of respondent fatigue.

To fulfil the above criteria, three questionnaire-based surveys were developed, a household survey, a hunter survey and a trader survey, as well as a village-based offtake survey to record hunters catch (Table 3). Focus group discussions were also carried out with hunters and traders to give broader context about these activities (see Chapter 3). Questionnaires delivered information for more than one purpose and were as short as possible to minimise the risk of respondent fatigue.

Table 3 Overview of data collected, sample sizes and estimated percentage of the total study site populations, the thesis chapters in which each dataset was used.

Survey	Chapter	Sample size (estimated % of population)	Brief description
Hunter survey	3,4,6	n=205 hunters (>90%)	Face-to-face questionnaire administered to hunters, eliciting information about livelihood activities, hunting behaviour and details of most recent hunting trip in terms of numbers and species killed
Trader survey	3	n=50 traders (>60%)	Face-to-face questionnaire administered to bushmeat traders, eliciting information about livelihood activities, trading behaviour and details of most recent trading transaction
Household survey	4,5	Start of project: n=480 (>90%) End of project: n=524 (>90%)	Face-to-face questionnaire administered to households at the start and end of GolaMA project interventions, eliciting information about household demographics and involvement in livelihoods, including bushmeat hunting and trading. The bean method was implemented along with direct questions (see Chapter 5).
Village-based recording of hunters' catch	6	n=50 hunters (<25%)	Village-based assistants recorded details of hunting trips of participating hunters, over continuous monitoring periods of several weeks. Only trip duration and species killed were recorded.

The household survey provided livelihood descriptions of hunting and trading households versus non-hunting or trading households, assessed change in prevalence in hunting and trading at the start and end of the project, and explored the bean method as a tool for monitoring these behaviours. The hunter survey explored the livelihood and demographic profiles of hunters, economic incentives and disincentives, key aspects of hunter-trader relationships, the range of species killed and harvest estimates. The trader survey explored livelihood and demographic profiles of bushmeat traders, economic incentives and disincentives for traders, key aspects of hunter-trader relationships, and the range of species sold along different trade routes. Village-based recording of hunters' catch was

designed to allow a comparative interpretation of harvest estimates from the hunter survey, and to trial this approach as a potential tool for community-based monitoring.

Sampling strategy

This research represents a case-study and the datasets are not intended to be representative of wider populations. Surveys were conducted across all villages, households, hunters and resident traders across a continuous geographic area, referred to as the study site, with sampling effort aiming to achieve universal sampling (i.e. 100% of the population). Chapter 6 gives more detailed discussion of potential sampling biases where universal sampling was not possible.

Villages included in the study

For the purposes of this study, I use the terms 'village' or 'town' interchangeably to refer to any permanent settlement with a town chief. Unless otherwise specified, any smaller semi-permanent 'camps' that fall under a village jurisdiction are considered part of the village. 'Settlement' is used to refer to any place inhabited by people on a permanent or semi-permanent basis (i.e. villages or camps). Clan 1 and clan 2 refer to the two clans that participated the GolaMA project (in chapter 5 these are referred to as Group 1 and Group 2 following a reviewers' recommendation).

All villages belonging to the two clans that participated in the GolaMA project were included in the study (Table 4). Only one village that belonged to clan 2 was not included in all surveys. This village initially chose not to participate in the GolaMA project, and subsequently joined after most data collection had already taken place. It was therefore only included as part of a small-scale study described in Chapter 5. The underlying reasons that clan 1 and clan 2 were selected to participate in the GolaMA project was because they had customary use of high conservation value forest adjacent to existing protected areas, and due to previously established relationships with the Society for the Conservation of Nature of Liberia, the organisation that implemented the GolaMA project.

In addition to the GolaMA project villages, four villages that did not participate in the GolaMA project were included in the study. The purpose of this inclusion was (1) to increase the sample sizes for datasets describing hunting and trading behaviour and (2) to enable interpretation of trends in hunting or trading prevalence with reference to a group which did not receive conservation project interventions. This study was not designed as an experimental impact evaluation of the GolaMA project so non-project villages are not intended to be 'control' villages but are used to allow qualitative comparisons with project households. Non-project villages were selected as the closest, geographically, to the GolaMA project villages, such that the survey covered all villages within a

continuous geographic area. Additional selection criteria were that non-project villages should share forest boundaries and use the same road network as non-project villages to access major urban centres such as Monrovia. These criteria aimed to ensure non-project villages had similar resource-use and livelihood characteristics as non-project villages, would experience similar environmental and socio-political influences that were not related the GolaMA project, and that data collection would be achievable under the practical constraint of travel time and costs.

Table 4 Villages included in the study, and sample sizes based on complete sampling approach in which all households and all identified hunters and traders were included in the survey, unless otherwise stated.

settlement type	vehicle access in dry season[a]	number of households (2017 survey)	number of households (2019 survey)	hunter survey sample size	trader survey sample size	village-based offtake survey
Non-project clans						
village	car	14 (data not used)[b]	not surveyed	0	0	
village	motorbike	19	13	11	1	
village	car	48	64	11	8	
village	motorbike	76[c]	98	28	5	
Clan 1						
village	motorbike	12	8	17	4	
village	none	12	11	14	1	yes
village	motorbike	14	11	5	0	
village	none	17	18	3	not surveyed	
village	motorbike	20	19	11	1	yes
village	motorbike	20	19	11	2	
village	none	31	31	22	0	yes
village	motorbike	74	64	23	6	yes
Clan 2						
camp	none	1	0	10	not surveyed	
camp	car	2	3	0	not surveyed	
village	car	2	5	0	0	
village	car	4	5	3	0	
village	car	7	7	8	3	yes
village	car	10	10	5	0	
village	car	111	138	28	19	yes
village	car	not surveyed	69	not surveyed	not surveyed	

[a] *During the rainy season vehicle access was limited to motorbikes only, with only occasional accessibility for cars*
[b] *Data were not used as all households in the village were those of National Park Staff (see main text)*
[c] *Complete sampling of households was not achieved, estimated to be 60-70% of total*

Demographic variables recorded during the household survey indicated that socio-demographic variables (household sizes, literacy levels, tribal identities) were similar across non-project villages as project villages with only one outlier which was dropped from analyses. This village had been designated as the operational base for the Gola Forest National Park and consequently, all households belonged to park rangers whose livelihoods were not representative of those across other villages. The villages in the study included those on historic sites as well as villages with more recent origins as mining, logging or hunting camps (GolaMA, unpublished).

For some aspects of the study, a complete-sampling approach was not possible (Table 4). The trader survey was conducted in a sub-sample of ten villages: villages or camps were not included due to their small size and inaccessibility (two camps), because no traders were identified or encountered (six villages) or due to time constraints (two villages). The village-based offtake survey was conducted in six villages, largely due to practical constraints (see Chapter 6 for details).

