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Coordinating Efforts to Protect the Common: Experimental Evidence from TURFs in Chile

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Abstract: This work presents the results of framed lab in the field experiments designed to study the ability of common pool resource users to simultaneously coordinate their harvests and investments in monitoring to deter poaching when this latter decision is taken independently by each member and also through voting within the group. The experiments were conducted with participants in the territorial use rights in fisheries (TURFs) management scheme that regulates access to nearshore fisheries along the coast of Chile. A total of 234 artisanal fishers were recruited from seventeen different communities. The experiments were applied during January 2017. Our results indicate that users of a common pool resource may have difficulties coordinating their efforts to deter poachers when monitoring decisions are independent and the penalties are low; however, the use of voting increases monitoring effort when penalties are high, increasing deterrence and sustainability of the fisheries.

Key Words: Common pool resources; economic experiments; enforcement; poachers; territorial use rights fisheries.

JEL Codes: Q48, H23, Q53, H31

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1. Introduction

Territorial use rights in fisheries (TURFs) is as fisheries management approach that allocates exclusive harvesting rights in a particular geographical location to a specific group of users. Solving the open access problem that often leads to over-exploited fisheries can allow members of a TURF to coordinate their harvest decisions to maximize the value of their resource stocks (Charles 2002, Christy 1982, Wilen et al. 2012). However, TURFs are prone to poaching from outsiders and, hence, must be defended from outside encroachment (Chávez et al. 2017, Chávez et al. 2010, Gelcich et al 2009, Gelcich et al 2017). Enforcing access to a TURF is usually done by a combination of TURF members' efforts and the government. Members of an organization holding a TURF have to solve the problem of simultaneously managing their use of the resource and defend it against encroachment, given the enforcement efforts of the government. This challenge has been recently explored by Chávez et al. (2017). By conducting a series of economic experiments with participants of the TURF system that regulates near-shore fishing along the coast of Chile and University students, they found that giving the responsibility for monitoring to resource users do not affect poaching, suggesting that users of a common pool resource may have difficulties coordinating their effort to deter poachers. In this paper, we investigate further this coordination failure. We do so with a series of new designed lab-in-field economic experiments with participants of the Chilean TURF system.

The experiments were framed as harvests of a valuable benthic mollusc called *loco*. Two groups of three individuals harvested from two separated stocks of *loco*. One group, called the insiders were able to communicate with each other, but not with the other group, the outsiders. The outsiders could not communicate with each other or with the insiders. In our baseline treatment, intended to serve as a control treatment, the outsiders could poach

from the insiders' zone without facing sanctions for their behavior. In the other four treatments, the outsiders could poach from the insiders' stock, but we consider different monitoring decisions mechanisms along with different levels of per unit sanction for poaching.

In two of these enforcement treatments, the insiders made independent decisions to invest in monitoring to detect poaching and with vary the level of fine. The other two enforcement treatments consider a voting mechanism for the decision to invest in monitoring under two levels of sanctions. These treatments allow us to consider whether a simple coordinating device as voting produces more deterrence and the potential effect of the fine level. In all cases the investments in monitoring are "second-order" contributions to a public good, and hence, insiders may under-provide monitoring resources. However, as a group they always have the incentive to invest enough in monitoring to deter the outsiders. Whether they are able to do so or not under different decision mechanisms (independent and voting) with different sanctions is the main question of this research.

Our work contributes to the literature that uses economic experiments to investigate self-governance and co-management of common pool resources (see, for example, Ostrom 1990, Ostrom 2006, Ostrom and Walker 1991, Ostrom, Walker, and Gardner 1992, among many others). We specifically focus on the possibility of co-protection of common pool resources from outside encroachment. To our knowledge, the only study that uses framed field experiments to examine the defense of common pool resources from poaching is Chávez et al. (2017). In this paper we extend their design to study different mechanism to provide self-protection to deter poachers.

The rest of the paper proceeds in the following way. In section 2 we provide of brief description of the Chilean TURF system. In section 3 we describe the design of our experiments, the theoretical benchmarks for each treatment, and the procedures we used to

implement our experiments. the results of our experiments are presented in section 4. In section 5 we conclude.

2. TURFs in Chile

In 1997, Chile implemented the Management and Exploitation Areas of Benthic Resources (MEABR) management system which assigns local artisanal fishing organizations exclusive use rights of all the benthic resources from specific geographic areas located within five nautical miles of the coast or inland waters. The MEABR regime was intended to promote conservation and rationalize the use of benthic resources, as well as to facilitate cooperation between artisanal fishing associations and the National Fisheries Service (SERNAPESCA, by its Spanish acronym). This regime was expected to become a durable management system that would enhance artisanal economic activity by creating rights to natural shoals of benthic resources (SUBPESCA 1995).

The MEABR management system has the potential to overcome some of the problems that led to the failure of the earlier species-specific individual quota program. Under the MEABR, local TURFs are responsible for developing a management plan at their own expense, including annual stock assessments to determine sustainable harvest levels, and defining the rules that govern how the resources will be harvested. By shifting much of the costs and responsibilities for managing the benthic resource to the local organizations that would also reap the benefits of these efforts, the MEABR system better aligns the incentives for efficient resource management. However, this approach faces important challenges. Success of MEABR system depends upon the ability of the TURFs to self-govern and overcome collective action problems. Although there is substantial variation in how each TURF is managed, most have been able to successfully implement a rationalized harvest plan that defines access privileges, sanctions for noncompliance by group members,

responsibilities for policing borders, and other duties associated with managing the TURF (Wilen et al 2012).

Similar programs have been used successfully for generations in the South Pacific (Wilen et al. 2012) and Japan (Cancino et al. 2007), but the Chilean MEABR program was established in the absence of any prior tradition and is still evolving. Some, but not all, of the essential elements usually observed in long-enduring commons (Ostrom 1990) are present in many of the Chilean TURFs, but their long-run success will depend upon whether the remaining hurdles can be overcome.

