Economic behavior of fishers under climate-related uncertainty: results from field experiments in Mexico and Colombia

Article

Accepted Version

Arroyo Mina, J. S., Revollo Fernández, D. A., Aguilar Ibarra, A. and Georgantzis, N. (2016) Economic behavior of fishers under climate-related uncertainty: results from field experiments in Mexico and Colombia. Fisheries Research, 183. pp. 304-317. ISSN 0165-7836 doi: https://doi.org/10.1016/j.fishres.2016.05.020 Available at http://centaur.reading.ac.uk/66128/

Economic behavior of fishers under climate-related uncertainty: results from field experiments in Mexico and Colombia

Abstract

This paper presents the results of economic experiments run among fishermen from the Mexican and Colombian Pacific. The experimental design aims at studying behavior under uncertainty concerning the possible effects of climate change on fisheries. We find that subjects' risk-aversion diminishes the level of catches and changes fishing practices (e.g. adopting marine reserves), provided that fishermen have *ex ante* information on possible climatic consequences. Furthermore, social preferences (e.g. for cooperation and reciprocity) also play an important role regarding extraction from common-pool resources. Other factors, such as income, gender and religion are also found to have some influence. These results have important implications for adaptation actions and the management of coastal fisheries.

1. Introduction

The livelihoods and regional development of millions of people in developing countries depend to a large extent on the fishing sector. For example, several Asian and Latin American countries are among the major fishing nations in the world and their populations receive up to 20% of their protein intake from fish products (FAO, 2012). Furthermore fisheries and aquaculture assure the livelihoods of 10-12 percent of the world's population (FAO, 2014). Nevertheless, although global fish catch has stabilized during the last decades, fish stocks have been depleted in a number of regions worldwide (Worm et al., 2006). A direct consequence of this situation is the risk on food security in a number of regions in the developing world (Smith et al., 2011; Srinivasan et al., 2010).

A changing climate is an additional factor of risk for a number of fisheries, especially for livelihoods in poorer regions (Badjeck et al., 2010). Furthermore, it is well acknowledged that the vulnerability of fishing livelihoods toward climate change impacts will be enhanced by poor fishery management (Brander, 2007; Allison et al., 2009; McIlgorm et al., 2010).

Thus, understanding stakeholders' decisions under these risky scenarios is of paramount importance for adaptation to climate change (Gowdy, 2008). Experimental economics provides a powerful tool for analyzing stakeholders behavior when dealing with common-pool resources (Cardenas and Ostrom, 2004) and with risky and uncertain situations in general (Sabater-Grande and Georgantzis, 2002; McAllister et al., 2011; Hasson et al., 2012).

Decisions in fisheries, such as the level of harvesting, or whether or not to comply with regulations, depend on a number of factors, chiefly fishermen's preferences. Among the preferences which are relevant in fishing decisions, fishermen's attitudes toward risks entailed in climate hazards play a major role in their actual behavior(Smith & Wilen 2005; Eggert & Lokina 2007; Nguyen & Leung 2009; Brick et al. 2011).Furthermore, fisheries, is a typical common-pool resource extraction activity. In such a context, fishers face the dilemma of individual against collective benefits. Experimental economics has proven to be a useful tool to analyze decision-makers' risk attitudes and other-regarding preferences in the laboratory or in the field. Then, attitudes elicited in an experiment reflect home-grown values which have been developed during a subject's social or professional interaction experiences. Therefore, experimental methods can be used to capture attitudes and preferences which both affect and are affected by the subject's real world activity. In this sense, the experiments with populations of fishermen will capture how this specific subject pool will behave in a simulated context resembling their real-life decision-making environment and, consequently, real-world fishery management (Moreno-Sanchez & Maldonado 2009; Revollo & Ibarra 2014; Revollo et al. 2016).

In spite of the regional importance of the fisheries sector in Latin America (Thorpe and Bennett, 2001), few studies in Latin America have used experimental economics for analyzing fishers' behavior in controlled economic environments (for more detail see Table I). Even fewer experimental studies have been carried out on adaptation to climate change (e.g. Hasson et al., 2010; Hasson et al., 2012). In the case of Latin America, Bernal et al. (2013) analyzed the adaptation strategies of farmers when confronted to water scarcity due to climate change. Although game theory has been used for studying fisheries and climate change (Bailey et al., 2010), as far as we know, no studies have been published on fisheries' adaptation to climate change using experimental methodology. The aim of this paper is to report results from field experiments on behavior toward climate change among fishermen. We present two studies in Latin America: one deals with the artisanal fisheries of Tribugá Gulf, Colombia; and the other deals with the abalone fishery, off Baja Peninsula, Mexico. We present both cases in detail in the next two sections. In both experiments, real monetary rewards were used to incentivize the decisions made by subjects in a controlled economic environment. In both experiments, the decision-making context involves extraction decisions from a common-pool resource under scenarios of external environmental change, framed as a risk affecting the returns of the extraction process. This paper is divided into five sections: the introduction is followed by materials and methods, results, discussion, and conclusions.

Table I. Summary of field experiments with fisheries in Latin America

2. Methods

2.1. Local context and study areas

2.1.1. The abalone fishery off Natividad Island, Baja Peninsula, Mexico

The abalone fishery off Baja, is one of the most valued fisheries in Mexico (25th place). In 2012, the value of a ton was almost 13,000 USD (CONAPESCA, 2012). While abalone in Mexico is mostly an export commodity, it indirectly contributes to domestic welfare and food security, since earned money is used to buy local food. It is exploited by 22 fishing cooperatives and generates about 20,000 jobs (both direct and indirect). Abalone catches have diminished to about 10% of the average volume harvested during the 1950s (Revollo and Saenz-Arroyo, 2012). Possible explanations for this sharp decrease are: over-exploitation, environmental changes, illegal harvesting, or a combination of these. The fact is that global climatic change is expected to have more impact on vulnerable fisheries. Indeed, ocean acidification will directly affect species with calcium carbonate skeletons (Perry, 2011), such as abalone. Furthermore, there is evidence that an increasing temperature and decreasing dissolved oxygen (i.e. hypoxia) in coastal ecosystems, due to carbon dioxide absorbed by marine waters (Roessig et al., 2004), provokes higher mortality rates in marine invertebrates such as abalones (e.g. Guzman del Proo et al., 2003).

