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Avoiding catastrophic collapse in small scale fisheries through inefficient cooperation: evidence from a framed field experiment

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Abstract

Small-scale fisheries are significant for poverty alleviation but are threatened by over-exploitation and climate change effects leading to more variable fish stocks, including potential negative drastic changes. Are fishers able to adapt? To shed light on this we run a common-pool resource experiment with fishers in Thailand. Fishers face either smooth resource dynamics, or resource dynamics entailing a negative threshold in the growth rate. Whether fishers form cooperate agreements or not depends on the treatment, which theory fails to predict. Groups confronted with the threshold are more likely to cooperate. However, they do not necessarily manage the resource more efficiently. Our analysis also reveals that whereas the threshold treatment is associated with more under-exploitation, over-exploitation is driven by socio-economic variables. Advancing understanding of behavioral responses to climate change effects needs more systematic explorations of how contextual factors influence outcomes. Our work can be seen as one attempt in this direction.

Keywords: Small-scale fisheries, common-pool resources, abrupt ecosystem changes, collective action, framed field experiment.

1. Introduction

Small-scale fisheries (SSFs) account for about 90% of the world's 40 million capture fishers and provide together about half of total global fish catch (Bené et al. 2007) In many low income countries SSFs are significant contributors to poverty alleviation and food security, accounting for more than 50% of total animal protein intake (Hall et al. 2013, FAO 2016). Many SSFs are however threatened by unsustainable over-exploitation stemming from open access regimes and governance failures. Demand for aquatic products is also expected to rise with an increasing population, which will add further pressure to an already heavily exploited resource (FAO, 2016). Moreover, climate change will increasingly change the quantity and variability of fish stocks across the globe. In certain regions, abrupt and potentially persistent changes to stock levels and growth rates are to be expected due to e.g., changes in water temperature and frequency of hypoxia in combination with changes in species composition (Cheung et al. 2016). Such abrupt and potentially persistent ecosystem changes, often referred to as regime shifts (Scheffer and Carpenter 2003, Scheffer 2009, Biggs, et al. 2012) have become increasingly common and have already occurred in many types of ecosystems, including fisheries (Rocha et al. 2015).

Decentralized resource management has increasingly being applied as a solution to deal with problems of over-exploitation. Some of the rights to the resource are then ceded to local users. If they manage to cooperate and collectively agree on a sustainable exploitation level they can overcome a tragedy of the commons (Hardin, 1968). However, in reality sustainable self-organized collective management is not easy to obtain (Ostrom et al. 2002), which is also true for SSFs (Camargo et al. 2008, Bené et al. 2009, Gelcich et al. 2013, Gelcich 2014). Nevertheless, the ability to deal with the increasingly challenging ecological conditions will crucially depend on whether fishers are able to adapt to them individually, *and* collectively. With this paper we test with a dynamic common-pool resource (CPR) experiment how groups of small-scale fishers in Thailand, sharing a common fishing ground, respond to a potential abrupt and persistent negative change in the growth rate of a fish stock. Should we expect more or less over-exploitation and cooperation when fishers are confronted with such ecosystem dynamics? Will fishers be able to collective keep the total exploitation level below the threshold, and thus avoid a catastrophic resource collapse? These are questions we set out to answer in this paper.

Insights from this study contributes to the existing literature on commons management and in particular to the experimental commons literature. Controlled experiments have been proven particularly useful for gathering data on drivers of human behavior in these systems (see e.g. Kopelman et al. 2002, Ostrom, 2006). In early experiments, the resource dilemma was typically described as a static situation and the focus was primarily on understanding how individual strategies, social interactions, and group outcomes changed over time as participants got more information about the behavior of the others. From these early studies we learned e.g. on the importance of communication (cheap talk) and about the ability to sanction free-riders (see Ostrom 2006 for an overview). These were factors that reduced social uncertainty by making it easier for conditional cooperators to identify other cooperators etc. However, these early experiments studies did not include important aspects of some of the challenges experienced by real resource users. For example, these designs often failed to capture crucial biophysical aspects[1]. An understanding of human behavior in CPR dilemmas needs to include not only relevant aspects of relationships among humans, but also how people interact with the temporal and spatial dynamics of the natural resource. In recent years, there has been an increased effort to address this issue with controlled experiments that incorporate ecological characteristics such as spatial resource dynamics (Janssen 2010, Janssen et al. 2010), resource interdependencies, (Lindahl et al. 2015), and endogenously driven resource dynamics (Cardenas et al. 2013). Osés-Eraso et al. (2008) compare for example behavior under exogenous and endogenously driven (human-induced), resource scarcity; Moreno-Sánchez and Maldonado (2010) compare behavior under contrasting resource states, (abundant versus scarce); Kimbrough and Vostroknutov (2013) determined the effects of differing resource replenishment rates; and Hine and Gifford (1996) examine the effect of an uncertain resource growth rate, to name a few. We contribute to this strand of literature by introducing a request game with an endogenously driven resource dynamics, where the resource follows a logistic-type of resource dynamics. Even though the logistic growth model has been used extensively within resource economics and is considered to be the canonical renewable resource model (Clark 1990) it has received substantially less attention in the CPR experimental field. To our knowledge, there are only a handful studies employing a similar design (see e.g. Schill et al. 2015, Noussair et al. 2015, Lindahl et al. 2016a, and Lindahl et al. 2016b). Unlike Noussair and colleagues we introduce and test the effect of an endogenously driven abrupt drop in the growth rate of such dynamics. Further, we allowed our participants to communicate. Communication was allowed to mimic the field as much as possible as communication is seldom forced nor banned in the field. We depart from all these three studies by running the experiment with resource users whose livelihood crucially depend on the resource[2]. The studies by Lindahl et al. and Schill et al. are both done in the lab with students as subjects.

Lab experiments provide the researcher with a “clean test tube” that enables control over contextual variables and facilitates causal inferences. Because they typically are conducted with students, they enable testing of complex designs and are relatively easy and cheap to run. The potential drawback of lab experiments is precisely that they use student participants instead of “real” resource users (Cárdenas and Ostrom 2004). To which extent experimental results can be generalized beyond the lab is an important question that has received much attention in the literature (see e.g., Levitt and List 2007, Falk and Heckman 2009). Whereas previous results from the lab, such as significance of communication, has been confirmed in CPR field experiments (Cardenas 2000), it has also been found that, depending on the social, cultural and ecological context, experimental outcomes can differ significantly (Henrich et al. 2005, Castillo et al. 2011, Prediger et al. 2011, Gneezy et al. 2016, Cárdenas et al. 2017). Our study allows us to investigate the extent to which exploitation behavior of resource users confronted (or not) with a potential abrupt decline in resource growth, depend on the social and economic characteristics of the users.

[1] A few early experiments did implicitly include resource dynamics in the form of probabilistic destruction (Walker and Gardner 1992), and the dependence of extraction cost on decisions in previous rounds (Herr et al. 1992). These studies, demonstrated that dynamics increased harvesting rates compared with a similar static setting.

[2] Noussair et al 2015 conducted their experiment with recreational fishers.

This study (together with previous studies by Lindahl and colleagues (see e.g., Lindahl et al. 2016a Lindahl et al. 2016b, Schill et al. 2015) complements also some previous theoretical work dealing with common pool resource management under the influence of regime shifts (Mäler et al. 2003, Kossiorios et al. 2008, Crépin and Lindahl 2009). These theoretical models are based on rationality assumptions, where users are assumed to either cooperate or not but nothing is said about when we should expect cooperation to emerge or not. In our setup cooperation is not given, it emerge (or not) potentially depending on treatment or other characteristics. Our results can thereby inform theoretical advances within this field

2. Methodological approach

Our main method of choice is a framed field experiment (see Harrison and List 2004) for a classification of experiments), complemented with interview- and observational data. We will return to the experimental design and procedure but first we introduce the case study area.

