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Sanctioned Quotas vs. Information Provisioning for Community Wildlife Conservation in Zimbabwe:

A Framed Field Experiment Approach

Herbert Ntuli, Anne-Sophie Crépin, Edwin Muchapondwa, and Caroline Schill

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

Herbert Ntuli, Anne-Sophie Crépin, Edwin Muchapondwa, and Caroline Schill*

Abstract

We investigate the behavioural responses of resource users to two policy interventions: sanctioned quotas and information provisioning. We do so in a context in which multiple resources (pastures and wild animal stocks) are connected and could substantially and drastically deteriorate as a result of management. We perform an experimental study among communities that are managing common pool wildlife in Zimbabwe. We find that user groups manage these resource systems more efficiently when faced with either a policy intervention, or the possibility of a drastic drop in stocks, or a combination of both, compared to groups facing standard resource growth without possibility of a drastic drop. Although a sanctioned quota performs better than information under some circumstances, information can be a good substitute in situations when a quota is either suboptimal or expensive, as is the case in most developing countries. However, the combination of both interventions is better for managing complex ecosystems than either quota or information alone. Our main innovation is applicability of the experimental design, including complexities associated with linked resource systems. Our study also provides pragmatic evidence of the role of carrot and stick institutions versus information provisioning in governing common pool wildlife in Southern Africa. These results can inform policymakers and development practitioners. If they aim to avoid a drastic drop in linked resources, they can use a policy intervention with either a sanctioned quota or information. The combination of both types of intervention might be most appropriate.

Key Words: collective action, common pool resources, laboratory experiments, regime shift, social ecological system, threshold

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

1. Introduction

Imagine a local African community that lets its animals feed on grasslands and gains revenues from touristic activities linked to the wild elephants in the neighbourhood. These two activities are not independent, because wild elephants' feeding habits prevent bush encroachment, thus maintaining healthy grasslands. In addition, the way the local community manages the elephants can substantially influence their reproduction. If the elephant population drops too low, it would become harder for them to reproduce. Too few elephants would then result in bush encroachment, preventing domestic animals from grazing. This scenario would be called a regime shift, from an elephant-rich grassland to an elephant-poor bushy area, which provides far fewer ecosystem services for the local community. Can the community spontaneously succeed in maintaining the elephant stock and grassland quality at a satisfying level? What kind of policy intervention would help reach the desired outcome? Should the authorities inform the community about these dynamics? Should they instead introduce a quota, a lower limit for the elephant stock, which, if trespassed, would be sanctioned with punishment in the form of a fine?

This paper aims to investigate the effects of two types of policy interventions on the management of two interlinked resource systems: a stock of elephants and the grazing areas in which they live. Both resources can exhibit abrupt change in their growth. In the context of a framed field experiment with communities managing wildlife in Southern Africa, we compare a policy intervention in the form of a quota (sanctioned by punishment) with an intervention that informs resource users about an endogenously driven, abrupt and persistent change in the growth rate of both resources.

Such regime shifts‒large, abrupt and potentially persistent changes in the structure and dynamics of an ecosystem‒can occur when some levels of key ecosystem variables reach beyond a tipping point because of either endogenous or exogenous processes. They often result in substantial decrease in the availability and provisioning of ecosystem goods and services (Biggs et al. 2012). Regime shifts are often difficult to anticipate, costly, and sometimes impossible to reverse because the pathway of recovery of an ecosystem differs from its pathway of degradation (Folke et al. 2004; Scheffer and Carpenter 2003; Suding and

*Corresponding author: Herbert Ntuli (h.ntuli@uct.ac.za), School of Economics, University of Cape Town, Private Bag X3, Rondebosch, 7701, South Africa. Anne-Sophie Crépin, the Beijer Institute of Ecological Economics, Stockholm, Sweden. Edwin Muchapondwa, University of Cape Town. Caroline Schill, the Beijer Institute of Ecological Economics. We thank the CAMPFIRE communities around the Gonarezhou National Park in Zimbabwe for their willingness to participate in the surveys. We are grateful for research funding from the Swedish International Development Cooperation Agency (Sida) through the Environment for Development (EfD) Initiative at the University of Gothenburg, and the Mäler Scholarship awarded by the Beijer Institute of Ecological Economics in 2017. Last but not least, we thank both friends and colleagues for their useful comments.

Hobbs 2009). There is growing interest in the study of regime shifts in ecosystems across the globe and how to address them (See e.g. Scheffer and Carpenter 2003; Folke et al. 2004; Fischer et al. 2009; Biggs et al. 2012; Brock et al. 2012; Crépin et al. 2012; Dakos et al. 2015). This literature focuses on the drivers of regime shifts, their impacts on the provision of ecosystem goods and services, and how these impacts affect people's livelihoods (Gordon et al. 2008). Evidence suggests that the frequency and intensity of regime shifts is increasing with increasing human pressure and climate change impacts (Brander 2010; Brierley and Kingsford 2009; Jiao 2009; Overland et al. 2008). Therefore, comprehending the fundamental structure and dynamics of social-ecological systems (SESs) becomes imperative, particularly in circumstances where multiple resource systems are linked and the livelihoods of poor rural communities depend heavily on the goods and services provided by nature.

This study is motivated by a common pool resources (CPR) problem where collective action is needed to manage the resource in a sustainable manner and avoid regime shifts. We choose to focus on CPRs because their joint utilization presents severe management and coordination challenges and because this form of management is common in developing countries. A significant proportion of CPRs, such as wildlife, forests, rangelands and water resources, are held in the hands of indigenous communities. There is fear that local communities can actually run down these natural resources in the absence of sound CPR institutions and effective external enforcement. CPRs are not necessarily governed by explicit common property protocols, which demand the development of specific institutions to protect the resource. Furthermore, these rules need to adapt to local conditions and change over time in response to changes in the resource system, and the social, economic and political environment.

We consider local communities that are involved in wildlife conservation under the banner of the *Communal Areas Management Programme For Indigenous Resources* (CAMPFIRE) in Zimbabwe[1]. Under this programme, a Rural District Council manages wildlife on behalf of local communities and generates revenues by selling hunting licences to foreign hunters through safari operators. Every year, a CAMPFIRE community gathers information about the number of elephants roaming its conservation area[2] and uses this as justification when applying for a quota (Ntuli and Muchapondwa 2017). Almost no CAMPFIRE communities in the study area engage in non-consumptive tourism due to the huge capital outlays involved, e.g., marketing, accommodation and transportation, thereby making trophy hunting the most dominant activity. The African elephant (*Loxodonta*

[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] 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).

africana) is the backbone of CAMPFIRE projects. Elephants generate more revenue than all other species of wildlife combined. However, sustainability of this income source depends on how local communities manage the stock of elephants. In addition, elephants cause more damage to the community compared to other wildlife species by destroying field crops and sometimes killing or injuring human beings if provoked. Communities retaliate by killing elephants using crude means such as poisoning and setting up wire snares.

Many case studies of different types of regime shifts have been documented in social-ecological systems (SESs) across the globe in a database referred to as the Regime Shifts Database (Biggs et al. 2015). However, there is limited research on humans' behavioural responses to regime shifts that affect the flow of ecosystem goods and services in SESs. None of these studies considers linked resource systems where multiple ecosystem resources interact. In addition, there is limited understanding of the relative effectiveness of different institutional features such as sanctioned quotas versus information to influence outcomes in a regime shift context. The few existing studies in this area use lab experiments (Lindahl et al. 2016a; Schill et al. 2015) or focus on fisheries with framed field experiments in Colombia (Schill and Rocha 2017) and Thailand (Lindahl and Jarungrattanapong 2018) and highlight the influence of local contexts. To our knowledge, no such study has been undertaken on a terrestrial ecosystem in Africa, a very different context.

We aim to bridge this gap by comparing behavioural group responses to endogenous punishment and a latent endogenously driven regime shift using framed field experiments involving CAMPFIRE communities in Zimbabwe. We picture a CPR in which the renewal rate of the resource drops dramatically below a certain stock threshold level, triggering an endogenously driven regime shift. Our approach builds on the work of Lindahl et al. (2016a), but differs in that we consider a regime shift in a resource system (grassland) that is caused by a perturbation in another resource system (elephant stock). In natural ecosystems, most resources are linked: changes in one system due to external pressure affect dynamics in another system. This could result in either collapse or substantial reorganisation of the entire ecosystem; hence, it is essential to understand these dynamics. The use of punishment as a means to enforce policy prevails across the globe, suggesting that punishment is a panacea for all environmental problems, yet non-punishment institutions may perform equally well or even better under certain circumstances (Aquino et al. 2015). Therefore, we aim to answer the following question: How does knowledge of the resource system compare with a quota enforced through punishment (a fine) in influencing collective resource exploitation strategies?

2. Literature Review

2.1 The Role of Elephants in Shaping the Savanna Ecosystems

The African elephant is considered a mega-herbivore and keystone species whose activities and population variations can cause profound changes in ecosystems, including extinctions of other species (Western 1989). Elephants have substantial influence on their habitat (Chafota and Owen-Smith 2009; Moe et al. 2009; Guldemond and Van Aarde 2008). Although elephants prefer grazing to browsing, they are water-dependent, non-selective bulk feeders with substantial forage needs. Nearly 80% of an elephant's day is spent feeding, and an adult elephant can consume up to 180 kg per day (Kerley et al. 2006). An elephant's diet consists of grasses, small plants, fruit, twigs, roots, tree bark and leaves. They tend to shift diets, either grazing or browsing in response to 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). We contribute to this literature by considering the management of elephants in a way that simultaneously benefits livestock and other wildlife species through the creation of adequate space for pastures.

