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Efficient and Sustainable Management of Shared Fisheries in Thailand: Self-Governance or Regulation?

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Abstract

Artisanal fisheries are significant for poverty alleviation, but they are severely threatened by overfishing and climate change effects. Governance solutions can be hard to find when their implementation and success depend on both social and ecological contexts. In this study, our objective is to increase our understanding of behavioral strategies adopted by artisanal fisheries under different types of regulations using a field experiment in the form of a so-called common-pool resource (CPR) experiment with 540 artisanal fishers in Nakorn Si Thammarat province, Thailand. Our results reveal that: (i) a quota treatment provide higher overall efficiency and leads to more sustainable management compared to the treatment with an unregulated fishery. (ii) the higher probability of punishment in the quota treatment promotes more equal sharing of payoffs from the experiment among group members compared to a quota treatment with a low probability of punishment; and (iii) a higher degree of monitoring in the quota system prevents resource depletion. Our results suggest that the community empowerment in these artisanal fishery communities is not strong enough to make fishers cooperate effectively without regulation and that a quota system may be one plausible solution. Our results also suggest, however, that the design of the monitoring and punishment systems may need careful consideration to ensure a sustainable solution.

Keywords: *quota; self-governance; total allowance catches; artisanal fisheries; lab-in-the-field experiment*

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1. Introduction

In Thailand, the majority of fishermen are artisanal fishers, meaning that most fishers' livelihood in Thailand depends on their daily catches. Unfortunately, these fisheries, which utilize about 80% of all fishing vessels in Thailand, are facing several threats including overfishing and climate change effects. Department of Fisheries (2015) reported two important signs showing that the fishery resources these fishers depend upon are severely degraded; (i) the decline of catch per unit effort (CPUE) and (ii) the exceeding of the optimal level of fish catches based on the estimated maximum sustainable yield (MSY). The CPUE in the Gulf of Thailand has been declining from approximately 300 kilograms per hour in 1961 to approximately 27 kilograms per hour in 2011, whereas the CPUE in the Andaman Sea also has been decreasing from about 400 kilograms per hour in 1966 to approximately 90 kilograms per hour in 2018. Furthermore, for example, the estimated fishing efforts for demersal fish in the Gulf of Thailand and the Andaman Sea exceeded the MSY efforts by 32.8 percent, and 5.3 percent respectively. To address this challenge, the Department of Fisheries has introduced a quota system in terms of total allowance efforts (TAE) for the commercial fishery in 2017. At the moment there is no regulation for the artisanal fishery, one reason being that solutions are more challenging to find when their design and success depend on both social and ecological context, however, the quota system has been put forward as one potential solution.

In a common pool resource (CPR) system a resource user, e.g. a fisher, is confronted with the following dilemma: to choose an extraction level that will benefit the entire group of fishers (sharing the same fish stock) or choose an extraction level that will maximize his or her individual return. If they all think alike and act as individualists it will lead to a so called 'tragedy of the commons' (Hardin 1968) associated with over-exploitation and in a worst-case resource depletion, unless users find a way to cooperate, avoid the tragedy and together choose a sustainable extraction level (Ostrom 1992).

In this study, we aim to increase our understanding of behavioral strategies adopted by artisanal fishermen under different types of regulations using a field experiment in the form of a so-called common-pool resource (CPR) experiment. One advantage of using an experiment (over for example questionnaires or interviews) is that it can capture real behaviour because the participants are facing real incentives and make decisions based on these incentives. Moreover, by letting groups (that are similar) face different types of regulations (called treatments) one can estimate if there are differences in behavioral responses and outcomes (e.g., in terms of over-exploitation) under different types of regulations. By doing this, it will allow the surfacing of potential issues (e.g., in terms of effectiveness and unintended consequences) before scaling up interventions. The approach is a way to minimize the cost of trying a new approach in real life if it does not work. The two main specific objectives of this study are (i) to test how fishermen who are regulated by a quota (total allowance catches: TAC) with punishment perform in comparison with a self-regulated fishery (self-governance) with no punishment, in terms of efficiency and sustainable resource use, and (ii) to test how fishermen who are regulated by a quota with a high probability of punishment performs in comparison to a regulated quota with a low probability of punishment, in terms of efficiency and sustainable resource use. To answer these questions, three treatments were introduced, namely, a self-governance treatment, a regulated quota treatment with a low probability of punishment, and a regulated quota treatment with a high probability of punishment.

2. Literature Review

The prevalence of CPRs and their associated inefficiencies have given rise to an extensive literature aiming at identifying factors influencing management (Bromley et al. 1992; Ostrom et al. 2002). Laboratory experiments have been proven valuable for gathering empirical data on drivers of human behavior in CPR systems (see, e.g., Kopelman et al. 2002; Ostrom 2006 for comprehensive overviews). Recently, studies have also demonstrated the advantage of using experiments for analyzing the potential impact of temporal resource dynamics in such systems (Janssen (2010); Janssen et al. (2010); Castillo et al. (2011); Prediger et al. (2011); Cardenas et al. (2013); Lindahl et al. (2016a), Schill et al. (2015)).