2.1 Case study area

The experiment was performed with fishers in Tha Chat Chai village, situated in the Phuket province, the biggest island of Thailand and located in Andaman Sea. The total population in Tha Chat Chai village is estimated to around 2,490 or 940 households. About 38% of the population belongs to the so-called Mogans, referred to as "Chao Lei" (sea people) by the Thais. Most fishers in this village are Mogan and follow the Mogan tradition by making their living from fishing and harvesting sea products (e.g. diving and plunging for sea cucumbers, oysters, pearls and shell fish). Their income depends heavily on what they are able to catch from the sea, using traditional and low-tech methods, and their catches rely heavily on the abundance of sea animals in the area. Even though some villagers earn income by working in other sectors (as unskilled labor), for example in the tourism sector, the main source of income is still from fishery and their incomes are realized on a daily basis. Most of them have low levels of education and some are even illiterate.

2.2 Experiment design

How can we transform a commons dilemma problem, involving not only strategic elements, but also complex resource dynamics into a comprehensive decision task for our resource users? We chose to modify an experimental design with said features already developed, tested and evaluated through laboratory experiments by Lindahl and colleagues (Lindahl et al. 2016a and Schill et al. 2015 for details). Their basic design includes two treatments. In one treatment the natural resource growth rate entails a logistic-type of resource dynamics (henceforth referred to as the 'no threshold treatment'), while the other entails a latent abrupt drop beyond a critical threshold in the resource stock (referred to as the 'threshold treatment'). We had to simplify their design slightly in order to account for illiteracy (everything had to be communicated verbally). Figure 1 illustrates the dynamics we used for the no threshold treatment (left graph), and the threshold treatment (right graph) (please note that these graphs were not used in the actual experiment).

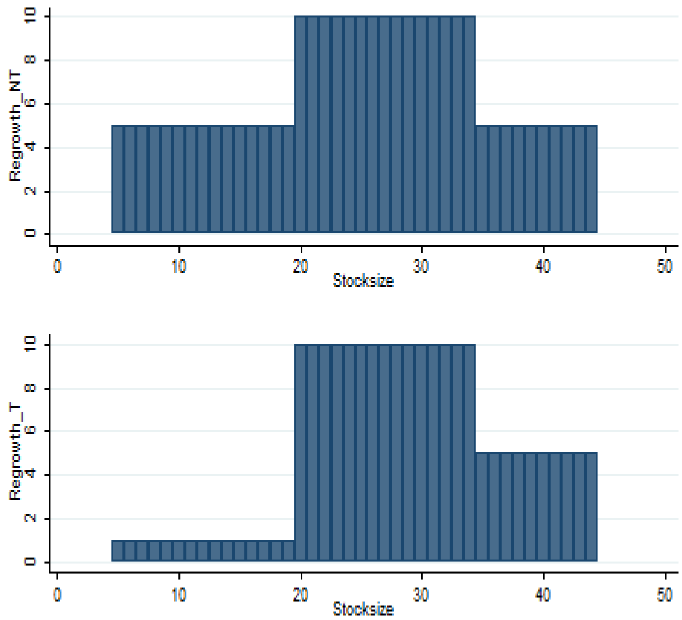

Figure 1: Resource dynamics. The upper graph illustrates resource dynamics for the no threshold treatment, the lower graph for the threshold treatment

The following features hold for both treatments: the minimum resource stock size which allows for renewal is five units, while the maximum resource stock size is 45 units; the maximum sustainable yield (regrowth) is ten resource stock units, which occur between stock sizes 20 and 34. For stock sizes above 34 units the growth rate is five. Thus for stock sizes between 20 and 50 the resource dynamics is identical for the two treatments but for stock sizes below 20 units it differs; for the no threshold treatment the growth rate is five units, but for the threshold treatment, only one unit. Lindahl and collegues used more 'steps' of renewal rates for each treatment (9 instead of 3). They also used written instructions with figures and tables to explain the resource dynamics and the rules of the game. We instructed our participants verbally about the rules of the game and used small fake fish as symbols that we lay out to explain the resource dynamics. In the beginning of the experiment we placed 50 pieces of the fake fish on a table and adjusted the number depending on participants' extraction and the growth rate. We also indicated the growth rate with a simple table (instructions are available as supplementary material). The institutional setting of this experiment was kept simple, i.e. rules and norms were self-imposed and not costly. To mimic the field as much as possible we allowed for face-to-face communication during the entire experiment, but decisions were kept anonymous (see below).

2.3 Experimental procedure

We recruited 96 fishers from the Tha Chat Chai village. Appointments were arranged with the help of the headman's assistant and the experiments were performed at the public meeting building in the village during 4 days.[3] They were recruited with the help of a show-up fee of 200

[3] Before the field experiment a pretest was first conducted with students at Mahidol University in Bangkok. After the experiment we invited the participants to a meeting where we informed the participants about the purpose of the experiments, we explained the two treatments we had used and we invited them to ask questions and give feedback to the experiment.

Baht and they also earned additionally on average 300 Baht (average total earnings ~ which correspond to a day's income from fishing, corresponds to approximately, 6.7 Euro or 7.8 US dollars). Each session lasted approximately one and a half hours and each subject participated only once. We gathered 12 groups for the threshold treatment and 12 groups for the no threshold treatment (summary statistics describing the subject pool are presented in Table 1). The groups were kept separate and could not see, nor hear each other. Upon arrival, the subjects were informed about the experiment in general, the interview and payment procedures. They were also informed that their decisions in the experiment and their interview responses would be kept anonymous and that there would be a post-experiment information session at the last day of the experiments. After signing a consent form they were randomly assigned to a group of 4 and each group were seated around a table.

The fishers were then told that together with the other fishers in their group, they had access to a renewable fish stock from which they could fish, each fish unit being worth 20 Baht (corresponds to approximately 0.52 Euro or 0.6 US dollars), over a number of rounds. To keep the individual fishing decisions anonymous, the fishers indicated their individual decision for each round on a protocol sheet (available as supplementary material), using numbers or markers, which were collected by the experiment leader after each round (and then returned to the subjects before the next round). The experiment leader calculated the sum of the units fished as well as the new fish stock size (based on the table in the instructions) and communicated orally and with the fish symbols this new resource stock size to the group. Each group went through two practice rounds.

They were told that the experiment would end either when they depleted the resource stock or when the experiment leader decided to end the game, but that this end time was unknown (to avoid an end game effect). To ensure that the number of rounds was uncertain we released the parallel groups (participating in the same session) at the same time (where some groups had played more rounds).

If the group's total harvest was equal to or exceeded the number of available resource units in one round (X_t), the resource regeneration was zero and the experiment ended. The payment (p_{it}) to subject (i) in that period t was based on her harvest share (h_{it}) of the group's total harvest in period t, n denoting group size (see Equation 1).

$$p_{it} = \frac{h_{it}}{\sum_{i \in n} h_{it}} X_t \qquad (1)$$

After the experiment we held interviews with each participant, after they were paid privately, one by one.

2.4 Interviews and complementary data

The post-experiment interview form was designed to extract individual and group attributes (see supplementary material). We asked for example for a number of socio-economic variables such as age and gender, years of education, household income, number of members of household, expenditures and savings behavior, if they have a side income, how much of their catch they typically consume themselves vis-a-vis sell, if they were born in the village.[4] During the experiment assistants were taking notes on communication and cooperation behavior; for each group and round a note was made if the group was able to reach an agreement (followed by communication) and if this agreement was being respected by all group members.

2.5 Formulating hypotheses

When formulating hypotheses we rely on methods from repeated game theory and to be able to make comparisons when possible we follow the procedure by Lindahl et al (2016a). Because our time horizon is indefinite (Carmichael, 2005) the discount factor can represent the probability that the game will continue to the next period (Fudenberg and Tirole, 1998) (see details in the appendix). The subjects in our experiment receive an update on the stock level X_t at the beginning of each period and can deduce the actions taken by the other players. They can thereby condition their strategies on current and past stocks which allows us to assume Markov strategies (Maskin and Tirole 2001). We only consider equal sharing equilibrium outcomes and we focus on pure strategies.

