Crop Foraging, Crop Losses, and Crop Raiding

Catherine M. Hill

Department of Social Sciences, Faculty of Humanities & Social Sciences, Oxford Brookes University, Oxford, UK

cmhill@brookes.ac.uk

ABSTRACT

Crop foraging or crop raiding concerns wildlife foraging and farmers' reactions and responses to it. To understand crop foraging and its value to wildlife or its implications for humans requires a cross disciplinary approach that considers the behavior and ecology of wild animals engaging in this behavior, the types and levels of competition for resources between people and wildlife, people's perceptions of and attitudes towards wildlife including those that forage on crops, and discourse about animals and their behaviors and how these can be used for expressing dissent and distress about other social conflicts. So, to understand and respond to 'conflicts' about crop damage we need to look beyond what people lose, i.e., crop loss and economic equivalence, and focus more on what people say about wildlife and why they say it.

KEY WORDS

crop damage

crop protection

human-wildlife conflict

people-primate conflict

primate foraging strategies

INTRODUCTION

"Crop raiding" is commonly used to mean the action of, or results of, wild animals damaging standing crops by feeding on or trampling them (Hill 2017a). Animals that engage in these activities are often labelled 'crop raiders', and their actions as 'crop raiding' (Humle & Hill, 2016). To raid is "to attack (a place or group) in a sudden and unexpected way: to enter (a place) suddenly in a forceful way in order to look for someone or something: to enter (a place) in order to steal or take something" (Merriam-Webster Online, accessed June 30, 2014). Yet, as far as we can tell, when animals forage on crops they do so to feed and not to steal from, attack or alarm farmers. Labelling crop foraging as 'crop raiding' or animals that forage on crops as 'crop raiders' labels the foraging animal the 'reprobate' and the farmers the 'victims' of a 'hostile', 'violent' and 'unlawful' act. This 'mis'-use of language impacts the ways we understand and research these relationships, encouraging an emphasis on modifying animal and/or farmer behavior as the appropriate approach for conflict mitigation (Hill 2015). Increasingly though it is recognized that while 'human-wildlife conflicts' can be represented as a mis-match between human and wildlife needs and activities, they are usually better understood as "conflicts between people about wildlife" (Madden & McQuinn 2017, p. 148), because of their different values, beliefs and power relations (Hill 2015, Redpath et al. 2013). A failure to identify and address prevailing social conflicts can mean that, irrespective of how effective or easily applied technical solutions are in reducing the costs of sharing space with wildlife (for example, crop losses), they will not necessarily impact local conflict narratives or experiences (Dickman 2010, Madden 2004). Consequently, it is important, as a researcher or as a wildlife manager, to be aware of the social complexities of these situations.

Nonetheless, the terms ‘raid’, ‘raiding’ and ‘raider’ may be apt descriptions of farmers’ experience of wildlife crop foraging events. Studies of farmer accounts of crop damage by wildlife indicate that farmers sometimes describe the behavior of wildlife in terms that imply they regard these animals’ actions as antagonistic, aggressive and intentional (Knight, 2003, Webber & Hill 2014). Alternatively, farmers’ use of these words may echo the terms they hear researchers, conservationists, and wildlife officers using (Hill 2017b).

CROP FORAGING AS A FOOD-GETTING STRATEGY

Primates and elephants are often cited as major crop pests in Africa and Asia, and pose particular problems for farmers because of their capacity for learning, combined with dietary and behavioral flexibility (Else 1991, O’Connell-Rodwell et al. 2000, Strum 1994), enabling them to access and consume a wide range of cultivars (Osborn & Hill 2005). Macaques (*Macaca* spp.), baboons (*Papio* spp.) and vervet and tantalus monkeys (*Chlorocebus* spp.) dominate the primate crop foraging literature (see Supplemental Table 1). Members of these genera, and chimpanzees (*Pan*), are overrepresented in the literature on primate responses to anthropogenic factors more generally (McLennan et al. 2017), which may account in part for their domination of the primate crop foraging literature. However, ‘conflicts’ associated with primates have been reported for animals from 2 Strepsirhine families (Lorisidae and Lemuridae) and 6 Haplorhine families (Atelidae, Cebidae, Pietheciidae, Cercopithecidae, Hylobatidae and Hominidae) (Baker et al. 2017). Not all of these ‘conflicts’ are necessarily crop foraging incidents, but recent reviews confirm many Old World and New World primate species, regardless of their nutritional and locomotor specializations, forage on field and tree crops (Hill 2017c, McKinney et al. 2015, Priston & McLennan 2013).