Households, hunters and traders

The household survey encompassed all households in all villages, where a household was defined as a group of people who habitually 'eat from the same pot'. Hunters and traders were identified from a previous household survey conducted by GolaMA in 2015 (GolaMA, unpublished), from group meetings with hunters and chief hunters, from snowball sampling, and from the interviewers' own personal knowledge of the people in each village. Due to the personal familiarity of the research team with the study site it is considered likely that the overwhelming majority hunters and traders were identified with these methods. In particular, information from chief hunters is likely to be comprehensive as these individuals are responsible for allowing and regulating all hunting activity. Research technicians had a good relationship with chief hunters, who would have had little incentive to conceal identities of hunters. Thus, the team identified only eight hunters who either declined to participate or who could not be located during the study. The 205 hunter participants are estimated to represent over 95% of all hunters.

The sampling of traders may have been less comprehensive, and it is estimated that at least 60-70% of residents who sold bushmeat were identified. Research technicians who identified traders were themselves ex-bushmeat traders and so had direct access to the local trader network in clan 2, but were less familiar with traders in clan 1, and relied on traders self-identifying or being identified by others through snowball sampling. The survey methods excluded any people who were not resident in study site villages. As discussed in Chapter 3, a potentially significant proportion of bushmeat traders may have been non-residents and therefore were not included. Possible types of sampling

bias associated with village-based monitoring and the hunter survey are discussed in detail in Chapter 6.

The research team

The data collection was carried out by a team of six research technicians who were all either locally born citizens or who had been living in the study site for several years prior to the study. The research technicians were therefore familiar with the study site and would have been known personally or by indirect family associations, to many of the participants. Research technicians were of the opinion that their existing relationships would be likely to promote more truthful reporting, as respondents would have felt that falsehoods would be easily detected.

This team included four research technicians who were employed by the GolaMA project (all male) to carry out a range of social and ecological surveys, and two additional research technicians (both female) who were recruited from the town in which the GolaMA project had a field office. The latter were not involved in the hunter survey interviews or village offtake study. Recruitment was based on people's literacy and availability. In some instances, data collection was assisted by additional GolaMA staff members. The hunter and trader focus group discussions were facilitated respectively by a male and female GolaMA staff, who each had experience in focus group facilitation and were also local residents in the study site. In two larger villages, data collection for the household survey in 2017 was assisted by a female GolaMA volunteer, who joined the team to ensure there was at least one female interviewer in each 2-person interviewer team.

All those involved in collecting data were trained in the methods and ethical procedures and underwent regular refresher training and de-briefing sessions. Research technicians were fluent in a range of local dialects, and interviewer-pairs were arranged to ensure that at least one member spoke the tribal languages of participants in each area. Where appropriate, interviewers translated the questionnaire for respondents and recorded answers in English. Many participants preferred to use English, but preferences for the indigenous languages of Mende or Gola were also common. Pre-survey training included exercises in which questionnaires were translated by research technicians, and back translated by someone who had not heard the original version.

Research technicians resided in a village where the GolaMA field office was located (this village was also part of the study) and travelled to other villages to conduct surveys in teams of two or more. Typically, research technicians would spend two or three days in each village, depending on the number and availability of survey participants, then proceed to the next-nearest village. The GolaMA research technicians were also responsible for collection of ecological survey data throughout the

study period. This meant they regularly visited study villages and were able to collect some data for hunter and trader surveys opportunistically during such visits, i.e. whenever hunters or traders were encountered.

Timing of data collection

The timing of surveys was determined largely by practical considerations: most data collection took place during the dry season when villages were easier to access (Oct-July), was fit around ecological surveys being carried out concurrently by the research team and avoided peak agricultural periods such as harvests (Fig 2). I was in the field throughout most of the data collection period, but was in the UK in Sep 2016, from Sep to Aug 2018, and after July 2019.

Ethics

Free, prior informed consent was obtained from all study participants, and from the local authorities at the level of villages and clans. Introductory public meetings were held in all study villages prior to data collection. Meetings were attended by village leaders, who included the women, youth and hunter representatives, and were facilitated by GolaMA project staff. At these meetings GolaMA staff explained the purpose of GolaMA project (this had also been described in separate meetings previously), and the overall aim of the research. The latter was described as being to learn about peoples' livelihoods, wildlife use and specifically the hunting and trading of bushmeat. It was explained that anyone would be free to take part, or to choose not to participate, and that this decision would have no consequences for the individuals or for the communities as a whole. It was emphasised that people's free choice to participate in the research would not affect any of the GolaMA project activities, or their eligibility to be involved in those. People at the meetings were informed that all data would be confidential; that results would be presented in reports that could be read by government bodies and the wider public; that participants could withdraw consent to participate at any point by telling any researcher or GolaMA staff member; and that survey results would be shared with participants in meetings after the study's completion. It was explained that participants would not receive any payment for participation. All participants in questionnaire surveys were similarly provided with this information. Results of the household, hunter and trader survey data collected at the start of the project were shared with community members by GolaMA staff in April 2017 during visits to villages. A printout summarising the main findings at the clan level was used by staff as a basis to discuss the results at a meeting, and this was publicly posted in each village. Findings were discussed in more detail in separate meetings of key stakeholders, including the clan chiefs and GolaMA project managers in 2019 (GolaMA in prep).