Proposition 1: Each stock size x between 5 and 50 can be sustained, through harvesting the growth rate H_x at that stock size, as an equal sharing Markov Perfect Equilibrium (MPE) if in period t, the expected discounted value of one resource unit is large enough for each player i in the game, i.e., if $\delta_{it} \geq \hat{\delta}_{it}$.

$$\text{where } \hat{\delta}_{it} = \frac{50^2 n^2 - [(100-x)4-(50-x)](50-x)}{50^2 n^2 - [(100-x)4-(50-x)](50-x-H_x)} \tag{2}$$

The proof of proposition 1 can be found in the appendix. Even though all stock sizes can be obtained, there may be some there are more or less likely than others. From equation 2, one can see that the value of $\hat{\delta}_{it}$ depends on the growth rate of the resource at that particular stock size x. For example, for a high growth rate, the incentive to deviate and deplete the resource is low because the expected discounted value of the sum of future payoffs is also high and consequently the critical value of the discount factor is low. So for stock sizes where the growth rates differ between the treatments, (is the same) the critical value of the discount factor will also differ (be the same). In the appendix we have calculated these critical values of the discount factor for all stock sizes for both our treatments, the results can be found in Table A3 and is illustrated in Figure 2 below.

[4] We also asked them about details of their fishing activities, about attitudes towards cooperative activities etc., and about their past experiences of abrupt changes in fish stocks. These variables did not show up as significant in any of our analyses so we refrain from providing more details about them.

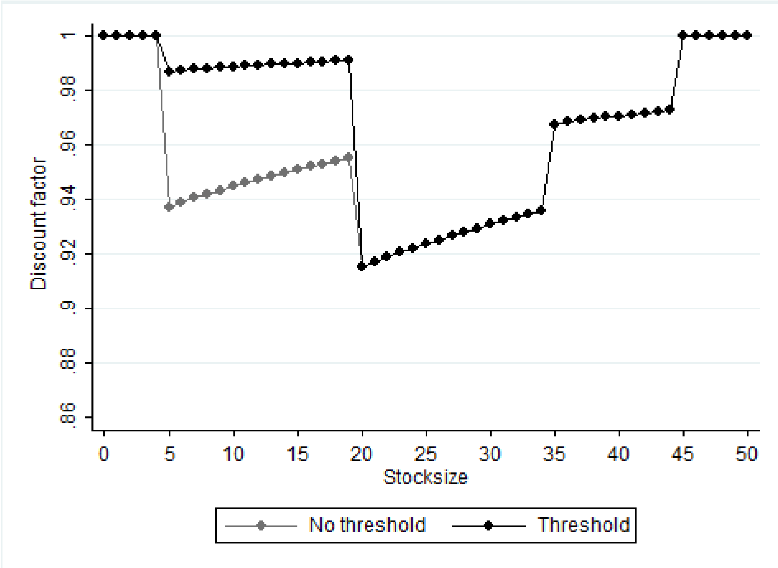

Figure 2: Critical values for the discount factor for each stock size, separated by treatment

Proposition 2: Between stock sizes 5 and 19 MPE outcomes are less likely to be sustained in the threshold treatment than in the no threshold treatment. For other stock sizes, where resource growth of both treatments is identical, equilibrium outcomes are equally likely to be sustained.

Proposition 2 follows from Table A3 and Figure 2 and given certain restrictions on the distributions of the discount factor (see the Appendix). From proposition 2 we know that in the region where we find over-exploitation (stock sizes between 5 and 19) MPE are less likely to be sustained for the threshold treatment. Thus, it is reasonable to expect fewer cases of over-exploitation in the threshold treatment. This leads us to our first hypothesis.

Hypothesis 1: The threshold treatment will be associated with less over-exploitation compared to the no threshold treatment.

In this game we define a group as cooperative if members in that group are able to reach agreements about exploitation levels for the entire duration of the experiment and that these agreements are followed by all the members of that group. A cooperative group of users maximizing their joint earnings (following the optimal strategy) should harvest 30 units in the first period, and then, in each subsequent period, harvests the maximum sustainable yield, here 10 units, as long as they think the game will continue (i.e. as long as the discount factor is high enough, see below). If they think (with high enough probability) that the game will end, they should harvest the remaining stock units. This is true for both treatments (see Table A2 in the appendix for optimal claims for each stock size)[5]. But, is this something we can expect? This leads to our second hypothesis.

Hypothesis 2: Cooperative groups (regardless of treatment) will to follow the optimal strategy. Consequently they will be equally efficient in their management of the resource, which implies that for cooperative groups the average stock size between the treatments will be equal.

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[5] If, for some reason, the stock falls below 30 units, the optimal strategy is to let the resource recover until it reaches at least 30 units (most rapid approach) and then harvest 10 units for the subsequent periods

Please note that we define over-exploitation as exploitation above this optimal level (and vice versa for under-exploitation). Efficiency is measured as the share of harvest over the maximum possible.

Our first two hypotheses involve expected behavior and outcomes on group levels. They are identical to hypotheses stated by Lindahl et al (2016a), which will allow us to compare overall behavioral outcomes at the group level (lab vs. field). But what can we expect on the individual level? Will socio-economic background variables influence behavior and if so, can we detect any specific behavioral pattern for the threshold, respectively the no-threshold treatment? The implicit assumption invoked in our theoretical exercise above is that users are homogenous in how they reach decisions. They can differ with respect to their subjective discount rates but we assume that the distribution of these subjective discount rates does not differ between the treatments. This leads to our third hypothesis

Hypothesis 3: Individual decisions about whether to cooperate or not should be independent of treatment (and depend only on the subjective discount rate). Within a group, cooperative or not, individual decisions about how much to exploit should be independent of socio-economic variables.

3. Results

Descriptive statistics based on the interview data are presented in Table 1 for each treatment separately. Average age of participants differs slightly between the two treatments; participants in the no threshold treatment are on average 5 years older (comparing 48 with 43) on a five percent significant level, but we cannot find significant differences for the other socio-economic variables[6]. More women than men showed up to participate in the experiment but the gender distribution between the two treatments does not differ significantly.

Table 1: Descriptive statics of participants

	No threshold	**Threshold**	
	Mean *(Std. dev.)*	*Mean* *(Std. dev.)*	*p-value*
Income per month (in Baht)	13573 (9803)	14085 (12803)	0.8775
Saving per month (in Baht)	3775 (4803)	3492 (5163)	0.7070
Size of household	4.271 (1.997)	3.833 (1.389)	0.3757
Percentage of catch consumed	27.313 (25.455)	29.042 (27.029)	0.9704
Age	48.81 (12.895)	43.35 (11.77)	0.0465
Years of education	4.083 (3.114)	4.333 (2.587)	0.4512
Gender (male=1)	0.333 (0.476)	0.313 (0.468)	0.827

[6] The average income is about 14 000 Bath per month, they save a bit more than 3500 bath per month (which is about 25% of their income), they consume about 30% of their catches. About 80 % of the participants state that women in their family are involved in the fishing activities and the average household size is 4 members.

Born in the village (yes=1)	0.292 (0.459)	0.229 (0.425)	0.485
Side income (yes = 1)	0.479 (0.505)	0.354 (0.483)	0.214

We have used non-parametric Mann-Whitney tests for continuous variables[7] and Pearson's chi-square tests for proportions (all p-values are two-sided). There are 48 observations in each treatment.

We now proceed to analyze the experimental outcome. In Table 2 below we report average over-exploitation for the two treatments, as well as average under-exploitation, average stock size and average efficiency. All averages are group level averages to ensure we do not violate the assumption on independence[8] Table 2 reveals that there are no significant differences between the two treatments with respect to exploitation behavior (i.e., for over-exploitation, under-exploitation, stock size and efficiency). This in turn implies that we reject hypothesis 1. The threshold treatment is not associated with less over-exploitation.

Table 2: Overall exploitation behavior, separated by treatment

	No Threshold	**Threshold**	
	Mean *(Std. dev.)*	*Mean* *(Std. dev.)*	*p-value*
Efficiency (group average)	0.534 (0.221)	0.582 (0.207)	0.4529
Over-exploitation (group average)	2.695 (4.735)	1.677 (3.987)	0.2810
Under-exploitation (group average)	- 4.387 (3.502)	-6.253 (4.415)	0.4188
Stock size, after harvest before growth (group average)	27.896 (11.510)	32.940 (10.060)	0.3556

We have used non-parametric Mann-Whitney tests (all p-values are two-sided). There are 12 groups in each treatment.