Despite their significance in the ecosystem, the elephant population is dwindling due to a combination of exogenous and endogenous factors. Illegal wildlife harvesting is one of the biggest threats challenging both the existence of elephants in Zimbabwe and the CAMPFIRE programme itself[3]. Continued unabated poaching in the absence of sound CPR institutions could drive the elephant population to unprecedented low levels, challenging the recovery of the population and possibly triggering a regime shift in the savanna grassland ecosystem[4]. Indeed, elephants are known to modify their habitat by controlling the population of bushes, thereby converting savanna woodlands into grasslands (Sithole et al. 2012). The coexistence of woody plants and grasses characterizes the savanna's vegetation structure and composition. Water availability, nutrients, fire and large herbivores influence their respective proportions (Van Langevelde et al. 2003; Scholes and Archer 1997). Harvesting elephants beyond a certain threshold might trigger a massive expansion of bushes – a phenomenon commonly known as bush encroachment. This occurs when grassy landscapes with a relatively low cover of woody plants rapidly and irreversibly increase shrub cover (Moleele

[3] We acknowledge the role of ivory trade in driving commercial poaching. Local communities play a significant role in commercial poaching as a point of entry and source of information and sometimes provide services for meagre remuneration in return (Ntuli and Muchapondwa 2017; Muchapondwa 2003).
[4] http://regimeshifts.org/item/70-bush-encroachment#more, retrieved May 16, 2018

et al. 2002). Bush encroachment reduces grass productivity and can hinder access by cattle, 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. The linkage between the population of large herbivores and resource quality is well documented in the literature (Zyambo 2015; Bond 2008).

2.2 CPR's, Policy Interventions and Regime Shifts

Maintaining large-scale cooperation in CPR management and utilization is fraught with the dilemma of cooperation, in which resource users overexploit the resource (Rustagi et al. 2011). Group members have incentives to overexploit or degrade the resource because the consumption of CPRs reduces the amount available to others (rivalry) and excluding others is difficult (non-excludability) (Ostrom 2003). Unless users develop robust CPR institutions to constrain their behaviour, this eventually leads to a "tragedy of the commons" (Hardin 1968). Such behaviour results in modification of the ecosystem, but its outcome is not known with certainty. Linkages between resource systems in an ecosystem, the presence of thresholds, and regime shifts could potentially worsen the situation (Lindahl et al. 2016a,b; Schill et al. 2015; Crépin et al. 2012). Even marginal changes in management (harvesting or nutrient release, for example) could cause drastic and potentially irreversible ecosystem transformations (Crépin et al. 2012; Mäler et al. 2003).

Improved system knowledge is increasingly gaining attention among scholars as a possible intervention for stabilizing large-scale cooperation in CPRs in general (Ostrom 2007) and in CPRs facing potential regime shifts in particular (Lindahl et al. 2016a; Schill et al. 2015). These studies demonstrated that the threat of reaching a critical tipping point, beyond which the growth rate dropped drastically, triggered more effective communication within a group, enabling stronger commitment for cooperation and more knowledge sharing. Our study adds to this work by addressing the question: what institutional factors are more or less important for management of common pool resources? We focus in particular on the role of quotas (sanctioned with punishment) in comparison with information about systems dynamics.

In another study, Lindahl et al. (2016b) used lab experiments to examine 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, due to both under- and overexploitation. We define overexploitation as exploitation above the optimal level of resource extraction such that the stock dwindles below its optimal level and vice-versa for under-exploitation. Quotas have been in use in Zimbabwe's wildlife sector for quite some time, but ineffective monitoring and enforcement due to budgetary constraints have led to limited results.

The role of punishment in stabilizing large-scale cooperation has received considerable attention in the CPR literature (e.g., Akpalu and Martinsson 2012; Casari and Luini 2009; Nikiforakis et al. 2007; Ostrom 2006; Murphy and Cardenas 2004; Masclet et al. 2003). These studies used CPR games such as lab and framed field experiments, and public goods experiments to investigate the relationship between punishment and cooperation. Punishment can be monetary or non-monetary. There is, however, general consensus in all these studies that punishment (whether monetary or non-monetary) increases cooperation. Masclet et al. (2003) established that, with both punishment types, contributions increased by a similar amount in the beginning, but monetary punishment resulted in higher contributions over time. Casari and Luini (2009) found that peer (collective) punishment led to higher levels of cooperation and appeared to be the strongest deterrent to free-riding behaviour. However, punishment can fail if employed suboptimally (Aquino et al. 2015), thereby necessitating the use of other policy instruments.

Ostrom et al. (1994) emphasized the importance of communication in stabilizing large-scale cooperation in CPRs. However, from a policy standpoint, communication is not very intuitive because in real life one cannot force people to communicate or prevent them from doing so. It is something that typically emerges endogenously from the community. People communicate whenever there is need, e.g., when they face a difficult challenge that is threatening the whole society (Lindahl et al. 2016a). For the type of problem we envisage, communication is neither prohibited nor forced. We want to mimic realistic conditions as much as possible, and one important element is the possible spontaneous emergence of communication, which deserves a particular method of study developed in Schill et al. (2015), allowing communication and gathering additional information in the form of a questionnaire and experimental notes that could help inform different information-sharing decisions. We also acknowledge the contribution of many studies to our understanding of the commons and collective action. Substantial evidence from CPR experiments suggests that individuals are not only motivated by self-interest, but also other-regarding preferences or pro-social behaviour such as altruism, warm-glow, trust, equity, reciprocity and conditional cooperation. These contribute to stabilizing large scale cooperation in CPRs (Martinsson et al. 2013; Rustagi et al. 2011; Fischbacher and Gachter 2010; Kocher et al. 2008; Bowles 2003; Levine 1998; Fehr and Schmidt 1999; Ostrom et al. 1994).

The CPR literature is populated with different of types of experiments, ranging from laboratory experiments to natural field experiments (Harrison and List 2004). A conventional laboratory experiment is often performed in a classroom with university students and with a neutral, context-free description of the problem. The subjects are often isolated and are not allowed to communicate with each other, unless communication is a treatment. A natural field experiment is another extreme, where actual resource users take decisions in their natural environment without knowing that they are participating in an experiment. In this study, we use a framed field experiment, which is in between these two extremes. By doing so, our study takes the laboratory experiment to the field and uses actual resource users who face the common pool resource dilemma in real life. Compared to standard laboratory and natural field experiments, a framed field experiment sacrifices some of the controlled environment for increased realism, but lacks some aspects of a natural environment because subjects are aware that they are involved in an experiment (Lindahl et al. 2012, 2016a; List 2006). The idea is to perform a controlled experiment that captures important characteristics of the real world to reveal how well the behavioural results represent real resource users (Lindahl et al. 2012).

The role of information as a policy instrument should not be underestimated, as a tool to either complement or substitute punishment when punishment yields suboptimal results. This paper differs from previous studies in that we compare the relative effectiveness of sanctioned quotas and information in stabilizing large-scale cooperation in CPR management. Our primary focus and interest is the manifestation of regime shifts (resource dynamics reorganisations) in CPRs, which are triggered by resource users' actions. Indeed, these regime shifts could be avoided if communities were able to invest in robust CPR institutions to coordinate extraction. Specifically, we would like to know how people will behave, and whether they are able to avoid the tragedy of the commons, when they are faced with either punishment or a regime shift.

3. Experimental Strategy

3.1 Experimental Design

This study adapts a CPR game developed by Budescu et al. (1992), which is structured as a request game. This formulation is more appropriate compared to other CPR games, such as the investment game developed by Ostrom et al. (1994), because it fits well the problem of CPR extraction in the context of CAMPFIRE communities. We capture real-life experiences by mimicking the dynamic aspects of complex ecological systems such as connectivity and the resource's threshold and hysteresis[5] effect. In real life, communities in the study area organize meetings to share vital information and discuss issues affecting the whole community. We capture this novelty by allowing time out so that subjects can share information at any time when the need arises, rather than imposing restrictions on communication. As a result, discussions will not be limited in terms of time, content and who

[5] Hysteresis occurs because of the presence of internal feedback loops that maintain the system state, thereby making it difficult to reverse (Biggs et al. 2012).

is involved. Lindahl et al. (2016a) and Schill et al. (2015) used a similar approach with endogenous communication. To approximate an infinite time horizon, the game is played for an unknown number of periods, although the subjects know its maximum duration.