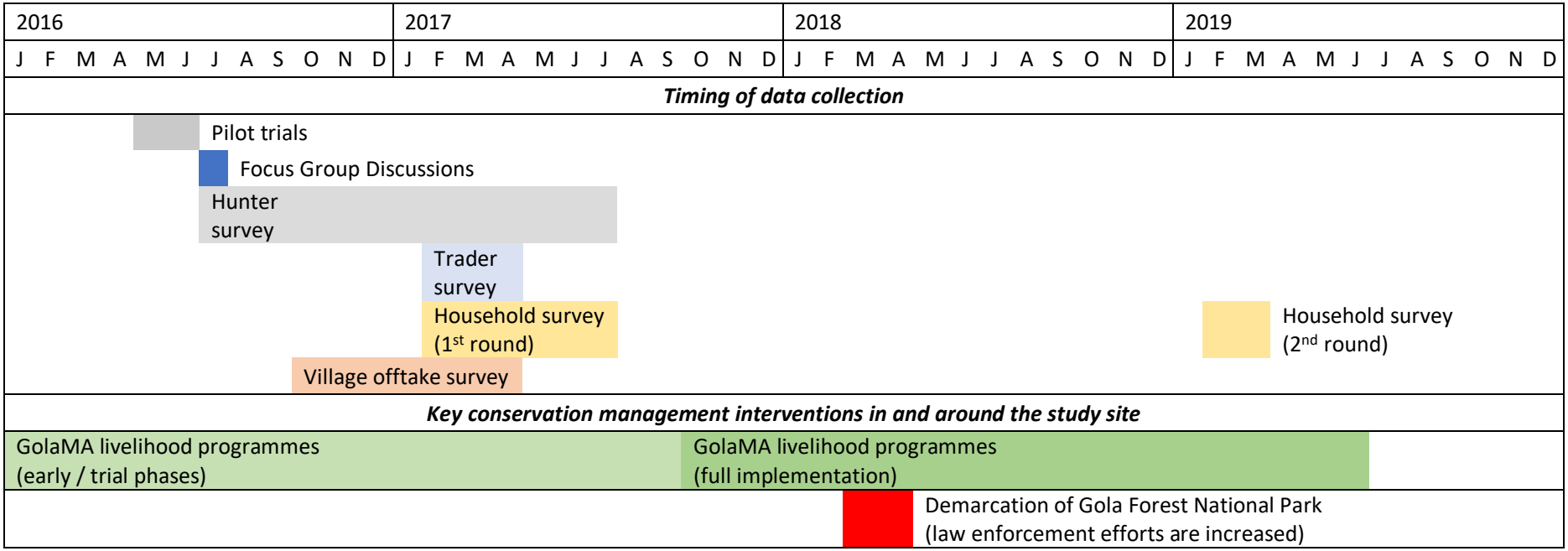

Figure 2. Timing of data collection and of conservation interventions at the study site. GolaMA livelihood programmes consisted of training and equipment to support income from bee-keeping, perennial crop agriculture (peanuts, beans), swamp farming techniques, cocoa farming. A small loans scheme and an adult literacy evening class were also provided. In the early / trial phase, schemes were rolled out on a smaller scale than in the full implementation stages, being offered primarily only to selected groups of participants. For example, during trial phases bee-keeping groups were limited to approximately 15 persons; perennial crop agriculture was offered to specific village groups; the small loans scheme was only available to womens' loans groups and maximum loans were initially limited; cocoa training was only available to those with cocoa farms and evening literacy classes were not yet offered. In the full implementation phases, bee-keeping was expanded as carpenters were trained to produce bee-hives locally and these were bought by the project for bee-keepers, agricultural demonstration plots were established in all villages and training was offered to more participants, small loans schemes were available to any type of loans group and maximum loans were higher, cocoa farmer training was offered to anyone and some participants were trained as farmer-teachers, and adult literacy classes were provided in larger villages.

Trial of survey formats

Informal conversations with hunters and non-hunters during the 18 months prior to the start of the research, indicated that people felt comfortable discussing all aspects of their own and others' hunting and bushmeat trading activities. This impression was supported by a household survey conducted by the GolaMA project in 2015 in which people readily identified themselves as hunters or bushmeat traders and shared information about these activities (GolaMA, unpublished). Therefore, it was considered appropriate to use face-to-face interviews to obtain information from hunters and traders.

While people were evidently comfortable discussing hunting and bushmeat trading, it was assumed that responses might be susceptible to some level of social desirability bias given that most hunting and trading practices were illegal. It was anticipated that these activities would be more susceptivle to mis-reporting following GolaMA project interventions, for example, once people had signed agreements with the project stating they would refrain from hunting or trading as a condition of participation in livelihood support programmes. Therefore, in order to measure prevalence of hunting and trading at the end of the project, it was considered appropriate to use specialised methods that aim to minimise misreporting of sensitive behaviour by preserving respondents' anonymity. A short pilot trial was conducted to compare different approaches in terms of how straightforward they were to implement and how they would be received by respondents.

A trial of the randomised response technique (RRT) and unmatched count technique (UCT) was conducted as part of the hunter survey (described above). These techniques were used to explore killing of high profile protected species: a topic that was potentially more sensitive than other hunting behaviours, since some hunters were aware of its illegality, and GolaMA activities included raising awareness of the protected species laws. The RRT questions were administered at the end of the hunter survey questionnaire to the first 108 hunters who were approached for the survey, covering 13 villages. A UCT question was also administered to 95 hunters from this group. For the remaining surveys, administered to 142 hunters, questions about killing protected species were asked directly. Because some hunters were interviewed on more than one ocassion, 45 hunters responded both to RRT/UCT and subsequently to the direct questions.

The RRT was used to ask hunters four questions about whether, in the previous 10 years, they had killed any of four species. Chimpanzee (*Pan troglodytes*), Forest Elephant (*Loxodonta cyclotis*), Pygmy Hippopotamus (*Choeropsis liberiensis*) and Bongo (*Tragelaphus eurycerus*) were chosen as species that were high priorities for conservation efforts with protected status that was relatively widely publicised in Liberia.

The RRT method was implemented using a bag with 6 coloured balls: 2 red, 2 blue, 2 white. Respondents were instructed to draw 2 balls from the bag, without revealing their colours to the interviewer, and to answer 'yes' to the question if they had 2 red balls, 'no' if they had 2 white balls, or truthfully for any other colour combination. Dummy questions were used to demonstrate the answering format. Estimates of true prevalence were calculated as proportion of observed 'yes' responses minus the probability of a 'forced' yes (i.e. 1/9), divided by the probability of a truthful answer (i.e. 7/9) (Table 5; Nuno and St John, 2015).

The UCT was applied to ask about killing of chimpanzees (*Pan trogolodytes verus*) in the previous 10 years. Chimpanzees were selected since this species was thought to be killed more frequently than the others. Respondents were shown a sheet with pictures of four other bushmeat species, two of which were known to be commonly killed (a duiker and porcupine) and two of which were considered to be rarely killed (leopard and crocodile). Half of the picture-sheets also showed a chimpanzee. Respondents were instructed to state how many of the animals shown they had killed in the previous 10 years. Treatment was randomised between respondents, such that n=38 hunters were shown the version that included a chimpanzee and n=43 the version without. Estimated prevalence was calculated as the difference in the means of the two groups (Table 5).

Table 5. Reported prevalence of killing high-profile protected species in the previous 10 years by hunters, obtained from a trial implementation of the randomised response technique, unmatched count technique and direct questions.

In the last 10 years, have you...	Randomised Response Technique (n=108)	Direct question (n=142)	Unmatched Count Technique (n=81)
killed any chimpanzee	56%	27%	40%
killed any pygmy hippopotamus	2%	11%	-
killed any bongo	19%	19%	-
killed any elephants	0%	0.1%	-

Correlations between responses given to UCT and the RRT question about killing of chimpanzees were explored using a 'quasi-poisson' generalised linear model with poisson errors and a dispersion parameter to allow for over-dispersion. The UCT response was modelled as a function of the RRT response and the treatment group, including interaction term. Results indicated that estimates of chimpanzee killing based on UCT did not correlate with RRT responses (estimated RRT effect =0.02, estimate S.E. = 0.05, p=0.6, n=81).

