Sanctioned Quotas Versus Information Provisioning for Community Wildlife Conservation in Zimbabwe: A Framed Field Experiment Approach

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30 October 2020

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ABSTRACT

We investigate the behavioural responses of natural common-pool resource users to three policy interventions – sanctioned quotas, information provisioning, and a combination of both. We focus on situations in which users find utility in multiple resources (pastures and wild animal stocks) that all stem from the same ecosystem with complex dynamics, and management could trigger a regime shift, drastically altering resource regrowth. We performed a framed field experiment with 384 villagers from communities managing common-pool wildlife in Zimbabwe. We find that user groups are likely to manage these natural resources more efficiently when facing a policy intervention (either a sanctioned quota, receiving information about a drastic drop in the stocks' regrowth below a threshold, or a combination of both), compared to groups facing no intervention. A sanctioned quota is likely to perform better than providing information about the existence of a threshold. However, having information about the threshold also leads to higher efficiency and fewer depletion cases, compared to a situation without any intervention. The main contribution of this study is to provide insights that can inform policymakers and development practitioners about the performance of concrete and feasible policy interventions for community wildlife conservation in Southern Africa.

Key Words: common-pool resources, behavioural experiments, regime shifts, information, sanctioned quota, thresholds, Southern Africa, elephants

JEL Codes; C93, D01, D02, Q57, Q58

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1. INTRODUCTION

Imagine a local African community with livestock feeding on pastures (savanna grasslands), which gains revenues from tourism around wild elephants. These two activities are linked because wild elephants' feeding habits prevent bush encroachment, thus maintaining a healthy stock of pastures critical for livestock. The local community manages the elephants through community hunting, which can substantially influence their reproduction. Below some threshold, the elephant population would have difficulties to reproduce, a phenomenon called depensation. Too few elephants would then result in bush encroachment and fewer pastures for livestock. This scenario could be pictured as a drastic shift between two 'regimes' in the local ecosystem, where the pasture yielding grasslands – rich in elephants – switches to bushy area – with few elephants and fewer ecosystem services. The latter regime is difficult to reverse.

We investigate here the effects of three types of policy interventions on the sustainable management of natural resources in a community wildlife conservation context in Southern Africa. In such a context, common-pool resources (CPRs) are often coupled, simply because they are produced in the same ecosystem, which exhibits complex dynamics: multiple species interact with each other and their environment, sometimes leading to drastic changes, such as regime shifts (Biggs et al. 2012), as for elephants and pastures used for livestock grazing. What kind of policy intervention can support sustainable management of CPRs in such a context? Should the authorities inform communities about stock dynamics and potential regime shifts? Should they instead introduce a quota for the elephant stock, which, if exceeded, would trigger a sanction? Or should they use a combination of both interventions?

Ecosystem regime shifts – large, abrupt and potentially persistent changes in the structure and dynamics of an ecosystem – can occur when values of key ecosystem variables cross a threshold (Biggs et al. 2012). They often substantially change the availability of ecosystem services that human well-being depends upon (Biggs et al. 2012; Rocha et al. 2015). Regime shifts are costly, often difficult to anticipate, and sometimes impossible to reverse because the pathways for degradation and recovery differ from each other (Folke et al. 2004; Scheffer and Carpenter 2003; Suding and Hobbs 2009).

Indigenous communities in Southern Africa manage a substantial share of CPRs, such as wildlife, forests, rangelands, and water resources. Without sound CPR institutions or effective external policies, they risk overexploitation. Seventy per cent of households in the region live in marginalized rural areas and depend heavily on natural resources under communal tenure for survival (DeGeorges and Reilly 2009). They are thus particularly vulnerable to regime shifts. Unfortunately, such shifts are hard to detect early for example because elephants reach maturity slowly, so people perceive environmental change only long after it has occurred.

This study is motivated by a CPR dilemma where collective action is required to manage several CPRs produced in one ecosystem in a sustainable manner and to avoid regime shifts. We focus on CPRs because their joint utilization can present severe management and coordination challenges and because they are common in developing countries. In this study both pastures and elephants are CPRs and benefit the community, but for simplicity, individual resource users only influence the elephant population directly through hunting. Poor management could trigger a regime shift leading to an abrupt and persistent change in the growth rates of both CPRs. We use a framed field experiment with communities managing wildlife under the *Communal Areas Management Programme for Indigenous Resources*

(CAMPFIRE)[1] in Zimbabwe. We compare a policy intervention in the form of a quota (sanctioned with costly punishment) with an intervention that informs resource users about a potential regime shift and an intervention where both instruments are combined.

Comprehending human behaviour in relation to regime shifts is imperative, particularly in the context where livelihoods of poor rural communities depend heavily on the associated ecosystem services. However, despite an abundance of case studies of different types of regime shifts across the globe (see e.g., www.regimeshifts.org), there is limited empirical research on humans' behavioural responses to regime shifts that affect the flow of ecosystem services. This research is dominated by experimental approaches because it is challenging to observe how exactly behaviour changes in relation to a regime shift in the field. Most of these studies use controlled behavioural experiments in the form of CPR games (Lindahl et al. 2021).

The effects of ecosystem regime shifts on individual and collective behaviour has been studied in the laboratory (lab) with students as participants (Schill et al. 2015; Lindahl et al. 2016a; Lindahl et al. 2016b; Maas et al. 2017; Ahsanuzzaman et al. 2022), and in the field with small-scale fishers in Colombia (Schill and Rocha 2019; Rocha et al. 2020) and Thailand (Lindahl and Jarungrattanapong 2022), or communal farmers in Namibia and South Africa (Prediger et al. 2011). None of these experiments have considered the effects of ecosystems regime shifts in a context relevant for community wildlife conservation, a context in which the resources coming from the same ecosystem are coupled. Each of the two linked CPRs' (pastures and elephants) growth rates can drop dramatically below some threshold stock levels (depensation). Passing the thresholds triggers an ecosystem regime shift (bush encroachment). By doing so, our approach builds on the study by Lindahl et al. (2016a), who studied behavioural responses to a drastic drop in one CPR.

Moreover, there is limited understanding of the relative effectiveness of institutional features such as sanctioned quotas[2], information about resource dynamics or the combination of both to influence sustainable outcomes in a regime shift context. While there are some insights from a lab context (Lindahl et al. 2016b), we are not aware of any field experiment that tests different interventions with participants from communities for which ecosystem regime shifts are of serious concern.

2. THE STUDY AREA

2.1 CAMPFIRE communities

This study focuses on local communities involved in wildlife conservation under CAMPFIRE in Zimbabwe. Communities can receive wildlife products and income from trophy hunting under a benefit-sharing arrangement with their respective Rural District Councils (RDCs), who formally hold ownership of the wildlife on their behalf. Individual community members are not permitted to hunt elephants, yet illegal harvesting can occur. This arrangement is expected to generate adequate incentives for CAMPFIRE communities to protect wildlife from poachers

[1] CAMPFIRE is a programme that was initiated by the government of Zimbabwe during the 1980s in order to strike a balance between rural development and conservation by involving local communities in wildlife conservation. By having such an arrangement, it is believed that local communities will have adequate incentives to protect wildlife, while at the same time benefiting through conservation of the resource.

[2] By definition, a sanctioned quota is a quota such that when it is exceeded resource users are punished for failing to obey the rules.

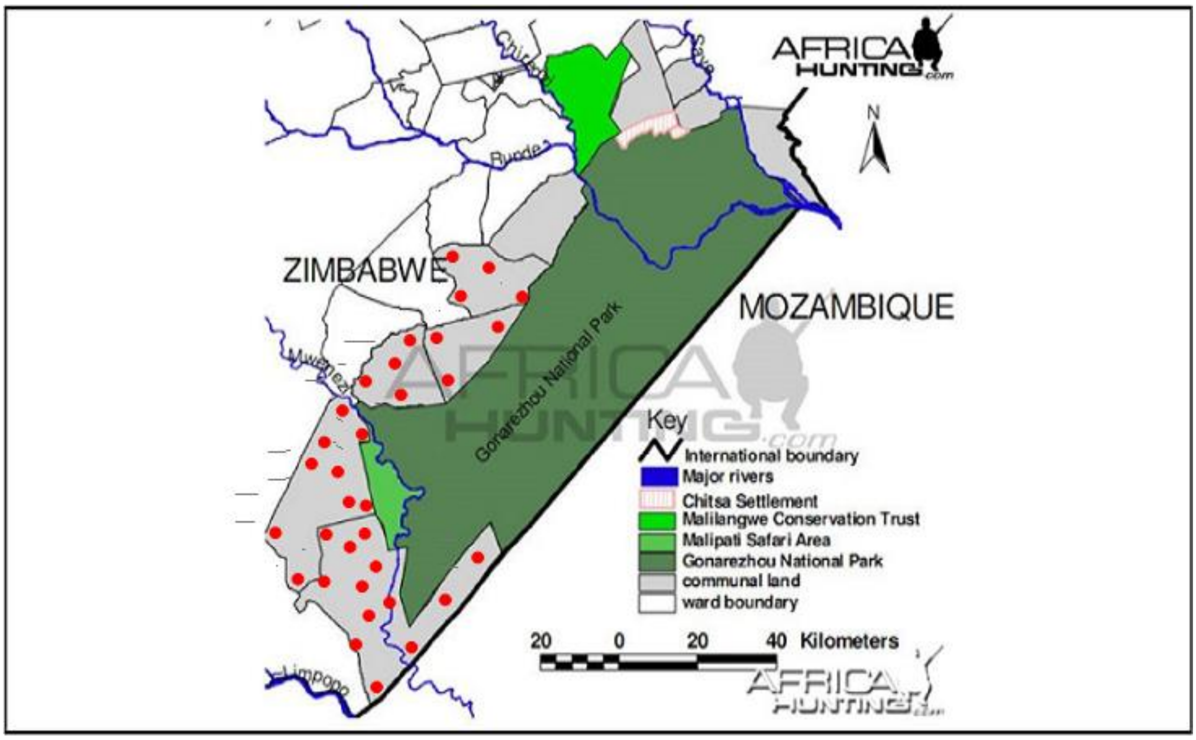
(Murombedzi 1999; Ntuli 2015), while a quota system based on scientific management principles ensures that community harvest is sustainable.

A CAMPFIRE community gathers yearly information about the number of elephants roaming its conservation area[3] to provide evidence for good management when applying for a hunting quota from the national wildlife agency (Ntuli and Muchapondwa 2017). Together with their RDC, communities sell hunting licences to foreign hunters through safari operators. Trophy hunting is the most dominant activity, due to its higher profits compared to other touristic activities.

2.2 Gonarezhou National Park

Gonarezhou National Park (GNP, 5053 km2) forms part of the Great Limpopo Trans-frontier Park linking Gonarezhou with the Kruger National Park in South Africa and the Limpopo National Park in Mozambique. GNP is Zimbabwe's second largest national park. Figure 1 shows the map of GNP, neighbouring conservancy areas and communal areas, and the CAMPFIRE villages[4] that participated in the experiment.

Figure 1: Map of the study area.



Gonarezhou National Park (dark green), CAMPFIRE communities (N = 33) participating in the experiment (red dots), conservancy areas (light green) and communal areas bordering the park (grey). Source: AfricaHunting.com

The park is located between 22°22′S and 31°22′E, in natural region V characterised by arid conditions, thus less suitable for rain-fed agriculture thereby making livestock rearing and

[3] This is a piece of land bordering the national park, commonly referred to as the wildlife buffer zone, which the community is allowed to keep, provided they use it for conservation work (Ntuli and Muchapondwa 2017).
[4] The villages belong to three different CAMPFIRE projects, but they are close to each other and share similar characteristics.

wildlife conservation the two most viable livelihood options (Gandiwa and Kativu 2009; Ntuli and Muchapondwa 2017). CAMPFIRE communities predominantly live from subsistence agriculture (livestock and crop cultivation). The vegetation is a typical semi-arid savanna, dominated by Mopani (*Colophospermummopane*) woodlands mixed with grasslands in some areas and thorn bushes in others (Gandiwa 2011; Gandiwa and Kativu 2009). Although the combination of woodlands and grasslands is the most dominant, shrubs and thorns have invaded the area (Cunliffe et al. 2012).

2.3 The role of elephants in shaping savanna ecosystems

The African elephant is a mega-herbivore. Its activities (for example feeding) and population variations profoundly shape local ecosystems (Western 1989; Pellew 1983). Elephants open up forests and woodlands, thus creating favourable habitats for other species and increasing biodiversity (Zyambo 2015).

However, the elephant population is dwindling due to increased poaching and resulting changes in ecosystem dynamics. Illegal wildlife hunting is one of the biggest threats challenging the existence of elephants in Zimbabwe and CAMPFIRE (Muchapondwa 2003; Ntuli and Muchapondwa 2017). Continued poaching could drive the elephant population to unprecedented low levels, challenging the recovery of the population and possibly triggering a regime shift in the savannah grassland ecosystem, often referred to as bush encroachment[5] (Biggs et al. 2018). Hunting elephants below some threshold might trigger bush encroachment, which reduces grass productivity and hinders cattle from accessing pastures, with substantial negative economic impacts on livestock production (Moleele et al. 2002; Smit 2004). See Annex A.1 for more details on the role of elephants in shaping savanna ecosystems.

3. LITERATURE REVIEW

3.1 Cooperation in the face of thresholds in shared resources

The study is related to a large body of experimental literature on how the existence of a threshold in a shared resource affects cooperation. The experimental context is most commonly a public good provided only if sufficient investment is made (e.g., Bagnoli and Mckee 1991; Rapoport and Suleiman 1993; Marks and Croson 1999; Croson and Marks 2000; Barrett and Dannenberg 2014; Alberti and Cartwright 2016). Alternatively, the context is a CPR, which yields returns only if it is not destroyed by excessive use (e.g., Murphy and Cardenas 2004; Rustagi et al. 2011; Schill et al. 2015; Lindahl et al. 2016a, b; Maas et al. 2017; Ahsanuzzaman et al. 2022). In both contexts, a pre-specified threshold determines whether individuals receive a common reward or avert a common damage through their individual decisions. Recent experimental studies, which examine cooperative behaviour to avert potentially catastrophic climate change also investigate the role of information about thresholds and punishment (e.g., Milinski et al. 2008; Barrett and Dannenberg 2012; Barrett and Dannenberg 2014).