We start with the logistic growth function shown in equation [1], which has been used extensively in the literature to model resource growth (Johannesen and Skonhoft 2004; Murray 2002; Kot 2001; Clark 1990). We modify it as shown in equation [2] to capture resource dynamics with a threshold (Lindahl et al. 2016a; Schill et al. 2015). Let *X* represent a resource stock at time *t* which obeys logistic-type resource dynamics, with growth rate *r* and carrying capacity *K.* Let *h* denote harvest at time *t* of this resource. Then the stock dynamic equation representing the logistic growth function can be written as:

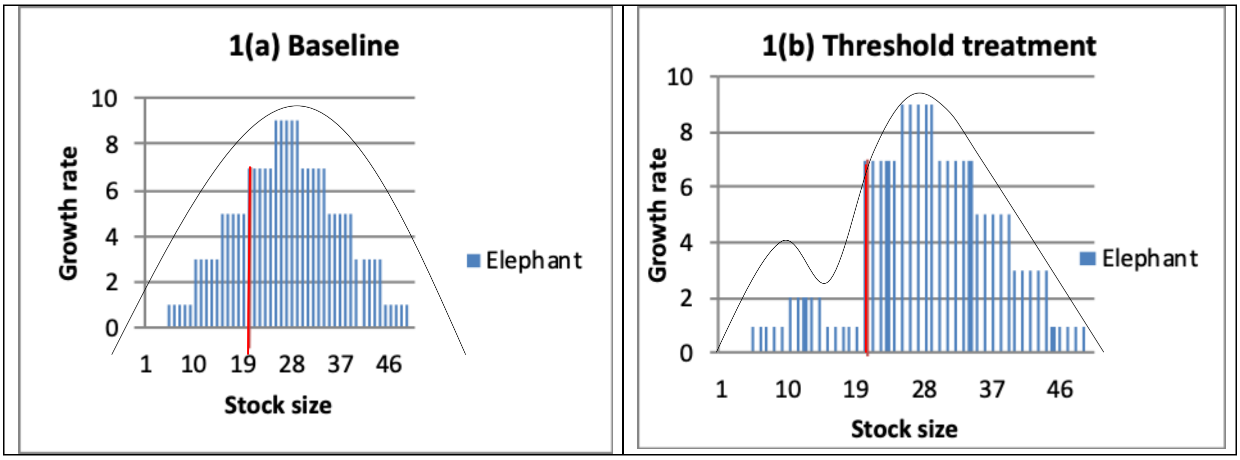
$$\dot{X} = rX\left[1 - \frac{X}{K}\right] - h \qquad [1]$$

If we 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 (Lindahl et al. 2016a; Clark 1990). The boundary solution is attainable when the resource reaches extinction. In the theoretical literature, a threshold is captured by adding a sigmoid term to the logistic growth function, such as a "Holling-type" III predation term (Ludwig et al. 1978). Non-convexities are known to occur in ecosystems such as coral reefs, forests, wildlife and grasslands (Scheffer and Carpenter 2003). 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:

$$\dot{X} = rX\left[1 - \frac{X}{K}\right] - b\frac{X^{\theta}}{a^{\theta} + X^{\theta}} - h \qquad [2]$$

where *b* denotes the maximum uptake rate, *a* half saturation, and exponent θ introduces the non-convexity. Maximizing welfare subject to equation [2] may yield up to three interior solutions, of which two are stable and one unstable (Lindahl et al. 2014). This model captures the critical threshold and associated hysteresis effects in the dynamics of resources with endogenous regime shift. In their experiments, Lindahl et al. (2016a; 2012) and Schill et al. (2015) used a discretized form of such a non-concave growth function to analyse behavioural responses to regime shifts in CPR management. Figure 1(a) below illustrates the continuous logistic resource dynamics and its discrete approximation used in the experiments, while figure 1(b) shows the corresponding curves to illustrate resource dynamics with an endogenous regime shift in the resource's growth rate. We use this particular coarse discretization in the experiment because it is easy to communicate to the experiment subjects and also easier to simply calculate regrowth rate in a limited time in a way that can be conveyed to the participants.

Figure 1: Logistic Growth Function with Threshold and No Threshold for Elephants



Source: figures adapted from Lindahl et al. (2012)

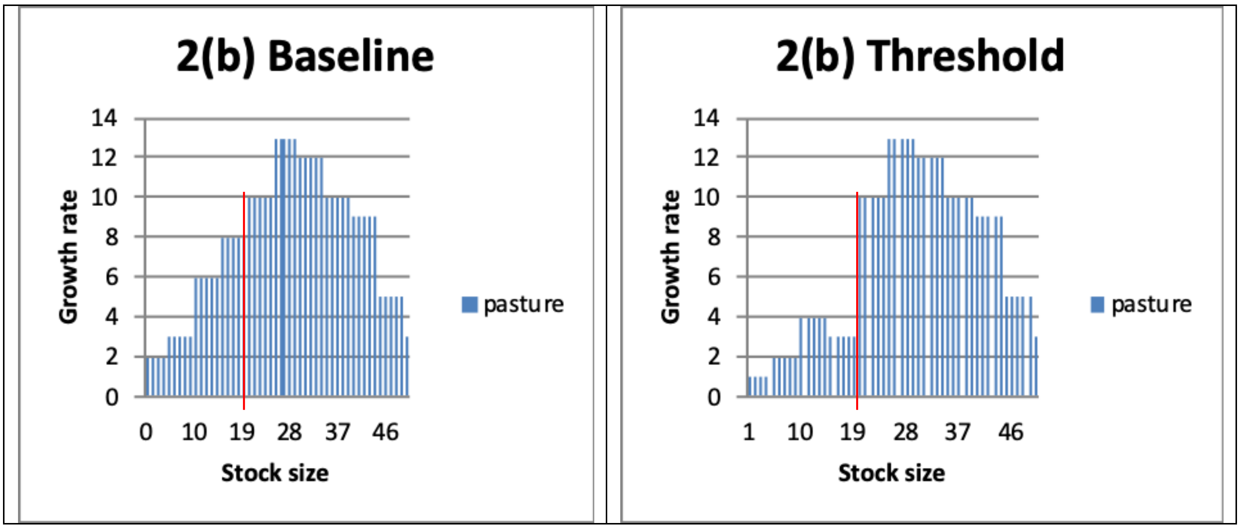
In these models, the minimum resource stock size allowing for possible reproduction is 5 units, while the resource growth rate changes by steps of 5 units. Furthermore, the maximum resource stock size and maximum sustainable yield are set to 50 and 9 resource stock units, respectively. The resource dynamics under both models are identical from 20 resource stock units and above as shown in both figures, i.e., to the right-hand side of the red vertical line. For the threshold model, if the resource stock size falls below 20 resource stock units, the regeneration drops dramatically, from a regeneration rate of 7 to a rate of 1. To recover to a high growth rate once the resource stock is depleted below 20 units, it must be left to rebuild up to 25 units or more. This captures the threshold and hysteresis effects. For a more comprehensive discussion of that part of the experimental design, we refer the reader to Lindahl et al. (2016a; 2012). We use this same design to allow comparisons with the results obtained in several mentioned studies led by Lindahl and Schill.

We add on to the work of Lindahl et al. (2016a) by connecting two resource systems that interact with each other. The elephant population dwelling[6] in the community's conservation area helps control the number of bushes and is thus connected to availability of pastures. For simplicity, we assume that this relationship follows dynamics similar to the stock of elephants, i.e., the quality of pastures increases with number of elephants up to a certain level beyond which the population degrades the resource, *ceteris paribus*. The graph showing the number of elephants and resource quality is skewed to the left to mimic explosion in the population of bushes as the number of elephants diminishes. This situation is exacerbated by a potential regime shift (red vertical line). Figures 2(a) and 2(b) illustrate the

[6] In real life, elephants are actually roaming in and outside the protected areas, thereby traversing the community's conservation area. For simplicity, we assume that the elephants dwell within the community to avoid the complications involved in modelling fugitive resources. This is a design issue that is controlled in the experiment and can be relaxed in future studies to increase the level of complexity.

resource dynamics of the pastures without and with a regime shift respectively, as the number of elephants increases.

Figure 2: Growth Functions with Threshold and No Threshold for Pastures



Source: own diagram

The size of pasture area is dependent on the stock of elephants. Therefore, we position the threshold in the stock of pastures at the same level as the threshold in elephant stock. This is to avoid unnecessary confusion emerging from thresholds located at different positions. This assumption could be relaxed in future studies to study variations in the SES's characteristics. The stock of pastures amounts to 3 resource units with 50 elephants and 2 resource units with fewer than 5 elephants left. The maximum pasture stock 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 9 units.

Following Lindahl et al. (2016a), we present only discrete versions of these resource growth models to our experimental subjects in the form of a pictogram without and with a threshold (see figures in the annexes A1 and A2). The experimental subjects cannot directly influence the amount of pasture, but they can reduce the number of elephants through harvesting, which does affect the amount of pasture. The subjects can simultaneously observe the dynamics of both the resources (elephants and pastures) and then decide on their next move. We first tested this experimental design with students at the University of Cape Town and again with a community located in the study area and made necessary adjustments to address minor issues before going to the field.

3.2 Experimental Protocol

Experiments were conducted in 33 CAMPFIRE villages located in the Malipati communal area adjacent Zimbabwe's Gonarezhou National Park. These villages fall under three different CAMPFIRE projects, but their proximity to each other implied that they had similar characteristics. We collected our data during two time periods from 23 June to 11 July 2017 and from 28 September to 20 October 2018 because the first round of experiments left us with too few observations to produce a meaningful analysis of the results.[7]

About 16 subjects were invited from a different village each day and then divided into groups of four subjects corresponding to four treatments: baseline, a quota policy with punishment (the "policy" treatment), information about the threshold (the "threshold" treatment), and the policy treatment plus the threshold treatment. The baseline treatment represented the no-treatment scenario where the stock dynamics followed the standard logistic growth function. For the threshold treatment, participants managed a resource exhibiting non-concave growth dynamics, while in the policy treatment they faced a quota sanctioned by punishment. The policy-threshold treatment combined both interventions. In total, 384 subjects were recruited from the 33 CAMPFIRE villages, with 24 groups per treatment and 96 groups in total. We used help from local leadership to recruit the subjects. During the first wave of recruitment in June 2017, our participants came from two CAMPFIRE projects that were located adjacent to each other. For CAMPFIRE projects with many beneficiaries, we invited participants from different parts of the villages, taking into consideration the distance between locations; in small projects, we recruited only once to avoid possible contamination of the results. For the second wave in September 2018, we recruited participants from new villages in another project which was not previously sampled during the first wave, but was in the same area.

