Evaluating the role of co-management in improving governance of marine protected areas: an experimental approach in the Colombian Caribbean

Jorge H. Maldonado (jmaldona@uniandes.edu.co)
Rocio del Pilar Moreno-Sanchez (romoreno@uniandes.edu.co)

CEDE – Universidad de los Andes
Carrera 1E 18A-10 Bloque A Of. 311
Bogotá - Colombia

Selected Paper prepared for presentation at the 13th IASC international Conference, Hyderabad, India, January 10-14, 2011

Evaluating the role of co-management in improving governance of marine protected areas: an experimental approach in the Colombian Caribbean[1]

J.H. MALDONADO[2], R. P. MORENO-SANCHEZ[3]

ABSTRACT

Complexities associated with the management of common pool resources (CPR) threaten governance at some marine protected areas (MPA). In this paper, using economic experimental games (EEG), we investigate the effects of internal communication, external regulation and the interaction between internal regulation and non-coercive authority intervention—what we call co-management—on fishermen's extraction decisions. We perform EEG with fishermen inhabiting the influence zone of an MPA in the Colombian Caribbean. The results show that co-management exhibits the best results, both in terms of resource sustainability and reduction in extraction, highlighting the importance of strategies that recognize communities as key actors in the decision-making process for the sustainable use and conservation of CPR in protected areas.

Key words: Common-pool resources, governance, co-management, experimental economic games, fisheries, Latin America.

---

[1] Previous versions of this paper have been published. First, it was published at the working paper series from the Department of Economics, Universidad de los Andes (Documentos CEDE 2009-15). Recently, a new version has appeared in Ecological Economics (Ecol Econ 69 (2010): 2557-2567). This manuscript includes the results from the latter version.

[2] Center of Economic Development Studies (CEDE), Department of Economics, Universidad de los Andes. jmaldona@uniandes.edu.co

[3] Center of Economic Development Studies (CEDE), Department of Economics, Universidad de los Andes. romoreno@uniandes.edu.co

1 INTRODUCTION

Marine protected areas (MPA) worldwide are intended to conserve—and in some cases provide for sustainable use—the resources and biodiversity they host. In developing countries, however, MPA are exposed to pressures generated by human activities, the most important of these being tourism and fishing. The conflict between conservation goals in MPAs and fishermen's private interests is typical of common-pool resources, characterized by both non-excludability and rivalry (Feeny *et al.*, 1990; Ostrom, 1990). At fisheries individual fishermen only assume the private costs of their actions, ignoring the social costs, and collectively engaging in the over exploitation of a resource they perceive as "free" (Gordon, 1954; Hardin, 1968). Hardin (1968), suggested that the self-centered and shortsighted behavior of these leads to the overuse and rapid depletion of fisheries' resources, in what he calls "the tragedy of the commons."

Hardin (1968) proposed two general solutions for avoiding "this tragedy": (i) establishing private property rights; and (ii) establishing state property rights, whereby access and use are clearly instituted and regulated. That is the case of the National Natural Park "Corales del Rosario y San Bernardo" (NNP-CRSB), located in the Colombian Caribbean Sea.

This park is considered to be of great strategic importance, as it conserves the most developed fringe of the coral reef of the Continental Colombian marine platform (UAESPNN, 2006). One of the most visible sources of pressure on this protected area's resources is its exploitation by native communities. Similar to other protected marine areas around the world, the creation of a national park with laws and regulations controlling access and use has not been sufficient to protect it from exploitation. In the NNP-CRSB, many species are endangered and some of them have even apparently disappeared locally. In response to this reduction in resources, fishermen have increased their efforts, not only by fishing for longer periods and at greater distances from port, but also, in some cases, by violating regulations—using inappropriate fishing techniques, extracting fish smaller than the minimum size allowed, and even extracting prohibited species. This has resulted in conflict between local communities and park authorities, mining MPA governance and making *de jure* state property seem more *de facto* open access (Camargo *et al.*, 2009).

Given the problems of assigning property rights and the often weak enforcement of fishery regulations, there has been a shift towards the decentralization of the management of fisheries, especially in developing countries. In the case of decentralization, the communities themselves are responsible for defining the regulatory framework, both with respect to what is and is not allowed, and in determining the appropriate punishment if the regulations are not obeyed (Ostrom, 1990). This suggests that, to some extent, fishermen exhibit others-regarding preferences (e.g., Bolton and Ockenfels, 2000; Dufwenberg and Kirchsteiger, 2004; Fehr and Schmidt, 1999).

Experimental evidence has also shown that individuals do not always behave purely out of self-interest, and that they often make decisions that balance their own and collective interests (Davis and Holt, 1993; Kagel and Roth, 1995). Many field and lab experiments support the argument that the behavior of an individual might be determined by—in addition to the possibility of pure material gain—a consideration of others-regarding preferences (Cárdenas, 2004); among these, such elements as altruism, fairness, reciprocity and reputation could play a relevant role (Castillo and Saysel, 2005; Fehr and Gachter, 2000, Fehr and Schmidt, 1999).

The success and sustainability of internal norms strongly depends on many factors; among these are the institutional environment, the social cohesion of the relevant communities, the size of the groups involved, and the degree of interaction these communities have with the market. Some authors argue that it is doubtful that a pure self-governing institution is a realistic option for a case as complex and diverse as fisheries in a modern industrial society, inasmuch as market pressures and the reality of integration with surrounding societies may effectively undermine collective management (Rova, 2004). An intermediate solution would be to combine state regulation and user self-management —what is known as co-management—as suggested by Feeny *et al.* (1990). Co-management has been seen as an alternative that would improve both the effectiveness and equitability of fishery management as well as compliance with agreed upon rules (Jentoft, 1989; McCay, 1996).

Although many economic experimental games aimed at analyzing the behavior of individuals in response to daily-life problems have been carried out in the field (Cárdenas *et al*. 2000; Cárdenas *et al*. 2002; Cárdenas, 2003; Cárdenas, 2004; Vélez *et al*., 2010), few have tested combinations of institutions in which cooperation and external intervention play simultaneous roles.

In this study, we apply a framed field economic experiment—i.e., a laboratory experiment using real framing (fishing decisions) and real decision-makers (fishermen) (Harrison and List, 2004). In the experiment, we compare four different fishery management approaches using a common pool resource model: (i) open access; (ii) external regulation with random monitoring and monetary punishment; (iii) internal communication; and (iv) co-management. These management strategies are compared using a between subject design, across real fishermen inhabiting the national park's influence zone. Within the context of the conflict between park authorities and local communities, and given the deterioration of the marine resources in the NNP-CRSB, the objective of this paper is to investigate the effect of introducing a co-management strategy on fishing decisions, relative to open access or external regulation strategies. Additionally, we investigate whether behavior differs depending on actual place of residency—that is, whether fishermen living in communities located within the park behave differently than those living in communities located outside of it.

Based on the motivations discussed above, the contribution of this paper is to analyze the complementarities between repeated communication and non-coercive government intervention —what we call co-management—in reducing extraction for two possible levels of stock. In particular, the non-coercive government strategy we test here requires the participation of officials from the NNP-CRSB, individuals who work with communities on environmental education issues. The involvement of a real official from the NNP-CRSB as an additional participant in the experimental game, one which depends on an environmental education strategy—as opposed to relying on such coercive strategies as penalties—constitutes an innovative approach for field experimental games analyzing CPR dilemmas.

The findings are analyzed using parametric and non-parametric tests; they show that the co-management rule is the best strategy in terms of both reducing extraction and in sustaining the resource. The parametric analysis also shows that extraction decisions depend on socioeconomic characteristics such as per capita income and the main income-generating activity; and the condition of the stock (at present and previous periods), among others. Complementing these findings, this study shows that co-management rule might be an effective strategy not only for individuals located inside national parks but also those located outside of them.