We present the case of the fishing cooperative that operates in Natividad Island (27^{O}51´09´´N/115^{O}10´09´´O), located in mid-Baja Peninsula (Figure 1). Both the fishing cooperative and the NGO Comunidad y Biodiversidad (COBI A.C.) have implemented a pilot program of marine reserves around Natividad Island (Micheli et al., 2012). Under this context, we designed a field experiment with the inhabitants of Natividad Island in order to study the determinants of their behavior in a harvesting experiment, framed as a common-pool resource in the presence of a changing climate.

Figure 1. Natividad Island, Baja Peninsula, Mexico

2.1.2. The Tribugá Gulf fishery, Colombia

The Tribugá Gulf is located in the northernmost Colombian Pacific, Province of Chocó (N5°30'06''/W77°16'09''), dominated by a tropical rain forest climate, with 28°C mean annual temperature (Figure 2). The Tribugá Gulf fishery sector is characterized by artisanal fisheries that mainly use longlines (hooks) and fishing nets. The target species are snapper, Pacific sierra, seashells (locally known as "piangua") and prawns. In this area, artisanal fishing is the main livelihood for most coastal communities, but in recent years fish stocks have been declining in both capture volume and catch size. Caicedo et al. (2008) reckon that the increase in fishing effort, the use of unconventional fishing practices and climate change effects are among the main causes of this decline.

In this case, the livelihoods of coastal communities are vulnerable to climate change effects due to the lack of proper fisheries management, lack of both basic services (electricity, water, sewage) and social security, as well as geographical isolation from the rest of the country. Such a situation leads to a poverty trap, as demonstrated by Rebellón (2004), using an adapted version of the model of Brander and Taylor (1998). It is shown there, that more effort by the families in the Colombian Pacific generates higher levels of income by over-fishing. Thus, it is interesting to assess the behavior of fishermen under this vulnerability context, looking at possible improvements in fishery management in the region.

Lopez et al. (2004), Cardenas (2008), and Moreno and Maldonado (2009) have analyzed the behavior of stakeholders in Colombian fisheries by means of experimental economics. We present the results of a fishing-game-under-uncertainty experiment, which is adapted from Ostrom et al. (1994), Cardenas and Ostrom (2004) and Sabater-Grande and Georgantzís (2002), in order to assess the decision-making of artisanal fishers, under uncertainty caused by potentially changing climate conditions in the Gulf of Tribugá.

Figure 2. Tribugá Gulf, Colombia

2.2. Experimental design

Due to specific contexts and logistics for each case, we adapted experimental designs for each site. Thus, econometric methods (see below) somehow differ in both approach and variables. In spite of these differences, the main objective of this study remains the same in both cases[1]. We therefore reckon that results, are nevertheless comparable for drawing valid conclusions.

2.2.1. Natividad Island, Mexico

Field experiments were carried out at Natividad Island, and included both men and women older than 16 years. A public invitation was made to the whole population. It was attended by 37 people (N=37, 26 men and 11 women), who represented approximately 15% of the total adult population in the island with an average monthly income of $630 USD. For the baseline treatment (BL), all participants played ten rounds. In the first five (rounds 1-5), they had to decide on catches from one to ten resource units, knowing that their monetary rewards (in accumulated points converted to real currency at the end of the session) would depend on individual and group decisions.[2] In the setup implemented, Nash equilibrium is achieved by harvesting ten units of resource, while the social optimum is obtained with one harvested unit per round. Participants are told that the resource recovery rate was 50% for each round.

For the second sub-session, (rounds 6-10), participants were told that the recovery rate would change for the rest of the game and that the change would depend on whether a random climatic variation (e.g. El Niño Southern Oscillation -ENSO) would be present in that round[3]. Besides, they were told to choose between either implementing a marine reserve or not,

[1] Payoffs tables and experimental protocols were tested in both Mexico and Colombia with pilot experiments. These were carried out with both students and fisheries-related colleagues for improving the experimental design before being applied in the field. This is a standard guideline in experimental economics which warrants unbiased decision-making among players. Please refer to payoffs tables and experimental protocols in the Appendix.

[2] In the Appendix A, we provide details on the experimental economics: decision sheets and the table of scores.

[3] The stochastic component (i.e. treatment on fisheries uncertainty due to climate change effects) was not included in the baseline treatment during the first rounds of the experiment (rounds 1-5 in the Mexican experiment) in order to have a reference for comparison among treatments. Otherwise, we would not be able to disentangle the effects from climate change uncertainty from the "normal" conditions of fishermen's decision-making.

according to the scenarios shown in Table II. This decision to implement or not a marine reserve is maintained for the remaining rounds and cannot change in subsequent rounds. The decision is made before starting round six and held until the end. Participants were then asked to form two groups for the rest of the game: one including those choosing a marine reserve (N=30) and another including those deciding not to implement the reserve (N=7). The last five rounds follow the same logic as the first five: participants' profits depend on both individual and group extractions. Communication among the participants was forbidden, in all cases, before, after, or during the harvesting decisions.

Table II. Scenarios shown to participants in the climatic change / marine reserves at Natividad Island, Baja Peninsula, Mexico

Payoffs were calculated following Cardenas and Ramos (2006), considering that fisheries resources should be considered as common-pool resources, because usually the individual interest is in contradiction of the collective interest. Hence, subject *i*'s earnings in round *t* are given by:

$$\pi_{it} = (Price \cdot X_i) + \left(Price \cdot \frac{1}{N} \cdot Recovery\ Rate \cdot \left(maxQuantity - \sum_i X_i\right)\right)$$

Where:

X_i is harvesting level of participant *i* whose values range from one to ten and *Price* denotes the price of the common-pool resource. *N* is the number of participants in each group and *Recovery Rate* is the rate at which the remaining fish stock can regenerate at the end of each harvesting period. This depends on the scenario, as shown on Table II. *Max Quantity* is the maximum level of fish stock that is recovered in each round and the sum of all extraction levels, *Xi* correspond to the fish stock level actually harvested at the end of each round.

It is worth noting that a subject's payoff increases in own individual extraction but decreases in the total amount harvested, indicating the existence of horizontal externality among individual decision-makers in the extraction game. In other words, the benefits of each participant depend on both individual and group extractions (Ostrom et al., 1994). Hence, the collective benefits are assumed to be the asset value of the natural resource (i.e. the value of a fish left alive in the sea).