Each subject received a show-up fee[8] of $5 and was randomly assigned to one of four groups of four participants each. The show-up fee corresponded approximately to the shadow price of labour in the rural areas. Each experimental session lasted for approximately two hours and was divided into two stages. During the first stage, all subjects played the baseline treatment regardless of which group they belonged to. This stage was used for training, and participants were not paid. In stage 2, we administered four different treatments: baseline, a quota policy sanctioned with punishment, information about the threshold, and a quota with punishment in combination with threshold information. All treatments were played the same day to avoid contamination, with the help of four well-trained research assistants.

Upon arrival, subjects were seated and asked to complete and sign a consent form. The instructions common to all the groups (baseline instructions) were read aloud as part of training. The assistants then read the specific instructions to each group after participants were assigned to the four different treatments (please refer to annex A2 for instructions). Subjects were then divided into four groups of four participants each by picking from a jar

[7] We discovered an error in the Excel formula used during data collection in the first period. We didn't find any literature on how to deal with this type of error, so we decided to remove all the contaminated observations from our sample and instead gather additional observations so that the error would not influence the result.
[8] All amounts reported in this paper are in USD unless otherwise stated.

with cards of four different colours. Several practise rounds using the baseline instructions were administered to all 16 participants in stage 1 so that the subjects internalised the game, after which a question and answer session was conducted to clarify issues. The subjects were told that each one of them represented a fictive resource user and together with the other participants in the group, they had access to a renewable CPR, say elephants, from which they could harvest units, each worth $0.25, over a number of periods. What happened to the harvested resource also affected the availability of another renewable resource, say, pastures. A unit of pasture was worth $0.10 to the group as a whole. We carefully calibrated these values because the difference in "price" between elephants and pasture was likely to drive the results. Emphasis was placed on the fact that they shared both resources communally and what they did as individuals affected others in the group.

Similar to the study by Lindahl et al. (2016b), subjects in the policy treatment faced a regulated quota in the form of a Total Allowable Catch (TAC) pegged at a lower limit of 20 resource stock units, and identical to the threshold treatment by Lindahl et al. (2016a). The TAC in each period was defined as the difference between the current stock and the lower limit, i.e., $TAC_t = X_t - \overline{X}$, where $\overline{X}$ is the lower limit. So at the beginning of the game the policy treatment group received a quota of 30 resource stock units that they could harvest. In each period, the information about the stock of elephants, stock of pastures, quota and overall payoff was communicated to the whole group. Subjects could choose whether or not to respect the quota. If they violated the quota, the participants could be caught and fined with probability 1/6, as the decision to control the participants was determined through throwing a six-sided dice. The number on the dice would correspond to the person being controlled. If the dice showed numbers 5 or 6, no control was made. If controlled, the subject forfeited his or her current period elephant harvest and was put under temporary prohibition for one round. Such a moratorium was consistent with non-monetary punishment faced by offenders in the CAMPFIRE projects, since most of them cannot afford to pay a fine (Ntuli and Muchapondwa 2017).

To guarantee anonymity of individual requests, subjects indicated their individual harvest on a protocol sheet (request slip), which the research assistants collected after each decision-making round. Before the next round, the assistants calculated the sum of the individual harvests as well as the new resource stock size and communicated both orally and in writing to the groups, and to individuals, using a balance sheet. The current stock size was calculated using the following equation:

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

where X_t represented current stock size, X_{t-1} denoted stock in the previous period or initial stock size in the current period, h_{it} was the harvest of individual i in period t, r_t was the regeneration in period t and n denoted the group size.

We allowed but did not force subjects to communicate during any stage of the game, i.e., there was no designated communication phase. Neither the instructions nor the research assistants suggested when to communicate. Subjects discussed the individual harvest rate, but what the subjects actually wrote down in each round was kept anonymous. This setup is consistent with community wildlife management in CAMPFIRE projects. The experiment ended either when the stock of elephants was depleted or when the experimenter decided to end the session early. The experiment was terminated if the group's total harvest matched or exceeded the number of available resource units in any given period, i.e.,

$$\sum_{i \in n} h_{it} \geq X_t \ .$$

To avoid an end-game effect, i.e., harvesting all before the game ends, the exact end period was unknown to the subjects.

If the harvest was larger than the stock, subjects shared the earnings proportionally according to their catch claim. Subjects were told that the resource being harvested was an asset with a value at the end of the game. If a group left something in the common pot after the end of the experiment, then the remainder was multiplied by $0.30 and shared among its members. The price of 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.

If each subject i in period t harvested h_{it} from the common pot, then the payoff (π_{it}) of each subject in time period t was calculated as a share of the group's total harvest in period t as follows:

$$\pi_{it} = \frac{h_{it}}{\sum_{i \in n} h_{it}} X_t$$

At the end of the experiment, the payoff of subject i was given by:

$$\pi_i = \sum_{t=1}^{\infty} \pi_{it} + \frac{pX_T}{n}$$

where X_T was what remained in the common pot at the end of the game, given p, the per unit price of the resource (a live elephant) in the common pot.

After the experiment, the subjects completed a questionnaire capturing information about individual attributes such as age, gender, and educational background, whether the subjects understood the game, and group characteristics such as the group's cooperative capacity and whether communication within the group was effective or not. To complement the self-reported variables collected through the questionnaires, research assistants also took notes on these matters according to a common protocol. At the end of the experiment, subjects were called individually and paid.

4. Formulating Hypotheses

Following Lindahl et al. (2014), we formulated three hypotheses based on the experimental design and repeated game theory methods. According to theory, the solution obtained when individuals maximize net benefits in the absence of constraints might not be socially desirable. Resource users pursue individual goals at the expense of the group's objective because they get more benefits individually when they behave in a selfish manner; however, if they cooperate, the group gets more benefits compared to the situation when each person acts individually. If groups communicate, and in the presence of learning, intuition suggests a drop in the harvest rate over time to avoid depletion. The ability to communicate yields a favourable outcome where the harvest rate is equalized. With self-interested behaviour, resource users do not always take precautionary measures to avoid an outcome that is unfavourable unless their actions are constrained. Without regulation or knowledge of the resource system, users may unintentionally harvest a common pool resource beyond its limit. Punishment or information might influence the behaviour of self-interested individuals so that they cooperate to achieve a common goal.

Hypothesis 1. We expect that the proportion of groups that deplete the resource in the baseline treatment is at least as high as in the other three treatments.

Even with limited computational skills, resource users are able to arrive at the solution of the game through learning, i.e., resource users minimize the deviations from the optimal solution and increase efficiency levels over time. Lack of regulation and knowledge result in inefficiency, i.e., overexploitation might occur when the participants pursue individual objectives, while under-exploitation might occur when resource users pursue a precautionary strategy to avoid crossing a threshold or depleting the resource. An intervention might help to foster collective action so that resource users gravitate towards an optimal solution.

Hypothesis 2. We expect the baseline treatment to be associated with equal or more overexploitation compared to the interventions in the absence of treatment. We also expect our interventions to be associated with equal or higher overall efficiency.

Punishment and the provision of information are both appropriate interventions given that both institutional features affect behaviour. The former instrument imposes a constraint on the objective function of the resource user to force cooperation in the group, while the latter relaxes the constraint. Ideally, punishment redistributes the benefits to the society, while the individual being controlled suffers a loss. On the other hand, theory posits that people cooperate when resources are scarce (Ostrom 2007). The knowledge that the benefits will be reduced in the future for all group members if individuals behave in a self-interested manner might force people to cooperate or take the resource dynamics into consideration. This happens with most common pool resources that people depend on for survival, the depletion of which reduces the welfare of every member of the community.

Hypothesis 3. We expect little variation between the threshold (information) and the policy (quota) treatment in terms of group dynamics and efficiency.

The three hypotheses will guide our analysis of the results. Our predictions depended on the assumption that the subjects are rational individuals with the cognitive skills to solve real-life challenges. We proceed to present the results.

5. Results

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[9] 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 also showed stability in our policy variables between the two time periods and hence justify combining the data from the two time periods in our analysis. We present only the results of the full sample, since the analysis of the two different time periods did not significantly differ from each other. The complete analysis is available in the appendix.

The participants were not paid during the training session, and learning could occur, so the results of stage 2 (where money was used as an incentive for the participants to show behaviour consistent with real-life situations) are not directly comparable to the results of stage 1. However, stage 1 variables might have an influence on stage 2 variables, hence the reason for including these variables in our regression models.

5.1 Characterization of the Sample

Table 1 illustrates sample characteristics, including sample size and some socioeconomic variables. The 384 observations were collected as follows: 196 observations (51%) were collected in 2017, while 188 observations (49%) were collected in 2018. The average age in the sample was 38.2 years, while the average number of years in school was 6.9 years. Approximately 69% of the respondents were female, 6.0% had participated in an experiment before and 87.0% indicated that they trusted each other during the experiment.

[9] We used nonparametric tests, which do not impose any form of distribution on the data.