To test our second hypothesis we zoom in on cooperative groups (members have reached agreements about exploitation levels for each round and in each round these agreements are also followed by all group members). We restrict our analysis to groups that were able to form agreements about exact exploitation levels for each round. Moreover, we only consider equal-sharing cooperative agreements as this is in line with our theoretical definition and derivations. To this end we calculated the Gini coefficient for each group and only included groups with a Gini coefficient below 0.01[9]. This resulted in 8 equal sharing cooperative groups in the threshold treatment and 4 in the no threshold treatment.

First, can we say something about what makes a group cooperative or not? To answer this question we run a logistic regression with cooperation as dependent variable. The best model, evaluated based on the Aikaike criterion, is presented below in Table 4[10].

Table 3: Logistic regression with (equal sharing) cooperation as dependent variable

[7] For all continuous variables in Table 1 and 2 we can reject normality on a 1 percent level according to Shapiro-Wilks tests.
[8] In reality we have 265 observations accounting for each round and group. However, because the game is a dynamic game and decision in one period most likely affect decisions also in the next period we need to compare group averages.
[9] Some groups kept a rotating scheme to be sure to maximize joint earnings. At the end of the experiment a few members of those groups could therefore end up with one more resource unit than the other(s) in that group resulting in a Gini coefficient above zero (but still below 0.01).
[10] Please note that we also tested for other socio-economic variables such as gender, monthly average income (per household member), savings behavior (as a percentage of income) if they had a side income, how much of their catch they kept for consumption, years of education, and if they were born in the village. These variables were not significant however and based on the AIC excluded from the model.

	Odds ratio (std. err.)	*p-value*
Constant	0.000** (0.000)	0.064
Treatment (threshold=1)	12.803*** (15.870)	0.040
Age (group average)	1.176* (0.108)	0.078
LR Chi2	6.58**	0.037
AIC	32.695	
N	24	

Table 3 reveal that cooperative agreements are more likely to form when the group is confronted with the threshold treatment. Thus, whether or not groups form cooperative agreements (that last during the entire duration of the experiment) is endogenous to the treatment.

We then want to know whether cooperative groups manage the resource optimally, or at least closer to the optimal level compared to non-cooperative groups. We are also interested in whether or not fishers are able to avoid the threshold. Figure 3 shows that 10 out of 12 groups manage to avoid the threshold, and that these groups tend to under-exploit the resource. Crossing the threshold happens for one cooperative group and one non-cooperative group. Figure 3 also shows that for the no-threshold treatment, there are more non-cooperative groups and that these groups either over-exploit or under-exploit the resource. There are not many cooperative groups in the no-threshold treatment but out of these groups, only one clearly over-exploits the resource.

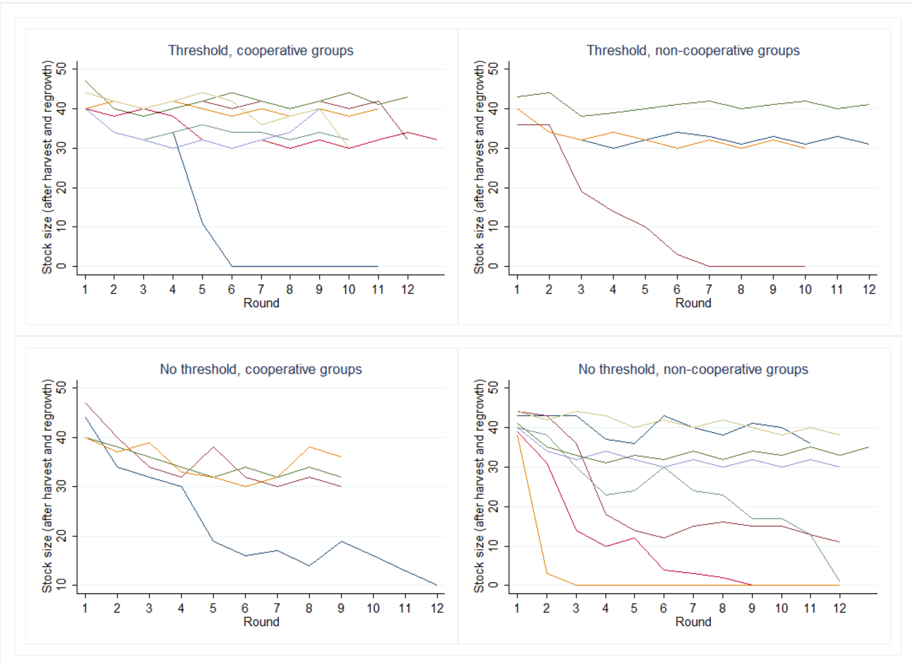

Figure 3: Stock sizes over time for each group, separated by treatment and by being cooperative (or not). Note that the end period differs across groups.

Figure 4 confirms that cooperative groups do not manage the resource optimally, that they tend to under-exploit the resource. Figure 4 also shows that there is only a small difference between cooperative and non-cooperative groups (including observations from both treatments, left-hand side). Mann-Whitney tests (see Table 4) confirms that cooperative groups do not outperform non-cooperative groups.

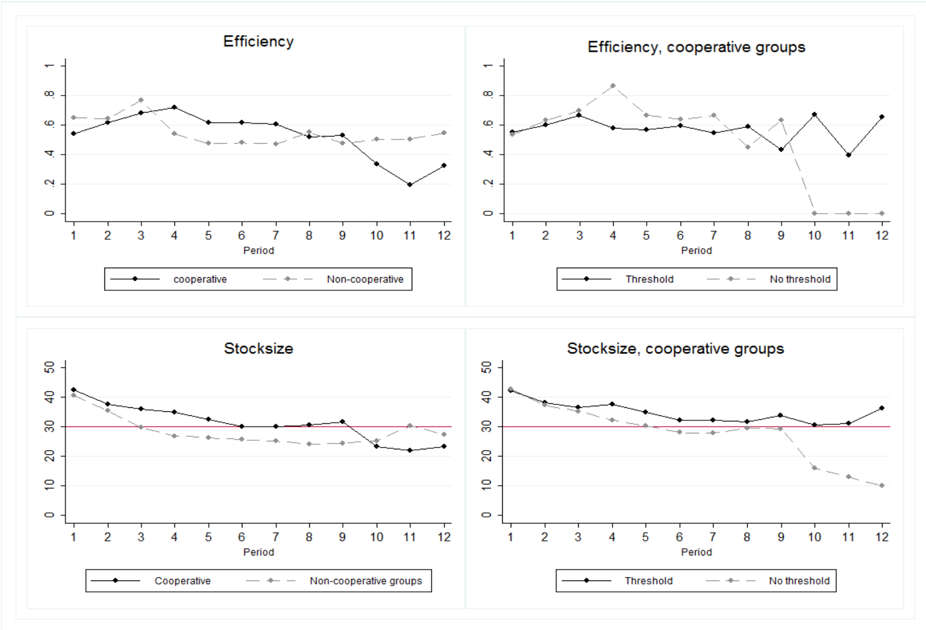

Figure 4: Average stock size and efficiency over time, separated by treatment and by being cooperative (or not).

Table 4: Exploitation behavior for cooperative vs non-cooperative groups.

	Cooperative groups	**Non-cooperative groups**	
	Mean	*Mean*	*p-value*
	(Std. dev.)	*(Std. dev.)*	
Efficiency (group average)	0.589	0.527	0.6442
	(0.174)	(0.246)	
Over-exploitation (group average)	1.350	3.021	0.2217
	(3.529)	(4.990)	
Under-exploitation (group average)	-6.228	-4.412	0.1409
	(3.845)	(4.132)	
Stock size, after harvest before	33.668	27.168	0.1190
growth (group average)	(8.137)	(12.582)	

We have used non-parametric Mann-Whitney tests (all p-values are two-sided). There are 12 cooperative groups and 12 non-cooperative groups.