In the direct questioning format, hunters were asked how many of each of the species they had killed in the previous 10 years, rather than whether or not they had done so. This phrasing was used

as it was considered more permissive: i.e. it implies the interviewer expects hunters to have killed at least one of each species. Eliciting numeric answers also provided information about frequency which was lacking from RRT/UCT method. Comparison between the direct responses and the RRT and UCT methods are shown in Table 5. For chimpanzee killing, a smaller proportion of respondents reported the behaviour directly compared to RRT, but the reverse was true for pygmy hippopotamus and elephant. The difference in chimpanzee prevalence estimates could indicate that this activity was under-reported and potentially sensitive. However, this interpretation may not hold for several reasons. The sample of hunters who responded to the RRT format may not be comparable to the direct question sample. This is the RRT was administered adhoc to the first hunters to be identified and surveyed, while the direct questions were administered to hunters who were identified later in the study. The most readily identified hunters would likely be those for whom hunting forms a main component of their social identity, who are also more likely to own guns, have been hunting for a long time, and have had opportunities to kill chimpanzees. It was also noted that several respondents (n=11, 8%) in the direct question sample volunteered the information that they had killed chimpanzees in the past, but it had been longer than 10 years ago. The RRT does not allow for this nuanced response, so hunters who had killed the species, but over 10 years ago, may have responded with 'yes'.

Feedback from interviewers indicated that respondents found the both the RRT and UCT methods confusing and both were time-consuming to explain and demonstrate. The UCT format of giving a numeric response without identifying which species had been killed, was particularly counter-intuitive for respondents. Throughout the study, interviewers had the impression that most hunters were comfortable reporting answers openly, suggesting that the level of sensitivity was not high enough to warrant the time needed to implement these methods. Nevertheless, both methods could likely have been improved: for instance with thorough pre-testing of items for the UCT (Hinsley *et al.* 2017).

The bean method was seen as a potentially more straightforward approach than RRT or UCT (Lau *et al.* 2013; Chapter 5). To explore this assumption, randomly chosen individuals from a nearby non-study village, were shown the RRT approach described above and the bean method (see Chapter 5). Interviewers demonstrated the methods with examples of sensitive questions (e.g. have you ever stolen something) and elicited answers to bushmeat hunting and trading questions using both methods. Respondents were then asked which methods they had found easy or difficult to understand and which they felt best ensured their answers could not be determined by the interviewer, and the reasons for their answers. Respondents unanimously reported that the bean method was easiest to understand, and approximately 50% considered it the more 'secretive'

method (the trial was conducted with approximately 20 respondents, but unfortunately the data have not been kept so exact numbers cannot be presented). Feedback from interviewers indicated the bean method was straightforward and fast to administer. Based on this trial, the bean method was considered to be an appropriate technique that could be a useful tool to measure potentially sensitive behaviours.

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Chapter 4. Audience segmentation to improve targeting of conservation interventions for hunters

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Chapter 5. The bean method as a tool to measure sensitive behaviour

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Chapter 6. Consequences of survey method for estimating hunters' harvest rates

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(30 pages)

Chapter 7. Discussion

The work in this thesis focusses on understanding the diversity of resource users in a remote forest edge region of Liberia and then applying tools from social sciences to target behaviour change efforts more effectively . I aimed to describe a hunting system in Liberia and to advance conservation practices in three key areas. First, I aimed to gain an understanding of hunting and trading behaviour in the context of social relationships and financial incentives. Second, I explored tools to improve interventions aiming to reduce hunting by differentiating potential target groups and, third, I examined ways to measure resource-use behaviour that can account for potential biases, yet remain straightforward to implement.

To build an understanding of the hunting system, I found valuable insights were gained by considering the social context of behaviour, which revealed that inter-personal relationships were influential and that different incentives operated for hunters and traders (Chapter 3). While some traders were influenced by confiscation of meat at roadblocks, hunters cited time demands of agricultural activities as an important constraint on hunting. Such findings suggested that designing different interventions to be targeted toward each of these groups may improve outcomes.

The value of better-targeted interventions was further supported by results of 'audience segmentation' (Chapter 4), a marketing approach to differentiate groups across multiple traits, such as socio-demographic and behavioural characteristics (Albrecht, 1996). Audience segmentation identified distinct patterns in livelihoods and hunting behaviour with implications for how interventions might be better targeted toward different groups of hunters. For instance, training to improve yields from cocoa was identified as an appropriate approach for the group characterised as "local trappers". However, such an intervention could be less effective in reducing hunting among the "non-local gun-hunter" group, since very few gained income from cocoa farming.

To monitor changes in behaviour, I demonstrated the potential value of the bean method (Lau et al., 2011) in addressing the problem that sensitive or illicit activities may often be under-reported (Chapter 5). This technique provided evidence that trading behaviour had decreased over a 2-year period, a finding which was supported by local anecdotal reports. I further explored ways to improve understanding of resource-use patterns by examining the quality of data used to describe harvest rates (Chapter 6). Harvest data can underpin resource management decisions and is often used in monitoring, as well as being fundamental for defining target groups for the project to engage with. Comparing two harvest data survey methods, I found that results differed substantially due to issues such as non-random sampling of hunters and reporting error. This finding showed that

understanding the range of hunters' behavioural profiles could improve survey designs, and that harvest estimates require cautious interpretation in hunting studies.

Taken together, my results show there are valuable opportunities to improve design of conservation interventions by focussing more on who they are aimed at, and how to accurately measure and monitor people's behaviour. Tools from the social sciences, including marketing, can be adapted for site-based conservation management and are a valuable resource for conservationists seeking to improve behaviour change outcomes. In the following discussion, I first consider the local implications of my findings for the GolaMA project site, in terms of 1) opportunities to improve intervention designs, and 2) appropriate tools to monitor hunting and trading behaviour which address data quality issues. I then discuss the wider implications of our work for conservation practice, in terms of understanding, influencing and monitoring resource-use behaviour.

Implications for conservation at the GolaMA site

This study is the first to describe a rural hunting system in Liberia. The system shares many similarities to hunting systems from across West and Central Africa, for example, that traders are mainly women, in the diversity of harvested species, and in the high variability between hunters in terms of effort and hunting income (e.g. Bachmann et al., 2019; Coad et al., 2010; Foerster et al., 2012; Kumpel, 2006). The main conservation strategies applied across the Gola Forest, such as protected areas, law enforcement and livelihood-support interventions (Chapter 2) are also widely used elsewhere (e.g. Brooks et al., 2013; Cronin et al., 2017; Tranquilli et al., 2014). The GolaMA site is, however, within one of the largest forest tracts remaining in the upper Guinea Forest biome (Christie et al., 2007) and has low human population density and deforestation rates compared to elsewhere in the region (Hansen et al., 2000 accessed via www.globalforestwatch.org). In addition, the presence of diamond and gold deposits exerts an important local influence on livelihood strategies. Thus, while the discussion below explicitly considers the GolaMA site, it inevitably touches on topics that are likely to be relevant for hunting systems elsewhere. I discuss two central management implications of my work: (1) how behaviour change interventions might be improved and (2) appropriate methods for monitoring hunting and trading activity.