The experimental literature focuses on whether external regulation improve efficiency and sustainable uses of common-pool resources. For example, Cardenas (2004) studied the role of external regulations (high and low punishment and a 20% monitoring probability) and self-regulation on extraction behavior of forest users using CPR experiments in Colombia. The study found no significant difference in extraction behavior between the three treatments. The researcher suggested that individuals' extraction behavior may partly depend on social norms regarding cooperative behavior and subjective valuation of the benefits and costs of the regulation. Velez et al. (2010) also tested the effects of external regulation with penalties (fixed quota) compared to a case with self-regulation without penalties with fishers in Colombia using a static CPR game. The study suggests that the complementary relationship between informal communication and external regulations is effective in reducing harvests in some areas but cannot be supported in general.

Some studies found evidence that external regulations can crowd out the intrinsic motivation of optimum resource uses. Travers et al. (2011) investigated the effect of different institutions including peer pressure, self-governance, external sanction and incentive collective payment using the CPR games with villagers in Cambodia. The authors found that self-governance had the greatest effect in reducing extraction. The authors explain that it may be because exogenous institutes fail to interact with group decision-making in the same manner as a self-governance system. This could imply that social norms governing behavior can be undermined in the presence of external sanctions. Abatayo and Lynham (2016) also investigated whether external regulation could crowd out the intrinsic motivation of individuals to reduce extraction in a CPR setting. Contrasting to Travers et al (2011) they found that resource extraction behavior did not significantly differ when rules were endogenously created versus exogenously imposed. The authors argued that crowding out effects found in previous studies may be the result of a failure to disentangle the confounding effects of strategic learning and communication from the effect of exogenous regulations. This could help explain the effects found by Lindahl et al (2016). By using a dynamic CPR game, Lindahl et al. (2016) evaluated the role of catch quota with punishment as an external regulation to avoid ecosystem regime shift, an abrupt drop in the resource regeneration rate, in a CPR system. They found that the quota treatment was associated with lower efficiency, which stemmed both from under- and over-exploitation. The authors hypothesize that the users in the quota treatment fail to get a proper understanding of the resource dynamics, when the responsibility for management is transferred fully to the authority, which over time can lead to more unsustainable resource management.

Other related studies have focused on the endogenous emergence of self-regulation rules. Casari and Plott (2003) applied a static CPR experiment to test the effect of peer punishment (costly weak sanction and strong sanction). The results show that the introduction of sanctions improve resource use efficiency compared to a no sanctioning condition. Further, under a strong sanctioning regime resource use efficiency can be higher compared to a weak sanctioning regime. Akpula and Martinsson (2011) applied a static CPR game to test whether costly punishment with ostracism (or social exclusion) were effective in reducing over-harvests. The study shows that introducing ostracism to vote out other members based on a simple 50% voting rule, decreased harvests significantly in comparison with a non-ostracism treatment. In addition, Przepiorka and Diekmann (2020) found no difference between their control condition (without any regulation) and the treatment in which participants received feedback on their past decisions in private, also in a CPR experiment. However, cooperation improved when users could provide non-binding promises and received feedback in public.

These studies show that when it comes to regulating common pool resources like small-scale fisheries, there may not be a 'one size fits all' type of solution. Regulations can lead to better managed resources, but not necessarily, and moreover, the design of the regulation needs to be carefully considered. We contribute to this literature by using temporal resource dynamics. Most of the previous studies, except Lindahl et al (2016), have used static or fixed resource dynamics. Unlike Lindahl et al (2016) we decided to run the experiment with real resource users, and we test different levels of punishment.

3. Methodological approach

3.1 Experimental Design

We used a common pool resource (CPR) experiment to answer our research questions. The purpose of using the CPR experiments is typically to test under what conditions we can expect collective action to emerge, i.e. if resource users to cooperate (or not) around shared resources, and by extension to attain sustainable resource use (Ostrom 2006; Janssen, Lindahl, and Murphy 2015). In our CPR experiment each individual can either choose an extraction level (i.e. how much to fish from a shared fishing ground) that would benefit the entire group or choose an extraction level that would maximise individual returns. Each action an individual takes in the experiment affects the shared resource (fish stock), which in turn affects the individuals' returns (i.e. their livelihoods). The resource stock dynamics is represented by a discrete version of a logistic-type of resource dynamics as illustrated in Figure 1.

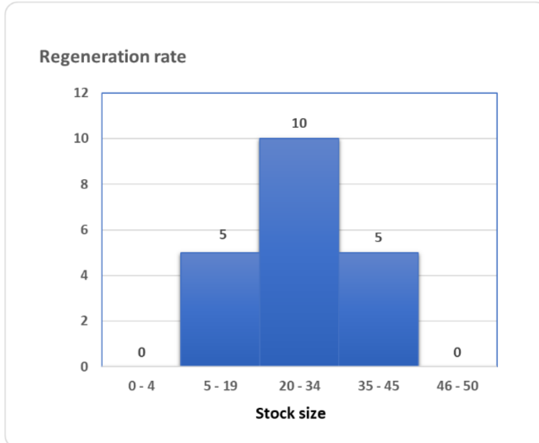

Figure 1. Regeneration rate

The three treatments we test are as follows.

Treatment 1: Self-governance or unregulated treatment without punishment as a control group, the participants (groups) are not regulated, they can however communicate with each other and make agreements. Punishment is not allowed. The game ends when the fish stock is depleted or by the decision of the experimenter.