Maintaining cooperation in CPR management entails a dilemma (Rustagi et al. 2010). It is best for the whole group to sustain the resource, but each group member has incentives to consume more, thereby reducing the amount available to others (rivalry), while excluding others from using the resource is difficult (non-excludability) (Ostrom 2003). Unless robust governance institutions facilitate collective action, a "tragedy of the commons" might result (Hardin 1968). Lindahl et al. (2016a, b) and Schill et al. (2015) examined whether more or less tragedies of

[5] See http://regimeshifts.org/item/70-bush-encroachment#more for a detailed description and examples of bush encroachment regime shifts, retrieved November 15, 2022.

the commons can be expected in situations with regime shifts. Our study complements these findings by examining whether knowledge of potential regime shifts could alter the situation in a context where linkages between natural resources exist.

3.2 Regime shifts and policy interventions

Improved (eco)system knowledge is gaining attention among scholars as a possible intervention for stabilizing cooperation in CPRs (Ostrom 2007) and, in particular, those facing potential regime shifts (Schill et al. 2015; Lindahl et al. 2016a, b). Although punishment is widely used, it is generally agreed that resource users can manage CPRs efficiently if good information is provided. The efficacy of these two interventions has been tested in different contexts: different types of resources (Rustagi et al. 2011; Lindahl et al. 2016b), whether punishment is employed in a group setting to foster cooperation in a voluntary contributions mechanism (Masclet et al. 2003) and where a quota is issued by authorities and resource users are required to comply (Lindahl et al. 2016b).

Previous experimental studies also tested different types of information using either a CPR or public goods game, e.g., conveying information about total harvest for the whole group (group behaviour), recommending a level of harvest or contribution or information about the existence of a threshold (e.g., Ostrom and Walker 1991; Lindahl et al. 2016a). Schill et al. (2015) and Lindahl et al. (2016a) demonstrated that if users knew that a regime shift could drastically influence the availability of a valuable resource, they would share more knowledge, which was key to collectively avert the regime shift.

Van Dijk et al. (1999) conducted a lab experiment with students to examine information requirements for resource dilemmas under uncertainty. Their results indicated that when tacitly coordinating choice behaviour, group members tend to rely solely on the environmental information they are certain about. Based on a threshold public goods experiment with undergraduate students, Marks and Croson (1999) experimentally tested the efficacy of a voluntary contributions mechanism for the funding of lumpy public goods in informationally limited settings. The authors found no significant differences in the rate of successful provisions or level of group contributions when subjects had limited vs. complete information about the valuations of others.

The role of punishment in stabilizing cooperation has received considerable attention in the literature (e.g., Masclet et al. 2003; Murphy and Cardenas 2004; Ostrom 2006; Nikiforakis et al. 2010; Casari and Luini 2009; Akpalu and Martinsson 2012). Previous studies used lab and framed field experiments with public goods and CPR games to investigate the relationship between punishment and cooperation. The consensus is that punishment increases cooperation (Casari and Luini 2009; Balliet et al. 2011) but can fail if used sub-optimally (Aquino et al. 2015), thereby requiring the complement of other policy instruments. Information could serve as a policy instrument to either complement or substitute punishment.

The experimental literature also examined the effects of two kinds of punishment institutions: monetary and nonmonetary sanctions. Akpalu and Martinsson (2012) investigated how social ostracism affected harvest in a CPR experiment with young fishers in Ghana. They found that the possibility to ostracise other group members at a cost to the remaining members significantly decreased over-fishing in comparison with a situation where ostracism was not possible. In a public good experiment, Casari and Luini (2009) compared alternative punishment institutions and found higher cooperation levels under a consensual punishment institution than under autonomous individual punishment. In a study to investigate the effects of monetary and nonmonetary punishment in a voluntary contributions mechanism with university students, Masclet et al. (2003) established that both types of punishment increased contributions. Nonmonetary sanctions initially raised contributions by as much as monetary sanctions, but in later periods monetary sanctions were more effective. However, the costs of enforcing monetary sanction equalized overall earnings under both systems.

Using a public good experiment to analyse behaviour in a decentralized asymmetric punishment institution, where participants differ in the effectiveness of their punishment, Nikiforakis et al. (2010) observed remarkable similarities between outcomes in asymmetric and symmetric punishment institutions. Controlling for the average punishment effectiveness of the institutions, they found that asymmetric punishment institutions are as effective in fostering cooperation and as efficient as symmetric institutions. Rustagi et al. (2011) combined experimental measures of conditional cooperation and surveyed measures on costly monitoring among 49 forest user groups in Ethiopia with measures of natural forest commons outcomes and found that costly monitoring was a key instrument with which conditional cooperators enforced cooperation.

Lindahl et al. (2016b) used lab experiments to examine how institutional factors influenced the management of CPRs. Specifically, they examined the role of mandatory limits such as quotas in avoiding ecosystem regime shifts and found that regulated systems on average were associated with slightly lower efficiency compared to information, due to under- and over-exploitation.

3.3 Identified gaps in the literature

Except for Lindahl et al. (2016b), previous experimental studies have examined the effects of punishment and information policies on cooperation independently and in separate studies and found that both exhibit a statistically significant positive effect on cooperation (Balliet et al., 2011; Lindahl et al. 2016a). To the best of our knowledge, both policies have so far only been compared in the lab (Lindahl et al. 2016b), and without investigating their joint effect on CPR use. In contrast, our study combines two types of punishment institutions using a framed field experiment approach: equivalent to monetary punishment, participants forfeit their elephant harvest in the current round if the quota is violated and are then put under temporary harvest prohibition (moratorium) for one round to mimic nonmonetary punishment.

Our primary focus is whether the manifestation of regime shifts in CPRs could be avoided if communities were able to invest in robust CPR institutions to coordinate extraction. We would like to know how resource users would behave in such situations, whether they would be able to avoid the tragedy of the commons, and the role of sanctioned quotas, threshold information, or both, for sustainable resource use in the outcome.

Quotas have been in use in Zimbabwe's wildlife sector for a long time, but with limited results, probably due to budgetary constraints limiting monitoring and enforcement. We contribute to this work by testing two policies in the field, separately and in combination: information provision and sanctioned quotas, in a context, where multiple resources are linked.

4. EXPERIMENTAL STRATEGY

4.1 Experimental Design

Our experimental design builds on a dynamic CPR request game (Budescu et al. 1992) designed by Lindahl et al. (2016a). It mimics CPR extraction in CAMPFIRE communities, and allows to capture dynamic aspects of complex ecosystems, such as connectivity of resources, and thresholds. It also allows to test three different policy scenarios: sanctioned quotas, information provisioning, and a combination of both.

In this game, four participants share a renewable CPR. During several rounds, participants take private decisions about how much to harvest from the CPR. They have complete knowledge about the underlying resource dynamics. At the end of each round, the resource regenerates according to its size and the participants receive information about the new stock size. We first present the essential elements of the underlying ecological dynamics and then describe the policy scenarios that we developed[6].

4.1.1 Ecological dynamics

Experiment participants faced either a resource dynamics with or without a threshold, below which a regime shift would occur. Following Lindahl et al. (2016a), we approximate resource growth without the potential of a regime shift using a standard concave growth function and add a "Holling type" III predation term (Ludwig et al. 1978), which introduces a threshold and a potential regime shift. Figure 2(a) illustrates a continuous logistic function of the resource dynamics for elephants and the discrete approximation we used in the experiment. Figure 2(b) shows the corresponding elephant resource dynamics with a threshold. For both scenarios, the maximum stock level is 50, the minimum stock level allowing for growth is 5, and the growth rate changes by steps of 5 resource units. Moreover, above a stock level of 19, the resource dynamics of both scenarios is identical. For the threshold scenario, if the resource stock falls below a level of 20, the growth rate drops dramatically (from 7 to 1).

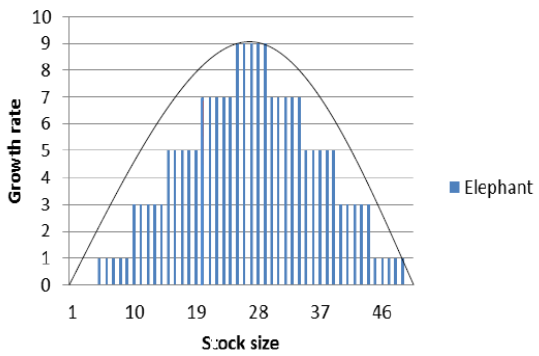
To reflect the context of wildlife conservation in Southern Africa, elephant stock and pastures are linked. The quality of pastures increases with the number of elephants up to a certain level beyond which the elephant population degrades the pastures, *ceteris paribus*. For simplicity, we assume similar resource dynamics for both pastures and elephants and the threshold in the stock of pastures is at the same level as the threshold in the elephant stock. This implies that crossing the threshold in the stock of elephants impacts both elephants and pastures. Figures 2(c) and 2(d) illustrate the dynamics of the pastures without and with a threshold respectively.

The maximum pasture growth attainable is set to 13 resource stock units, corresponding to the situation when the stock of elephants is 25 units at its maximum sustainable yield of nine units. The skewness in the pasture graphs mimics explosion of bushes as the number of elephants diminishes. This situation is exacerbated by a threshold (red vertical line). Figures 2a and 2b are adapted from Lindahl et al. (2016a).

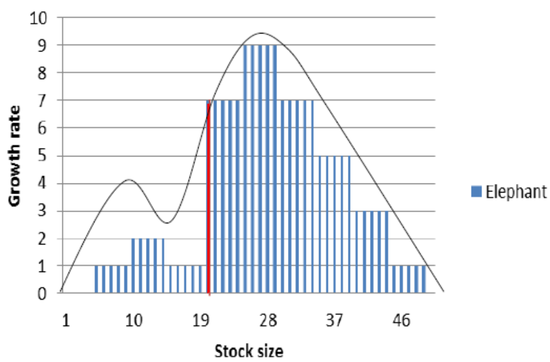
[6] We refer the reader to Annex A.2 for more details on how the resource growth with and without threshold is modelled theoretically in the literature.

Figure 2: Resource dynamics with and without thresholds.

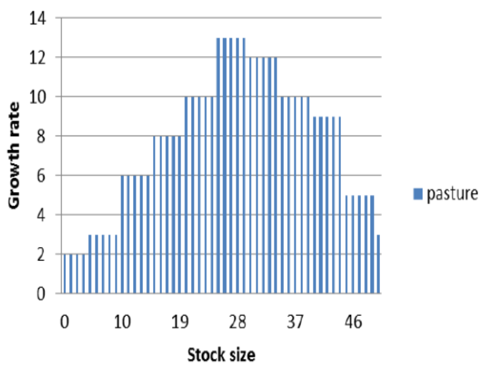
(a) No threshold



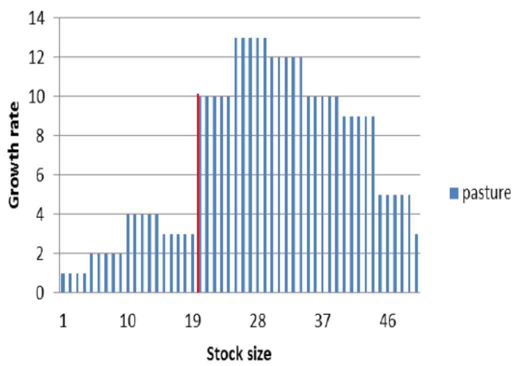
(b) Threshold



(c) No threshold



(d) Threshold



The experiment participants cannot directly influence the amount of pasture, however, they can observe both resource dynamics and then decide on their next move. The stylized versions of these resource dynamics as communicated to the participants appear in Figures B.1 and B.2 in the annex.

4.1.2 Institutional design and treatments

Participants could face one of three different policy interventions: sanctioned quotas, information provisioning, and a combination of both. We introduced sanctioned quotas in the form of a 'total allowable catch' (TAC) pegged at an elephant stock level of 20, following Lindahl et al. (2016b). Hence, the TAC in each round was variable and defined as the difference between the current level of elephants and the level of 20, i.e., $TAC_t = X_t - \bar{X}$, where $\bar{X}$ is the lower limit of 20 elephants. For example, in the first round, it was 30 elephants. At the beginning of each round, groups were told the round's quota. However, participants could choose whether to respect the quota or not. While the TAC was the same as in Lindahl et al. (2016b), the implementation of sanctions differed. In Lindahl et al. (2016b), if the stock fell below a level of 20 (i.e., the quota was violated), the whole group was not allowed to harvest until the stock had recovered. In our study, participants knew that if the stock fell below a level of 20, each participant faced a probability of 2/3 of being controlled and if caught cheating would forfeit the current harvest and be put under harvest prohibition for the next round.

The quota design corresponds to quotas in the participating CAMPFIRE communities in two ways: 1) trophy hunting quotas for elephants are usually allocated to the entire community (not divided among community members), and 2) punishment does not include an additional fine, since most offenders in CAMPFIRE cannot afford to pay a fine (Ntuli and Muchapondwa 2017). To mimic reality, participants were only informed about the policy with a sole focus on the elephants (i.e., there was no further information about the pastures).

In the information provisioning intervention, participants were told that there is a threshold below which the growth rate of both elephants and pastures drops drastically. Hence, in this intervention, groups faced resource dynamics with a threshold. This treatment is similar to that of Lindahl et al. (2016b). However, in that study, participants only faced one resource instead of the two connected resources.