Measured on a scale from 0 to 5 (where zero denotes lack of understanding and five a high level of understanding), our results indicate an average level of understanding of the game of 3.8 as reported by the participants. About 74.0% of the respondents came from a shrub-dominated area, suggesting that a regime shift could be underway in some CAMPFIRE communities. Communication occurred 100% of the time in all groups. However, the groups differed with regard to what they talked about, whether they managed to reach an agreement, and whether subjects actually committed to the agreement, i.e., the attributes of effective communication as defined by Lindahl et al. (2014).

Table 1: Sample Characteristics

Socioeconomic variables	**Obs.**	**Median**	**Mean**	**Std. dev**
Age [No. of years]	384	37	38.15	6.85
Gender [0=F, 1=M]	384	0	0.31	0.21
Education [No. of years]	384	7	6.92	2.42
Have you played a game like this before? [0=N, 1=Y]	384	0	0.06	0.13
Level of understanding [Rate, 0 – 5]	384	4	3.83	1.05
Group members trusted each other [0=N, 1=Y]	384	1	0.87	0.33
Live in grass/shrub dominated area [0=S, 1=G]	384	0	0.26	0.56
Period [0=period one, 1=period two]	384	0	0.49	0.50

Source: Fieldwork data June 2017 and September 2018.

Table 2 illustrates that the average individual payoff was about $15.10, which was equivalent to three days' wages in rural areas in Zimbabwe. This payoff ranged from $6.87 to $27.85 per individual. The average group payoff was $59.32 with a standard deviation of $4.68, equivalent to one day's salary. On average, all the groups earned similar incomes in stage 1 of the experiment and variability between treatments and within groups was lower in stage 1 than in stage 2 (Table 3). This supports the assumption that the different groups had similar characteristics. Some groups in the baseline and threshold treatments earned slightly higher income in stage 2 than in stage 1 compared to groups in the two policy treatments (policy only, and policy plus information). Overall, most groups in the baseline treatment earned less compared to groups in the other three treatments in stage 2.

Table 2: Individual and Group Payoffs (US$)

	Individual payoff	**Group payoff**
Min	$6.87	$53.86
Max	$27.85	$70.57
Average	$15.10	$59.32
Std. dev.	$1.22	$4.68

Source: Fieldwork data June 2017 and September 2018

In total, stage 1 had 4,216 (43.4%) rounds played during the training sessions, while stage 2 had 5,488 (56. 6%) rounds. More than 60% of the groups under the interventions were able to play more than 10 rounds, while fewer groups in the baseline treatment exceeded 10 rounds. The results in Table 3 show that 67 groups reached stocks below 20 for the elephant stock in the first stage with no threshold, while only 46 groups crossed stock threshold at 20 in the second stage. The same is true for the stock of pastures. Stage 2 results show that more groups in the baseline (16) reached stocks below 20 — the level of the threshold in the other treatments — than in the other three treatments (9, 11, and 10 respectively for the policy, threshold and policy-threshold treatments), and the difference is statistically significant at the 1% level. Overall, all treatments depleted the stock of elephants 42.7% of the time in the first stage and 19.8% of the time in the second stage of the experiments. The design of the game did not allow participants to deplete the stock of pastures.

Table 3: Percentage of Times Group Depleted Stock and Crossed Thresholds

Treatment		**Crossed both thresholds**		**Depleted stock of elephants**		**Recovered after crossing threshold**	
		Stage 1	*Stage 2*	*Stage 1*	*Stage 2*	*Stage 1*	*Stage 2*
Baseline	Freq.	18	16	11	13	0	2
	%	75.0	66.7	45.8	54.2	0.0	8.3
Policy	Freq.	14	9	13	2	3	4
	%	58.3	37.5	54.2	8.3	12.5	16.7
Threshold	Freq.	19	11	8	3	3	3
	%	79.2	45.8	33.3	12.5	12.5	12.5
Policy-threshold	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**

Source: Fieldwork data June 2017 and September 2018

Surprisingly, the number of times the groups playing the baseline treatment depleted the stock of elephants increased from 11 in stage 1 to 13 in stage 2. In contrast, in the other three treatments, fewer groups faced such tragedy in the second period. There could also be some erosion of trust in the baseline between stage 1 and 2 caused by cheating in the previous stage of the game, which would lead to more depletions. However, this did not happen with the other three treatments. All groups that depleted in stage 2 had already depleted in stage 1, except in the baseline treatments, where two groups depleted in stage 2 that had not depleted in stage 1. The policy-threshold treatment experienced the largest decrease in the number of depletion cases, followed by the policy treatment, while the threshold treatment recorded the least decrease of the three interventions.

Most groups that crossed the threshold were careful not to deplete the resource, particularly under the policy, threshold, and policy-threshold treatments. Furthermore, although some groups that crossed the threshold did not deplete the resource, most of them failed to fully recover from the situation to a stock above the threshold. Crossing the threshold did not necessarily lead to depletion in the presence of communication. Group members would abstain from exploitation either to recover the resource or to at least maintain a certain stock although it was low. Very few groups were able to recover fully after crossing the threshold, suggesting that some groups were caught in a low-level equilibrium trap that was difficult to escape from even with intervention.

Table 4 illustrates individual behaviour. Individuals in stage 1 harvested 2.30 units on average for all treatments, with the highest average recorded under the baseline treatment (2.51 units) and the lowest under the policy-threshold treatment (2.16 units). Overall, average harvest decreased to 2.10 units in stage 2 with the highest recorded harvest also under the baseline treatment (2.32 units). Our results suggest that there is slightly more inequality in quantity harvested in stage 1 than in stage 2 (standard deviation of 1.80 vs 1.42). The differences in second stage inequality associated with the harvest between treatments are not statistically significant, suggesting that inequality may not be an important variable affecting mean stocks and efficiency in the second stage.

Table 4: Mean Individual Harvest and Inequality

Treatment	**Stage1 Harvest**		**Stage2 Harvest**		**Stage1 Inequality**		**Stage2 Inequality**	
	Mean	*Std.*	*Mean*	*Std.*	*Mean*	*Std.*	*Mean*	*Std.*
Baseline	2.51	1.94	2.32	1.37	0.296	0.026	0.294	0.028
Policy	2.48	2.11	2.14	1.78	0.295	0.018	0.281	0.017
Threshold	2.19	1.56	2.07	1.22	0.295	0.018	0.281	0.017
Threshold-policy	2.16	1.65	1.94	1.21	0.290	0.017	0.279	0.186
Total	**2.30**	**1.80**	**2.10**	**1.42**	0.294	**0.291**	**0.283**	**0.023**

Source: Fieldwork data June 2017 September 2018

Table 5 show the mean intermediate stock of elephants and the stock of pastures in stage 2 calculated as the sum of initial stock and growth subtracting harvest. As anticipated, our results show that both the intermediate stocks of elephants and pastures for the baseline treatment were significantly lower than in the other three treatments. The Kruskal-Wallis test revealed that the difference between treatments was statistically significant at the 1% level. The intermediate stock of elephants was significantly higher under the two policy interventions with quota and punishment compared to the baseline and threshold treatments. The mean intermediate stocks of elephants under the interventions fall in the neighbourhood of the optimal range (25 - 30), which is consistent with the solution of the game.

Table 5: Stock of Elephants and Pastures

Treatment	**Obs.**	**Elephants**		**Pasture**	
		Mean	*Std. dev*	*Mean*	*Std. dev*
Baseline	24	20.87	4.73	8.61	1.12
Policy	24	29.51	5.98	9.06	0.74
Threshold	24	25.70	3.91	9.66	1.28
Policy-threshold	24	30.34	4.56	9.18	1.12
Total	96	26.60	6.08	9.13	1.13

Source: fieldwork data June 2017 and September 2018

Lindahl et al. (2016a) defined efficiency as the share of actual joint earnings over the maximum possible. Table 6 shows that average efficiency in stage 1 is 64.7%, while in stage 2, average efficiency rose to 72.3%. Overall efficiency increased in all treatments as we moved from stage 1 to stage 2. This could be attributed to the learning effect. The lowest level of efficiency in stage 2 was recorded under the baseline treatment (55.8%) and the highest was recorded under the policy-threshold treatment with 81.1%.