Treatment 2: Regulated quota (total allowance catches: TAC) treatment with a low probability of punishment (0.1). Participants can communicate with each other and make agreements as in the self-governance treatment. All participants need to make a decision about how many fish they want to catch (as in treatment 1) , they also need to make a decision whether or not they want to inspect the catches of other group members (before the experimenter give them the feedback of total catches in that period). If any participant requests to monitor the catches of other group members, the experimenter will check the catches of all group members. If it is found that any participants catch exceeds the quota (the optimal claim level calculated by the experimenter in each period), these participants will be punished by a 50% deducting of their payoff in that particular period by an external regulator (such as authorities in real life or experimenter in this study). The monitoring cost for those who request it is 5 baht ($US 0.14[4]) per request. If no participants request to monitor the number of catches, the experimenter will draw a lot with a 0.1 probability of punishment. Information about the new stock size, aggregate

[4] $US 1 was approximately 35 baht in 2022.

harvest, and the quota (which corresponds to the optimal claim) in each period will be provided by the experimenter before all participants make decisions for numbers of catches and monitoring request.

Treatment 3: Regulated quota (total allowance catches: TAC) treatment with a high probability of punishment (0.4), the experimental rules are the same as in Treatment 2 except that the probability of punishment in this treatment is 0.4.

The experiment involved 135 groups (540 participants) in total, of which 46 groups (184 fishers) were played the self-governance without punishment treatment and 44 groups (176 fishers) were played the regulated quota with low probability of punishment treatment, as well as 45 groups (180 fishers) were played the regulated quota with high probability of punishment treatment (Figure 2).

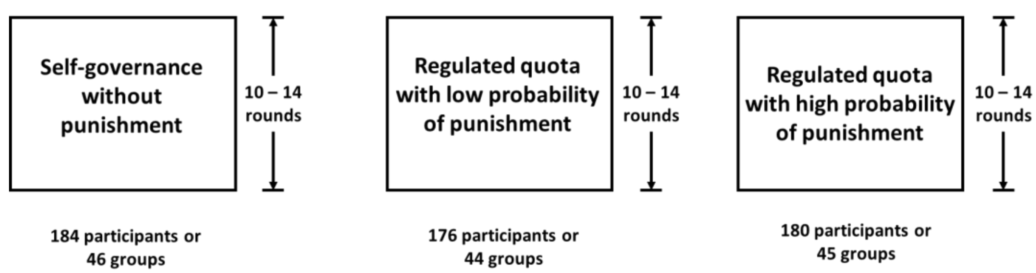

Figure 2. Experimental Treatments

3.2 Formulating hypotheses

To formulate hypotheses, follow the approach of Lindahl et al (2016) and rely on methods from repeated game theory. We thereby assume an indefinite time horizon (Carmichael 2005), which implies that the discount factor represents the probability that the game will continue to the next period (Fudenberg and Tirole 1998). We also assume that the players receive an update on the stock level X_t at the beginning of each period, which implies that they can deduce information on the other players' actions. For example, they know if someone has deviated from an agreed cooperative strategy. They can thereby condition their strategies on current and past stock sizes. In fact, we assume that they condition their strategies only on this piece of information, i.e., they use Markov strategies (Maskin and Tirole 2001).

Using our game theoretic approach we can deduce that each stock size of the game, $X \in \{5,6,7,\ldots,45\}$, can be sustained as a Markov Perfect Equilibrium if the discounted value of one resource unit is large enough for each player i in the game (i.e., the players believe the game will continue to the next period with a relatively high probability). If the discount factor, δ_i, for one (or more) of the players falls below some critical value $\delta\hat{}(X)$, the equilibrium cannot be sustained any longer. This critical value will vary with the growth rate and consequently stock size (see Lindahl et al. (2016) for more details and proof).

The optimal outcome of the game is the one where the group is able to maximize joint earnings. This outcome is obtained if the group harvests 25 units in the first period, and then, in each subsequent period, harvests the maximum sustainable yield, here 10 units, as long as the discount factor for each group member is high enough (i.e., higher than the critical value, $\delta\hat{}(X)$. This is true regardless if there is a quota or not. Thus, if groups manage to cooperate the two systems (a regulated and an unregulated system) would perform equally well. If, however, some groups do not manage to cooperate, or even so fail to exploit optimally a regulated system would outperform an unregulated system and a higher level of punishment would outperform a lower level of punishment (see Lindahl et al 2016 for details and proof). We can formulate the following hypotheses:

Hypothesis 1: We expect the unregulated (self-governance) treatment to be more over-exploited compared to the regulated quota treatments. Therefore, we also expect the quota treatments to have a higher overall efficiency and less depletion cases compared to the unregulated treatment (comparing treatment 1 with treatment 2 and 3).

Hypothesis 2: We expect the quota treatment with low probability of punishment to be more over-exploited compared to the quota treatment with high probability of punishment. Therefore, we also expect the quota treatment with high probability of punishment to have a higher overall efficiency and less depletion cases (comparing between treatment 2 with treatment 3).

Hypothesis 3: We expect efficient groups to share the resource equally (they cooperate). Hence following hypotheses 1 and 2 we also expect the quota treatments to be associated with more equal sharing compared to the self-governance treatment. We also expect the quota treatment with high probability of punishment to lead to more efficient outcomes and hence more equal sharing compared to the quota treatment with low probability of punishment.