Given the two different resource dynamics and these two different policy scenarios, we tested four different treatments (see Table 1): 1) Baseline treatment (BT, no policy intervention); 2) Sanctioned quota treatment (SQT); 3) Threshold information treatment (TIT); and 4) Sanctioned quota plus threshold information treatment (SQT-TIT). In treatments 1) and 2), groups faced resource dynamics without thresholds (see Figure 2a and 2c). In treatments 3) and 4), groups faced resource dynamics with thresholds (Figure 2b and 2d).

Table 1. Experimental treatments

<table>
<tr><th>Treatment</th><th>Policy interventions</th><th>Resource dynamics</th><th>Experiment set-up</th></tr>
<tr><td>Baseline treatment (BT)</td><td>--</td><td rowspan="2">No thresholds (concave growth function)</td><td rowspan="4">In each round, participants, in groups of four, made private decisions about elephant harvest. Each harvested elephant was worth $0.25. These harvest decisions affected the availability of pastures. Each unit of pasture was worth $0.10 to the whole group.</td></tr>
<tr><td>Sanctioned quota treatment (SQT)</td><td>When elephant stock fell below a level of 20, someone in the group would be punished with a probability of 2/3. Punishment implied forfeiting the elephant harvest of the current round and not being allowed to harvest for one round.</td></tr>
<tr><td>Threshold information treatment (TIT)</td><td>Participants were informed that the elephant and pasture stocks exhibited a threshold (at a stock level of 20) below which growth rates were substantially lower.</td><td rowspan="2">Thresholds (non-concave growth function)</td></tr>
<tr><td>Sanctioned quota + threshold information treatment (SQT-TIT)</td><td>Combination of SQT and TIT (see above)</td></tr>
</table>

The same type of resource dynamics applied simultaneously to both elephants and pastures, see Figure 2. Each treatment was repeated 24 times (N=24).

In all treatments, participants were allowed to communicate throughout the experiment and share information at any time. This choice, in line with the original design by Lindahl et al. (2016a), was motivated by wanting to mimic local conditions as much as possible. Communities in the study area organize meetings to share vital information and discuss issues affecting the whole community. We first tested this experimental design with students at the University of Cape Town and again, in a pilot, with a community located in the study area. We then made necessary adjustments to address minor issues before going to the field.

4.2 Experimental Procedure

We collected experimental data in 33 CAMPFIRE villages in Zimbabwe (Figure 1) during two time periods: 23 June to 11 July 2017 (51%) and 28 September to 20 October 2018 (49%). With the help from local leadership, we recruited in total 384 participants using household lists for each village[7]. Each day, we randomly invited 16 participants, whom we randomly assigned to one of four groups (i.e., 96 groups in total), which in turn were randomly assigned to one of the four treatments (BT, SQT, TIT, and SQ-TIT; i.e. 24 groups per treatment) using lotteries with equal probabilities. Each participant received a show-up fee[8] of $5 (approximately the daily local shadow price of labour) and participated only once. We did not elicit any personal characteristics of the participants before the game to verify successful randomisation. However, as Table A5.9 shows, there were no significant participant differences with regards to standard socio-economic characteristics (i.e. age, gender, number of years in school, and income) across the treatments.

Participants were seated and asked to complete and sign a consent form. The instructions (see Annex B.3) were read aloud. Each experimental session lasted for approximately two hours and was divided into two stages. The first stage, in which all groups played the baseline treatment (BT) after a set of practice rounds, was used for training purposes only (to make sure that all participants understood the game) and participants were not paid. The practice rounds in Stage 1 always lasted 20 minutes. After Stage 1, an open question and answer session was conducted to clarify remaining issues. In Stage 2, the groups played the treatment that was randomly assigned to them. This stage was timed at one hour (which was not known to the participants) so that the games ended either when the stock of elephants was depleted or the time expired. The end round was unknown to the participants to approximate an infinite time horizon and avoid an end-of-game effect.

The participants were told that each of them represented a resource user and together with the other participants in the group, they had access to a renewable stock of elephants (CPR) from which they could harvest units, each worth $0.25[9], over a number of rounds[10]. They were told that what happened to the harvested elephants also affected the availability of another renewable resource (pastures) (see Figure 2). A unit of pasture, equivalent to one hectare (a

[7] We invited the head of each household. If he or she could not participate, the spouse or eldest child participated instead. Once someone from a household participated, the household was deleted from the list of sampled households.
[8] All amounts reported in this paper are in USD unless otherwise stated.
[9] We decided the fictive unit prices of both resources after testing this experimental design with students at the University of Cape Town and again in a pilot with a community located in the study area. We took into consideration the project's budget, the required sample size, easy calculations, and the fact that elephants have higher value than pastures.
[10] Harvesting elephants was not associated with any costs (i.e., there was no difference between economic and sustainable yield) to keep the experiment as simple as possible apart from the introduced ecological complexity (as suggested by Lindahl et al. 2016a).

commonly used unit in the region), was worth $0.10 to the whole group. Hence, the payoff π_{it} of participant i in round t, was calculated according to her elephant harvest h_{it} plus her corresponding share of pastures P_t:

$$\pi_{it} = p_e * h_{it} + \frac{p_p P_t}{n} \quad [1]$$

where p_e and p_p denoted the unit prices of elephants and pastures, respectively, and n was the group size. If, in any round, the total elephant harvest exceeded the available stock, i.e., $\sum_{i\in n} h_{it} \geq X_t$, the experiment ended and $\hat{\pi}_{iT}$ was calculated based on the participant's share of the terminal stock that will be harvested to extinction ($\hat{X}_T$):

$$\hat{\pi}_{iT} = p_e \frac{h_{iT}}{\sum_{i\epsilon n} h_{iT}} X_T + \frac{p_p P_T}{n} \quad [2]$$

Participants knew that if there were still elephants left at the end of the experiment, they were valued at p_e+0.05= $0.30 each and shared among group members. Thus, the value of an elephant in the remaining stock was slightly higher to avoid a potential end-game effect. This is consistent with the idea that an animal in the bush is worth more than a dead animal. Therefore, at the end of the experiment, the payoff of participant *i* was given by:

$$\hat{\pi}_{iT} = p_e h_{iT} + \frac{p_p P_T}{n} + \frac{(p_e + 0.05) X_T}{n} \quad [3]$$

where X_T denoted the remaining elephant stock at the end of the experiment and $(p_e + 0.05)$, the per unit price of a living elephant. The payoff functions (Eq. 1-3) were calculated in the same way in all treatments, hence, the optimal payoffs should be the same in all treatments. We emphasized that participants shared both resources communally and what they did as individuals affected others in the group.

After each round, participants communicated their harvest decisions using a request sheet (see Annex B.5). To ensure that individual decisions were anonymous, participants were asked to disperse for a few minutes while they made a decision and submitted their request sheet before they joined the group for the next round. This was similar to what happens in real life when individuals go to hunt. Before the next round, the assistants calculated the sum of individual harvests and the new elephant and pasture stock sizes. They communicated this information orally and in writing to the groups, and to individuals, using a balance sheet. Groups playing the SQT and SQ-TIT also received information about the quota (calculated as the number of remaining elephants in that round minus 20). In the quota treatments, whether someone in the group was punished was determined by throwing a six-sided dice, where numbers one to four corresponded to one of the four participants in the group. To mimic reality, the numbers five and six represented the case where no one was controlled.

Participants were allowed to communicate face-to-face during any moment of the game, except when they made decisions. Neither the instructions, nor the research team suggested whether, when, or how to communicate. Participants could discuss their individual harvest rate, but their actual harvest requests were kept anonymous, which is consistent with harvesting under community wildlife management in CAMPFIRE projects.

After the experiment, the participants completed a questionnaire (see Annex B.4) capturing information about individual attributes (such as age, gender, and educational background) and their perceptions of the experiment. For example, participants were asked whether they understood the game, how they assessed trust among group members, the group's capacity to cooperate, and whether or not agreements were made. To complement this self-reported information, research assistants also took notes on these matters during the experiment following a protocol. At the very end, participants were called individually and paid privately according to the payoff functions presented earlier. For further details about the instructions, see annexes A.4 and B.3 respectively.

5. FORMULATING HYPOTHESES

We formulated two hypotheses based on the experimental design and relevant literature (Schill et al. 2015; Lindahl et al. 2016a; b). Hypothesis 1 and its corollaries are similar to those tested in Lindahl et al. (2016a; b), while hypothesis 2 is new. Hypothesis 1 compares depletion cases between the three policy treatments and the baseline treatment. Corollaries 1 and 2 compare average stock sizes and average efficiency between the three policy treatments and the baseline treatment. Hypothesis 2 compares average efficiency and average stock sizes between the three policy treatments. All hypotheses depend on the assumption that the participants are rational individuals with the cognitive skills to solve real life challenges. Similar to Lindahl et al. (2016a), we define efficiency as the share of actual joint earnings over the maximum possible.

Hypothesis 1. We expect our policy treatments (SQT, TIT and SQT-TIT) to be associated with at least equal or fewer cases of depletion compared to the BT.

In all treatments, the optimal collective decision was to harvest 25 elephants in the first round and then harvest 9 elephants in each subsequent round (as long as the participants believed that the game would continue). Any deviation from that optimum provided a lower payoff and was therefore inefficient. While the collective optimal outcome was the same in all treatments, the individual incentives for deviation from this optimum differed between treatments. In Annex A.4.3, we computed the incentives to deviate from the optimal payoff and found a similar condition to Lindahl et al. (2016a)[11]. However, the condition here is more complex due to the presence of two stocks and the change we made to the participants' payoffs. Using this approach, it is clear that all policy treatments (SQT, TIT and SQT-TIT) generated lower expected payoffs (for the sum of elephants and pastures and assuming the players did not take more than their share of the allowed quota) than the BT for deviating outcomes below the threshold. Therefore, the incentives for deviation were lower in policy treatments, which should have lowered incentives for depletions and thus decreased their occurrence. Finally, one can show, in the same way as Lindahl et al. (2016a), that for a deviating player (in all treatments), the optimal deviation was to deplete the resource by claiming the current stock size in the first round.

Corollary 1. We expect our policy treatments (SQT, TIT and SQT-TIT) to be associated with equal or higher average stock sizes compared to the BT.

Corollary 2. We expect our policy treatments (SQT, TIT and SQT-TIT) to be associated with equal or higher average efficiency compared to the BT.

These corollaries are a direct consequence of the policy treatments generating lower payoffs for outcomes below the threshold. Moreover, in addition to these theoretical predictions, Lindahl et al. (2016a) also found that groups facing thresholds managed the resource more efficiently.

[11] See the supplementary material of Lindahl et al. (2016a) available online.

Hypothesis 2. We expect the sanctioned quota treatment (SQT) to be associated with equal or higher average efficiency and equal or higher average stock sizes compared to the threshold information treatment (TIT). We also expect the combination of both interventions (SQT-TIT) to be associated with equal or higher average efficiency and equal or higher average stock sizes compared to individual interventions considered in isolation (SQT and TIT).

The traditional view in the literature is that information alone cannot steer behaviour and additional incentives are required through appropriate policies (Aquino et al. 2015). Therefore, the TIT should have lower efficiency and lower average stock sizes than the SQT. The two hypotheses and corollaries will guide our analysis. To test the first hypothesis, we compare the proportion of groups that depleted the resource across treatments. To test corollaries 1 and 2 and hypothesis 2, we calculate and compare average stock sizes and average efficiency for each treatment and compare treatment differences in stock dynamics.

6. RESULTS

First, we focus on differences in general sample characteristics and between the different treatments (6.1), followed by differences between treatments in depletion cases, stock sizes, efficiency and dynamics over time (6.2). Last, we present a regression analysis aimed at identifying factors explaining the differences between treatments while controlling for relevant individual and group level attributes (6.3). We focus here only on Stage 2 results, as Stage 1 served for training purposes and participants were not monetarily incentivised. We focus our analysis on elephant stocks, as that is the resource that was directly influenced by participants' decisions.

We used non-parametric Kruskal-Wallis equality-of-population rank tests (KW) to compare across more than two independent samples. For pair-wise comparisons, we used Mann–Whitney–Wilcoxon tests (MWW) and to compare proportions, we used Fisher's exact tests (FET). We used group averages across all rounds as unit of observation, rather than average individual harvest decisions, because the latter were not independent observations. We used STATA 15 for the statistical analysis. For details of the analysis and comparison of Stage 1 and 2 results, see Table A5.1 to A5.9 in Annex A.5. Further details including separate analysis of the two different data collection time periods, which did not significantly differ from each other, are available upon request.

6.1. Sample characteristics and payoffs

Table 2 illustrates sample characteristics and payoffs. On average, participants were 38 years old, and had spent nearly 7 years in school. Approximately 69% of the participants were female, and 6% had participated in an experiment before. About 68% of the participants came from a shrub-dominated area, suggesting that a regime shift could be underway in some CAMPFIRE communities. Almost 80% of the participants indicated that they trusted each other during the experiment. Measured on a scale from 0 to 5 (where 0 denotes lack of understanding and 5 a high level of understanding), results indicate an average level of game understanding of 3.8. Communication occurred in all groups.

Table 2: Sample characteristics and payoffs. N=384 for all variables.

