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Wealth and risk heterogeneity effects in community-based wildlife management: Experimental evidence

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Abstract

1. Community-based conservation is a widely adopted wildlife governance approach, but questions remain about the conditions under which this form of wildlife governance achieves success. Particularly, participating communities are often marked by considerable wealth and risk heterogeneities that are driven by differences in livestock or agricultural holdings and varying exposure to wildlife depredation of those holdings.
2. The effect of these types of heterogeneity on successful conservation collective action is understudied, particularly in the case of risk heterogeneity. This lacuna limits policymakers' ability to effectively match the design of community-based programs to their particular settings.
3. Using established behavioural experimental techniques, we model the incentive structures underlying community-based wildlife conservation where actors differ in wealth and exposure to human–wildlife conflict. We conduct a modified binary linear voluntary contribution mechanism game, in which we vary subject endowments and risk of incurring a loss when participating in collective action and we find that the type of heterogeneity matters to collective action success.
4. On their own, the presence of either economic or risk heterogeneities (but not both) dampen cooperation compared with homogeneous groups, as do 'balanced' distributions of both heterogeneities (where individuals facing high risk levels receive high endowments and vice versa). However, groups with 'unbalanced' heterogeneities (where those facing high risk levels receive low endowments and vice versa) demonstrate cooperation at similar levels to that of homogeneous groups.
5. At the individual level, risk drives cooperative behaviour, although its impact is influenced by relative wealth levels when both forms of heterogeneity are present.
6. These findings suggest the need for a more in-depth look at the role and interaction of risk and wealth heterogeneities in conservation management.

KEYWORDS
behavioural economics, common pool resource management, community-based conservation, community-based natural resource management, human–wildlife conflict, public goods game

1 | INTRODUCTION

Community-based conservation (CBC) is a popular resource conservation approach involving the devolution of rights and control over the governed resource (Armitage, 2005; Child, 2009; Dyer et al., 2014; Gruber, 2010). First initiated in the 1970s (Child & Barnes, 2010; Roe et al., 2009), CBC has since been increasingly adopted as a formal wildlife governance approach, particularly within the global south (Gruber, 2010). Despite its popularity, in practice, the CBC approach has realized decidedly mixed outcomes in wildlife conservation. Some high-profile CBC efforts—such as select communities within Namibia's Conservancy and Zimbabwe's CAMPFIRE programs—have been presented as conservation successes (Boudreaux & Nelson, 2011; Heffernan, 2022; John Massyn, 2007; Koot et al., 2020). However, the approach often fails to meet its environmental protection and/or local development goals (e.g. Blaikie, 2006; Heffernan, 2022; Hutton et al., 2005; Nunan, 2006; Robinson et al., 2021). As such, much remains to be learned about the conditions under which the CBC approach achieves success. We explore the potential role that economic and risk heterogeneities (both individually and in combination) may have on the efficacy of CBC at realizing its wildlife protection goals.[1]

Heterogeneity has generally been identified as an important factor in determining the collective governance of resources (Andersson & Agrawal, 2011; Kumar, 2005; Ruttan, 2006, 2008; Spiteri & Nepalz, 2006; Thakadu, 2005), as has the inequitable distribution of wildlife risk and benefits at both the international and national scales (Jordan et al., 2020). However, little research examines the impact on collective resource governance of heterogeneous risk exposure at the community level, although heterogeneous exposure to human–wildlife conflict (HWC) is often found in CBC communities and there is ample evidence that risk, and how it is perceived and experienced, is a considerable modifier of behaviour in both wildlife governance (Bruskotter et al., 2017; Carter et al., 2020; Struebig et al., 2018) and collective action more broadly (Epstein, 1992; Slovic et al., 2002).

The interaction between wealth and risk heterogeneities is of particular interest since poorer households are frequently at greater risk of predation by wildlife because their lack of wealth can force them to occupy lands adjacent to core wildlife areas (Hartter et al., 2011; Kanapaux & Child, 2011). Wealth heterogeneity has been observed to undermine collective wildlife governance under many circumstances (Kerapeletswe, 2005; Thakadu, 2005). It is also commonly observed that people are risk-averse (Tversky & Kahnemann, 1992), but this aversion can be mitigated or exacerbated by reference points (e.g. the individual's status relative to her peers) (Clark et al., 2008).

Given the potential importance of both forms of heterogeneity for collective action, we might also expect the interactions between those heterogeneities to have important implications for CBC governance. More specifically, economic heterogeneity could influence the impact of risk resulting from HWC. Limited observations from the field suggest this may be the case, as poorer residents in Namibian conservancies are observed to be more likely to seek formal conservancy membership, even when facing high predation risks (Kanapaux & Child, 2011; Silva & Mosimane, 2012).

This study explores how the likelihood of cooperating in the collective management of wildlife changes when individuals face varying risks of losses, particularly when others in the community are more (or less) wealthy than themselves. We conduct a behavioural laboratory experiment using a binary linear voluntary contribution mechanism (VCM) game (Lugovskyy et al., 2017) mirroring the core incentive structure underlying many CBC programs.

The results of our experiment suggest that, in settings where cooperation entails risk (e.g. CBC participants conserve wildlife and consequently face an increased possibility of predation of crops or livestock), groups that have unidimensional heterogeneity in either risk or wealth (but not both) are less likely to cooperate. At the individual level, wealth heterogeneity depresses cooperation across the board, while risk heterogeneity reduces the likelihood of cooperation by high-risk individuals but increases inclination to cooperate by low-risk individuals.

However, cooperative outcomes at both the group and individual levels diverge when wealth and risk heterogeneities interact. In groups with 'unbalanced heterogeneity' (e.g. poorer individuals face a higher risk of depredation and vice versa), cooperation levels approximate that of homogeneous groups. By contrast, groups exhibiting 'balanced heterogeneity' (e.g. poorer individuals face lower risks of depredation and vice versa) are significantly less likely to fully cooperate. At the individual level, when facing low risk, people with high wealth are more likely to cooperate than those with low wealth. We find the opposite for high-risk environments, where those with low wealth are more likely to cooperate than their high-wealth counterparts. These findings highlight the need to tailor CBC programs to communities, particularly their risk and wealth distribution and lend insight into the potential relative motivation of groups within those communities.

2 | COMMUNITY-BASED GOVERNANCE IN A HETEROGENEOUS WORLD

The CBC approach can include a wide range of governance arrangements that vary significantly in both conceptualization and design, and there is no universal agreement about which governance approaches should fall under the label of 'CBC' (Adams & Hulme, 2001; Bandyopadhyay et al., 2009; Child, 2009; Child & Barnes, 2010; Gruber, 2010; Measham & Lumbasi, 2013; Murphree, 2009). Therefore, we adopt the definition used by Child (2009), in which 'CBC' refers to a collection of economic, political and organizational principles that rely on the devolution of rights (*see also* Adams & Hulme, 2001; Child & Barnes, 2010).

The approach generally relies on the empowerment of local communities to manage natural resources located within their own territories, often with any or all of the goals of (a) empowering and developing local communities, (b) recognizing traditional knowledge or culture and (c) encouraging the conservation or sustainable use of those resources (Armitage, 2005; Child, 2009; Gruber, 2010; Tsing et al., 2005). With regards to wildlife resources, CBC is commonly implemented as an incentive-based approach (Lyons, 2013), predicated on the assumption that people will sustainably manage their wildlife stocks when they perceive that (a) they have ownership (or some other form of enduring rights) in the wildlife and (b) the benefits (economic and non-economic) they receive from engaging in the sustainable management of wildlife outweigh the costs they incur by doing so (Jones & Weaver, 2009; Murphree, 2009).