2.2.2. Tribugá Gulf, Colombia

Before explaining the experimental design applied in the Gulf of Tribugá, Colombia, is important to note that this design is different from that applied in Natividad Island (Mexico), due to differences in fisheries management in both areas and the type of fishing practices. Natividad Island (Mexico), abalone fishing (deep sea fishing) is performed, whose average prices generated a high level of income for fishermen in the area and therefore there fishing cooperatives that manage a vigorous productive and industrial infrastructure, including support research laboratories aquaculture. Instead, in the Gulf of Tribugá (Colombia), shrimp, prawns, snapper or Sierra (net and hook fishing) is performed, the average price does not allow the angler to reach the minimum level of monthly income to survive, situation which does not facilitate fisheries management in the area.

Field experiments were carried out in Nuquí, Coquí, Panguí, Joví, Arusí, Termales, El Valle, Jurubirá and Tribugá, coastal communities in the Tribugá Gulf, Province of Chocó, Colombia, including both men and women older than 16 years. A public invitation was made to the whole population. It was attended by 160 people (142 men and 18 women), who represented approximately 8% of the total adult population in the Gulf, with an average monthly income of $220 USD. We formed groups of five people and all groups were administered the same experiment with the same treatments. Before starting, an explanation of the game context, its rules, and monetary retributions were explained to all participants.[4] They were told that their individual earnings (in accumulated point convertible in real currency at the end of the session) would depend on both their individual and group decisions.

They made decisions for 20 rounds of which the first ten (rounds 1-10) corresponded to the baseline treatment. For the last ten rounds (rounds 11-20), participants were informed that the recovery rate would change for the rest of the session, depending on the occurrence of a random climatic variation (e.g. El Niño Southern Oscillation -ENSO). Besides, they were asked to choose between either implementing a marine reserve or not[5]. Thus, within each group, each

[4] In Appendix B, we provide details on the experimental economics: decision sheets and the table of scores.

[5] The stochastic component (i.e. treatment on fisheries uncertainty due to climate change effects) was not included in the baseline treatment during the first rounds of the experiment (rounds 1-10 in the Colombian experiment) in order to

player must choose, individually and confidentially, whether to play 11-20 rounds under an insurance (i.e. with a marine reserve) or not (i.e. open-access fishing without marine reserve). The last 10 rounds follow the same logic of the baseline treatment, and the level of earnings depends still on both individual and group extractions. Furthermore, two more treatments were implemented during the experiment:

a) Communication treatment (n=80): all five participants within each group can communicate for five minutes before rounds 11-20, so they can share their experiences and learn from rounds 1-10 in order to set up a harvesting strategy for the rest of the game.

b) Voluntary enforcement treatment (n=80): the monitor explains the negative effects of overfishing and therefore suggests a minimum level of extraction (one unit) in each round. It is also noted that harvesting over this recommended level will be enforced. However, participants can vote on whether each player's harvesting levels should be inspected in each round. If the inspection mechanism is voted, participants harvesting above the socially optimal unit, are fined with minus 100 points for each additional unit extracted from the common pool.

Both the experimental designs and hence, the models, presented differences between both countries in order to adjust for local and institutional realities. Thus, the theoretical model for the economic experiment applied in Colombia is presented as follows.

Payoffs were calculated following Cárdenas (2010)[6], with a model that simulates the social dilemma of Common Pool Resource (CPR) Hence, the individual harvesting level that maximizes the private benefit of each participant (x_i); in other words, the agent's objective function is defined by his own effort x_i, and aggregate efforts by other agents, $\sum x_j$. Formally, the private profit Y_i of the agent is given by the expression:

$$Y_i = ax_i - \frac{1}{2}bx_i^2 + \phi\left(ne - \sum_{j=1}^{N} x_j\right)$$

have a reference for comparison among treatments. Otherwise, we would not be able to disentangle the effects from climate change uncertainty from the "normal" conditions of fishermen's decision-making.

[6] The theoretical model implemented is adapted from Cardenas (2010) and extensively described in Georgantzis et al. (2013).

where, a is the income from each harvested unit, b is the decreasing marginal parameter , φ is the externality cost due to stock depletion and *n* is the number of players φ represents the cost that each agent i incurs due to the externality emerging from the aggregate extraction by all other agents. The Nash solution obtained is given by:

$$x_i^N = \frac{a - n\varphi}{b}$$

Cárdenas (2010) suggests that a=60, b=5, φ = 20 and that the minimum harvesting quantity = 1. It follows that in the Nash equilibrium,

$$x_i^N = \frac{a - n\varphi}{b} = \frac{60 - 20}{5} = 8$$

Thus, a player maximizing own profits, and taking others' individual extraction levels as given, harvests eight units in each round. For this reason, this model, as suggested Ostrom, Garner and Walker (1994), shows that this situation will result in a social dilemma associated with over-exploitation of CPR. In order to incorporate the possibility of adopting a marine reserve insurance against climate change, we follow Sabater-Grande and Georgantzis (2002) and Georgantzís et al. (2009). It is important to note that this is a type of economic experiment, which studies the behavior of fishers (Tribugá Gulf, Colombia) confronted to risky economic decisions. For this reason, the experiment implements a design where fishermen can decide whether or not get assurance[7] against unexpected events (e.g. climatic change) that possibly, affects fisheries and consequently social welfare.

Following this approach, in rounds 11-20 players are faced with a lottery *(q, X)* giving a payoff *X* with a probability *q*. The scheme is designed to compensate the risk of obtaining *X=0* (with a probability of *1-q*) with a risk premium which is an increasing (linear) function of the probability of the unfavorable outcome, as implied in:

$$q \cdot X(q) = c + (1 - q) \cdot r \rightarrow X(q) = \frac{c + (1 - q) \cdot r}{q} \qquad \textbf{(4)}$$

The experiment assumes a continuum of lotteries *(c, r)*, that for the fishing game under uncertainty is represented by a continuum of Nash Equilibria, compensating riskier options with an increase in the expected payoff; in other words, if the player decides not to buy the insurance

[7] The assurance is associated with the meaning of a protected area or marine reserve thanks to the application of economic experiments in Colombia, 2015: http://www.eltiempo.com/estilo-de-vida/ciencia/nueva-area-marina-golfo-de-tribuga-cabo-corrientes/15474539

and fishing is adversely affected by climate change, the expected payoff for the player will be low or even negative. In summary, the experiment shows that fishermen may have negative payments if their decision was not to get insurance (i.e. a protected marine reserve) in the presence of unexpected events (i.e. climate variations) that affect fishing. This experimental design is consistent with the suggestion by Micheli F, Saenz-Arroyo A, Greenley A, Vazquez L, Espinoza Montes JA, Rossetto M, et al. (2012), who successfully demonstrate that under future scenarios of frequent and/or persistent disturbance, increasing resilience to climatic impacts through networks of marine reserves may be the most effective tool that local communities and nations worldwide have to combat the negative impacts of global climate change on marine ecosystems and livelihoods.

