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The Effects of Growing Groups and Scarcity on the Use of a Common Pool Resource – a Lab-in-the-Field Experiment with Lake Victoria Fishers

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Abstract
Using a lab-in-the-field experiment with Ugandan fishers, we study if and how the use of a common pool resource changes when the resource is either scarce or abundant and when the number of users increases over time. Both resource scarcity and a growing group require users to be more constrained, that is, more cooperative, in order to maintain the resource. However, the results show that fishers do not curtail their harvesting behavior under increased pressure, leading to rapid overexploitation when scarce resources are used by a growing group. This implies a particular need for sustainable management when scarce resources are exposed to in-migration.

Keywords Resource scarcity · Group growth · Common pool resources · Cooperation · Lab-in-the-field experiment

JEL C90 · D90 · Q22

1 Introduction

Many natural common pool resources for which no access restrictions exist are at risk of being overexploited. How to avoid overuse of common pool resources has long been debated (Hardin 1968; Ostrom 1990). Climate change further exacerbates the risk of overexploitation, both because climate change threatens natural resources themselves and because it can

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trigger migration and increase the number of users for certain resources. The confluence of already dwindling natural resources and a growing number of users represents one of the greatest challenges of the 21st century (Gatiso et al. 2015). So far, there is little evidence on how a growing number of users changes the use of natural resources. The use is, of course, intensified simply by the increased number of users. In addition, user behavior may change as a result of a growing group or even the mere threat thereof. The anticipation of a growing number of users may have an adverse impact on harvesting behavior, especially if the resource is already scarce and native users expect little cooperation from new incoming users.

In this paper, we examine how a growing number of users affects the exploitation of a shared resource. Using a lab-in-the-field experiment with Ugandan fishers at Lake Victoria, we compare the effects of a growing group on harvesting behavior between an abundant and a scarce natural resource. The fish stock in Lake Victoria is a good example of a threatened natural resource whose use will intensify in the coming years due to in-migration. Lake Victoria is the largest freshwater lake in Africa and the second largest freshwater lake in the world. For all three riparian countries (Tanzania, Kenya, and Uganda) the lake is the most important source of fish and responsible for 2-3% of the GDP. The most important fish species are the Nile Perch, which is mainly used for export, and Mukene, which is mainly used for local consumption or animal food (LVFO 2016). Both fish species are threatened by overfishing and ecological changes due to eutrophication, climate change, and a decrease in water level (Mkumbo and Marshall 2015; Gownaris et al. 2017; Mgaya 2017). The fishery at Lake Victoria is mainly small scale with currently over 200,000 fishers at over 1,500 landing sites. The fishers work in small boats with a length between 4 and 12 m, which are propelled with paddles, sails, or outboard motors, and the typical crew consists of two or three fishers (LVFO 2016). Although small scale, the export-led boom in fisheries since the 1990s under open access, combined with poor compliance with fisheries regulations, has led to an oversized fishing fleet and unsustainable patterns of biomass extraction, both in terms of scale and fishing methods (Odada et al. 2004; Matsuishi et al. 2006; LVFO 2017).

Around 184 million people currently live in the Lake Victoria basin and the population has increased by about 3% in only five years. Compared to the neighboring countries, Uganda has seen the largest increase during this period, at 3.6%. The population growth is not due to the birth rate, which has fallen during this period, but to in-migration. Due to climate change and associated water scarcity in the interior of the country, increasing in-migration to the Lake Victoria watershed is expected. Up to 38.5 million people could move to the Lake Victoria area by 2050, intensifying the use of the lake and the demand for fish (Béné et al. 2009; Rigaud et al. 2021). Such a development would put even more pressure on an already scarce resource that many people in the region rely on (Mgale and Nikusekela 2017; Njiru et al. 2008).

The important question that arises in light of this situation is how users of the lake respond to increased pressure because of a potentially higher number of users and whether the response depends on whether the resource is abundant or scarce. Using a lab-in-the-field experiment to shed light on this question has the advantage that we study directly the behavior of the relevant actors and that we still get the control necessary to identify causal effects. Conducting the experiment with students or other convenience samples would have been less complicated and costly. However, it is questionable whether the behavior of undergraduate students who only share their university affiliation and have little to do with the cooperative management of a common resource in their everyday lives, allows conclusions to be drawn about our research question. Apart from the general criticism that the behavior of university students from industrialized rich democratic countries is not representative of human behavior and sometimes rather unusual (Henrich et al. 2010), it is important for our research question to examine the behavior of the actors who are actually exposed to the problem of scarce resources and increasing use. The fishers at Lake Victoria are a more suitable subject pool with ecological validity, as they deal with the use and conservation of a common resource on a daily basis. This environment allows for a more authentic measurement of decisions and their impacts as the fishers bring their years of experience to the experiment. Although the decisions in the experiment are made anonymously, the fishers share the lifestyle and dependence on a resource and thus have much more in common than students in a conventional lab experiment.

In several experimental treatments, we vary the scarcity of the resource and whether or not the group of users is growing to study the effects on the use of the resource. The combination of these two factors allows us to test whether a growing group has different effects depending on the scarcity of the resource. The experimental results show that resource scarcity tends to lead to higher harvest rates and faster depletion of the resource, but only in growing groups are the effects statistically significant. Thus, if a scarce resource is exposed to in-migration, there is a high risk that it will be overexploited and quickly depleted. While resource scarcity has already been studied in case studies and experiments (see the next section), the result on growing groups is a new finding that has important policy implications for the management of common pool resources.

Conducting the experiment in the field with the relevant actors makes the implementation of the study more complicated than with convenience samples. In designing and analyzing the experiment, we took into account possible issues relating to the education and understanding of the participants, the anonymity of the decisions, and the randomization of treatments. Nevertheless, certain limitations remain in such an investigation, which we discuss in the concluding section.

The following sections present the relevant literature (Sect. 2), the design and implementation of the experiment (Sect. 3), the results (Sect. 4), and the conclusions (Sect. 5). We present here only the most important results while the less important results can be found in the Supplementary Information (SI).

2 Background and Related Literature

There are a number of studies, in particular case studies in developing countries, that show that resource scarcity is related to high risk of regional conflict, especially when these regions face population growth and inequality (Gurr 1985; Maxwell and Reuveny 2000; Obioha 2008; Homer-Dixon 1994; Homer-Dixon and Deligiannis 2009). More relevant to our purpose are the experimental studies that examine the effect of resource scarcity on users' harvesting behavior (Rutte et al. 1987; Osés-Eraso and Viladrich-Grau 2007; Osés-Eraso et al. 2008; Hoenow and Kirk 2021; Prediger et al. 2014; Gatiso et al. 2015; Blanco et al. 2015; Aquino and Reed 1998). Experiments with student participants show that users reduce harvesting in the face of greater resource scarcity, although eventual depletion is rarely avoided (Rutte et al. 1987; Osés-Eraso and Viladrich-Grau 2007; Osés-Eraso et al.

2008). This suggests that greater pressure on the resource, and thus the need for cooperation, may actually lead to more cooperation. However, the experiments with real resource users show a mixed picture. Hoenow and Kirk (2021) find that Namibian small-scale farmers reduce harvest when the resource is scarce, similar to the student experiments. In contrast, Blanco et al. (2015) find in an experiment with participants from a region in Colombia with a high risk of future water shortage that resource scarcity leads to higher extraction and thus less cooperation. Gatiso et al. (2015) similarly find in an experiment with Ethiopian forest users that resource use and likelihood of depletion increase in the presence of scarcity. Prediger et al. (2014) compare how participants from resource-rich and participants from resource-poor regions in southern Namibia behave in a public goods game and a joy-of-destruction game. They find no significant differences in the public goods game while coming from a resource-poor region is associated with higher anti-social behavior in the joy-of-destruction game.

Regarding the effects of a growing number of users, to our knowledge there is no experimental study yet that exogenously varies whether the group of users of a shared resource grows or remains constant. We are also not aware of such a study for public goods games. What comes closest are studies that compare cooperation behavior in public goods games between small and large groups. The results of this literature are mixed; some studies find a negative effect of group size on cooperation (Marwell and Schmitt 1972; Bonacich et al. 1976; Nosenzo et al. 2015) while others find that the direction of the effect depends on the specifications of game played (Isaac et al. 1994; Barcelo and Capraro 2015). Weber (2006) uses a minimum-effort coordination game to compare growing groups with groups that start off large. He shows that groups that start small and are gradually joined by new members perform significantly better than groups that start large. A necessary condition for the better performance of the growing groups is that the newcomers are informed about the outcomes in the previous rounds. The minimum-effort coordination game has different incentives for players than a common pool resource game, but if coordination matters, we might expect growing groups to perform better than large groups.

A related yet distinct literature examines the correlation between migrant status and cooperative behavior. Goldbach et al. (2018) compare the behavior of migrant and veteran fishers in Ghana in a one-shot common pool resource game and find no significant difference in harvesting behavior between the two groups. Vorlaufer and Vollan (2020) examine the behavior of migrant and veteran villagers in a rural area in Zambia. They vary the group composition in a public goods game so that groups are either populated with only migrants or only veterans, evenly mixed, populated with a majority of migrants, or a minority of migrants, and this is known to the players. The results show no significant difference in the cooperation rates between the different group compositions; neither the veterans nor the migrants change their contributions depending on the group composition.