Opportunities to improve intervention design

Effectively targeting livelihood support interventions

At the GolaMA project site, I found livelihood-support programmes and hunting regulations could be improved by targeting distinct needs and motivations of different resource-users, rather than taking a "one-size-fits-all" approach. For instance, it seems likely that hunters and traders respond

differently to law enforcement and agricultural programmes (Chapter 3), while patterns of citizenship, hunting and access to income from cocoa or palm plantations could determine which type of hunters become involved in livelihood support programmes (Chapter 4). Managers at the GolaMA site use several types of interventions aiming to reduce hunting pressure in community-managed forests. Conservation activities encompass livelihood-based approaches, establishment of governance structures and community-level regulations and enforcement, which sit alongside protected area management across the wider landscape. My work suggests that the process of defining target groups could provide a useful framework for decisions about where and how to implement these various types of interventions.

One of the key challenges facing managers in GolaMA, as elsewhere, is balancing the livelihood needs of people against the goal of safeguarding wildlife (Wicander and Coad, 2015). This study found high livelihood dependence on bushmeat: approximately 40% of households were involved in hunting or trading, and bushmeat represented the largest income source for a majority of hunters (74%) and traders (78%). Bushmeat has also been shown to play a substantial role in rural diets, both in the study site and across Liberia (GolaMA, unpublished; Ordaz-Németh et al., 2017), which underscores the need to ensure people's well-being is not negatively impacted by restricted access to wildlife resources.

My work using segmentation approaches (Chapter 4) suggests that both equitability and effectiveness of livelihood interventions might be improved by distinguishing different types of resource users, and using this as a basis for targeted intervention design. The results of Chapters 3 and 4 highlight potential for better targeting of women and non-local residents who may have specific livelihood needs. For instance, traders, many of whom were women, can incur substantial financial losses due to confiscation of meat at roadblocks and may abandon their activities as a result (Chapter 5). Added to this, the range of non-bushmeat income sources available to female traders may be constrained by cultural norms and barriers, such as access to education (Leach, 1994). In some hunting systems, woman can play a powerful role in motivating hunters, for instance, by refusing to sleep with partners who do not hunt, or openly disrespecting non-hunters (Lowassa et al., 2012), and insights into hunter-trader relations in GolaMA (Chapter 3) suggest similar mechanisms may occur. Thus, explicitly considering female traders in designing interventions could help ensure hunting restrictions are effective without disproportionately impacting women. Additionally, a better understanding of women's roles in the bushmeat system could help identify barriers for behaviour change, and may reveal opportunities to leverage existing social mechanisms (Leisher et al., 2016).

In designing well-targeted livelihood interventions at GolaMA, as elsewhere, there is also a need to better understand potential feedback mechanisms between different income generating activities (Larrosa et al., 2016). For example, of the livelihood programmes offered by the project, the small loans scheme was particularly well received by women and was seen by many as a way to expand or start small business enterprises selling petty goods (*pers. obs*). I found many female bushmeat traders gained additional income from petty goods businesses (Chapter 3), suggesting that credit schemes could be a promising way to support non-bushmeat livelihoods for female traders. However, transportation costs associated with running small business enterprises were often offset by sale of bushmeat in the urban markets where goods are purchased. With high transportation costs, travelling 'empty-handed' to the city to purchase stock for a small business required a large amount of capital. Traders could get around this by transporting meat to sell at the urban market, which generated cash that could be re-invested into purchase of goods (Chapter 3). Studies elsewhere suggest such patterns are not unusual (Bachmann et al., 2019; Cowlishaw et al., 2005; Kümpel et al., 2010). Thus, an increase in petty goods enterprises could also increase incentives for bushmeat trading. So, while credit schemes may be important to improve socio-economic conditions of female traders, robust mechanisms are needed to ensure loans are not reinvested into bushmeat activities.

Another potentially vulnerable group, with distinct livelihood needs, could be resource users of non-local ancestry such as settlers from elsewhere in Liberia or transient migrants. Audience segmentation results showed that non-local citizenship was a clear factor that differentiated potential target groups at GolaMA (Chapter 4), and it also seems likely that non-locals can be under-represented in hunting studies more generally, due to sampling biases. Under the community-based management framework being implemented at GolaMA, decisions over resource use rights were to be placed in the hands of local management bodies who were likely to be mainly comprised of indigenous citizens. As in other settings, this local governance system could disempower non-local residents (Agrawal and Gibson, 1999; Suich, 2013). Citizenship could be associated with specific barriers for livelihood activities and income generating opportunities, such as land tenure security (Corriveau-Bourque, 2010). At GolaMA, non-local ancestry was tied to patterns of hunting behaviour, experience of law enforcement and livelihood portfolios with non-locals typically having high exposure to law enforcement and low probability of income from plantation crops such as cocoa or oil palm. This was especially true for the 'non-local gun hunter' group, a potentially important target group with high hunting impacts and few other income sources (Chapter 4).

Clearer understanding of the underlying processes affecting livelihood decisions of local versus non-local citizens could help improve interventions. For instance, training of cocoa farmers and provision of equipment to process palm oil are a central component of livelihood support activities in the Gola landscape, among other financial mechanisms (e.g. Bulte et al., 2012; Voors et al., 2011). Our findings suggest it may be important to complement these programmes with activities specifically tailored to suit non-local groups, for instance, bee-keeping or annual agriculture may be more appropriate as these can deliver returns after much smaller investments of time and resources. Further work to understand which types of hunters participate in different livelihood schemes, and the extent to which their behaviour is altered as a result, is needed to develop more effective and equitable livelihood programmes. The groups identified through the segmentation exercise (Chapter 4) provide a useful starting point to monitor behaviour-change more strategically in order to address these knowledge gaps.

A broader perspective on potential target groups

The scope of this work was largely focussed on hunting and trading behaviour in the GolaMA forest communities. However, the full supply chain extends to consumers and urban distributors and a broader perspective on where to target interventions could be valuable. Informal reports in GolaMA suggested that a single, trusted buyer in Monrovia played a disproportionate role in facilitating and encouraging commercial exploitation of bushmeat resources (Chapter 3). Targeting such an individual could be an effective means to disrupt the illegal trading system, as a high proportion of traders relied on their trust-based personal relationship to this contact, built over several years. Currently, efforts to reduce hunting and trading often focus on rural forest communities where hunting takes place, or on urban consumer populations (Bachmann et al., 2019). However, my work in GolaMA suggests that at least in some settings, there could be an overlooked group of relatively few individuals who buy and redistribute meat from many hunters or traders. Such individuals may act as financial sponsors, with sufficient capital to advance loans to hunters and traders, thereby reducing economic risks for those closer to the supply end of the chain. Anecdotal reports (Chapter 3) suggested that several hunters and traders were actively recruited and incentivised by the same individual. The extent to which this pattern is found elsewhere remains unclear, although a large-scale study across the supply chain around Tai National Park in Ivory Coast, found no such structures (Bachmann et al., 2019).