Table 6: Average Efficiency by Treatment

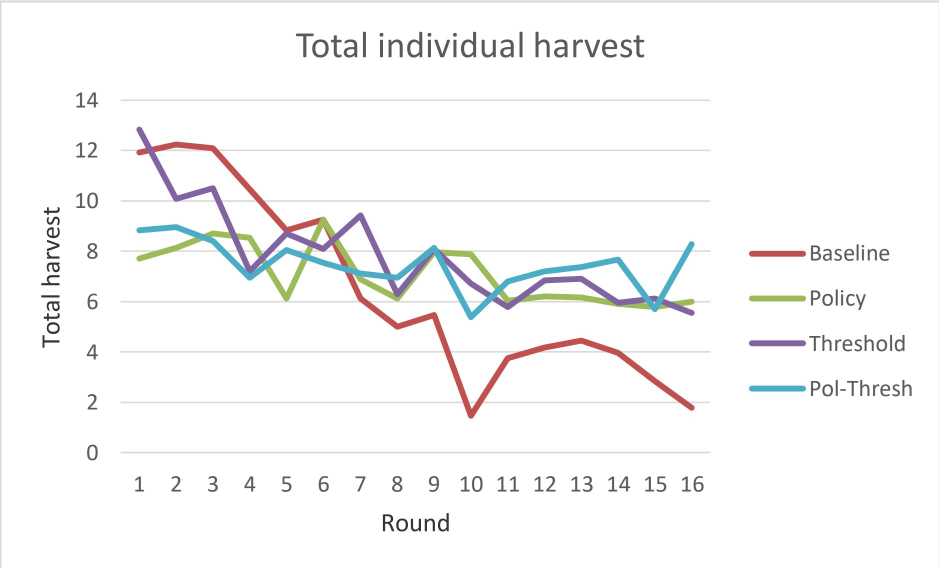
Treatment	**Average Efficiency**					
	Elephant stock		Pasture stock		Total efficiency	
	Stage 1	*Stage 2*	*Stage 1*	*Stage 2*	*Stage 1*	*Stage 2*
Baseline	0. 366	0.420	0.783	0.798	0.574	0,588
	(0.508)	(0.491)	(0.523)	(0.523)	(0.516)	(0.507)
Policy	0.465	0.710	0.775	0.829	0.620	0,760
	(0.503)	(0.292)	(0.424)	(0.343)	(0.463)	(0.318)
Threshold	0.569	0.559	0.813	0.894	0.691	0,732
	(0.432)	(0.377)	(0.396)	(0.258)	(0.414)	(0.318)
Policy-threshold	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)**

Source: fieldwork data June 2017 and September 2018

5.2 Stock Dynamics

Figure 3 illustrates the dynamics of harvesting levels in stage 2 for the different treatments. The graph shows an apparent downward trend in the baseline treatment (red curve), while the other three treatments seem to stabilize after the initial rounds. In particular, the harvesting level under the baseline treatment starts off at a higher level and then plunges down towards zero as we approach round 10, when most of the depletion cases occurred. The levels of harvest between the policy, threshold and policy-threshold treatments differ significantly between round 1 and 6 but converge after round 6. However, stability occurs way below the optimal solution of the game or MSY of 9 resource stock units.

Figure 3: Total Individual Harvest for Elephants

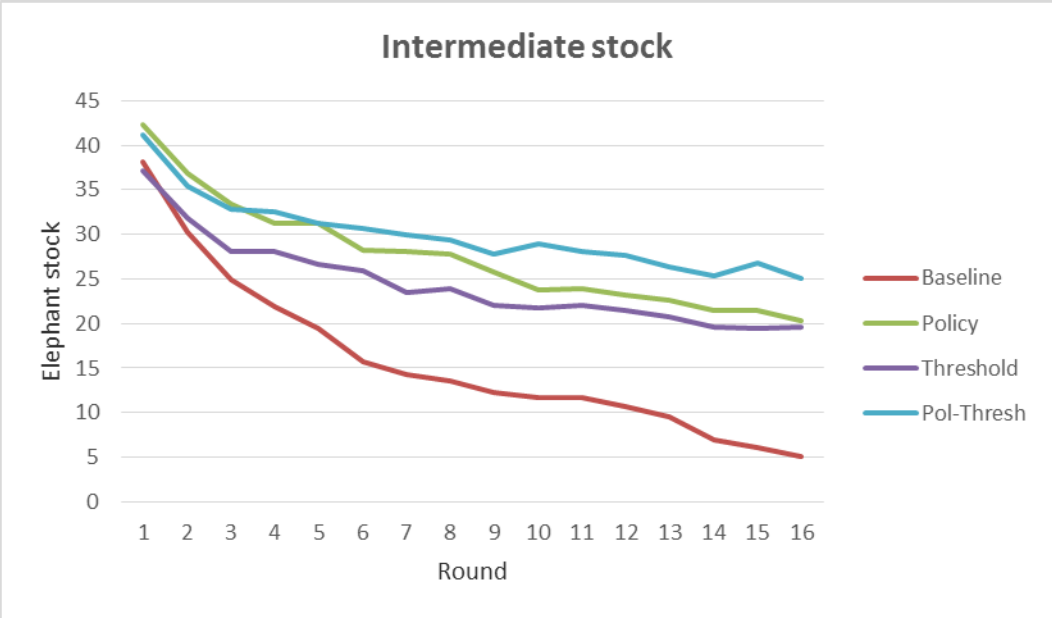


Source: Fieldwork data June 2017 and September 2018

Figure 4 illustrates the intermediate stocks of elephants across treatments in the second stage. These stocks exhibit a greater variability from round 1 up to the end of the game. The stock under the baseline treatment continues to fall because of overexploitation, while the stocks under the other three treatments seem to stabilize after eight rounds. The policy-threshold treatment achieves the highest stock level followed by the policy treatment, while the baseline treatment achieves the lowest stock level throughout stage 2. A constant gap seems to be maintained between the threshold and the policy-threshold treatment, while the policy treatment starts off at the same level as the policy-threshold treatment and later on converges with the threshold treatment.

The dynamics of the intermediate stock of elephants for the policy-threshold treatment seems to stabilize around the optimal level of 25 elephants, which could act as a focal point. This result is consistent with the results in Table 4. The other two interventions (policy and threshold) stabilize below 25, while making sure to stay just above 20, which is inefficient. The policy and threshold treatments also generate overexploitation after round 5 and round 9 respectively and then stabilize in the 20 – 25 region, thus avoiding crossing the threshold. However, the participants deviate from the optimal solution most of the time. Overexploitation in the baseline treatment occurred very early, after round 2, and the intermediate stock continued to fall over time towards zero.

Table 4: Time Series of Intermediate Stock Levels in Stage 2

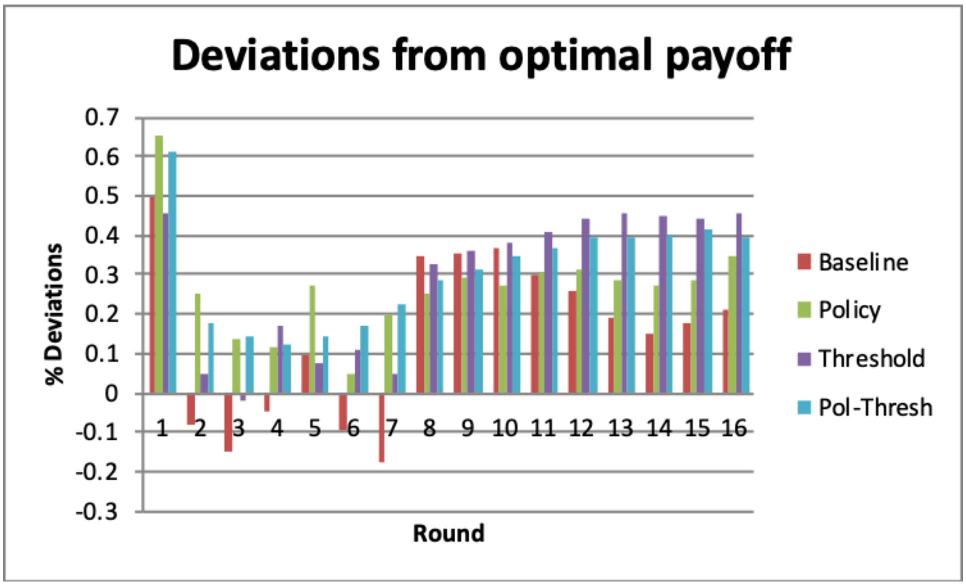


Source: Fieldwork data June 2017 and September 2018

Over- and under-exploitation both represent inefficiencies in resource extraction. While overexploitation can result in depletion of the resource or a low sustained stock level, under-exploitation reduces the benefits to the resource users. Figure 5 represents stage 2 deviations from optimal payoffs over time. We observe that the baseline treatment initially overexploited the resource until round 7, while the threshold and policy interventions almost never overexploited the resource. Although the results in Table 6 suggest that the combination of policy and threshold treatments seemed to produce the most efficient outcome in stage 2, analysis of these deviations over time suggest that all groups under-exploited most of the time, which was also inefficient.

Our results suggest that introducing the threshold and quota in the second stage resulted in under-exploitation of the resource from round 7 onwards for the groups facing either an abrupt change in the regeneration rate or a sanctioned quota, since the three interventions had larger positive deviations most of the time compared to the baseline scenario. Both the threshold and policy-threshold treatments had a similar effect due to the threshold effect, i.e., a larger deviation compared to the baseline and policy-only treatment. Compared to the interventions, the baseline treatment behaved slightly more efficiently after round 7. This result is consistent with Lindahl et al. (2016b), who found that regulated systems on average are associated with lower efficiency, which stems both from under- and overexploitation. Figure 5 shows no evidence of the learning effect. Had there been an improvement in efficiency over time because of the learning effect, we would have expected all the groups to minimize these deviations such that the distance between the actual and optimal point would have become smaller and smaller over time.