Against this background, our paper aims to fill an important gap in the literature by exogenously varying whether the group of resource users grows or not and identifying the effect on harvesting behavior under both resource abundance and resource scarcity.

3 Implementation of the Experiment, Treatments, and Hypotheses

3.1 Implementation

The lab-in-the field experiment was conducted with a total of 658 fishers in 37 sessions (average session size 18) spread across 26 different landing sites in Uganda (see the map in Fig. 1). The experiment was carried out in August and September 2022 in cooperation with local authorities who helped to prepare and translate the instructions, find research assistants, plan the travel itinerary, organize the necessary on-site arrangements, and communicate with the fishers.[1] Participants were recruited with the help of the chairperson at each landing site. They announced the sessions at the landing sites and invited participants. The target group was boat owners, captains and crew members, aged 18 and older, who could read Luganda and had at least some experience with smartphones. The latter requirement was established for practical reasons because the pilot sessions had shown that conducting the experiment with people with no smartphone experience was too time consuming.

The sessions were conducted by two German researchers and three local research assistants in facilities close to where the fishers work and live. A sample picture of a session is shown in the SI (Fig. A1). Before the subjects completed the common pool resource game,

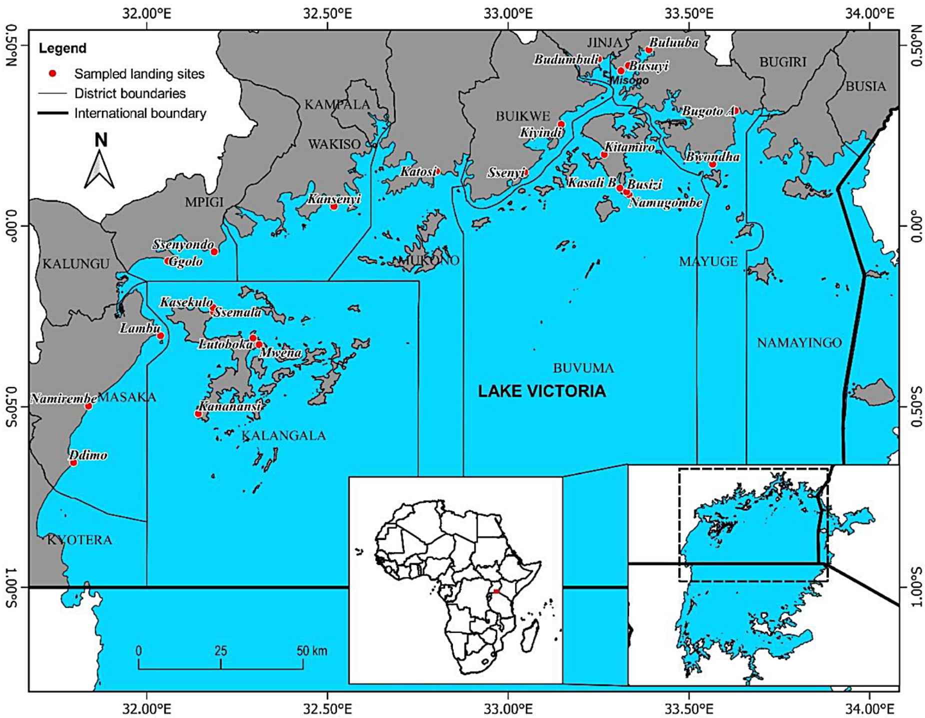

Fig. 1 Map showing the sampled landing sites (red dots) at Lake Victoria, Uganda

[1] While this paper has no co-authors from Lake Victoria, it is part of a larger project that will explicitly involve the local community in the research and produce collaborative articles. More detailed information can be found on the project website: https://www.eco.uni-heidelberg.de/multitip/index.html.

they played another unrelated game which is not part of this paper. The payoff from this game was not known to the subjects until the very end of the experiment. In addition, a relatively long demographic questionnaire was inserted between the different games in order to reduce possible spill-over effects.[2]

The Ugandan research assistants had received extensive training on how to execute the experiment and were standing in front of the room to run a session. The number and the role of the research assistants did not change between sessions. In particular, the experimental instructions were explained orally by the same research assistant in all sessions based on a treatment-specific script (one version is provided in the SI). The oral presentation was accompanied by posters on a flipchart explaining the games with pictures and several examples. The research assistant guided the participants step by step through the examples and showed the implications of making different harvesting decisions. After the examples, participants were asked to answer some control questions.[3] Participants were provided with tablets with which they submitted their decisions and learned the results. As in the oral presentation, pictures were used to prompt decisions and display results. The games were programmed with the software program oTree (Chen et al. 2016). The tablets were connected through a local network, which ensured that all participants were on the same page and did not click through the games too quickly or too slowly. Each tablet was equipped with a physical cover, ensuring that decisions and feedback were kept private. The research assistants helped the participants who had difficulties to understand the instructions or to submit their decisions.

3.2 Games and Treatments

The game we use to study the effects of resource scarcity and growing groups follows in many ways the game of Gatiso et al. (2015) who study the effects of resource scarcity on cooperative behavior of Ethiopian forest users. As we will explain below, our game deviates from the standard dynamic common pool resource game in order to make it easier and more understandable for participants in the experiment. However, the key characteristic that with multiple players the resource is exhausted faster in the Nash equilibrium than in the social optimum is retained in our game.

All subjects played two common pool resource games. They were informed that their decisions in the two games were anonymous and that they must not talk to other participants during the games. The first game was used to familiarize the subjects with the mechanics of the game and the second game was used to implement the different treatments. Both games were presented to the subjects in the context of fishing. The instructions explained that there is a lake from which fishers can catch fish in 10 consecutive rounds. Starting from a certain initial stock of fish, a total of up to 80% of the current stock can be caught by the fishers in each round. This available 80% of fish is broken down to the number of fishers and each of the fishers is informed how many fish he or she is allowed to catch as a maximum. If 80%

[2] The other game was a lottery and subjects learned only at the end of the session whether they were lucky or not in the lottery. The treatments in the lottery game were desynchronized with the treatments in the common pool resource games so that we can control for possible spill-over effects.

[3] The purpose of the control questions was twofold. First, they were part of the process of making the games understandable to all participants. Second, we use the answers to the control questions in the regression analyses as a control variable for how quickly participants understood the games.

of the remaining fish are less than one fish per fisher, then the lake is essentially fished out. When this happens, the game ends. Table 1 shows the maximum allowable catch per fisher by selected fish stock levels and number of fishers playing. The maximum allowable catch ensures that the game can be played for at least three rounds in all treatments and increases the chance that it will last until an additional user joins the group in the treatments with growing groups. Without the restriction, it would be possible for players to take so much in the first round that the game would end immediately. In practical terms, the maximum allowance can be justified by the time and budget constraints of Lake Victoria fishers which do not allow them to fish as much as they might like.

After the fishers have made their catch decision in one round, the fish stock grows by 10% until the next round. However, the fish stock can never become larger than the initial stock. After each round, the fishers learn how many fish the other fishers in their group have caught and by how many fish the stock grows before the next round starts. After the 10th and final round, the fish stock grows again by 10% and the resulting fish are distributed equally to all fishers. This makes it socially optimal for the group of fishers to maintain the fish stock until the end. If the fishers fish out the lake in an earlier round, the game ends after that round.

Our game differs from the traditional dynamic fishing model, in which fishers decide on costly fishing effort and the yield initially increases with more effort, but later decreases because the catch per unit effort decreases as the fish stock declines (see e.g. Djiguemde 2020). In our game, the removal of a fish increases the probability that more fish will be caught than will grow back, meaning that fewer fish will be available for everyone in the next round. Beyond that, there is no negative external effect of an additional harvesting effort. This departure from standard dynamic common pool resource games makes the game easier for participants to understand. The game by Gatiso et al. (2015) has a similar structure, with a common pool resource that grows between rounds and a limit on how much each player can take in a round depending on the current stock.

In the second game, a total of six different treatments were implemented (see Table 2 for an overview). In two treatments with growing groups, two fishers start the game and catch fish in the first five rounds. There is a third player who is passive in these first five rounds and can only observe the decisions of the two fishers. In the sixth round, the passive player

Table 1 Maximum allowable catch per fisher by fish stock and number of fishers

	Maximum catch per fisher	
Fish stock	2-player group	3-player group
80	**32**	**21**
70	28	18
60	**24**	**16**
50	20	13
40	**16**	**10**
30	12	8
20	8	5
10	4	2
5	2	1
4	1	1
3	1	0
2	0	0
1	0	0

The numbers in bold show the starting endowments for the games played by 2-player or 3-player groups

Table 2 Overview of treatments implemented in game 2

Treatment	Initial fish stock	Group size in rounds 1–5	Group size in rounds 6–10
2_Low	40	2	2
2_High	80	2	2
3_Low	40	3	3
3_High	80	3	3
2+1_Low	40	2	3
2+1_High	80	2	3

joins the group, so that in the last five rounds a total of three fishers catch fish from the lake. The later addition of a third fisher is common knowledge from the start, so that the two resident fishers can already take this into account in the first half of the game. This reflects the real situation on Lake Victoria, where fishers are well aware of the in-migration and the potential impact on their livelihoods (Nyboer et al. 2022). In the *2+1_Low* treatment, the initial fish population is 40 fish and, in the *2+1_High* treatment, it is 80 fish. The higher initial stock means that there are more fish to catch overall and that they reproduce faster. The maximum growth rate with high stock is 7 fish compared to 4 fish with low stock. Nevertheless, it is possible that even the high initial stock is quickly fished out because 80% of the current stock can be fished in each round.