The paper is organized as follows: following the provision of background, we present our theoretical model. From this, we arrive in the third section at our experimental design and game procedures. In the fourth part of the paper, we present our main findings. We present our conclusions in the fifth section.

2 THE COMMON POOL RESOURCE EXPERIMENT

2.1 A dynamic common pool resource game

The experiment is a framed field experiment, which in our case means that we represent an actual fishing problem with real resource users. The common pool resource (CPR) for a fishery is described by the difficulties in excluding people from fishing where open access exists, yet where at the same time, only one person can consume a specific unit of the given resource. Essentially, the key characteristic of the common resource problem is that, if acting alone, an individual has an incentive to appropriate more of the resource than if coordinating with others regarding how much of the resource should be appropriated—i.e., the Nash solution and the social optimal solution differ. The model presented below is based on the one proposed by Cárdenas (2004). We extend this model by introducing certain dynamic effects by letting the catch rate for fish in one period determine the stock of fish in the following period. The benefits (and costs) that a fisherman receives from catching fish can be divided into two categories: (i) a private benefit, function $f(x_i, S)$; and (ii) the benefits from (or costs of) the catching decisions of all relevant fishermen such as affects the resource's availability for others, function $g(.)$.[4] The features of non-exclusion and rivalry when fishermen decide to fish are given by the following pay-off function for fisherman i in period t:

$$\pi_{i,t} = f(x_{i,t}, S_t) + g(\sum_i x_{i,t}) = \alpha x_{i,t} - \frac{\beta x_{i,t}^2}{2S_t} + \gamma \sum_{i=1}^{n} (e - x_{i,t}) , \qquad (1)$$

where $\alpha > 0, \beta \geq 0, S > 0, \gamma \geq 0$. The first two terms of equation (1) —private benefits— shows individual revenues depending on parameter α (e.g., the price of the fish), the individual catch rate (x_{it}), and the individual cost of extraction based on the catch rate,

[4] It is assumed that $f_x \geq 0, f_{xx} \leq 0, f_S \geq 0, f_{SS} \leq 0, g_x \leq 0, g_{xx} \geq 0$.

the stock, and a technical parameter associated with the cost, β. The last expression shows the effect of the joint catch rate on individual benefits. Parameter e represents the maximum amount that each fisherman can catch, which is assumed to be equal for all fishermen and that, aggregated as n fishermen—ne—reflects the maximum amount of fish that it is possible to catch, given the fishermen's technical capacity. In this way, the expression $\sum_{i=1}^{n}(e-x_{i,t})$ shows the availability of the resource after extraction by n fishermen, while parameter γ represents the extent of individual benefits affected by the common-pool resource availability.

We introduce the inter-temporal effects of the catch rate by letting the stock of fish change according to the following evolution equation:

$$S_{t+1} = S_t - \sum_{i=1}^{n} x_{i,t} + F(S_t) = S_t - \sum_{i=1}^{n} x_{i,t} + \theta S_t (1 - \frac{S_t}{K}) \quad . \qquad (2)$$

The evolution equation shows that in period $t+1$, the resource will equal the stock at the beginning of period t, minus the extraction of all fishermen during that period plus the net growth function, $F(S_t)$, which depends on the parameters θ and K.[5]

Given these functional forms, the Nash equilibrium for this model is obtained using the maximization of each fisherman's net present value of benefits subject to the evolution equation:

$$\max_{x_{i,t}} \sum_{t=0}^{T} \delta^t \pi_{i,t} = \sum_{t=0}^{T} \delta^t \left\{ \alpha x_{i,t} - \frac{\beta x_{i,t}^2}{2S_t} + \gamma n e - \gamma \sum_{i=1}^{n} x_{i,t} \right\}$$
$$s.t. \quad S_{t+1} = S_t - \sum_{i=1}^{n} x_{i,t} + \theta S_t (1 - \frac{S_t}{K}) \quad , \qquad (3)$$

where δ represents the discount factor $(\delta=1/(1+r))$, and r is the relevant discount rate.

Considering the first order conditions for this problem and abstracting from those related to state and co-state variables, the maximization condition with respect to the decision variable implies that

$$x^{p}{}_{i,t} = \frac{S_t}{\beta}(\alpha - \gamma - \delta \lambda_{t+1}) \quad . \qquad (4)$$

This expression represents the game's Nash equilibrium, and shows that the optimum private catch rate depends positively on the stock and parameter α, and negatively on the costs of catching fish (β), the impact on aggregated benefits (γ), and the discounted inter-temporal price of the stock of the resource ($\delta\lambda_{t+1}$), which is the user cost. In a static framework, fishermen would not consider the latter term.

[5] We can assume that the growth function is a logistic function, one where parameter θ represents the implicit growth rate and parameter K the carrying capacity of the resource.

In order to obtain the catch rate that maximizes the social welfare, a central planner would aggregate the benefits of all fishermen *n*:

$$\max_{x_{i,t}} \sum_{i=1}^{n} \sum_{t=0}^{T} \delta^t \pi_{i,t} = \sum_{i=1}^{n} \sum_{t=0}^{T} \delta^t \left\{ \alpha x_{i,t} - \frac{\beta x_{i,t}^2}{2S_t} + \gamma n e - \gamma \sum_{i=1}^{n} x_{i,t} \right\}$$

$$s.t. \quad S_{t+1} = S_t - \sum_{i=1}^{n} x_{i,t} + \theta S_t (1 - \frac{S_t}{K}) \quad . \qquad (5)$$

The first order condition with respect to the catch rate then implies that

$$x^{soc}{}_{i,t} = \frac{S_t}{\beta}(\alpha - n\gamma - \delta\lambda_{t+1}) \quad . \qquad (6)$$

Expression (6) shows that when analyzing the social welfare, the optimal catch rate must be lower than that indicated in expression (4), as the proportion of the available stock of fish affecting benefits (γ) needs to be aggregated for *n* fishermen in order to capture the full cost of the catch rate decisions.

3 EXPERIMENTAL DESIGN AND PROCEDURES

At every location, a group of 25 to 30 people was gathered and organized into subgroups of five persons each. Each five-person group represented the collective decision-making entity with respect to the experiment; each member made individual, private and confidential decisions that were treated anonymously. The experiment was performed in two stages, both of which were divided into ten rounds. During the first stage of the experiment, all of the groups played a CPR game without any regulations (open access). During the second stage—i.e., the last ten periods—the groups were randomly allocated one of three possible treatments: (i) open access or baseline, (ii) external regulation, or (iii) co-management.

Expressions (4) and (6) are used to construct the pay-off tables that participants used during the game. Following the CPR experiments conducted by Cárdenas (2004), we determined that each participant should be able to extract any integer amount between 1 and 8.[6] To create the pay-off matrix utilized in the experiment, we set the parameters as $\alpha = 100; \beta = 800;$ and $\gamma = 20$. In order to make the game cognitively easier and understandable for the subjects, we decided to only simulate two levels of stock—a high level (abundant) and a low level (scarce). More specifically, we set the former at 80 units and the latter at 40 units. Based on this, we constructed two payoff tables, one for each stock level. The pay-off tables show the net benefits for individual *i* of different combinations of individual and aggregated extractions (see Appendix A). If a player does not take into account the inter-temporal effects of his or her decisions, the model predicts that the term $\delta\lambda$ converges to zero. Expression (4) then reduces to

---

[6] Cárdenas (2004) argues that it is convenient to eliminate the zero extraction option when conducting experiments so as to avoid conflicts that arise due to villagers' strong aversion to prohibitions against using resources altogether.

$$x^{p}{}_{i,t} = \frac{S_t}{\beta}(\alpha - \gamma) \qquad (7)$$

Expression (7) is equivalent to a myopic Nash equilibrium, which we used as a benchmark in the experiment. To obtain Nash equilibriums, we used the parameters and two levels of stock mentioned above; this yields a Nash equilibrium equal to 8 units (40 units per group) for the high stock level and 4 units (20 units per group) for the low stock level. Given that *x* ranges between 1 and 8 and that the benefit function is quadratic for the level of extraction and non-linear for the level of stock, the predicted Nash equilibrium for abundance (high stock) is a corner solution, while that for scarcity is an interior solution. On the other hand, the social equilibrium corresponds to a level of extraction of 1 unit (5 units per group) for either stock level.