The costs associated with wildlife governance frequently arise because of HWC, a term referring to monetary and non-monetary harm caused by wildlife to human lives, livestock, crops or infrastructure. In CBC programs, the goal is generally for communities to use their wildlife resources to attract income, frequently from photo tourism or trophy hunting, with resulting benefits being distributed to community members, either directly (e.g. in the form of cash payments or meat distributions) or indirectly (such as through infrastructure improvements). Yet, this program structure creates a social dilemma as the cost of HWC is born by the corresponding individual while wildlife-generated income is often shared across the whole community.

Countries in Southern and Eastern Africa have garnered significant attention because they adopted national CBC policies, with Namibia's Conservancy and Zimbabwe's CAMPFIRE programs among those frequently presented as examples of the approach's potential (e.g. Kahler & Gore, 2015; NTB, 2019; Nuwer, 2017). However, the scaling-up of initial CBC pilot programs into uniform, national approaches has led to criticism that policymakers are 'wishing away' the overall heterogeneity of CBC communities by erroneously treating them as cookie-cutter, homogeneous groups (Richard & Ratsirarson, 2013). Communities involved in CBC often vary across a range of measures, both internally and with respect to each other (Agrawal & Gibson, 1999; Poteete & Ostrom, 2004). Particularly, communities can differ in in terms of their wealth and income (King & Peralvo, 2010; Mehta & Heinen, 2001; Sarker & Røskaft, 2011; Snyman, 2014; Thakadu, 2005).

Similarly, predation risk and the resulting loss to private welfare can be heterogeneous in CBC areas because HWC is strongly correlated with proximity to core wildlife areas and households located closer to wildlife habitat, therefore, tend to experience more frequent depredation (De Boer & Baquete, 1998; Granados & Weladji, 2012; Naughton-Treves, 1998; Regmi et al., 2013; Sogbohossou et al., 2011). In addition to proximity, population density and natural and manmade barriers (e.g. rivers and roads) can serve to shield certain locations from predation (De Boer & Baquete, 1998; Granados & Weladji, 2012; Hartter et al., 2011).

Predation risk and wealth heterogeneity are observed to overlap in CBC communities, with poorer households at the greatest risk of HWC because their lack of resources can force them to the edges of core wildlife areas (Hartter et al., 2011; Kanapaux & Child, 2011). The resulting increase in HWC can, in turn, exacerbate the poverty of these households by reducing food supplies and limiting economic opportunities (ibid). While the literature implies that the relationship between wealth and risk is important, the effect it has on collective action behaviour and, hence, common pool resource management success remains understudied.

3 | METHODS

3.1 | A model of community-based wildlife management

3.1.1 | Underlying CBC scenario

Our experiment is based on the following stylized CBC scenario. An individual lives in a community that collectively earns wildlife-based income, which is divided equally among the community's residents. This individual has an identified economic interest that is at risk of harm from wildlife. The individual can avoid this harm through the preventative killing of that wildlife, and she views lethal approaches as being more effective than alternate non-lethal methods. However, the utilization of preventative killing reduces wildlife populations, resulting in a decrease in the community's income (by diminishing the attractiveness of the community as a tourism or hunting destination) which, in turn, results in community members receiving a smaller distribution of money.

If, on the other hand, the individual uses non-lethal deterrent efforts (such as guarding crops/livestock, digging trenches or using fladry or chilli bombs), wildlife stocks do not suffer, but there is a chance that the individual suffers significant losses from HWC.[2] These non-lethal efforts can be (or are often perceived as being) less permanent, more costly and/or more labor intensive (with resulting opportunity costs such as foregone education or other employment) than lethal deterrence (Barua et al., 2013; McManus et al., 2015). Other community members have similar livelihoods and are faced with the same HWC deterrence choices.

This scenario is, of course, very much a simplification of a complex issue, and CBC participants in the real world are faced with a host of personal and institutional (cultural, legal and/or political) motivators that can influence whether and how they choose to address the problem of HWC. It is also frequently the case that benefits are not paid directly to participants (e.g. Salerno et al., 2020) and, when they are, they are often not evenly or equitably distributed within communities, with local elites capturing much of CBC-derived benefits (Groom & Harris, 2008; Lubilo & Hebinck, 2019; MacKenzie et al., 2017; Morton et al., 2016; Mosimane & Silva, 2015; Naidoo et al., 2016). Finally, residents can be unaware of the magnitude and/or distribution of benefits derived from the managed resource (Awung & Marchant, 2020; Krause et al., 2013).

Nevertheless, we employ this simplified CBC scenario—participants engage in a purely cost–benefit calculation in deciding whether to adopt non-lethal deterrence, direct benefits are distributed evenly among them, and the magnitude of group benefits is known—in our experiment for two reasons. First, this scenario closely approximates both the incentive and distributional assumptions undergirding the formation of many prominent CBC programs (Nelson, 2010): (1) the CBC approach hinges on the central tenet that people will contribute to wildlife conservation if the perceived benefits of doing so at least equal the perceived costs (Mogende & Kolawole, 2016; Thakadu, 2005) and (2) CBC proponents and designers assumed that wildlife-generated economic benefits would be openly and equitably distributed throughout the communities (Magole et al., 2008). Second, as mentioned above, by simplifying motivators and benefit distribution in our experiment, we can specifically focus on and generate inferences about the potential impacts of risk and wealth heterogeneity without the worry that those inferences may be the artefact of unaccounted-for interactions involving other variables. The impact of other motivators, elite capture and incomplete information remain important considerations that may be worthy of inclusion in subsequent experiments.

3.1.2 | Formalized game

The stylized CBC scenario outlined above can be formalized as the following game: Individual, i, is part of a group N (i.e. $i \in N$ where $N = \{1, \ldots, n\}$). Every period she chooses whether to contribute to a group effort, a_i (e.g. collectively conserving wildlife stocks by adopting non-lethal preventative methods to deter HWC). If she contributes, $a_i = 1$, otherwise, $a_i = 0$ (i.e. she undermines conservation efforts by defaulting to preventative killing). If, and only if, she engages in the collective effort (i.e. $a_i = 1$), she runs the risk, p_i, of incurring a cost, c (e.g. the loss of crops from HWC), which is subtracted from her private earnings she receives, e_i (e.g. agricultural income). There is a benefit associated with participating in the collective effort—every group member receives a benefit, b (e.g. tourism income), for each group member that also decides to contribute. Thus, the expected payoff function is

$$E(\pi_i) = e_i - a_i p_i c + b \sum_i^N a_i.$$

In this setting, wealth and risk heterogeneity may be introduced by varying the endowment, e_i, and the risk of predation, p_i, respectively.

To qualify as a social dilemma underlying collective resource management, individual and group incentives must be at odds. In other words, in a game such as this, the following must hold.[3] First, defection is the dominant strategy for individuals if the payoff for defecting is greater than that for participating:

$$\pi_i^{a_i=0} > E\left(\pi_i^{a_i=1}\right),$$

$$e_i + bA > e_i - p_i c + b\left(A_{-i} + 1\right),$$

$$p_i c > b,$$

where $A_{-i} = \sum_{j=1, j \neq i}^{N} a_j$.

The expected loss to the individual from HWC must be greater than the benefit derived from the conserved wildlife stocks. Therefore, the individual best response is to defect, $a_i = 0$, and the Nash equilibrium is defection by all members, $A = 0$ (where $A = \sum_i^N a_i$).