Of particular concern is illegal poaching (Aburto et. al. 2013, Moreno and Revenga 2014). Surveys of TURF fishers and leaders in central Chile reveal that they believe that poaching and the difficulties of deterring poaching are key problems in the management of TURFs. Moreover, TURF members and their leaders desire greater support from government authorities to deter poaching (Gelcich et al 2009, Gelcich et al. 2017). Lack of government support in monitoring and sanctioning may diminish the motivation TURF members to monitor their resource to deter poaching (Davis et al. 2015).[1]

Our study is motivated by the Chilean TURF experience with respect to deterring poaching. In particular, we are concerned with the ability of common pool resource users to simultaneously coordinate their harvests and investments in monitoring to deter poaching under different mechanisms to coordinate monitoring decisions. The areas in which our experiments were conducted are all under the MEARBs regime. In each of the communities we visited, there was at least one MEARB currently operating; thus, the 234 fishers who participated in the experiments were members of unions or cooperatives which operate benthic management areas.

[1] However, local TURFs have tried to protect their territories by patrolling and chasing intruders out of their management areas (Chávez et al 2010). At times these incidents have escalated to violent encounters, including murders.

3. Experimental Design and Procedures

Our objective is to examine how a group of individuals simultaneously manage their exploitation of a common pool resource and defend it against poaching under various monitoring decisions conditions. In all treatments, except in the baseline treatment, the resource users invest in monitoring. We consider the monitoring investment as an individual independent decision and also through a voting option, in both cases we varies the level of sanctions to be imposed if a poacher is detected. With these treatments we ask whether a simple mechanism as voting may increase coordination efforts to deter poaching. In this section, we describe the design of our experiments.

3.1 Experimental Design

Our experimental design follows Chávez et al. (2017). Each of our experiments consist of six individuals divided into groups of three. We call one group the 'insiders' and the other the 'outsiders' throughout the paper (we avoided these terms in the experiments). The experiments were framed as managing the exploitation of Chilean abalone, or *loco*, from two zones or stocks of *loco*. The insiders are given access to the blue zone and the outsiders have access to the yellow zone as depicted in the Figure 1. In all treatments the outsiders may poach in the blue zone. The resource in both zones evolves over time according to a stock dependent growth function and aggregate harvests. The growth rate in both zones is 10% of the remaining stock in a period in discrete units; that is, each stock grows by one unit for every 10 units of loco that are left in the zone. The insiders have access to the more valuable stock—the initial stock in the blue zone is 100 units while the initial stock in the yellow zone is 55 units. Harvest capacity for each individual harvester is six units per period, and the net value of each harvested *loco* is a constant 200 Chilean pesos. Each session considered two independent stage (or activities). When activity/stage 1 ended, we reset the exercise and started over again the activity 2 with a new period 1.Each stage lasted a maximum of 15

periods, but each zone could be closed earlier if its stock fell below a critical value (see Figure 2). This critical value is 40 units in the blue zone and 20 units in the yellow zone. These critical values were chosen so that individuals could harvest at capacity in the last period before the zone was closed. The critical level in the blue zone is 40 because in most of our treatments both insiders and outsiders could harvest in the blue zone. The critical level is 20 in the yellow zone, because only the outsiders could harvest in that zone.

Figure 1: Insiders and outsiders in the blue and yellow zones, respectively

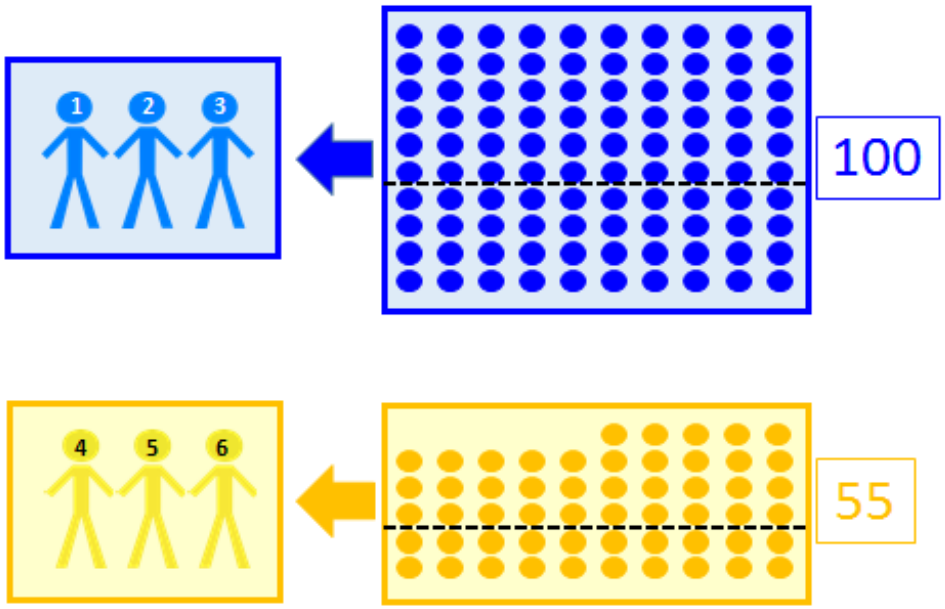

Figure 2: Stages in an Experimental Session
(two stages with up to fifteen rounds per stage)

	ROUND														
Stage 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Reset the exercise and start over.														
Stage 2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	End of exercise.														

3.1.1 Treatments

We conducted five treatments as described below. In each treatment the insiders were able to communicate with each other, but not with the outsiders. The outsiders were not able to communicate with each other or with the insiders. In all treatments the outsiders could poach from the blue zone but the insiders could not poach from the yellow zone. Poaching could be sanctioned in four of the five treatments. If an outsider was caught poaching from the blue zone in these treatments, he or she was sanctioned with a fixed per unit fine. We vary the level of the fine. Specifically, the fine was either $ 650 or $ 1,300 for each blue loco poached in the low-fine and high-fine cases, respectively. We conducted the following five treatments.