3. Results

3.1. Natividad Island, Baja Peninsula, Mexico

In the first stage (baseline treatment) of the experiment, the average catch was 4.6 units of the resource. In the second stage, where a treatment is applied under climate change uncertainty, the average catches decrease (3.3 units). Interestingly, when analyzing the evolution of the average catches before and after the implementation of marine reserves, along with the presence of the hypoxia phenomenon, it is observed that the level of catches for the whole group (both with and without reserves), is reduced in about 38%. In contrast, when the experiment treatment change, the group without marine reserves reduced their harvesting level in 20% (p-value<0.01), while the group with marine reserves reduced catches in 46% (p-value<0.01). Hence, both groups, after learning the possibility of a climatic event, decided to reduced their average catch (Figure 3).

About 75% of participants decided to implement a marine reserve during the second stage of the experiment. Besides, when asked the percentage that they would devote to creating marine reserve with or without a scenario of climatic variability (i.e. hypoxia), they responded that a 41-50% of the fishing ground would be converted into marine reserve in the presence of hypoxic conditions, and 21-30% otherwise.

Figure 3. Average harvesting levels for the baseline (left panel) and climatic variability (right panel) treatments (p-value < 0.01). ANOVA to test whether the normality and hetersokedasticity

assumptions are accepted. It is verified that harvesting levels are significantly different across treatments.

3.2. The Tribugá Gulf, Colombia

The results show that the average extraction for 11-20 rounds (control treatments communication and voluntary-enforcement) in context of climate change uncertainty, are always lower compared to those obtained in rounds 1-10 (baseline). Particularly, the results show an average decrease from 4.55 extraction units (baseline treatment) to 3.55 units under the communication treatment, and an even further decrease to 2.55 units under the voluntary-enforcement treatment (Figure 4) (p-value<0.05).

The results suggest that the average extraction decisions of fishermen, who participated in the common-pool resource game, are clearly influenced by the treatments as evidenced by Cardenas et al. (2002), Cardenas et al. (2003), Cardenas and Ostrom (2004), Cardenas (2010), Lopez et al. (2009), Maldonado and Moreno (2010), Ostrom et al. (1994), Ostrom (2005) and Velez et al. (2008).

In other words, to interpret the behavior of participants during 11-20 rounds, under the inclusion of treatments (communication and regulation) and the possibility that fishing is affected by unexpected events, such presence of natural changes (water heating, migration of species, seasonality of the resource), or defection in commitments set by the community, the results show that the extraction levels fall.

Additionally, most participants (152 out of 160) chose to adopt a marine reserve as insurance against uncertain climatic variation in each round (rounds 11-20).

Figure 4. Average harvesting levels for the baseline (left panel), communication and voluntary-enforcement (right panel) treatments (p-value < 0.05). ANOVA to test whether the normality and heterocedasticity assumptions are accepted. It is verified that harvesting levels are significantly different across treatments.

3.3. Econometric estimation

3.3.1. Natividad Island[8]

An econometric model was applied for assessing the socioeconomic and social capital variables that influence decisions on common-pool resources and climatic variability among islanders at Natividad Island. Table III shows the variables introduced in our model. The model takes the form:

$$CATCH_{i,t+1} = \beta_0 + \beta_1 \cdot CATCHI_{i,t} + \beta_2 \cdot CATCHJ_{i,t} + \beta_3 \cdot POINTS_{i,t} + \beta_4 \cdot CLIMATE_{t+1} + \beta_5 \cdot TREAT_t + \beta_6 \cdot GENDER_i + \beta_7 \cdot FISH_i + \beta_8 \cdot RESERVE_{i,t} + V_i$$

The dependent variable is harvesting level in the reference period, while all other independent variables are introduced with a lag, assuming that what is decided in a given period depends on strategies and feedback from past rounds, except climatic variations.

Table III. Variables introduced in the econometric model

Table IV shows the results of the econometric estimation. Among the statistically significant variables (p<0.1), the ones that measure the harvesting behavior of participant *i* (*CATCHI*) and participant j (*CATCHJ*) reveal that, for each fish stock unit away from the social optimum in the previous round, participant *i* will harvest about 0.53 additional units of the resource stock. Furthermore, for every unit extracted by other players away from the social optimum, participant *i* will harvest 0.48 units in the next round. Another significant variable was *GENDER*, indicating that women's extractions are 0.70 units lower than men's. Besides, changing treatment from a baseline to a random climatic event (*TREAT*) in the following round, leads to reductions of 0.44 fish stock units under a marine reserve treatment, while this reduction is of

[8] We applied a balanced panel data model since we had both cross-section information (i.e. harvesting levels of participants in each round) and a time series (ten rounds). After comparing the estimates of two panel- data methods (fixed and random effects) and with the results of a Hausmman test, we decided to use a random-effects panel-data model. We decided to use a random-effects model since it included variables that do not change within individuals, but that do change among individuals. Breusch-Pagan, Hausman and F-tests were performed. Besides, auto-correlation and heterocedasticity tests were used in order to choose the best model specification (for more detail see: Revollo, 2012).

0.22 without a marine reserve. The possibility of climatic variations (*CLIMATE*) induced participants to lower their extraction in 0.24 of resource units.

