

## RESEARCH ARTICLE

# An experimental game to examine pastoralists' preferences for human–lion coexistence strategies

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## Abstract

1. Reconciling conflicts between wildlife conservation and other human activities is a pervasive, multifaceted issue. Large carnivores, such as the African lion *Panthera leo* are often the focus of such conflicts as they have significant ecological and cultural value but impose severe social and financial costs on the communities that live alongside them.
2. To effectively manage human–lion conflict, it is vital to understand stakeholder decision-making and preferences regarding mitigation techniques and coexistence strategies.
3. We used a novel experimental game framed around lions and livestock protection, played across eight villages in Tanzania, to examine stakeholder behaviour in response to three incentive structures: support for non-lethal scaring, and individual- and community-level subsidies for provision of wildlife habitat.
4. We found that non-lethal deterrent methods were the preferred mitigation strategy and that individual subsidies most increased the provision of wildlife habitat. Subsidies that were conditional on other community members' decisions were less effective at increasing habitat choices. Player characteristics and attitudes appeared to have little influence on game behaviour. However, there was some evidence that gender, wealth, perceptions of respect, and the behaviour of other players affected decision-making.
5. Achieving success in managing conservation conflicts requires genuine stakeholder participation leading to mutually beneficial results. Our findings suggest that, while incentive-based instruments can promote pro-conservation behaviour, these may be more effective when targeted at individuals rather than groups. We demonstrate how experimental games offer a practical and

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engaging approach that can be used to explore preferences and encourage discussion of conflict management.

#### KEYWORDS

African lion, conservation conflicts, experimental games, human–wildlife conflict, incentives, stakeholder engagement

## 1 | INTRODUCTION

Negative interactions between people and wildlife, often termed human–wildlife conflicts (HWCs), emerge when the presence or behaviour of wildlife poses actual or perceived, direct, and recurring threat to human interests or needs, leading to negative impacts on people and wildlife (IUCN, 2020; Nyhus, 2016). Examples include damage to crops and predation on livestock (Poza et al., 2021), direct attacks on humans (Packer et al., 2019), disease transmission between wildlife and people (Gibb et al., 2020) and retaliatory killing or lethal control of the species involved (Ontiri et al., 2019).

Human–wildlife conflicts exemplify the fundamental challenge of reconciling local concerns for security and development, with international concerns for saving threatened species (Peterson et al., 2010; Treves et al., 2006). HWCs may, therefore, be reframed as human–human conflicts or, more broadly, conservation conflicts (Redpath et al., 2015), that is, conflicts between stakeholders with differing goals and values rooted in economic, socio-political and cultural history (Redpath et al., 2013). Escalating anthropogenic pressures and rapid human encroachment into remaining wilderness areas (Haddad et al., 2015; Watson et al., 2014) increase the risk of contact between humans and wildlife. The management of conservation conflicts to mitigate negative outcomes for biodiversity and wellbeing is, therefore, becoming increasingly important.

Apex predators such as the African lion *Panthera leo* are often the focus of conservation conflicts. Lions are a conservation flagship species, with important ecological, cultural and economic value (Di Minin et al., 2012; Ripple et al., 2014; Stolton & Dudley, 2019). Yet they pose a severe threat to human life (Packer et al., 2005; Sommers et al., 2010) and can incur considerable social and financial costs on the communities who live alongside them (Kissui, 2008; Packer et al., 2005). Livestock depredation is widespread, with lions targeting culturally and economically valuable cattle (Muriuki et al., 2017). Attacks on humans, although rare, generate intense hostility and greatly increase levels of fear (Kushnir & Packer, 2019). Other impacts, including mental health issues and opportunity costs due to movement restriction or the need for guarding are less well understood (Barua et al., 2013; Dickman & Hazzah, 2016). Lion populations have declined by >43% over the last two decades (Bauer et al., 2016), with local extinctions in several regions of the species' range (Riggio et al., 2013). Realised or perceived negative impacts of lions on communities and subsequent retaliatory killing is a key driver of these declines (Bauer et al., 2016; Dickman et al., 2014).

This issue is exemplified in the Ruaha-Rungwa landscape of south-central Tanzania, a high priority region for carnivore conservation. This landscape is considered to be one of only four lion 'strongholds'

in East Africa (defined as areas with stable populations of >500 individuals based on 2006 IUCN assessments; Riggio et al., 2013). Previous surveys of communities in this area revealed that nearly two-thirds of respondents had experienced livestock depredation (Dickman et al., 2014), with lion and spotted hyena being responsible for the majority of attacks. Consequently, lions in this landscape have experienced high levels of human-induced mortality due to retaliatory and preventative killing, with at least 136 lions killed between 2006–2018 (Coals et al., 2020; Dickman et al., 2014).

Identifying solutions for managing human–lion conflict is, therefore, a priority for people and wildlife in this landscape, as elsewhere. Conservation advocates tend to assert their interests through legislation and enforcement which renders lethal retaliation illegal and/or socially unacceptable (Carter et al., 2017; Redpath et al., 2017). To reduce livestock losses to lions, technical interventions are often implemented and include physical barriers, improved guarding and non-lethal deterrents such as visual and auditory scaring devices (Lesilau et al., 2018; Lichtenfeld et al., 2014; Miller et al., 2016). Conservation performance payments, providing financial incentives conditional on a specific conservation outcome, have been suggested as an additional strategy to encourage human–wildlife coexistence (Dickman et al., 2011; Zabel & Holm-Müller, 2008). Examples include payments based on the number of carnivore reproductions that occur on village land (Zabel & Holm-Müller, 2008), or incentives to protect habitats and set aside areas of land to be free of human use (Mishra et al., 2003; Nelson et al., 2010). The effectiveness of these management interventions varies widely and is context-dependent (Eklund et al., 2017; Miller et al., 2016) but particularly for performance payments, there are limited operational examples from which to assess effectiveness and acceptability (Nelson et al., 2010; Persson et al., 2015).

Experimental games are emerging as a low risk, low-cost tool in the exploration of conservation conflicts and acceptable mitigation solutions (Rakotonarivo, Bell, Abernethy, et al., 2021; Rakotonarivo, Jones, et al., 2021; Redpath et al., 2018). Games allow affected stakeholders to explore the potential of various mitigation methods, including those that are sensitive, such as lethal control, in a safe and relaxed atmosphere (Rakotonarivo, Jones, et al., 2021). Experimental games have been used to understand the effects of payments and incentives in a range of situations. These include harvesting of fish from protected areas (Travers et al., 2011), pesticide use and cooperative management (Bell et al., 2016), forest resource use (Andersson et al., 2018) and preferences for conflict interventions in response to crop-raiding (Rakotonarivo, Jones, et al., 2021).

In this study, we developed an experimental game framed around lions and livestock protection, for a case study of rural,

pastoralist communities in the Ruaha landscape of Tanzania. First, we use the game to explore individual preferences for coexistence strategies and to test the effects of three incentive structures on players' propensity to scare lions using non-lethal deterrents and to provide wildlife habitat. Second, using structured survey data we explore the relationship between within-game behaviour and attitudes/characteristics known to affect stakeholder support for conservation, such as wealth, education, and experience of stock loss (Hazzah et al., 2017; Kideghesho et al., 2006).