T1. Baseline: In this treatment, the outsiders could poach from the insiders' zone without facing sanctions for their behavior. The insiders can communicate with each other between rounds while the outsiders cannot, and the insiders harvest from a more valuable stock.

T2. Local Enforcement-No voting-Low Fine: This treatment is the same as the Poaching treatment except that the insiders could invest in monitoring the outsiders to detect poaching. Each insider makes an independent decision to invest in monitoring according to the schedule (0%, 5.6%, 11.1%, 16.7%, 22.2%, 27.8%, 33.3%, 38.9%, 44.4%, 50%). The marginal cost of achieving a higher monitoring probability is 100 pesos (50% of price of loco). Thus, for example, if the insiders collectively invest 400 pesos, then outsiders are monitored with probability 22.2%. Note, however, that given the 650 pesos per unit sanction, to make the expected per unit sanction exceed the value of a *loco* the insiders must collectively invest 600 pesos to make the monitoring probability 33.3%.

T3. Local Enforcement-No voting-High Fine: This treatment is the same as T2 except that fine is 1,300 pesos per loco poached. Considering this sanction, insiders must collectively

invest 300 pesos, which consequently implies that the monitoring probability will be 16.7%, enough for the expected penalty to be above the price of a loco.

T4- Local Enforcement-Voting-Low Fine: This treatment is the same as the Poaching treatment except that, similar to T2, the insiders could invest in monitoring the outsiders to detect poaching. The level of monitoring is determined by a group vote. Each insider vote on how much each person in the group should invest in monitoring according to the schedule (0%, 16.7%, 33.3%, 50%). The probability that receives the most votes is the winner, and each member of the group will equally share the cost of that monitoring effort regardless of how much the person voted. If there is a tie (which only happens if each person votes for a different number), then the middle vote will be the winner. The marginal cost of achieving a higher monitoring probability is 300 pesos collectively (100 pesos per member). Thus, for example, if the insiders vote to collectively invest 900 pesos, then outsiders are monitored with probability 50%. Given the 650 pesos per unit sanction in this treatment, to make the expected per unit sanction exceed the value of a *loco* the insiders must collectively invest 600 pesos to make the monitoring probability 33.3%.

T5- Local Enforcement-Voting-Low Fine: This treatment is the same as T4 except that fine is 1,300 pesos per loco poached. In this treatment, the insiders need to vote to invest only 300 pesos in a period (probability in this case will be 16.7%) to make the expected fine greater than the marginal benefit of poaching.

The main question of this study is whether the insiders are able to coordinate their monitoring investments with different decision mechanisms (and sanctions) to deter poaching.

3.1.2 Theoretical benchmarks.

In Table 1, we present theoretical benchmark equilibria for treatments under consideration. (The derivations are presented in the Appendix). We present cooperative and non-cooperative symmetric individual harvest benchmarks for each zone. In a cooperative benchmark solution harvesters in a zone coordinate their harvest strategies to maximize the joint payoffs of the group. I a non-cooperative equilibrium harvesters are not able to coordinate their harvest choices so they choose pure Nash strategies. We present symmetric individual harvests by insiders and outsiders over all periods; symmetric poaching by the outsiders in the blue (insider) zone; the terminal period, that is, the last period a zone is open; minimum symmetric monitoring costs to deter the outsiders in treatments T2 and T4 (Low Fine) and T3 and T5 (High Fine), and finally symmetric payoffs for insiders and outsiders.[2]

T1-Baseline: In this treatment the outsiders can freely poach from the blue zone; consequently, there is no incentive for the insiders to limit their harvests to conserve their resource and they will harvest to capacity until their zone is depleted. The outsiders, behaving non-cooperatively, will use their harvest capacity to first harvest from the inside zone. After the inside zone is depleted, the outsiders will move to the yellow zone and harvest at capacity there until the zone is depleted. Harvesting at capacity by both insiders and outsiders in the blue zone will deplete it in just three periods. Since the outsiders do not harvest in their zone while they are poaching in the blue zone, the yellow zone lasts for six periods until it is depleted.

T2 and T4-Local Enforcement-Low Fine: In these treatments the insiders invest in monitoring their zone for poaching. They can do so with very different mechanisms; while in T2 the

[2] We do not present cooperative harvest strategies by the outsiders mainly because we do not give the outsiders a mechanism to coordinate their harvests (e.g., communication) so we do not predict that they will be able to develop cooperative strategies.

insider decide independently on monitoring investment, in T4 they vote. In both treatments the fine per unit of *loco* poached is low (650 pesos). Recall from our previous discussion of these treatments that each insider makes an independent decision to invest in monitoring according to the schedule (0%, 5.6%, 11.1%, 16.7%, 22.2%, 27.8%, 33.3%, 38.9%, 44.4%, 50%) with constant marginal cost of 100 pesos or vote according to the schedule (0%, 16.7%, 33.3%, 50%) with constant marginal cost of 300 pesos in T2 and T4, respectively. Given the 650 pesos per unit poaching sanction and the 200 pesos unit value of harvest, minimum monitoring to deter the outsiders in a period is 33.3%, costing the inside group 600 pesos. If the insiders fail to reach this level of monitoring, then outsiders are not deterred at all. Moreover, if they are not deterred they will poach to capacity in the blue zone until it is depleted. Thus, the value of deterrence for a group of insiders in a period is the value of 18 units of the resource, or 3,600 pesos. Since the insiders can deter the outsiders in a period if they spend 600 pesos, it is always worthwhile for the insiders as a group to invest in complete deterrence.

However, deterring the outsiders requires a significant amount of coordination. If the insiders are not able to coordinate their monitoring investments well enough, then they do not deter the outsiders and it is wasteful to invest in any monitoring. In this case, the equilibrium outcomes in this treatment are the same as in the T1-Baseline treatment. Note that the value of coordinating their harvests is zero if the insiders cannot simultaneously coordinate their monitoring investments. The equilibrium outcomes for treatments T2 and T4 in Table 1 all assume that the insiders fully deter the outsiders (at least until the end period) at minimum monitoring cost.