Table IV. Econometric estimations for explaining the individual harvesting decisions (CATCH) of participants in the Natividad Island experiment

3.3.2. Tribugá Gulf, Colombia[9]

An econometric model was applied for assessing the decision-making of artisanal fishers, under uncertainty caused by potential climate change conditions in the Gulf of Tribugá. Table V shows the variables introduced in our model. The model takes the form:

$$CATCH_{i,t+1} = \beta_0 + \beta_1 \cdot EXPER_i + \beta_2 \cdot CIVIL_i + \beta_3 \cdot INCOME_i + \beta_4 \cdot SCHOOL_i + \beta_5 \cdot RELIGION_i + \beta_6 \cdot GENDER_i + \beta_7 \cdot CLIMATE_{t+1} + V_i$$

Table V. Variables introduced in the econometric model

Table VI shows the results of the econometric estimation. So, for the variable EXPERIENCE, it suggests that more years of fishing experience do not necessarily lead to decreases in the levels of extraction by the fisher (p-value<0.01). Hence, the average behavior of fishermen remains invariant to their experience. Furthermore, the negative sign of the SCHOOL variable indicates that a higher education level implies a greater commitment to sustainable fishing decisions (p-value<0.01). With respect to income, the result suggests that for every percentage point increase in the level of income resulting from fishing activities, extraction decisions are increased by 5.7% (p-value<0.01). AGE was not statistically significant.

[9] Like in the empirical evidence of Natividad Island, we applied a balanced panel data model since we had both cross-section information (i.e. harvesting levels of participants in each round) and a time series (twenty rounds). After comparing the estimates of two panel-data methods (fixed and random effects) and with the results of a Hausmman test, we decided to use a random-effects panel-data model. We decided to use a random-effects model since it included variables that do not change within individuals, but that do change among individuals. Furthermore, following the recommendations of Baltagi (2008) and Hsiao (2003), the estimates are correct, as there is no autocorrelation, nor hetersokedasticity (for more detail see: Arroyo, 2013).

Now, consider the change in the second part of the session with respect to baseline, introducing uncertainty in the decision-making context and two treatments (communication and enforcement), this then affects the levels of captures in rounds 11-20. In fact, the fishermen reduce their levels of catch by 0.08 of common-pool resource units. Particularly, as explained above, there is a clear effect of communication and enforcement on catch decisions.

Table VI. Econometric estimations for explaining the individual harvesting decisions (CATCH) of participants in the Tribugá Gulf experiment

4. Discussion

We provide evidence of behavior in controlled environments by Mexican and Colombian fishing communities under a scenario of climatic variability. In the case of Mexico, the average extraction decrease from the baseline treatment to the climate change treatment was 46%; while in Colombia the decrease ranged between 22% (communication treatment) to 44% (voluntary-enforcement treatment). These results could be explained under the light of three types of factors: the subjects' aversion towards an external risky influence (i.e. climate change), social preferences (e.g. cooperation and reciprocity), and other demographic elements (e.g. income, gender and religion).

4.1. Climate-related risk aversion

When confronted with a treatment where harvesting levels depended on a climatic influence in the second stage of the experiments, most participants in both countries (95% in Colombia and about 83% in Mexico) decided to adopt an insurance against climatic risks, in the form of a marine reserve. Such a scenario implies that fishers would be willing to change fishing practices in order to secure a less risky flow of future income. These results suggest that information on climatic variability inhibits common-pool resource over-exploitation. In this case, fishers would adopt sustainable fishing practices, like lowering their extractions towards a social optimum or implementing marine reserves before a climate change scenario, not necessarily because of pro-environmental preferences, but in order to minimize their expected disutility. This is a standard result as fishermen frequently are confronted with decision-making in the presence of uncertainty (Smith and Wilen, 2005; Eggert and Lokina, 2007; Nguyen and Leung, 2009).

Adaptation to climate variability in fisheries could be helped by information on the risks of climate change in fishing productivity and therefore in their future livelihoods. Furthermore, adaptation actions could include the encouragement for implementing marine reserves among coastal communities. In fact, Micheli et al. (2012) have demonstrated that marine reserves enhance resilience under climatic variability, acting as an ecological insurance against climate change. This is important because, to date, no specific actions or programs are aimed at adapting the Mexican fishery sector to climate change impacts (Ibarra et al., 2013). Similar situations can be found elsewhere in Latin America, including Colombia.

Now, as in the experiment, fishermen face certain types of uncertainty for decisions that ignore other fishermen. For this reason, each participant had to privately decide whether she would overharvest and how many additional units she would overharvest as it happens in usual fisheries operations (Gelcich et al., 2013). Finally, as pointed out by Gelchich et al. (2013), an additional source of uncertainty faced by each fisherman, both in the experiment and in the real world, is due to the horizontal externality emerging from the extraction decisions of other fishermen.

4.2. Social preferences

Apart from the subject's attitude towards the risk of climate change, social preferences are also important in determining participants' behavior. Indeed, when managing common-pool resources, such as fisheries, it is always useful to remind that the willingness to cooperate of one agent will depend on the behavior of other agents (Keser and Van Winden, 2000). In fact, Cardenas and Ostrom (2004) point out that the empirical evidence of experimental economics on common- pool resources, show that groups who can effectively communicate (i.e. possibility of cooperation), establish a set of social norms, reducing, consequently, over-exploitation.

In our experiments, we found that participants presented a more sustainable behavior in common-pool resources extraction after participating in the baseline treatment. This result can be explained also by a certain degree of cooperation, trust, and reciprocity. According to Fehr and Leibbrandt (2011), cooperation and low impatience are drivers for such a behavior. Moreover, social preferences such as altruism and cooperation might enhance productivity

(Carpenter and Seki, 2011), but in contrast, competition may lead to lower cooperation (Carpenter and Seki 2006; Stoop et al. 2010). In the experiment carried out in Natividad Island, the fact that variables CATCHI (difference between social optimum harvest and the participant's i actual harvest in the previous round. In other words, it measures the willingness to cooperate of participant i) and CATCHJ (difference between social optimum harvest and the participant's j actual harvest in the previous round. It measures the willingness to cooperate of the rest of participants) were statistically significant, implies that cooperation was an important factor in determining the harvesting levels. In this way, a participant conditioned her catch to the harvesting level of the rest of the group.

Trust and reciprocity were, therefore, other important factors among participants' behavior. The importance of trust has been highlighted by McAllister et al. (2011), who found that, under a risky treatment, trust depended on reciprocity, that is to say, participants reckoned that it was riskier not to reciprocate among trusting individuals than in a do-nothing treatment. Revollo and Ibarra (2013) found in a common-pool resource lab experiment among Mexican students, that players showed a certain degree of reciprocal punishment (i.e. higher harvesting levels) if they noticed that the rest of the group did not cooperate on resource conservation. In fact, Kraak (2011) reviewed the evidence that reciprocity is an important factor to fishermen in non-anonymous treatments for more sustainable practices.