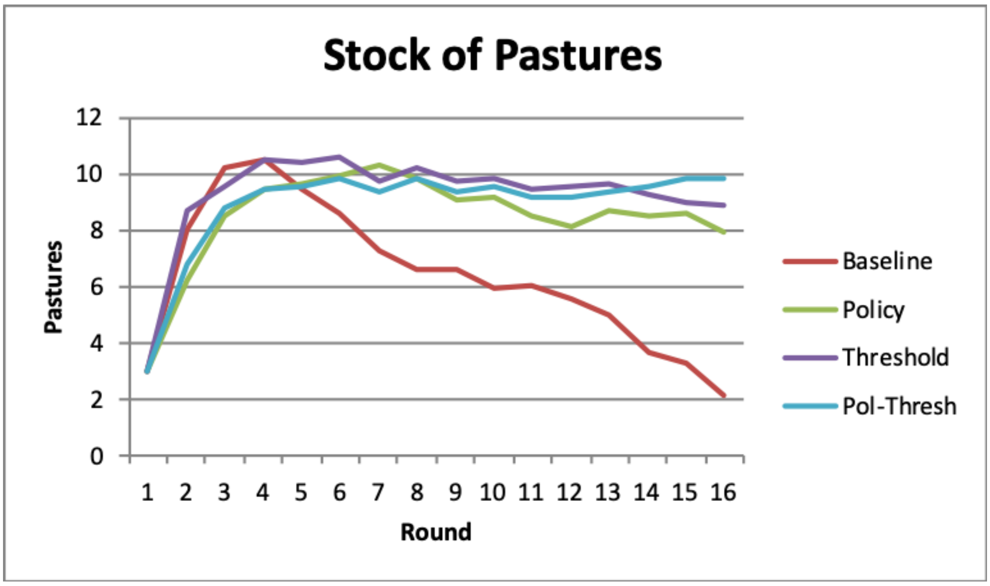
Figure 5: Percent Deviations from Optimal Payoffs



Source: fieldwork data June 2017 and September 2018

Figure 6 shows the stock dynamics of pastures in stage 2. The results reveal that the stock of pastures for baseline treatment deteriorates tremendously over time, while the policy, threshold, and policy-threshold treatments seemed to stabilize between 8 and 10 units of pastures. The baseline treatment did not show any sign of stability, suggesting that the participants were less careful in managing both stocks. Figures 3 and 4 confirm that participants in the policy, threshold and policy-threshold treatments were able to strike a balance between their harvesting level and the growth of the elephant stock, i.e., they were more careful in their behaviour than in the baseline treatment. Even though the baseline treatment has the worst performance, the observed outcome under all treatments falls short of the ideal situation where the participants would follow the optimal solution of the game.

Figure 6: Stock Dynamics of the Pastures



Source: Fieldwork data June 2017 and September 2018

5.3 Regression Analysis

Table 7 summarizes the results of seven regression models where the dependent variables are stage 2 variables such as the mean stocks of elephants and pastures, median stocks, differences in first and second stage mean stocks, and efficiency. After controlling for the time period of the surveys (June 2017 or September 2018), the CAMPFIRE project, inequality, age of the participant, gender, and education, these models explain over 42.0% of the variation in the dependent variable, except for the mean stock of pastures in stage 2. Similar to Lindahl et al. (2016a) and Schill et al. (2015), no strong evidence emerged of the role of socioeconomic variables (such as age and schooling) in explaining mean stocks, median stocks, the gap between stage 1 and stage 2 stock sizes, and efficiency in stage 2.

Table 7: Regression Results

Independent variables	**Mean stock St2**		**Median stock St2**		**Mean difference (St1 - St2)**		**Efficiency St2**
	Elephant	*Pastures*	*Elephant*	*Pastures*	*Elephant*	*Pastures*	*Total*
Policy	8.535***	0.392	7.830***	8.321***	-8.497***	-8.757***	0.337***
	(1.396)	(0.267)	(1.400)	(1.560)	(1.260)	(1.426)	(0.029)
Threshold	2.903***	0.824***	2.205	3.026**	-1.290***	-1.445	0.176***
	(1.049)	(0.333)	(1.476)	(1.644)	(1.323)	(1.462)	(0.032)
Policy-threshold	7.726***	0.358	7.785***	8.223	-7.685***	-6.490***	0.388***
	(1.182)	(0.322)	(1.440)	(1.604)	(1.309)	(1.455)	(0.031)
Stage1 variable†	0.378***	0.270***	0.332***	0.381***	0.621***	2.160***	0.074
	(0.065)	(0.104)	(0.081)	(0.091)	(0.077)	(0.387)	(0.058)
	0.452	0.180	0.131	0.174	-0.452	-1.034	-0.003
Period	(0.893)	(0.212)	(0.992)	(1.105)	(0.893)	(1.013)	(0.020)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Project	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gini index	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other††	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.513	0.208	0.437	0. 421	0.592	0.478	0.730
Observations	96	96	96	96	96	96	96

Source: fieldwork data June 2017 and September 2018
Standard errors are shown in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
† Stage 1 variable represents Mean stock St1, Median Stock St1, Mean diff St1 and Efficiency St1 respectively
†† Other characteristics such as age, gender, education, trust, understanding and communication

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 models. This provides further justification for presenting the pooled results, since the individual results of each time period sample tell the same story as the total sample. There is weak evidence for the role of gender and inequality on second stage (dependent) variables. Our results seem to suggest that men are more careful in their harvesting than women, and inequality in the first stage reduces efficiency in the second stage. Contrary to our result, Lindahl et al. (2016a) and Schill et al. (2015) found that women were more careful in harvesting than men.

For each of the models in Table 7, we interpret the coefficients of the three treatments (i.e., policy, threshold, and policy-threshold intervention) in relation to the baseline category. Most of the time, the three treatments and the stage 1 variables explain variability in the dependent variables. Exceptions include the mean stock of pastures under both policy interventions, the median stock of elephants in the threshold treatment, the median stock of pastures under the policy-threshold treatment, the mean difference in the stock of pastures for the threshold treatment, and the stage 1 variable's impact on efficiency. Regarding the influence of the two policy interventions relative to the baseline category, the magnitude of the coefficients provides strong evidence of the superiority of punishment institutions over information provisioning. The results of the regression model with mean stock difference as the dependent variable seem to suggest that the gap between stage 1 and stage 2 stocks widens as we move from baseline to the other treatments. The magnitude of the first stage variables also suggest that their impact is much smaller compared to the interventions, in particular their impacts on the stock of elephants. The results of nonparametric tests in the annexes also support the finding that the difference between treatments is significant, period does not matter and that our two time period samples actually came from the same population.

6. Discussion

The purpose of this study was to examine the effects of two interventions on the management of two linked resource systems: a policy intervention in the form of a sanctioned quota and an intervention where resource users were given information about an endogenously driven, abrupt and persistent changes in the growth rate of the CPR. Efficient management of pastures depended on how well elephants were managed.

6.1 Discussion of Results in Relation to the Hypotheses

Consistent with other experimental and theoretical studies (hypothesis 1), resource users were able to avert a tragedy of the commons 50% more often with intervention than without intervention. CPR users tend to avoid disasters when the benefits of doing so are greater than the costs of avoiding it (Lindahl et al. 2016a). Our results seem to suggest that information provided to resource users could help them avoid disasters, but not necessarily manage optimally. This intervention could work as an alternative to the usual policy instruments where quotas are administered to resource users and offenders face the risk of a punishment. The combination of information provisioning and punishment institutions produced superior results compared to the two interventions working individually. Aquino et al. (2015) noted that punishment sometimes fails to yield the desired results, i.e., when its employment is suboptimal, in which case the use of information might produce superior results. In the long run, the use of punishment might be costly compared to information provisioning. The constant gap maintained between the threshold and policy-threshold could be a result of the positive reinforcement between the threshold and the policy intervention.

We expected a drop in the rate of harvest and variability among groups in terms of important variables such as stock size and efficiency to occur under all treatments due to the learning effect, hypothetical bias, monetary incentive and the treatment effect. Contrary to expectations from hypothesis 3, there seems to be slightly more variability associated with the stock of elephants in the two policy treatments (quota policy alone and quota plus threshold). We expected greater variability in the baseline and the total sample according to hypothesis.

Overall, policy and threshold treatments were all associated with higher efficiency on average in stage 2 of the experiments, which supports hypothesis 2. The combination of the two interventions resulted in even higher efficiency, but the relatively small difference in efficiency between the combined intervention and the two separate interventions indicates a decreasing marginal effect of combining the policies. Taking a closer look at efficiency, we observe that the threshold treatment achieved the highest loss of efficiency in stage 2 after round 7, which contradicts the finding of Lindahl et al. (2016b) that unregulated systems with a threshold were essentially associated with a higher average efficiency. Furthermore, they found a strong association between regulated systems and under-exploitation, while the unregulated system was associated with overexploitation. Analysis of deviations from the optimal payoff over time suggests that all groups in various treatments under-exploited the resource most of the time after a certain point in time. Under-exploitation does not only reduce the benefits accruing to resource users, but can also increase human-wildlife conflicts and resource degradation as the population of elephants continues to grow, a dimension not represented in our experimental set-up. Evidence from experimental notes indicates that under-exploitation could be a result of averting punishment or avoiding tragedy.

Surprisingly, there was also loss of efficiency associated with the baseline treatment as we moved from stage 1 to stage 2, which contradicts the idea of increased efficiency as a result of the learning effect. We would have expected participants to learn and thus minimize deviations from the optimal solution and hence become efficient over time. The magnitude of the first stage variables also suggests that their impact could be negligible compared to the interventions.

6.2 The Role of Context

We believe that the socio-ecological context, particularly the type of resource system that we are considering, is of utmost importance to explain discrepancies with previous findings. Regression analysis suggests that contextual factors are more important than the different treatments in explaining variability in our dependent variables. The importance of context is confirmed by the evidence of very large and highly significant coefficients of the constant term in all models. Unobservable variables such as hypothetical bias and learning effect could be strong drivers of the observed behaviour. But this could also capture the effect of socioeconomic factors not included in the experimental design, such as income, employment, etc. Under both circumstances, the constant is likely to absorb all the unobservable contextual factors.