The three incentive treatments include (1) support to compensate the cost of non-lethal deterrents, (2) individual subsidies for provision of wildlife habitat and (3) community subsidies for provision of wildlife habitat. We hypothesised that (1) in a scenario where no incentive was offered for any action which benefits lion conservation, stakeholders would prefer the use of non-lethal deterrents over sacrificing land for wildlife habitat and (2) in a scenario where stakeholders received subsidies for providing wildlife habitat, the number of habitat choices would increase, and more so when subsidy levels were higher.

## 2 | METHODS

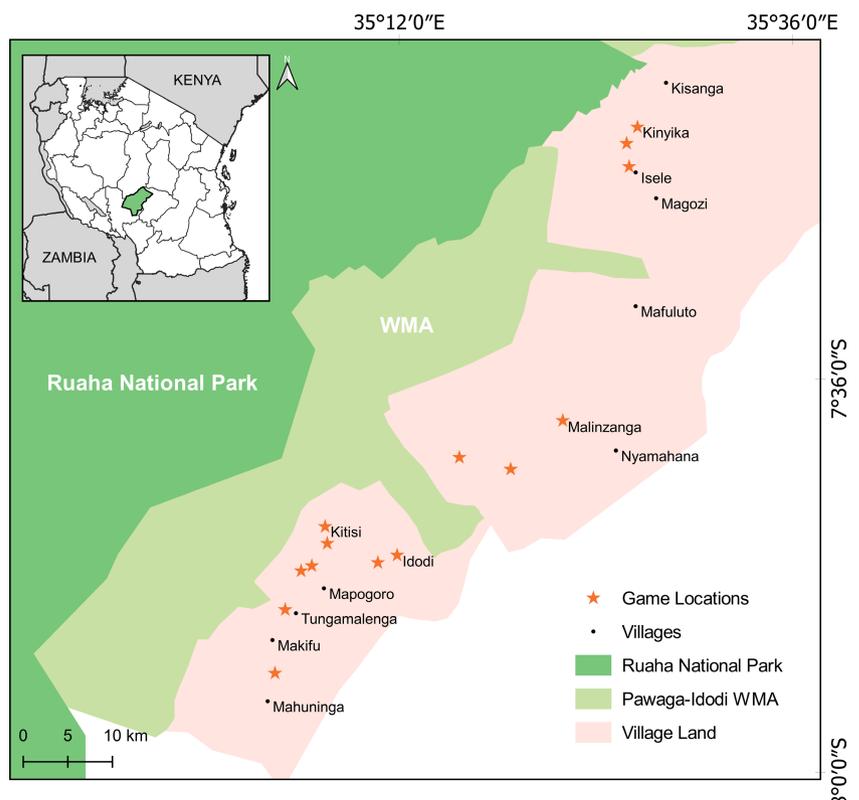
### 2.1 | Study area and population

We conducted experimental games in village land adjacent to the Ruaha National Park (RNP) and Pawaga-Idodi Wildlife Management Area (WMA), in the Iringa Rural District of Tanzania (Figure 1). The Ruaha landscape is home to globally important populations of several

threatened carnivore species, harbouring an estimated population of 3779 lions, at least 200 adult cheetahs, and the third largest population of the endangered African wild dog (Abade et al., 2014; IUCN, 2007; Strampelli et al., 2021). The village land located on the south-east border of RNP is inhabited by more than 60,000 people from at least 30 different ethnic groups (Abade et al., 2019). The dominant ethnic group are the Hehe, who are agriculturalists indigenous to the region. However, in recent decades there has been a significant in-migration of pastoralists and agro-pastoralists including the Bena, Sukuma, Barabaig, and Maasai (Dickman, 2008).

There are no fences separating RNP and the WMA from the village land and, thus, wildlife can move freely. Local communities previously reported highly negative attitudes towards lions and other carnivores due to their predation on livestock (Dickman et al., 2014). Although depredation accounts for a small percentage of total stock loss, direct experience of depredation is widespread and generates intense hostility (Dickman et al., 2014). The importance of Ruaha's carnivore populations and the level of human–carnivore conflict in the area highlight the need for continued research into human–carnivore interactions and potential coexistence strategies in this landscape.

During the day, livestock graze across the village land, typically guarded by a herder and untrained guarding dogs. At night, herds are contained in enclosures made predominantly from thorn bushes. The use of non-lethal deterrents such as lights, horns or fire is relatively rare in this area (Abade et al., 2014). Cultural lion hunting by some ethnic groups in this landscape has traditionally been used by young men to gain social status. These traditional hunts are now uncommon (though they still occur, with two events in 2019). Levels of



**FIGURE 1** Study area in the Iringa Rural District of Tanzania showing the Ruaha National Park, the Pawaga-Idodi Wildlife Management Area and the village land. Inset indicates the location of Ruaha National Park within Tanzania. Experimental games were conducted at 14 locations across eight villages.

retaliatory and preventative killing remain relatively high (27 events in 2019; Grau pers. comm). There can also be mixed motivations, where retaliatory hunts serve some traditional purpose, with young men receiving community accolades and sometimes gifts for killing problem lions (Dickman, pers. comm).

The Ruaha Carnivore Project (RCP), a research organisation established in 2009 (now part of Lion Landscapes; [www.lionlandscapes.org](http://www.lionlandscapes.org)), provides several benefits to local communities including assistance for building wire bomas, school scholarships and employing local warriors as ‘Lion Defenders’ to assist with livestock protection. A camera-trapping initiative, known as ‘community camera-trapping’ is also used to link community benefits directly with wildlife presence. Camera traps are placed on village lands and each village receives points for any wildlife photos captured. At the end of each quarter, these points are translated into benefits requested by the community such as medical supplies, school supplies and veterinary medicines.