In the case of external regulation, the Nash equilibrium corresponds to an individual extraction of six units for high stock and three units for low stock.

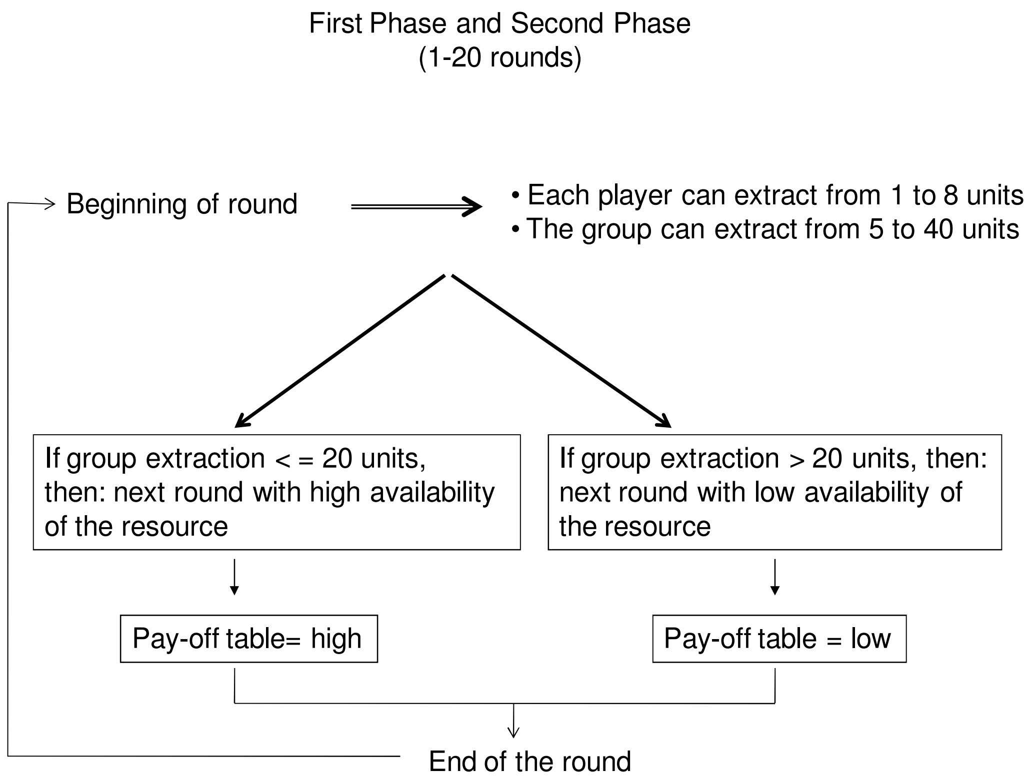
The dynamic part of the game was designed as follows: if the aggregated extraction of the group's five members exceeds 20 units, the stock of the resource for the next round becomes low; the low availability of the resource in next round is caused by over-extraction during the current round. Under a low-stock scenario, every unit of extraction earned fewer points than under a high-stock scenario, inasmuch as the low availability of the resource implies more effort per unit of fish caught—which translates into fewer benefits. Conversely, if extraction by the whole group is less than or equal to 20 units, during the next round the stock of the resource becomes abundant (i.e., there is high availability). High stock requires less effort per unit of fish caught, and thus translates into higher returns. Figure 1 shows the dynamic component of the experiment.

During the first ten periods, there was open access fishing for every group. During the last ten periods, conversely, each group was randomly exposed to one of the following treatments.

- *Treatment 1: Open access*. This treatment was assigned to the control group; the same conditions prevailed as during the first stage.
- *Treatment 2: External regulation with fine***.** The objective of this treatment was to induce subjects to extract only one unit of the resource, using an imposed fine as an external regulator. In order to simulate imperfect enforcement, the monitoring decision was random and every player had a one-tenth probability of being monitored per round. Operatively, imperfect monitoring was carried out using 10 balls in a bag—five white and five red, with each red one being numbered. Each player was assigned a corresponding number. For each fishing round, a ball was taken from the bag—if it was white, no monitoring occurred; if it was red, the player whose number corresponded to that on the ball was inspected. If the individual inspected had violated the rule (to extract one unit), he or she had to pay a fine equivalent to 200 points per each unit extracted above what was allowed; this was deducted from the gains made during that round. The ball was then returned to the bag; in this way, each player had the possibility of being monitored more than once. All of the other rules were the same as in the baseline, and decisions, as well as fines, were kept private and confidential. No communication was permitted between players.

- *Treatment 3: Internal communication*. Under this treatment, before starting the second stage the group had the opportunity of communicating among members. They had five minutes to discuss, and even to plan, a strategy for playing the rest of the game. The group members then made their final decisions in private and under strict confidentiality for the first round of the second stage. For each successive round, the group was given one minute to talk between rounds.
- *Treatment 4: Co-management, with internal communication and external non-coercive intervention.* Under this treatment, before starting the second stage, the group had the opportunity to talk for up to five minutes with a national park ranger, who was introduced to the game as an "advisor." The ranger had to base his or her conversation on a pre-designed script, effectively expressing his or her ideas about conserving park resources and trying to persuade each group member to extract only one unit of the resource. After that, the group had five minutes to discuss the ranger's recommendations between themselves. Any interventions by the park officer were recorded. The group members then made their final decisions—in private and under strict confidentiality—for the first period of the second stage; the total amount extracted was then announced. For each successive round, the park representative was given one minute to talk with the group, following which, group members had one minute to discuss.

Figure 1. The dynamic component of experiment.



The anonymity and confidentiality of individual decisions were guaranteed by seating players back-to-back as well as by the presence of a researcher who monitored and supervised each group and collected the individual extraction levels written down by the fishermen. With the support of an environmental educator—an expert in working with communities—the game was explained to each group of fishermen. To facilitate this–inasmuch as the participants all tended to come from low-educated communities—different visual aids were used, such as drawings and posters. In addition, following explanation, three training rounds were carried out in order to ensure that the participants fully understood the game before starting it.

Every participant in the experiment obtained points, convertible into money; the average final payment was thus equivalent to the income they would have obtained during a typical working-day. At the current rate, this payment is equivalent to 10 dollars per player. Payments were confidential.

Following completion of the experiment, the participants filled out surveys. The main results of the game were then presented and discussed openly with the subjects and park officers.

4 THE RESULTS

The experiment was carried out in eight northern Colombian fishing communities, and was inclusive of 235 subjects. Three of the communities are located within the borders of the NNP-CRSB; the other five are located outside of them, yet extract resources from the park area. In addition to testing the effects of the co-management treatment, we were interested in learning whether communities located inside and outside the park borders responded differently to the different management strategies.

Within the communities located inside the park, players averaged 31 years of age; 13 percent were women and the per capita income was equivalent to around 68 dollars. Outside the park, the average age of players was close to 39; only 3 percent of players were women and per capita income was lower than that of players residing inside the park, with an average of 52 dollars. Most of the participants reported fishing as their main activity (66 percent for those inside the park, and 82 percent for those outside of it). The distribution of players for each zone based on the treatment they were subjected to is presented in Table 1.