To test hypothesis 2 we also need to test whether exploitation behavior of cooperative groups that played the threshold treatment differ from exploitation behavior of cooperative groups playing the no threshold treatment. Right hand side of Figure 4 and two-sided Mann-Whitney tests reveal that there are no significant differences with respect to efficiency $Mean_T$=0.577, Std_T=0.174; $Mean_{NT}$=0.615, Std_{NT}=0.197; p=0.8651) or with respect to stock size ($Mean_T$=34.640, Std_T=9.098; $Mean_{NT}$=31.722, Std_{NT}=6.486; p=0.6104). To conclude we can party reject our second hypothesis; although we cannot detect any significant differences between the two treatments when we zoom in on cooperative groups, cooperative groups do not manage the resource optimally.

Next we proceed to analyze if other variables influence individual decisions observed in the experiment. Inefficient vis-à-vis efficient exploitation behavior arise either because users over-exploit the resource or because they under-exploit the resource. We find both types of behavior. We therefore run tobit regressions with either the average of per-period individual over-exploitation or under-exploitation (in absolute values) as dependent variables. This means we have one observation for each individual. Over- respectively under-exploitation is calculated as the distance between actual exploitation and the equal-sharing optimal individual claim. Besides the treatment and groups effects, we also controlled for age, gender, years of education, average monthly household income, household size, average monthly household savings, if they have a side income e.g. from tourism (which means that they can diversify their income), how much of their catch they keep for consumption vis-à-vis sell and if they were born in the village. Our analysis reveal that some of these socio-economic factors do influence behavior in the game. The best models, evaluated based on the Aikaike criterion is presented in Table 5 below.

Table 5: Tobit regressions

	Average individual cver-exploitation		*Average individual under-exploitation (absolut values)*	
	Coefficient (Std error)	*p-value*	*Coefficient (Std error)*	*p-value*
Constant	-19.855*** (6.757)	0.004	0.101 (0.322)	0.753
Age	0.337*** (0.122)	0.007		
Gender (male =1)			0.402 (0.265)	0.132
Treatment (threshold=1)	-8.827 (6.114)	0.152	0.680** (0.339)	0.048
Born in village (yes=1)	-7.469** (2.989)	0.014		
Side income (yes=1)	6.832** (3.079)	0.029		
Size of household			0.123** (0.056)	0.030
Percentage of catch consumed			0.008** (0.003)	0.036
F	4.86***	0.001	3.20	0.016
AIC	289.210		264.961	
N	96		96	

Individual over- or under-exploitation (compared to an equal sharing optimal claim) as dependent variable, ML estimates, robust standard errors clustered at the group level.

Results suggests that we can reject also our third hypothesis and that we in fact need different models to explain over- respectively under-exploitation. An individual under-exploits more on average when being confronted with the threshold treatment. If a fisher has a bigger household and consumes relatively more of their own catch (instead of selling it) he or she also tends to under-exploit more. However, the treatment influence behavior more than these socio-economic variables. Contrasting, whether or not an individual over-exploits does not seem to depend on the treatment. Instead, over-exploitation is clearly associated with fishers born outside of the village and fishers with a side income. This influence is comparably also quite strong.

4. Conclusions

Groups of fishers confronted with a latent, abrupt and potentially persistent drop in the resource growth rate are more likely to form cooperate agreements compared to groups confronted with a 'normal' logistic-type of resource dynamics. Thus, whether or not groups form cooperative agreements is endogenous to the treatment agreement, something which theory fails to predict. This result corroborates what Lindahl et al. (2016a) found in the lab. However, we also find some contrasting results. Over-exploitation was not so frequent and we cannot conclude statistically that the threshold treatment is associated with less over-exploitation. Further, in our field experiment, cooperative groups (taking all cooperative groups together) do not manage the resource more efficiently than non-cooperative groups. Lindahl et al. (2016a) find that cooperative threshold groups stay pretty close to the optimum and that there is a distinct difference in efficiency between cooperative and non-cooperative groups. One reason for this difference could be that in the field we observed different types of cooperative agreements. In our analysis we have restricted ourselves to groups that form strict agreements, meaning there is an agreement on exact exploitation for each user in each round. In the field we also observed that some groups formed agreements on 'ranges of stock sizes' they should aim for as a group (without specifying the exact numbers). In some cases these groups were able to stay within the agreed upon range and in some cases this range was also pretty close to the optimal range. Another potential explanation is the differences in design. In our case the drop in the growth rate once crossing the threshold is more 'severe' than the threshold implication used by Lindahl et al. (2016a), which could induce more cautious behavior, leading to more under-exploitation in the field. However, we also cannot rule out differences in education and literacy as explanatory variables. Turning to our regression analysis we detect an interacting effect between the ecological dynamics users are confronted with, the socio-economic characteristics of the resource user and exploitation behavior. Whereas, over-exploitation behavior (which is quite rare) is independent of treatment and driven by socio-economic variables (age, if they were born outside the village and if they can diversify their income), under-exploitation is more likely if the fisher face the threshold treatment, has a bigger household and consumes a high percentage of the catch, i.e. if the livelihood is more dependent on the natural resource.

In the commons literature there is an increasing recognition towards the role of contextual factors for the emergence and dynamics of cooperation (Anderies et al. 2011, Dietz and Henry 2008) but, as far as we understand, context related to ecological conditions has received relatively little attention in the experimental commons literature, with some notable exceptions. Prediger et al. (2011) explore experimentally the differences in cooperative behavior between farmers in Namibia and South Africa, who are similar in ethnic origin but face different ecological constraints; grasslands in Namibia are more sensitive to over-grazing and more likely to become irreversibly degraded. They find that the Namibian resource users behave more cooperatively in the game and also note that Namibian resource users have a longer experience of cooperative resource management and intact traditional norms. Gneezy et al. (2015) compare experimental outcomes in two different fishing communities. They observe that in one of the communities, ecological constraints favor more cooperative activities (to avoid and coordinate over risky activities). They observe higher levels of cooperation in the experiments in those communities. These experimental studies show that ecological factors influence the experimental behavior of resource users and should be included in the set of contextual factors to explore further in CPR research. We find that current ecological conditions can influence behavior and that the direction and extent can also depend on current individual socio-economic conditions. Our experiment and our design contributes to this literature and can be seen as one additional attempt to approach this research gap and suggest that attention should also be given to the role of resource dependency, within such a context.

Climate change is expected to increase the variability of supply of many natural resources. In some regions of the world sudden changes and scarcities may then threaten livelihoods. At the same time, governments are not always able to effectively manage the use of these resources, and collective action by local communities is needed to ensure the continued availability of these resources. Many scholars turn to the work of Ostrom and her design principles to understand when we should expect successful collective action (Ostrom 1990). This has also the case for small-scale fisheries (see e.g. Cinner et al. 2012). The first design principles seem particularly relevant to highlight here. The importance of clearly defined boundaries. With climate change and the associated increasing scarcities, variabilities, and uncertainties this condition is being challenged. Under what circumstances can such increasingly challenging conditions strengthen collective action, and under what circumstances do collective action risk failing? It is within this context we also highlight the role of resource dependency. Some studies emphasize that resource dependency is more likely to lead to resource over-exploitation and degradation of fisheries (see e.g. Cinner et al. 2012). Some solutions therefore center on making these fisheries more economically efficient while at the same time incentivizing fishermen to leave the sector. Our study does not confirm these results, nor their implications. Such strategies fail to fully recognize the different potentials and limitations fishermen face, such as geographical immobility and restricted opportunities for livelihood diversification which characterizes many SSF communities. Although we cannot derive direct policy conclusion based on this study, our work can be seen as one piece of a larger puzzle, where future pieces are yet to be discovered. Based on our study we hypothesize (for future research) that the strategies that individual fishermen are likely to adopt and consequently their likelihood to avoiding collapse will depend on resource dependency, but interacting with the social ties within the community, as well as with current ecological conditions. This in turn leads to another of Ostrom's design principle, the importance of arenas for conflict resolution. Such an arena could be equally important for building social relationships and for knowledge sharing (about ecological conditions), which we think can be essential in these vulnerable communities, especially under geographic mobility restrictions.