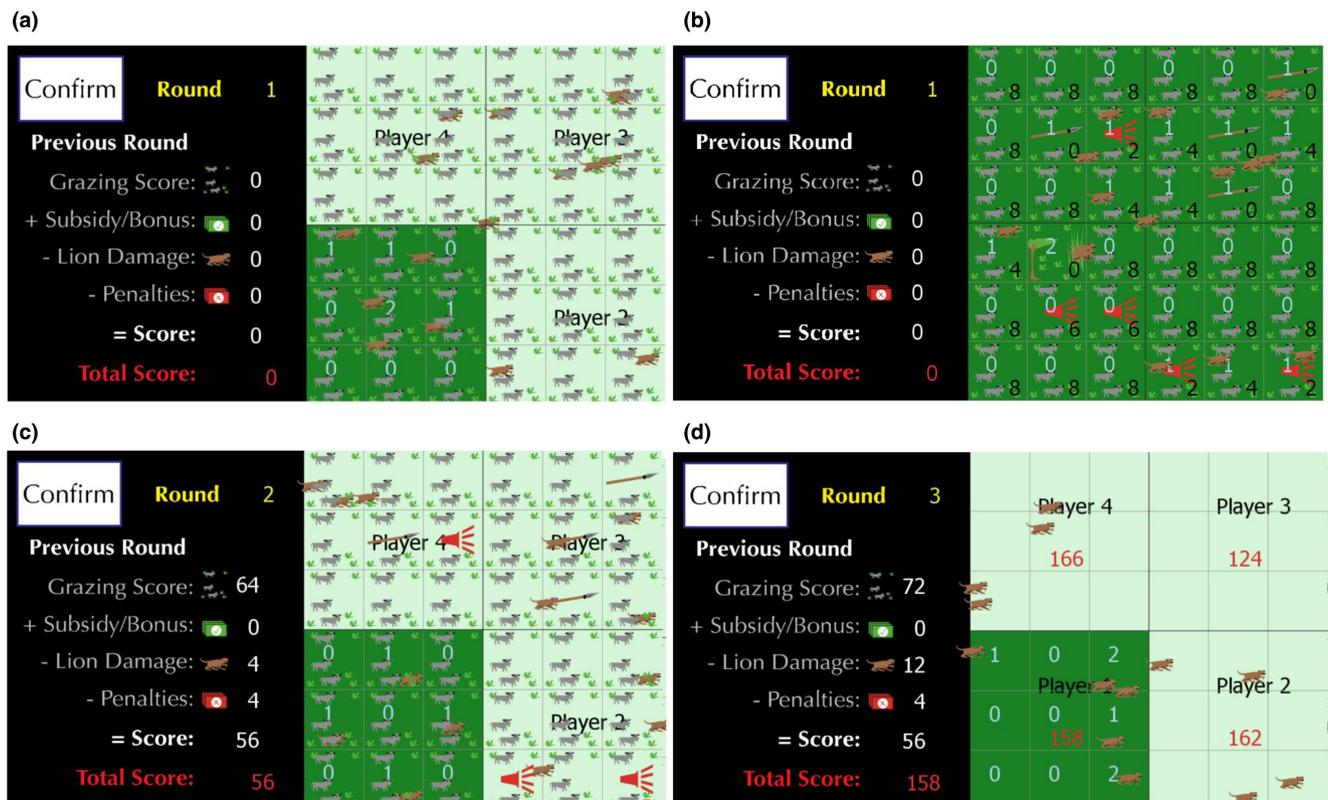
## 2.2 | Game design

We developed an experimental game to be played by four participants using tablet computers linked by a mobile hotspot. The game was created using NetLogo (Wilensky, 1999), a multi-agent modelling

environment, and is part of a suite of NetLogo-based games developed to examine conflicts between people, wildlife and resources (Bell et al., 2016; Rakotonarivo, Bell, et al., 2021; Rakotonarivo, Jones, et al., 2021).

Each of the four players makes management decisions on nine cells arranged in a 3×3 contiguous section of the game board (Figure 2). In each of these cells a player can either (1) graze livestock, (2) graze livestock and scare lions off cells using non-lethal methods (horns, lights), (3) graze livestock and attempt to spear lions in the cell (lethal control) and (4) leave the cell free from livestock to provide habitat for lions and wild prey (lion habitat). Each option has different costs, benefits and parameter settings (Table 1). The parameter values and game settings were pre-tested by ~50 players, made up of community members and RCP staff, prior to data collection.

In each game round, there are a number of lions in the landscape which select cells based on the ‘attractiveness’ of the land-use options. Each management choice has a ‘weight’ assigned to it, with bigger weights meaning higher probability of attracting lions (Table 1). Wildlife habitat is the most attractive option, given that lions will avoid people and hunt wild prey where possible (Patterson et al., 2004; Valeix et al., 2012). Lion habitats have a ‘neighbourhood effect’ of adding to the weight of any cell around them (Table 1), affecting eight cells in total. This captures the increased likelihood of livestock depredation near the boundaries of protected areas and



**FIGURE 2** Examples of the game screen at various stages of the game. (a) Bottom-left corner of the landscape is the active player at the start of Round 1; the white number in each cell is the number of lions in the cell. (b) Game screen after all four players have made decisions; management decisions of each player are visible; the black numbers show the score for each cell. (c) Game screen at the start of Round 2; actions taken by other players in previous turn are visible; the scores of the active player in the previous round are shown in the left-hand panel. (d) Game screen showing the total score for each player at the end of the practice game.

TABLE 1 Parameters for different management decisions

	1. Graze 	2. Graze and scare 	3. Graze and kill 	4. Lion habitat 
Grazing score 	8	8	8	0
Subsidy 	0	0	0	X [4,8,12] <sup>a</sup>
Damage 	-4 per lion	-4 per lion	-4 per lion	0
Cost 	0	-2 <sup>b</sup>	-4	0
Weight	10	5	2	90
Effectiveness		80%	30%	
Habitat neighbourhood effect	None	None	None	Adds 5 points of weight to all squares in a neighbourhood of 1

<sup>a</sup>In some treatments a subsidy of X points is awarded for each square of lion habitat, where X is an integer taking one of three values [4, 8, 12].

<sup>b</sup>In the 'support for deterrents' treatment this cost is reduced to zero.

natural habitats (Loveridge et al., 2010). Lions on grazed cells generate livestock losses (Table 1). The participant's overall score on their set of  $n = 9$  squares is calculated as:

$$\text{Score} = \sum_{n=1}^9 \text{Grazing score}_n + \text{Subsidy}_n - \text{Lion damage}_n - \text{Costs}_n.$$

Each game starts with 16 lions 'roaming' the landscape. Lions move independently and stochastically among the landscape cells and decisions of players in the current round can affect payoffs in future rounds. 'Scaring' displaces lions from cells that experience it with a probability of 80% (Table 1). In any given round, if a player chooses to scare on any of their cells, lions in those cells will move to another location probabilistically based on cell weights. If a player chooses the lethal option, the lion will be removed from the landscape with a probability of 30% (Table 1). The number of lions in subsequent rounds therefore decreases based on the frequency of killing choices. 'Failed' attempts at scaring or spearing result in lions remaining in the cell on which the decision has been made. Once all four players have confirmed their decisions in the current round, the position of lions in the landscape will reorient for the following round.

### 2.3 | Experimental design and data collection

Each session started with a short practice game of three rounds, to enable players to become familiar with the tablets and the game setup. This was followed by four randomly ordered treatments of six to eight rounds each (Table 2). The number of rounds was randomised to prevent participants from anticipating the conclusion of a game. Treatments were designed to emulate common conservation interventions. For example, the Support for Deterrents treatment represents free provision of equipment such as lights or horns.

The bonuses for provision of wildlife habitat are similar to conservation performance payments, offering financial or other incentives for particular conservation actions. Incentives may be provided to the individual actor (Individual Subsidy treatment) or given to the community (Community Subsidy treatment), for example via donation of funding/supplies to schools or clinics.

Communication between participants was permitted at the start of each round to mirror real-world decision-making. Players were informed of the changes in parameters before beginning each new treatment (Table 2). Following the game, we administered a questionnaire survey with each player (Table S1). This enabled us to collect detailed information on participants, including household demographics and socio-economic characteristics, experience with carnivore conflict and attitudes towards wildlife, trust and equity.