Important considerations for fisheries management can be drawn from our results, given the fact that real-world stakeholders showed reciprocity and willingness to cooperate (Gowdy, 2008; Venkatachalam, 2008). Indeed, the success of external (i.e. governmental) regulations depends on the existence of informal rules or local ecological knowledge among stakeholders. For example, Velez et al. (2008) argue that external regulation should complement existing informal regulations for fisheries management in Colombia. A similar result was found by Vollan et al. (2013) for Namibian and South African rural herders. Such results suggest that co-management regimes should be seriously considered for managing common-pool resources, such as fisheries. Indeed, Moreno-Sanchez and Maldonado (2009) found that experiments under a co-management treatment showed more sustainable harvesting levels in a marine protected area off Colombia. In fact, co-management could offer effective sustainability results when dealing with small-scale fisheries, as demonstrated by Defeo and Castilla (2005) for several Latin American examples.

4.3. Other factors

Other factors explaining fisher's decisions on lowering their harvest after the baseline treatment were income and religion in the Colombian experiment, and gender in both cases. First, income is a standard result in experimental economics. Second, in the Tribugá Gulf study, although the number of male participants outnumbered those of women (12%) the GENDER variable was statistically significant. This result was also observed in Natividad Island, with a larger percent of female participants (29%). Thus, women presented more sustainable catches than men. Indeed, there is empirical evidence that women are more risk-averse in general (Eckel and Grossman, 2008; Croson and Gneezy, 2009), and have more sustainable attitudes than men (Davidson and Black, 2001; Agarwal, 2009; Revollo, 2012). And third, religion was statistically significant for the Colombian experiment (this variable was not tested in the Mexican experiment) explaining the decrease in harvesting levels. Few studies have demonstrated the actual influence of a belief in decision-making towards the environment, but in general, these show that it does have a positive influence (Chermak and Krause, 2002; Owen and Videras, 2007), although in other public-good experiments this relationship was not evident (Anderson and Mellor, 2009).

5. Conclusion

We have studied the behavior of fishermen communities in a controlled experimental harvesting environment of common-pool resources. The subjects were familiar with the decision-making problem they faced in the experiment. Thus, their reactions to our treatment factors had the expected sign. The vast majority would react to climate change through risk-reducing mechanisms like a marine reserve or any sort of insurance. Also, depending on their social and educational background, learning from past experience leads them to more sustainable harvesting levels, avoiding common-pool resource depletion. Climate-related risk-aversion is an idiosyncratic behavioral reaction to an external factor leading to lower catches or changes in fishing practices (e.g. adopting marine reserves), provided that fishermen have information in advance of possible climatic consequences.

We suggest that the results from both experiments support the conclusion that the behavior for sustainable fishing is likely to be achieved, if and only if, control mechanisms are established to encourage both fisheries management and improvement of life quality to inhabitants in both studied areas. For example, as suggested by González, G., Díaz, Y. and Puentes, V. (2015), the work done in Tribugá Gulf-Colombia reveals that regulation of less selective fishing gear may be a possible alternative in the region, because the tendency is towards a drastic reduction in fishing. Either way, the Exclusive Zone for Artisanal Fisheries in the Tribugá Gulf, which is the result of a process of community and government participation, shows that it is necessary to work on marketing chains for the fishermen for improving their income and hence their quality of life. Furthermore, social preferences (e.g. cooperation and reciprocity) also played an important role in determining a more sustainable attitude in common-pool resources extraction. Other factors, such as income, gender and religion had also some influence.

Additionally, it is important to note that in both countries, the results of the experiments were complemented by a survey that sought to strengthen governance processes of local communities for the collective construction of sustainable fishery agreements. In case of Colombia and Mexico, we asked the fishermen if they agreed to implement an area of fisheries reserves, which could be either an exclusive artisanal fishing zone, a closed area or an area where responsible fishing is carried out. In other words, the question involves the possibilities for fishermen to establish agreements for sustainable fisheries.

Finally, this paper presents empirical evidence on the economic behavior of fishermen and their behavior on the management of common pool resources, in a context of uncertainty (climate events). For this reason, the results of economic experiments applied to fishing groups in Mexico and Colombia, concluded on the importance of the implementation of marine reserves. Thus, this paper attempts to collaborate and complement the few studies in this field of experimental economic methods and climatic phenomena that have developed in developing countries, such as Latin America.

References

Agarwal, B., 2009. Gender and forest conservation: The impact of women's participation in community forest governance. Ecological Economics 68, 2785-2799.

Alpizar, F., Cárdenas, J.C., 2011. Experimentos de campo y economía del desarrollo. In: Brañas GP (ed) Economía experimental y del comportamiento. Antoni Bosch, Barcelona, España.

Allison, E.H., Perry, A.L., Badjeck, M.C., Neil Adger, W., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L., Dulvy, N.K., 2009. Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries 10 (2), 173-196.

Anderson, L.R. and Mellor, J.M., 2009. Religion and cooperation in a public goods experiment. Economics Letters 105(1), 58–60.

Arroyo, S., 2013. Normas sociales de la población dedicada a la pesca en el pacífico colombiano: una exploración desde el laboratorio económico. Tesis de Posgrado en Economía, Universidad Nacional Autónoma de México, UNAM.

Badjeck, M.C., Allison, E.H., Halls, A.S., Dulvy, N.K., 2010. Impacts of climate variability and change on fishery-based livelihoods. Marine Policy 34 (3), 375-383.

Bailey, M., Rashid Sumaila, U., Lindroos, M., 2010. Application of game theory to fisheries over three decades. Fisheries Research 102 (1), 1-8.

Baltagi, B., 2008. Econometric Analysis of Panel Data. John Wiley & Sons Limited.

Bernal-Escobar, A., Cuervo-Sanchez, R., Pinzon-Trujillo, G., Maldonado, J.H., Glacier Melting and Retreat: Understanding the Perception of Agricultural Households That Face the Challenges of Climate Change. In: 2013 Annual Meeting, August 4-6, 2013, Washington, DC, 2013. Agricultural and Applied Economics Association.

Brander, K.M., 2007. Global fish production and climate change. Proceedings of the National Academy of Sciences 104 (50), 19709-19714.

Brander, J.A., Taylor, M. S., 1998. The simpliest economics of eastern island: A Ricardo-Malthus model of renewable resources use. American Economic Review 88 (1), 119-138.