Table 1. The number of players residing inside and outside the park based on the treatment they were subjected to.

	Outside of the park	Inside of the park	Total players
Baseline	25	20	45
External reg.	45	25	70
Communication	15	25	40
Co-management	45	35	80
Total	130	105	235

Results are derived for two central variables: first, sustainability of the resource use, measured as percentage of rounds in which the groups reached a high stock level, and second, extraction decisions.

4.1 Sustainability of the resource use

Recalling that the stock level in the game reflects the inter-temporal effects of decisions, we measure the sustainability in the use of the resource as the proportion of periods that a group achieves a high stock during a stage of the game. The measurement ranges from 0 to 100 percent; the closer the number to 100, the higher the level of sustainability. The results, presented in Table 2, show that while during the first stage (periods 1-10), on average, the stock exhibited abundance 39 percent of the rounds. During the second stage (rounds 11-20) players that continued having open access maintained high stock availability for 42 percent of the time. For them, the difference between Stages 1 and 2 is not statistically significant.[7] Under the treatment featuring external regulation, high stock was achieved 67 percent of the rounds during the second stage. This is significantly higher than what was achieved under the baseline. Under the communication treatment, groups reached high stock of the resource 80 percent of the rounds, 25 percent more than under the baseline. Finally, under the treatment featuring co-management, abundance was achieved 89 percent of the time; this is about 50 percent above what was achieved under the baseline, the greatest increase in abundance compared with the other rules.

Table 2. The effect of management strategies on the percentage of periods under abundance.

Stage	Treatment			
	Baseline	External regulation	Communication	Co-management
Stage 1	39%	32%	55%	40%
Stage 2	42%	67%	80%	89%
Difference	3% ns	35%***	25%***	49%***
MWS	1.02 ns	13.09***	7.54***	20.35***

Asterisks denote statistical significance in differences between stages.
*** significant at 1% ** significant at 5% * significant at 10% ns non-significant

[7] Given that there is no *a priori* information by which we can assume any particular distribution, we performed two parametric tests: 1) a t-test on the difference in means, and 2) a non-parametric test, a Mann-Whitney statistic, MWS (Wilcoxon test), performed to evaluate the hypothesis that two independent samples are from populations with the same distribution. In all cases, statistical significance of the two tests coincided with each other.

In Table 3, we present the results for resource sustainability during the second stage, comparing performance by location, i.e. inside versus outside the park. The difference in the proportion of periods with high stock levels is significant across locations for the open-access treatment and external-regulation treatment; there is no significant difference for the co-management treatment. If the proportion of periods showing high availability reflects the sustainability of the use of the resource, the external regulation and communication treatments applied to those players living outside the park proved to be relatively less effective as a tool for encouraging sustainable use of the resource; this reflects the reluctance of those communities located outside the park to comply with external and coercive rules. The results also show that the impacts associated with co-management are consistently better for communities located both inside and outside the park.

Table 3. The percentage of periods in the second stage during which stock was highly available according to location and treatment.

Location	Treatment			
	Baseline	External regulation	Communication	Co-management
Outside of the park	32%	60%	63%	89%
Inside of the park	55%	80%	90%	89%
Difference	23%***	20%***	27%***	0% ns
MWS	4.90***	5.39***	6.45***	0.141 ns

Asterisks denote statistical significance in differences between stages.
*** significant at 1% ** significant at 5% * significant at 10% ns non-significant

4.2 Extraction decisions

According to the design of the experiment, the expected theoretical extraction level under the non-cooperative setting is eight units for high stock and four units for low stock; the social optimum is one unit. Nonetheless, when players were exposed to the game under the baseline treatment (i.e., during the first stage), the total average extraction was 4.6 units, which apparently seems to constitute a moderate extraction, given the range of plausible extractions (1-8). What is relevant for our analysis, however, is the extraction averages under each stock level. For high stock, the average extraction was 5.49 units, which is almost three units below the expected Nash equilibrium for that level of stock. This finding, which assumes open access, confirms the previous findings from the field experiment literature, where individuals deviated from self-centered and individualistic behavior when making individual decisions that seemed to incorporate collective interests, even where no institutions were present. However, for low stock and open access, the average extraction was 4.31 units, almost one third of unit above the expected equilibrium, which constitutes a privately inefficient response from players. Recall that although the private equilibrium for low stock is four units, individuals might still extract up to eight units. This result is analyzed with detail in Maldonado & Moreno (2009). Cárdenas et al. (2004) find a similar response in the field experiments they carried out in Colombia, likewise using interior solutions like the one we used here for low stock.

The most interesting part of the analysis concerns what happens during the second stage (periods 11-20), when the treatments are applied to the game. As shown in Figure 2, extraction reduced when treatments were incorporated. Both external regulation and communication reduced extraction to, on average, 3.7 and 3.4 units, respectively. These differences, compared with Stage 1, are statistically significant. Extraction of groups subjected to the co-management treatment, in turn, was reduced to an average of 2.4 units; thus, co-management treatment was the most effective rule in reducing extraction.

Figure 2. Path of average extraction decisions along the 20 rounds for the different treatments

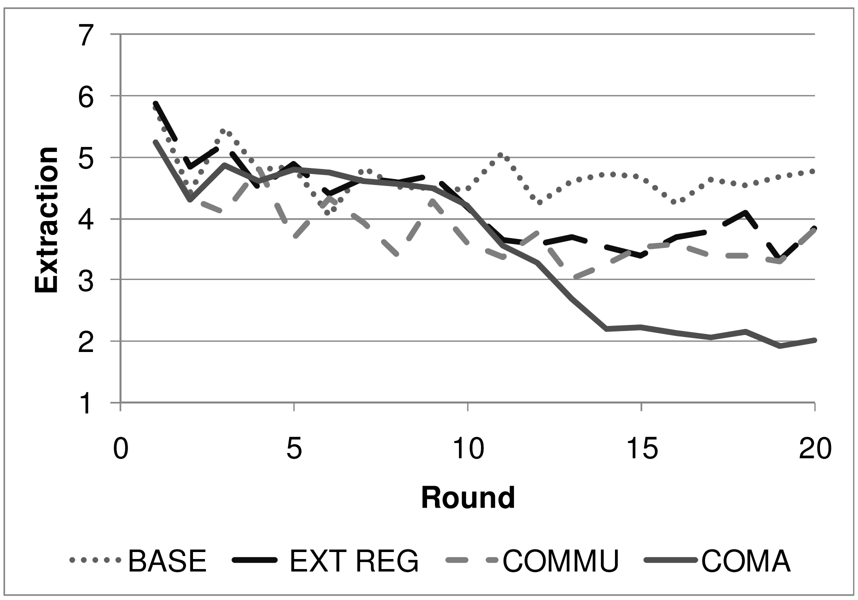


Table 4 shows the results on extraction levels, considering the two possible resource levels. In the cases of external regulation and communication it was observed that during the second stage individuals extracted about one unit less, for both high and low stock, than they did during the first stage; this constituted a significant difference. When the co-management treatment is applied, individuals reduced extraction, compared with an open access scenario, by 2.46 units under abundance and 1.49 units under scarcity (Table 4); those reductions are highly significant, and greater than those associated with either external regulation or communication. These findings confirm the main hypothesis of this paper: the co-management rule reduces extraction in both stock resource levels more than any other management rule tested.