The games were facilitated by a three-person team (R.S. and two local field assistants) between May and July 2019. The game settings, instruction protocol and questionnaires were piloted prior to data collection in April 2019. Games were implemented in Swahili, with instruction also provided in two local languages, Maa and Barabaig. The study was approved by the Newcastle University Faculty of Science, Agriculture and Engineering Ethics Committee (19-SAR-010) and the Tanzania Commission for Science and Technology (2019-95-NA-2018-348). We received oral or written consent from participants (dependent on literacy) following provision of information sheets (written in Swahili) and detailed spoken translations. Participants were informed that all data would be anonymised, and only aggregated results would be published. Fieldwork was hosted by RCP, who provided logistic support, field assistants and local contacts. We ensured that before each session all participants were aware that the lead author was independent of RCP, that only the aggregated results would be shared with RCP and emphasised the neutrality of the research.

TABLE 2 Treatment conditions

Treatments	Details	Subsidy for lion habitat	Cost of scaring lions
Baseline	Default parameters used	0	2
Support for deterrents	Cost of non-lethal scaring option reduced to zero	0	0
Individual subsidy	Bonus given to each player for every cell of lion habitat they provide	4, 8 or 12 <sup>a</sup>	2
Community subsidy	Bonus given for each cell of habitat across the entire game landscape, and the total shared equally among the four players	4, 8 or 12 <sup>a</sup>	2

<sup>a</sup>Subsidy values were randomly selected at the start of the game and kept constant for the remainder of the session.

In total, we conducted 43 game sessions across eight villages (Figure 1), with a total of 172 players. Participants were found using word-of-mouth and recruitment at market days and community events. Only one representative per household was permitted to participate in the game, preferably the head of the household or person who was responsible for making livestock management decisions, in most cases men. All respondents, with one exception, were from households owning livestock, and we targeted individuals who relied primarily on livestock as a source of income, mainly the Maasai and Barabaig ethnic groups.

At the start of each session, we dedicated sufficient time to the practise game to ensure comprehension, typically ~30 min. The use of images and a Swahili game screen allowed accessibility to participants with low literacy, who were also closely assisted by facilitators. The full session (practice, 4 game treatments, individual questionnaires) lasted between 2–3h. We offered phone airtime vouchers to compensate participants for their time and provided refreshments during the game session. Although it is common practice in experimental economics to provide variable incentives based on scores (i.e. prizes), there is precedence in the experimental games literature for flexibility in incentive structure depending on local context (Bell et al., 2015; Meinzen-Dick et al., 2016; Rakotonarivo, Bell, Abernethy, et al., 2021). Our aim was to ensure that players used the game as a tool to express their preferences and think about how they would behave in reality, rather than fixate on rewards (Hur & Nordgren, 2016) and aim to win.

To gain additional details on participants' rationale for their decisions and attitudes towards management options, at the end of study period we invited 20 random participants to attend a debriefing. These informal discussions were conducted in groups of 5 and were not audio recorded. During these 30-min debriefings, notes and direct quotes were taken to further understand participants' reasoning and motivations.

## 2.4 | Data analysis

We examined two game outcomes measured at the individual participant level: (1) decisions to provide wildlife habitat and (2) decisions to scare lions. We modelled these outcomes as the number of scare or habitat provisioning decisions using linear mixed-effects (LME)

models in the NLME package (Pinheiro et al., 2021). Both outcomes were measured as counts and were, therefore, log transformed to normalise the data. Player ID was included as a random effect (RE) nested within Game ID, to account for unmeasured individual and inter-group variation. As the data consisted of repeated measures of the same individuals, we also controlled for learning by including round in the game as an explanatory variable, and by including an autocorrelation structure to adjust for serial correlation between rounds.

To examine the lagged effect of one round on the next, we ran additional LMEs excluding the first round. We then considered the amount of lion damage suffered in the previous round, and the sum of habitat and scare decisions of the three other players in the previous round as fixed effects. Model selection involved stepwise selection of fixed effects based on the Akaike Information Criterion (AIC). We used likelihood ratio tests to compare and identify the best model. If models differed significantly, the model with the lowest AIC was selected. For models that did not differ significantly, the model with fewer degrees of freedom was selected, and we subsequently interpreted the results of the most parsimonious model.

To relate behaviour in the game to demographic and attitudinal variables, we extracted the RE coefficients for each player and each game group in the final model, which included all rounds of the game. To determine whether individual RE could be explained by any measured player characteristics, we calculated correlation coefficients between RE and each socio-demographic variable. For each game group we also calculated the mean of several socio-demographic variables and categorised gender and ethnic group as either mixed or uniform. We then compared these variables with the RE effect of game ID to examine group-level variation. Because the data were not normally distributed (they contained categorical and ordinal data) we used the heterogenous correlation function of the POLYCOR package (Fox, 2019) to estimate polychoric and polyserial correlation coefficients. We used this post-hoc analysis approach to avoid over-parameterisation of the LME due to the large number of player characteristics measured and the mixture of numeric, categorical, and ordinal data.

We used a bootstrapping procedure to resample the observed data and constructed mean correlation coefficients ( $r$ ) and confidence intervals (CI) for the 100 bootstrapped  $r$ -values (Fieberg et al., 2020). We then discuss those correlations where  $r$  exceeds

the critical value considered to be significant for Pearson's correlations and the 95% CI do not overlap this value (i.e. where we are 95% confident that the true  $r$  value exceeds the critical cut-off that would be expected based on the known distribution of Pearson's  $r$ ). The critical value at  $\alpha = 0.05$  is  $r = 0.15$  for our sample of players ( $df = 170$ ) and  $r = 0.30$  for our sample of groups ( $df = 41$ ). All analyses were conducted in R version 3.6.3 (R Core Team, 2020). For a full list of the variables included in the analysis see Table S2.

### 3 | RESULTS

#### 3.1 | Participant characteristics

The average age of the participants was 32.6 years old. Players owned a mean of 30.4 livestock, typically a mixture of cattle, goats and sheep (Table S3). More than half of the players (57%) had no formal education. Of the 43% that attended school, the average time spent in education was 7.4 years, equivalent to completing primary school. Most participants were men (89%) and of the pastoralist ethnic groups Maasai (44%) and Barabaig (40%). 77% of players reported no livestock losses to lions in the past year, and 23% reported an average of three livestock killed over the last 12 months.

More than half of the participants recognised some benefits of the presence of lions, particularly at the village level (Figure 3: P1-P2). These pertained to tourism and the receipt of benefits from RCP's Community Camera Trapping programme (see Methods Section 2.1). 55% of participants had received benefits from RCP, including wire bomas, attending educational film nights, assistance from Lion Defenders and through the community camera trapping initiative. Most participants reported that it was not acceptable to kill lions for either prestige (83%) or to protect family and livestock (66%; Table S3). When asked about the acceptability of various options for fostering coexistence with lions, the majority viewed actions such as lethal control and trophy hunting tourism as unacceptable, with negative responses of 90% and 94%, respectively

(Table S3). No households received income from trophy hunting tourism. In contrast, both non-lethal deterrents and provision of wildlife habitat were perceived as being acceptable by 95% of participants. Photo tourism was viewed as a positive action by 99% of players, although only 5% of households received any income from photo tourism (Table S3).