Brick, k., M. Visser, & Burns, J., 2011. Risk Aversion: Experimental Evidence from South African Fishing Communities. Economic Research Southern Africa Working Papers, 227.

Caicedo, J., Zapata, L. y Roldan, A., 2008. Diagnostico Pesquero Rápido de Bahía Málaga, Buenaventura, Pacífico Colombiano. Programa Marino Costero: Programa Cambio Social para la Conservación. WWF- COLOMBIA.

Cárdenas, J.C., 1998. Groups, commons and regulations: experiments with villagers and students in Colombia. In: IEA CONFERENCE VOLUME SERIES, 2005. Basingstoke; Macmillan Press; New York; St Martin's Press, p 242.

Cárdenas, J., Maya, D., and López, M., 2002. Manglares, comunidad y cooperación. Pontificia Universidad Javeriana. WWF Colombia. Colgrafics ltda.

Cárdenas, J., Maya, D., and López, M., 2003. Métodos experimentales y participativos para el análisis de la acción colectiva y la cooperación en el uso de recursos naturales por parte de comunidades rurales. Departamento de Desarrollo Rural y Regional. Facultad de Estudios Ambientales y Rurales. Pontificia Universidad Javeriana.

Cárdenas, J.C., Ostrom, E., 2004. What do people bring into the game? Experiments in the field about cooperation in the commons. Agricultural Systems 82 (3), 307-326.

Cárdenas, J.C., Ramos, P.A., 2006. Manual de juegos económicos para el análisis del uso colectivo de los recursos naturales. Proyecto Regional Cuencas Andinas, GTZ, Centro Internacional de la Papa, Lima, Perú, Lima City.

Cárdenas, J.C., 2008. Social preferences among the people of Sanquianga in Colombia. Centro de estudios sobre desarrollo económico. Universidad de Los Andes. Facultad de Economía. Santafé de Bogotá. Colombia.

Cárdenas, J.C., Janssen, M., Bousquet, F., 2008. Dynamics of rules and resources: three new field experiments on water, forests and fisheries. In: List, J., Price, M., (Eds.), Handbook on experimental economics and the environment, Edward Elgar Publishing, New York.

Cárdenas, J., 2010. Dilemas de lo colectivo: Instituciones, pobreza y cooperación en el manejo local de los recursos de uso común. Colección CEDE 50 años, Facultad de Economía.

Carpenter, J.P., Seki, E., 2006. Competitive Work Environments and Social Preferences: Field Experimental Evidence from a Japanese Fishing Community. BE Journal of Economic Analysis and Policy: Contributions to Economic Analysis and Policy 5 (2), 1-23.

Carpenter, J., Seki, E., 2011. Do social preferences increase productivity? Field experimental evidence from fishermen in Toyama Bay. Economic Inquiry 49 (2), 612-630.

Castillo, D., Saysel, A.K., 2005. Simulation of common pool resource field experiments: a behavioral model of collective action. Ecological Economics 55 (3), 420-436.

Chermak, J.M. and Krause, K., 2002. Individual Response, Information, and Intergenerational Common Pool Problems. Journal of Environmental Economics and Management 43(1), 47–70.

CONAPESCA, 2012. Anuario estadístico de Pesca y Acuacultura. SAGARPA, México.

Croson, R., Gneezy, U., 2009. Gender differences in preferences Journal of Economic Literature 47, 448-474.

Davidson, P., Black, R., 2001. Women in natural resources management: Finding a more balanced perspective. Society and Natural Resources 14 (8), 645-656.

Defeo, O., Castilla, J.C., 2005. More than one bag for the world fishery crisis and keys for co-management successes in selected artisanal Latin American shellfisheries. Reviews in Fish Biology and Fisheries 15 (3), 265-283.

Eckel, C., Grossman, P.J., 2008. Differences in the economic decisions of men and women: experimental evidence. , in: Plott, C.R., Smith, V.L. (Eds.), Handbook of experimental economics results. North-Holland, Amsterdam, 509-519.

Eggert, H.K., Lokina, R.B., 2007. Small-scale fishermen and risk preferences. Research in Agricultural & Applied Economics 22(1), 49-67.

FAO, 2014. The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2012. The state of world fisheries and aquaculture. Food and Agriculture Organization of the United Nations, Rome.

Fehr, E., Leibbrandt, A., 2011. A field study on cooperativeness and impatience in the tragedy of the commons. Journal of Public Economics 95 (9), 1144-1155.

Gelcich, S.,Guzman, R., Rodríguez-Sickert, C., Castilla, C. and Cárdenas, J.C., 2013. Exploring External Validity of Common Pool Resource Experiments: Insights from Artisanal Benthic Fisheries in Chile. Ecology and Society 18 (3), 1-5.

Georgantzís N., Arroyo-Mina J., & Guerrero D., 2013. Studying Economics Reduces Overexploitation in a Common Resource Experiment. Theoretical Economics Letters 3(5B): 31-39. http://dx.doi.org/10.4236/tel.2013.35A2006.

Georgantzís, N., García, A., Jaramillo, A., 2009. El papel del Género en la Toma de Decisiones bajo Incertidumbre. Cuadernos Económicos de ICE, 77, 151–163.

González, G., Díaz, Y., Puentes, V., 2015. Evaluación Integral de la Pesca Artesanal en el Golfo de Tribugá, Norte del Pacífico Colombiano. La Timonera 20: 40-44. http://www.limcol.org/TimoneraMagazinePdf/20/timonera%2020Evaluacion%20de%20la%20pesca%20integral%20en%20tribuga.pdf.

Gowdy, J.M., 2008. Behavioral economics and climate change policy. Journal of Economic Behavior & Organization 68 (3), 632-644.

Guzmán del Proo, S.A., Palau, L.C., Perez, J.B., Laguna, J.C., Fragoso, R.H., 2003. Effects of the "El Niño" event on the recruitment of benthic invertebrates in Bahia Tortugas, Baja California Sur. Geofisica Internacional 42 (3), 429-438.

Hasson, R., Lofgren, A., Visser, M., 2010. Climate change in a public goods game: investment decision in mitigation versus adaptation. Ecological Economics 70 (2), 331-338.

Hasson, R., Lofgren, A., Visser, M., 2012. Treatment effects of climate change risk on mitigation and adaptation behaviour in an experimental setting. South African Journal of Economics 80 (3), 415-430.