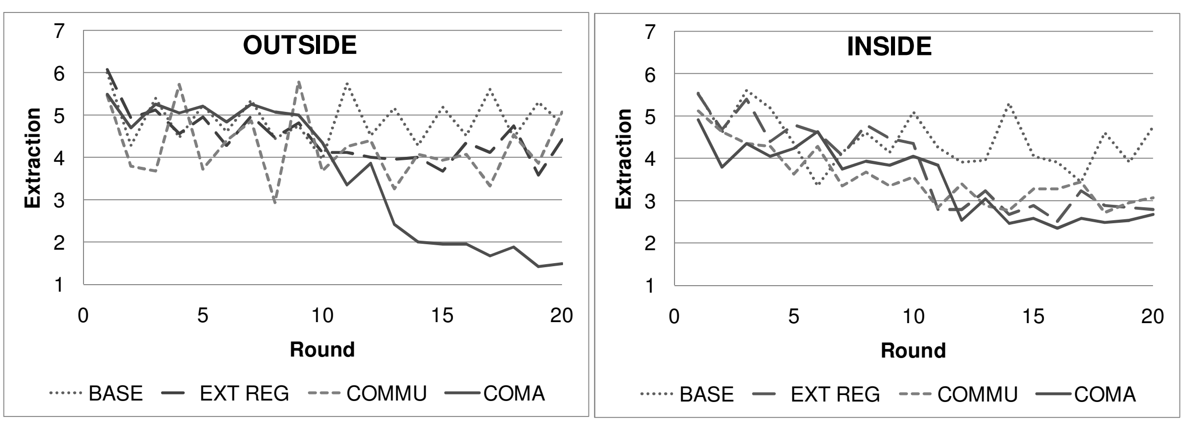
Table 4. The effect of management strategies on extraction decisions for both high and low resource-stock levels.

Stage	Baseline		External regulation		Communication		Co-management	
	High	Low	High	Low	High	Low	High	Low
Stage 1	5.49	4.31	5.51	4.48	4.41	3.87	4.81	4.54
Stage 2	5.15	4.24	3.59	3.80	3.53	3.13	2.35	3.04
Diff	0.33 ns	0.07 ns	1.93***	0.65***	0.89***	0.75***	2.46***	1.49***
MWS	1.35 ns	0.34 ns	9.73***	3.80***	4.90***	2.27**	15.73***	5.37***

Asterisks denote statistical significance in differences between stages.
*** significant at 1% ** significant at 5% * significant at 10% ns non-significant

Another issue to be addressed from this study is the effect of community location on extraction decisions. Figure 3 shows some differences in the way rules are adopted by communities inside or outside the MPA. Communication and external regulation seem to be more effective rules for those communities located inside rather than outside the park boundaries. In turn, co-management rule exhibits the greatest reduction in both cases, with a more significant reduction in communities outside the park.

Figure 3. Path of average extraction decisions along the 20 rounds for the different treatments separated by location



When considering stock levels, results show that players living in communities located outside the park extracted more on average than those located inside the park, for both stock conditions. However, Table 5 confirms that these extraction decisions varied among treatments. Under open access, communication and external regulation treatments, extraction averages for communities located inside the park tended to be significantly lower than those for communities located outside it. The effect was different, however, under the co-management treatment: here, on average, players residing outside the park decided to extract less than players residing inside it when the stock was abundant. When the stock was scarce, the difference between inside and outside communities was not significant. This observation suggests an interesting policy implication: while external regulation or communication did not have a strong effect on the decisions made by fishermen living outside the park, compared with the effect on those living inside it, co-management did induce outside players to reduce their extraction to the lowest observed extraction averages. This could imply that when outside fishermen are recognized by authorities and when education, training and participation are used as tools for encouraging reduction in extraction patterns, they are open to legitimizing external interventions and complying with rules aimed at the sustainable use of resources.

Table 5. Average extraction decisions for each treatment according to location with respect to the park during Stage 2 for both high and low resource stocks

Treatment	Stock level	Location		Difference	MWS
		Outside	Inside		
Baseline	Low	4.41	3.93	0.47 *	1.77 *
	High	6.15	4.43	1.72***	5.30***
	Total	4.96	4.21	0.76***	3.59***
External regulation	Low	3.98	3.12	0.86 **	2.46 **
	High	4.18	2.81	1.37***	6.49***
	Total	4.1	2.87	1.23***	7.03***
Communication	Low	3.38	2.56	0.82**	1.98**
	High	4.48	3.12	1.36***	4.90***
	Total	4.08	3.06	1.02***	4.69***
Co-management	Low	3.2	2.85	0.35 ns	0.36 ns
	High	2.08	2.69	-0.61***	-5.82***
	Total	2.2	2.71	-0.51***	-5.30***

Asterisks denote statistical significance in differences between locations.
*** significant at 1% ** significant at 5% * significant at 10% ns non-significant

The explanation for extraction behavior under co-management treatment at both locations could be that the design of this rule allowed individuals to make better informed and self-governing decisions, legitimating a norm suggested through non-coercive intervention (participants can take or leave the ranger's suggestion).

4.3 Parametric analysis

Previous results provide some evidence that rules such as external regulation, communication and co-management are able to modify extraction behavior; co-management seems the most effective in terms of reducing extraction and inducing sustainability in the management of the resource. The results also suggest that participants living in communities located outside of the park may have different incentives than those living in communities located inside of it. Consequently, their decisions may also be different. These results, however, do not consider the effects of certain variables, such as socioeconomic conditions and multivariate relations. A parametric analysis is therefore proposed in order to validate these results.

In our econometric model, the dependent variable is the level of extraction, and the statistical unit of analysis is the individual observation of the level of extraction for each round. Given that there are several observations associated with each particular player (10 rounds), the data are treated as a panel, wherein the correlated error with respect to the observations for each participant is considered apart from the error associated with between-player differences. As the dependent variable takes discrete values for integers one through eight, the model specification shall consider this characteristic. When using OLS, the specification of the model can fail to predict the extraction properly since OLS allows negative and continuous values. For that reason, a Poisson specification would be a more appropriate model for the available data. The main drawback associated with the Poisson model is the implicit assumption that the mean and the variance are the same. When analyzing the variable, we found a mean value of 3.39 and a variance of 4.99, which suggests that over-dispersion may not be a strong problem. Alternatively, the same models were estimated using OLS. Predictions from OLS never take negative values for extraction, making the OLS specification adequate for our purposes. We report both Poisson and OLS estimations. Poisson coefficients should read as semi-elasticities, while OLS coefficients can be read directly as marginal effects.

We use several categories of independent variables:

a. *Treatment variables*. The main hypothesis of this study questions whether different rules have different impacts on individual decisions. To test this, we introduce two categorical variables: **communication**, and **external regulation**, which take a value of one if the player was exposed to each treatment, and zero otherwise. Given that co-management treatment implies the participation of a park ranger, and that we had three different rangers helping with the experiments, interaction variables are created for controlling for the ranger and the exposure to this rule; in that way, we created three additional variables to test this treatment and the ranger involved.

b. *Dynamic variables*. Two other variables relevant to analyzing behavior in the game are the **current-round stock level** and the **previous-round stock level**; both categorical variables take a value of one if during the round in question the stock was high, and zero otherwise. A variable capturing a time **trend** along the rounds was also included to capture dynamic effects during the game.
c. *Socioeconomic and demographic variables*. The characteristics of individual players may exert influence on their final decisions. During the analysis of data, variables related to gender, age, education level and income were tested. However, all but the latter exhibited non-significance, and therefore they were not included in the final model. The only variable kept in the final model is **per capita income**, calculated by dividing the household income by its size. Finally, in order to capture differences between participants inside and outside the MPA, there is a categorical variable, **location**, which takes a value of one if the player lives inside the park, and zero otherwise.
d. *Perception variables*. In the survey applied to game participants, questions about perception were included; some of them were used as controls in the model. From several variables tested, one variable that turned out to be important and thus was included in the model is **usefulness of participation**, represented by a categorical variable taking a value of one if the respondent agreed to the question: *Do you think that participating in meetings about the management of the park is useful for solving natural resource-related conflicts*?