In addition, there are four treatments in which constant 2-player groups and 3-player groups complete the game with either a low initial stock of 40 fish or a high initial stock of 80 fish. These treatments serve as control treatments which allow the comparison between the behavior of fishers in the treatments where the group size increases from 2 to 3 fishers, and the behavior of fishers who complete the game with a constant group size of either 2 or 3 fishers.

In the first game, all subjects play with an initial stock of 60 fish to familiarize themselves with the mechanics of the game. The subjects play in the same group and in the same group size in which they complete the subsequent second game. An exception are the players, who watch in the first half of game 2 and are only allowed to actively fish in the second half. These individuals complete the first game alone with an initial stock of 20 fish. This exclusion in game 1 and the first half of game 2 is to ensure that these individuals are indeed perceived as newcomers. The low initial fish stock in game 1 and the passive rounds in game 2 ensure that the newcomers start the active part in game 2 in an unfavorable position compared with the other established fishers.

After the experiment, subjects answered a questionnaire on their personal background and their life as a fisher. At the end, subjects left the room one by one to receive their earnings from one of the research assistants. Participants were paid all the fish they earned in the two games. For each fish they received 100 Ugandan shillings regardless of the treatment. Participants earned on average 6,213 Ugandan shillings in the two common pool resource games, which corresponds to approximately half of their daily wage.[4] Completing the two common pool resource games together with the questionnaire at the end took about 1.5 h.

The six treatments shown in Table 2 were randomized at the session level. Because the games had to be explained orally to all participants in the same session, randomization at

[4] This amount does not include the earnings from the other game and the show-up fee. We provide information about average payoffs by treatment and role in the game in Table A1 in the SI.

the individual level was not possible. The division into the roles of established fishers and newcomers in the treatments with growing groups was randomized at the individual level. Care was taken to ensure that the earnings of the newcomers could not fall below a minimum level and, during the oral presentation of the game, it was not yet clear who would play which role in the game. Due to the randomization at session level, which was unavoidable for practical reasons, the individual characteristics are not completely evenly distributed across the treatments (see Table A2 in the SI). For this reason, we primarily use multivariate estimation models in the analyses, in which we can control for individual characteristics of the participants.

3.3 Theoretical Background

In the game, players can collectively extract 80% of the available resource in each round. In the Nash equilibrium, players would do just that, emptying the resource pool very quickly. In all treatments, the resource would be completely fished out after only 3 rounds of the game (see Table 3). Even for the treatments with a high initial resource stock, the game would be over after only 3 rounds, as players can deplete the pool very quickly by taking out the maximum possible. This means that newcomers in the treatments with growing groups cannot fish at all and do not receive payoffs, which reduces the average individual payoff compared to the game with constant 2 players. In contrast, in the social optimum, the resource stock is kept constant over the entire duration of the game. The players collectively withdraw only to the extent that the pool grows from one round to the next. Due to the fact that players can only take whole fish and that newcomers in the treatments with growing groups enter the game later, asymmetric behaviors and payoffs may occur between members of a group. However, it is true for all treatments that players only take so much that the resource stock grows back almost completely in each round and that the games last for the entire 10 rounds. To achieve the social optimum, players must take significantly less than is possible. Expressed in figures, the harvest rate, defined as the ratio between what is harvested and what could be harvested, is 100% in the Nash equilibrium and between 11% and 14% in the social optimum. The small range in the social optimum arises because several slightly different scenarios lead to the maximum possible group payoff. Importantly, these harvest rates calculated for the Nash equilibrium and the social optimum apply equally to

Table 3 Social optimum and equilibrium payoffs by treatment

	Social optimum			Nash equilibrium		
	Number of rounds	Group payoff	Average individual payoff	Number of rounds	Group payoff	Average individual payoff
2_Low	10	81	40.5	3	40	20
2_High	10	151	75.5	3	82	42
3_Low	10	80	26.7	3	42	14
3_High	10	151	50.3	3	81	27
2+1_Low	10	80	26.7	3	40	13.3
2+1_High	10	151	50.3	3	80	26.7

all treatments. Neither resource scarcity nor the growth of the group change anything about the harvest rates in equilibrium and the social optimum. This distinguishes the game from theoretical models in which the size of the group or the resource determines whether a social dilemma exists or not (e.g. Olson, 1965).

What changes between treatments is the value of the resource, the number of active players, and thus possibly the difficulty of containing extraction. Table 3 demonstrates that the payoffs that players receive in equilibrium and in the social optimum differ between treatments. For instance, if the groups with a low initial stock succeed in cooperating and reaching the social optimum, they receive roughly the same payoff as the groups with a high initial stock without any cooperation in the Nash equilibrium. The lowest payoffs in equilibrium and in the social optimum occur with a large or growing group that starts the game with a low stock level. This distinguishes our game from the game of Gatiso et al. (2015), in which scarcity leads to faster exhaustion in equilibrium, but has no effect on the players' payoffs because scarcity of the resource is compensated by a higher value (conversion rate). Although resource scarcity does not change equilibrium payoffs, Gatiso et al. observe a reduced willingness to cooperate in the form of higher harvest rates when the resource is scarce. The authors argue that scarcity spurs selfish motives, which is likely to be exacerbated in our setting where scarcity is associated with a lower resource value. Based on this, we formulate our first hypothesis:

Hypothesis 1: Resource scarcity will increase harvest in the common pool resource game and the likelihood of depleting the pool compared to resource abundance.

As there has not yet been a study on the willingness to cooperate in growing groups, we cannot derive a hypothesis directly from the literature. However, there are two possible reasons why a growing group may cooperate less than a group of constant size. First, adding an additional user to a small group has a similar effect on individual equilibrium payoffs as reducing the initial stock level. A growing group has lower individual payoffs in the Nash equilibrium and in the social optimum than a constant small group (compare *2_Low* vs. *2+1_Low* and *2_High* vs. *2+1_High* in Table 3). This may reduce the willingness to cooperate, just as a lower resource stock. This only applies to the comparison of growing groups and constant small groups. The individual payoffs do not differ between growing groups and constant large groups (compare *3_Low* vs. *2+1_Low* and *3_High* vs. *2+1_High* in Table 3). The second reason for a potentially lower level of cooperation in growing groups applies to the comparisons with both small and large groups and has to do with the formation of social norms. Nyborg et al. (2016) define a social norm as "a predominant behavioral pattern within a group, supported by a shared understanding of acceptable actions and sustained through social interactions within that group." Applied to our game, a social norm may emerge in which group members tacitly agree not to take more from the pool than grows back and implement and sustain this norm through corresponding actions. If this description is correct, then the formation of social norms in growing groups is more difficult than in constant groups because the newcomers, as long as they are passive, cannot signal their agreement with the social norm through actions. The incomplete interaction within the group in the first half of the game may thus prevent the formation of a cooperative social norm and thereby also negatively influence the second half of the game, even when the interaction within the group is then complete. Based on these considerations, we formulate the following hypotheses:

Hypothesis 2: Adding an additional user will increase harvest in the common pool resource game and the likelihood of depleting the pool compared to a constant small group.

Hypothesis 3: Adding an additional user will increase harvest in the common pool resource game and the likelihood of depleting the pool compared to a constant large group.[5]

4 Results

In the following, we describe our sample of fishers who participated in the experiment, how quickly the resource is depleted in the different experimental treatments, and how the treatments and other factors influence the harvest behavior of the fishers.

4.1 Sample Characteristics

Table 4 presents the main characteristics of the sample, which we will later use as control variables in the empirical analyses. Sample characteristics separated by treatment are shown in Table A2 in the SI. Most participants are male (85.9%) and only a minority are female (14.1%). The average age is 35 years. Most participants originally come from Central Uganda and East Uganda, the two regions bordering Lake Victoria. A small proportion of 5.3% are from North Uganda, which is a region that experiences droughts and is identified as an out-migration hotspot (Rigaud et al. 2021). More than half of the participants (56.7%) are engaged in other activities besides fishing to generate income: as farmers, salesmen, or by rearing livestock. For the remaining participants (42.1%), fishing in Lake Victoria is the only source of income. Because priority was given to people who could read and had experience with smartphones, more than half of the participants (56.9%) are boat owners, 38.4% are captain of a boat, and 3.6% are crew members. This distribution is not representative but suitable for our research question, since it is mainly the boat owners and captains who decide how much fishing is done with which gear. Roughly 60% of the participants live on the mainland and 40% live on an island.

In addition to the characteristics shown in Table 4, we control for correct answers to the control questions in the econometric analyses. Three control questions were asked equally in all treatments. Each of these questions was answered correctly by more than half of the participants (the proportions range from 59 to 84%). One third of the participants (33%) answered all three questions correctly, three quarter (75%) answered at least two questions correctly, and almost all (96%) answered at least one question correctly.