Second, at the group-level, contribution in a linear game is socially optimal if the payoff for contribution is greater than that for defection. In other words, the expected group payoff from full contribution must be greater than expected group payoffs from all but one individual contributing:

$$E\left(\pi_N^{A=N}\right) > E\left(\pi_N^{A=N-1}\right),$$

$$\sum_{i=1}^{N} e_i - \sum_{i=1}^{N} p_i c + N^2 b > \sum_{i=1}^{N} e_i - \sum_{i \in a_i=1}^{N} p_i c + N(N-1)b.$$

As endowments are not affected by a_i, endowments cancel out, irrespective of endowment heterogeneity. All p_i except $p_{i \in a_i=0}$ (i.e. the risk of the individual that does not contribute) cancel out, leaving:

$$Nb > p_{i \in a_i=0} c.$$

This means that so long as the group benefits from an individual's contribution outweighs the individual's expected loss from contribution the social optimum for the group is full contribution $A = N$.[4]

3.2 | Experimental design of heterogeneous community-based wildlife management

Using this model, we conducted the following two-stage experiment.[5] Stage 1 determined the participants' risk tolerance using a risk elicitation task based on Holt and Laury (2002). In this stage, participants were asked to make 10 choices between a certain payout and a 50% chance of an alternate 250 Experimental Currency Units (ECU)[6] payout (Table A1). The certain payouts began at 25 ECU and increased in 25 ECU increments until they matched the alternate payout. Assuming the participants have a linear risk tolerance, their choices allow for the classification of their relative risk aversion based on the stage at which they opt for the certain over the alternate payout. Participants were paid for one of their 10 choices, selected at random, with the payoff determination withheld until the end of the experiment.

Stage 2 was a binary choice VCM (i.e. public goods) game, parameterizing the social dilemma, sketched out above. The decision setting was repeated for 15 rounds. Subjects were randomly assigned to groups of four ($n = 4$) and remained in the same group throughout the experiment (i.e. groups were fixed). Participants received an ECU endowment (e_i) each round, the value of which was determined by the treatment they were in. In each round, participants decided whether to invest in the collective group effort for that round (a_i). If the participants invested in the group effort, they incurred a risk of losing 30 ECUs (c_i) from their endowment. These risks were independent of one another across treatments. Regardless of whether they themselves invested in the group effort, the participants received a benefit from *any* group member's investment (including their own) in the amount of eight ECUs for each participant that contributed (*b*).

There were five treatments—one homogeneous treatment, two *uni*dimensional heterogeneity treatments and two *multi*dimensional heterogeneity treatments (listed in Table 1). Participants participated in one treatment only and this treatment remained the same over the 15 periods comprising the experiment. All treatments were identical in group payoffs to ensure that group incentives remained the same, so that differences in contribution across groups could be attributable to changes in the distribution of, rather than the total magnitude of, wealth and risk. In heterogeneous treatment conditions (HET WEALTH, HET RISK, HET BAL and HET UNBAL), there were two types of participants with varying risks (p_i) and endowments, depending on the treatment.

After each round, individuals received information on (i) how many group members invested, (ii) whether they incurred a loss (if they invested) and (iii) their total earnings ($e_i - c_i$) for the round. Participants received full information about their own respective risk and endowments and about the risk and endowment levels of the others in their group but did not receive specific information regarding who invested (only total contributions, see discussion above). Information from previous rounds was available to participants when they made their decisions.

We highlight that we varied the relative risk and payoff that individuals received from cooperation to approximate the wealth and risk heterogeneity endemic in the incentive structures observed in the field. Unlike some previous studies (e.g. Burns & Visser, 2008; Cardenas, 2003; Hayo & Vollan, 2012) we do not account for participants' 'real-life' socio-economic status but instead integrate heterogeneity in the experiment's payoff structures. This design allows us to determine the effect of the heterogeneous incentives structures themselves as opposed to participant characteristics. Our study is, thus, complementary to field and lab work focused on socio-economic differences in common pool resource management.

We recognize that, in the field, a landowner's wildlife deterrence actions may impact the likelihood of predation of a neighbouring landowner's property. For instance, the use of non-lethal preventative measures may transfer HWC to neighbours. Similarly, preventative killing of wildlife could reduce predation risk for others in the community, although this relationship is not clear, and the opposite may also be true (e.g. Teichman et al., 2016). Nevertheless, we assume independent risks in the experiment. First, this assumption significantly simplifies the game, increasing participant understanding and the likelihood of participants making deliberative decisions. Second, risk heterogeneity in public goods game has not been experimentally studied before, indicating the need for a heterogeneous risk baseline before expanding risk interactions.

The experiment used was programmed and conducted using Z-Tree (Fischbacher, 2007). Participants were all in the same room, but there was no face-to-face communication.[7] Before participating in any stage, each participant received on-screen and printed instructions which were also read publicly. The experiment was conducted in late 2018 and early 2019 at a large Midwestern university. Subjects were undergraduate students from diverse majors. The experiment lasted less than 45 min and subjects earned an average of $19.10, including a $7 show-up fee.

This experiment received IRB approval and we obtained written informed consent from all subjects before participation. Under IRB guidelines, participants received the informed consent forms and were asked to carefully review the document outlining the experiment, potential compensation and any associated risks. Thereafter, subjects had the opportunity to ask the experimenter present any remaining questions. If recruits were willing to participate, they were asked to date and sign informed consent forms. There were no consequences (aside from foregone compensation) if a recruit chose not to participate in the experiment. No identifying information is included in this article or publicly available data.

We note that behavioural laboratory experiments are a widely accepted approach to developing our understanding of why and when collective resource governance succeeds or fails (Ostrom, 2006). In the real world, the sheer complexity of CBC situations can make it

TABLE 1 Overview of treatments.

Treatment	Individual types	Risk of loss (p_i) if invested ($a_i = 1$)	ECU endowment (e_i)	Number of subjects
Homogeneous group (HOM)		0.5	42	28
Heterogeneous wealth (HET WEALTH)	High wealth	0.5	48	28
	Low wealth	0.5	36	
Heterogeneous risk (HET RISK)	High risk	0.7	42	28
	Low risk	0.3	42	
Heterogeneous balanced (HET BAL)	High risk/high wealth	0.7	48	28
	Low risk/low wealth	0.3	36	
Heterogeneous unbalanced (HET UNBAL)	High risk/low wealth	0.7	36	28
	Low risk/high wealth	0.3	48	

Note: All participants face the same cost, *c*, of 30 ECUs and receive the same benefit, *b*, (8 ECUs) from the group for each individual that decided to contribute. Furthermore, the values used in the experiment result in the social optimum being full cooperation (see formal model above).

difficult to (a) determine the impact and causality of a specific variable of interest and (b) draw generalizations across communities or resource types. By strictly controlling the circumstances under which individuals interact, experiments permit the researcher to isolate and investigate the impact of individual variables (Lunn & Choisdealbha, 2018; Pisor et al., 2020). Experiments are especially useful in the investigation of potential causal mechanisms influencing policy outcomes (Lunn & Choisdealbha, 2018).

The controlled nature of laboratory experiments limits our ability to make specific hypotheses about the magnitude of the variables' impact in the field or to draw comparisons of the study to any specific situation (Galizzi & Navarro-Martinez, 2018; Reindl et al., 2019). However, studies have found that behavioural tendencies observed in the laboratory can mirror those found in the field, although the presence, strength and significance of those similarities can vary widely (Galizzi & Navarro-Martinez, 2018; Potters & Stoop, 2016; Reindl et al., 2019; Voors et al., 2012). As such, it is generally accepted that laboratory findings can support the formulation of *qualitative* inferences about the directional impact of variables (Kessler & Vesterlund, 2015). These inferences can then be tested across a range of conditions in the field to determine their applicability and, where appropriate, used to understand and design more effective management regimes.