3.3 Experimental Procedure

The 540 actual artisanal fishers from Nakorn Si Thammarat province[5], located in the south of Thailand, were recruited with the help of the coordinator from the Save Andaman Network foundation. Upon arrival, the experimenter welcomed and informed them briefly about the experiment and the research team. The order of treatments was randomly determined prior to the actual experiment to minimize the possible bias. To assign participants to a group, participants drew lots to separate into groups of four randomly. Precaution was taken to avoid, if possible, assigning individuals from the same household or close friends to the same group. In cases where relatives are identified within the same group, participants will be reassigned to different groups. Participants were allowed to participate only once. All participants received 200 baht (US$ 5.71) as a show-up fee for their participation regardless of their performance in the game.

In each group, they were seated around a table. The experimental leader in each room read the consent form and asked the participants whether they wanted to participate in the experiment. If they agreed, they needed to sign the consent form. Participants were informed that each of them represented a resource user, and that, together with the other participants in the group, they had access to a common renewable resource stock from which they could harvest units, each worth 10 baht (US$ 0.29), over a number of periods. To keep individual harvest decisions anonymous, participants indicated their individual harvest on a protocol sheet, which the experimenter collected after each decision-making period. The experimenter calculated the sum of the individual harvests as well as the new resource stock size (based on the tables in the instructions) and communicated (written and orally) this new resource stock size to the group. However, what the participants actually wrote down in each period was kept anonymous. Participants were told that the

[5] Nakhon Si Thammarat province (5,734 households) was the second highest rank in terms of number of fishery households, while the first rank was Songkla province (5,965 households) (Community Development Department, 2015). Regarding number of fishing boats in 2019, total number of fishing boats were 32,529 boats including 21,460 boats of the small-scale fishery and 11,069 boats for the commercial fishery. In Nakhon Si Thammarat province, there were 3,467 boats of the small-scale fishery and 851 boats of the commercial fishery in 2019 (Department of Fisheries, 2019).

experiment would end either if they depleted the resource stock[6] or when the experimenter decided to. To avoid the endgame effect, this ending time information was unknown. If the group's total harvest was equal to or exceeded the number of available resource units in one period, the resource regeneration would be zero and the experiment would end.

During each period, participants decided how much fish they wanted to catch. Their individual catch could be between 0 (which is to not fish at all) and the total amount of resource available in the current period, which depended on how much fish was collectively extracted in the previous periods. After each period, the new resource stock was calculated by the experimenters. Only the new stock size and aggregate harvest was disclosed to the group to maintain anonymity of individual harvesting levels. As long as there was resource left, participants were allowed to continue playing. To make sure participants understood the game, the experimental leader went through an example, clarified remaining questions and played two practice periods with the group before the actual experiments started.

The experimental team for each group included at least: one experimental leader (reading out the instructions and making sure that everyone understood the experiment), a resource stock calculator, a resource stock calculator assistant, and two observers. Experimental leaders rotated across treatments to minimize experimenter biases. Local research assistants fluent in the local dialect played an important role in providing participants with assistance throughout the experiment.

3.4 Interviews and complementary data

After the experiment, the participants were interviewed using a questionnaire, specifically designed to identify and analyze individual and group attributes. Questions about socio-economic factors were asked in the questionnaire (e.g. age, gender, and educational background, income). They were also asked control knowledge questions regarding the resource dynamics and asked to also indicate whether they were certain, or not, about their answers. For example, we ask them to indicate on a five-level Likert scale (Likert, 1932), ranging from not at all (scale value of 1) to absolutely certain (scale value 5), if they understood the resource dynamics. During the

[6] If the group's total harvest was equal to or exceeded the number of available resource units in one period, the resource regrowth was zero, and the experiment ended for this group. The payment for that period was then based on her harvest in that period, as a share of the group's total harvest, in the same period.

experiment, assistants were taking notes on communication and cooperation behavior for each group and period. A note was made (1) if their group communication was effective (where effective communication was defined as being able to reach agreements, (2) if their group managed to cooperate (where cooperation was defined as being able to reach agreements and that these agreements are being followed by all group members and (3) if they understood the resource dynamics (as being perceived by the observers). At the end, subjects were paid privately, one by one.

4. Experimental Results

We first look at the overall picture of the data, comparing means and proportions of the three treatments. Descriptive statistics based on the interview data are presented in Table 1 for each treatment separately. We have used non-parametric Mann-Whitney test for continuous variables and Pearson's χ^2 tests for proportions[7] (all p-values are two-sided) to test for the systematic differences between the treatments. There are 184 observations for the self-regulated treatment and 176 observations for the regulated quota treatment with a low probability of punishment as well as 180 observations for a regulated quota treatment with a high probability of punishment. There are no systematic differences between the treatments with respect to any of the socio-economic variables except fishery income. Average fishery income in the regulated quota treatment with a low probability of punishment is slightly higher than in other treatments on a five percent significant level. We did not find any significant difference for participant's ambiguity aversion preferences[8] and participants' attitude about the impact of climate change on fishery stock. Moreover, risk preference[9] of participants differs slightly between the three treatments. The average earning of total payment including a show-up fee, and payoffs were approximately 487 baht (US$ 14), which was higher than the average minimum wage (340 baht (US$ 9.7)).

[7] Non-parametric tests were applied because the variables we tested were not normally distributed. Normality is rejected according to a Shapiro-Wilk's normality test. The non-parametric ordinal data and porprotion data were tested by the Mann-Whitney test and Pearson's χ^2 test, respectively.
[8] In the ambiguity question, we asked participants to choose between losing money for certain and having a chance (without specifying the actual probability) of losing either some money or nothing.
[9] In risky question, we asked participants to choose between losing money for certain and having a chance with a specific probability of losing either some money or nothing.