Crop foraging is a potentially risky behavior, where risk is defined as 'exposure to potentially unfavorable circumstances' (Smith et al. 2000, p. 1946). Animals engaging in this activity are at risk of being injured or killed by people protecting their crops, and there is documented evidence of retaliatory killings of elephants and primates (Choudhry 2004, Katsvanga et al. 2006, McLennan et al. 2012, Priston 2005). Various wildlife species that engage in crop foraging activities and/or live close to humans, are reported to show elevated levels of glucocorticoid hormones (i.e. stress hormones). Glucocorticoid hormones are involved in the mammalian stress response (Palme et al. 2005); elevated levels of these hormones indicate physiological stress. For example, chimpanzees at Kasongoire, Uganda, which forage in sugar cane plantations and crop fields, where they regularly encounter guards, have higher cortisol levels than chimpanzees living within the nearby Budongo Forest Reserve (BFR), which have little contact with villagers. The elevated cortisol levels in the Kasongoire community probably reflect stresses associated with their encounters with people (Carlitz et al. 2016). Further evidence that sharing space with humans is stressful for primates comes from a study of vervet monkeys in South Africa. Monkeys at sites identified as areas of high anthropogenic impact had higher cortisol levels than those living in low impact areas (Fourie et al. 2015). Similar results are reported for other species that damage crops, including elephants in Kenya (Ahlering et al. 2011) and Asiatic black bears (*Ursus thibetanus*) in China (Malcom et al. 2014). However, while elevated glucocorticoid hormone levels imply animals' experience of crop foraging events is stressful, it tells us little about the kinds and levels of stress animals are willing to endure to access crops, or how or why animals incorporate crop feeding within their foraging strategies. To understand these more fully we must examine animals' behavior during crop foraging events, in tandem with nutritional analyses and life history parameters.

Behavior of animals during crop foraging events

Engaging in high risk foraging opportunities is predominantly a male strategy to access high quality food to sustain large body size, which confers a reproductive advantage (e.g., chimpanzees - Wilson et al. 2007; Indian elephant - Sukumar 1991). Crop foraging in elephants appears strongly sex biased, with adult males much more likely to forage on agricultural crops than members of female-led family herds (Chiyo & Cochrane 2005, Songhurst 2017, Sukumar & Gadgil 1988), and crop foraging behavior tends to begin after males leave their natal groups (Lee & Moss 1999, cited in Chiyo et al. 2011). Patterns within the primate crop foraging literature are less clear. Adult male chimpanzees at Bossou, Guinea (*Pan troglodytes verus*) spend more time feeding on crops (Hockings et al 2009), yet female Sumatran orangutans (*Pongo abelii*) feed on tree fruit crops more frequently than adult males (Campbell-Smith et al. 2011). Sub-adult baboons at Gilgil, Kenya, were more likely to forage on crops than other age groups (Strum 2010), but more recent reports from a variety of species indicate that crop foraging is an activity engaged in, to some degree, by all age-sex classes, though usually initiated by adults of either sex, or sub-adult males (Hockings et al. 2009, Priston et al. 2012, Saj et al. 2001, Schweitzer et al. 2017, Wallace & Hill 2012). However, female primates with infants appear less likely to enter farms than other group members (Fairbanks & McGuire 1993; Hockings 2007; Saj et al. 1999; Tweheyo et al. 2005), are usually the first to leave the farm in response to people's activities and exhibit more vigilance behaviors (active watching or scanning the environment) on farms than other group members (Wallace & Hill 2012).