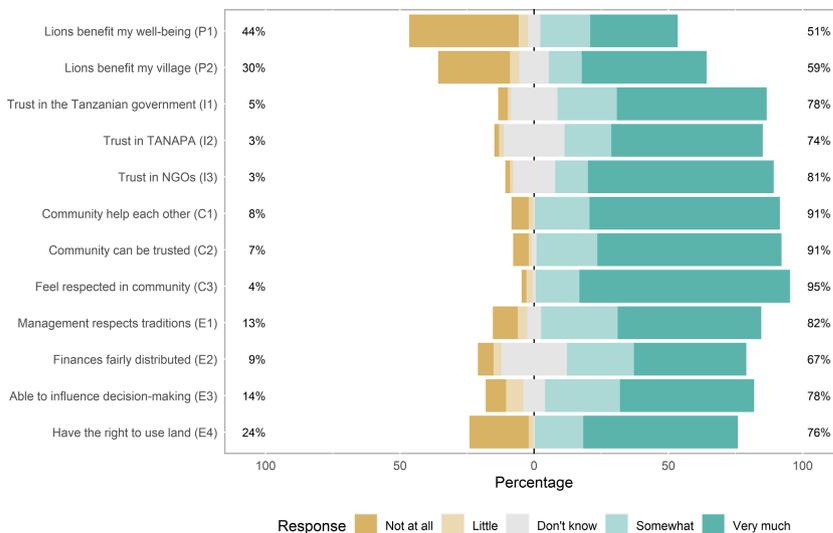
Participants reported highly positive attitudes regarding trust and equity (Table S3). Measures of community trust exceeded 91% (Figure 3: C1-C3). NGOs were the most trusted type of organisation, with 81% players viewing them positively (Figure 3: I1-I3). However, a large proportion of participants reported 'Don't know' responses to the three questions on institutional trust, and also with regard to the fair distribution of finances for wildlife management (Figure 3: E2), suggesting some uncertainty regarding these issues. Of questions relating to fairness and equity, 24% of participants felt that they did not have the right to use the land around their village according to their wishes (Figure 3: E4).

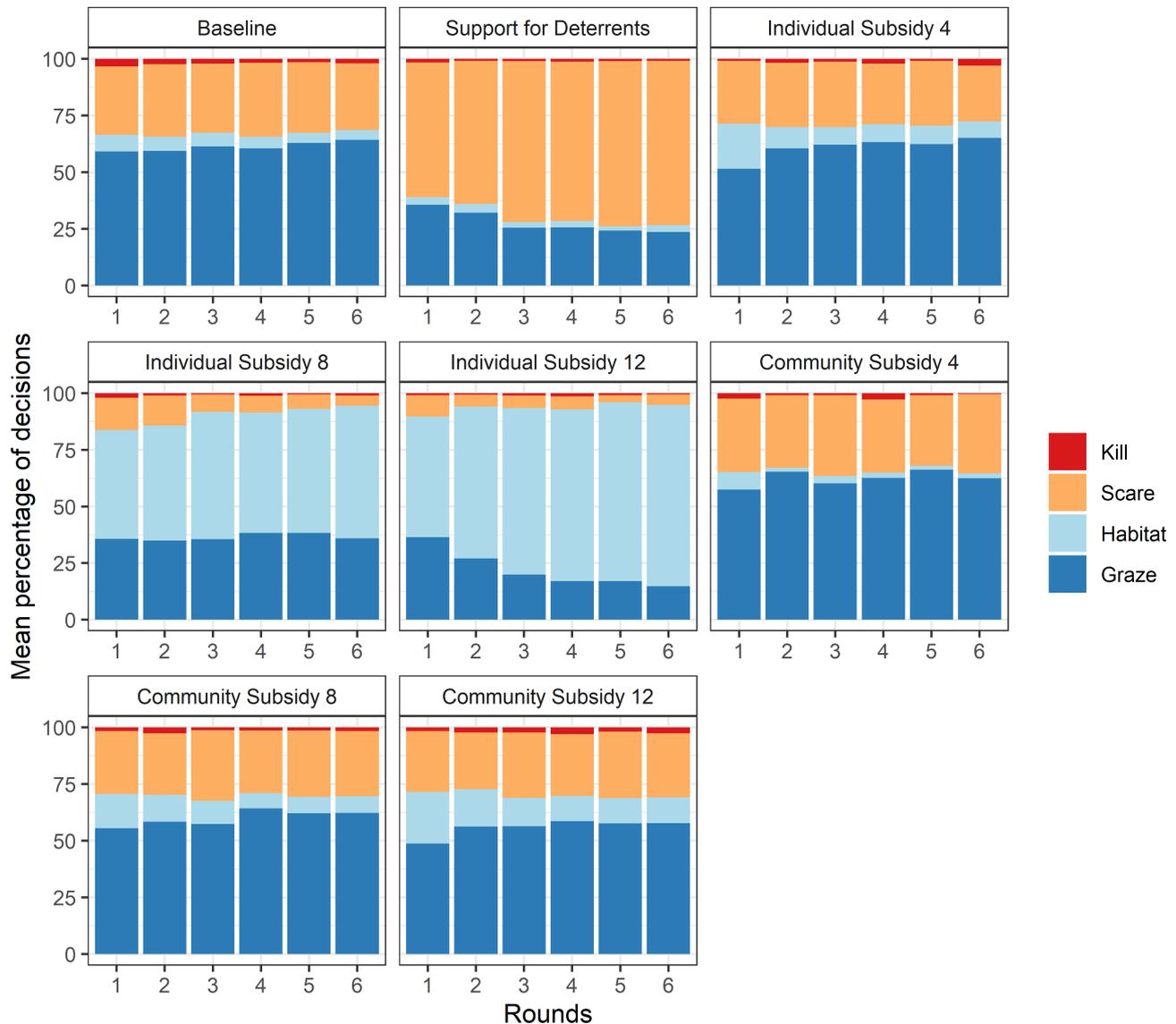
Individuals were asked to rate their familiarity with each of the other three players on a scale of 1-4 (from '1: I hardly know this person' to '4: I know them well'), to obtain an overall familiarity with the group ranging between 3% and 12. 87% of players had total scores of  $\geq 9$  indicating that, unsurprisingly for a small rural community, the majority of players knew each other. When participants were asked what their main goal was when playing the game, 48% said it was to win and 43% said it was to behave as they would in real life (Table S3).

#### 3.2 | The effect of game variables on players' willingness to provide wildlife habitat

In the Baseline (no intervention) treatment, on average, the proportion of cells over which players chose to graze livestock without using any deterrents ranged between 59% and 64% across rounds, whilst mostly choosing non-lethal scaring in the remaining cells (Figure 4). Across all treatments and rounds, kill decisions made up

**FIGURE 3** Diverging stacked bar chart of responses to questions on perceptions of lions (P1-P2), community trust (C1-C3), institutional trust (I1-I3) and equity (E1-E4). Answers were provided on a Likert scale from 'Not at all' to 'Very much' ( $N = 172$ ). NGOs, non-governmental organisations; TANAPA, Tanzania National Parks Authority.