4 | HYPOTHESES

We turn to field and experimental literature to generate hypotheses about the specific impacts of risk and economic heterogeneities, and their interaction, on cooperation in social dilemmas akin to community-based wildlife governance. To the authors' knowledge, there are no binary decision public goods games that study heterogeneity effects on cooperation. We, thus, rely on two-player prisoner's dilemma and n-player linear public goods[8] games to motivate our hypotheses. We provide hypotheses for group and individual behaviours.

4.1 | The impact of wealth heterogeneity on CBC

Field evidence suggests a negative impact of wealth heterogeneity on collective action. While deleterious effects may be overcome (a) if individuals possessing greater resources also stand to benefit more from providing the collective good (Olson, 1965; Ruttan, 2008) or (b) through effective institutional design (Andersson & Agrawal, 2011), a number of studies find negative impacts. Thakadu (2005) observes that socioeconomic heterogeneity tends to undermine wildlife governance efforts by making it more difficult for participants to reconcile diverse interests. This form of heterogeneity generally has a negative impact unless economic stakes of cooperation are high (Kerapeletswe, 2005). In the broader field-based common-pool resource literature, meta-analyses conclude that wealth and income heterogeneities undermine collective action (Andersson & Agrawal, 2011; Bardhan & Dayton-Johnson, 2002; Ruttan, 2008). King and Peralvo (2010), however, find it challenging to isolate a single wealth effect, further demonstrating the potential utility of experimental studies.

The behavioural experiment literature is mixed regarding the potential impact of wealth/endowment[9] heterogeneity, with results being dependent on the game structure and information provided. In prisoner's dilemmas—games that have binary decisions similar to this experiment but only two players—asymmetric payoffs (which is not a direct correlate of wealth heterogeneity, but related) lead to a reduced likelihood of cooperation (Ahn et al., 2007; Beckenkamp et al., 2007; Sheposh & Gallo Jr, 1973). In linear public goods games, however, Chan et al. (1996, 1999) and Hofmyer et al. (2007) find little effect on group cooperation as wealth heterogeneity increases. Other public goods experiment-based studies suggest that economic heterogeneity is likely to have a deleterious impact on collective action (Anderson et al., 2008; Fung & Au, 2014; Seçilmiş & Güran, 2012), especially when individuals are aware of differences in wealth levels (Anderson et al., 2008). Given subjects having full information and the absence of corrective institutions, we, thus, hypothesize that wealth heterogeneity undermines collective action:

> **H1.** Wealth heterogeneity hypothesis: Under conditions of full information, the presence of endowment heterogeneity will decrease groups' overall rate of contribution to collective action.

To understand the drivers of wealth heterogeneity effects we must explore contribution behaviour at the individual level: are high-wealth individuals compensating for lower cooperation by low-wealth individuals or do all individuals reduce their cooperativeness? Field studies involving wildlife-oriented CBC provide conflicting evidence for individual cooperativeness, alternately finding that wealth is positively correlated (Bandyopadhyay et al., 2009; Lindsey et al., 2007) or negatively correlated (Kanapaux & Child, 2011; Silva & Mosimane, 2012) with participation in wildlife conservation.

Most public goods experiments examining the proportion of endowments contributed by participants in a heterogeneous environment have found that *high*-endowment players contribute a *lower* proportion of their endowments than do *low*-endowment players (Buckley & Croson, 2006; Cardenas et al., 2002; Chan et al., 1996; Cherry et al., 2005; Hargreaves Heap et al., 2016; Kingsley, 2016; Rapoport & Suleiman, 1993; Visser & Burns, 2015). However, at least two studies found no significant difference between players of different endowment levels regarding the *absolute* amount of endowments contributed to a collective pool (Hofmyer et al., 2007; Seçilmiş & Güran, 2012). These experiments differ in design from ours, in that our design requires a binary decision rather than a continuous contribution decision, and it is, thus, not clear how similar absolute contributions (but lower proportions) in a continuous game translate into contribution behaviour in a binary setting. Furthermore, these papers generally do not explore the likelihood of free-riding behaviour by endowment setting.[10]

While there are competing explanations for the observed behaviour, previous studies have indicated the importance of general contribution expectations and conditional cooperation motivations in explaining differences in behaviour across individuals (Andreoni, 1995; Fehr & Schmidt, 1999; Fischbacher et al., 2001). Translating this to the current experiment, if low-endowment individuals expect high-endowment individuals to be more likely to cooperate, this will increase their proclivity to cooperate as well. In contrast, if high-endowment individuals expect low-endowment individuals to be less cooperative given their endowment constraints, high-endowment individuals will in turn reduce their rate of cooperation. We, thus, hypothesize that

H2. Individual wealth hypothesis: Participants' endowment will be negatively correlated with their likelihood of contributing to collective action.

4.2 | The impact of risk and risk heterogeneity in CBC

We identified no field studies that explicitly examined the potential impact of risk heterogeneity on CBC; rather, the focus has been on the relationship between exposure to HWC and the development of negative attitudes toward wildlife and/or specific wildlife species (Carter et al., 2014; Songorwa et al., 2000; Spiteri & Nepalz, 2006). These negative attitudes may lead to an increase in the killing of wildlife (defecting in our experimental scenario), but the effect of heterogeneous HWC exposure on collective wildlife governance has not been established in the academic literature, suggesting a need for research in this area.

In contrast, there is an extensive experimental literature on risk attitudes and behaviour in the face of risk (for seminal works see, e.g. Holt & Laury, 2002; Tversky & Kahnemann, 1992). The literature studying the effects of risk on collective action success predominantly models risk as a likelihood of common pool resource collapse or other uncertainty about payouts from the public good (Cardenas et al., 2017; Cherry et al., 2005; Fischbacher et al., 2014; Fisher et al., 1995; Gangadharan & Nemes, 2009; Levati & Morone, 2013; Rocha et al., 2020; Théroude & Zylbersztejn, 2019; Turpie & Letley, 2021). These risks are, thus, either collective or homogeneous, unlike in the current experiment where risks are heterogeneous and manifest at the individual level. We, thus, derive predictions from general risk behaviour observed in the literature rather than these collective action studies.

It is widely established that individuals are predominantly risk averse (Holt & Laury, 2002) although this may be dependent on reference points—in other words, whether individuals perceive potential outcomes as relative gains or losses (Kahneman & Tversky, 1979; Tversky & Kahnemann, 1992). In conjunction, individuals become less likely to take a gamble as expected returns from the gamble decreases or the risk of loss increases. In our experiment, we, thus, expect high-risk individuals to be less likely to cooperate compared with individuals facing a lower risk of private losses if they cooperation.

The tendencies of individuals faced with risk have implications for group behaviour in the presence of risk heterogeneity. Combining risk aversion and conditional cooperation provides reason to believe that risk heterogeneity will lead to less cooperative behaviour. Studies suggest that about 50% of individuals will only cooperate if others do so as well (Fischbacher et al., 2001; Frey & Meier, 2004), so a decline in cooperation by high-risk individuals may drive a corresponding drop in cooperation by those facing lower risks. Thus,

H3. Risk heterogeneity hypothesis: The presence of risk heterogeneity will reduce collective action at the group level compared with homogeneous risk settings.

H4. Individual risk hypothesis: Increased risk of loss will negatively impact the likelihood that individuals participate in collective action.