The study area was dominated by Shangani-speaking communities (90%), with minority groups also living in the same area speaking, e.g., Ndau and Ndebele. There was a very high participation of women in the experiment, representing the female domination in the study area due to its proximity to the South African border. Most men were employed on neighbouring farms in South Africa and stayed there for long periods at a time. In contrast, women were involved in cross-border trading and always returned back home. Our result that women were less careful in harvesting than men, which contrasts with previous results (Schill and Rocha 2017; Lindahl and Jarungrattanapong 2018), could be the effect of context. Hunting wild animals is in the domain of men in most African communities, while fishing is done by both men and women in Asian countries where the studies of Lindahl and Schill were conducted.

An important aspect of CAMPFIRE communities is that conservation was a usual concern. In particular, we suspect that if one talked particularly about elephants, participants all tended to switch into conservation mode because they were used to hearing the message "conserve elephants". Elephants were valuable assets in the eyes of the community, and so we would expect the results to differ if we instead had considered less iconic species such as different species of fish, or antelopes such as kudu (*Tragelaphus strepsiceros* and *imberbis*), impala (*Aepyceros melampus*), and nyala (*Tragelaphus angasii*). Experimental economics has still not managed to examine whether people behave towards wildlife in the same way as toward most other assets. For instance, do CAMPFIRE communities place a higher value on their stock of elephants than those communities who do not own elephants, i.e., the endowment effect? This question is very important because wildlife is an asset that doubles up as a pest to the same communities.

Another key aspect of the communities we were dealing with was their egalitarian nature. Egalitarian societies are based on the principle that all people are equal, i.e., equal sharing, caring for each other, etc. We believe this is one reason why we did not observe variation in measured inequality.

6.3 Communication

Communication is identified in both theoretical and experimental studies as an important variable to enable cooperation among resource users and in turn avert potential disasters. Lindahl et al. (2016a) observed different levels of communication and cooperation among resource users. They found that communication arose most of the time because of resource scarcity, in order to avoid depletion. Following the experimental design in Lindahl et al. (2016a), we also allowed communication to arise endogenously. Our results show that all groups (100%) engaged in communication (whether verbal or nonverbal), although the effectiveness of their communication was not the same. What differentiated the groups was the message communicated and whether or not they reached an agreement. Communication is an integral part of CAMPFIRE communities, especially when dealing with matters that affect everybody in the community, such as wildlife conservation. Although theory suggests that communication leads to equal performance among groups, our experimental set-up did not specifically test the role of communication in efficient resource management. However, allowing for communication is likely to have played an important role in avoiding depletion in the presence of interventions. Inability to move out of a low-level equilibrium trap is a typical feature of the management of ecosystems and resources with a tipping point because of ineffective communication. However, lack of understanding of resources dynamics and poor management skills can also play a role. When communities are poor, the trade-off between satisfying basic livelihood needs now and future inability to satisfy these needs due to a regime shift can exacerbate overexploitation.

6.4 Complexity of the Social-Ecological System

A significant contribution of this paper is the complexity added by looking at linked resource systems in the experimental design of Lindahl et al. (2016a). Subjects could understand the higher degree of complexity of the underlying social-ecological system in the context of common pool wildlife in Southern Africa. This shows the practicality of using this design for both lab and field experiments across resource systems. By introducing linked resource systems, our study shows progression towards a realistic situation that will allow scholars and policymakers to study more realistic ecosystem dimensions and thus gain insight into behavioural responses in complex social-ecological systems. This is also a timely study given the evidence of bush encroachment in CAMPFIRE communities, as indicated by increasing participation in the programme. As a result, the link between elephants and pastures was easy to explain and the participants could grasp the story in the experiment.

In real life, users are not aware of all interlinkages between resources. They are also typically not aware of the threshold location and how it may interact with thresholds in other resources. Although resource users are not able to fully exploit their cognitive skills to find the optimal solution in complex systems where resource systems are linked, this study demonstrates resource users' ability to avoid disasters, in particular when an appropriate intervention is administered. Moreover, a disaster in one system might trigger resource users to become careful in order to avoid disaster in another system. The observed outcome under all treatments falls short of the ideal situation where the participants would follow the optimal solution of the game. Deviation from the optimal solution is likely to be a result of difficulties in cooperating, and also limited cognitive ability to grasp complex system dynamics. In particular, the gap between the optimal stock of pastures (13 resource units) and the observed outcome could be associated with lack of cooperation or complexity in SESs limiting computational ability of resource users. Indications from experimental notes show that participants seemed to calculate and thus base their decisions on the stock dynamics for elephants rather than the stock of pastures and payoffs[10]. This interesting result illustrates how people take decisions about a complex system by simplifying reality. This ability to abstract from reality when taking complicated decisions might have serious repercussions on managing interlinked resources with a potential threshold of variable probability. Such a situation requires resource users to take joint decisions based upon system knowledge rather than knowledge of single resources, since a decision made for one part of the system might not necessarily lead to sustainable management of another resource. Further investigations of the implications of complexity and cognitive limitations on behaviour are needed.

Finally, our paper provides policymakers and development practitioners alike with pragmatic results and suggestions to improve their wildlife management policies and strategies. Given the behaviour of the participants in the four different treatments, we better understand how we could apply different management policies to achieve different outcomes. For instance, making resource users aware of the critical point (for both the quota and threshold) results in under-exploitation as resource users try to avoid crossing to the unwanted region of the distribution. An important lesson is that knowing the position of the critical point might alter the behaviour of resource users in line with the precautionary principle. The policy-threshold treatment can thus be used to approach an optimal outcome, while the policy or threshold treatment could be used as precautionary measures under different types of conservation objectives. The baseline treatment characterises open access regimes with poor information where there are no institutions in place to constrain the behaviour of resource users, thereby resulting in tragedy of the commons (Hardin 1968).

7. Conclusion

The objective of this study was to examine behavioural responses to a quota-punishment intervention and knowledge about a threshold in terms of resource extraction strategies and collective action. Similar to the studies of Lindahl et al. (2016a) and Schill et al. (2015), we found that the existence of regime shifts in both resources significantly influenced resource users' exploitation strategies, with or without a quota and punishment policy. More efficient resource management outcomes were observed under the policy treatments (a quota with and without information), followed by threshold treatment (information about the threshold, without a punitive quota policy), then finally the baseline without either the threshold information or the punitive quota policy. Further, the combination of both interventions (threshold-policy treatment) produced more efficient outcomes.

[10] This might be a result of the complications involved in calculating decimals.

The take-home message is that resource users behave differently when facing either a policy intervention that combines a quota sanctioned by punishment or information about a regime shift. The results are likely to depend on the policy design and the context and type of resource under consideration. This has implications for wildlife policy. For example, if policy makers need to pursue a precautionary approach, then either a policy intervention with quota and punishment or information can be employed to help resource users avoid a tipping point that will result in much lower resource growth. If an optimal outcome is the main target, then the combination of both interventions (i.e., quota-punishment and information) might be appropriate. If higher levels of collective action are required, then the combination of quota-punishment and information will work more efficiently compared to the employment of either quota-punishment or information in isolation. Viewed as a carrot-stick method, the quota-punishment intervention is also superior to information in fostering collective action behaviour, possibly due to the incentives imbedded in the instrument.

We conclude by going back to our original local African community that lets its animals feed on grasslands and gains revenue from touristic activities linked to the wild elephants in the neighbourhood. The two activities are not independent, because wild elephants' feeding habits prevent bush encroachment, thus maintaining a healthy grassland ecosystem that supports livestock production. Therefore, the way the local community manages the elephants substantially influences their reproduction and the ecosystem. If the elephant population drops too low, it becomes harder for them to reproduce. Too few elephants would then result in bush encroachment, preventing domestic animals from grazing. This shift from an elephant-rich grassland to an elephant-poor bushy area would provide far fewer ecosystem services for the local community. This study demonstrated that the community can succeed in maintaining the elephant stock and grassland quality at a satisfactory level by receiving relevant information or through a quota — that is, a lower limit for the elephant stock. This quota, if trespassed, would be sanctioned with punishment in the form of a fine or a combination of both interventions. The best outcome is obtained through a combination of information provision and sanctions.

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Annexes

Table A1: 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 A2: 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 A3: Kruskal-Wallis Equality-of-Populations Tank Test (by Treatments)

	Stock of elephants	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 A4: Kruskal-Wallis Equality-of-Populations Rank Test (by Period)

	Stock of elephants	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: Two-Sample Wilcoxon Rank-Sum (Mann-Whitney) Test

Elephant population				
	Baseline	Policy	Threshold	Policy-threshold
Baseline		-4.41*** (0.0000)	-3.44*** (0.0006)	-5.00*** (0.0000)
Policy			2.56** (0.0102)	-0.32 (0.74)
Threshold				-2.99*** (0.0028)
Policy-threshold				

Table A6: Two-Sample Wilcoxon Rank-Sum (Mann-Whitney) Test

Stock of pastures				
	Baseline	Policy	Threshold	Policy-threshold
Baseline		-1.38 (0.1671)	-2.88*** (0.0039)	-1.74* (0.0813)
Policy			-2.40** (0.0163)	-0.598 (0.5497)
Threshold				1.537 (0.1243)
Policy-threshold				