Understanding the parameters of crop foraging activities is central to understanding the dynamics of these behaviors, but there are few systematic studies of primate behavior on farms and/or during crop foraging (Hill 2017b). The majority of primate crop foraging events, across a range of species, occur within 0-50m of the farm edge, and especially where there is a distinct boundary between croplands and areas of natural vegetation (Hill 2017b). Wallace & Hill (2012) found that primate groups moved further into farms than did single animals during crop foraging events. This is consistent with results from studies of primate foraging in risky environments, where animals remain near the edge of high-risk habitat (Cowlishaw 1997), and typically are in larger groups under higher-risk conditions (Hill & Lee 1998). However, studies of crop foraging baboons in Nigeria (Warren 2003), Uganda (Wallace & Hill 2012) and Zimbabwe (Schweitzer et al. 2017), and elephants in Botswana (Songhurst et al. 2017), found that group size was reduced during crop foraging events, which is counter to theories about large group size as a response to predation threat (Van Schaik 1983, Hill & Lee 1998). Reducing group size during crop foraging could be a strategy to minimize the likelihood of being detected by farm guards, or a consequence of certain animals choosing not to enter fields. Other behaviors observed during crop foraging events that could reduce farmer detection rates include reduced rates of vocalization (chimpanzees - Tweheyo et al. 2005, Wilson et al. 2007, baboons - Warren 2003), increased group cohesiveness and vigilance (chimpanzees - Hockings et al. 2012) and accessing farms in the evening or at night after farmers have left (orangutan - Campbell Smith et al. 2011; chimpanzees – Krief et al. 2014; Moor macaques - Zak & Riley 2017). Crop foraging by elephants is predominantly a nocturnal activity (Chiyo et al. 2005, Sukumar 1990). Elephants at some sites were observed to further reduce detection risks by avoiding foraging on crops at times of full moon/ high visibility and instead foraging during periods of high rainfall, when visibility is reduced, and farmers are more likely to sleep at home rather than remain on farms overnight (Barnes et al. 2006). These variable behavior patterns observed across sites and species most likely reflect a compromise between the degree to which animals perceive moving into crop lands to be a risky activity, the level of risk they will accept, and the value of crops to them (Hill 2017b).

WHY PRIMATES FORAGE ON CROPS

Why do animals forage on crops, particularly if using crops is a risky strategy? Most primate species have the capacity and tendency to switch between different food types. This raises the question of whether they switch in response to scarcity of preferred foods or to optimize nutritional intake (Lambert & Rothman 2015). The latter suggests that crops are used as 'fallback' foods; the former suggests animals are following an optimizing strategy. A key question is whether primates engage in crop foraging activities as a response to food shortages, or as an optimal foraging strategy.

Crops as 'fallback' foods

If animals are using crops as 'fallback' foods, i.e., 'foods whose use is negatively correlated with the availability of preferred foods', (Marshall & Wrangham 2007, cited in Lambert & Rothman 2015. p. 500), we would expect to see heavier use of crops either where natural habitat is lost or severely degraded, or during seasons of reduced wild food availability. Indeed, a common assumption within the conservation literature is that animals, including primates, are forced to feed on crops because of significant loss of natural habitat (Choudary 2004, Mekonnen et al. 2012, Singh et al. 2011). Primates are thought to have switched to include more crop foods within their diet as a response to rapid habitat degradation (McLennan 2013) or when wild food was suddenly less available because of a natural event such as a cyclone (LaFleur & Gould 2009). Furthermore, many primates exhibit seasonal patterns in their crop foraging activities, increasing their reliance on crop foods during periods of reduced availability of wild foods, as predicted. For example, tufted capuchins (*Sapajus nigritus*), in southern Brazil, forage on pine sap intensively during periods of wild fruit and seed shortage (Mikich & Liebsch 2014), and bearded capuchins (*Sapajus libidinosus*) use crop foods more extensively during periods of reduced wild fruit availability (de Freitas et al. 2008). Chimpanzees at Bossou, Guinea, and Bulindi, Uganda, also spend more time feeding on crops during periods of wild fruit scarcity (Hockings et al. 2009, McLennan 2013). At Kibale National Park (KNP), Uganda, crop foraging on bananas was associated with forest fruit shortages, specifically *Mimusops bagshawei*. Different species targeted different plant parts; chimpanzees fed on banana pith more often during periods of reduced forest fruit availability whereas baboons (*Papio cynocephalus*) targeted banana fruits. However, primate foraging activity on maize crops at this site was unrelated to forest fruit availability (Naughton Treves et al. 1998). In some instances crop use by primates is more likely a response to crop availability, or perhaps even food preferences. Seiler & Robbins (2015) report a positive association between the number of days mountain gorillas (*Gorilla beringei beringei*) foraged outside Bwindi Impenetrable National Park, Uganda, and the availability of palatable crops, and no evidence that crop foraging was a response to reduced food availability within the park. Studies of elephant crop foraging activities also report that elephants foraged on crops even when wild foods were plentiful (southern India – Sukumar

1990; Sumatra – Nyhus et al. 2000). Therefore, while some animals may resort to increased crop foraging to cope with shortfalls in wild food availability, there is clear evidence that this is neither the only or the main reason why primates or other wildlife engage in this activity.