Table 1. Descriptive statistics of the participants

Independent variables	Treatment: Self-governance Mean (Std. dev.)	Regulated quota treatment with a low prob. of punishment Mean (Std. dev.)	Regulated quota treatment with a high prob. of punishment Mean (Std. dev.)	Kruskall-Wallis test/ Pearson χ^2test (p-value)
Age (years)	45.8044	44.3864	43.6556	2.032
	(12.5430)	(13.6482)	(14.0416)	(.3620)
Education level (years of schooling)	8.00	8.3522	7.90	1.604
	(3.3649)	(3.2197)	(3.2220)	(.4484)
Born in village (yes=*1*, No=0)	.8261	.8580	.8833	2.4250
	(.3801)	(.3501)	(.3219)	(.297)
Fishing experience (years of fishing experience)	24.4837	23.9091	23.7111	.542
	(13.6874)	(13.2671)	(14.0221)	(.7624)
Household income (baht/month)	15916.27	17185.23	15591.26	1.972
	(8824.875)	(20965.19)	(11195.66)	(.3730)
Fishery income (baht/month)	9768.511	11052.46	9816.667	.014
	(6284.167)	(16300.7)	(8033.954)	(.9931)
Share of fishery income	.8942	.8881	.9083	1.766
	(.2079)	(.1997)	(.1841)	(.4135)
Household expenditures (baht/month)	9518.533	9065.341	9322.778	1.414
	(5481.879)	(5566.737)	(7638.822)	(.4931)
Net household income or household savings (baht/month)	6397.734	8119.886	6268.486	1.091
	(6564.222)	(18760.15)	(7969.575)	(.5796)
Global warming have a negative effect on the fish stock in the future (0=No and 1=Yes)	.7554	.7273	.7389	.3763
	(.4310)	(.4466)	(.4405)	(.828)
Do you go to fish alone? (0 = No and 1 = Yes)	.1522	.1420	.1167	1.0254
	(.3602)	(.3501)	(.3219)	(.599)
Risk aversion or ambiguity aversion (0 = No and 1 = yes)	.375	.4375	.5333	9.3431
	(.4854)	(.4975)	(.5003)	(.009)
Ambiguity aversion (0=No and 1=Yes)	.1685	.2273	.2333	2.8249
	(.3753)	(.4203)	(.4241)	(.244)
Risk lover (0 = No and 1 = Yes)	.3804	.2898	.20	14.3666
	(.4868)	(.4550)	(.4011)	(.001)
N (participants/groups)	184/ 46	176/44	180/45	-

Note: The Kruskall-Wallis test and the Pearson χ^2test was used to test for a continuous data and a ratio data, respectively.

We then proceed to look closer into over-exploitation and under-exploitation. Over-exploitation (or under-exploitation) of a participant in a specific period is calculated as the distance between the equal-sharing optimal individual claim and the actual individual exploitation. Then, in each period, a participant can either over-exploit, under-exploit, or exploit optimally. Figure 3 demonstrates over-exploitation and under-exploitation for the self-governance treatment, the regulated quota treatment with a low probability of punishment and the regulated quota treatment with a high probability of punishment. The light grey bars correspond to average under-exploitation for each period. The black bars similarly correspond to average over-exploitation. With respect to over-exploitation there is a significant difference between the treatments. The self- governance case is associated with the highest level of over-exploitation, followed by the regulated quota treatment with a high probability of punishment. The regulated quota treatment with a low probability of punishment is associated with the lowest level of over-exploitation. This confirms when we test of proportion between self- governance and the regulated quota with low probability of punishment (p-value<0.01 in Table 2) and between self-governance and the regulated quota with high probability of punishment (p-value<0.01 in Table 2).

We look at the Gini coefficient, as a measure for equal sharing, where a low value (less than .05) would indicate that the group earnings are equally distributed among the group members. We used a dummy variable to indicate if a group was equal sharing or not, where a dummy value of 1 indicate equal sharing and 0 indicate unequal sharing. The equal sharing group was defined as 1 if the Gini coefficient is below .05[10]. Table 2 shows that there is significant difference between the self-governance and the regulated quota with low probability of punishment (p-value<.05) and between the two regulated quota treatments (p-value<.01). With respect to number of groups that depleted the resource, we found a significant difference between the self-governance and the regulated quota treatment with low probability punishment (p-value<.01) but not between the high and low probability of punishment in the regulated quota treatments.

10 We noticed in the experiment that some groups used different agreements to try and optimize harvest, which could imply that subjects in a specific group could earn a few more resource units over the entire duration of the experiment, resulting in a slightly higher Gini coefficient (but still lower than .05).