Variable	Baseline	Sanctioned quota	Threshold information	Sanctioned quota and threshold information	All
Age [# years]					
Median	35	37	35	37.16	37
Mean	37.5	36.58	37.04	37	38.15
(Std. Dev.)	(13.59)	(13.58)	(12.15)	(13.30)	(13.52)
Gender [1=M]					
Median	0	0	0	0	0
Mean	0.290	0.310	0.317	0.308	0.31
(Std. Dev.)	(0.44)	(0.46)	(0.49)	(0.45)	(0.46)
Education [# years]					
Median	9	7	7	6	7
Mean	7.66	7.22	7.67	6.97	6.92
(Std. Dev.)	(4.05)	(3.62)	(3.57)	(4.27)	(4.01)
Played similar game before? [1=Y]					
Median	0	0	0	0	0
Mean	0.031	0.052	0.063	0.083	0.057
(Std. Dev.)	(0.175)	(0.223)	(0.243)	(0.278)	(0.23)
Level of game understanding [0–5]					
Median	4	4	4	4	4
Mean	3.750	3.760	3.987	3.882	3.83
(Std. Dev.)	(1.124)	(0.830)	(1.026)	(1.035)	(1.05)
Group members trusted each other [1=Y]					
Median	1	1	1	1	1
Mean	0.688	0.791	0.844	0.865	0.796
(Std. Dev.)	(0.466)	(0.408)	(0.365)	(0.344)	(0.403)
Live in grass vs. shrub dominated area [1=Y]					
Median	0	0	0	0	0
Mean	0.188	0.302	0.354	0.427	0.317
(Std. Dev.)	(0.466)	(0.564)	(0.542)	(0.576)	(0.544)
Individual payoff (range: $6.87-$27.85)					
Median	$9.28	$11.70	$10.35	$12.18	$11.03
Mean	$9.39	$11.28	$10.42	$11.45	$10.62
(Std. Dev.)	($3.53)	($2.82)	($2.20)	($2.75)	($2.83)
Group payoff (range: $53.86-$70.57)					
Median	$35.50	$47.80	$42.6	$48.80	$45.30
Mean	$36.83	$45.17	$41.62	$45.96	$42.36
(Std. Dev.)	($11.38)	($7.42)	($6.04)	($7.75)	($2.22)

Questionnaire and game data.

The groups differed with regards to what they talked about (e.g., how much to harvest, if the stock was being depleted and whether someone in their group harvested more than what was agreed), and whether or not they managed to reach an agreement. Individual payoffs ranged from $2.93 to $23.80, excluding the show-up fee, with an average of about $10.62 (equivalent to two days' regional wage income), while group payoffs ranged from $20.15 to $53.95, with an average of about $42.36.

6.2 Treatment differences in depletion cases, stock sizes, efficiency and dynamics over time

Overall, 20% of the groups depleted the stock of elephants, see Table 3. The majority of depletion cases (13) was associated with the BT. In the policy treatments, much fewer groups depleted the resource. There was one depletion case in the SQT-TIT, two cases in the SQT, and three cases in the TIT respectively. These treatment differences were significant (FET; p = 0.031, Table 3). Pairwise comparisons (Table 4) suggested only significant differences between the BT and the policy treatments, i.e., SQT (p = 0.006), TIT (p = 0.016) and SQT-TIT (p = 0.002).

Out of the 96 groups in total, 46 groups reached elephant stocks below 20 sometime during the game (see Table 3). Most of these cases (16) occurred in the BT. In the SQT, TIT and SQT-TIT it occurred in 9, 11, and 10 cases respectively. These treatment differences were significant (FET; p = 0.010). Most groups who crossed the threshold were careful not to deplete the resource. Group members would abstain from exploitation, aiming to recover the stock or at least maintain a low stock level. However, most of them failed to fully rebuild a stock above the threshold.

Table 3: Summary statistics. Mean stocks of elephants (after harvesting, before reproduction), depletion cases, cases with elephant stock levels below 20, and recovery cases from elephant stock levels below 20.

		Treatment					χ^2 / Fisher' s exact test[§] & Kruskal-Wallis test[†] (P-value)
		BT	SQT	TIT	SQT-TIT	Total (All Treatments)	
Stock of elephants	Mean	20.87	29.51	25.70	30.34	26.60	0.020
	SD	4.73	5.98	3.91	4.56	6.08	
Groups with elephant	Freq	16	9	11	10	46	
stock below 20	%	66.7	37.5	45.8	41.7	47.9	0.010
Recovered with stock	Freq	2	4	3	4	13	
below 20	%	8.3	16.7	12.5	16.7	13.5	0.056
Depleted stock of	Freq	13	2	3	1	19	
elephants	%	54.2	8.3	12.5	4.2	19.8	0.031

Baseline treatment (BT); Sanctioned quota treatment (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information treatment (SQT-TIT)

§ χ^2 / Fisher's exact test used to compare proportions across treatments

† Kruskal-Wallis test used to compare means across treatments

There were significant differences in mean elephant stock sizes (after group harvest and before reproduction) across the treatments (KW; p = 0.02; see Table 3). Pair-wise comparisons revealed that mean elephant stocks in the BT were significantly lower (p = 0.001) than in each policy treatment (see Table 4). The mean stocks of elephants under the three policy treatments fell in the optimal range (25 - 30), see Table 3. However, pair-wise comparisons revealed that average stock sizes in the SQT (p = 0.0102) and SQT-TIT (p = 0.0028) were significantly higher than in the TIT (Table 4).

Table 4. Pair-wise comparisons between each treatment in relation to depletion cases, average stock size, and average efficiency. Values indicate test statistics of Mann –Whitney–Wilcoxon tests, exact p-values in parentheses.

	SQT	**TIT**	**SQT-TIT**
BT			
Depletion cases	-0.458 (0.006)	-0.417 (0.016)	-0.500 (0.002)
Stock size	-4.41 (0.000)	-3.44 (0.001)	-5.00 (0.001)
Efficiency	-0.298 (0.000)	-0.139 (0.000)	-0.347 (0.000)
SQT	--		
Depletion cases		0.0417 (0.959)	-0.0417 (0.959)
Stock size		2.56 (0.010)	-0.32 (0.740)
Efficiency		0.151 (0.020)	-0.057 (0.440)
TIT	--	--	
Depletion cases			-0.0833 (0.846)
Stock size			-2.99 (0.003)
Efficiency			-0.208 (0.000)

Baseline treatment (BT); Sanctioned quota treatment (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information treatment (SQT-TIT)

Table 5 shows the results of average efficiency for the stock of elephants. The total average efficiency was 0.627. The lowest efficiency level was recorded under the BT (0.420) and the highest was recorded under the SQT-TIT (0.767). Statistical analysis revealed that treatment differences in average efficiency were significant (KW; p = 0.000). In fact, we found statistically significant differences in average efficiency between the BT and each policy treatment (p<0.000 for each pair-wise comparison; see Table 4). Furthermore, pair-wise comparisons between each policy treatment revealed that average efficiency in the TIT (0.559) was significantly lower than in the SQT (0.710) (p = 0.020), and the SQT-TIT (0.767) (p = 0.000). There was no significant difference between the SQT and SQT-TIT (p = 0.44).

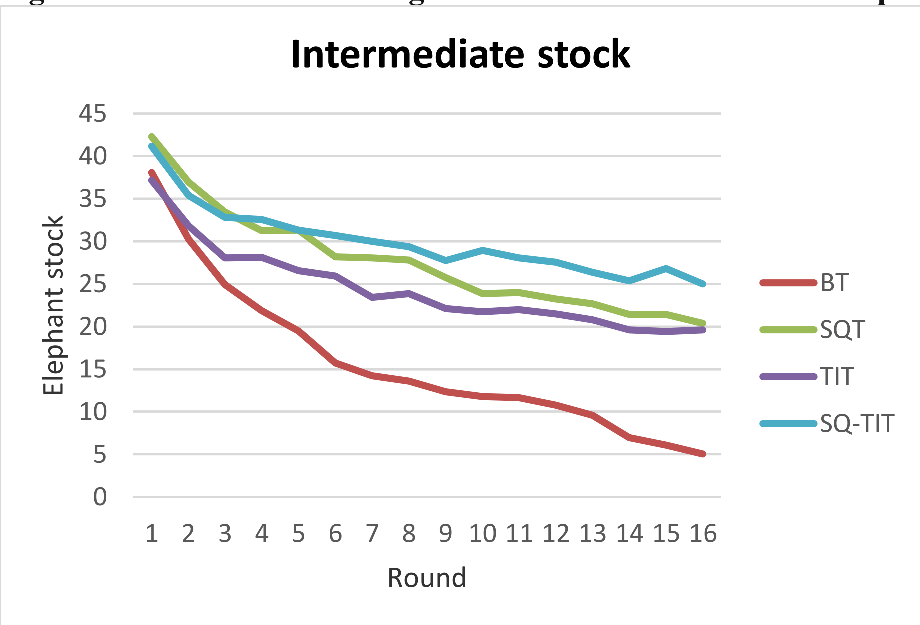
Table 5: Average efficiency by treatment

Treatment	**Average efficiency** for the elephant stock	
	Mean	Std. Dev
BT	0.420	(0.491)
SQT	0.710	(0.292)
TIT	0.559	(0.377)
SQT-TIT	0.767	(0.239)
Total	**0.627**	**(0.375)**
Kruskal-Wallis test† (P-value)	0.000	

Baseline treatment (BT); Sanctioned quota (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information (SQT-TIT)
Source: fieldwork data June 2017 and September 2018
† Kruskal-Wallis test used to compare means across treatments

Figure 3 illustrates the dynamics of the average intermediate stock of elephants across the four treatments. Under the BT, the stock of elephants decreased continuously due to overexploitation starting already after round 2 and reached the lowest level at the end of the experiment due to the many depletion cases in this treatment (see Table 3). Under the policy treatments, the stock seemed instead to stabilize after about eight rounds. The SQT-TIT achieved the highest average stock level followed by the SQT. A constant gap seemed to be maintained between the TIT and the SQT-TIT, while the SQT started off at the same level as the SQT-TIT and later on converged with the TIT.

Figure 3: Time series of average intermediate stock levels for elephants



Baseline treatment (BT); Sanctioned quota treatment (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information treatment (SQT-TIT)
Source: fieldwork data June 2017 and September 2018

The dynamics of the intermediate stock of elephants for the SQT-TIT seemed to stabilize around the optimal level of 25 elephants, which could act as a focal point. In the SQT and TIT, the stocks stabilized below 25, which was inefficient but remained above the threshold (20).

6.3 Regression analysis

We used ordinary least squares (OLS) regression to examine the drivers of performance measured in terms of stock levels and efficiency. Table 6 summarizes the results of three OLS regression models aiming to determine average treatment effects on the respective dependent variables (mean and median stocks of elephants and efficiency) while controlling for relevant Stage 1 variables and other individual and group level attributes. After controlling for time period of the surveys (June 2017 or September 2018), CAMPFIRE communities, participants' age, gender, education and inequality of harvest, these models explained over 42% of the variation in the dependent variable in Stage 2.

Table 6: Regression model results

	Dependent variables		
Independent variables	**Mean stock elephant**	**Median stock elephant**	**Average efficiency**
SQT	7.590***	6.832***	0.337***
	(1.334)	(1.407)	(0.035)
TIT	2.348**	1.632	0.170***
	(1.010)	(1.320)	(0.035)
SQT-TIT	6.957***	6.961***	0.385***
	(1.219)	(1.335)	(0.036)
Stage1 variable†	0.376***	0.334***	0.080
	(0.064)	(0.068)	(0.063)
Time period	0.853	0.571	0.004
	(0.841)	(0.946)	(0.021)
Gender	3.026***	3.320**	0.037
	(1.119)	(1.450)	(0.034)
Level of understanding of the game	7.935**	8.717*	-0.100
	3.689	(4.883)	(0.108)
Constant	4.280	4.484	0.403***
	(3.921)	(5.472)	(0.108)

R^2	0.563	0.493	0.740
Prob > F	0.0000	0.0000	0.0000
Observations	96	96	96

Baseline treatment (BT); Sanctioned quota treatment (SQT); Threshold-information treatment (TIT); Sanctioned quota and threshold-information treatment (SQT-TIT)
Source: fieldwork data June 2017 and September 2018
Standard errors are shown in parentheses
A categorical variable is used to represent the four treatments. The baseline treatment is supressed or omitted so that a comparison is made between each policy treatment and the baseline category.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
† Stage 1 variable represents Mean stock St1, Median Stock St1, and Efficiency St1 respectively

There was evidence that gender has an effect on the mean and median stock of elephants. Our results seem to suggest that men were more careful in their harvesting than women. The coefficient for the constant term in the regression model for average efficiency is small and highly significant.

The three policy treatments and the Stage 1 variables explained variability in most of the dependent variables. Exceptions included the median stock of elephants in the TIT and the Stage 1 variable's impact on efficiency. Regarding the influence of the policy treatments relative to the baseline category, the magnitude of the coefficients partially supports the claim we made earlier about the superiority of punishment institutions over information provisioning, based on the results of the pair-wise comparisons mentioned above (see Table 4). To support this claim, we show in the annex that the difference between punishment and information was statistically significant by using the TIT as the reference in the regression (see Table A5.3). The magnitude of the first stage variables also suggested that their impact was much smaller compared to the interventions, in particular their impacts on the stock of elephants. Our results show that the period when the experiment was performed did not matter since the coefficient was insignificant suggesting that our two-time period samples actually came from the same population.

7. DISCUSSION

The purpose of this study was to examine the effects of two different interventions and their joint effect on the management of natural CPRs subject to potential regime shifts: a sanctioned quota, information about a potential regime shift and the combination of both. Our experiment was carried out in a context in which multiple resources stem from the same ecosystem with complex dynamics and were thus coupled. In real life, efficient management of pastures depends on how well elephants are managed.

7.1 Discussion of results in relation to the hypotheses

Overall, the descriptive statistics support our hypotheses and corollaries. Consistent with Hypothesis 1, resource users were able to avoid depletion of the elephant stock 50% more often with policy treatments than without. As illustrated in Figure 3, the participants in the treatment groups seemed to gravitate towards the optimal solution suggesting that there could be learning over time. From the literature, failure to locate the optimum solution is caused by many factors such as lack of understanding of the game due to the complexities, limited time, lack of effective communication or selfish behaviour, whereby participants try to maximize individual gains at the expense of the group (Ostrom and Walker 1991; Casari and Luini 2009; Lindahl et al. 2016a, b; Lindahl and Jarungrattanapong 2022). Post-experimental interviews revealed that selfishness or cheating could be one of the main reasons for not achieving the optimum solution even though there was communication among the group members.