The results for the model are presented in Table 6 for both Poisson and OLS panel models. Our main hypothesis, that treatments are effective in reducing the level of extraction, is confirmed: communication, regulation and co-management did reduce significantly extraction levels. Judging from the results, co-management represented a more effective approach than external regulation and communication did, as the value of coefficients associated to co-management double those from the other treatments.

Having different rangers participating in co-management rule affected group performance in a significant way: individuals with ranger C reduced extractions on average more than those with ranger B, and both did so less than those with ranger A. These results imply that officers might have different abilities and use different strategies in dealing with communities, and these distinctions may result in significant differences in players' decisions. In fact, results are so different for the various rangers that we decided to further investigate their characteristics in an attempt to clarify our findings.

Table 6. Results from Poisson and OLS specifications (with random effects) for the general model

Variables	Poisson panel model			OLS Panel model		
	Coef.	Std. Err.		Coef.	Std. Err.	
External regulation (1 yes 0 no)	-0.220	0.076	***	-0.973	0.239	***
Communication (1 yes 0 no)	-0.237	0.095	**	-1.084	0.295	***
Co-management ranger A (1 yes 0 no)	-0.487	0.096	***	-1.909	0.296	***
Co-management ranger B (1 yes 0 no)	-0.694	0.106	***	-2.321	0.318	***
Co-management ranger C (1 yes 0 no)	-0.786	0.108	***	-2.596	0.318	***
Current stock level (1 high 0 low)	0.149	0.031	***	0.621	0.098	***
Previous stock level (1 high 0 low)	-0.171	0.029	***	-0.633	0.093	***
Trend (rounds)	-0.012	0.004	***	-0.037	0.012	***
Per capita income (minimum monthly wages)	0.285	0.110	***	0.963	0.341	***
Location (1 inside 0 outside)	0.004	0.088	ns	0.010	0.270	ns
Participation is useful (1 yes 0 no)	-0.071	0.075	ns	-0.257	0.225	ns
Participation is useful * inside (1 yes 0 no)	-0.086	0.117	ns	-0.422	0.356	ns
Constant	1.555	0.080	***	4.803	0.248	***
Observations		2190			2190	
Wald chi2(k)		224.6	***		286.8	***

Asterisks denote statistical significance in differences in coefficients.
*** significant at 1% ** significant at 5% * significant at 10% [ns] non-significant

In Table 7 there is a summary of some characteristics of park rangers we believe might determine their abilities during the game. Although it is not conclusive, rangers with groups reaching the lowest extraction have a longer experience working with communities at this MPA. This effect might be the result of trust and confidence gained from a longer relationship between rangers and communities. As Table 7 shows, what seems to matter for extraction decisions is not the experience with communities but the specific experience with those in the MPA influence zone. Differences found among rangers could be associated not only with experience in the MPA but also with the way they approach the group, their rapport with the subjects and the rangers' ability to communicate with the local population.

Table 7. Some characteristics of park officers participating in the co-management rule

Characteristic	Ranger A	Ranger B	Ranger C
Age (years)	34	27	26
Born in the area (1 yes 0 no)	Yes	No	Yes
Work experience with communities (years)	6	4	7
Work experience with the MPA (years)	0.5	4	7
Academic level	College	College	Technician
Groups in which participated (inside)	2	2	3
Groups in which participated (outside)	4	3	2
Extraction of associated groups (units)	2.84	2.29	2.06

With respect to the level of stock, we found that current abundance has a positive effect on extraction, while previous-round abundance exhibits a negative effect. One way of analyzing these dynamic effects is by combining previous and current stock availabilities along with observed coefficients. In Table 8, the effect of combining previous and current stock on extraction decisions is shown. The previous and current low availability constitute the baseline. When the previous stock level was low and the current stock level is high, individuals will tend to extract more (0.62 units more than the baseline case); conversely, when the previous availability was high and the current stock level is low, extraction is reduced by 0.63 units. When players faced high availability during the previous and current round, the level of extraction remains the same compared to the baseline case (the value is not statistically different from zero). Those results are coherent with expected player behavior with respect to resource extraction under different stock levels.

Table 8. The effect of changes in stock availability on extraction decisions.

		Current stock	
		Low	High
Previous stock	Low	0	0.621***
	High	-0.633***	-0.012 ^{ns}

Asterisks denote statistical significance in differences between coefficients.
*** significant at 1% ** significant at 5% * significant at 10% ^{ns} non-significant

The trend variable is significant and negative, showing a downward tendency during the game, as observed in Figures 1 and 2.

The per capita income coefficient shows that players with less income extracted less than those with higher levels of income; here, the effect is significant. It is important to recall, however, that among participants income levels did not exhibit high variance.

Perception analysis shows that individuals who believe that participating in meetings for problem-solving at the MPA is useful, tend to extract less of the resource during the game; however, the effect is not statistically significant in this model.

From the non-parametric analysis, some differences in the results with respect to the location were evident. However, in this general model, the variable itself showed no significance with respect to extraction decisions. The location effect seems to be absorbed by other variables when a multivariate analysis is performed. To better understand the impact of location, we estimate an alternative model in which treatment variables interact with location. Results are presented in Table 9.

Table 9. Results from OLS and Poisson specifications (random effects) for the model differentiating treatments by location

Variables	Poisson panel model			OLS Panel model		
	Coef.	Std. Err.		Coef.	Std. Err.	
External regulation (1 yes 0 no)	-0.177	0.091	*	-0.853	0.298	***
External regulation * inside (1 yes 0 no)	-0.181	0.150	ns	-0.501	0.482	ns
Communication (1 yes 0 no)	-0.184	0.125	ns	-0.903	0.403	**
Communication * inside (1 yes 0 no)	-0.116	0.179	ns	-0.386	0.574	ns
Co-management ranger A (1 yes 0 no)	-0.619	0.116	***	-2.333	0.367	***
Co-management ranger A * inside (1 yes 0 no)	0.333	0.186	*	1.066	0.592	*
Co-management ranger B (1 yes 0 no)	-0.832	0.135	***	-2.830	0.413	***
Co-management ranger B * inside (1 yes 0 no)	0.323	0.205	ns	1.174	0.628	*
Co-management ranger C (1 yes 0 no)	-1.128	0.153	***	-3.449	0.454	***
Co-management ranger C * inside (1 yes 0 no)	0.558	0.202	***	1.476	0.610	**
Location (1 inside 0 outside)	-0.023	0.126	ns	-0.123	0.418	ns
Current stock level (1 high 0 low)	0.155	0.031	***	0.652	0.098	***
Previous stock level (1 high 0 low)	-0.166	0.029	***	-0.606	0.093	***

Trend (rounds)	-0.012	0.004	***	-0.037	0.012	***
Per capita income (minimum monthly wages)	0.233	0.109	**	0.834	0.342	**
Participation is useful (1 yes 0 no)	-0.055	0.074	ns	-0.178	0.229	ns
Participation is useful * inside (1 yes 0 no)	-0.149	0.115	ns	-0.622	0.364	*
Constant	1.589	0.086	***	4.906	0.276	***
Observations		2190			2190	
Wald chi2(k)		259.5	***		312.0	***

Asterisks denote statistical significance in coefficients.
*** significant at 1%   ** significant at 5%   * significant at 10%   ns non-significant

Parametric analysis confirms that all treatments generated reduction in the extraction of the resource. Further, we wanted to analyze the magnitude of every treatment and compare them all to find out whether different strategies have a different impact on resource management. To do that, we estimated marginal effects for treatments and location, performing Wald tests on linear combinations of parameters from the OLS model. Results are reported in Table 10. These tests show that the impact of treatments depends considerably on the location. In particular, it is observed that although regulation and communication reduced extraction in both locations, they were less effective in communities outside the MPA. In contrast, co-management treatment exhibited larger and significant coefficients when tested in outside communities.