4.3 | The Interaction of wealth and risk

While there are no studies on the interaction effect between wealth and *private* risk heterogeneity,[11] there is evidence that wealth and risk effects interact. As mentioned above, risk attitudes change depending on reference points. Prospect theory (Kahneman & Tversky, 1979; Tversky & Kahnemann, 1992) conjectures that individuals are loss averse and, thus, more risk averse when they perceive outcomes as losses. We use this insight to motivate a group-level heterogeneity interaction hypothesis. Individuals receive at least some utility from relative wealth or income compared with their peers (Clark et al., 2008). This places high-endowment individuals into the domains of losses because any loss in income could result in lower-endowment individuals catching up or overtaking them in terms of relative wealth. In contrast, low-endowment individuals are more likely to view outcomes as gains because of the possibility of catching up to their peers. This implies that higher-endowment individuals will be more risk-averse than low-endowment individuals. This effect will be more evident in high-risk settings, where differences in risk attitudes can be observed, than in lower-risk settings, where the lower stakes mean there is less opportunity for low-endowment individuals to catch up. This implies:

H5a. Heterogeneity interaction hypothesis: Groups with high-endowment/low-risk and low-endowment/high-risk individuals (HET UNBAL) will be more cooperative than groups with high-endowment/high-risk and low-endowment/low-risk individuals (HET BAL).

Arguably, the converse hypothesis is also justified. Behaviour predicated on reference points critically relies on how individuals perceive their situation. High-endowment individuals, given that they are already financially better off than low-endowment individuals, may operate within the domain of gains (as opposed to losses proposed above) because any benefit from the risky action is seen as a means to expand their financial lead rather than allowing others to catch up if a loss occurs. Consequently, they may exhibit more risk seeking behaviour. In contrast, low-endowment individuals may perceive the risky action as potentially causing them further fall behind and, thus, feel themselves operating in the domains of losses, which results in greater risk aversion. Thus, we formulate the following competing hypothesis:

> **H5b.** Heterogeneity interaction hypothesis: Groups with high-endowment/high-risk and low-endowment/low-risk individuals (HET BAL) will be more cooperative than groups with high-endowment/low-risk and low-endowment/high-risk individuals (HET UNBAL).

5 | RESULTS

5.1 | Risk preferences

In Stage 1, approximately 90% of the participants evidenced the expected linear risk tolerance, consistently selecting the probabilistic payout at lower guaranteed payouts (or always/never selecting it) and, at a certain guaranteed payment value, switching to consistently selecting guaranteed payments thereafter. However, 16 participants did not have evidence of linear risk preferences.[12] To avoid issues of non-linear risk preferences, the responses for Stage 1 were coded to reflect the total number of decisions in which the participants selected the probabilistic outcome. Subjects had a mean score of 4.01 on this measure of risk tolerance (with a maximum risk tolerance of 10 and a minimum risk tolerance of 0), suggesting slight risk aversion (consistent with risk aversion observed by Holt & Laury, 2002). We use these data to control for differing risk attitudes across experimental groups.

5.2 | Overview

Similar to other social dilemma experiments (Chaudhuri, 2011; Zelmer, 2003), groups cooperated more than Nash equilibrium predictions, indicating some willingness to overcome the collective action problem posed. As expected, cooperation rates varied considerably across treatments and periods, ranging from over 70% cooperation rate to less than 30% (see Figure 1 for details). Cooperation tended to decrease over time but did not result in zero cooperation. Overall, groups in the single heterogeneity treatments (HET WEALTH and HET RISK) tended to be less cooperative than groups in the homogenous treatment. While the HET BAL treatment performed around or below the homogenous treatment, the HET UNBAL groups cooperated at similar or greater rates than the homogenous treatment groups.

A group-level analysis, however, obscures the variation in cooperative behaviour within the treatment groups. Figure 2 displays the rate of cooperation of individuals of different risk and wealth types. In the single heterogeneity treatments, there is little difference in the rate of cooperativeness between subjects with different endowments (Figure 2a, black lines) but subjects facing different risks exhibit slightly different proclivities to cooperate (Figure 2a, red lines). The difference is more striking in the HET BAL and HET UNBAL treatments (Figure 2b). Subjects facing higher risks (dashed lines) are considerably less likely to cooperate than subjects in the same treatment facing lower risks (solid lines of the same colour). This suggests a wealth and risk interaction

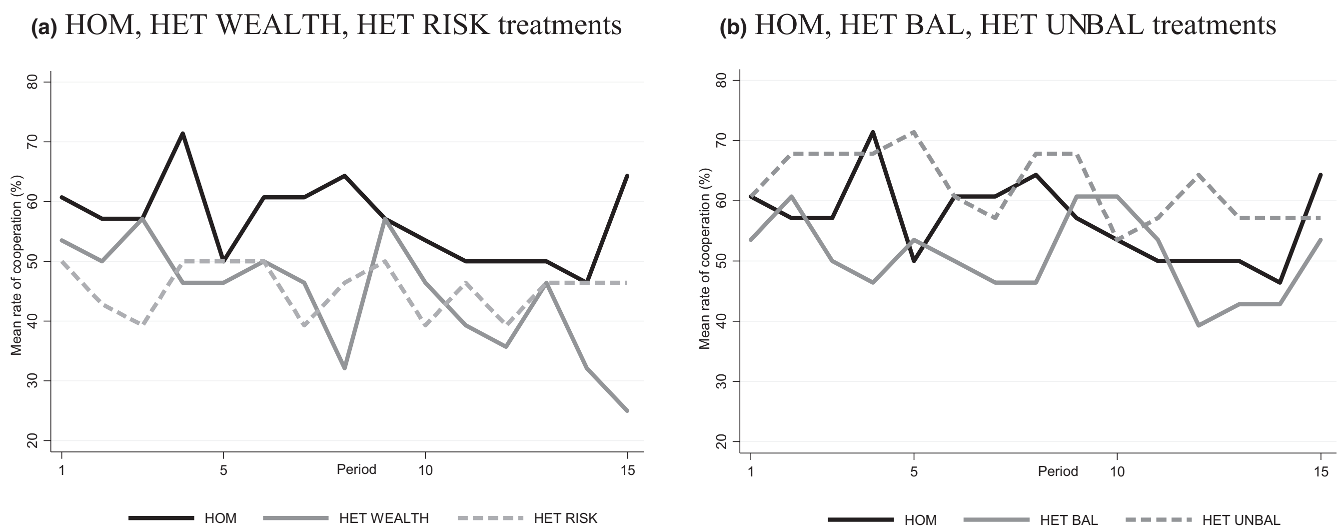

FIGURE 1 Mean rate of cooperation. (a) HOM, HET WEALTH, HET RISK treatments. (b) HOM, HET BAL, HET UNBAL treatments. *Mean rate of contribution* refers to the percentage of individuals cooperating within each group in each period, averaged across groups in each treatment. Nash equilibrium predicts 0% cooperation.