[5] The pre-registration of the experiment, including the hypotheses, can be found under the following link: https://aspredicted.org/blind.php?x=LZ1_K46. The pre-registration contains another hypothesis that involves the interaction between resource scarcity and increasing number of users. The testing of this hypothesis can be found in the SI (Table A11).

Table 4 Sample characteristics

	Total sample ($N=658$)	
Variable	N	%
Gender		
Female	93	14.1
Male	565	85.9
Age		
18–25	128	19.5
26–35	238	36.1
36–45	190	28.9
46–55	75	11.4
56–65	20	3.0
66–80	7	1.1
Region of origin		
Central Uganda	390	59.3
East Uganda	157	23.9
North Uganda	35	5.3
Southern Uganda	54	8.2
Non-Uganda	20	3.0
No Answer	2	0.3
Other occupation		
Only fisher	277	42.1
Farmer	118	17.9
Livestock rearing	107	16.3
Salesman	148	22.5
No answer	8	1.2
Crew role		
Owner	374	56.9
Captain	252	38.4
Crew member	24	3.6
No answer	7	1.1
Fisher type		
Mainland fisher	390	59.3
Island fisher	268	40.7

4.2 Resource Depletion

Table 5 shows separately by treatment and round how the average fish stock changes over time, how many groups have depleted the pool, and how many groups are still fishing. As the socio-demographic variables are not completely evenly distributed across the treatments (see Table A2 in the SI), the table only gives a rough indication of the effect of the treatments on fish behavior and the use of the resource. For this reason, we will rely on econometric estimation methods in which we can control for the socio-demographic characteristics of the participants.

To investigate how the treatments influence the exploitation of the resource, we use a cox proportional hazards model, which is an analytical tool for modeling survival times. Similar to classic linear regression or logistic regression models, the cox proportional hazards model is used to analyze the simultaneous effect of multiple variables on a dependent variable. The dependent variable measures whether an event occurs at a point in time or not,

Table 5 Average fish stock, share of groups that are still fishing, and share of groups that have depleted the pool by treatment and round

Round	Average resource stock	Share of groups still fishing	Share of groups that have overfished	Average resource stock	Share of groups still fishing	Share of groups that have overfished
	2_Low (No. of groups = 41)			*2_High* (No. of groups = 36)		
1	40	1.00	0.00	80	1.00	0.00
2	31	1.00	0.00	62	1.00	0.00
3	25	1.00	0.00	51	1.00	0.00
4	20	0.98	0.02	43	1.00	0.00
5	16	0.95	0.05	37	1.00	0.00
6	13	0.90	0.10	31	0.94	0.06
7	11	0.83	0.17	27	0.94	0.06
8	9	0.78	0.22	23	0.92	0.08
9	7	0.68	0.32	20	0.89	0.11
10	6	0.59	0.41	17	0.86	0.14
	3_Low (No. of groups = 30)			*3_High* (No. of groups = 30)		
1	40	1.00	0.00	80	1.00	0.00
2	31	1.00	0.00	57	1.00	0.00
3	24	1.00	0.00	42	1.00	0.00
4	18	1.00	0.00	32	1.00	0.00
5	14	1.00	0.00	25	1.00	0.00
6	11	0.93	0.07	20	0.97	0.03
7	9	0.87	0.13	16	0.93	0.07
8	8	0.80	0.20	13	0.87	0.13
9	7	0.77	0.23	11	0.77	0.23
10	6	0.67	0.33	8	0.60	0.40
	2+1_Low (No. of groups = 54)			*2+1_High* (No. of groups = 54)		
1	40	1.00	0.00	80	1.00	0.00
2	32	1.00	0.00	62	1.00	0.00
3	25	1.00	0.00	50	1.00	0.00
4	20	0.98	0.02	41	1.00	0.00
5	17	0.96	0.04	35	1.00	0.00
6	14	0.89	0.11	31	0.93	0.07
7	11	0.78	0.22	26	0.89	0.11
8	8	0.70	0.30	21	0.85	0.15
9	7	0.59	0.41	18	0.74	0.26
10	6	0.52	0.48	14	0.70	0.30

and the estimated parameters indicate how the explanatory variables influence the probability of the event. The model assumes that the effects of the explanatory variables on the time until the event occurs (survival time) are constant over time. The hazard function in the model represents the probability that an individual will experience the event within a given time interval, and the estimated coefficients show how the hazard function changes with the explanatory variables (Cleves 2008). As dependent variable we use the "resource survival time" which is defined as the number of rounds that an individual is able to fish before the pool is depleted and the game ends. This variable ranges from 3 to 10. It takes the value 3, if the group still fishes normally in round 3, overfishes the pool in round 4, and the game must end after that. If a group overfishes the pool in round 10, the variable takes the value 9 and if a group does not overfish at all, it takes the value 10. Since not all groups deplete the resource pool within the 10 rounds of play, we have right-censored data and include an additional binary variable that indicates whether a group has depleted the pool within the game time or not when fitting the models.

Table 6 shows the estimation results for comparisons between the groups with a high initial resource stock and a low initial resource stock. Columns 1 and 2 include the data from the treatments with constant 2 players, columns 3 and 4 include the treatments with constant 3 players, and columns 5 and 6 include the treatments with growing groups. The table shows both individual-level estimates with one individual as the unit of observation (and standard errors clustered at the group level) and group-level estimates with one group as the unit of observation. We control for gender, age, region of origin, occupation, crew role, and whether the fishers live on an island or on the mainland. The control variables are measured individually for the individual-level estimates and as average or proportion of the group for the group-level estimates. Individuals for whom information on socio-demographic characteristics is missing are excluded from the individual-level estimates but included in the group-level estimates. Both types of estimations at individual and group level provide very similar results. There is no statistically significant effect of an initial low resource stock on

Table 6 Results from cox proportional hazards models for comparisons between low and high resource stocks

	2 players		3 players		2+1 players	
	Individuals	Groups	Individuals	Groups	Individuals	Groups
	(1)	(2)	(3)	(4)	(5)	(6)
Low stock	2.7763 (1.7250)	2.6164 (1.6459)	1.8021 (1.0103)	1.3282 (0.7398)	3.4210*** (1.2626)	2.9606*** (1.1289)
Control questions score	1.1709 (0.2017)	1.6623 (0.6825)	0.8638 (0.1329)	0.5482 (0.2800)	1.0425 (0.1201)	0.9750 (0.3470)
High harvest rate in round 1 of game 1	1.4566 (0.5505)	1.3877 (0.7936)	2.1259** (0.6732)	2.0002 (1.1109)	1.2284 (0.1991)	1.6281 (0.6420)
Resource survival time in game 1	0.5553*** (0.0579)	0.5145*** (0.0781)	0.8568 (0.0896)	0.8530 (0.1274)	0.7870*** (0.0425)	0.7994*** (0.0658)
Control variables included	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	146	77	178	60	318	108
Wald Chi2	1159.25***	37.36***	25.63**	7.81	50.88***	26.75***

Numbers show hazard ratios; numbers in parentheses are standard deviations. Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Estimations shown in columns 1, 3, and 5 are at the level of individuals, estimations shown in columns 2, 4, and 6 are at the level of groups. The dependent variable is *resource survival time* for an individual or a group. Explanatory variables: *Low stock* is a dummy variable that takes the value 1 for the treatments *2_Low*, *3_Low*, and *2+1_Low*, and the value 0 otherwise; *Control questions score* is the number of correctly answered control questions for the individuals, which can take values between 0 and 3, or the average number of correctly answered questions for the groups; *High harvest rate in round 1 of game 1* is a dummy variable that takes the value 1 if an individual's harvest rate or a group's average harvest rate in round 1 of game 1 is above 0.5, and the value 0 otherwise; *Resource survival time in game 1* is the number of rounds in which the resource is still available to individuals or groups in game 1. The control variables included are gender, age, region of origin, occupation, crew role, and whether fishers live on an island or the mainland, which are measured individually or as average or proportion of the group. Individuals for whom information on socio-demographic characteristics is missing are excluded from the estimations at the individual level but included in the estimations at the group level. The complete table with the estimated effects of the control variables can be found in Table A3 in the SI resource survival time for the treatments with a constant number of users. In contrast, for the groups with a growing number of users, we find a statistically significant effect of resource scarcity on resource survival time. Individuals in growing groups and an initial low resource stock have a 3.4 times higher risk of resource depletion (hazard ratio = 3.421; $p = 0.001$) than individuals in growing groups and an initial high resource stock. The results at the group level show that growing groups that start with a low resource stock have a 3 times higher risk of resource depletion (hazard ratio = 2.961, $p = 0.004$) than those that start with a high resource stock.

The hazard ratios are also greater than 1 for the constant groups, which shows that also in the constant groups there tends to be a higher risk of resource depletion when the groups start with a low stock. The effects are not statistically significant, which is due to the fact that the number of observations and the estimated effects are smaller than in the growing groups. We have carried out ex-post power analyses which take into account the number of observations, the coefficient and standard deviation, and the event probability (see Table A5 in the SI). The results show that the statistical power is quite high in all models (76.0–99.9) except for the group-level estimates for the 3-player comparison (11.2). The effect size required to reliably identify existing effects is somewhat larger for the constant groups than for the growing groups. But we also see that the effect of a low stock that we estimate at the individual level for growing groups would also have been statistically significant for the constant groups.