Crop foraging as an optimizing strategy

An optimal foraging lens provides an alternative explanation of why primates engage in crop foraging. If primates include crops in their diets as a way of optimizing foraging strategies then they should experience some overall benefit from this activity, as reflected by nutritional status and/or reproductive success (Hill, 2017b). Crops are usually highly clumped in space and time (Strum 1994), require less processing or handling time compared with many wild foods, contain lower levels of nondigestible fiber (Rode et al. 2006), and may also be calorically more dense than wild foods (Forthman-Quick & Demment 1988, Riley et al. 2013). These features are all likely to improve animals' foraging efficiency (Strum 1994), whereby energetic benefits of using crop foods outweigh energy expenditure required to locate, consume and digest them. By contrast, the costs to animals of engaging in crop foraging activities comprise increased risk of injury or death, and amplified risk of exposure to pathogens of human and/or livestock origin (Hill 2017b).

To date there are few studies of primate crop foraging that are easily analyzed within an optimal foraging framework. However, studies of baboons in Kenya and Nigeria indicate that these animals are probably incurring energetic and reproductive benefits by engaging in crop foraging activities. Strum compared life history variables of baboons that fed on crops and garbage with those of animals who fed exclusively on wild foods at Gilgil, Kenya. The group that accessed crop and garbage foods had a smaller home range, rested more, spent less time feeding and displayed shorter interbirth intervals than did those who ate only wild foods (Strum, 2010). Furthermore, there was no evidence that the group with access to anthropogenic foods experienced either higher mortality rates (Strum 2010) or higher parasite loads (Eley et al. 1989), as might be expected as a consequence of increased risk of contact with human, livestock and food waste. From the available evidence the benefits associated with crop and garbage foraging outweigh potential costs associated with these activities at this site, at least in part because immune response to pathogen attack is more effective under conditions of good nutrition (Coop & Kyriazakis, cited in Weyher et al. 2006). Similarly, olive baboons in Nigeria, with access to crops, exhibited higher energy intake and energy balance (Lodge et al. 2013), higher fertility and lower mortality (Higham et al. 2009, Lodge et al. 2013), and reduced gastrointestinal parasite loads (Weyher et al. 2006) compared to groups with no access to crops. Again, the nutritional benefits of foraging on crops appear to outweigh costs associated with the activity, and crop foraging may even provide a buffer against seasonal nutritional stress at this site (MacLarnon et al 2015).

Elephants that crop forage also gain nutritional benefits that appear to confer reproductive benefits. Observations of elephants at Amboseli National Park, Kenya, indicate that animals that crop forage can get 38% of their daily food intake in 10% of the time it would take to achieve the equivalent intake of wild foods (Chiyo et al. 2005), thus crop foraging substantially enhances foraging efficiency. Male elephants which forage on crops achieve a larger body size compared to males of a similar age who do not eat crops. However, they only achieve larger body sizes once they begin utilizing crops within their diets, i.e., crop foraging affects body size rather than larger body size allows animals to crop forage (Chiyo et al. 2011). These results are consistent with the theory that high-risk foraging behavior, such as crop foraging, has an ‘energetic payoff’. Additionally, larger body size confers reproductive advantages on male elephants – they experience early onset of musth (Lee et al. 2011), and longer periods of musth, meaning they have a longer reproductive lifespan than their smaller peers. Furthermore, annual reproductive performance shows a positive correlation with musth duration, and there is evidence that female elephants may preferentially select larger-bodied mates (Hollister-Smith et al. 2007, Moss 1983, Poole 1989, all cited in Chiyo et al. 2011).

The examples above focus on crop foraging as an energy maximization strategy. However, primates and other animals may instead be incorporating crops within their diets to maximize protein intake, reduce fiber intake, avoid plant secondary compounds or balance micro-nutrient intake (Felton et al. 2009, McLennan & Ganzhorn 2017, Riley et al. 2013). For example, Seiler & Robbins (2015) postulate that mountain gorillas forage on eucalyptus bark because of its high sodium content, and elephants in KNP, Uganda reportedly seek out crops for their relatively high sodium content (Rode et al. 2006). However, there is no evidence that primates at KNP require crop foods to supplement their mineral intake (Rode et al. 2003).

Understanding why wildlife forage on crops is important when trying to develop effective, humane, non-lethal ways of protecting crops. If, for example, wild animals forage on crops because they face acute reduced food availability then it is likely they will persist in this behavior even when faced with significant risk while doing so. But, if they do it because it is a more energetically or nutritionally efficient option compared with using available wild foods, then it should be possible to increase their perception of risk to the point where the costs of engaging in crop foraging will outweigh any benefits acquired.