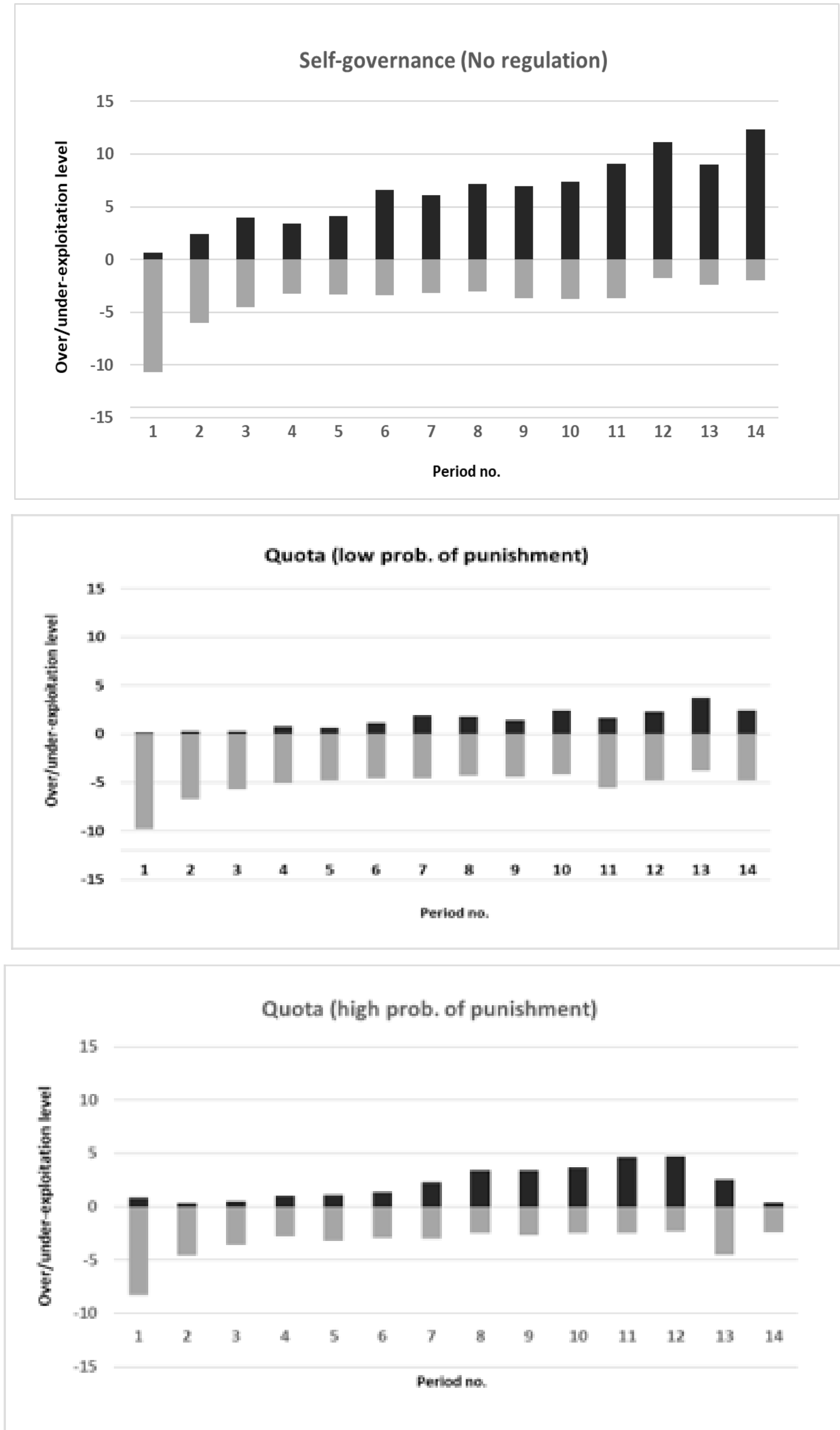

Figure 3. Average over-exploitation and under-exploitation in resource stock units in each treatment.

Table 2. Testing for systematic differences between treatments

	Treatments			Pearson's χ^2 test	Test of proportion
	Self-governance	Regulated quota treatment with a low prob. of punishment	Regulated quota treatment with a high prob. of punishment		
	Mean (Std. Err.)	Mean (Std. Err.)	Mean (Std. Err.)	p-value (χ^2 stat)	p-value (z-stat)
over-exploitation (1 = over-exploitation and 0 = under-exploitation)	67 participants out of 117 participants	16 participants out of 176 participants	30 participants out of 180 participants	.000 (43.5426)	-
	√	√	-	-	.0000 (6.1525)
	√	-	√	-	.0000 (4.2603)
	-	√	√	-	.0331 (-2.1305)
Equal sharing (1 when Gini coef. <.05 and = 0 when Gini coef. >= .05)	29 groups out of 46 groups	36 groups out of 44 groups	24 groups out of 45 groups	.016 (8.2938)	-
	√	√	-	-	.0468 (-1.9878)
	√		√	-	.3477 (.9391)
	-	√	√	-	.0041 (2.8666)
Number of groups that resource depleted.	18 groups out of 46 groups	4 groups out of 44 groups	11 groups out of 45 groups	.004 (10.9877)	-
	√	√	-	-	.0009 (3.3148)
	√		√		.1328 (1.5032)
		√	√		.0530 (-1.9345)

4.1 Over-Exploitation and Under-Exploitation

To test our hypotheses and further explore the data we run regression analyses. Besides testing our hypotheses, we are interested in getting a better understanding of potential drivers of over-exploitation when compared to optimal exploiters or under-exploiters. To analyze individual exploitation behavior we run the Tobit regressions with average individual over-exploitation as the dependent variable (Table 3). We cluster at the group level to control for group effects. Further, we also control for treatment effects and other socio-economic variables (e.g. household savings and fishing experience) and participants' attitudes (e.g. risk attitude and attitude to climate change impact on fishery stocks). The analysis shows that some fisher characteristics and socio-economic factors, influences behavior in the experiment. The best model, evaluated based on the Akaike information criterion (AIC) is presented in Table 3.