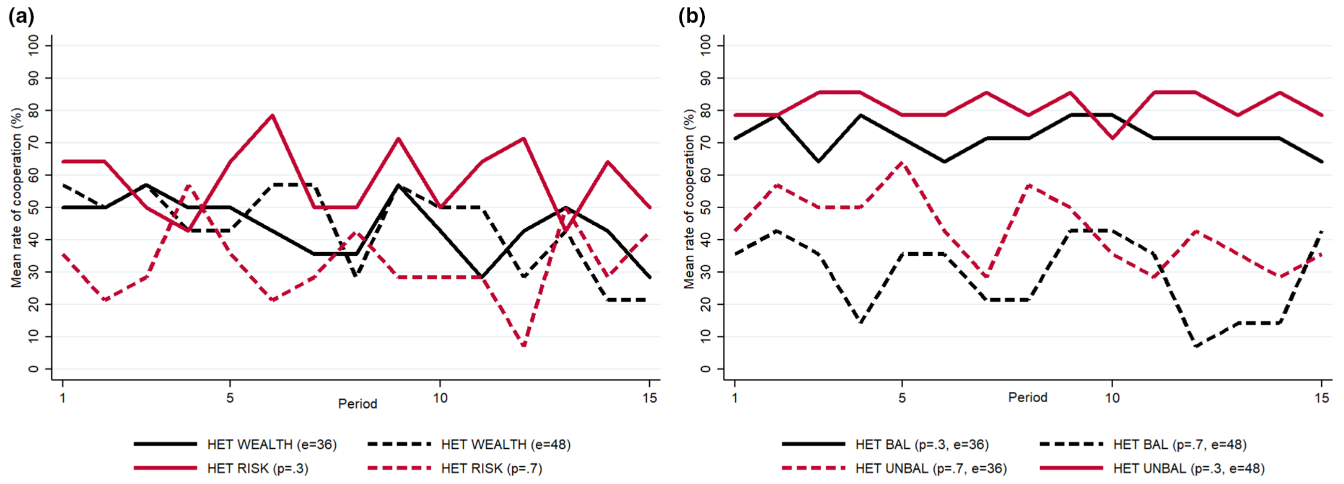

FIGURE 2 Mean rate of cooperation at the individual level. (a) HET WEALTH, HET RISK treatments. (b) HET BAL, HET UNBAL treatments. *Mean rate of contribution* refers to the percentage of individuals of a given incentive type cooperating within group in each period, averaged across groups in each treatment. Nash equilibrium predicts 0% cooperation.

effect. We expand on these observations in the statistical analysis below.

5.3 | Group results—Heterogeneity *type* matters

Result 1. Wealth heterogeneity significantly reduces the likelihood of full cooperation.

Result 2. Groups facing risk heterogeneity are less likely to cooperate fully than homogenous groups, but this difference is not significant once accounting for risk preferences and previous period's contribution decisions.

Result 3. Multi-dimensional heterogeneity can have diverse effects. When low-wealth individuals face high risk and high-wealth individuals face low risk, cooperation levels are similar to those in homogeneous groups. Groups with low-wealth/low-risk and high-wealth/high-risk, on the other hand, are significantly less likely to cooperate compared with homogenous groups.

We conducted a random-effects ordered logit regression with error terms clustered at the group level (Table 2, Model 1) to account for the categorical nature of the dependent variable (0–4 individuals cooperating) and the panel structure of the data, including possible correlation of the error term within groups. We included dummy variables for the treatments to determine significant differences in cooperation behaviour across treatments.

Results suggest that treatments did not significantly change the likelihood of one additional group member investing in the group project.[13] However, this lack of significance could be the result of nonlinear treatment effects across different dependent variable categories (i.e. a violation of the parallel regression assumption, underlying the ordered logit analysis, see for example, Williams, 2016). In other words, ordered logit assumes that the magnitude by which a treatment effects the likelihood of an additional person cooperating is the same whether that person is the first, second, third or fourth group member. Williams (2016) observes that the parallel regression assumption is often violated and, indeed, a Brant test confirmed that this was the case here.[14]

We accounted for the violation by recoding the dependent variable as 1 if there was full cooperation (i.e. all group members invested in the group project), 0 otherwise, and using random effects logit regressions (Models 2–4 in Table 2).[15] We focused on full cooperation (rather than alternative categorizations of success or failure in a binary logit model) because that outcome represents the social optimum in the social dilemma presented. We included the following independent variables: (i) treatment dummies; (ii) period—to account for cooperative decay observed in Figure 1; (iii) lagged group investment—the number of individuals cooperating in the previous round to account for group dynamics; (iv) mean risk preferences of group members—to control for possible risk attitude variation across treatments and (v) a single-group session dummy—while most subjects were in the lab with one or two other groups, on some occasions we only had enough volunteers to form a single group for that testing session; controlling for this variable accounts for a lack of anonymity about other group members that might have encouraged greater cooperation.

From Models 2 through 4 (Table 2), we find that unidimensional heterogeneity reduces the likelihood of full cooperation, although this effect is only significant for wealth heterogeneity. We, thus, find support for the Wealth Heterogeneity Hypothesis (H1) but must reject the Risk Heterogeneity Hypothesis (H3). Multidimensional heterogeneity has a more nuanced impact on the likelihood of full cooperation. When high risk is paired with high

TABLE 2 Group investment decisions.

Grouped investment decision[a]	# of investments (1)[b]	Full investment[c] (2)	(3)	(4)
HET WEALTH	0.304[d]	0.195*	0.324***	0.332*
	(0.264)[e]	(0.060)	(0.040)	(0.082)
HET RISK	0.334	0.106*	0.293	0.388
	(0.299)	(0.093)	(0.186)	[0.308]
HET BAL	0.573	0.100**	0.174**	0.111***
	(0.599)	(0.022)	(0.017)	(0.001)
HET UNBAL	1.739	0.906	0.835	1.039
	(0.613)	(0.912)	(0.724)	(0.951)
Period			0.914**	0.908**
			(0.012)	(0.0010)
Lagged group investment			2.161**	1.841*
			(0.031)	(0.078)
Mean risk preferences				2.079*
				(0.076)
Single-group session				2.900*
				(0.058)
Observations	525	525	490	490
# of groups included	35	35	35	35
# of sessions included	17	17	17	17
# of periods included	15	15	14	14
χ^2	5.12	9.01*	29.27***	52.55***

[a]Regressions are random effects panel (ordered—Model 1) logit models with errors clustered at the group level.

[b]Model 1 dependent variable: # of contributions in the group (0–4).

[c]Models 2–4 dependent variable: full contributions = 1, otherwise 0; about 10% of group investment instances are fully cooperative (see Figure A1 for a histogram of group investment levels).

[d]All results are displayed as odds ratios.

[e]*p*-values in parentheses.

**p*-value ≤0.1.; ***p*-value ≤0.05.; ****p*-value ≤0.01.

endowments and low risk is paired with low endowments (HET BAL), groups are significantly less likely to cooperate fully than homogenous or multidimensional heterogeneity (HET UNBAL) groups (where high-risk individuals receive high endowments and vice versa).

In support of the first heterogeneity interaction hypothesis (H5a), the highest likelihood of full cooperation is in homogenous groups and heterogeneous groups where poorer individuals are facing higher risks of losses. Groups with high-endowment/high-risk and low-endowment/low-risk individuals (HET BAL) are significantly less cooperative than homogeneous and HET UNBAL groups, indicating that we must reject Hypothesis 5b. The results are suggestive of high-endowment individuals operating in the domains of losses, while low-endowment individuals operate in the domain of gains. These effects are robust to changes in model specifications (contrast Models 2–4). This finding suggests that the type and distribution of heterogeneity are important to understanding collective action success.

5.4 | Results for individual behaviour

Result 4. When controlling for treatment types, there is no statistical difference in cooperation behaviour between high- and low-endowment individuals, implying that reductions of cooperativeness among wealth heterogeneous groups arise from level effects (i.e. both high- and low-wealth individuals have a reduced willingness to cooperate).

Result 5. Risk is a strong driver of cooperative behaviour, but these effects are moderated by wealth. Faced with low risk, high-wealth individuals are more likely to be cooperative than low-wealth individuals. In settings with high risk this proclivity is reversed—low-wealth individuals are more likely to contribute compared with high-wealth individuals.

TABLE 3 Individual investment decisions.