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Appendix

Table A1: Regeneration rate

Stock size	Growth NT	Growth T		Stock size	Growth NT	Growth T		Stock size	Growth NT	Growth T
50	0	0		32	10	10		14	5	1
49	0	0		31	10	10		13	5	1
48	0	0		30	10	10		12	5	1
47	0	0		29	10	10		11	5	1
46	0	0		28	10	10		10	5	1
45	5	5		27	10	10		9	5	1
44	5	5		26	10	10		8	5	1
43	5	5		25	10	10		7	5	1
42	5	5		24	10	10		6	5	1
41	5	5		23	10	10		5	5	1
40	5	5		22	10	10		4	0	0
39	5	5		21	10	10		3	0	0
38	5	5		20	10	10		2	0	0
37	5	5		19	5	1		1	0	0
36	5	5		18	5	1		0	0	0
35	5	5		17	5	1				
34	10	10		16	5	1				
33	10	10		15	5	1				

Table A2: Optimal claims

No threshold				Threshold			
Stock size	Optimal claim	# rounds until 30 (R)	Harvest during R	Stock size	Optimal claim	# rounds until 30 (R)	Harvest during R
50	30	1	30	50	30	1	30
49	29	1	29	49	29	1	29
48	28	1	28	48	28	1	28
47	27	1	27	47	27	1	27
46	26	1	26	46	26	1	26
45	25	1	25	45	25	1	25
44	24	1	24	44	24	1	24
43	23	1	23	43	23	1	23
42	22	1	22	42	22	1	22
41	21	1	21	41	21	1	21
40	20	1	20	40	20	1	20
39	19	1	19	39	19	1	19
38	18	1	18	38	18	1	18
37	17	1	17	37	17	1	17
36	16	1	16	36	16	1	16
35	15	1	15	35	15	1	15
34	14	1	14	34	14	1	14
33	13	1	13	33	13	1	13
32	12	1	12	32	12	1	12
31	11	1	11	31	11	1	11
30	10	1	10	30	10	1	10
29	9	1	9	29	9	1	9
28	8	1	8	28	8	1	8
27	7	1	7	27	7	1	7
26	6	1	6	26	6	1	6
25	5	1	5	25	5	1	5
24	4	1	4	24	4	1	4
23	3	1	3	23	3	1	3
22	2	1	2	22	2	1	2
21	1	1	1	21	1	1	1
20	0	1	0	20	0	1	0
19	4	2	4	19	0	2	0
18	3	2	3	18	0	3	0
17	2	2	2	17	0	4	0
16	1	2	1	16	0	5	0
15	0	2	0	15	0	6	0
14	4	3	4	14	0	7	0
13	3	3	3	13	0	8	0
12	2	3	2	12	0	9	0
11	1	3	1	11	0	10	0
10	0	3	0	10	0	11	0
9	4	4	4	9	0	12	0
8	3	4	3	8	0	13	0
7	2	4	2	7	0	14	0
6	1	4	1	6	0	15	0
5	0	4	0	5	0	16	0

4	4			4	4		
3	3			3	3		
2	2			2	2		
1	1			1	1		

Table A3: Critical discount factor

Stock size	Discount factor NT	Discount factor T	Stock size	Discount factor NT	Discount factor T
50	1	1	24	0,921805	0,921805
49	1	1	23	0,920223	0,920223
48	1	1	22	0,918597	0,918597
47	1	1	21	0,916925	0,916925
46	1	1	20	0,915205	0,915205
45	1	1	19	0,954759	0,990612
44	0,972601	0,972601	18	0,953762	0,990397
43	0,972066	0,972066	17	0,952732	0,990175
42	0,971522	0,971522	16	0,951668	0,989945
41	0,970966	0,970966	15	0,950567	0,989706
40	0,970399	0,970399	14	0,949429	0,989459
39	0,96982	0,96982	13	0,948249	0,989203
38	0,969229	0,969229	12	0,947027	0,988937
37	0,968625	0,968625	11	0,94576	0,98866
36	0,968008	0,968008	10	0,944444	0,988372
35	0,967377	0,967377	9	0,943078	0,988072
34	0,935604	0,935604	8	0,941657	0,98776
33	0,934367	0,934367	7	0,940177	0,987434
32	0,933102	0,933102	6	0,938637	0,987094
31	0,931807	0,931807	5	0,93703	0,986738
30	0,930481	0,930481	4	1	1
29	0,929124	0,929124	3	1	1
28	0,927733	0,927733	2	1	1
27	0,926307	0,926307	1	1	1
26	0,924845	0,924845	0	1	1
25	0,923345	0,923345			

Proofs

Assume the following strategy for each player *i*, where the total number of players in the group is four: *a)* In the first period, take (*50-X*)/4 units of the resource (to reach a stock size of *X*) and then from the second period and onwards take H_x/n units, where H_x denotes the sustainable yield to keep stock size *X, b)* If in some period *t*, someone deviates from this strategy profile (i.e. the new stock size is not *X*), then deplete the resource in the next period, *t+1*, i.e. claim the entire stock size.[11] Equation (A1), gives the payoff P_{DC} of a player *i* who deviates when all other players play according to the strategy profile which sustain the stock size x, h_{jt} represents the claimed harvest of player *j* where $j \neq i$.

$$P_{DC} = \frac{X_t^2}{X_t + \sum_{j \in n, j \neq i} h_{jt}} \quad \text{(A1)}$$

If all players deplete the resource in the same period, the associated payoff for each player is *X/4*. Let δ_{it} denote the expected discounted value of 1 unit harvested capturing the subjective probability of player *i* that the game will continue for one more period (in period *t*). Equation (A2) shows the total payoff, for player *i* who follows the strategy above for the entire game, given that all other players do so as well. The first term refers to the payoff in the first period (period 0) and the second term the sum of the continuation payoffs in all subsequent periods.

$$P_{CC} = \frac{50-x}{4} + \sum_{i=1}^{\infty} \delta_{it}^{t} \frac{H_X}{4} \quad \text{(A2)}$$

From these two equations (A1-A2) we can derive the necessary conditions for the outcome (a sustained stock size of *X*) to be sustainable as an equilibrium outcome. In the very first period, the stock size *X* can be obtained if equation A3 holds:

for all $i \in 1,2,3,4$

$$\frac{50-X}{4} + \sum_{i=1}^{\infty} \delta_{it}^{t} \frac{H_X}{4} \geq \frac{50^2}{50 + \frac{50-X}{4}(4-1)} \Leftrightarrow$$

$$\frac{1}{1-\delta_{it}} 4 \frac{H_X}{4} \geq \frac{50^2 4}{50 + \frac{50-x}{4}(4-1)} - \left(50 - x - 4\frac{H_X}{4}\right) \Leftrightarrow$$

$$\frac{\left((100-x)4 - (50-x)\right) H_X}{50^2 4^2 - \left((100-x)4 - (50-x)\right)(50 - x - H_X)} \geq 1 - \delta_{it} \Leftrightarrow$$

$$\delta_{it} \geq \frac{50^2 4^2 - \left((100-x)4 - (50-x)\right)(50-x)}{50^2 4^2 - \left((100-x)4 - (50-x)\right)(50 - x - H_X)} \quad \text{(A3)}$$

In the subsequent periods, because each period is a proper subgame, we need to check that the continuation payoff at time *t*, is larger than the deviation payoff. Note that in subsequent periods, there is no longer any uncertainty about the regeneration rate because the true scenario will be revealed after the first period. Thus, the following needs to hold:

for all $i \in 1,2,3,4$

$$\sum_{i=1}^{\infty} \delta_{it}^{(t-t)} \frac{H_X}{4} \geq \frac{(x + H_X)^2}{x + H_X + \frac{H_X(4-1)}{4}} \Leftrightarrow$$

[11] The maximum possible amount to claim is the current resource stock size and in case of depletion each player gets a payoff which corresponds to his/her percentage of the sum of all claims that period (see equation 1). Hence for a deviating player, the optimal deviation is then to deplete the resource in period *t*, i.e. claim the current stock size.

$$\frac{1}{1-\delta_{it}} \geq \frac{(x+H_X)^2 4^2}{\big((x+H_X)4 + H_X(4-1)\big)H_X} \Leftrightarrow$$

$$\frac{\big((x+H_X)4 + H_X(4-1)\big)H_X}{(x+H_X)^2 4^2} \geq 1-\delta_{it} \Leftrightarrow$$

$$\delta_{it} \geq \frac{(x+H_X)^2 4^2 - \big((x+2H_X)4 - H_X\big)H_X}{(x+H_X)^2 4^2} \qquad \text{(A4)}$$

For all parameters in our model, we have verified that if equation A3 holds then equation A3 also holds.[12] In Table A3 we present the critical discount rates (from equation A3) for all stock sizes for our two treatments.