Effective behaviour change mechanisms

To develop future interventions at GolaMA, it will be important to clearly identify the mechanisms by which livelihood support programmes are expected to influence hunting behaviour. In this

regard, the finding that there were relatively large financial returns from bushmeat for both hunters and traders (Chapter 3) indicates hunting reduction is unlikely to be achieved simply by making 'alternative' activities more profitable than hunting. It also was found that non-economic factors, such as inter-personal trust between hunters, traders and urban distributors, could create social barriers for behaviour change which may not be addressed by interventions that focus on economic drivers. Nevertheless, the monitoring results (Chapter 5) showed that financial factors can play a role in behaviour-change at GolaMA, whereby financial risks due to law enforcement could make 'safer' income sources more attractive, but these may operate differently for hunters and traders.

The apparent decrease in bushmeat trading over the 2-year study period suggested that road-block confiscations can be an effective disincentive for some traders (Chapter 5), but the patterns in hunting activity suggest that law-enforcement efforts may need to be highly coordinated across trade-routes to effectively reduce hunting pressure. This was consistent with findings from Chapter 3, in which traders reported meat confiscation to be a major challenge for making profit from meat trading. Studies elsewhere have similarly shown perceptions of law enforcement can act as a deterrent for illegal wildlife use (Chen et al., 2018). Several residents observed that hunters catch was diverted along alternative routes in response to increased meat confiscation at the roadblock to Monrovia. Thus, law enforcement efforts could reduce bushmeat hunting by introducing high financial risk but this needs to be coordinated across the landscape. Strengthening the transboundary collaboration between the Governments of Liberia and Sierra Leone (Hillers, 2013) could be an important way to maximise the impact of law enforcement efforts and reduce illegal hunting and trading of wildlife.

Improving intervention design at GolaMA: an overview

Overall, my work suggests intervention design at GolaMA can be improved by identifying how specific groups of resource users might be targeted more effectively. Livelihood decisions of key groups, such as local and non-local citizens, and female traders, need to be better understood to ensure interventions are effective and equitable. Potential feedback mechanisms between hunting and other income generating activities also need to be identified to avoid unintended consequences of tools such as small loans schemes. As with many hunting systems, effective strategies to reduce hunting pressure on wildlife are likely to be multi-faceted (e.g. Bachmann et al., 2019; Van Vliet and Nasi, 2008) and require coordination across law enforcement and livelihood support tools. Going forward, intervention designs will benefit from better integration of behavioural theory into the processes of developing and monitoring interventions (see Jenks et al., 2010). This would help build

understanding of how different groups of resource users respond to behaviour change mechanisms, so that these can be more effectively targeted.

Appropriate tools to monitor intervention impacts

The bean method as a potential monitoring tool

An important challenge for GolaMA managers seeking to improve interventions is how to evaluate behaviour change. Communities should lead the process of developing monitoring systems that aim to support local management to ensure monitoring methods are fit for purpose and can be sustained (Turreira-García et al., 2018). However, many techniques used to measure sensitive behaviours are complex and can be hard to use (Hinsley et al., 2019; Lensvelt-Mulders et al., 2005). I found the bean method was suitable for implementation by local communities as it was straightforward to design and administer surveys, equipment could be obtained locally, and raw results could be interpreted without statistical training. Hunting was not found to be a highly sensitive issue in GolaMA, but sensitivity could increase in the future, for example, due to the introduction of community forest regulations that are currently being developed. The bean method provided a questioning format that allowed resource users to report activities without sharing their answers openly, and as it had few drawbacks in terms of costs or time, it could be a useful monitoring tool to complement direct questions.

At the time of writing in May 2020, community forest management plans for the two clans participating in the GolaMA project had not been fully developed. Depending on the desired management outcomes that are ultimately agreed, a simple monitoring programme to assess behavioural prevalence at regular intervals could be appropriate (e.g. annually or as often as resources allow). Resource-permitting, such a programme could implement the bean method alongside direct questions during a household survey, as demonstrated in Chapter 5. To reduce costs it may be possible to explore alternative administration modes such as group interviews (e.g. following Lowndes et al., 2012), although close attention to sampling will be important to interpret results. Organisations supporting community-based management in GolaMA should consider conducting workshops or training events designed to support communities in developing appropriate monitoring tools, presenting the bean method as a potentially useful and flexible method.

There is also a need across Liberia for a more widely implemented monitoring programme aimed at determining longer term trends in bushmeat use. Such a programme might be supported by external agencies using methodologies which are harmonised at a national or regional scale. The bean

method could also play a role in such wider monitoring efforts, as a rapid means to assess prevalence of potentially sensitive behaviours. However, the method is limited in terms of being able to assess underlying patterns at the individual-level. In general, reliable information about resource use can be hard to obtain so drawing information from several sources is key to gaining a robust insight into patterns (Anglewicz et al., 2013). As an alternative questioning format that can be compared to direct questions, I found bean method was useful to help gauge response reliability (Chapter 5), but the overall extent to which respondents are likely to give truthful answers is not well understood (Cerri et al., 2017; Lau et al., 2011). Other types of information, such as patrol or law enforcement records, or ecological surveys, should therefore be sought wherever possible as a means to triangulate results (Gavin et al., 2010; Keane et al., 2011). Ultimately, monitoring approaches will be most valuable where information about prevalence can be coupled with insights into underlying drivers of behaviour (Jenks et al., 2010).

Use of harvest data for monitoring

Previous work has suggested that harvest data metrics, such as catch per hunter-day, and mean body mass of prey, might be useful to understand patterns of wildlife use and could be practical in community-based management settings (Ingram et al., 2015; Marrocoli et al., 2019). However, my work at GolaMA adds to a substantial body of literature (e.g. Dobson et al., 2019; Keane et al., 2011; Knapp et al., 2010; Maunder et al., 2006; Rist et al., 2010) showing that harvest rate metrics are susceptible to several sources of bias which are hard to minimise or quantify. As such, catch data might be most useful when it is viewed alongside several alternative data sources, rather than as a standalone monitoring tool. Following the establishment of conservation management plans in the GolaMA site, the introduction of hunting regulations will mean that harvest surveys may be unable to obtain information from hunters lacking permits, or those operating outside designated hunting zones. This constraint will add to sources of bias already present, and further limits the degree to which harvest data can be expected to reveal patterns across the wider hunting system (Rist et al., 2008).

Despite these limitations, harvest assessments could be important from the perspectives of communities and managers may wish to incorporate information about hunters catch for purposes such as setting quotas or permit fees (Marrocoli et al., 2018). To design future harvest rate surveys at GolaMA, my work suggests it is important to ensure: sampling captures the range of hunting behaviour and trip lengths; that hunting effort is quantified as thoroughly as possible; and that potential reporting error is minimised. Results can be better interpreted if potential sources of bias

are identified, so further work to help to clarify relationships between catch and factors which may be unevenly sampled, such as hunting base or trip duration, would be valuable.