CROP DAMAGE

Few studies have systematically monitored crop damage by primates. However, where data are available measured losses vary between farms and seasons, even at the same site (Hill 2000, Naughton-Treves et al. 1998, Wallace 2010, Warren et al. 2007, Webber 2006). Red-tailed monkeys (*Cercopithecus ascanius schmidti*) at KNP, Uganda, were responsible for 15% of crop damage in one year, but in another year for only 1% of damage recorded (Baranga et al. 2012). Farmers living around KNP, lost, on average 4-7% of their crops each growing season to wildlife (Naughton-Treves 1997); farmers on the edge of the BFR, Uganda, experienced average annual losses of 10% of maize and 9% of cassava crops to baboon foraging activities, with a few individuals losing over 50% of their annual crop (Hill 2000). A few subsistence farmers in Buton, Sulawesi, lost up to 70% of their crops from foraging by Buton macaques (*Macaca ochreata brunnescens*) and wild pigs (*Sus scrofa*) (Priston 2005, Priston et al. 2012). Commercial farmers in Mauritius were reported experiencing crop damage by long-tailed macaques (*Macaca fascicularis*), worth more than 1 million GBP at the time of investigation (Bertram & Ginsberg 1994, cited in Dickman 2013), and rhesus macaques (*Macaca mullata*) and patas monkeys (*Erythrocebus patas*) in Puerto Rico (escapees and their descendants from primate research facilities), were estimated to have caused economic losses among commercial farmers of 1.13-1.46 million USD per annum over the period 2002-2006 (Engeman et al. 2010).

By contrast, the Zanzibar red colobus monkey (*Procolobus kirkii*) appeared to improve crop productivity by foraging on young coconuts, perhaps through a beneficial pruning effect (Siex & Struhsaker 1999), and chimpanzees in Guinea Bissau who fed on cashew fruits were said to be ‘assisting’ farmers because farmers harvested the cashew nuts from chimpanzee feeding remains on the ground rather than having to climb to access the fruits (Hockings & Sousa 2012). Therefore, the amount of crop damage sustained through primate foraging activities is highly variable, and in a few cases, somewhat controversially, might be viewed as potentially beneficial to farmers.

Quantifying crop damage can be problematic. There is little consistency across studies with regard to methods used to assess crop damage, and/or the ways in which it is reported. Factors other than damage by wildlife can also impact final crop yields very significantly, and yet these variables are rarely, if ever, built into damage monitoring systems. For example, growing conditions and yields within a field may be highly variable because of spatial variation in soil quality, water availability, levels of weeds, degree of exposure to light and wind, or vulnerability to plant diseases and insect/invertebrate damage. Additionally, wildlife, including primates, feed on a variety of crop plant parts, damage to some of which does not necessarily kill the plant or prevent it producing some yield (e.g., bushbuck in Uganda browse on sweet potato vines which may reduce the final yield of tubers but does not necessarily prevent the plant from producing some yield (Hill, unpublished data). Therefore, estimates and costings of damage by wildlife are unlikely to be particularly accurate, despite their widespread use (Hill 2017a). Indeed, quantification of crop damage tells us little about impacts of wildlife damage on farming households because they neither take into account the indirect or ‘hidden’ costs of sharing landscapes with wildlife, nor reflect the role, value or cultural significance of specific crops.

CROP ‘RAIDING’ – THE EXPERIENCE OF LOSING CROPS TO PRIMATES

The underlying motivation for many researchers interested in crop damage or livestock predation by wildlife is to facilitate animal conservation by reducing impacts of wildlife on people’s economic activities and personal safety, thereby removing obstacles to people’s willingness or capacity to tolerate wildlife. Consequently, many studies of conflicts about wildlife focus on the direct impacts of animal presence or behavior on their human neighbors, such as crop and livestock losses, damage to property and human injury or death (Hoare 2000, Thurgood et al. 2005). These impacts are examined, and understood, as being a consequence of the direct action of wildlife on human resources. For example, wildlife forage on crops or predate livestock which reduces household economic resources and/or food security (Ogra 2008). Many, if not most, studies of conflicts about wildlife have, until recently, focused mainly on exploring these direct costs of sharing landscapes with ‘problem’ wildlife (human-elephant interactions - Hoare 2000, Songhurst 2010, Wilson et al. 2013; human-carnivore interactions - Dar et al. 2009, Merrigi & Lovari 1996; human-primate interactions - Priston et al. 2012, Strum 1994, 2010, Warren et al. 2007). However, increasingly the importance of hidden or indirect costs is recognized, with research focusing more on lost opportunity costs as a consequence of having to guard crops, forego other income-generation activities (Harrison et al. 2015, Hill 2004, Naughton-Treves 1997), or withdraw children from school to protect crops (Harrison et al. 2015, Hill 1997, MacKenzie et al. 2015, Naughton-Treves 1997). Other studies have examined the impacts of increased risk of, or fear of, injury and disease when guarding crops (Khumalo & Yung 2013), and even psychosocial impacts on household health and wellbeing (Jadhav & Barua 2012). Mayberry et al. (2017) report that 72% of participants in their study in Botswana felt unsafe outside village areas because of the risk and fear of encountering elephants. Consequently, villagers experienced reduced freedom of movement to visit relatives and collect fuelwood, and had to curtail farming and herding activities because of actual encounters with elephants. Such factors affect people's conjectures about risk of crop losses, their decisions about future actions, inclination to accept crop damage, and attitudes towards wildlife. Such indirect costs can impact significantly on people's economic and social wellbeing, yet 'hidden' costs are difficult to quantify or compare systematically across studies.