To illustrate the difference between high and low initial resource stock graphically, Fig. 2 shows the cumulative proportions of groups that deplete the resource pool in the two treatments with growing groups over the course of the game. In the *2+1_Low* treatment, the share of groups that deplete the common resource pool is 48.4% which compares to 29.6%

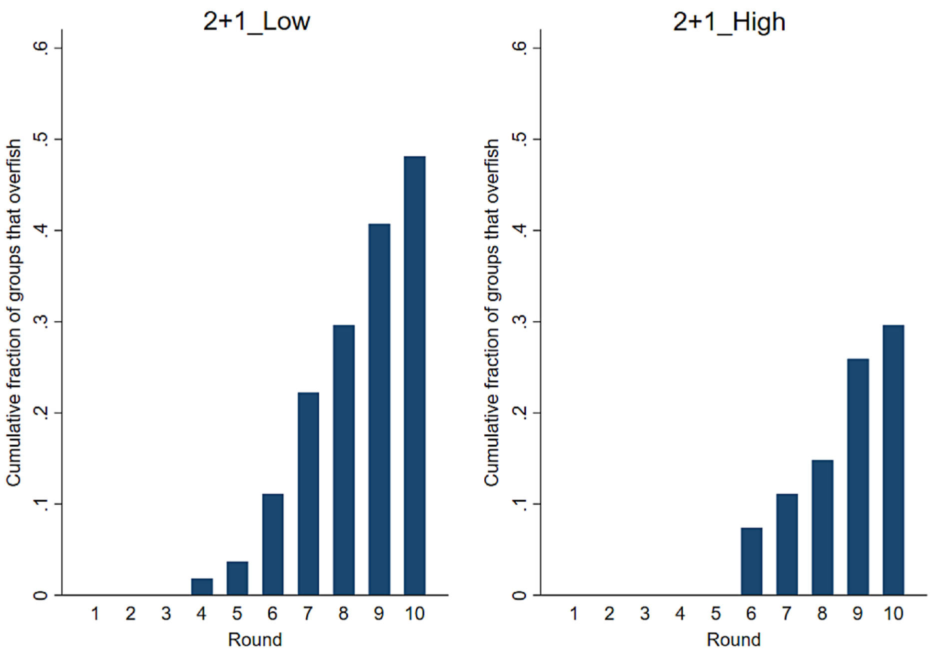

Fig. 2 Resource depletion in the treatments with growing groups

of groups in *2+1_High*. The overfishing in the other treatments is shown in Fig. A2 in the SI.

Table 7 shows the effects of a growing group when we compare the treatments with an increasing number of users and a constant number of users at the same initial resource stock. Columns 1 and 2 compare *2_Low* and *2+1_Low*, columns 3 and 4 compare *3_Low* and *2+1_Low*, columns 5 and 6 compare *2_High* and *2+1_High*, and finally columns 7 and 8 compare *3_High* and *2+1_High*. We again show results estimated at the individual level with one person as the unit of observation (standard errors clustered at the group level) and

Table 7 Results from cox proportional hazards models for comparisons between growing and constant groups

	2_Low & 2+1_Low		3_Low & 2+1_Low		2_High & 2+1_High		3_High & 2+1_High	
	Individuals	Groups	Individuals	Groups	Individuals	Groups	Individuals	Groups
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Group growth	1.0210 (0.3636)	0.7752 (0.3163)	1.2826 (0.4814)	1.5141 (0.6543)	0.9014 (0.5293)	0.9906 (0.6688)	0.6851 (0.2801)	0.6954 (0.3562)
Control questions score	1.1673 (0.1220)	1.6202 (0.5183)	1.0742 (0.1121)	1.1880 (0.4859)	0.8877 (0.1511)	0.5683 (0.2504)	0.9582 (0.1525)	0.7308 (0.3129)
High harvest rate in round 1 of game 1	1.4686** (0.2585)	2.0425* (6.0933)	1.3760* (0.2599)	1.7101 (0.7310)	1.1579 (0.3072)	1.3023 (0.6820)	1.5684* (0.3783)	1.9663 (0.9321)
Resource survival time in game 1	0.7355*** (0.0477)	0.7049*** (0.0608)	0.7573*** (0.0506)	0.7437*** (0.0703)	0.7529*** (0.0693)	0.7315** (0.0965)	0.8700* (0.0646)	0.8962 (0.0941)
Control variables included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	238	95	249	84	226	90	247	84
Wald Chi2	59.18***	36.16***	67.42***	25.04***	49.12***	16.84*	19.95	11.84

Numbers show hazard ratios; numbers in parentheses are standard deviations. Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Estimations shown in columns 1, 3, 5, and 7 are at the level of individuals, estimations shown in columns 2, 4, 6 and 8 are at the level of groups. The dependent variable is *resource survival time* for an individual or a group. Explanatory variables: *Group growth* is a dummy variable that takes the value 1 for the treatments *2+1_Low* and *2+1_High*, and the value 0 otherwise; *Control questions score* is the number of correctly answered control questions for the individuals, which can take values between 0 and 3, or the average number of correctly answered questions for the groups; *High harvest rate in round 1 of game 1* is a dummy variable that takes the value 1 if an individual's harvest rate or a group's average harvest rate in round 1 of game 1 is above 0.5, and the value 0 otherwise; *Resource survival time in game 1* is the number of rounds in which the resource is still available to individuals or groups in game 1. The control variables included are gender, age, region of origin, occupation, crew role, and whether fishers live on an island or the mainland, which are measured individually or as average or proportion of the group. Individuals for whom information on socio-demographic characteristics is missing are excluded from the estimations at the individual level but included in the estimations at the group level. The complete table with the estimated effects of the control variables can be found in Table A4 in the SI results estimated at the group level with one group as the unit of observation. The results of the two different types of estimation are very similar. They show that group growth has no statistically significant effect on the risk of resource depletion. The hazard ratios estimated for the comparison between growing groups with a low stock and constant 3-player groups with a low stock are greater than 1, which means that group growth tends to increase the likelihood of depletion. In all other comparisons, the hazard ratios are close to 1 or smaller. The ex-post power analysis (Table A5 in the SI) shows that the statistical power in the models in Table 7 is low, which is mainly due to the small effects together with the relatively large standard errors. The estimated effects are considerably smaller than the effect sizes that would be required for statistical significance. The effect sizes required to identify the effect of growing groups are comparable to the effect sizes required for low stock. In other words, if group growth had a similarly large effect as a low resource stock, then we would have found it with high probability.

In many models in Tables 6 and 7, we see that the harvest rates in the first round in game 1 and the resource survival time in game 1 have a significant effect on the risk of resource depletion in game 2. We see these effects in both the individual-level and group-level estimates. The harvest decision in the first round of the first game, before receiving any information about the behavior of the other group members, can be interpreted as individuals' basic willingness to cooperate, where a lower harvest rate represents a greater cooperative inclination. The results show that a cooperative decision in the first round of the first game is associated with a significantly lower risk of resource depletion in the second game. In particular, the group-level estimates show that groups in which the members start the first game uncooperatively have significantly higher risk of depleting the resource in the second game. The estimated hazard ratio of 2.04 in column 2 in Table 7, for instance, means that groups in which the members take a lot from the resource at the beginning of the first game (average harvest rate of the group greater than 0.5) have about twice the risk of overexploiting the resource in the second game than groups that take little at the beginning of the first game (group average less than 0.5).

The resource survival time in game 1 measures the success of the entire group in collectively preserving and using the resource for as long as possible. Again, we find that success in the first game is an important predictor of success in the second game. The hazard ratios below 1 indicate that a longer resource survival time in the first game is associated with a lower risk of resource depletion in the second game. For instance, the hazard ratio of 0.70 in column 2 in Table 7 means that a one-round longer resource survival time in game 1 is associated with a 30% lower risk of resource depletion in game 2.

In the next section, we will take a closer look at individuals' harvesting behavior and in particular compare the harvesting behavior of established players, who fish from the beginning of the game, and that of newcomers, who only fish in the second half of the game.