Individual investment decision[a]	All treatments (5)	(6)	(7)	HET BAL & UNBAL (8)	(9)
Low risk	4.208***[b]	1.037	1.289		
	[0.006][c]	[0.961]	[0.708]		
High risk	0.377**	0.213**	0.287**		
	[0.032]	[0.029]	[0.033]		
Low endowment	1.070	0.384	0.450		
	[0.886]	[0.176]	[0.230]		
High endowment	1.026	0.396	0.414		
	[0.955]	[0.213]	[0.179]		
Low risk × low endowment		6.658*	4.530	20.21***	11.75***
		[0.082]	[0.117]	[0.000]	[0.000]
Low risk × high endowment		18.85***	14.65***	63.23***	42.26***
		[0.006]	[0.004]	[0.000]	[0.000]
High risk × low endowment		5.254*	4.111	3.073*	3.738**
		[0.095]	[0.105]	[0.089]	[0.029]
High risk × high endowment		1.759	1.453		
		[0.539]	[0.634]		
Lagged investment decision			1.341		3.141***
			[0.223]		[0.001]
Lagged loss			0.963		0.607
			[0.856]		[0.157]
Lagged # of others investing			1.030		0.935
			[0.718]		[0.653]
Risk preferences (total risk)			1.362***		1.199
			[0.001]		[0.350]
Single-group session			1.760		3.000**
			[0.163]		[0.015]
Period			0.954***		0.948*
			[0.001]		[0.066]
Observations	2100	2100	1960	840	784
# of groups included	35	35	35	14	14
# of sessions included	17	17	17	7	7
# of periods included	15	15	14	15	14
χ^2	40.46***	87.82***	154.6***	77.96***	219.1***

[a]Regressions are random effects panel logit models with errors clustered at the group level.
[b]All results are displayed as odds ratios.
[c]*p*-values are in parentheses.
**p*-value ≤0.1.; ***p*-value ≤0.05.; ****p*-value ≤0.01.

We now turn to analysing the variation in individual behaviour observed in Figure 2. We use random effects logit regressions to assess how incentive structures and other characteristics affect the likelihood of cooperating (the dependent variable is 1 if an individual invests in the group project and 0 otherwise). This model specification allows us to account for subject and group effects over time. We cluster the error term at the group level to control for possible correlation among error terms within groups. Results are displayed in Table 3.

Models 5 through 7 use data from all treatments and use medium endowment and medium risk (i.e. the values used for homogeneous endowment and risk treatments, respectively) as the reference category. Models 8 and 9 use data from only the multidimensional heterogeneity treatments (HET BAL and HET UNBAL) to test for individual-level interaction effects between wealth and risk (i.e. to explain why low risk in these multidimensional groups is only significant in the low-endowment setting). Models 8 and 9 use high endowment, high risk as the reference category.

We test for robustness of these results by including different combinations of the following independent variables: (i) the individual's investment decision in the prior round, (ii) whether the individual experienced a loss in the previous period, (iii) how many group members contributed in the previous round—to account for conditional cooperation, (iv) the individual's risk preference, (v) whether the individual was in a single-group session and (vi) period.[16]

Models 5–7 indicate that high and low endowments have no significant impact on the likelihood of those individual cooperating compared with individuals receiving medium endowments and there is no significant difference between the high and low endowment coefficients. We, thus, reject the individual wealth hypothesis (H2), which relied on the linear public goods literature to predict that high-endowment individuals would contribute less toward the group and vice versa.

Risk, on the other hand, appears to be a strong driver of cooperation behaviour. Across the three model variants (Models 5–7), individuals facing a high risk of loss were between 62% and 78% less likely to contribute than those facing medium risk. By contrast, individuals with low risk were over four times more likely to contribute in Model 5, although the coefficient loses both magnitude and significance in Models 6 and 7. This loss of significance, however, is likely an artefact of a varying effect of the interaction between low risk and endowment, which we explore in our discussion of Models 8 and 9, below. There is, thus, evidence to support the individual risk hypothesis (H4) although the effect is moderated by wealth.

Compared with those with high-risk/high-endowment, individuals in other multidimensional pairings (high-risk/low-endowment, low-risk/high-endowment and low-risk/low-endowment) were significantly more likely to contribute. Models 8 and 9 indicate that low risk has a particularly strong effect on cooperation behaviour when paired with high endowments. While all individuals with *low risk* were more likely to cooperate than their high-risk/high-endowment comparators, Model 9 suggests that low-risk/high-endowment individuals were over 42 times more likely to contribute compared with the approximate increase of 12 times for the low-risk/low-endowment groupings.[17] An interaction effect also exists for individuals facing *high risk* in that those individuals may be more cooperative when they also have *low endowments* (over three times as likely to cooperate in our experiment than high-risk/high-endowment individuals).

6 | DISCUSSION

Our common-pool resource experiment, examining the impact of risk and wealth heterogeneity on collective action, resulted in four significant findings. First, unidimensional heterogeneity appears to depress group cooperation. In the presence of either wealth or risk heterogeneity (but not both), groups may be less likely to cooperate to collectively manage wildlife. Second, risk exposure may be a significant driver of individuals' likelihood to cooperate. While wealth heterogeneity decreased inclination to contribute by *both* wealthy and comparatively poorer individuals, risk heterogeneity resulted in significantly different cooperation behaviour across individuals with different risk exposures.

Third, our experiments suggest that the presence of multidimensional heterogeneity may vary in its impact, with some *groups* being *more* likely to exhibit cooperative behaviour than groups facing unidimensional heterogeneity. This is particularly the case when groups are comprised of wealthy members less prone to risk and comparatively poorer members exposed to greater risk. These types of groups are similarly (or more) cooperative to homogeneous groups. Fourth, and finally, risk and wealth may interact to affect collective action behaviour by disparately impacting the decision-making of categories of individuals. Individuals facing *low* risks are more likely to contribute when they have *greater* endowments, while those facing *high* risks are more likely to contribute when they have *lower* endowments. While this finding is specific to settings of wealth and risk heterogeneity, this interaction may have implications for strategies to encourage collective action among different groups and suggests a need for more research exploring the broader relationship between wealth and risk in social dilemmas.

Given the apparent novelty of our focus on the interrelation between economic and risk heterogeneities, it is perhaps not surprising that field-based studies provide little relevant analyses. Nevertheless, our findings do find some initial support from the field. Regarding our finding that economic heterogeneity undermines collective action, researchers and practitioners have observed the potential negative impact of such heterogeneity on real-world CBC efforts (Kerapeletswe, 2005; Thakadu, 2005). Additionally, our findings regarding the significance of individual risk levels, and the corresponding need to incentivize high-risk individuals in the presence of unidimensional heterogeneity, are bolstered by the results of studies by Kahler et al. (2013) and Gargallo (2021). In the former study, field research in two Namibian conservancies found that poaching was most likely to occur in areas where residents perceived the greatest risk of HWC, suggesting that those experiencing greater risk may have more incentive to undermine collective action by using lethal deterrence (Kahler et al., 2013). The latter study recognizes the additional burdens faced by higher-risk households and suggests the possible appropriateness of differentiated direct payouts based on risk exposure (Gargallo, 2021).

Our findings regarding the interplay of risk and endowment on individual and group contributions also find some preliminary support in the academic literature. Two studies of Namibian conservancies found that poorer residents were more likely to seek formal conservancy membership (Kanapaux & Child, 2011; Silva & Mosimane, 2012), even when those residents faced higher risks of predation (Kanapaux & Child, 2011). While formal membership is generally necessary for individuals to share in the distribution of direct benefits, residents can (and do) refuse to become members because of philosophical differences with their conservancy's ideology (Silva & Mosimane, 2012). Therefore, by seeking to become members, these individuals are at least affirming their support for, and intent to comply with, their conservancies' efforts at wildlife conservation.