**FIGURE 4** Mean percentages of four game decisions (kill, scare, habitat and graze) made by 172 players in Ruaha, Tanzania across treatments and rounds of the ‘lion game’.

<4% of choices (Figure 4). We, thus, focussed our analysis on the provision of wildlife habitat and use of non-lethal deterrents.

Individual Subsidies generated an increase in the amount of wildlife habitat provided in comparison to the Baseline, although the effect was strongest for higher subsidies (i.e. 8 and 12; Table 3; Figure 4). For the Community Subsidies, a subsidy of 4 points had no effect on number of habitat choices, while 8 and 12 points did increase habitat provision in comparison with the Baseline, but to a much lower extent than the Individual Subsidies (Table 3; Figure 4).

For the Baseline treatment, round number did not influence the number of habitat choices. However, as players progressed through the Community 8 and 12, and the Individual 4 games, the number of habitat decisions decreased. Conversely, with the higher Individual Subsidies habitat choices increased across rounds (Table 3).

There was a moderate autocorrelation ( $\phi = 0.43$ , 95% CI [0.40, 0.46]), indicating a positive correlation between choices of individuals across rounds. There were also substantial REs for Player ID and Game ID, indicating variation between subjects and groups. 15% of the residual variation in the model could be explained by Player ID and 24% by Game ID (Table 3).

An additional model, excluding round 1 data, allowed us to examine the lagged effect of one round on the next. Round number and lion damage suffered in the previous round did not improve the model and were removed (see Table S4 for full summary of model selection). In the Baseline treatment, the number of habitat squares provided by other players in the previous round had a positive effect on an individual's habitat choices in the current round (Table 4), suggesting that participants were taking cues from each other. As indicated by the interaction term, this positive relationship significantly increased in the Individual 4 and Community 8 and 12

**TABLE 3** Output of the linear mixed-effects model for no. of habitat choices made by 172 players in 43 games sessions. No. observations = 4516

Random effects	Game ID	Player ID: Game ID			Residual
Std. Dev.	0.184			0.115	0.468
Fixed effects	Value	SE	df	t-value	p-value <sup>a</sup>
(Intercept)	0.306	0.048	4329	6.378	<0.001
Rounds	-0.012	0.008	4329	-1.460	0.144
Support for deterrents	-0.124	0.053	4329	-2.324	<0.05
× Rounds	0.000	0.012	4329	0.004	0.997
Individual subsidy 4	0.501	0.078	4329	6.384	<0.001
× Rounds	-0.062	0.018	4329	-3.548	<0.001
Individual subsidy 8	1.039	0.076	4329	13.645	<0.001
× Rounds	0.059	0.017	4329	3.513	<0.001
Individual subsidy 12	1.196	0.074	4329	16.264	<0.001
× Rounds	0.097	0.016	4329	5.737	<0.001
Community subsidy 4	0.061	0.077	4329	0.797	0.426
× Rounds	-0.017	0.017	4329	-0.981	0.326
Community subsidy 8	0.275	0.075	4329	3.692	<0.001
× Rounds	-0.043	0.017	4329	-2.540	<0.05
Community subsidy 12	0.457	0.071	4329	6.398	<0.001
× Rounds	-0.056	0.016	4329	-3.394	<0.001

<sup>a</sup>Bold values indicate relationships that are statistically significant.

**TABLE 4** Results of the most parsimonious linear mixed effects model for no. of habitat choices when excluding round 1. No. observations = 3828. Habitat others = the total number of habitat squares provided by other players in the previous round

Random effects	Game ID	Player ID: Game ID			Residual
Std. Dev.	0.119			0.141	0.421
Fixed effects	Value	SE	df	t-value	p-value <sup>a</sup>
(Intercept)	0.224	0.023	3641	7.542	<0.001
Habitat others	0.019	0.007	3641	2.744	<0.01
Support for deterrents	-0.096	0.028	3641	-3.383	<0.001
× Habitat others	-0.007	0.012	3641	-0.565	0.572
Individual subsidy 4	0.029	0.045	3641	0.634	0.526
× Habitat others	0.035	0.010	3641	3.419	<0.001
Individual subsidy 8	0.923	0.070	3641	13.234	<0.001
× Habitat others	0.010	0.008	3641	1.188	0.235
Individual subsidy 12	1.502	0.085	3641	17.577	<0.001
× Habitat others	-0.009	0.008	3641	-1.077	0.282
Community subsidy 4	-0.058	0.044	3641	-1.317	0.188
× Habitat others	-0.010	0.017	3641	-0.608	0.543
Community subsidy 8	-0.071	0.045	3641	-1.585	0.113
× Habitat others	0.047	0.009	3641	5.001	<0.001
Community subsidy 12	0.102	0.045	3641	2.266	<0.05
× Habitat others	0.022	0.009	3641	2.583	<0.01

<sup>a</sup>Bold values indicate relationships that are statistically significant.

treatments (Table 4), while remaining comparable to the Baseline in all other treatments. With the exclusion of round 1, the main effects of Community Subsidy 8 and Individual Subsidy 4 were no longer significant (Table 4).

### 3.3 | The effect of game variables on players' willingness to use non-lethal scaring

Support for Deterrents significantly increased the number of scare choices in comparison to the Baseline (Table 5; Figure 4). Offering Individual Subsidies reduced the amount of scaring as players began to switch to habitat provision (Table 5; Figure 4), with the higher subsidies of 8 and 12 having the greatest effect. When offering Community Subsidies, only subsidy level 12 had an effect and resulted in reduced scaring (Table 5).

For the Baseline treatment, round number did not influence the number of scare choices. However, as participants progressed through the Support for Deterrents game, the effect of this treatment on number of scare decisions increased (Table 5). Conversely, with the higher Individual Subsidies the strength of the effect decreased across rounds (Table 5). There was a moderate autocorrelation ( $\rho = 0.36$ , 95% CI [0.32, 0.38]), and the RE of Player ID explained 16% of the residual deviation in the model, while Game ID explained 19% (Table 5).

Excluding round 1, we again see an effect of other player decisions on individual choices. In the Baseline treatment, the number of scare choices made by other players in the previous round had

a positive effect on individual scare choices in the current round (Table 6). This positive relationship significantly increased in the Individual 4 and Community 8 treatments (Table 6), while remaining comparable to the Baseline in all other treatments. Rounds and lion damage in the previous round were not significant and did not improve the model so were removed (Table S4). With the exclusion of round 1, Community Subsidy of 8 significantly decreased no. scare choices in comparison to the Baseline (Table 6).