Coping with crop damage – protecting crops

Crop protection methods often fall into one of two broad categories; active methods such as guarding, hunting and retribution killing; passive methods such as barriers, traps, poisons and visual and olfactory repellents. Traditional approaches to crop protection against primates include guarding and chasing animals (using dogs, slingshots, firecrackers, bells and other noise-makers), basic fencing, and even culling. Guarding can be very effective but for maximum effectiveness guards need to take an active approach to the task, patrolling the field boundaries frequently, making noise, and vigorously chasing away any animals seen approaching the field boundary (Hill & Wallace 2012, Naughton-Treves 1998, Schweitzer et al. 2017). Some studies report guarding is ineffectual (e.g. Riley 2007) but perhaps in these cases farm guards are combining guarding activities with other farm-based activities, wrongly assuming human presence on the farm is an adequate deterrence for foraging primates (Hill & Wallace 2012). However, guarding is costly in terms of people's time and labor (Hill 2005) and may conflict with other household labor needs.

There are many alternate crop protection strategies proposed but few of them have been systematically evaluated under field conditions. Electric fencing has been used effectively in Japan to protect fruit crops against Japanese macaques (*Macaca fuscata*) (Honda et al. 2009) but is too costly for many small scale/subsistence farmers. Hedges get mixed reports, with some people suggesting they have little effect on keeping primates out of crops (Wang et al. 2006). However, field trials of various types of barrier in Uganda found that jatropha hedges (*Jatropha curcas*), when positioned to obscure primates' view of habitat refuges, reduced crop foraging events by baboons and guenons by 85%. A crop foraging event is when one or more animals enter a farm and interact with one or more crop items. Ocimum (*Ocimum kilimandscharicumand*) barriers were ineffective as deterrents but when combined with mesh fences reduced primate crop foraging events by up to 90%. Barbed wire fences varied in their effectiveness as deterrents to primates entering fields; a 4-strand fence reduced maize cob losses by 80% during field trials, but a 3-strand fence had little impact on crop foraging activity and associated maize losses (Hill & Wallace 2012).

Planting buffer zones of crops that are unappealing to primates between areas of natural habitat and fields, avoiding cultivating crops that primates prefer or placing them in less vulnerable parts of the farm are commonly raised in the literature (Hockings & Humle 2009, Hockings & McLennan 2012, Riley 2007). These are all strategies to make farmlands less attractive to wildlife. However, where farms are small, as is common in many smallholder systems, putting aside land for buffer crops may cause significant hardship if it reduces land available for planting key food or cash crops. Therefore, choice of buffer crops should consider market value as well as harvesting costs (Riley & Priston 2010), and fit within existing work schedules to avoid creating labor bottlenecks, or additional economic hardship. Likewise, where land holdings are small, maintaining soil fertility through careful crop rotation and fallowing may impede farmers' capacity to avoid planting crops that are attractive to primates in vulnerable locations. Furthermore, crops that are unappealing to one species may be preferred by other wildlife species and/or animals may change their food habits over time and begin using crops that were previously untouched (Hill 2017b).

Enrichment planting/diversionary feeding to encourage animals away from crops is reported as successful at some sites. Fruit trees were used in Curú Wildlife Refuge, Costa Rica to attract capuchins away from important commercial crops (Baker & Schutt 2005). Kaplan et al. (2011) found that in Cape Town, South Africa, provisioning urban baboons away from areas they normally accessed anthropogenic foods in was effective provided baboons were denied access to their normal feeding areas. A form of diversionary feeding (attracting animals away from crops by provisioning them at alternate locations) was adopted at various sites in Japan, using diversionary feeding of Japanese macaques (*Macaca fuscata*) to entice them away from fields, and turning these events into an opportunity for Japanese tourists to view monkeys (Knight 2011). However, despite success as a tourism venture, this strategy failed to reduce primate crop feeding activities; the macaque population size increased and over habituation enhanced the animals' crop foraging capacity (Knight 2017).