4.3 Harvest Behavior

Figure 3 presents the harvest behavior of established fishers and newcomers over the course of the game separately for *2+1_Low* and *2+1_High*. The harvest rates shown are defined as the number of fish caught by an individual divided by the maximum number possible. The gray bars show the percentage of groups that can still fish in the respective round, when they have not (yet) emptied the pool. The solid lines include all groups that are still fishing in the

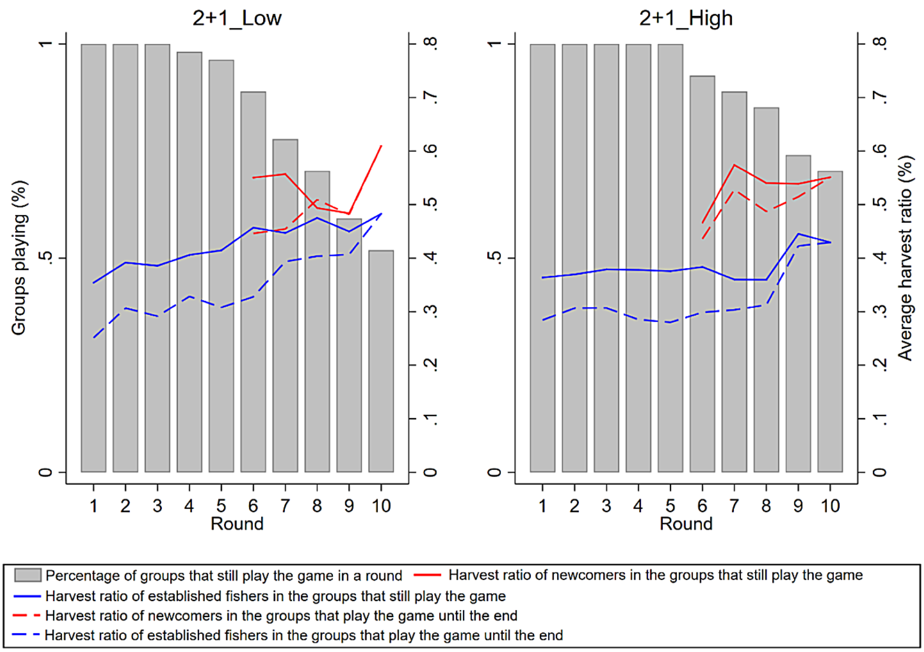

Fig. 3 Average harvest rates in the treatments with growing groups

respective round, while the dashed lines only include the groups that have never exhausted the resource and have played the game to the end. In both treatments, when the resource is scarce and when it is abundant, newcomers fish on average more than established fishers, which is plausible given their disadvantaged role. The behavior of established fishers appears to depend on resource scarcity. When the resource is abundant, the average harvest ratio of established fishers is very stable over time and only increases at the end of the game in the last two rounds. By contrast, when the resource is scarce, the average harvest rate of the established fishers increases from the beginning of the game until the end. The comparison between the solid and dashed lines shows that the groups that have never exhausted the resource have lower harvest rates from the outset, which applies to both the established fishers in round 1 and the newcomers in round 6.

Table 8 shows results from linear regression models on the behavior of the newcomers in the first round in which they are allowed to play the game (round 6). Above all, we want to know whether entry into a successful group differs from entry into a less successful group. For this purpose, we define successful groups as those groups in which the established fishers have a lower average harvest rate in the first five rounds than the median across all groups in the same treatment. An unsuccessful group is then defined by an above-median average harvest rate of the established fishers in the first five rounds. The results in Table 8 confirm that the group's history does indeed make a difference. The newcomers take less in their first round if the established fishers have taken little up to that point. This tendency is particularly pronounced and statistically significant when the resource is scarce. When the resource is abundant, this tendency is smaller and statistically insignificant, but there is no significant interaction effect between treatment and group history.

Table 8 Results of linear regression models comparing the behavior of newcomers entering successful or unsuccessful groups

	2+1_Low & 2+1_High	2+1_Low	2+1_High
	(1)	(2)	(3)
Low stock	0.2010** (0.1004)		
Successful	−0.1824* (0.0935)	−0.2975*** (0.1055)	−0.1284 (0.0953)
Low stock x successful	−0.1157 (0.1285)		
Control questions score	0.0885** (0.0436)	0.1770*** (0.0609)	−0.0359 (0.0682)
High harvest rate in round 1 of game 1	0.1998** (0.0938)	0.1185 (0.1529)	0.2826** (0.1166)
Resource survival time in game 1	−0.0149 (0.0176)	−0.0331 (0.0275)	0.0121 (0.0246)
Control variables included	Yes	Yes	Yes
Constant	0.4358 (0.3349)	0.5659 (0.5647)	0.2104 (0.5221)
Number of observations	98	48	50
R square	0.3241	0.4913	0.4355

Numbers show marginal or discrete effects; numbers in parentheses are standard deviations. Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variable is a newcomer's *harvest rate* in round 6. Explanatory variables: *Low stock* is a dummy variable that takes the value 1 for the treatment *2+1_Low*, and the value 0 otherwise; *Successful* is a dummy variable that takes the value 1 if the average harvest ratio of the established fishers in rounds 1 to 5 is below the treatment median, and the value 0 otherwise; *Low stock x successful* is an interaction term between *Low stock* and *Successful*; *Control questions score* is the number of correctly answered control questions for the individuals, which can take values between 0 and 3; *High harvest rate in round 1 of game 1* is a dummy variable that takes the value 1 if an individual's harvest rate in round 1 of game 1 is above 0.5, and the value 0 otherwise; *Resource survival time in game 1* is the number of rounds in which the resource is still available to individuals in game 1. The control variables included are gender, age, region of origin, occupation, crew role, and whether fishers live on an island or the mainland. Individuals for whom information on socio-demographic characteristics is missing are excluded. The complete table with the estimated effects of the control variables can be found in Table A6 in the SI

Table 9 presents the results of random effects panel regressions which account for the panel structure of the data and unobserved differences among individuals and groups. The dependent variable is an individual's harvest rate or a group's average harvest rate per round, and the control variables are the same as in the cox proportional hazards model above. As before, the control variables are included but are only shown in the SI (Tables A7 and A8). We also include the average harvest rate of the other group members from the previous round as an explanatory variable to test the extent to which fishers respond to others' behavior. Columns 1 and 2 include the treatments with constant 2 players, columns 3 and 4 include the treatments with constant 3 players, and columns 5–7 include the treatments with

Table 9 Results from random effects panel regression models for comparisons between low and high resource stocks

	2 players		3 players		2+1 players		
	Individuals	Groups	Individuals	Groups	Individuals	Only established fishers	Groups
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low stock	0.0280 (0.0327)	0.0250 (0.0279)	0.0197 (0.0423)	−0.0057 (0.0293)	0.0678** (0.0273)	0.0936*** (0.0277)	0.0696*** (0.0205)
Lagged harvest rate of other group members	0.0584** (0.0297)		−0.0050 (0.0368)		−0.0744*** (0.0276)	−0.0705** (0.0284)	
Newcomer					0.0809*** (0.0284)		
Control questions score	0.0134 (0.0153)	−0.0024 (0.0190)	−0.0211 (0.0194)	−0.0234 (0.0225)	0.0092 (0.0141)	−0.0057 (0.0140)	−0.0097 (0.0195)
High harvest rate in round 1 of game 1	0.1590*** (0.0324)	0.0697** (0.0324)	0.1070*** (0.0346)	0.0388 (0.0271)	0.1358*** (0.0267)	0.1385*** (0.0266)	0.0648*** (0.0237)
Resource survival time in game 1	−0.0386*** (0.0091)	−0.0456*** (0.0084)	−0.0177* (0.0091)	−0.0270*** (0.0075)	−0.0174*** (0.0051)	−0.0162*** (0.0051)	−0.0164*** (0.0044)
Control variables included	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.8755*** (0.1444)	0.7691*** (0.1045)	0.8713*** (0.1885)	0.6639*** (0.1160)	0.5634*** (0.0983)	0.6046*** (0.0977)	0.6085*** (0.0846)
Number of observations	1276	701	1553	545	2095	1789	947
Number of individuals or groups	146	77	178	60	301	213	108
Wald Chi2	108.57***	88.94***	67.70***	58.59***	161.82***	142.45***	215.68***

Numbers show marginal or discrete effects; numbers in parentheses are standard deviations. Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Estimations shown in columns 1, 3, 5, and 6 are at the level of individuals, estimations shown in columns 2, 4, and 7 are at the level of groups. The dependent variable is an individual's *harvest rate per round* or a group's *average harvest rate per round* (except of the first round). Explanatory variables: *Low stock* is a dummy variable that takes the value 1 for the treatments 2_*Low*, 3_*Low*, and 2+1_*Low*, and the value 0 otherwise; *Lagged harvest rate of other group members* is the average harvest rate of the other group members in the previous round; *Newcomer* is a dummy variable that takes the value 1 if the person is a newcomer and the value 0 otherwise; *Control questions score* is the number of correctly answered control questions for the individuals, which can take values between 0 and 3, or the average number of correctly answered questions for the groups; *High harvest rate in round 1 of game 1* is a dummy variable that takes the value 1 if an individual's harvest rate or a group's average harvest rate in round 1 of game 1 is above 0.5, and the value 0 otherwise; *Resource survival time in game 1* is the number of rounds in which the resource is still available to individuals or groups in game 1. The control variables included are gender, age, region of origin, occupation, crew role, and whether fishers live on an island or the mainland, which are measured individually or as average or proportion of the group. Individuals for whom information on socio-demographic characteristics is missing are excluded from the estimations at the individual level but included in the estimations at the group level. The complete table with the estimated effects of the control variables can be found in Table A7 in the SI growing groups. It is important to note that the groups that deplete the resource in an early round drop out of the analysis from that round onwards.

The panel regression results confirm the findings we have seen so far. A scarce resource leads to significantly higher harvest rates, but only for the growing groups and not for the groups of constant size. The adverse effect of a low stock in the treatments with growing groups is even more pronounced if we consider only the established fishers. Established players starting with an initial low resource stock have on average an 9.4 percentage points higher harvest rate than established players starting with an initial high resource stock. We also see that newcomers have significantly higher harvest rates than the established fishers, confirming the impression of Fig. 3. On average, newcomers have an 8.1 percentage points higher harvest rate than established players.