Similar to the studies of Lindahl et al. (2016a) and Schill et al. (2015), we found that a latent regime shift significantly influenced resource users' exploitation strategies. Given adequate and timeous information about potential regime shifts, CPR users could avoid disasters by operating above the threshold when the benefits of doing so were greater than the costs of avoiding it, thereby using their resources more efficiently and sustainably (Lindahl et al. 2016a). We also found that the combined effect of information about a potential regime shift (TIT) and a sanctioned quota (SQT) lead to more efficient resource use in comparison to a situation without information or sanctioned quotas (i.e., BT). Our results suggest, as previously found, that information about a potential regime shift could help resource users avoid disasters, but not necessarily manage the CPR optimally.

Our results support Corollary 1 and 2 because the interventions were associated with higher average stock sizes and efficiency. Figure 3 shows that policy treatment groups were able to sustain higher average stock sizes throughout the experiment and above the threshold (apart from the last three rounds in the TIT). Consistent with Hypothesis 2, an intervention based on sanctioned quotas resulted in higher efficiency than threshold information, as well as the combination of sanctioned quotas with threshold information. We did not find a difference in efficiency between the sanctioned quota and the combined intervention, indicating no additional effect of combining policies. Contrary to Lindahl et al. (2016b), the results revealed that regulated systems on average were associated with higher efficiency. In our experiment, in the SQT and SQT-TIT the players faced a risk of being inspected if the stock fell below the threshold and an individual moratorium only if they were caught taking out more than their share of the quota. In Lindahl et al. (2016b), all players faced a moratorium if the stock fell below the threshold, no matter the size of their harvest. This collective sanction might have created incentives for free-riding, which we did not find in our experiment. That might explain why the results differed and our regulated treatments showed higher efficiency than the unregulated ones. In addition, punished players had to give back their current harvest which was not the case in Lindahl et al. (2016b). That also increased the incentives for staying above the threshold in our treatment.

Although we considered here two linked resources (elephants and pastures), the task for our participants' was to take action on just one resource (the elephant stock). At the same time, we provided them also with information about how their decisions would affect another resource (pastures). We made that choice because this mimicked our participants' everyday decision-making context. To make things as simple as possible, we assumed the thresholds were reached simultaneously in both resources. Whether or not (and to what extent) our participants based their decisions only on the information they received about the elephants, our experimental design might not be distinctively different from previous studies (e.g., Schill et al. 2015; Lindahl et al. 2016a, b) but it still introduces elements of complexity in the environment that resource users are likely to face. Hence, we suggest to investigate that question in future work, along with testing the effect of how participants make decisions when faced with two resources coupled through their interactions in the ecosystem and with different thresholds.

7.2 Policy design for wildlife conservation

Our study suggests that providing information about resource dynamics or specific stock levels could work as an alternative policy intervention to e.g., sanctioned quotas, a more conventional policy instrument. While combining a conventional policy, such as sanctioned quotas, with providing information about potential regime shifts produced better results compared to only providing information, the combination did not perform better than sanctioned quotas alone. However, we have not considered regulation costs. In the long-run, sanctioned quotas could be more costly than providing threshold information. A constant gap is maintained between the TIT and SQT-TIT as a result of combining both policies (Figure 3). In theory, the effect of the combined intervention could be (i) greater than that of the SQT, (ii) greater than that of the TIT, and (iii) greater or less than the sum of the effects from the separate interventions. When comparing both average efficiency and stock size, we did not find any significant difference between the SQT-TIT and SQT, highlighting that combining policies did not necessary yield better results than just using sanctions.

The take home message is that resource users behave differently when facing an intervention that either provides a quota sanctioned by punishment or information about a regime shift. This has implications for wildlife policy. For example, if policy makers need to pursue a precautionary approach, then either a policy intervention with sanctioned quotas or threshold information could be employed to help resource users avoid a regime shift that will result in much lower resource growth. If an optimal outcome or high levels of collective action are the main targets, then either sanctioned quotas or the combination of both interventions (sanctioned quota and threshold information) might be appropriate and more efficient compared to threshold information in isolation, provided administrative costs of an additional policy are lower than the benefits of combining them.

Communication has been identified in both case studies and previous experimental studies as an important variable to enable cooperation among resource users in general (Ostrom 2006; Pretty 2003) and to avert potential disasters in particular (Tavoni et al. 2011; Schill et al. 2015; Lindahl et al. 2016b; Ahsanuzzaman et al. 2022). Communication is one area that policy interventions can nurture by providing arenas for people to come together. All groups made use of the option to communicate in our study, which emphasises the importance of communication as a critical precondition for collective action.

Finally, our results are likely to depend on the specific context we consider. Considerable evidence suggests that behavioural responses can be strongly influenced by cultural and ecological contexts (Cárdenas and Ostrom 2004; Henrich et al. 2005; Schill et al. 2019). The highly significant coefficient of the constant term in the regression model for average efficiency might be capturing the effects of contextual factors alongside other unobservable variables explaining variability in our dependent variable. However, the coefficient is small implying that the effects of unobservable contextual factors could be negligible.

8. CONCLUSION

This study compared behavioural responses to different policy interventions all designed to prevent over-exploitation of two linked CPRs with thresholds; an intervention relying on quotas sanctioned with punishment, an intervention relying on informing resource users about a latent endogenous regime shift, and a combination of both interventions. In respect to efficient resource management, the combined intervention (sanctioned quota and threshold information) and the sanctioned quota performed best, followed by the intervention relying on providing information about the threshold (significant difference with both first options).

We conclude by returning to the local African community that we described in the very beginning. This community depends strongly on revenues from wild elephants in the neighbourhood as well as healthy grasslands for livestock production. However, the fewer elephants there are, the higher the risk that the local ecosystem may undergo an undesirable regime shift since the feeding habits of wild elephants prevents bush encroachment, thus maintaining healthy grasslands. A shift from healthy grasslands rich in elephants to bushy areas poor in elephants would provide far fewer ecosystem services for the local community. This study illustrated that such a community can succeed in maintaining both resource stocks at a satisfactory level through sanctioned quotas or by receiving information about the potential regime shift.

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ANNEXES

A.1 The role of elephants in shaping the savanna ecosystems

The African elephant is a mega-herbivore and keystone species whose activities and population variations can cause profound changes in ecosystems (Western 1989) and in their habitat (Guldemond and Van Aarde 2008). Elephants are water-dependent, non-selective bulk feeders with substantial forage needs. They eat grasses, small plants, fruits, twigs, roots, tree bark and leaves. They spend nearly 80% of their day feeding. Adults can consume up to 180 kg each per day (Kerley et al. 2006). They tend to shift diets, either grazing or browsing following seasonal changes in food availability and quality (Miller and Coe 1993). Thus, their feeding behaviour can radically change an ecosystem (Pellew 1983).

While a strand of literature concentrates on loss of biodiversity due to the negative impact of elephants on woodlands, another strand focuses on the ecological importance of elephants in opening up forests and woodlands, thus creating favourable habitats for other species and increasing diversity (Zyambo 2015).

Despite their significance, the elephant population is dwindling due to a combination of exogenous and endogenous factors. Illegal wildlife harvesting is one of the biggest threats challenging the existence of elephants in Zimbabwe and the CAMPFIRE programme itself (Muchapondwa 2003; Ntuli and Muchapondwa 2017). Continued poaching could drive the elephant population to unprecedented low levels, challenging the recovery of the population and possibly triggering a regime shift in the savannah grassland ecosystem[12]. Indeed, elephants modify their habitat by controlling the population of bushes, thereby converting savannah woodlands into pasture-yielding grasslands (Sithole et al. 2012). The coexistence of woody plants and grasses characterizes the savannas' vegetation structure and composition. Water availability, nutrients, fire and large herbivores influence their respective proportions (Scholes and Archer 1997; van Langevelde et al. 2003). Harvesting elephants beyond a certain threshold might trigger a massive expansion of bushes – bush encroachment. This occurs when shrub cover rapidly and irreversibly increases in grassy landscapes (Moleele et al. 2002). This reduces grass productivity and can hinder cattle from access, with substantial negative economic impacts on livestock production (Moleele et al. 2002; Smit 2004). The loss of grazing areas due to this regime shift suggests a positive relationship between number of elephants and quality of pastures (Zyambo 2015).

A.2 Modelling of resource growth without and with a threshold

We assume that resource users maximize a welfare function which is made up of benefits and costs of managing elephants subject to stock dynamics. The resource users therefore choose harvest to maximize net benefits as follows:

$$\underset{h}{Max}\ \pi(X, g) = P_X h(X) + g(X) - c(h)$$

where $\pi(X, g)$ represents profits, $h(X)$ stand for the harvest, P_X is the price pe [1] of harvest for the elephant stock, $g(X)$ is the value of the stock of pastures and $c(h)$ is the management cost (which we assume to be zero in the experiment for simplicity). We assume that all the functions obey the usual properties that are stipulated in the bio-economic literature (e.g., see Johannesen and Skonhoft 2004; Mukanjari et al. 2013; Ntuli and Muchapondwa 2017). To approximate resource growth without a threshold, we follow Lindahl et al. (2016a) and use the standard concave growth function [1] (Clark 1990; Kot 2001; Murray 2002; Johannesen and

[12] http://regimeshifts.org/item/70-bush-encroachment#more, retrieved May 16, 2018

Skonhoft 2004). Let *X* represent a resource stock at time *t*, with growth rate *r* and carrying capacity *K*. Let *h* denote harvest at time *t* of this resource.

$$\dot{X} = rX\left[1 - \frac{X}{K}\right] - h \qquad [2]$$

Assume that resource users maximize welfare subject to equation [1], then we obtain one unique stable interior solution and one boundary solution which is unstable (Clark 1990; Lindahl et al. 2016a). The boundary solution is attainable when the resource reaches extinction. We modify [2] as shown in equation [3] to capture resource dynamics with a threshold (Schill et al. 2015; Lindahl et al. 2016a). The theoretical literature often captures a threshold by adding a sigmoid term to the standard concave growth function, such as a "Holling-type III" predation term (Ludwig et al. 1978). The dynamics of a stock *X* showing non-concave growth dynamics over time *t*, with growth rate *r* and carrying capacity *K*, can be modelled as follows:

$$\dot{X} = rX\left[1 - \frac{X}{K}\right] - b\frac{X^{\theta}}{a^{\theta} + X^{\theta}} - h \qquad [3]$$

where *b* denotes the maximum uptake rate, *a* half saturation, and exponent θ introc... ...ne non-convexity. Maximizing welfare subject to equation [3] may yield up to three interior solutions, of which two are stable and one unstable (Lindahl et al. 2016a). This model captures a critical threshold and associated hysteresis effects in the dynamics of resources with endogenous regime shift.

A.3. Calculation of current stock

The current stock size was calculated using the following equation:

$$X_t = X_{t-1} - \sum_{i \in n} h_{it} + r_t \quad [4]$$

where X_t represented current stock size, X_{t-1} denoted stock in the previous round, h_{it} was the harvest of individual i in round t, r_t was the regeneration in round t and n denoted the group size. This equation for the stock dynamics is standard in the literature and it states that the current stock is found by subtracting the total harvest by the community and adding the regeneration rate to the previous stock size.

A.4 Incentives to deviate

Suppose there are n player and each player $i \in \{1, \ldots, n\}$ adopts a Markov strategy such that over the periods $\tau \in \{1, \ldots, t\}$, the elephant harvest in period 1 is $(50 - X)/n$ and then in each subsequent periods until period $t - 1$, H_X/n where H_X is the sustainable yield to maintain stock size X. In the last period, the players share the entire stock between themselves. These stock levels automatically correspond to a total quantity of pasture P_X where *X* denotes the elephant stock in that period. Let δ_i represent the expected discounted value of one unit of harvest for player i. Let r denote the rate of time preference, Δ, the length of the period and μ_i the probability that the game will continue one more period. Then $\delta_i = \mu_i e^{-r\Delta}$, which we assume to be the same for each player during the whole time.

The total pay-off obtained from this strategy, for a player assuming that all other players adopt the same strategy, is denoted Π_X and is derived from the sum of the three different pay-off functions (1)-(3) for this elephant stock:

$$\Pi_X = p_e\left(\frac{50 - X}{n} + \sum_{\tau=2}^{t-1} \delta_i \ \frac{H_X}{n} + \delta_i \ \frac{X}{n}\right) + \frac{p_P}{n}\left(P_{50-X} + \sum_{\tau=2}^{t-1} \delta_i \ P_X + \delta_i \ P_0\right)$$

If someone would deviate from this strategy in some period s so that the new stock is not X, then the player would choose to deplete the resource in the next period and claim the entire stock size. In that case each player would get a payoff corresponding to the share of her claim in relation to others. So, for any player who would choose to deviate from the main strategy, the optimal deviation would be to harvest the whole stock. Here is the payoff in period s of a player i who deviates when all others follow the strategy profile above:

$$\Pi_{DC} = p_e X \frac{X}{X + \frac{n-1}{n} H_X} + \frac{p_p}{n} P_0$$

The total payoff for a player who deviates in period s, given that all other follow the cooperating strategy is then:

$$\Pi_{DC} = p_e \left(\frac{50 - X}{n} + \sum_{\tau=2}^{s-1} \delta_i \ \frac{H_X}{n} + \delta_i \ \frac{X^2}{X + \frac{n-1}{n} H_X} \right) + \frac{p_p}{n} \left(P_{50-X} + \sum_{\tau=2}^{s-1} \delta_i \ P_X + \delta_i \ P_0 \right)$$

If all players deplete the resource in the same period s, the pay-off for each player in that period is then $p_e X/n$.