Based on the Model 1 in Table 3, we cannot reject hypothesis 1. We found that the self-governance treatment is associated with more over-exploitation compared to both regulated quota treatments (p-value<.01). This result implies that the quota treatments provide higher overall efficiency and more sustainable resource management. This may be because the community empowerment in these communities is not strong enough to make fishers cooperate effectively. This reason is consistent with information from the focus group discussions where fishers thought it was impossible that fishers could come to an agreement on a self-governance quota allocation. We also found that fishers who fish alone are likely to over-exploitation less compared to fishers who fish with their family or workers (p-value<.01). Risk preferences and attitudes towards environmental impact on fisheries were not significant in explaining over-exploitation.

We did not find a significant difference in over-exploitation between the two regulated quota treatments (Model 2 in Table 3). The higher probability of punishment treatment does not provide higher efficiency. Further, our result shows that no fishers' characteristics and socio-economic variables influence behavior in the game.

Result 1. *We cannot reject hypothesis 1, however, we reject hypothesis 2, The self-governance treatment is associated with more over-exploited compared to both regulated quota treatments. There is, however, no the significantly difference for over-exploitation between two regulated quota treatments.*

Table 3. Effects of treatments on over-exploitation

Independent variables	Model 1: Effects on regulated quota on over-exploitation		Model 2: Effects on punishment probability on over-exploitation	
	dy/dx (Std. Err.)	p-value	dy/dx (Std. Err.)	p-value
Dependent variable: Over-exploitation (1 = over-exploitation and 0 = under-exploitation)				
Regulated quota treatment with a high prob. of punishment (Yes = 1 and No = 0)	-.1435** (.0451)	.001	.0698 (.0444)	.116
Regulated quota treatment with a low prob. of punishment (Yes = 1 and No = 0)	-.2192** (.0476)	.000	-	-
Net household income or household savings (baht/month)	-.000002 (.0000)	.461	-.000004 (.0000)	.106
Fishing experience (years of fishing experience)	.0003 (.0014)	.808	.0018 (.0015)	.203
Do you go to fish alone? (0=No and 1=Yes)	-.1116** (.0386)	.004	-.0158 (.0448)	.724
Global warming will have a negative effect on the abundance of fish in the future (0 = No and 1 = Yes)	-.0672 (.0358)	.061	-.0553 (.0396)	.162
Risk lover (0 = No and 1 = Yes)	.0240 (.0404)	.553	-.0145 (.0420)	.730
Prob > chi2	.0002		.1558	
AIC	486.3188		265.8002	
BIC	520.2254		292.6439	
N (participants)	512		342	

Note: 1. * and ** indicate significance at 5%, and 1% levels, respectively.

2. Clustered standard errors at the group level are in parentheses.

4.2 Equal Sharing

We also explore the potential drivers of sharing the harvest equally. The Gini coefficients for each group were calculated. We then let cooperation be defined as having a Gini coefficient of less than 0.05. A logistic regression was then used with cooperation, defined based on the Gini coefficient, as dependent variable. Again, we used the stepwise approach to choose the best model based on the Akaike criterion. With respect to equal sharing (Model 1 in Table 4), our result reveals that there is no difference between the self-governance treatment and the quota treatment with a high probability of punishment. We find, however, the quota treatment with a low probability of punishment has significantly less (negative) influence on equal sharing compared to the self-governance treatment (p-value<.05). The more experience of fishers in the groups, the higher is the equal sharing is (p-value<.05).

With respect to equal sharing (Model 2 in Table 4), we partly reject hypothesis 3. The high probability of punishment in the regulated quota treatment is associated with higher equal sharing compared to the low probability of punishment in the regulated quota treatment (p<.01). However, that the low probability of punishment treatment is associated with less equal sharing compared to the self-governance treatment which is inconsistent with our hypothesis.

Result 2. *We partly reject hypothesis 3. A regulated treatment with low punishment leads to less equal sharing compared to self-governance treatment. However, the high probability of punishment in the regulated quota treatment is associated with more equally sharing compared to the low probability of punishment in the regulated quota treatment.*

Table 4. The determinants on equal sharing

Independent variables	Model 1: Self- governance and regulated quota on equal sharing		Model 2: High and low probability of punishment on equal sharing	
	dy/dx (Std. Err.)	p-value	dy/dx (Std. Err.)	p-value
Dependent variable: Equal sharing (1 = equal sharing and 0 = unequal sharing)				
Regulated quota treatment with a high prob. of punishment (Yes = 1 and No = 0)	.1079 (.1039)	.299	.2937** (.1021)	.004
Regulated quota treatment with a low prob. of punishment (Yes = 1 and No = 0)	-.1946* (.0934)	.037	-	-
Education level (years of schooling)	.0567 (.1474)	.701	-.1841 (.1923)	.339
Fishing experience (years of fishing experience)	.0136* (.0065)	.036	.0154 (.0093)	.097
Prob > chi2	.0071		.0015	
AIC	168.8533		103.2354	
BIC	183.3797		113.1899	
N (groups)	135		89	

Note: 1. * and ** indicate significance at 5%, and 1% levels, respectively.