Table 10. Wald tests for combinations of parameters for treatments by location

Treatment	**Inside**		**Outside**		**Difference**	
External regulation	-1.477	***	-0.853	***	-0.624	*
Communication	-1.412	***	-0.903	**	-0.509	ns
Co-management Ranger A	-1.390	***	-2.333	***	0.942	*
Co-management Ranger B	-1.779	***	-2.830	***	1.051	*
Co-management Ranger C	-2.096	***	-3.449	***	1.353	**
Comparison between treatments	**Inside**		**Outside**			
Co-management Ranger A vs. external regulation	0.086	ns	-1.480	***		
Co-management Ranger B vs. external	-0.302	ns	-1.977	***		

regulation				
Co-management Ranger C vs. external regulation	-0.620	ns	-2.597	***
Co-management Ranger A vs. communication	0.022	ns	-1.429	***
Co-management Ranger B vs. communication	-0.367	ns	-1.926	***
Co-management Ranger C vs. communication	-0.684	ns	-2.546	***
Communication vs. external regulation	0.064	ns	-0.051	ns
Co-management Ranger B vs. Ranger A	-0.389	ns	-0.497	ns
Co-management Ranger B vs. Ranger C	0.317	ns	0.620	ns
Co-management Ranger A vs. Ranger C	0.706	ns	1.117	**

Asterisks denote statistical significance in differences between location.
*** significant at 1% ** significant at 5% * significant at 10% ns non-significant

A comparison among treatments shows that difference between communication and external regulation rules was not statistically significant, implying a similar marginal effect on resource's management. Table 10's findings also reveal that differences in results among rangers were not significant, except for the case of rangers A and C when participating in games at outside communities. In turn, co-management treatment had better results than did other rules within outside locations.

These results confirm that rules play an important role in defining the pattern of use of common pool resources. Other characteristics, such as socioeconomic and perception variables, also play an important role, and the interaction between them generates the current pattern of resource use in the protected area.

5 CONCLUSIONS

Co-management can be defined as an institutional arrangement in which several degrees of power and responsibility are shared between state and local agents for the management of a CPR. This arrangement implies shared governance of resources between state regulation and self-governing institutions. In this study, we test collaborative management strategies by conducting a CPR experiment in which we combined repeated communication between players with external non-coercive intervention by actual natural park rangers; we find that this rule can be highly effective in reducing extraction compared with other rules. The effectiveness of co-management rule was consistent for all locations where the games were carried out.

The results from our study support some previous findings from other experiments (Ostrom, 2000). First, unlike predictions based on standard theory, we found individuals do not extract the maximum amount of resources allowed; i.e., their decisions deviate from the predicted Nash equilibriums (Cárdenas, 2004), results that we observed under abundance. Second, the field experiments we performed within fishing communities confirm previous empirical evidence related to the role of treatments such as communication and external regulation in the management of CPRs, reducing extraction (Cárdenas, 2004; Vélez *et al*., 2010). However, our findings reveal that these rules do not play a prominent role in controlling the levels of extraction associated with CPRs, in particular, with respect to communities located outside protected areas, when compared with co-management treatment.

The second hypothesis of this study is that location of communities regarding the MPA has an effect on extraction decisions. We show that communities located outside the MPA were more reluctant to reduce extraction by both external regulation and internal communication. However, when they had the opportunity of interacting with authorities through the co-management rule, the levels of extraction were significantly lower compared with those under any other treatment. Communities outside the park do not receive information from environmental-education programs as much as those inside the park, though that they might be exposed to similar control and surveillance procedures (because the outsiders do fish inside the park). In consequence, the outside communities responded more favorably to a park ranger using a non-coercive intervention than they did to methods of control and surveillance.

The results from our study contribute both to behavioral economics and the CPR management literature for two reasons. First, we included a treatment wherein an actual park ranger—one who works on environmental education for local communities—participated as an agent in the experiment with the purpose of testing reinforcement effects between communication and non-coercive authority intervention as an alternative to coercive external regulation or communication alone. Although some might think that this is a loss of control in the experiment, we believe that for practical purposes it is important to understand that different rangers might have different impact on the implementation of policies. This innovative treatment showed the best results in terms of extraction levels, not only for communities located inside the park but also for those located outside of it. This finding suggests that non-coercive strategies could generate better responses from communities than coercive ones, in terms of the conservation and improved management of CPRs. Thus, we argue that information sharing between communities and authorities may increase awareness and reduce extraction beyond what is achieved with just internal communication. This may not be only because of reduced asymmetries in information brought about by interaction between local users and park officials, but also because communication allows agents to recognize that social conservation goals, community interests, and individual interests can be satisfied simultaneously, and that they are complementary rather than opposing interests.

According to previous participative workshops carried out with communities in the area, resource users recognize that over-exploitation and the use of inadequate fishing methods cause degradation and, in the end, deplete marine resources. They can be, however, trapped if they are unable to communicate with one another and have no way to develop trust, or do not have the capacity to explicitly recognize that they share a common goal. In such cases, some external support is necessary to break out of the perverse logic of their situation (Ostrom, 1990). This is when the role of authorities—in providing information and education, in facilitating and encouraging community participation in the decision-making process, in developing strategies, and in monitoring and controlling activities—becomes crucial. Under co-management treatment, strategies suggested by park rangers seem to be legitimized when individuals decide to cooperate and reduce extraction.

The other contribution is the one related to what in this paper we call resource sustainability. We measured the sustainability in the use of the resource by analyzing the proportion of rounds in which individuals allowed the resource to reach a state of high availability. During open access the number of rounds with low resource availability exceeded the number of rounds with abundance. This suggests that individuals act myopically, in the sense that they do not take into account the effect of current decisions on the future state of the resource. Conversely, during the second stage of the game, when rules were imposed, individuals maintained a higher number of rounds with high resource availability. This shows that rules can play a relevant role in inducing individuals to incorporate future effects into their current extraction decisions regarding the state of the resource being exploited or, at least, inducing cooperation to take better advantage of increased payoffs as a consequence of better managing the resource.

Parametric analyses confirmed our findings derived from non-parametric tests, regarding the role of rules in reducing extraction, location effects, and the fact that the condition of the resource (whether high or low) is an important determinant of participants' extraction decisions. The parametric analysis yielded another interesting finding that challenges a generally held belief: richer agents extract more than poor ones. This latter result constitutes a motivation for further research.

In addition to their value for testing new rules, field experiments also work as a pedagogical tool that encourages local users to actively participate in, communicate, and discuss problems related to CPR. This is an important aspect of the experiments, especially with respect to fishermen who often have low levels of education, such as are generally found in developing countries.

6 ACKNOWLEDGEMENTS

This work was carried out with the aid of a grant from the Latin American and Caribbean Environmental Economics Program (LACEEP). The Colombian Institute for the Development of Science and Technology (COLCIENCIAS), which funded a project in the *Parque Nacional Natural Corales del Rosario y San Bernardo* (PNN-CRSB), also contributed greatly to our research. We also received a grant from the American National Oceanic and Atmospheric Administration (NOAA), and funding and support from the Center for Economic Development Studies (CEDE) at the Universidad de los Andes.

We received important and timely advice from different persons, among others, Peter Martinsson, Juan Camilo Cárdenas, Juan Robalino, and Christian Jaramillo. Erik Freas and Julie Bleha provided us with some very useful assistance with respect to the language of this paper. Apart from these contributions, the remaining errors are our responsibility.

We would also like to express our gratitude to the team that helped us with the field work, leaded by Sandra Lucia Mendoza. Finally, we are very thankful to the communities and park officers that participated in this research.