### 3.4 | Correlation of participant characteristics with random effects

The RE of Player ID explained ~15% of the residual variation in the models for both habitat choices and scare choices (Tables 3 and 5). Most of the players' demographic and attitudinal characteristics were not correlated with the REs (see Table S5 for full correlation matrix). For habitat decisions there was a weak positive correlation with gender ( $r = 0.27$ , 95% CI [0.20, 0.34]), and a weak negative correlation with total livestock owned ( $r = -0.21$ , 95% CI [-0.25, -0.16]) suggesting that women and those with more livestock were less likely to choose habitat provisioning in their games. For scare decisions there were weak positive correlations with responses to the questions 'Do you feel you are respected in this community?' ( $r = 0.23$ , 95% CI [0.16, 0.30]) and 'Do you feel that current wild-life management schemes respect your local traditions and culture?' ( $r = 0.25$ , 95% CI [0.18, 0.32]). These responses were measured on a

TABLE 5 Output of the liner mixed effects model for no. of scare choices made by 172 players in 43 games sessions. No. observations = 4516

Random effects	Game ID	Player ID: Game ID			Residual
Std. Dev.	0.150			0.127	0.512
Fixed effects	Value	SE	df	t-value	p-value <sup>a</sup>
(Intercept)	1.199	0.047	4329	25.255	<0.001
Rounds	0.003	0.009	4329	0.296	0.767
Support for deterrents	0.500	0.057	4329	8.812	<0.001
× Rounds	0.034	0.013	4329	2.645	<0.01
Individual subsidy 4	-0.186	0.085	4329	-2.195	<0.05
× Rounds	0.016	0.019	4329	0.857	0.392
Individual subsidy 8	-0.694	0.082	4329	-8.470	<0.001
× Rounds	-0.040	0.018	4329	-2.191	<0.05
Individual subsidy 12	-0.801	0.079	4329	-10.096	<0.001
× Rounds	-0.041	0.018	4329	-2.210	<0.05
Community subsidy 4	0.041	0.083	4329	0.495	0.623
× Rounds	0.002	0.019	4329	0.114	0.909
Community subsidy 8	-0.087	0.081	4329	-1.073	0.283
× Rounds	0.003	0.018	4329	0.164	0.870
Community subsidy 12	-0.188	0.077	4329	-2.433	<0.05
× Rounds	0.013	0.018	4329	0.736	0.462

<sup>a</sup>Bold values indicate relationships that are statistically significant.

**TABLE 6** Results of the most parsimonious liner mixed effects model for no. of scare choices when excluding round 1. No. observations = 3828. Scare others = the total number of scaring squares provided by other players in the previous round

Random effects	Game ID	Player ID: Game ID			Residual
Std. Dev.	0.081			0.158	0.483
Fixed effects	Value	SE	df	t-value	p-value <sup>a</sup>
(Intercept)	1.064	0.053	3641	20.213	<0.001
Scare others	0.019	0.005	3641	3.475	<0.001
Support for deterrents	0.390	0.074	3641	5.300	<0.001
× Scare others	0.004	0.006	3641	0.639	0.523
Individual subsidy 4	-0.339	0.090	3641	-3.758	<0.001
× Scare others	0.033	0.010	3641	3.181	<0.01
Individual subsidy 8	-0.773	0.065	3641	-11.946	<0.001
× Scare others	-0.003	0.010	3641	-0.283	0.778
Individual subsidy 12	-0.876	0.062	3641	-14.163	<0.001
× Scare others	0.007	0.013	3641	0.556	0.578
Community subsidy 4	0.200	0.112	3641	1.779	0.075
× Scare others	0.033	0.010	3641	3.181	0.145
Community subsidy 8	-0.294	0.093	3641	-3.151	<0.01
× Scare others	0.029	0.011	3641	2.781	<0.01
Community subsidy 12	-0.197	0.086	3641	-2.308	<0.05
× Scare others	0.007	0.013	3641	0.556	0.475

<sup>a</sup>Bold values indicate relationships that are statistically significant.

Likert scale from -2 (not at all) to 2 (very much) and the correlation suggests that those who responded more positively to these questions made more scare choices.

Several of the socio-economic and attitudinal characteristics were intercorrelated (Table S5). For example, the number of livestock lost to lions was moderately correlated with village ( $r = 0.44$ , 95% CI [0.39, 0.48]), with gender ( $r = 0.41$ , 95% CI [0.31, 0.52]) and with total number of livestock owned ( $r = 0.32$ , 95% CI [0.23, 0.41]). Years of formal education and ethnic group were moderately correlated with each other ( $r = 0.38$ , 95% CI [0.34, 0.42]). On average, the Barabaig had only 1.4 years of education, compared with 6.3 years for the Bena and Hehe. In addition, there were strong correlations between several of the trust and equity questions (Table S5).

The RE of Game ID explained 24% of the residual variation in the model for habitat choices and 19% for scare choices. Comparing group-level variables to the RE coefficient for Game ID, revealed a moderate negative correlation between gender and scare decisions ( $r = -0.48$ , 95% CI [-0.59, -0.37]), with groups comprised solely of men making more scare choices than mixed gender groups (there were no women-only groups in our sample). No further patterns were detected (Table S6).

## 4 | DISCUSSION

Large carnivores can have profound impacts on the wellbeing of communities in rural landscapes. We provide evidence that experimental

games can be used to evaluate the acceptability of mitigation interventions to encourage human-carnivore coexistence. Our results support our hypothesis that stakeholders in the Ruaha landscape, Tanzania, prefer the use of non-lethal deterrents in the absence of incentives, and this preference increased when the cost associated with this intervention was reduced to zero. Non-lethal deterrents include anything you might use to scare an animal, but most participants interpreted this option as a torch. Monetary payments based on individual habitat choices incentivised players to provide wildlife habitat and this effect strengthened with increasing subsidy levels. However, when the subsidy was shared based on community-level habitat choices only the mid to high subsidy levels increased habitat provision and to a much lesser extent than the individual-based subsidies, with a decreasing effect across rounds. Finally, gender and wealth (here indicated by size of livestock herd) and the participants' social status appear to affect, if weakly, decision-making on interventions.

Increasing payment levels has been found to improve engagement in pro-conservation behaviour in several studies (Handberg & Angelsen, 2019; Rakotonarivo, Jones, et al., 2021; Tuanmu et al., 2016). However, our results suggest that these incentives are more effective when targeted towards individuals rather than being shared by the group, concurring with several other studies (Gatiso et al., 2018; Midler et al., 2015; Ngoma et al., 2020). In Africa, due to the history of community-based resource management and ill-defined land tenure and land-use rights (Dickman et al., 2011; Goldman, 2011), incentive schemes have typically targeted groups

rather than individuals (Gatiso et al., 2018) despite mixed evidence for the success of such approaches (Hayes et al., 2019). Community-based payments require functional systems of collective action (Dickman et al., 2011) and create a social dilemma with the potential for free-riding, where non-complying individuals can benefit from payments while not bearing the cost (Vollan et al., 2018). Our data provides evidence of this dilemma as habitat provision in the community treatment declined across rounds, suggesting that individuals may have been adapting their strategy in response to other players' cooperativeness (Narloch et al., 2012).

We highlight, however, that games may not accurately reflect complex real-world social interactions, and we emphasise the importance of capturing narratives around game results. Informal debriefings provided anecdotal evidence that most participants approached the games 'to win' but, in reality, benefits for the community were considered important. For example, one player stated that "Because it's only a game, people are looking at points. In real life you cannot live without your community, you have to help each other". Thus, although people may respond more strongly to individual benefits, the importance of community action and incentives is likely to be more nuanced when relating to real-world management strategies. The debriefing discussions also revealed that the preferred mitigation options among participants were torches/lights and improved livestock enclosures.