2. Clustered standard errors at the group level are in parentheses

3. Equal sharing = 1 when Gini Coefficient < .05 and = 0 when Gini Coefficient >=.05

4.3 Resource Depletion

Finally, we wanted to explore the drivers of resource depletion. We run the logistic regression with resource depletion as the dependent variable. Resource depletion is equal to 1 when the groups depleted resource before the game ended and is equal to 0 when otherwise. The Akaike criterion was used as a criterion to choose the best model. Our analysis (Model 1 in Table 5) reveals that the low probability of punishment in the regulated treatment is likely to lead to less resource depleted compared to the self-governance treatment ($p<.05$). The high probability of punishment is, however, likely to lead to more resource depletion compared to the low probability of punishment treatment (p-value<.01). We also find that the more monitoring in the quota system, the less likely it is that the fish stock will be depleted (p-value<.05). Further, the more fishers understand the resource dynamics, the less likely it is that fish stock will be depleted (p-value<.01).

Table 5. Determinants on resource depletion

Independent variables	Model 1: Self-governance and regulated quota on resource depletion		Model 2: high and low probability of punishment on resource depletion	
	dy/dx (Std. Err.)	p-value	dy/dx (Std. Err.)	p-value
Dependent variable: Resource depletion (1 = Yes and 0 = No)				
Regulated quota treatment with a high prob. of punishment (Yes = 1 and No = 0)	.2363 (0.1632)	.148	.3212** (.1016)	.002
Regulated quota treatment with a low prob. of punishment (Yes = 1 and No = 0)	-.1897* (.0766)	.013	-	-
No. of monitoring when the catches exceeded the quota	-.0712* (.0277)	.010	-.0447* (0.0208)	.031
Understanding of resource regeneration rates (Yes = 1 and No = 0)	-.6248** (0.1243)	.000	-.7173** (.1196)	.000
Prob > chi2	.0001		.0000	
AIC	117.1471		58.7474	
BIC	131.6734		68.70195	
N (groups)	135		89	

Note: 1. * and ** indicate significance at 5%, and 1% levels, respectively.

2. Clustered standard errors at the group level are in parentheses

Result 3. *The result shows that participants in the high probability of punishment are more likely to deplete the resource stock compared to participants in the low probability of punishment. Monitoring and understanding of resource generation also influence the number of depletions.*

5. Conclusion and discussion

This study aims to evaluate the role of the regulated quota systems as a policy to avoid resource depletion. We applied a controlled behavioral experiment with 540 artisanal fishers in Nakorn Si Thammarat province, which reported the second-highest number of artisan fishers in Thailand in 2015. The main results from the experiments reveal that the quota treatments provide higher overall efficiency and more sustainable resource management which is consistent with the lab results by Lindahl et al (2016). An explanation for why we find this result (and cannot confirm studies showing no difference in performance between regulated and unregulated or self-governance systems) could be because the community empowerment in these communities is not strong enough to make fishers cooperate effectively. This reason is consistent with information from the focus group discussions revealing that most fishers disagreed with the community quota allocation being a good solution because they thought it was impossible that fishers could come to an agreement on a self-regulated quota allocation. In contrast with Cardenas (2004) and Abatayo and Lynham (2016) who found that resource extraction behavior does not significantly differ when rules are endogenously created versus exogenously imposed. It seems participants in their study were able to induce cooperative behavior with fair allocation, however, participants in our study stated they would find it difficult to build trust, especially if there are conflicts in their real life. Our results, however, show that fishers are likely to cooperate if they view an externally imposed regulation in the form of a quota to be an efficient resource allocation mechanism (Agrawal, 2001). In addition, we found no significant difference in over-exploitation between the two regulated quota treatments, implied that participants in our study were not sensitive to the change of the probability of punishment. It could be because of difficulties in evaluating the difference in expected outcomes of the different expected values of punishment (Bahník and Vranka, 2022).

Furthermore, our results also show that the high probability of punishment in the regulated quota treatment is associated with more equal sharing of payoffs from the experiment compared to the low probability of punishment treatment. When participants know there was a high chance of being punished for over-exploitation, they are more likely to follow fair rules or norms. The cost of being caught outweighs the potential short-term gain from being selfish. This result suggests that the quota system will promote income equality if the patrol system is sufficiency effective. In addition, this study finds that the high probability of punishment in the quota treatment had more depletion compared to the low probability of punishment treatment. It is possible that the higher probability of punishment may lead to a consensus that responsibility of resource management should be left to the external authority. Participants may then shift the focus from the benefits of voluntarily cooperation to noncompliance with a regulation. A higher chance of punishment may trigger non-compliances being more present bias. Non-compliances may think they are going to be punished anyway soon, they then shift toward more immediate gains and make resources deplete faster.

Moreover, to prevent jeopardizing future resource stocks, the study shows that the more monitoring in the quota system (and hence a higher likelihood of getting caught for those who violate the quota regulation), the less likely it is that the fish stock will be depleted. It is implied that the quota system without an effective monitoring system may not guarantee that the fish stock will not be jeopardized in the future. Furthermore, educating fishers to understand how the fish stock regenerates depending on the current stock of fish will help to avoid resource depletion. If fishers do not understand regeneration, they may prioritize short-term catches by assuming that fish stocks are infinite or will recover quickly. With this knowledge, however, participants better grasp future consequences and are more likely to delay gratification in favor of long-term results. This result is consistent with a suggestion provided by Baland and Platteau (1996) that when rules are understood by members of the user groups or the benefit flows in predictable, it would help to sustain common resources uses.

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