If the insiders also coordinate their harvest choices they will pursue the strategy of maintaining maximum sustained yield until the last several periods in which they harvest at capacity so that the stock is below its critical level at period 15. In the final period there is

sufficient stock remaining so that that both insiders and outsiders can harvest at capacity. Thus, there is no reason for the insiders to try to deter the outsiders in the last period. The insiders' total cost of deterrence over fourteen periods is 8,400 pesos (2,800 pesos per each insider). Note that no sanctions are levied on the outsiders.

In Table 1, we also present the outcome in which the insiders are not able to coordinate their harvests, but they are able to deter the outsiders. In this case the blue zone is depleted in six periods. In that sixth period, there is sufficient stock of the blue resource so that both insiders and outsiders can harvest at capacity. Thus, the insiders maintain their deterrence of the outsiders for only five periods, at a total cost of 3,000 pesos (1,000 pesos per each insider). Outsiders are never sanctioned.

Whether the insiders are able to coordinate their harvest or not, the outsiders harvest at capacity in their own zone, depleting it in three periods. Since the insiders will not try to deter them in the last period of their harvests in the insider zone, the outsiders will poach at capacity in the final period in the inside zone. Thus, regardless of whether the insiders coordinate their harvests or not, the outsiders will harvest 54 units from their zone in three periods, and then an additional 18 units from the insider zone. The only difference is that the outsiders have to wait until period fifteen to poach when the insiders coordinate their harvests.

Table 1 reveals the insiders are always better off if they can deter the outsiders, whether they can coordinate their harvest strategies or not. To see this, note that the insider payoffs for the T2 and T4 benchmarks are higher than their payoffs under undeterred poaching in the baseline treatment. Note that the possibility of deter poachers may have a significant effect on the welfare of the insiders. Specifically, if the insiders are able to coordinate both, monitoring efforts and harvest, they may earn 2,2 times more than under non-controlled poaching. Even if the insider are only able to coordinate monitoring effort, but

not harvest, they may earn 1,7 times more than under the baseline treatment. Our experiments consider the joint coordination of harvests and deterrence by the insiders. It is clear that there is no value to coordinating their harvests if they cannot deter the outsiders.

T3 and T5-Local Enforcement-Low Fine: These treatments are the same as T2 and T4, respectively, except that the fine for each poached *loco* is 1,300 pesos. This implies further the minimum monitoring to deter the outsiders in a period is 16.7%, costing the inside group 300 pesos. If the insiders fail to reach this level of monitoring, then outsiders are not deterred at all. Since the insiders can deter the outsiders in a period if they spend only 300 pesos, again, it is always worthwhile for the insiders as a group to invest in complete deterrence. As we show in Table 1, because the minimum monitoring needed to deter poachers is lower under T3 and T5 as compared with T2 and T4, the insiders not only are always better off if they can deter the outsiders, but they are also better off deterring with the high fine as compared with the low fine. To see this, note that the insider payoffs for the T3 and T5 benchmarks are higher than their payoffs under undeterred poaching in the baseline treatment and also higher than their payoffs under T2 and T4.

Table 1: Equilibrium benchmarks. Symmetric individual harvests, monitoring costs and payoffs.

Treatment	Harvests	Poaching	Terminal period	Monitoring costs	Payoffs (pesos)
T1. Baseline-Poaching	There is no incentive for the insiders to coordinate their harvests in this treatment.				
Noncoop insiders	18	-	3	-	3,600
Noncoop outsiders	36	18	6	-	7,200
T2 and T4. Local Enforcement-Low Fine	It is always beneficial for the insiders to coordinate investments in monitoring to deter the outsiders in this treatment. All outcomes here assume that this occurs.				
Coop insiders	54.3	-	15	2,800	8,060†
Noncoop insiders	36	-	6	1,000	6,200†
Noncoop outsiders	24	6	3	-	4,800
T3 and T5. Local Enforcement-High Fine	Outcomes in this treatment are the same as in the Local Enforcement treatment, except that the insiders spend less on monitoring.				
Coop insiders	54.3	-	15	1,400	9,460†
Noncoop insiders	36	-	6	500	6,700†
Noncoop insiders	24	6	3	-	4,800

† Harvest payoff less share of monitoring costs.

3.2 Experimental Procedures

The experiments were conducted with members of fishing organizations operating under the Management and Exploitation Areas of Benthic Resources (MEABR) system in the Los Lagos region in southern Chile. Invitations to participate in the experiments were extended through the leader of each TURF. Efforts were made to recruit participants from all the TURFs operating in the sample area. A total of 234 artisanal fishermen were recruited from the following communities: Anahuac, Isla Tenglo, Pelluco, La Arena, Sotomó, Amortajado, Carelmapu, Pureo, Bahía San Antonio, Contao, Quildaco, Tentelhue, San Pedro El Manzano, Puntilla Quillón, Pichicolo, Punta Pichicolo, and Chumeldén. The experiments were conducted in January 2017. Figure 3 is a map of the communities (and TURFs) in which we ran the experiments. Experimental treatments were distributed across the communities to avoid concentrating particular treatments in particular communities. A summary of the number of subjects and groups by experiments treatment is contained in Table 2.