Taste aversion experiments with baboons initially looked promising as a way of deterring crop foraging behaviors but have been unsuccessful under field conditions (Forthman et al. 2005). Preliminary work with captive primates has demonstrated that spent coffee grounds and to a lesser extent neem (*Azadirachta indica*) and ocimum essential oils act as feeding repellents, though these have yet to be trialed in the wild (O'Brien & Hill, 2018), and concentrated chili infusions in combination with other techniques have an aversive effect for some primates including red-tailed and blue monkeys (*C. mitis stuhlmanni*) (Hill & Wallace 2012). Finally, translocation of 'problem' animals or groups has been used with varying degrees of success, but is costly and potentially risky, and may just shift the problem to a new site, unless very carefully managed (Osborn & Hill, 2005).

People's perceptions of, and attitudes towards, primates that damage crops

Direct and indirect costs of sharing landscapes with wildlife, including primates, influence people's attitudes towards, and perceptions of, animals, thus lessen people's acceptance of wildlife and impede conservation initiatives (Campbell-Smith et al. 2010, Hill 2004, Linkie et al. 2007). However, people do not always regard wildlife that forage on their crops as problematic, accepting losses when they occur (Alexander 2000, Brightman 2017, Jala 1993, Naughton-

Treves 2002). In these circumstances, applying a 'conflict' framework to analyze crop damage is inaccurate and might even generate new 'conflicts' (Lee & Prison 2005, Riley & Prison 2010). Consequently, exploring perceptions of risks associated with wildlife, including risk of crop damage, and what influences people's beliefs and attitudes, is fundamental to understanding the impact of crop damage by wildlife on local people (Webber & Hill 2014).

People's perceptions of risk are multifaceted and changeable (Slovic 1987), differing within and between communities and conflict situations (Baird et al. 2009), and do not always concur with external assessments of risk but can be a 'surrogate for other social or ideological concerns' (Slovic 1987, p. 285). For example, farmers in Uganda consider baboons, chimpanzees and wild pigs (*Potamochoerus* sp.) to be a greater threat to crops than is borne out by independent measurement of crop damage, yet they underestimate damage caused by monkeys (*Cercopithecus* and *Colobus* spp.) and domestic goats (*Capra hircus*) (Webber & Hill 2014). Farmers in Sulawesi report that macaques (*Macaca maura*) feed on crops most days yet camera trap data confirm they only forage on crops on 23% of days (Zak & Riley 2017). The reasons for disparities between measured and perceived risk are not always apparent but are likely to be the result of synergies between people's individual experience, wider societal practices, cultural norms, outlooks and beliefs (Dickman 2013).

Farmers may respond differently to crop losses depending on the role or value of the crop within household livelihood strategies. For example, in Hoima and Masindi Districts in Uganda farmers have been relatively accepting of chimpanzees, because chimpanzees are thought to cause less crop damage than other species and are of ‘better character’ (Hill & Webber 2010, McLennan & Hill 2012). However, people are much less tolerant of chimpanzees when they forage on cash crops such as sugar cane, and there are now well documented cases of retaliatory killing and limited use of lethal crop protection methods (McLennan et al. 2012, Reynolds 2005, Reynolds et al. 2003). Animal visibility also appears to influence which animals farmers regard as particularly problematic. Larger body size often renders animals more visible to farmers, thus larger-bodied species are often blamed disproportionately for crop damage (Hill 2004, Naughton-Treves & Treves 2005, Okello 2005). However, body size alone does not adequately explain farmer perceptions of primate crop foraging species around the BFR, Uganda for example. Chimpanzees are the largest wild animal at this site, yet they are viewed much more positively than are baboons and other smaller-bodied species. Chimpanzees tend to travel in small groups and adopt a cryptic approach in farmland (Tweheyo et al. 2005). In contrast, baboons typically forage on farms in larger groups (Wallace 2010). Farmers detect relatively large groups most often and repeatedly fail to discover solitary animals or groups of 2-3 individuals foraging in fields (Wallace & Hill 2012). Thus, animal visibility on fields is influenced by animal behavior and group size as well as body size.