It is important to reiterate that the complex nature of human–wildlife interactions and related collective resource management cannot be captured by a single experimental study. We believe that the described game, upon which our experiment is based, mimics critical aspects of the collective action problem underlying community resource management in the presence of HWC, but it does not account for interrelated risk structures that may be prevalent in these scenarios and that may impact behaviour. For instance, a field experiment by Cardenas et al. (2017) suggests that collective (or interrelated) risks affect behaviour differently than private (i.e. independent) risks depending on the rate of market integration of a community.

Additionally, decision-making does not happen in a vacuum but is instead influenced by a mélange of cultural, historical, institutional, environmental and economic factors. Our findings are drawn from a controlled experiment involving individuals attending a university in the United States. Individuals from other locations and/or backgrounds may perceive or react differently to wealth or risk (and/or the heterogeneities thereof) when faced with the collective action dilemma modelled in our experiment (e.g. Nyhus, 2016). Additionally, individuals in field experiments (and perhaps, by extension, those engaging in normal interactions in the field) tend to display more pro-social behaviour than do individuals in the lab (Turpie & Letley, 2021). Our goal was to create a baseline experiment exploring the interplay of wealth and economic heterogeneities in a CBC environment. Consequently, these added complexities are beyond the scope of the current study. We emphasize the limitations of policy recommendations derived from individual experimental studies, and we encourage future follow-up experimental and field studies to more fully determine the role of risk and economic heterogeneities in collective wildlife resource management.

These caveats notwithstanding, our findings suggest that individual risk levels, economic heterogeneity and the interaction between risk and economic heterogeneities have the potential to significantly impact the real-world success of CBC programs. At the broadest level, conservation policies need to consider these heterogeneities (and the existence of heterogeneity more generally) rather than merely copying policy approaches that were successful elsewhere. Policymakers would be best served to first consider the makeup of the individual communities of interest and to adopt a policy that has the flexibility to accommodate the impacts (both good and bad) of the communities' various forms of heterogeneities. For instance, communities with significant wealth heterogeneity might need to encourage all members to increase cooperation, while communities with risk heterogeneities might benefit from targeting policies to members most prone to wildlife depredation to encourage collective action.

More specifically, one key implication of our findings involves low-wealth, high-risk community members. These individuals often border core wildlife areas, and their respective risk exposure and vulnerability means that they may have the greatest incentive to engage in preventative or retaliatory killing of wildlife. However, our research suggests that these individuals may also be more motivated to support CBC efforts (at least compared with their high-wealth counterparts) *if* they receive meaningful benefits from their participation. Direct, regular and reliable monetary payments may represent the opportunity for them to reduce their vulnerability through the diversification of their income sources (e.g. Salerno et al., 2020). While it is outside the scope of our experiment, existing research suggests that indirect (i.e. community-level) payouts are unlikely to have the same impact because these individuals are often geographically remote and therefore not as able to fully benefit from centrally located improvements such as schools, roads or boreholes (see, e.g. Abebe et al., 2020).

AUTHOR CONTRIBUTIONS

Stefan Carpenter conceived of this study, and both authors contributed to its design and focus. Ursula Kreitmair collected the data and she and Stefan Carpenter collaboratively analysed the data. Stefan Carpenter and Ursula Kreitmair co-wrote the manuscript. Both authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used for this study are archived in the Harvard Dataverse Repository https://doi.org/10.7910/DVN/UJLPFU.

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ENDNOTES

[1] We acknowledge that (1) the assessment of any wildlife governance approach necessarily involves both efficacy and value concerns, underlying 'ethical commitments' guide the selection of criteria by which success is measured, and the protection of wildlife represents only one possible measure of CBC success (Adams & Hulme, 2001; Miller et al., 2011); and (2) a vigorous debate exists regarding whether, more broadly, conservation efforts should primarily focus on anthropocentric or ecological goals. Without choosing a side on any of these issues, this study focuses on wildlife protection outcomes because the conservation of species is one criterion by which the success of CBC programs can be evaluated by policymakers and stakeholders.

[2] There is evidence that non-lethal approaches may sometimes be better at preventing HWC but lethal approaches are often perceived by participants as being more effective (Massé, 2016; McManus et al., 2015), and we rely on this perception in designing our experiment. Further, we recognize that CBC participants may be able to use a combination of lethal and non-lethal approaches. However, we assume for purposes of this experiment that unsanctioned lethal approaches (i.e., not ones involving trophy hunting or state-sanctioned removal of 'problem animals') are undesirable

from a sustainable governance standpoint. Further, CBC programs largely prohibit participants from engaging in the preventative or retaliatory killing of wildlife. Therefore, we designed our experiment to present a dichotomous choice of engaging in purely non-lethal prevention or employing the use of lethal methods (the latter of which would include combining lethal and non-lethal deterrence approaches).

[3] Standards assumptions of rational, risk-neutral, self-regarding, payoff-motivated actors apply.

[4] Note, this assumes independent probabilities of experiencing a loss due to human-wildlife conflict.

[5] Full instructions are available in the Appendix.

[6] Participants received payoffs in terms of ECU. At the end of the experiment these payoffs were exchanged into US dollars at a rate of 65 ECU = $1.

[7] The role of communication in successful collective action is well established (e.g., Ostrom, 2006; Turpie & Letley, 2021), and it is possible that allowing communication may have impacted our findings in this experiment. But, because of the lack of prior studies into the interplay of economic and risk heterogeneities, we prohibited communication so that we could establish a baseline set of findings. We encourage the inclusion of communication into future such studies to explore what role that variable may have in facilitating cooperation in a multi-heterogeneous environment.

[8] While the continuous linear public goods game differs from the binary game used in this study, the incentive structures are similar (Isaac & Walker, 1988) and the continuous linear public goods literature is sufficiently expansive to have studied endowment effects. The main difference to the game presented here is that continuous linear public goods games allow individuals to contribute toward the group resource in an amount ranging from 0 to the entirety of their endowment, while our game comprises a binary decision.

[9] Hereafter, endowment and wealth heterogeneity will be used interchangeably, unless otherwise noted.

[10] Two person prisoner's dilemmas studying heterogeneity do so in terms of asymmetric payoffs (Ahn et al., 2007; Beckenkamp et al., 2007; Sheposh & Gallo Jr, 1973) rather than endowment, meaning that high earning individuals benefit more from cooperation. These are different incentive structures than endowment heterogeneity presented in the experiment here and their predictions are thus not transferable to the current experiment.

[11] We have identified only one study examining the interaction between endowment and risk. However the study is a simulation (Abou Chakra et al., 2018), and models risk as the *collective* risk of a resource collapse (climate change in this case). The study suggests that privileged groups (Olson, 1965) with greater contribution ability and deriving greater benefits from the collective good are more likely to contribute when the risks of resource collapse are significantly high. Given the different risk structure modelled in that study, the results provide little insight here.

[12] This group of participants intermittently switched their responses; some used a pattern (alternating selecting the certain or probabilistic payouts) whereas other choices appear to be random.

[13] Note that we report our results using Odds Ratios.

[14] The Brant test was conducted using a pooled version of Model 1. Results indicate significant ($p \le 0.1$) differences across the binary logit regressions for all treatments. The null hypothesis of the Brant test is that there is no violation of the parallel regression assumption.

[15] We opted for this approach over generalized ordered logit models given the complexity added by the panel structure of the data. The resulting analysis is parsimonious and eases interpretation.

[16] For additional information on the rationale for including these control variables see the discussion in the group results section.

[17] Using Wald tests to compare coefficients of the two multidimensional low risk groups—*Low Risk × Low Endowment* and *Low Risk × High Endowment*—there is a significant difference between cooperative behaviour in Model 9—$p = 0.0848$, but not Model 8—$p = 0.2040$.

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SUPPORTING INFORMATION

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

Appendix S1. Participant instructions and stage 1 risk tolerance decisions.

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