Recommendations going forward

The effectiveness of ongoing work at the GolaMA project site could be improved by better understanding of the barriers and incentives underpinning livelihood decisions, better targeting of interventions and robust monitoring of outcomes. The foundation for all of these three areas is a broader and deeper understanding of social structures in the system and the variation that exists within and between groups when it comes to resource use behaviour. My thesis provides a starting point for developing this understanding1 and based on its findings I suggest the following priorities for future research and conservation activities in and around the GolaMA site.

1. **Evaluate effectiveness of interventions:** Conduct a follow-up survey to evaluate the effectiveness of the GolaMA interventions in terms of influencing people's behaviour. This should focus on identifying the barriers and mechanisms which facilitated or prevented behaviour change for different groups of people, and how features of intervention design and implementation promoted or inhibited livelihood decisions. Survey methods could include semi-structured interviews and focus group discussions designed to differentiate the experiences of key groups such as local versus non-local citizens. Specific topics to explore could include potential unintended feedbacks between hunting and small loans schemes, and whether hunting restrictions resulted in negative economic impacts on vulnerable groups.

2. **Adaptive intervention design:** Establish of an adaptive process of intervention development such that the results of a GolaMA follow-up survey can influence the design or implementation of future conservation projects in or around the site. The experience of RARE Pride Campaigns demonstrates that effective tools can be developed through an iterative process of applying, evaluating and then re-designing interventions (Jenks et al., 2010), and a similar model could be helpful in GolaMA.

3. **Monitor resource use:** Support communities to develop a monitoring programme that can assess patterns of resource use in each of the GolaMA Community Forests. The methods which are most appropriate will depend both on the specific questions that communities wish to address and the resources available. However, where possible information should be obtained in more than one way, for instance by applying the bean method alongside direct questioning formats, or from several sources, for instance, by pairing hunters' reports of effort, with sales of gun cartridges, or comparing catch composition to consumption surveys or camera trap records (e.g. Marrocoli et al., 2019).

Valuable insights are likely to come from local knowledge and informal observations, so capturing these within any monitoring system could be a cost-effective approach.

4. **Support transboundary law enforcement alongside livelihood support:** Support coordinated transboundary law enforcement efforts, particularly confiscation of meat at road-blocks, and explore opportunities to identify and bring to account any influential commercial buyers that may have a disproportionate role in driving illegal hunting. Financial risks from roadblock confiscations appeared to be effective in reducing bushmeat trade, and consistent, coordinated efforts could be a powerful tool in making bushmeat less economically appealing. However, the long-term effectiveness of this approach depends on the availability of other income generating opportunities for rural hunters and traders, and ensuring that enforcement is enacted in an ethical, and socially just manner. Resourcing and training across law enforcement agencies is needed in both Sierra Leone and Liberia for effective and equitable implementation of wildlife laws.

5. **Monitor long-term trends in hunting pressure and assess sustainability for key species:** Work towards developing national or regional-scale monitoring systems aimed at identifying trends in hunting pressure over long timescales (years to decades). Ideally, such a monitoring program would enable assessments of hunting patterns associated with different land management regimes and conservation interventions. It is also important to evaluate sustainability of hunting for different species, in order to design rules which can protect vulnerable species without causing unnecessary hardship on those who depend on bushmeat. Measures describing hunting and trading prevalence or frequency are likely to be more reliable metrics than catch per unit effort, but several sources of information should be evaluated if possible. Consistent reporting of law enforcement data, such as confiscation records, could be useful to support better monitoring. More generally, there is a need to increase the technical capacity within government agencies and civil society organisations to support the management of national or regional databases describing resource use. To support the design of effective rules, it is

Wider implications in the field of conservation

The research presented in this study addresses practical challenges faced by conservationists seeking to understand and influence people's behaviour in relation to the hunting and trading of bushmeat. Although the work focuses on one site in West Liberia many of the results have wider relevance across diverse conservation settings. Key findings relate to the following themes which will be discussed below: (1) the value of mixed-methods approaches for understanding social-ecological systems from the perspective of resource users; (2) the need to consider diversity in human populations to define target groups; and (3) the challenges associated with accurately measuring

behaviour. In exploring these themes, I look at two tools, audience segmentation and the bean method, which have been largely overlooked in conservation, but which could be appropriate for many settings.

Understanding resource use behaviour

While there have been significant moves to integrate social science techniques into conservation practice (Bennett et al., 2016a), many of those working in conservation lack technical skills and training when it comes to understanding and influencing human behaviour (Robinson et al., 2019). Consequently, conservation efforts may be hampered as social science techniques are not exploited to their full potential (Moon et al., 2019). The study presented here illustrates that the integration of social science techniques into standard conservation practices can be extremely useful, and that conservationists can gain broad insight into behavioural systems by applying a range of data collection approaches.

I found that focus group discussions and open-ended interview questions provided valuable context for understanding social elements of a hunting system (Chapter 3) and for interpreting apparent changes in behaviour (Chapter 5). This is consistent with several other studies of hunting systems, where mixed method approaches have revealed complex social and political structures across bushmeat supply chains (Bassett, 2005; Cowlishaw et al., 2005; Schulte-Herbrüggen et al., 2013; Van Vliet et al., 2015) and have helped identify motivations, attitudes and cultural nuances which can be fundamental for designing effective interventions (e.g. Katikiro, 2016; Nilsson et al., 2016). Techniques from social science disciplines, such as psychology, may be particularly well suited to reveal perspectives of resource users and the diverse attributes of different groups (Osbaldiston, 2013; Saunders et al., 2006; Selinske et al., 2018), which marketing tells us should be placed at the centre of intervention design (McKenzie-Mohr, 2000). Encompassing both qualitative and quantitative approaches, social science tools can help describe the social landscapes of resource use systems and identify non-economic factors influencing livelihood decisions, such as social norms, power structures and information flows (Ajzen, 1996; Schultz et al., 2007).

A clear understanding of resource use behaviour is valuable for defining target groups, as a key concern is selecting appropriate variables by which to differentiate people (McKenzie-Mohr, 2000). As such, segmentation analyses can be seen as part of an iterative process which uses mixed methods to identify potential drivers of behaviour, clustering to evaluate patterns between drivers and monitoring to assess which drivers are relevant for behaviour change. For instance, future segmentation exercises could draw on the qualitative and quantitative insights gained from the present study, to incorporate variables relating to attitudes toward the risks of meat confiscation,

land tenure concerns of local versus non-local citizens, or financial and non-financial relationships between hunters and traders. When it comes to monitoring conservation behaviour, information from varied sources can provide the necessary context to interpret apparent trends. This was demonstrated in Chapter 5, where anecdotal reports about traders' responses to law enforcement were a key source of information for assessing the reliability of apparent decreases in bushmeat trading. The susceptibility of some behavioural datasets to numerous sources of error and bias, illustrated in my comparison of harvest rate estimates (Chapter 6), further demonstrates that interpretation of behavioural studies may be greatly improved when results are viewed alongside other information sources.