[12] These calculations are available upon request.

Supplementary Material

INSTRUCTIONS (no threshold)

Normal text: read out loud the participants
Italics: Things you should do

Welcome and thank you for coming and participating in this activity!

It will take approximately 2 hours of your time.

During this activity we will play a game. After the game we would also like you to stay for some short interviews.

In this game you will be asked to take some decisions. You will receive 200 Bath for your participation in this activity. Depending on the decisions you make in the game, you can earn extra money. You will receive the money after the experiment (paid in private).

Why do we use money? We do not expect that the money you earn is a payment for taking part in the activity, nor the reason for you to be here. We use money because the exercise requires that you make some economic decisions that have consequences. It is to make the game realistic.

Before we start we want you to sign a consent form. The consent form says you are here voluntarily. It also informs you that the decisions that you take today will be anonymous. It will not be known to the other participants. Also when we analyze the results we will use numbers and color coding to identify you.

You will now be divided into groups of 4 people and thereafter we will explain the procedure more in detail.

Group division

Make group division. Each subject randomly picks a note which tells which group (color assigned) he will be assigned to and which number (1-4) he will be identified in that group (1-4). So for example if we have three groups playing at the same time we could have something like Blue (1,2,3,4); Gren (1,2,3,4) and Brown (1,2,3,4)

Think about how to deal with people from the same family (e.g. siblings, cousins) or close friends. Avoid putting in the same group if possible.

Explain common access to a fishing water (e.g. the sea)

In this game, we want you to imagine that you in this group have common access to a fishing ground (e.g. the sea).

Place the fish on the table, represented by the 'fake fish'

Although in reality it is impossible to know exactly how much fish there is in the sea, in this game we ask you to pretend that we can know how much fish there is.

Each of you can catch this fish from this common resource.

Explaining the game, catch, procedure etc

The game we will play lasts several rounds and in each round you take an individual and anonymous decision of how much fish to catch in that particular round.

For each fish you catch you get 20 Bath. So for example if you catch 20 fish you will earn 20*20 = 400 Bath.

So how do we keep track of you catch?

Introduce the records. Explain the procedure.

Show the decision protocol (which should be foldable to ensure anonymity)
In each round/period you mark how much fish you want to catch (the assistants are here to help you with this if you need). You can choose a number between 0 and the current number of fish available

(that is in the pool). These protocols will be collected by the assistants after each decision round. The assistants will give them to the experimental leader after each decision round.

Make sure that decisions are anonymous by for example using dividers or let them sit with their back towards each other's back.

The experimenter leader will in each round sum up the fish catch of the whole group. He/she will calculate the new stock size. You will get this information from the assistants (plus total catch in each round and earnings) on your protocol.

Explain that the resource is dynamic and grows

Now we will explain how the fish grows, which will be indicated by these symbols. *Show with the symbols*

The fish reproduce/grows between each new round. How much the fish stock grows depends on how many fish your group left in the previous round. We start with 50 fish in the first round. After the catch, if there is 46-50 fish left the stock does not grow. If there is 35-45 fish in the stock (big pool/pond/stock), there will be 5 more fish in the next round
Show with the magnets on the board how the stock grows from the biggest stock sizes.

If there is so much fish in the sea as in this "hypothetical" case– they may compete for food and have a hard time of finding each other to reproduce with the result that the fish stock does not grow so much.

If there is 20-34 fish in the stock (middle pool/pond/stock), there will be 10 more fish in the next round.

Show with the magnets on the board how the stock grows from the middle stock.
Here there is enough fish so that they can find mating partners and not too much so they compete for food.

If there is 5-19 fish in the stock (small pool/pond/stock), there will be 5 more fish in the next round.
Show with the magnets on the board how the stock grows from the small stock.
Reference to fish site: if there is too little fish they don't find enough partners and cannot reproduce.

For stock sizes below 5, the fish stock doesn't grow at all.

As long as there is fish to catch, the game continues for a number of rounds and you can earn money. We will not tell you the exact number of rounds. If there is no fish the game ends and you will not earn any more money.

If someone asks about how to share a harvest that is larger than the stock, answer: we will share proportionally according to your catch claim.

Examples

There are 50 fish in the beginning of the experiment. If you, for example, catch together 20 fish (for example 3+4+6+7) there are 30 fish left and the stock will then grow with 10 more fish. Then the fish stock will consist of (50-20+10) = 40 fish in round 2.

So now there is 40 fish. If you then catch 25 fish in total (10+5+5+5) there are 15 fish left and the stock will then grow with 5 more fish. Then the fish stock will consist of (40-25+5) = 21 fish in round 3.

Use the material (wooden fish and fish symbols when going through this example)

Communication?

What can you talk about?

You should not show the catch decision on balance sheet or the protocol to the other people in your group *(point to the balance sheet and protocol again)*.

However, you can talk to each other. You can talk about the game, the rules and your decisions but you cannot make any threats or arrangements for side-payments during or after this activity.

In case you have any questions just ask any of the assistants

Summary:

- The four of you share this fishing ground
- In each round you will take an individual decision of how many fish to catch
- As long as there is fish left the game continues (until the experimenter leader stops)
- The fish recovery depends on how much fish there is (point to magnets)
- Each fish is worth 20 bath.
- We do not tell you how many rounds we will play.

Do practice rounds

During the practice round(s), they do not earn money. We do not reveal who took what, only that "someone took" We calculate the total catch openly, growth and the new fish stock. Illustrating also with the magnets and the fake fish on the table.

Questions?

If not we can start the game which means that from now you earn money based on your decisions.

Remind them that they can ask questions
Remind them about the communication rules and then say we start the game.

Table to illustrate resource dynamics

Size of fish stock/pool	**Growth rate**
# fish between 0 - 5	0
# fish between 5 - 19 (small pool)	5
# fish between 20 - 34 (medium pool)	10
# fish between 35 - 45 (large pool)	5
# fish between 46-50	0

INSTRUCTIONS (threshold)

Normal text: read out loud the participants
Italics: Things you should do

Welcome and thank you for coming and participating in this activity!

It will take approximately 2 hours of your time.

During this activity we will play a game. After the game we would also like you to stay for some short interviews.

In this game you will be asked to take some decisions. You will receive 200 Bath for your participation in this activity. Depending on the decisions you make in the game, you can earn extra money. You will receive the money after the experiment (paid in private).

Why do we use money? We do not expect that the money you earn is a payment for taking part in the activity, nor the reason for you to be here. We use money because the exercise requires that you make some economic decisions that have consequences. It is to make the game realistic.

Before we start we want you to sign a consent form. The consent form says you are here voluntarily. It also informs you that the decisions that you take today will be anonymous. It will not be known to the other participants. Also when we analyze the results we will use numbers and color coding to identify you.

You will now be divided into groups of 4 people and thereafter we will explain the procedure more in detail.

Group division

Make group division. Each subject randomly picks a note which tells which group (color assigned) he will be assigned to and which number (1-4) he will be identified in that group (1-4). So for example if we have three groups playing at the same time we could have something like Blue (1,2,3,4); Gren (1,2,3,4) and Brown (1,2,3,4)

Think about how to deal with people from the same family (e.g. siblings, cousins) or close friends. Avoid putting in the same group if possible.

Explain common access to a fishing water (e.g. the sea)

In this game, we want you to imagine that you in this group have common access to a fishing ground (e.g. the sea).