Animals thought to be a threat to human safety may be less well tolerated than other species thought to be less threatening. Chimpanzees sometimes threaten or attack people (Hockings & Humle 2009, McLennan & Hill 2013) and declining tolerance for these animals at Bulindi, Uganda, is associated with the increased number of aggressive interactions people have experienced at this site (McLennan & Hill, 2012). Nevertheless, people’s fear of animals is not always directly related to the animal’s behavior but also to cultural beliefs about the animals or their behavior, particularly where animals are viewed as portents of evil or linked to ideas of witchcraft and the supernatural (Richards 2000, Simons e& Meyers 2001, Sousa et al. 2017). Alternatively, species are sometimes highly valued regardless of whether they engage in 'nuisance' behaviors or not. For example, crop damage by domestic animals is often tolerated to a much greater extent than is damage by wildlife (Hill 2005, Naughton-Treves 1998, Webber & Hill 2014), perhaps because livestock are highly valued and the economic returns of allowing animals to forage on crops outweighs the costs associated with crop damage (Naughton-Treves 1998). Tonkean macaques (*Macaca tonkeana*) are culturally important to the *To Lindu* people of Central Sulawesi, and are therefore afforded protection, even though they are known to forage on people's crops (Riley 2010). Similarly, in Nigeria, Sclater's guenon (*Cercopithecus sclateri*) is known to damage crops but this behavior is tolerated by those for whom the guenon is sacred (Baker et al. 2014). However, such views can change in response to increased exposure to ideas from outside, and animals previously tolerated or protected because of their cultural or spiritual status may become much less well tolerated, as is documented in parts of India for macaques (Anand et al. 2018).

Farmers' reactions towards animals, including perceptions of them, may not always be driven by experience of crop damage or other nuisance behaviors, but may be linked to social tensions or disputes between different human-interest groups or a figurative threat (Dickman 2010, Hill 2004, Knight 1999). For example, wildlife in Uganda are sometimes referred to as 'the Government's cattle'. The Government are regarded as the owners of the wildlife. When domestic livestock damage someone's crops the owner of the livestock compensates the farmer. However, there is no compensation for farmers whose crops are damaged by wildlife. In this context the Government is regarded as a ‘bad neighbor’ who does not behave responsibly. This contributes to farmers’ sense of outrage, disempowerment and of being treated unfairly (Hill 2005, Hiser 2012, Naughton-Treves 2001), and may result in people using ‘narratives of conflict’ to protest against or resist the imposition of externally mediated conservation agendas. This type of action could be interpreted as a form of political action, as was theorized by James Scott in his seminal work ‘Weapons of the Weak: Everyday Forms of Peasant Resistance’ (Scott 1985). Scott argues that people who feel themselves powerless engage in ‘everyday forms of resistance’, such as ‘foot-dragging, dissimulations, false compliance, feigned ignorance, desertion, pilfering, smuggling, poaching, arson, slander, sabotage, surreptitious assault and murder, anonymous threats’ (Scott 1985, p. 5) as a way of protesting against externally imposed rules or ideas they consider unfair. Within a ‘Weapons of the Weak’ framework, farmer conflict narratives could be understood as a way of expressing anger, frustration and a sense of dissolution of autonomy without engaging in direct conflict with potentially threatening authority figures. Additionally, farmers may use conflict narratives as a strategy for coping with the nuisance of sharing space with wildlife and to resist the burden of conservation philosophies, schemes, and actors who are frequently incompatible with their own priorities, agenda and sense of justice.

CONCLUSIONS

At first glance crop foraging or crop raiding is about animals securing food and people losing crops from animals’ foraging activities. However, in many instances human responses to crop damage by wildlife are more about conflictual relationships with other human groups – be they neighbors, government officials, conservationists or even researchers – rather than about the potential impacts of the animals' actions on human livelihoods and wellbeing. Consequently, to understand crop foraging more fully we need to consider if from many angles, exploring the reasons why and when animals incorporate crops within their diets, the direct and indirect impacts of wildlife crop foraging activities on farming households, and the ways in which people understand, articulate about and response to wildlife in and around their farms. Understanding the level of risk animals are willing to take to access crops, and how to manipulate their sense of 'risk' enables us to develop effective crop protection strategies and installations. Furthermore, understanding local people's perspectives and attitudes can help explain their responses to wildlife and the degree to which they may be able or willing to tolerate wildlife presence and/or behavior locally.

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Figure 1. Schematic representation of the interrelationship between crop foraging by wildlife, crop damage and farmer experience and response to crop damage by wildlife.