Figure 3. Fishing communities visited

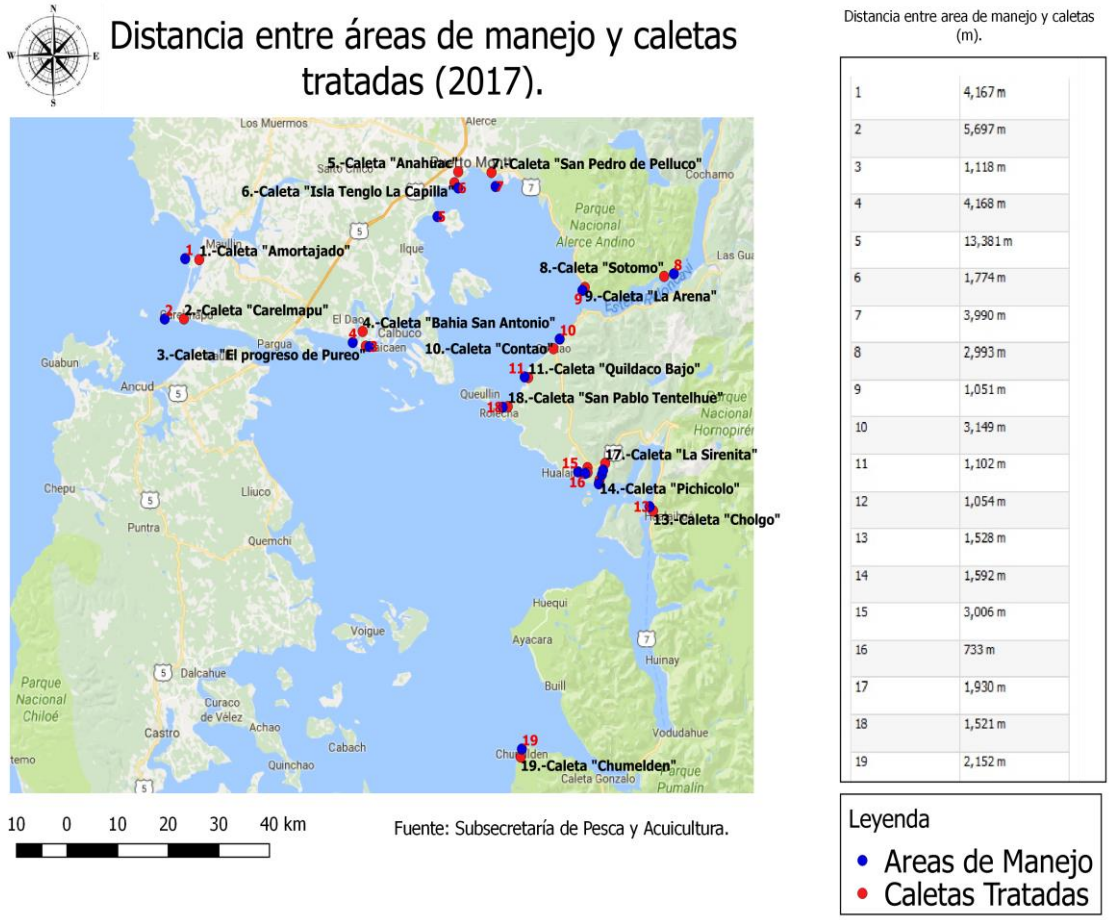

Table 2: Number of subjects and groups by treatment

Treatments	TURF members	
	Groups	Subjects
T1. Baseline	8	48
T2. Local Enforcement-No Voting-Low Fine	8	48
T3. Local Enforcement-No Voting-High Fine	8	48
T4. Local Enforcement-Voting-Low Fine	7	42
T5. Local Enforcement-Voting-High Fine	8	48
Totals	39	234

Upon arrival, participants signed consent forms and then were randomly assigned to groups of six, with three in the blue group (the insiders) and three in the yellow group (the

outsiders). (In the experiments, insiders were referred to as blue participants and outsiders were referred to as yellow participants). A maximum of two groups of six participated in a particular session. At the beginning of each session, the experimenters explained the experiment procedures. Ample practice rounds were conducted to familiarize the participants with the procedures. Control questions were asked about the procedures to determine whether the subjects were ready to participate in the experiments. The experiments were conducted with pen and paper. Insiders and outsiders were separated so that there was enough space for each subject to work in private. The blue and yellow resource stocks were displayed on a board that was visible to all.

In each round of the experiments, the insiders were first asked to leave the room to communicate with each other about any aspect of the activity for a maximum of three minutes. Outsiders remained seated in silence. When the insiders finished the communication stage, all subjects wrote down their decisions in private. In every round of each treatment, both insiders and outsiders decided how many locos to harvest. In each treatment the outsiders chose how much they would harvest in their zone and how much to poach from the blue zone. In addition, in treatments T2 and T3, the insiders independently chose their investments in monitoring. In treatments T4 and T5, the insiders vote on group monitoring. After the harvest and monitoring decisions were recorded, the results were announced and the harvests in each zone were removed from the display board.

In treatments T2, T3, T4, and T5, the experimenter then proceeded to a monitoring stage. To determine monitoring in any of these treatments a bag containing a total of 18 chips was used. Some chips in the bag were red and some were green. There were always 18 chips in the bag. The total number of red chips was always between 0 and 9, the rest were green. In T2 and T3 each insider was allowed to purchase red chips to determine whether one outsider participant was inspected. Each chip cost 100 pesos. Each insider could purchase 0,

or 1, or 2 or 3 red chips. The outsiders participants took turns to draw a chip from a bag. The more red chips the insiders purchased, the more likely an outsider participant was inspected. For example, if the insiders purchased three red chips (at a cost of 300 pesos), then an outsider would be inspected if one of the 3 red chips in the bag was draw. If the insiders purchased a total of 5 red chips (at a cost of 500 pesos), then an outsider would be inspected if any of the 5 red chips was draw. This process produces alternative levels of monitoring (0%, 5.6%, 11.1%, 16.7%, 22.2%, 27.8%, 33.3%, 38.9%, 44.4%, 50%) with each higher level above 0% costing 100 pesos.