In the first period, cooperation is an optimal outcome if the payoff from cooperating is larger than the payoff from not cooperating, $\Pi_X > \Pi_{DC}$. This condition transforms into:

$$p_e \left(\frac{50 - X}{n} + \sum_{\tau=2}^{t-1} \delta_i \ \frac{H_X}{n} + \delta_i \ \frac{X}{n} \right) + \frac{p_p}{n} \left(P_{50-X} + \sum_{\tau=2}^{t-1} \delta_i \ P_X + \delta_i \ P_0 \right) > p_e \left(\frac{50^2}{50 + \frac{n-1}{n}(50 - X)} \right) + \frac{p_p}{n} P_0$$

$$p_e \left(\frac{50 - X}{n} + \sum_{\tau=2}^{t-1} \delta_i \ \frac{H_X}{n} + \delta_i \ \frac{X}{n} - \frac{50^2}{50 + \frac{(n-1)(50-X)}{n}} \right) + \frac{p_p}{n} \left(P_{50-X} + \sum_{\tau=2}^{t-1} \delta_i \ P_X + (\delta_i \ - 1) P_0 \right) > 0$$

$$p_e \left(\frac{50 - X}{n} + (t-2)\widehat{\delta_i} \frac{H_X}{n} + \widehat{\delta_i} \frac{X}{n} - \frac{50^2}{50 + \frac{(n-1)(50-X)}{n}} \right) + \frac{p_p}{n} \left(P_{50-X} + (t-2)\widehat{\delta_i} P_X + (\widehat{\delta_i} - 1) P_0 \right) > 0$$

$$p_e \left(\frac{50 - X}{n} - \frac{50^2}{50 + \frac{(n-1)(50-X)}{n}} \right) + \frac{p_p}{n} (P_{50-X} - P_0) > \widehat{\delta_i} \left(p_e \left((2-t)\frac{H_X}{n} - \frac{X}{n} \right) + \frac{p_p}{n} \left((2-t) P_X - P_0 \right) \right)$$

Since the right hand side is always strictly negative $t > 2$, this is equivalent to :

$$\hat{\delta_\iota} > \frac{p_e\left(\frac{50-X}{n} - \frac{50^2}{50+\frac{(n-1)(50-X)}{n}}\right) + \frac{p_p}{n}(P_{50-X} - P_0)}{p_e\left((2-t)\frac{H_X}{n} - \frac{X}{n}\right) + \frac{p_p}{n}\left((2-t)P_X - P_0\right)}$$

$$= \frac{p_e\left(50 - X - \frac{n^2 50^2}{n50 + (n-1)(50-X)}\right) + p_p(P_{50-X} - P_0)}{p_e\left((2-t)H_X - X\right) + p_p\left((2-t)P_X - P_0\right)}$$

To compare with previous results we assume there are no pastures and obtain:

$$\hat{\delta_\iota} > \frac{\left(50 - \mathrm{X} - \frac{\mathrm{n}^2 50^2}{\mathrm{n}50 + (\mathrm{n}-1)(50-\mathrm{X})}\right)}{\left((2-\mathrm{t})\mathrm{H_X} - \mathrm{X}\right)}$$

This can be compared with equation S4 in Lindahl et al 2016a.

In a subsequent period T>1, cooperation is an optimal outcome if the payoff from cooperating is larger than the payoff from not cooperating. This condition transforms into:

$$p_e\left(\sum_{\tau=T}^{t-1} \delta_i \ \frac{H_X}{n} + \delta_i^t \frac{X}{n}\right) + \frac{p_p}{n}\left(\sum_{\tau=T}^{t-1} \delta_i \ P_X + \delta_i^t P_0\right) > p_e\left(\frac{X^2}{X + \frac{n-1}{n} H_X}\right) + \frac{p_p}{n} P_0$$

This condition is always satisfied if the previous was because

$$p_e\left(\frac{50-X}{n} + \sum_{\tau=2}^{T} \delta_i \ \frac{H_X}{n}\right) + \frac{p_p}{n}\left(P_{50-X} + \sum_{\tau=2}^{T} \delta_i \ P_X\right) > 0$$

So if players decide to deviate they will do it in the first period.

Now consider how the critical discount rate differs between treatments for the same stock levels. For any stock above the threshold these measurements are the same in all treatments. For stock levels below the threshold, and conditionally on the player deciding to comply, the quota treatments both imply that no harvest is made so the critical discount rate becomes:

$$\hat{\delta_\iota} > \frac{p_e(50 - X - n50) + p_p(P_{50-X} - P_0)}{-p_e X + p_p\left((2-t)P_X - P_0\right)}$$

For SQ all measurements remain the same as BT except for lower harvest rates within some range, where $H_X^T < H_X$:

$$\hat{\delta_\iota} > \frac{p_e\left(50 - X - \frac{n^2 50^2}{n50 + (n-1)H_X^T}\right) + p_p(P_{50-X} - P_0)}{p_e\left((2-t)H_X^T - X\right) + p_p\left((2-t)P_X - P_0\right)}$$

$$\hat{\delta_\iota} > \frac{p_e\left(50 - X - \frac{n50}{1 + \frac{(n-1)}{n50} H_X^T}\right) + p_p(P_{50-X} - P_0)}{p_e\left((2-t)H_X^T - X\right) + p_p\left((2-t)P_X - P_0\right)}$$

A.5 Analysis

Table A5.1: Percentage of times group depleted stock and crossed thresholds

Baseline (BT); Sanctioned quota (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information (SQT-TIT)

Treatment		**Crossed below 20**		**Depleted stock of elephants**		**Recovered after crossing below 20**	
		Stage 1	*Stage 2*	*Stage 1*	*Stage 2*	*Stage 1*	*Stage 2*
BT	Freq.	18	16	11	13	0	2
	%	75.0	66.7	45.8	54.2	0.0	8.3
SQT	Freq.	14	9	13	2	3	4
	%	58.3	37.5	54.2	8.3	12.5	16.7
TIT	Freq.	19	11	8	3	3	3
	%	79.2	45.8	33.3	12.5	12.5	12.5
SQ-TIT	Freq.	16	10	9	1	2	4
	%	66.7	41.7	37.5	4.2	8.3	16.7
Total	**Freq.**	**67**	**46**	**41**	**19**	**8**	**13**
	%	**69.8**	**47.9**	**42.7**	**19.8**	**8.3**	**13.5**

Baseline treatment (BT); Sanctioned quota treatment (SQT); Threshold-information treatment (TIT); Sanctioned quota and threshold-information treatment (SQT-TIT)

Source: fieldwork data June 2017 and September 2018

Table A5.2: Average efficiency by treatment

Treatment	Average efficiency					
	Elephant		Pasture		Total efficiency	
	Stage 1	*Stage 2*	*Stage 1*	*Stage 2*	*Stage 1*	*Stage 2*
BT	0. 366	0.420	0.773	0.798	0.574	0.588
	(0.508)	(0.491)	(0.523)	(0.523)	(0.516)	(0.507)
SQT	0.465	0.710	0.785	0.829	0.620	0,760
	(0.503)	(0.292)	(0.424)	(0.343)	(0.463)	(0.318)
TIT	0.569	0.559	0.813	0.894	0.691	0.732
	(0.432)	(0.377)	(0.396)	(0.258)	(0.414)	(0.318)
SQ-TIT	0.548	0.767	0.810	0.819	0.679	0.811
	(0.437)	(0.239)	(0.425)	(0.235)	(0.431)	(0.247)
Total	**0.498**	**0.627**	**0.795**	**0.835**	**0.647**	**0.723**
	(0.472)	**(0.375)**	**(0.442)**	**(0.340)**	**(0.457)**	**(0.358)**

Baseline (BT); Sanctioned quota (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information (SQT-TIT)
Source: fieldwork data June 2017 and September 2018

Table A5.3: Regression results with TIT as base category

Independent variables	Mean stock		Median stock		Efficiency
	Elephant	*Pastures*	*Elephant*	*Pastures*	
BT	-2.348**	-0.783**	-1.632	-2.364	-0.170***
	(1.010)	(0.339)	(1.320)	(1.843)	(0.035)
SQT	5.243***	-0.487	5.200***	4.848***	0.167***
	(1.262)	(0.298)	(1.353)	(1.541)	(0.018)
SQ-TIT	4.609***	-0.496	5.329***	4.932***	0.215***
	(1.049)	(0.322)	(1.235)	(1.359)	(0.018)
Stage1 variable[†]	0.376***	0.269**	0.334***	0.384***	0.080
	(0.064)	(0.102)	(0.068)	(0.079)	(0.063)
Time period	0.853	0.175	0.571	0.695	0.004
	(0.841)	(0.209)	(0.946)	(1.044)	(0.021)
Gender	3.027***	0.064	3.320**	3.859**	0.037
	(1.119)	(0.253)	(1.450)	(1.645)	(0.034)
Understanding level	7.935**	1.190	8.717*	9.307	-0.100
	(3.689)	(1.473)	(4.883)	(6.283)	(0.108)
Constant	6.628	6.029***	6.116	11.447	0.573***
	(4.104)	(1.779)	(5.807)	(7.625)	(0.110)
R^2	0.563	0.225	0.493	0.480	0.740
Prob > F	0.0000	0.0016	0.0000	0.0000	0.0000
Observations	96	96	96	96	96

Baseline (BT); Sanctioned quota (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information (SQT-TIT)
Source: fieldwork data June 2017 and September 2018
Standard errors are shown in parentheses
NB: A categorical variable is used to represent the four treatments. The baseline treatment is supressed or omitted so that a comparison is made between each treatment and the baseline category.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[†] Stage 1 variable represents Mean stock St1, Median Stock St1, and Efficiency St1 respectively

Table A5.4: Regression results

Independent variables	Mean difference [St1 - St2]	
	Elephant	*Pastures*
SQT	-8.497***	-8.757***
	(1.260)	(1.426)
TIT	-1.290***	-1.445
	(1.323)	(1.462)
SQ-TIT	-7.685***	-6.490***
	(1.309)	(1.455)
Stage1 variable†	0.621***	2.160***
	(0.077)	(0.387)
Period	-0.452	-1.034
	(0.893)	(1.013)
Constant	8,219	6.775***
Project	Yes	Yes
Gini index	3.132	-2.515
Age	-0.0658	0.0182
Gender [F=0, M=1]	5.196*	-0.682
Education	6.114	0.557
R^2	0.592	0.478
Observations	96	96

Baseline (BT); Sanctioned quota (SQT); Threshold information treatment (TIT); Sanctioned quota and threshold information (SQT-TIT)
Source: fieldwork data June 2017 and September 2018
Standard errors are shown in parentheses
NB: A categorical variable is used to represent the four treatments. The baseline treatment is supressed or omitted so that a comparison is made between each treatment and the baseline category.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
† Stage 1 variable represents Mean stock St1, Median Stock St1, Mean diff St1 and Efficiency St1 respectively

Because we collected the data during two different time periods, we carried out appropriate analysis and tests to show stability in the two samples and that the underlying story remained the same. For example, we used a Mann-W U test for significant differences in means, Levene’s test for the equality of variance, and a Kruskal-Wallis test to verify that both periods’ samples came from the same population, using nonparametric tests where appropriate. The analysis showed that the participants from the two time periods were similar in many respects and the results substantially agreed with each other. Most importantly, the results are similar between the two time periods and hence justify combining the data from the two time periods in our analysis.

Our results also confirm that the time period during which the interviews were conducted is not an important factor in explaining variability in the second stage variables since its coefficient is insignificant in all seven regression models (refer here to where to find the models).

Table A5.5: Levene's test for equality of variance among treatments

Stock of elephants	Stock of pastures
W_0 =1.58 df(3, 92) Pr > F = 0.20	W_0 =0.98 df(3, 92) Pr > F = 0.40
W_{50}=1.26 df(3, 92) Pr > F = 0.29	W_{50}=0.97 df(3, 92) Pr > F = 0.41
W_{10}=1.49 df(3, 92) Pr > F = 0.22	W_{10}=1.01 df(3, 92) Pr > F = 0.39

NB: Assess the equality of variances for a variable calculated for two or more groups (treatments)

Table A5.6: Levene's test for equality of variance between periods

Stock of elephants	Stock of pastures
W_0 = 1.61 df(3, 92) Pr > F = 0.21	W_0 = 0.17 df(3, 92) Pr > F = 0.67
W_{50}= 1.85 df(3, 92) Pr > F = 0.18	W_{50}= 0.16 df(3, 92) Pr > F = 0.69
W_{10}= 1.68 df(3, 92) Pr > F = 0.20	W_{10}= 0.23 df(3, 92) Pr > F = 0.62

NB: Assess the equality of variances for a variable calculated for two or more groups (two period) sample

Table A5.7: Kruskal-Wallis equality-of-populations rank test (by treatments)

	Average stock of elephants	Average stock of pastures
Chi-squared	35.76 ***	10.86 ***
Df	3	3
Probability	0.0001	0.0001

NB: Test hypothesis that several samples are from the same population

Table A5.8: Kruskal-Wallis equality-of-populations rank test (by period)

	Average stock of elephants	Average stock of pastures
Chi-squared	0.43	1.96
Df	1	1
Probability	0.51	0.16

NB: Test hypothesis that several samples are from the same population (no difference between the periods)