The lagged harvest rate of the other group members has a positive effect in the treatments with constant 2 players. The positive effect indicates reciprocal behavior or conditional cooperation, which we know from many other cooperation experiments. In the treatments with growing groups, the lagged harvest rate of the other group members has a significant negative effect. This suggests that there is no conditional cooperation in these treatments but rather the opposite; fishers harvest less when the others harvest more and they harvest more when the others harvest less.

To examine this result in more detail, we perform the same analysis in Table 10 separately for high resource stock and low resource stock and separately for the first half of the game when only the established fishers play the game (rounds 1–5) and the second half of the game when the established fishers and the newcomer play the game (rounds 6–10). The results show that the negative effect of the other group members' lagged harvest decisions is mainly driven by the behavior of the established fishers during the second half of the game with a low resource stock. This behavioral pattern may be related to the increased pressure on the already scarce resource. Based on a series of common pool resource experiments, Elinor Ostrom (Ostrom et al. 1994; Ostrom 1999) argues that individuals often use simple heuristics for which no game-theoretical explanations exist. One of these heuristics is that players increase their harvesting efforts until there is a sharp reduction in yield, at which point they reduce their investments, and when the yield recovers, the cycle starts all over again. It seems plausible that such heuristics are used when the pressure on the resource is particularly high. While this cycle should have a stabilizing effect on the overall harvest, ultimately the upward trend in harvest rates over time cannot be halted (see Fig. 3).[6]

[6] As one reviewer pointed out, this effect can also be caused by the fact that some groups have a very low stock towards the end of the game and therefore virtually every removal leads to a high harvest rate. In Table A10 of the SI, we present the same analysis separately for the groups that have a very low stock towards the end of the game, i.e. seven fish or less in round 8 (37 groups), and the groups that have a higher stock, i.e. more than seven fish in round 8 (17 groups). The negative effect of the lagged harvest rate of the other group members is maintained and significant in both cases, but it is indeed larger for the groups with a very low stock. The result remains the same if the division into groups is made at 10 fish in round 8.

Table 10 Results from random effects panel regression models for treatments with growing groups

	2+1_High			2+1_Low		
	Rounds 1–5	Rounds 6–10	Rounds 6–10 only established fishers	Rounds 1–5	Rounds 6–10	Rounds 6–10 only established fishers
Lagged harvest rate of other group members	0.0415 (0.0322)	0.0387 (0.0616)	0.0550 (0.0716)	−0.0268 (0.0378)	−0.2582*** (0.0691)	−0.2699*** (0.0787)
Newcomer		0.1584*** (0.0455)			0.0472 (0.0516)	
Control questions score	−0.0086 (0.0287)	−0.0323 (0.0265)	−0.0005 (0.0325)	−0.0019 (0.0258)	0.0395 (0.0285)	−0.0197 (0.0369)
High harvest rate in round 1 of game 1	0.1861*** (0.0521)	0.1284*** (0.0475)	0.1028* (0.0603)	0.1314*** (0.0461)	0.1222** (0.0586)	0.1485** (0.0700)
Resource survival time in game 1	−0.0163 (0.0104)	−0.0094 (0.0092)	0.0018 (0.0119)	−0.0165* (0.0089)	−0.0314*** (0.0112)	−0.0332** (0.0140)
Control variables included	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.7427*** (0.2014)	0.5876*** (0.2112)	0.3878 (0.2573)	0.5093*** (0.1623)	0.6107*** (0.2009)	0.6935*** (0.2341)
Number of observations	490	607	441	492	506	366
Number of individuals	107	145	99	106	136	94
Wald Chi2	32.45**	47.29***	29.62**	38.46***	43.59***	36.56***

Numbers show marginal or discrete effects; numbers in parentheses are standard deviations. Levels of significance: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The dependent variable is an individual's *harvest rate per round* (except of the first and sixth round). Explanatory variables: *Lagged harvest rate of other group members* is the average harvest rate of the other group members in the previous round; *Newcomer* is a dummy variable that takes the value 1 if the person is a newcomer and the value 0 otherwise; *Control questions score* is the number of correctly answered control questions for the individuals, which can take values between 0 and 3; *High harvest rate in round 1 of game 1* is a dummy variable that takes the 1 if an individual's harvest rate in round 1 of game 1 is above 0.5, and the value 0 otherwise; *Resource survival time in game 1* is the number of rounds in which the resource is still available to individuals in game 1. The control variables included are round of the game, gender, age, region of origin, occupation, crew role, and whether fishers live on an island or the mainland. Individuals for whom information on socio-demographic characteristics is missing are excluded. The complete table with the estimated effects of the control variables can be found in Table A8 in the SI

5 Discussion and Conclusions

Many natural resources, including fish stocks in Lake Victoria, are threatened by overexploitation and ecological changes. The prospect of an increasing number of users could make the situation even worse (Bené et al., 2009; Mgale and Nikusekela 2017; Njiru et al. 2008; Rigaud et al. 2021).

Against this background, we designed a lab-in-the-field experiment to investigate how fishers on Lake Victoria cope with these challenges under controlled conditions. Such experiments with "natural" populations are fundamentally different from experiments with more anonymous convenience populations. Although we implemented the experiment in a way to ensure that participants understood the game, for example, through detailed explanations, examples, control questions, and an extra game before the treatment interventions, we cannot rule out the possibility that some participants were not fully aware of the dynamics of the game and the implications of their decisions. The game itself had to be as simple as possible to facilitate understanding and maintain control. This implied, for example, that we chose the groups and the growth of the groups to be very small, which of course is different from the real-world situation. Randomization into treatments at the session level also entails some problems regarding the distribution of participants' socio-demographic characteristics across treatments, so we must primarily use regression analyses in which we control for these characteristics. Despite these limitations, we think that these types of experiments are an important complement to theoretical analyses and laboratory experiments with convenience samples, as they show the behavior of those populations that will be mainly affected by the problem at hand.

Our results show that the combination of resource scarcity and an increasing number of users compromises sustainable harvesting behavior compared to situations with resource abundance. Specifically, we find robust evidence in different econometric models that resource scarcity increases harvest rates and the risk of overexploitation in growing groups. Our first hypothesis, that a lower resource stock hinders cooperation, is thus confirmed for growing groups. The second hypothesis and third hypothesis, that group growth alone leads to poorer performance, cannot be confirmed.

The detailed analysis shows that the difference between resource scarcity and abundance in growing groups is mainly due to the behavior of established fishers, that is, fishers who are fishing from the beginning and who know that the group of users will grow. If the resource is abundant, the harvesting behavior of the established fishers is quite stable over time, even if the newcomers harvest more than they do. In contrast, if the resource is scarce, then the harvest rates of established fishers increase over time, even before the additional user enters the group. The behavior of the established fishers is also an important orientation for the newcomers. Our analyses show that the newcomers harvest cautiously when the established fishers have done so before, especially when the resource is scarce. Conversely, if the established fishers have already taken a lot from the resource, the newcomers do not hold back and make the situation even worse.

One plausible explanation for why the combination of resource scarcity and a growing number of users is particularly problematic is the strategic uncertainty that exists for established players in the first half of the game, when the incoming player is not yet in the group. Implementing a cooperative social norm is certainly easier if all players are involved from the beginning. Nyborg et al. (2016) argue that social norms must be actively sustained by social interactions. Even if the newcomers can observe the behavior of the established fishers in the first half of the game, it is not clear whether they will adapt to it, especially because they are in a disadvantaged position. We know in hindsight that the newcomers adapt to the norm of the established fishers, at least to some extent, but this is difficult to assess at the start of the game. By the time all players are in the group, it may be too late to establish a cooperative norm. We know about the relevance of (cooperative) behavior at the beginning of the game for overall performance from lab experiments with students. For example, Bühren and Dannenberg (2021) find that groups that start a cooperation game with a strict punishment institution perform significantly better than groups that introduce the strict punishment institution too late and then fail to deviate from an initial uncooperative norm. The reason why the late entry of the newcomer fishers into the group is problematic only when resources are scarce is presumably that cooperation is especially difficult in this situation and implementing a cooperative norm is especially important. Future research on shared resources may be interested in examining other aspects of group growth, for example, allowing early users to introduce an institution to establish a cooperative norm. Institution formation has been studied in a variety of experiments (Dannenberg and Gallier, 2020), but not yet in growing groups.

The general implication of our research is that sustainable management of natural resources is especially important when an increasing number of users is expected and the resource is already scarce. With regard to Lake Victoria, it appears that combating illegal fishing practices, ensuring compliance with regulations, improving conditions for alternative income sources, and limiting the pollution of the lake (Mgale and Nikusekela 2017; Njiru et al. 2008) will probably be even more important than thought if the projections for population growth in the region are correct. Possible measures include the implementation of climate-resilient adaptation strategies to improve an economic transition and investments into human capital and ensure lower dependency on fisheries, agriculture, and forestry (Rigaud et al. 2021). Since most regions are poorly prepared for increased in-migration streams and individuals' adaptation strategies to climate change are often short or medium termed (Rigaud et al. 2021; Nyboer et al. 2022), policy is well advised to provide guidelines and regulations to sustain natural resources and the livelihood of people.