To determine monitoring in T4 and T5 each insider voted on the number of red chips that each person in the blue group would buy. Specifically, each blue participant voted on whether each person in the blue group would purchase 0 or 1 or 2 or 3 red chips. The number of red chips that received the most votes was the winner, and each person in the blue group bought that number of red chips regardless of how that person voted. If there was a tie, then the middle vote was the winner. For example, if the votes were 0, 3, and 1, then 1 is the middle vote and each blue participant bought 1 red chip, and the group collectively invested in 3 red chips at a cost of 300 pesos, then, an outsider was inspected if any of the 3 red chips was draw. The process of voting in the voting treatments T4 and T5 produces alternative monitoring probabilities (0%, 16.6%, 33.3%, and 50%), with each higher level above 0% costing 300 pesos collectively (100 pesos for each insider).

In T2 and T3, if an outsider was found to have poached in the inside zone, a sanction of 650 pesos per unit of poached loco was deducted from that participants earnings. The sanction was 1,300 in T4 and T5.

Each experimental session considered two independent stage (or activities). When activity/stage 1 ended, we reset the exercise and started over again the activity 2 with a new period 1.Each stage lasted a maximum of 15 periods, but each zone could be closed earlier if

its stock fell below a critical value (see Figure 2).Each session lasted about two hours and thirty minutes. Participants were given a survey to complete at the end of each session to gather socio-economic information as well as the participants' perceptions of poaching activity and enforcement actions in their TURF.

Most of the participants are male (60%). The mean age of the participants was about 49 years old. About 65% of the sample reported having incomplete elementary school and only 20% reported complete high school education. The majority of participants were the main contributors to their family incomes (80%). Mean monthly family income among our participants was about 294,000 Chilean pesos about (US$ 436 given the exchange rate at the time): only 12% had monthly incomes above 450,000 Chilean pesos (about US$ 672). We also asked the participants about their main activity in their TURF: 34% are fishers/crew members, 11% are divers, 21%, and 23% are seaweed collectors. The remaining 11% reported that their main activities are small scale aquaculture, housekeeping, administrators, and other.

Participants in the experiments perceive that poaching in their TURF is an important problem. The mean response on a scale from 1 to 10 from "poaching is an irrelevant problem" to "poaching is a very relevant problem" was 6.8. Most participants report that their organizations actively monitor their TURF and also the majority report that members of the TURF patrol their area. Participants perceive that the monitoring efforts of the National Fisheries Service or the Navy are not very effective. The mean response on a scale from 1 to 10 that patrolling by the government is "ineffective" to "very effective" was 4.1.

4. Results

We now present the results of our experiments. In Table 3a and 3b are the terminal periods for each group, as well as mean and predicted terminal periods by treatment for stage 1 and stage 2, respectively. Table 4 contains mean individual levels of harvests, revenue from

harvests, penalties received by outsiders in treatments T2 through T5, monitoring investments by insiders in T2 and T3, the winner vote on monitoring in T3 and T5, and mean net payoffs. In addition, we have included predicted values from Table 1 in Table 3 for comparison. Our discussion of the results proceeds by treatment.

Table 3-a: Terminal Periods

Terminal period for each group-Activity/Stage 1

Treatment	T1. Baseline		T2. Local Enforcement-No Voting-Low Fine		T3. Local Enforcement-No Voting-High Fine		T4. Local Enforcement- Voting-Low Fine		T5. Local Enforcement-Voting-High Fine	
Zones	Blue	Yellow	Blue	Yellow	Blue	Yellow	Blue	Yellow	Blue	Yellow
	9	14	11	12	7	7	6	4	8	8
	5	6	9	8	8	6	12	6	6	8
	8	10	5	3	7	3	6	4	4	7
	8	9	7	3	6	7	14	8	7	8
	6	7[±]	5	3	15	15	11	6	5	6
	6	7	5	5	15[±]	15[±]	7	3	9	10
	15	15	6	4	6	5	7	10	11	6
	9	9	11	3	4	4			15	6
Mean	8.3	9.6	7.4	5.1	8.5	7.8	9.0	5.9	8.1	7.4
Predicted	3[†]	6[†]	(15, 6)[††]	3[†]	(15, 6)[††]	3[††]	(15, 6)[††]	3[†]	(15, 6)[††]	3[†]

[±] indicates that enough stock remained in the zone for it to remain open beyond the 15th period.

[†] Value is under the assumption that individuals choose non-cooperative harvest strategies.

[††] The first value assumes that individuals in the group coordinate their harvests to maximize the total earnings of the group, while the second value assume that individuals choose non-cooperative harvest strategies.

Table 3-b: Terminal Periods

Terminal period for each group-Activity/Stage 2

Treatment	T1. Baseline		T2. Local Enforcement-No Voting-Low Fine		T3. Local Enforcement-No Voting-High Fine		T4. Local Enforcement- Voting-Low Fine		T5. Local Enforcement-Voting-High Fine	
Zones	Blue	Yellow	Blue	Yellow	Blue	Yellow	Blue	Yellow	Blue	Yellow
	5	11	4	6	8	8	6	5	14	7
	5	9	6	5	6	4	8	4	6	7
	7	9	4	3	8	4	5	4	4	5
	4	7	6	5	7	5	8	6	6	9
	6	7	5	3	15[±]	13	9	7	4	7
	4	6	5	6	15[±]	15[±]	7	5	10	8
	8	11	6	3	5	3	8	7	8	5
	10	11	7	8	4[±]	4			15	15
Mean	6.1	8.9	5.4	4.9	8.5	7.0	7.3	5.4	8.4	7.9
Predicted	3[†]	6[†]	(15, 6)[††]	3[†]	(15, 6)[††]	3[††]	(15, 6)[††]	3[†]	(15, 6)[††]	3[†]

[±] indicates that enough stock remained in the zone for it to remain open beyond the 15th period.

[†] Value is under the assumption that individuals choose non-cooperative harvest strategies.

[††] The first value assumes that individuals in the group coordinate their harvests to maximize the total earnings of the group, while the second value assume that individuals choose non-cooperative harvest strategies.

Table 4: Mean individual outcomes and predictions (average over the two stages).