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In each round/period you mark how much fish you want to catch (the assistants are here to help you with this if you need). You can choose a number between 0 and the current number of fish available (that is in the pool). These protocols will be collected by the assistants after each decision round. The assistants will give them to the experimental leader after each decision round.

Make sure that decisions are anonymous by for example using dividers or let them sit with their back towards each other's back.

The experimenter leader will in each round sum up the fish catch of the whole group. He/she will calculate the new stock size. You will get this information from the assistants (plus total catch in each round and earnings) on your protocol.

Explain that the resource is dynamic and grows

Now we will explain how the fish grows, which will be indicated by these symbols. *Show with the symbols*

The fish reproduce/grows between each new round. How much the fish stock grows depends on how many fish your group left in the previous round. We start with 50 fish in the first round. After the catch, if there is 46-50 fish left the stock does not grow. If there is 35-45 fish in the stock (big pool/pond/stock), there will be 5 more fish in the next round
Show with the magnets on the board how the stock grows from the biggest stock sizes.

If there is so much fish in the sea as in this "hypothetical" case– they may compete for food and have a hard time of finding each other to reproduce with the result that the fish stock does not grow so much.

If there is 20-34 fish in the stock (middle pool/pond/stock), there will be 10 more fish in the next round.

Show with the magnets on the board how the stock grows from the middle stock.
Here there is enough fish so that they can find mating partners and not too much so they compete for food.

If there is 5-19 fish in the stock (small pool/pond/stock), there will be 1 more fish in the next round.
Show with the magnets on the board how the stock grows from the small stock.
Reference to fish site: if there is too little fish they don't find enough partners and cannot reproduce.

For stock sizes below 5, the fish stock doesn't grow at all.

As long as there is fish to catch, the game continues for a number of rounds and you can earn money. We will not tell you the exact number of rounds. If there is no fish the game ends and you will not earn any more money.

If someone asks about how to share a harvest that is larger than the stock, answer: we will share proportionally according to your catch claim.

Note there is an abrupt drop in the fish growth. If the number of fish is below 20, the fish stock can only grow by one fish per round. *Point to the small pool in the magnet board and in the table.*
If you want to be in the middle pool where the fish stock grows by 10 fish per round, the total catch of the group must be zero for some rounds. *Show example on the board.*

Examples
There are 50 fish in the beginning of the experiment. If you, for example, catch together 20 fish (for example 3+4+6+7) there are 30 fish left and the stock will then grow with 10 more fish. Then the fish stock will consist of (50-20+10) = 40 fish in round 2.

So now there is 40 fish. If you then catch 25 fish in total (10+5+5+5) there are 15 fish left and the stock will then grow with 1 more fish. Then the fish stock will consist of (40-25+1) = 16 fish in round 3.

Use the material (wooden fish and fish symbols when going through this example)

Communication?

What can you talk about?

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However, you can talk to each other. You can talk about the game, the rules and your decisions but you cannot make any threats or arrangements for side-payments during or after this activity.

In case you have any questions just ask any of the assistants
Summary:

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Do practice rounds

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Questions?

If not we can start the game which means that from now you earn money based on your decisions.

Remind them that they can ask questions
Remind them about the communication rules and then say we start the game.

Table to illustrate resource dynamics

Size of fish stock/pool	**Growth rate**
# fish between 0 - 5	0
# fish between 5 - 19 (small pool)	1
# fish between 20 - 34 (medium pool)	10
# fish between 35 - 45 (large pool)	5
# fish between 46-50	0

PROTOCOL

Participant no___________

Round	Catch	Earning Bath	Round	Catch	Earning Bath	Round	Catch	Earning Bath

QUESTIONNAIRE (used for the interviews)

Section 1: Background data

1. Gender:____________ 1. ☐ Female 2. ☐ Male
2. Marital status: 1. ☐ Single 2. ☐ Married 3. ☐ Divorced/Widow
3. Age: (specify) _______ years old
4. Education:
   1. ☐ No formal education 2. ☐ Primary school
   3. ☐ Secondary school 4. ☐ Vocational school
   5. ☐ Bachelor degree 6. ☐ Higher than bachelor degree (specify) …………
5. Size of Household:____________persons (including yourself)
6. No. of working household members (also includes unpaid work such as housework): _________________ persons (including yourself)

7. Household income (Baht/month): (If anyone has more than one source of income, please specify by source of income separately. Unit of household means they share their income)

Household member	Source of income	Monthly income (Baht)
1. Yourself	Fishery	
2. Yourself	Daily worker	
3. Your wife		
4. Your son		
5.		
6.		
7.		
8.		
Total household income		

8. Household expenditure:_________________________ Baht/month

9. Were you born in Tha Chat Chai village?

1. ☐ Yes 2. ☐ No, I was born in (specify province) ___________________

10. When have you lived in Tha Chat Chai village? Which years? (specify) ____________

11. Are children and women involved in the fishing activities?

1. ☐ No
2. ☐ Yes, 1. ☐ Only women
   2. ☐ Only children
   3. ☐ Both women and children
3. ☐ Others (specify)____

12. Do you expect your children continue working on fishery?

1. ☐ yes, I expect them continue working on fishery
2. ☐ No, I want them to work other jobs
3. ☐ Others (specify) ____

13. Do you want to have side income from other sources?

1. ☐ yes, because ____
   Specify what kind of job you want ______________________________
2. ☐ No, because ____
3. ☐ I already have side income from (specify) _______________________
4. ☐ Others (specify) ____

14. Do you think you will change to work in another job in the future?

1. ☐ yes, because ____
   Specify what kind of job you want _____________________________
2. ☐ No, because ____
3. ☐ Others (specify) ____

Section 2: Description of fishing activities

15.How long have you been as a fisherman? _________________ years.

16. Do you have your own boat?

1. ☐ No 2. ☐ Yes, I have __________ boats

17. Describe briefly the gear you use for fishing you have (access to):

____
____
____

18. How many hours per day (approx.) or how many day per week do you spend on fishing activities?

___________ hours/day or ______________ day/week

19. How do you know where you can catch fish/sea animals?

____

20. How do you normally catch fish/sea animals?

1. ☐ by yourself
2. ☐ together with other fishermen and sharing income
3. ☐ others (specify) ____

21. How much percentage of the sea animals you consume and sell of your total catch?

1. Consume _______% of your total catch and sell ________% of your total catch
2. Others (specify) ____

Section 3: Knowledge and attitudes about the fish abundance in the area

To what extent do the respondents agree with the following statements? Mark on the scale 1-5 (where 5 means agree completely and 1 disagree completely)

22. I have a good knowledge about variations in fish abundance, e.g. where and when to expect fish:

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

Comments: ____

23. I believe that our current fishing (generally in the community/in Thailand) will affect the abundance of fish in the future:

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

Comments: ____

24. I think that I will be able to make a good living from fishing in the next 10 years.

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

Reason that you **agree**: ___________________________________
Reason that you **disagree**: ____

25. Have you ever experienced a sudden (more dramatic) change in fish abundance? This would be something more dramatic then a seasonal variation, where you really notice that a particular specie(s) seems to have disappeared:

Yes______ No_______

If yes, describe how you noticed, which specie, when it was (approx year), if the change persisted for a long time (how long), what you think caused the change etc:

Which species that disappeared?	How long have you noticed it disappeared?	What caused they disappeared?
1.		
2.		
3.		
4.		

26. I think we will experience such dramatic/sudden and persistent changes in fish abundance in the future:

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

If yes, what do you think will be the main cause?:____________________

____

Section 4: Cooperative and communication activities

27. In the community we (fishermen) often discuss about fish and fishing (e.g. potential problems) with each other:

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

Comments ____

28. In the community we (fishermen) share our knowledge and experience with each other about fishing (e.g. where and when to fish):

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

Comments: ____

29. I believe that cooperation between the fishermen is something that is good/necessary for sustaining our livelihood:

1	2	3	4	5
Completely disagree	Disagree	Neither agree nor disagree	Agree	Completely agree

Reason that you **agree**: ____________________________________
Reason that you **disagree**: ____

30. Other comments (e.g. about fishing, about the game, advice to you children/grandchildren):

____

____

____

____