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Declarations

Competing Interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Aquino K, Reed II, A (1998) A social dilemma perspective on cooperative behavior in organizations, the effects of scarcity, communication, and unequal access on the use of a shared resource. Group Org Manage 23:390–413. https://doi.org/10.1177/1059601198234004

Barcelo H, Capraro V (2015) Group size effect on cooperation in one-shot social dilemmas. Sci Rep 5:1–17. https://doi.org/10.1038/srep07937

Béné C, Steel E, Luadia BK, Gordon A (2009) Fish as the 'bank in the water'– evidence from chronic-poor communities in Congo. Food Policy 34(1):108–118. https://doi.org/10.1016/j.foodpol.2008.07.001
Blanco E, Lopez MC, Villamayor-Tomas S (2015) Exogenous degradation in the commons: Field experimental evidence. Ecol Econ 120:430–439. https://doi.org/10.1016/j.ecolecon.2015.03.028
Bonacich P, Shure GH, Kahan JP, Meeker RJ (1976) Cooperation and Group size in the N-Person prisoners' Dilemma. J Conflict Resolut 20(4):687–706. https://doi.org/10.1177/002200277602000406
Bühren C, Dannenberg A (2021) The demand for punishment to promote Cooperation among like-Minded people. Eur Econ Rev 138:103862. https://doi.org/10.1016/j.euroecorev.2021.103862
Chen DL, Schonger M, Wickens C (2016) oTree—An Open-Source platform for Laboratory, Online, and Field experiments. J Behav Experimental Finance 9(January):88–97. https://doi.org/10.1016/j.jbef.2015.12.001
Cleves M (2008) An introduction to survival analysis using Stata. Stata
Dannenberg A, Carlo G (2020) The choice of institutions to solve Cooperation problems: a Survey of Experimental Research. Exp Econ 23:716–749. https://doi.org/10.1007/s10683-019-09629-8
Djiguemde M (2020) A survey on dynamic common pool resources: theory and experiment. Working papers hal-03022377, HAL. https://hal.inrae.fr/hal-03022377/document
Gatiso TT, Vollan B, Nuppenau E (2015) Resource scarcity and democratic elections in commons dilemmas: an experiment on forest use in Ethiopia. Ecol Econ 114:199–207. https://doi.org/10.1016/j.ecolecon.2015.04.005
Goldbach C, Schlüter A, Fujitani M (2018) Analyzing potential effects of migration on coastal resource conservation in Southeastern Ghana. J Environ Manage 209:475–483. https://doi.org/10.1016/j.jenvman.2017.12.059
Gownaris NJ, Pikitch EK, Aller JY, Kaufman LS, Kolding J, Lwiza KMM, Rountos KJ (2017) Fisheries and water level fluctuations in the world's largest desert lake. Ecohydrology 10(1):1–16. https://doi.org/10.1002/eco.1769
Gurr TT (1985) On the political consequences of scarcity and economic decline. Int Stud Quart 29:51–75. https://doi.org/10.2307/2600479
Hardin G (1968) The tragedy of the commons. Science 162(5364):1243–1248. https://doi.org/10.1126/science.162.3859.1243
Henrich J, Heine SJ, Norenzayan A (2010) The weirdest people in the world? Behav Brain Sci 33(2–3):61–83. https://doi.org/10.1017/S0140525X0999152X
Hoenow NC, Kirk M (2021) Does competitive scarcity affect the speed of resource extraction? A Common-Pool Resource Lab-in-the-field experiment on Land Use in Northern Namibia. World Dev 147:105623. https://doi.org/10.1016/j.worlddev.2021.105623
Homer-Dixon TF (1994) Environmental scarcities and violent conflict: evidence from cases. Int Secur 19(1):5–40. https://doi.org/10.1162/isec.19.1.5
Homer-Dixon T, Deligiannis T (2009) Environmental scarcities and civil violence. In: Baruch H, Behera N, Kameri-Mbote P, Grin J, Spring O, Chourou U, Mesjasz B, C., Krummenacher H (eds) Facing Global Environmental Change: Environmental, Human, Energy, Food, Health, and Water Security concepts. Springer, Berlin. https://doi.org/10.1007/978-3-540-68488-6_20
Isaac RM, Walker JM, Williams AW (1994) Group size and the voluntary provision of public goods. J Public Econ 54:1–36. https://doi.org/10.1016/0047-2727(94)90068-X
LVFO (2016) Regional status report on Lake Victoria biennial frame surveys between 2000 and 2016. Kenya, Tanzania and Uganda. Jinja, Uganda
LVFO (2017) Report of the lake-wide hydro-acoustic and environmental survey. Jinja, Uganda
Marwell G, Schmitt DR (1972) Cooperation in a three-person prisoner's dilemma. J Personal Soc Psychol 21(3):376–383. https://doi.org/10.1037/h0032319
Matsuishi T, Muhoozi L, Mkumbo O, Budeba Y, Njiru M, Asila A, Cowx IG (2006) Are the exploitation pressures on the Nile perch sheries resources of Lake Victoria a cause for concern? Fish Manag Ecol 13:53–71. https://doi.org/10.1111/j.1365-2400.2006.00477.x
Maxwell JW, Reuveny R (2000) Resource scarcity and conflict in developing countries. J Peace Res 37:301–322. https://doi.org/10.1177/0022343300037003002
Mgale YJ, Nikusekela NE (2017) Decline in Fish Stock and Livelihood of Small-Scale Fisheries in Shores of Lake Victoria, Tanzania. Int J Appl Agricultural Sci 3(4):87–91. https://doi.org/10.11648/j.ijaas.20170304.11
Mgaya YD (2017) Introduction. In: Mgaya Y, Mahongo S (eds) Lake Victoria Fisheries Resources. Monographiae Biologicae, vol 93. Springer, Cham. https://doi.org/10.1007/978-3-319-69656-0_1
Mkumbo OC, Marshall BE (2015) The Nile perch fishery of Lake Victoria: current status and management challenges. Fish Manag Ecol 22(1):56–63. https://doi.org/10.1111/fme.12084

Njiru M, Kazungu J, Ngugi CC, Gichuki J, Muhoozi L (2008) An overview of the current status of Lake Victoria fishery: opportunities, challenges and management strategies. Lakes Reservoirs: Res Manage 13:1–12. https://doi.org/10.1111/j.1440-1770.2007.00358.x

Nosenzo D, Quercia S, Sefton M (2015) Cooperation in small groups: the effect of group size. Exp Econ 18:4–14. https://doi.org/10.1007/s10683-013-9382-8

Nyboer EA, Musinguzi L, Ogutu-Ohwayo R, Natugonza V, Cooke SJ, Young N, Chapman LJ (2022) Climate change adaptation and adaptive efficacy in the inland fisheries of the Lake Victoria Basin. People Nat 4:1319–1338. https://doi.org/10.1002/pan3.10388

Nyborg K, Anderies JM, Dannenberg A, Lindahl T, Schill C, Schlüter M et al (2016) Social norms as solutions. Science 354(6308):42–43. https://doi.org/10.1126/science.aaf8317

Obioha EE (2008) Climate change, population drift and violent conflict over land resources in northeastern Nigeria. J Hum Ecol 23(4):311–324. https://doi.org/10.1080/09709274.2008.11906084

Odada EO, Olago DO, Kulindwa K, Ntiba M, Wandiga S (2004) Mitigation of environmental problems in Lake Victoria, East Africa: causal chain and policy options analyses. Ambio 33(1):13–23. https://doi.org/10.1579/0044-7447-33.1.13

Osés-Eraso N, Viladrich-Grau M (2007) Appropriation and concern for resource scarcity in the commons: an experimental study. Ecol Econ 63(2–3):435–445. https://doi.org/10.1016/j.ecolecon.2006.11.016

Osés-Eraso N, Udina F, Viladrich-Grau M (2008) Environmental versus human-induced scarcity in the commons: do they trigger the same response? Environ Resource Econ 40:529–550. https://doi.org/10.1007/s10640-007-9168-6

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press

Ostrom E (1999) Coping with the tragedies of the commons. Annu Rev Polit Sci 2:493–535. https://doi.org/10.1146/annurev.polisci.2.1.493

Ostrom E, Gardner R, Walker J (1994) Rules, games, and common-pool resources. Univ. Mich., Ann Arbor

Prediger S, Vollan B, Benedikt H (2014) Resource scarcity and antisocial behavior. J Public Econ 119:1–9. https://doi.org/10.1016/j.jpubeco.2014.07.007

Rigaud KK, de Sherbinin A, Jones B, Adamo S, Maleki D, Arora A, Casals Fernandez AT, Chai-Onn T, Mills B (2021) Groundswell Africa: Internal Climate Migration in the Lake Victoria Basin Countries. The World Bank, Washington, DC. https://doi.org/10.1596/36403

Rutte CG, Wilke HAM, Messick DM (1987) Scarcity or abundance caused by people or the Environment as determinants of Behavior in the Resource Dilemma. J Exp Soc Psychol 23:208–216. https://doi.org/10.1016/0022-1031(87)90032-1

Vorlaufer T, Vollan B (2020) How migrants Benefit Poor communities: evidence on collective action in Rural Zambia. Land Econ 96(1):111–131. https://doi.org/10.3368/le.96.1.111

Weber RA (2006) Managing growth to achieve efficient coordination in large groups. Am Econ Rev 96(1):114–126. https://doi.org/10.1257/000282806776157588