Treatment	Insiders	Outsiders in Insiders' Zone	Outsiders in Outsiders' Zone	Total Outsiders	
1. Baseline	30.8			68.4	Harvest
	18††	18††	18††	36††	Predicted Harvest
	6,125.5			13,687.5	Earnings
	3,600††	3,600††	3,600††	7,200††	Predicted Earnings
2. Local Enf-No Voting-Low Fine	45.6			41.1	Harvest
	(54.3, 36) †	6††	18††	24††	Predicted Harvest
	9,120.8			8,220.8	Harvest Revenue
	(10860, 7200) †	1200††	3600††	4800††	Predicted Revenue
					Penalty Received
	-	0††	-	0††	Predicted Penalties
	702.1				Monitor Costs Paid
	(2800, 1000) †	-	-	-	Predicted Monitoring Costs
	8,418.7				Earnigs
	(8060, 6200) †	1200††	3600††	4800††	Predicted Earnings
3. Local Enf-No Voting-High Fine	38.3			15.5	Harvest
	(54.3, 36) †	6††	18††	24††	Predicted Harvest
	7,667.7			3,108.3	Harvest Revenue
	(10860, 7200) †	1200††	3600††	4800††	Predicted Revenue
					Penalty Received
	-	0††	-	0††	Predicted Penalties
	1,866.7				Monitor Costs Paid
	(1400, 500) †	-	-	-	Predicted Monitor Costs
	5,801.0				Earnings
	(9460, 6700) †	1200††	3600††	4800††	Predicted Earnings

Treatment	Insiders	Outsiders in Insiders' Zone	Outsiders in Outsiders' Zone	Total Outsiders	
4. Local Enf-Voting-Low Fine	39.2			31.5	Harvest
	(54.3, 36) †	6††	18††	24††	Predicted Harvest
	7,833.3			6,292.9	Harvest Revenue
	(10860, 7200) †	1200††	3600††	4800††	Predicted Revenue
					Penalty Received
	-	0††	-	0††	Predicted Penalties
	1,307.1				Monitor Costs Paid
	(2800, 1000) †	-	-	-	Predicted Monitor Costs
	6,526.1				Earnings
	(8060, 6200) †	1200††	3600††	4800††	Predicted Earnings
5. Local Enf-Voting-High Fine	31.6			24.6	Harvest
	(54.3, 36) †	6††	18††	24††	Predicted Harvest
	6,316.7			4,925.0	Harvest Revenue
	(10860, 7200) †	1200††	3600††	4800††	Predicted Revenue
					Penalty Received
	-	0††	-	0††	Predicted Penalties
	1,256.3				Monitor Costs Paid
	(1400, 500) †	-	-	-	Predicted Monitor Costs
	5,060.4				Earnings
	(9460, 6700) †	1200††	3600††	4800††	Predicted Earnings

† The first value assumes that individuals in the group coordinate their harvests to maximize the total earnings of the group, while the second value assume that individuals choose non-cooperative harvest strategies.

†† Value is under the assumption that individuals choose non-cooperative harvest strategies.

4.1 Baseline-Poaching-No enforcement

Given undeterred poaching, harvests revenue for the insiders were lower than all the other treatments. In fact, note from Table 4 that average harvest revenue were nearly 33% lower in the Baseline-Poaching treatment than in the Local enforcement-no voting-low penalty treatment (T2). The lower difference is observed when comparing the baseline treatment with the Local Enforcement-with voting-high penalty treatment (T5). In this case, the average revenue is only approximately 4% lower in the Baseline treatment. Moreover, mean harvests for insider TURF were higher than the predicted non-cooperative outcomes.

The harvest revenue for the outsiders were significantly higher in the Baseline-Poaching treatment than in any other treatment. Using the results in Table 4, mean revenue were 13,687.5 pesos for the TURF outsiders under the Baseline, and only 8,220, 3,108, 6,292, and 4,925 pesos under T2, T3, T4 and T5, respectively.

Table 3 reveals that terminal periods under Baseline treatment were significantly higher than predicted. However, the difference was reduced during the second stage. Mean terminal dates for the blue zone was about double than predicted. The outsiders maintained the yellow zone for longer than the insiders maintained the blue zone.

4.2 Local Enforcement-Low Fine

In the Local Enforcement treatment insider groups are motivated to completely deter the outsiders from poaching in the blue zone. Presuming that risk neutral outsiders are deterred if the expected marginal sanction for poaching is greater than the marginal value of poaching, and given that the per unit fine for poaching under low fine is 650 pesos and the value of a loco is 200 pesos, insiders would have to invest enough to make the monitoring probability exceed 31% to deter the outsiders.

However, Table 4 shows that under T2 and under T4 the insider TURF members were able to partially deter outsiders. It is clear that, on average, the insider groups were better off

in terms of earnings under T2 and T4 as compared with the Baseline treatment with uncontrolled poaching.

The insiders invested significantly more in monitoring under T4 than under T2. However, the insiders were able to keep the insiders zone open for a longer period in T4 than in T2.

4.3 Local Enforcement-High Fine

Under these treatments, and presuming that risk neutral outsiders are deterred if the expected marginal sanction for poaching is greater than the marginal value of poaching, and given that the per unit fine for poaching under low fine is 1,300 pesos and the value of a loco is 200 pesos, insiders would have to invest enough to make the monitoring probability exceed 16% to deter the outsiders. We observe that the voting mechanism did not work with the high penalty (T5 vs. T3). In fact, the voting mechanism did result in a lower monitoring effort by the blue group. It is possible to notice that the difference in payoffs for insiders between these treatments is due to the difference observed in monitoring investment.

5. Conclusion

Unrestricted poaching, that is, poaching without the likelihood of a sanction, affected the insiders' ability to maintain their zone for the entire 15 periods, and their ability to coordinate their harvests to extract a part of the available surplus. The insiders maintained their stocks for longer than the Nash predictions, harvests and earnings by insiders and outsiders were significantly different from the Nash predictions.