The evidence for demographic and socio-economic variables such as age, gender and education being predictors of attitude and tolerance to wildlife is mixed (Kansky & Knight, 2014; Kideghesho et al., 2006; Kimmig et al., 2020), and thus our finding of the limited explanatory power of these variables is perhaps not surprising. We found positive correlations between number of scare decisions and perceptions of being individually respected in the community and feeling that current wildlife management schemes respect local culture. Several studies have found that perceptions of trust and equity affect uptake of management strategies and cooperation (Baynham-Herd et al., 2020; Rakotonarivo, Bell, Abernethy, et al., 2021; Rakotonarivo, Jones, et al., 2021). This highlights the need for interventions to be developed in an inclusive manner, with fair representation of stakeholder interests and genuine participation in decision-making processes (Armitage et al., 2020; Redpath et al., 2017; Sjölander-Lindqvist et al., 2015).

Furthermore, we found some evidence that women made fewer habitat choices and that mixed-gender groups made fewer scare choices than men-only groups. Women may be less likely to engage in pro-conservation behaviour due to higher levels of fear towards wildlife (Kaltenborn et al. Kaltenborn et al., 2006), differences in values, priorities and time constraints (Meinzen-Dick et al., 2014; Yang et al., 2018) or feeling excluded from conservation initiatives (Homewood et al., 2020; Ogra, 2009). Globally, participation in conservation and natural resource management is still largely dominated by men (Coleman & Mwangi, 2013; James et al., 2021). Cultural barriers in traditionally patriarchal societies, such as the Maasai and Barabaig, mean that women are often excluded from decision-making and political participation (Homewood et al., 2020; James et al., 2021).

The inclusion of women in community conservation initiatives allows for more diverse perspectives and is likely to lead to more socially optimal outcomes (Masuda et al., 2022; Sun et al., 2011). However, this relies on women's voices being heard and respected. Gaining a better understanding of the dynamics of mixed-gender groups, including variation in cooperation and leadership is, therefore, important. In particular, the number of women in a group may affect their ability to overcome social norms and personal reticence to actively participate in discussions (Agarwal, 2015). In our study, the correlations between gender and decision-making were weak ( $r < 0.3$ ) and, given that we targeted heads of households, our sample size of women was small ( $n = 19$ ). Future work could, therefore, examine these issues further by recruiting a more gender-diverse set of participants and including women-only groups.

Throughout the game, there was evidence of player learning and the decisions of other participants affected individual behaviour. This suggests that players were taking cues from each other and were more likely to choose a strategy that others had used. This finding lends support to assertions that social norms are an important predictor of environmental decision-making which must be considered when aiming for real-world behaviour change (St. John et al., 2015; Thøgersen, 2008). Levels of uncertainty, which can affect an individual's propensity to cooperate (Pollard et al., 2019), are reduced in our game, as players are able to see the decisions that others have made. Future studies could focus on the impacts of social norms and uncertainty on pro-conservation behaviour by allowing for different levels of transparency in decision-making between rounds and players.

Finally, both our questionnaire survey and debriefing interviews revealed that participants reported high levels of opposition to killing lions. These attitudes were reflected in the games, where such a low number of kill choices were made that they precluded further analysis. However, given that lion killings do still occur locally, it is likely that these attitudes do not guarantee real-world behaviour in response to conflict events, where the complexity of human-wildlife interactions goes beyond what can be captured in a game scenario. Furthermore, as killing carnivores without a permit is illegal, our findings may be a result of participants feeling unable to admit their true behaviours or biasing responses towards what they wanted us to hear.

Previous surveys in this landscape found that retaliatory killing was common (Dickman et al., 2014), suggesting that individuals are willing to admit to this behaviour in the presence of external observers. The apparent change in perceptions of carnivores in this area may be due to the positive impact of the Ruaha Carnivore Project (RCP), with just more than half of participants stating that they had received benefits from this project. However, exposure to this organisation may also have affected how respondents perceive and interact with international researchers (Clark, 2008; LaRocco et al., 2020). Responses may, therefore, have been affected by some combination of social desirability bias, where participants under-report behaviours considered to be 'bad', and demand characteristics, where participants change their responses based on their knowledge of the research (Krumpal, 2013; Nichols & Maner, 2008).

Future work could consider ways to reduce response bias and possible bystander effects, for example, by developing games which can be played anonymously by single players. However, similar work on human–elephant conflict in rural Gabon, where lethal control is also illegal, found that players were willing to shoot elephants in a game context to both protect crops and express discontent with current policies (Rakotonarivo, Bell, Abernethy, et al., 2021). This suggests that players are prepared to engage in illegal behaviour when playing experimental games (Redpath et al., 2018; Travers et al., 2011).

## 5 | CONCLUSIONS

Our findings suggest that incentive-based instruments are conducive to pro-conservation behaviour in this conservation conflict setting but that the amount and the level at which these incentives are provided is important. Future work could focus on identifying realistic thresholds for such payments. Non-lethal deterrents appeared to be the preferred mitigation strategy and assisting with the cost of provisioning and upkeep would likely increase their use. We highlight the importance of engaging with the entire community and ensuring that all stakeholders' opinions and traditions are respected when developing conservation initiatives. We also echo previous calls for a shift in focus from human attitudes to behaviour to better guide conservation management and assess program effectiveness (Nilsson et al., 2020).

This study provides some of the first evidence that games could play a role in investigating human–carnivore conflict management. Generalisation of these results for the wider human–lion conflict context is challenging, given that our participants had significant exposure to a wildlife research organisation and external management interventions. However, we found that the games were well received by the community, with players rapidly understanding and engaging with the NetLogo interface. Our study thus adds to previous work demonstrating the value of experimental games as a tool to investigate stakeholder perspectives and decision-making (Baynham-Herd et al., 2020; Janssen et al., 2014; Redpath et al., 2018). This approach is highly adaptable and applicable across a wide range of conflict contexts (Bell et al., 2016; Rakotonarivo, Bell, Abernethy, et al., 2021; Rakotonarivo, Jones, et al., 2021). Ultimately, to achieve success in managing conservation conflicts, it is necessary to go beyond understanding the ecological system, to develop inclusive approaches that lead to genuine stakeholder participation and improved social outcomes (Redpath et al., 2017).

### AUTHOR CONTRIBUTIONS

Rebecca Sargent, O. Sarobidy Rakotonarivo, Nils Bunnefeld and Marion Pfeifer conceived the research ideas and provided input on research design. Rebecca Sargent, O. Sarobidy Rakotonarivo and Andrew R. Bell designed the game and protocols. Data collection was conducted by Rebecca Sargent with planning and logistical assistance from BenJee Cascio, Ana Grau and Amy Dickman. Rebecca

Sargent and Stephen P. Rushton analysed the data. Rebecca Sargent led the manuscript development and all authors have contributed critically to drafts and given final approval for publication.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

The data for this study are available at <https://doi.org/10.6084/m9.figshare.20326188>

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## SUPPORTING INFORMATION

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

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