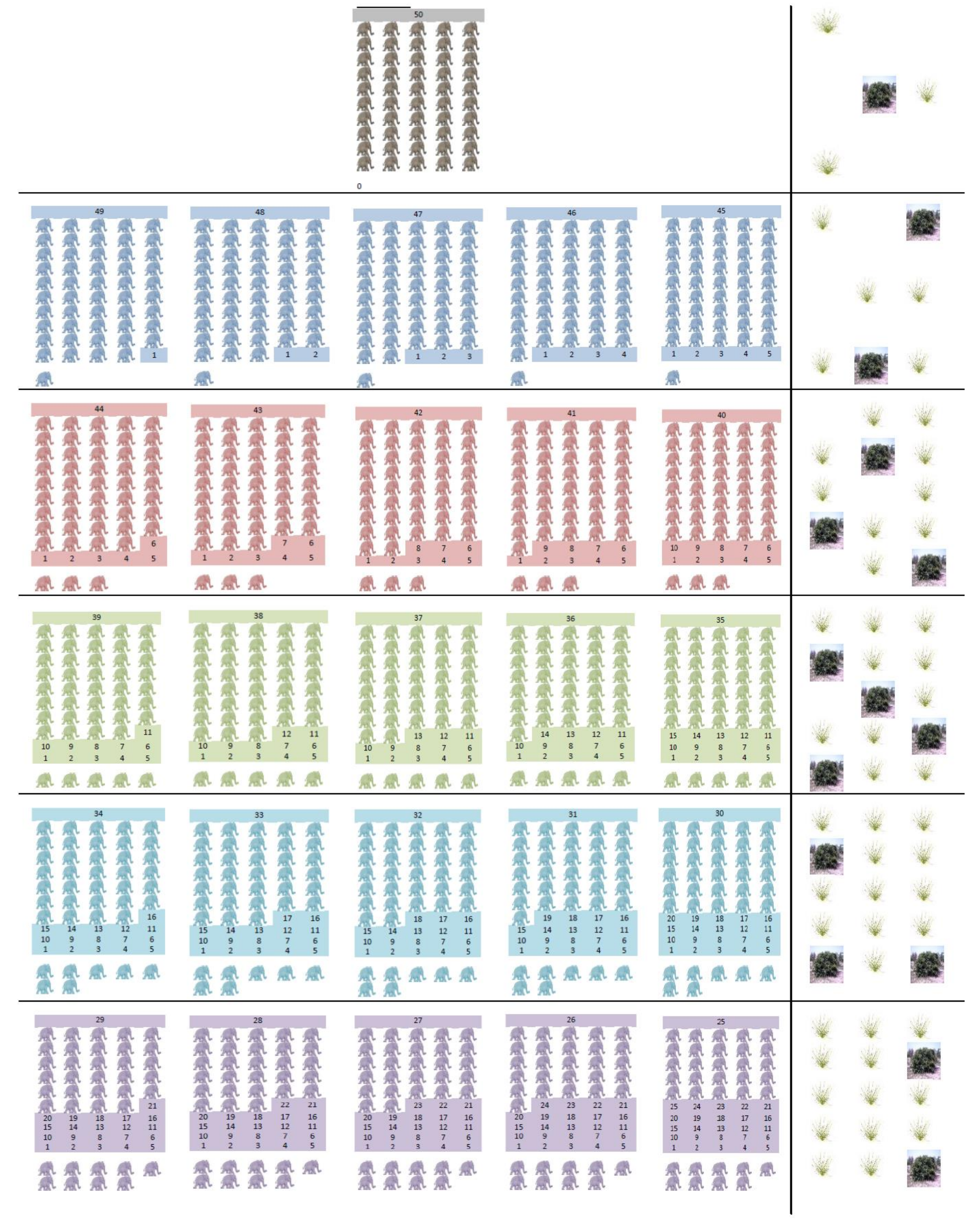
Table A5.9: Student t-test for successful randomization (Ha: diff != 0)

	Obs.	Age		Years in school		Employment		Gender	
		Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
SQT	24	36.577	1.595	7.221	0.408	0.545	0.099	0.310	0.036
BT	24	37.531	1.384	7.656	0.395	0.697	0.093	0.290	0.034
Diff		-0.954	2.111	-0.438	0.568	-0.153	0.135	0.020	0.054
Pr(|T| > |t|)		0.654		0.447		0.262		0.641	
	Obs.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
TIT	24	37.043	1.090	7.667	0.422	0.550	0.054	0.317	0.054
BT	24	37.531	1.384	7.656	0.395	0.697	0.093	0.290	0.040
Diff		-0.488	1.762	0.010	0.578	-0.177	0.107	0.027	0.067
Pr(|T| > |t|)		0.783		0.985		0.147		0.523	
	Obs.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
SQ-TIT	24	37.160	1.241	6.968	0.457	0.534	0.068	0.308	0.033
BT	24	37.531	1.473	7.656	0.395	0.697	0.092	0.290	0.040
Diff		-0.371	1.812	-0.688	0.691	-0.163	0.115	0.018	0.052
Pr(|T| > |t|)		0.684		0.456		0.172		0.690	
	Obs.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
TIT	24	37.043	1.181	7.667	0.313	0.550	0.046	0.317	0.065
SQT	24	36.577	1.484	7.221	0.317	0.545	0.087	0.310	0.045
Diff		0.466		0.446	0.452	0.055	0.153	-0.007	0.065
Pr(|T| > |t|)		0.594		0.873		0.342		0.745	
	Obs.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
SQ-TIT	24	37.160	1.321	6.968	0.467	0.534	0.057	0.308	0.043
SQT	24	36.577	1.486	7.221	0.417	0.545	0.078	0.310	0.036

Diff		0.583		-0.252	0.322	-0.011	0.324	-0.002	0.066
Pr(|T| > |t|)		0.621		0.573		0.298		0.774	
	Obs.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.	Mean	Std. Err.
SQ-TIT	24	37.160	1.241	6.968	0.459	0.534	0.044	0.308	0.035
TIT	24	37.043	1.081	7.667	0.333	0.550	0.055	0.317	0.061
Diff		-0.117		-0.699	0.587	-0.016	0.245	-0.009	0.298
Pr(|T| > |t|)		0.754		0.756		0.343		0.834	

Baseline treatment (BT); Sanctioned quota treatment (SQT); Threshold-information treatment (TIT); Sanctioned quota and threshold-information treatment (SQT-TIT)
Source: fieldwork data June 2017 – September 2018

B.1: Logistic growth function without threshold

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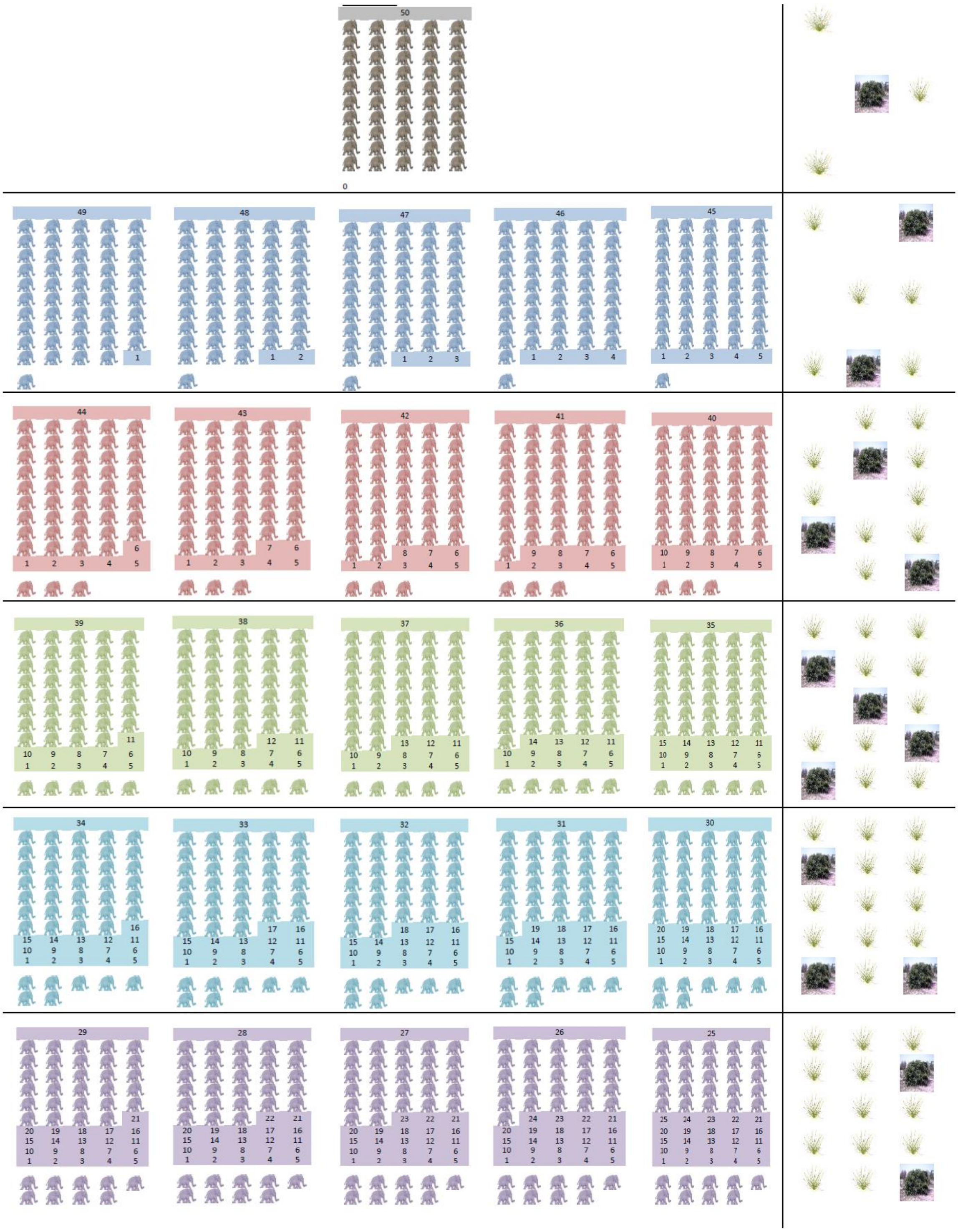
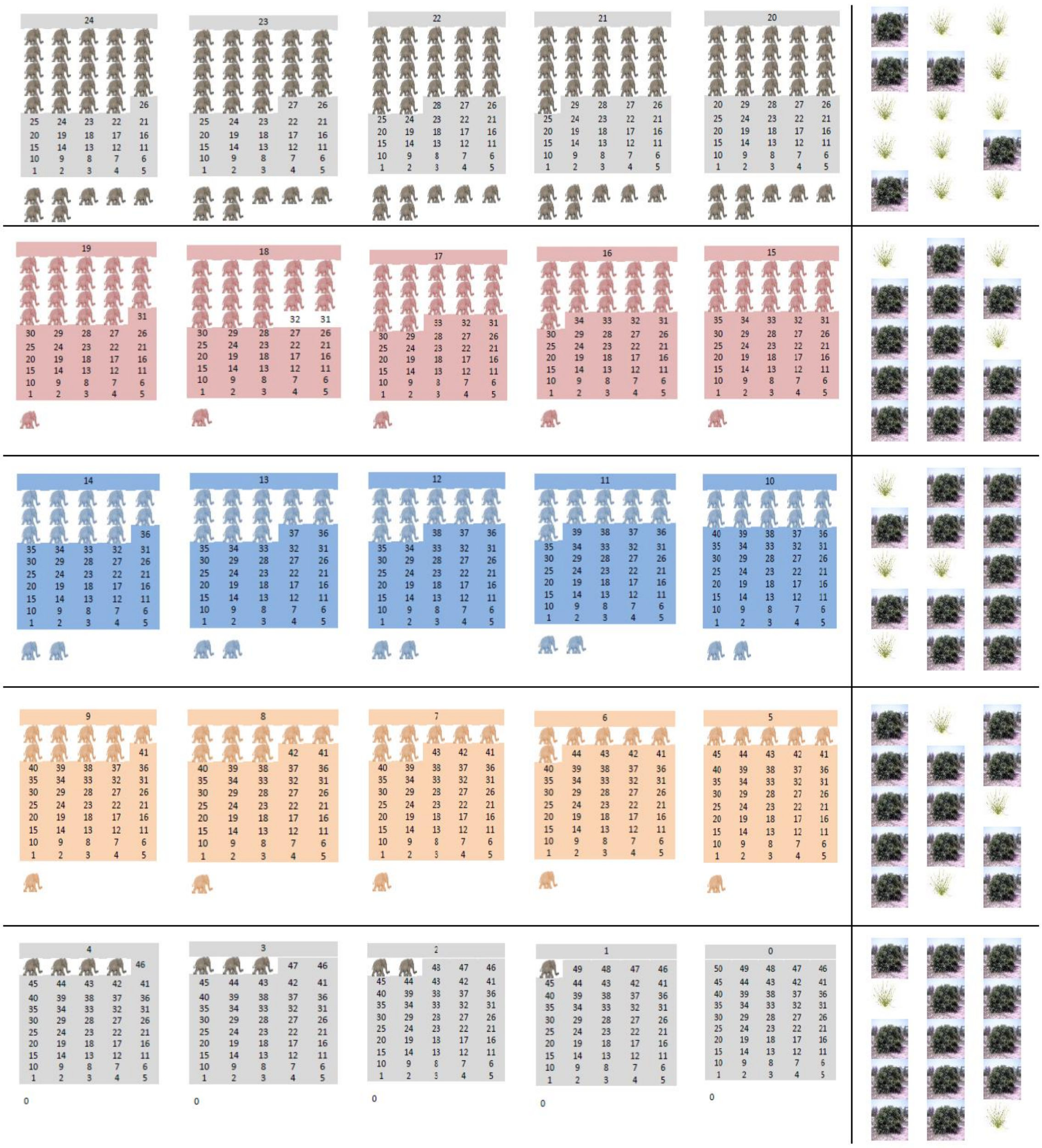
B.2: Logistic growth function with threshold





B.3: Instructions

[*Please read these instructions aloud. Read the normal text only. The instructions in italics or squared brackets are for the research assistant to follow*]

Introductions

Good morning/afternoon, thank you for coming and participating in this activity. Participation in this activity is voluntary. For participating in this activity, you will receive a show up fee of $X.

In this activity we will play a game. In this game you will be asked to make some economic decisions. Depending on the choices you make in this game, you will earn extra money.

The money you will earn is neither a payment for taking part in the activity, nor the reason for you to be here. We use money because the exercise requires that you make some economic decisions that have consequences. It is to make the game realistic.

The activity will take approximately 1 hours of your time.

Group division

You will now be divided into groups of X participants each. You will randomly pick a card which tells the group that you belong to and your identity number.

Each person participates only in one treatment and in one session.

[*Ask each participant to randomly pick a card from the urn. Avoid placing members of the same household or family in one group, please verify afterwards*]

Explain the idea of common pool resources (e.g., elephants and pastures), access and harvesting

Imagine that you are managing elephants and pastures. You share both elephants and pastures as a group.

But you take decisions about how many elephants to harvest individually, and what you do as individuals affects others in the group.

The quality of the pasture is linked to the number of elephants. Elephants help to improve the quality of pastures by keeping the number of bushes low in the wilderness.