One pattern that emerges is that for most of the treatments, perhaps with the exception of T5, fishing zones are closed earlier under activity 2 as compared with activity 1. Second, none of the treatment suggests that fishers were able to sustain the activities near the end. In fact, they were not even close; there are few group exceptions under some treatments. Third,

giving the insiders the opportunity to invest in their own monitoring did change the result from the Baseline. Specifically, the voting mechanism seems to have helped to contribute on investment on monitoring when the penalty was low (T4 vs. T2), but did not work with the high penalty (T5 vs. T3). In fact, with high penalty, the voting mechanism did result in a lower monitoring effort by the blue group.

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Appendix: Demonstrations of benchmark equilibria in Table 1.

In this appendix we demonstrate the equilibrium benchmarks that presented in Table 1.

Recall the fundamentals of stocks and harvesters. The initial insider stock is 100 units, and the stock is 'depleted' if it falls below the critical level of 40 units. The initial outsider stock is 55 units, and the stock is depleted if it falls below 20 units. The growth rate is 10% (in discrete units) in both zones. There are three harvesters in each zone, and harvest capacity is six units per harvester per period. There are 15 periods. Below we present group-level harvests. In Table 1 are symmetric individual harvests.

T1. Baseline

In this treatment the outsiders can freely poach from the insider zone. In this case there is no incentive for the insiders to attempt to conserve the resource. Therefore, they harvest at capacity in their zone until the stock is depleted. The outsiders also harvest at capacity in every round, but they poach in the insider zone until it is depleted, and then they harvest in the outside zone until it is depleted.

	Insider non-cooperative harvest of inside zone		Outsider non-cooperative harvest of outside zone	
Period	Inside stock at start of period	Aggregate harvest in inside zone during period	Outside stock at start of period	Aggregate harvest in outside zone during period
1	100	18+18 (outsiders)	55	0
2	64+6=70	18+18 (outsiders)	55	0
3	34+3=37	18+18 (outsiders)	55	0
4	1 - stock is depleted	Total harvest by insiders = 54	55	18
5			37+3=40	18
6			22+2=24	18
7			6, stock is depleted	Total = 108 (54 in inside zone, 54 in outside zone)
	Inside zone is depleted after 3 periods. Payoff per insider is 18 units.		Outside zone is depleted after 6 periods. Outsiders harvest an extra 54 units in the first three periods in the inside zone, then move to their zone in the 4rd period and harvest additional 54 units over the next three periods.	

To show that it is better for the outsiders to harvest in the inside zone and then in the outside zone instead of the reverse, the following is a demonstration of non-cooperative harvests if the outsiders deplete their zone first before moving to the inside zone. Notice that total harvests of the outsiders are lower with this strategy.

	Insider noncooperative harvest of inside zone		Outsider noncooperative harvest of outside zone	
Period	Inside stock at start of period	Aggregate harvest in inside zone during period	Outside stock at start of period	Aggregate harvest in outside zone during period
1	100	18	55	18
2	82+8=90	18	37+3=40	18
3	72+7=79	18	22+2=24	18

4	61+6=67	18+18 (outsiders)	6-stock is depleted	Outsiders move harvest to inside zone
5	31-stock is depleted	Total harvest by insiders = 72		Total harvest by outsiders = 72
	Inside zone is depleted after 4 periods.		Outside zone is depleted after 3 periods. Outsiders harvest an extra 18 units in the inside zone in the 4th period.	

T2, T3, T4, T5. Local enforcement

Whether the insiders coordinate their harvest to maximize their joint payoffs or not, they are better off deterring the outsiders from poaching. Hence, in Table 1 we present equilibrium benchmarks for when the insiders coordinate their harvests and when they do not, given that the outsiders are deterred.

Note in the following that there are 52 units of the inside stock available at the start of period fifteen. Hence, both groups can harvest at capacity in that period. There is no incentive for the insiders to deter poaching in the last period—they harvest to capacity and any remaining stock has no value after the final period is over. Since the outsiders know that insiders will not try to defend their zone in the last period, they will poach at capacity in the last period.

Cooperative benchmark

	Insider cooperative harvest of inside zone		Outsider non-cooperative harvest of outside zone	
Period	Inside stock at start of period	Aggregate harvest in inside zone during period	Outside stock at start of period	Aggregate harvest in outside zone during period
1	100	10	55	18
2	90+9=99	9	37+3=40	18
3	90+9=99	9	22+2=24	18
4	90+9=99	9	6-stock is depleted	
5	90+9=99	9		
6	90+9=99	9		
7	90+9=99	9		
8	90+9=99	9		
9	90+9=99	9		
10	90+9=99	9		
11	90+9=99	18		
12	81+8=89	18		
13	71+7=78	18		
14	60+6=66	18		
15	48+4=52	18 + 18(outsiders)		
	16 units at end of round so stock is depleted.	Total harvest= 163.		Total harvest by outsiders = 72, 54 in their zone and 18 in the insider zone.

The non-cooperative benchmark is below. Here the insiders are not able to coordinate their harvests, but they can coordinate their investment in monitoring to deter the outsiders. Note that insiders harvest to capacity in the fourth round, even if they don't deter the outsiders, and the stock is depleted in this round whether the outsiders are deterred or not. Therefore, the insiders will not defend their resource in the fourth period

Non-cooperative benchmark

	Insider cooperative harvest of inside zone		Outsider non-cooperative harvest of outside zone	
Period	Inside stock at start of period	Aggregate harvest in inside zone during period	Outside stock at start of period	Aggregate harvest in outside zone during period
1	100	18	55	18
2	82+8=90	18	37+3=40	18
3	72+7=79	18	22+2=24	18
4	61+6=67	18	6-outside stock is depleted	
5	49+4=53	18		
6	35+3=38	18+18 outsiders		
7	2-stock is depleted	Total harvest= 108.		Total harvest by outsiders = 72, 54 in their zone and 18 in the insider zone.