The use of tools that generate qualitative data was limited in my study, but these could have generated deeper insights into the hunting system. One constraint was a lack of resources to train local researchers who were unfamiliar with qualitative methods. Qualitative data collection techniques can demand specific research skills and a higher level of literacy than some quantitative methods, and this presented a barrier for their use in the rural Liberian setting. Added to this, the development of many tools from the social sciences, such as psychological scales to evaluate risk preferences, has been heavily biased toward populations of high-income countries making them inappropriate in most other settings (but see Charness et al., 2013). Building scientific research capacity in under-resourced countries has been identified as a key priority for conservation (Atickem et al., 2019), and evidently such training programmes need to focus on social science skills as well as ecological disciplines (St John et al., 2014).

Defining target groups

There is a growing momentum to bring social marketing tools more squarely into standard conservation practice, and others have made compelling arguments that this could improve demand-reduction campaigns (Greenfield and Veríssimo, 2019; Olmedo et al., 2017), use of flagship species (Verissimo et al., 2011), reduction of human-wildlife conflicts (Veríssimo et al., 2019) and conservation messaging (Kidd et al., 2019). My findings demonstrate that the nascent field of 'conservation marketing' is similarly relevant for site-based management, and that tools to define target groups and monitor behaviour can be extremely valuable in rural sites where the type of data which can be collected may be constrained. Proponents of conservation marketing have identified that defining target groups is an important step for improving behaviour-change outcomes (Kidd et al., 2019; Verissimo et al., 2011; Wright et al., 2015). My work suggests that audience segmentation can be an effective tool to achieve this (Chapter 4), supporting a recommendation that it should be more widely adopted as standard practice.

The socio-economic wellbeing of resource users is an important concern for achieving sustainable management of natural resources (Lele et al., 2010). However, designing interventions that achieve socio-economic goals alongside conservation is challenging (Wicander and Coad, 2018). Results from Chapters 3 and 4 suggest that both equitability and effectiveness of livelihood interventions might be improved through distinguishing different types of resource users, based on factors such as citizenship, gender and livelihood portfolios, and using groups' profiles as a basis for targeted intervention design. Resource users vary in terms of how conservation restrictions could impact their livelihoods and the barriers they face in accessing alternative income sources (Coomes et al., 2004; Sunderland et al., 2014); segmentation approaches could help managers evaluate the needs of potentially vulnerable groups and identify mechanisms to influence resource-use behaviour more effectively.

There are a large number of analytical approaches to audience segmentation and these vary greatly in their complexity and assumptions (e.g. Boslaugh et al., 2005; Wang, 2010). My findings support the use of multi-variate techniques to group people according to multiple traits rather than a single characteristic. This approach is also favoured by marketers and a large body of literature describes segmentation methods (e.g. Schmid et al., 2008). One of the key elements for successful segmentation is choosing appropriate variables, which requires a thorough understanding of the system and the factors which influence responsiveness to interventions (Barber et al., 2012). Unfortunately, a good understanding of the ways different people respond to conservation interventions is currently lacking, and addressing this knowledge gap is challenging (Junker et al., 2017; Veríssimo, 2013). Building a robust evidence base for behaviour-change mechanisms will therefore go a long way to enable conservationists to leverage tools such as audience segmentation.

Measuring behaviour

My findings highlight the challenges of obtaining reliable information about behaviour and reiterates the usefulness of specialised techniques from the social sciences for conservation (Nuno and St. John, 2015). Response reliability, the degree to which people give consistent answers to the same question, is given relatively little attention in conservation studies but can be an important source of measurement error (Schwarz and Oyserman, 2001). Parallel use of alternative questioning formats, as I demonstrated with the bean method, may be a useful way to gauge response reliability.

The simple format of the bean method suggests it could be readily adapted for different types of uses, and our extension of the method to answers with more than one category demonstrates its flexibility. Future applications could explore alternative administration modes, or ways to obtain different types of answers such as by using symbols to represent answers falling into distinct

categories. Importantly, in the absence of a validation study (Bova et al., 2018; Lensvelt-Mulders et al., 2005) the extent to which the bean method encourages truthful reporting remains unknown and future work is needed to address this question. The literature on specialised questioning techniques contains a wealth of studies seeking to validate approaches and improve their performance (e.g. Böckenholt et al., 2009; Chang et al., 2018; Cruyff et al., 2016; Gingerich et al., 2016). Applying similar focus to the circumstances under which the bean method can be most effective, would support the development of this potentially useful tool. For instance, I found the time demands for training and administration were extremely low, suggesting that it may have strengths as a rapid assessment tool.

Information about harvest rates can be central to understanding resource use. For instance, in the present study, data describing hunters catch revealed which species were killed (Chapter 3) and contributed to differentiating potential target groups (Chapter 4). However, as I demonstrate in Chapter 6, obtaining representative samples in studies of resource use can be challenging and results can be skewed by several sources of bias (Tourangeau and Yan, 2007). This may be particularly true of hunting systems, which characteristically show high variability among both hunters and hunting trips (e.g. Rist et al., 2008), and where hunting regulations may introduce the added problem of social desirability bias (Gavin et al., 2010). Correlations among behavioural traits can lead to large biases if traits are non-randomly sampled. For example, hunters who achieved the highest catch were also likely to be based in remote forest camps that are relatively inaccessible to researchers. Therefore, understanding the full range of people's behavioural profiles could help reveal possible implications of non-random sampling, providing a further reason why this should be a priority for conservation programmes.

My results in Chapter 6 imply that comparisons or syntheses of resource use data from different sources, although these can be helpful to assess broad patterns (e.g. Ávila et al., 2017; Hudson et al., 2017; Ingram et al., 2015), may be flawed if biases associated with different data collection methods are not accounted for. Large-scale projects, such as the Agrarian Change Project (Sunderland et al., 2017) in which consistent methodology are applied across large spatial scales, may help minimise some sources of bias. However, data quality remains a challenge, and issues such as reporting error may vary across sites.

Summary

My study adds to arguments that conservation practice can be improved by adopting approaches which explicitly focus on human behaviour and the factors that promote behaviour change. I suggest that improvements to intervention design needn't involve complex or costly methods, but rather a

shift in focus that takes in the diverse perspectives of resource-users and the factors which influence behaviour. The work presented here demonstrates how tools from the social sciences, including audience segmentation and the bean method, can be useful to improve targeting of interventions and to monitor potentially sensitive behaviour. The degree to which bias can affect datasets describing resource use highlights the need to base decisions on a range of information sources. Conservation outcomes could be improved by ensuring that complex drivers of human behaviour are captured in intervention designs and placed at the centre of efforts to influence how humans interact with the natural world.

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