Elephants can also have value as hunting trophies. The price is $0.20 for each elephant harvested. For example, if you harvest 5 elephants you will earn $1; if you harvest 20 elephants you will earn $4 and so on. [Show picture]

Each unit of pasture is worth $0.10 per unit per group.

Explain the game

The game lasts several rounds and in each round you make a decision about how many elephants to harvest as an individual.

In each round, you will get a request slip where you indicate your decision. Research assistants will collect the request slips at the end of each round.

[*Show the participants what a request slip looks like*]

You mark on the request slip with an X how many elephants you would like to harvest. You can choose a number between zero and the current stock of elephants available.

[*Make sure that the subject's decisions are anonymous*]

When you make a decision, you will be asked to move away from each other or turn your back on each other so that other group members will not see what you have done.

After decisions about how much to harvest have been made in each round, the experimenter will record, calculate and reveal to the whole group the total harvest and new stock sizes of the elephants and pastures.

You will also get a balance sheet that will be updated by the research assistants and given back to you before the next round.

[*Show the participants what a balance sheet looks like*]

The balance sheet will show you the current stock sizes of the elephants and pastures, total harvest and your earnings.

After the game, the balance sheets will be collected by the research assistants.

[*Fill in the details of the participants before handing in the request slip and balance sheet*]

You are allowed to communicate anytime during the game. But when it is time to make a decision, you can only do so as an individual.

As long as there are elephants to harvest, the game continues for a number of rounds and you can earn money. If there are no elephants left, the game ends and you will not earn any more money.

We will not tell you the exact number of rounds.

If the harvest is larger than the stock, you will share proportionally according to your catch claim.

The stock of elephants is an asset with value. You can sell it at the end of the game and get additional money which can be shared among the group members.

a) **Instructions for the baseline treatment**

Explain that both resources are linked, dynamic and grow

Your stocks of elephants and pastures grow between each round. How much the stock grows depends on how many elephants your group left in the previous round. Growth in the pastures is linked to the number of elephants you have.

You will start with 50 elephants in the first round. With 50 elephants the stock does not grow. Our stock of pastures will be 3 resource units.

[*Show this on the picture*]

After harvest, if there are 45-49 elephants in the stock, there will be 1 more elephant in the next round. The stock of pastures will be 5 units, i.e., two additional units gained.

[*Show this on the picture*]

If there are 25-29 elephants in the stock, there will be 9 more elephants in the next round. The stock of pastures will be 13 units, i.e., ten additional units gained starting with the original three units.

[*Show this on the picture*]

If there are 10-14 elephants in the stock, there will be 3 more elephants in the next round. The stock of pastures will be 6 units, i.e., seven units lost from thirteen units previous gained.

[*Show this on the picture*]

If there are 0-4 elephants, there is no growth. The stock of pastures will be 2 units, i.e., eleven units lost from thirteen units previous gained.

[*Show this on the picture*]

b) **Instructions for the threshold information treatment**

Substitute the resource dynamics and grow

Your stocks of elephants and pastures grow between each round. How much the stock grows depends on how many elephants your group left in the previous round. Growth in the pastures is linked to the number of elephants you have.

You will start with 50 elephants in the first round. With 50 elephants the stock does not grow. Our stock of pastures will be 3 resource units.

[*Show this on the picture*]

After harvest, if there are 45-49 elephants in the stock, there will be 1 more elephant in the next round. The stock of pastures will be 5 units, i.e., two additional units gained.

[*Show this on the picture*]

If there are 25-29 elephants in the stock, there will be 9 more elephants in the next round. The stock of pastures will be 13 units, i.e., ten additional units gained starting with the original three units.

[*Show this on the picture*]

If there are 15-19 elephants in the stock, there will be 1 more elephants in the next round. There is a sharp drop in the elephant population. The stock of pastures will be 3 units, i.e., ten units lost from thirteen units previous gained. There is also an explosion in the population of bushes.

[*Show the pictures on the board*]

If there are 10-14 elephants in the stock, there will be 2 more elephants in the next round. The stock of pastures will be 4 units, i.e., nine units lost from thirteen units previous gained.

[*Show the pictures on the board*]

If there are 0-4 elephants, there is no growth. The stock of pastures will be 2 units, i.e., eleven units lost from thirteen units previous gained.

[*Show this on the picture*]

c) Instructions for the sanctioned quotas treatment

i) For the sanctioned quotas treatment use, resource dynamics for the baseline

ii) For the sanctioned quotas-threshold information treatment, use the resource dynamics for threahold

We will now introduce some rules.

In this game, you are given a quota as a group. The quota is calculated as the difference between the current stock size and a lower limit 20 units. You will receive a quota as long as the current stock in each round is greater than 20 resource units.

For example your quota at the beginning of the game is 50 – 20 = 30 elephants. If you have 35 elephants left, your quota is 35 – 20 = 15 and so on. If the stock of elephants is below 20 units, your quota will be zero.

If the total harvest exceeds the quota, then the following rule applies.

The experimenter will throw a dice and the number on the dice would correspond to the person being controlled. If the dice show numbers 5 or 6, no control is made.

If you are controlled, then you will lose your harvest and put under temporary prohibition for one round for the first time offender, two rounds for the second time and so on.

Question and answer session

Do you have and questions? Allow them to ask questions and provide answers.

Rehearsals

You will now play some practise rounds. Allow them to ask further questions. Ask them if they are ready to start the game.

Short Test [*Read questions aloud. Ask four questions randomly to each subject***]**

Q1. How do you know your group? 0 = other 1 = group number and colour

Q2. What do you think is the purpose of having an ID number in the game?

Q3. How long does the game last? 0 = other responses 1 = 2hrs

Q4. Am I allowed to talk with other members of the group? 0 = No 1 = Yes

Q5. I make decision about how many elephants to harvest as an individual. 0 = No 1 = Yes

Q6. What I do as an individual does not affect the whole community. 0 = No 1 = Yes

Q7. Growth in the elephant population linked to growth in the pastures. 0 = No 1 = Yes

Q9. If we reduce number of elephants the number of bushes will also reduce. 0 = No 1 = Yes

Q10. If we harvest all the elephants our pastures will greatly improve. 0 = No 1 = Yes

Q11. How many elephants do we start with? 0 = other 1 = 50

Q12. With 50 elephants, our stock of elephants will grow by 0 = other 1 = zero

Q13. If we harvest 25 elephants as a group, there will be ______ more elephants in the next round. 0 = other 1 = 9

Q13. If we harvest 40 elephants as a group, the stock of pastures will be ______ units in the next round. 0 = other 1 = 6

Q14. If we harvest 48 elephants as a group, the stock of elephants in the next round will not grow and the stock of pastures will be 4 units. 0 = No 1 = Yes

Q15. If we want to have 10 units of pastures as a group, how many elephants can we harvest?

0 = other 1 = any of these (11, 12, 13, 14 or 15)

Q16. If 4 elephants remain in the urn at the end of the game, what happens to them?

0 = other 1 = (0.75*4)/4

Test results

Area	Group	ID	Q1	Q2	Q3	Q4

Start

We will now start to play the game.

B.4: Questionnaire

Section A: Identification

A1	Questionnaire No.	
A2	Interviewer code	
A3	Name of respondent	
A4	ID No	
A5	Contact number	
A6	Date of interview	

A7	Time	
A8	Area code	
A9	Group No	
A10	Group colour	
A11	Group size	
A12	Treatment	

Section B: Participant characteristic

			Code
B1	Age of the participant		
B2	Gender of the participant	0 = Female 1 = Male	
B3	Marital status	1 = Single 2 = Married 3 = Widow 4 = Widower	
B4	Household size		
B5	Educational level	a. Number of years in school	
		b. Level 0 = None 1 = Primary 2 = Secondary 3 = Tertiary	
B6	Did you receive training relevant to natural resource management? 0 = No 1 = Yes Number of training courses received? ___________		

B7	Employment status 0 = Unemployed 1 = Employed 2 = Self employed	

	Agriculture income (past 12 months)	
	Employment income (past 12 months)	
	Self-employment (past 12 months)	
	Remittances (past 12 months)	
	Total household income (past 12 months)	
B8	Do you belong to any community-based organization? 0 = No 1 = Yes How many organizations do you belong to? _____________	

Section C: Participant's perception

About the game		Code
C1	Have you played a game like this before? 0 = No 1 = Yes 2 = DK	
C2	Did you understand the game the game you played today? 0 = No 1 = Yes	
C3	Using a scale from 1 to 5 what was your level of understanding?	
C4	On a scale from 1 to 5 please rate the level of understanding of other participants in your group	
C5	Did you observe any differences between phases I and II of the game? a) No observation 0 = No 1 = Yes b) Threshold 0 = No 1 = Yes c) Quota 0 = No 1 = Yes d) Punishment 0 = No 1 = Yes	
C6	In the game we did just now, was someone in your group a friend? 0 = No 1 = Yes	
C7	Did your group use the same strategy during the 1st and 2nd phase of the game? 0 = No 1 = Yes 2 = DK	
C8	Did you harvest more in the 2nd phase than in the 1st phase? a) As an individual 0 = No 1 = Yes b) As a group 0 = No 1 = Yes 2 = DK	
C9	Were you surprised when the game finished? 0 = No 1 = Yes	
C10	[If yes] How many more rounds did you expect that you would play? No more rounds _______ Less than 5 rounds _________ More than 5 ________	

Perception on communication

C11	Did you engage in communication in your group? 0 = No 1 = Yes 2 = DK	
C12	How many people did you communicate with in your group?	
C13	Using a scale from 0 to 5, please rate the content of the message communicated in your group a) First phase __________ b) Second phase __________	
C14	Using a scale from 0 to 5, please rate the clarity of the message communicated	
C15	Using a scale from 0 to 5, please rate the clarity of the message's objective	
C16	Was communication in your group effective? 0 = No 1 = Yes 2 = DK	
C17	Using a scale from 0 to 5, please indicate the extent to which communication achieved the objectives of the group	

Perception on cooperation

C18	Do think participants cooperated in your group? 0 = No 1 = Yes 2 = DK	
C19	Did you cooperate more in the 2nd phase than in the 1st phase? a) As an individual 0 = No 1 = Yes b) As a group 0 = No 1 = Yes 2 = DK	
C20	Using a scale from 0 to 5, please rate the level of cooperation in your group a) First phase __________ b) Second phase __________	
C21	Using a scale from 0 to 5, please indicate the extent to which cooperation managed to achieve the goals of the group	
C22	Do you think members in your group trusted each other? 0 = No 1 = Yes 2 = DK	
C23	Using a scale from 0 to 5, please rate the level of trust in your group a) First phase __________ b) Second phase __________	

C2 4	What happened to the level of trust? a) First phase Increased over time [ ] Decreased over time [ ] Nothing [ ] b) Second phase Increased over time [ ] Decreased over time [ ] Nothing [ ]	

Section D: Changes in wildlife abundancy, knowledge and attitudes

D1	Do you think there is plenty of wildlife out there in the bush? 0 = No 1 = Yes 2 = DK	
D2	Do you think there are species that are threatened in this area? 0 = No 1 = Yes 2 = DK a) Do you have any idea how many species might be threatened? ______ b) Which species are threatened? ________________________________	
D3	How many times did you eat bush meat during the past twelve months? ______	
D4	Where do you think this bushmeat came from? 0 = Own 1 = Friend 2 = Buy 3 = DK	
D5	Kgs of bushmeat consumed per person per year __________________	
D6	Do you know anyone who hunts wild animals in this area? 0 = No 1 = Yes 2 = DK a) How many people do you know? _____________ b) Who do you think are the perpetrators? 0 = Local people 1 = External 2 = DK	
	c) Do you know of any relatives who sometimes hunt wild animals? 0 = No 1 = Yes 2 = DK	
	d) Do you know of any friends who sometimes hunt wild animals? 0 = No 1 = Yes 2 = DK	
D9	To your knowledge, how many poaching incidences do you think happened during the past 12 months? _______	
D10	How many households do you think are involved in illegal harvesting of wildlife in your community? _________	
D11	To your knowledge, how many households do you think sell bushmeat in your community? _______	
D12	Out of the total number of households that you know are involved in illegal harvesting of wildlife, how many do you think were caught within the past 12 months? ____	
D13	Using a scale from 1 to 5, please indicate the level of confidence you have with your answers above	

D14	Have you ever heard of ivory trade? 0 = No 1 = Yes 2 = DK a) From who? 1 = Friend 2 = Neighbour 3 = Relative 4 = Meeting 5 = Other b) What do you know? Explain ____	
D15	Do you think poaching is good or bad? 0 = No 1 = Yes 2 = DK Why do you say so? ____	
D16	What do you think are the main reasons why people illegally hunt elephants? Don't know [ ] Destroy crops [ ] Dangerous animal [ ] Bush meat [ ] Ivory trade [ ] Other [ ]	
D17	How far is your home from the boundary or fence of the game park?	
D18	How farm is your home to the nearest town?	
D19	Did household suffer wildlife intrusion past 12 months? 0 = No 1 = Yes 2 = DK	
D12	Did community receive wildlife income within the past five years? 0 = No 1 = Yes 2 = DK How much did you receive? ______________________	
D13	Do you have a wildlife management committee in place? 0 = No 1 = Yes 2 = DK	
D14	Please rate the effectiveness of the committee using a scale from 0 to 5	
D15	Has the committee organized any meeting past 12 months? 0 = No 1 = Yes 2 = DK How many meetings were organised? ____________ Please rate meeting attendance on a scale from 0 to 5	
D16	Does your project have a constitution? 0 = No 1 = Yes 2 = DK Were you involved in developing the constitution? 0 = No 1 = Yes 2 = DK	

END

B.5 Request sheet

Group ______ ID number ______ Date ______ Time _______

Round	

Number of elephants requested

1	2	3	4	5	6	7	8	9	10

11	12	13	14	15	16	17	18	19	20

21	22	23	24	25	26	27	28	29	30

31	32	33	34	35	36	37	38	39	40

41	42	43	44	45	46	47	48	49	50