7 REFERENCES

Bolton, G.E., Ockenfels, A. 2000. ERC: A Theory of Equity, Reciprocity and Competition. American Economic Review. 90, 166-193.

Camargo, C., Maldonado, J.H., Alvarado, E., Moreno-Sánchez, R., Mendoza, S. Manrique, N., Mogollón, A., Osorio, J.D., Grajales, A., Sánchez, J.A. 2009. Community Involvement in Management for Maintaining Coral Reef Resilience and Biodiversity in Southern Caribbean Marine Protected Areas. *Biodiversity and Conservation* 18: 935-956, doi: 10.1007/s10531-008-9555-5.

Cárdenas, J.C. 2003. Real Wealth and Experimental Cooperation: Experiments in the Field Lab. *Journal of Development Economics,* 70: 263-289.

Cárdenas, J.C. 2004. Norms from Outside and from Inside: An Experimental Analysis on the Governance of Local Ecosystems. *Forests Policy and Economics,* 6: 229-241.

Cárdenas, J.C., Ahn, T.K., Ostrom, E. 2004. Communication and Cooperation in a Common-Pooled Resource Dilemma: a Field Experiment. in S. Huck (Editor), *Advances* in *Understanding Strategic Behavior: Game Theory, Experiments, and Bounded Rationality*, New York: Palgrave.

Cárdenas, J.C., Stranlund, J., Willis, C. 2000. Local Environmental Control and Institutional Crowding-Out. *World Development*, 28 (10): 1719-1733.

Cárdenas, J.C., Stranlund, J., Willis, C. 2002. Economic Inequality and Burden-Sharing in the Provision of Local Environmental Quality. *Ecological Economics*, 40: 379-395

Castillo, D., Saysel, A.K. 2005. Simulation of Common Pool Resource Field Experiments: A Behavioral Model of Collective Action. *Ecological Economics,* 55: 420–436.

Davis, D., Holt, C. 1993. Experimental Economics. Princeton: Princeton University Press. 572p.

Dufwenberg, M., Kirchsteiger, G. 2004. A Theory of Sequential Reciprocity. *Games and Economic Behavior,* 47: 268-298.

Feeny, D., Berkes, F., McCay, B., Acheson, J.M. 1990. The Tragedy of the Commons Twenty-Two Years Later. *Human Ecology,* 18: 1-19.

Fehr, E., Gachter, S. 2000. Fairness and retaliation: the economics of reciprocity. *J. Econ. Perspect*. 14: 159–181.

Fehr, E., Schmidt, D. 1999. A Theory of Fairness, Competition and Cooperation. *Quarterly Journal of Economics*, 114: 817-851.

Gordon, H.S. 1954. The Economic Theory of a Common-Property Resource: The Fishery. *Journal of Political Economy,* 62: 124-142.

Hardin, G. 1968. The Tragedy of the Commons. *Science,* 162: 1243-1248.

Harrison, G., List, J. 2004. Field Experiments. *Journal of Economic Literature,* 42: 1009-1055.

Jentoft, S. 1989. Fisheries Co-management: Delegating Government Responsibility to Fishermen's Organizations. *Marine Policy*, April: 137-154.

Kagel, J.H., Roth, A.E. (Eds.). 1995. The Handbook of Experimental Economics, Princeton University Press, Princeton, NJ.

Maldonado, J.H. & Moreno-Sánchez, R.P. 2009. "Does Scarcity Exacerbate the Tragedy of the Commons? Evidence from Fishers' Experimental Responses". Documento CEDE 2009-22, Uniandes, Bogotá, October 2009.

McCay, B.J. 1996. Common and Private Concerns. In: Hanna, S., Folke, C., Mäler, K-G. (Editors), Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment, Washington, D.C.: Island Press, 313p.

Ostrom, E. 1990. Governing the Commons: The Evolution of Institutions for Collective Action, New York: Cambridge University Press, 280p.

Ostrom, E. 2000. Collective Action and the Evolution of Social Norms. Journal of Economic Perspectives. 14, 137–158.

Rova, C. 2004. The Importance of Trust and Legitimacy in the Management of Common-Pool Resources: Lessons Learned from Implementation of a Fishery Co-management System in a Complex Society. *Working Paper*. Political Science, Lulea University of Technology, Sweden.

UAESPNN. 2006. Plan De Manejo Del Parque Nacional Natural Corales del Rosario y San Bernardo. UAESPNN. DTC. Cartagena.

Vélez, M.A., Murphy, J., Stranlund, J.K. 2010. Centralized and Decentralized Management of Local Common Pool Resources in the Developing World: Experimental Evidence from Fishing Communities in Colombia. Economic Inquiry. 48, 254-265.

8 APPENDIX A. PAY-OFF TABLES

The green pay-off table for HIGH resource availability, and the pink pay-off table for LOW resource availability.

Green Pay off table or HIGH availability		My own level of extraction (fish catch)							
		1	2	3	4	5	6	7	8
Their level of extraction (rest f the group)	4	795	860	915	960	995	1020	1035	1040
	5	775	840	895	940	975	1000	1015	1020
	6	755	820	875	920	955	980	995	1000
	7	735	800	855	900	935	960	975	980
	8	715	780	835	880	915	940	955	960
	9	695	760	815	860	895	920	935	940
	10	675	740	795	840	875	900	915	920
	11	655	720	775	820	855	880	895	900
	12	635	700	755	800	835	860	875	880
	13	615	680	735	780	815	840	855	860
	14	595	660	715	760	795	820	835	840
	15	575	640	695	740	775	800	815	820
	16	555	620	675	720	755	780	795	800
	17	535	600	655	700	735	760	775	780
	18	515	580	635	680	715	740	755	760
	19	495	560	615	660	695	720	735	740
	20	475	540	595	640	675	700	715	720
	21	455	520	575	620	655	680	695	700
	22	435	500	555	600	635	660	675	680
	23	415	480	535	580	615	640	655	660
	24	395	460	515	560	595	620	635	640
	25	375	440	495	540	575	600	615	620
	26	355	420	475	520	555	580	595	600
	27	335	400	455	500	535	560	575	580
	28	315	380	435	480	515	540	555	560
	29	295	360	415	460	495	520	535	540
	30	275	340	395	440	475	500	515	520
	31	255	320	375	420	455	480	495	500
	32	235	300	355	400	435	460	475	480

Red Pay off table or LOW availability		My own level of extraction (fish catch)							
		1	2	3	4	5	6	7	8
Their level of extraction (rest f the group)	4	790	840	870	880	870	840	790	720
	5	770	820	850	860	850	820	770	700
	6	750	800	830	840	830	800	750	680
	7	730	780	810	820	810	780	730	660
	8	710	760	790	800	790	760	710	640
	9	690	740	770	780	770	740	690	620
	10	670	720	750	760	750	720	670	600
	11	650	700	730	740	730	700	650	580
	12	630	680	710	720	710	680	630	560
	13	610	660	690	700	690	660	610	540
	14	590	640	670	680	670	640	590	520
	15	570	620	650	660	650	620	570	500
	16	550	600	630	640	630	600	550	480
	17	530	580	610	620	610	580	530	460
	18	510	560	590	600	590	560	510	440
	19	490	540	570	580	570	540	490	420
	20	470	520	550	560	550	520	470	400
	21	450	500	530	540	530	500	450	380
	22	430	480	510	520	510	480	430	360
	23	410	460	490	500	490	460	410	340
	24	390	440	470	480	470	440	390	320
	25	370	420	450	460	450	420	370	300
	26	350	400	430	440	430	400	350	280
	27	330	380	410	420	410	380	330	260
	28	310	360	390	400	390	360	310	240
	29	290	340	370	380	370	340	290	220
	30	270	320	350	360	350	320	270	200
	31	250	300	330	340	330	300	250	180
	32	230	280	310	320	310	280	230	160