Hsiao, C., 2003. Analysis of Panel Data. Second edition, Cambridge University Press.

Ibarra, A.A., Sánchez Vargas, A., Martínez López, B., 2013. Economic impacts of climate change on two Mexican coastal fisheries: Implications for food security. Economics: The Open-Access, Open-Assessment E-Journal 7 (36), 1-40.

Keser, C., Van Winden, F., 2000. Conditional cooperation and voluntary contributions to public goods. The Scandinavian Journal of Economics 102 (1), 23-39.

Kraak, S., 2011. Exploring the 'public goods game' model to overcome the Tragedy of the Commons in fisheries management. Fish and Fisheries 12 (1), 18-33.

López, M. C., Maya, D. L., Mosquera, S. L., Vélez, M. A., 2004. Reglas y normas para el manejo del recurso pesquero. Pontificia Universidad Javeriana, WWF Colombia.

López, M. C., Murphy, J.J., Spraggon, J.M. and Stranlund, J., 2009. Comparing the Effectiveness of Regulation and Pro-Social Emotions to Enhance Cooperation: Experimental Evidence from Fishing Communities in Colombia. Economic Inquiry 50 (1): 131-142.

McAllister, R.R.J., Tisdell, J.G., Reeson, A.F., Gordon, IJ., 2011. Economic behavior in the face of resource variability and uncertainty. Ecology and Society 16 (3 (6)), 1–24.

McIlgorm, A., Hanna, S., Knapp, G., Le Floch, H.P., Millerd, F., Pan, M., 2010. How will climate change alter fishery governance Insights from seven international case studies. Marine Policy 34 (1), 170-177.

Micheli, F., Saenz-Arroyo, A., Greenley, A., Vazquez, L., Montes, J.A.E., Rossetto, M., De Leo, G.A. 2012. Evidence that marine reserves enhance resilience to climatic impacts. PloSone 7 (7):e40832.

Moreno-Sanchez, R.P., Maldonado, J.H., 2009. Evaluating the role of co-management in improving governance of marine protected areas: An experimental approach in the Colombian Caribbean. Ecological Economics 69 (12), 2557-2567.

Nguyen, Q, Leung, P., 2009. Do fishermen have different attitudes toward risk? An application of Prospect Theory to the study of Vietnamese fishermen. Journal of Agricultural and Resources Economics 34(3), 518-538.

Ostrom, E., Gardner, R., Walker, J., 1994. Rules, Games and Common-Pool Resources. University of Michigan Press, Ann Arbor.

Ostrom, E., 2005. Understanding Institutional Diversity. Nueva Jersey: Princeton University Press.

Owen, A.L. and Videras, J.R., 2007. Culture and public goods: The case of religion and the voluntary provision of environmental quality. Journal of Environmental Economics and Management 54(2), 162–180.

Perry, R.I., 2011. Potential impacts of climate change on marine wild capture fisheries: an update. Journal of Agricultural Science-London, 149: 63-75.

Rebellón, C., 2004. Relación entre el stock de un recurso de propiedad común y el crecimiento de la población que lo explota. El caso de la extracción de la piangua en la Ensenada de Tumaco, Colombia. Revista Desarrollo y Sociedad 54. Universidad de los Andes. Santafé de Bogotá. Colombia.

Revollo, D.A., 2012. Eficiencia técnica, social y económica de la pesquería de abulón bajo un esquema de gestión por medio de reservas marinas: el caso de Isla Natividad, Baja California, México. Tesis de Posgrado en Economía, Universidad Nacional Autónoma de México, UNAM.

Revollo, D.A., Ibarra, A.A., 2014. Measures of risk associated to regulations compliance: a laboratory experiment on the use of common-pool resources. Journal of Risk Research 17(7), 903-921.

Revollo, D.A., Saenz-Arroyo, A., 2012. The Historical Ecology of Abalone (Haliotis Corrugata and Fulgens) in the Mexican Pacific. Mexico y la Cuenca del Pacifico 15 (45), 89-111

Revollo Fernández, D.A., A. Aguilar Ibarra, A. Sáenz-Arroyo and Micheli, F., 2016. Exploring the role of gender in common-pool resources extraction: evidence from laboratory and field experiments in fisheries. Applied Economics Letters (in press).

Rodriguez-Sickert, C., Guzmán, R.A., Cárdenas, J.C., 2008. Institutions influence preferences: Evidence from a common pool resource experiment. Journal of Economic Behavior & Organization 67 (1), 215-227.

Roessig, J.M., Woodley, C.M., Cech Jr, J.J., Hansen, L.J., 2004. Effects of global climate change on marine and estuarine fishes and fisheries. Reviews in Fish Biology and Fisheries 14 (2), 251-275.

Sabater-Grande, G., Georgantzis, N., 2002. Accounting for risk aversion in repeated prisoners' dilemma games: An experimental test. Journal of Economic Behavior & Organization 48 (1), 37-50.

Smith, M.D., Wilen, J.E., 2005. Heterogeneous and correlated risk preferences in commercial fishermen: The perfect storm dilemma. Journal of Risk and Uncertainty 31(1), 53-71.

Smith, M.D., Roheim, C.A., Crowder, L.B., Halpern, B.S., Turnipseed, M, Anderson, J.L., Asche, F., Bourillón, L., Guttormsen, A.G., Khan, A., 2011. Sustainability and global seafood. Science 327 (5967), 784-786.

Srinivasan, U., Cheung, W., Watson, R., Sumaila, U., 2010. Food security implications of global marine catch losses due to overfishing. Journal of Bioeconomics 12 (3), 183-200.

Stoop, J., Noussair, C.N., Van Soest, D., 2010. From the lab to the field: Cooperation among fishermen. Journal of Political Economy 120 (6), 1027-1056.

Thorpe, A., Bennett, E., 2001. Globalisation and the sustainability of world fisheries: a view from Latin America. Marine Resources Economics 16, 143-164.

Vélez, M., Stranlund, J., Murphy, J., 2009. What motivates common pool resource users? Experimental evidence from the field. Journal of Economic Behavior & Organization 70 (3), 485-497.

Vélez, M.A., Murphy, J.J., Stranlund, J.K., 2008. Centralized and decentralized management of local common pool resources in the developing world: experimental evidence from fishing communities in Colombia. Economic Inquiry 48 (2), 254-265.

Venkatachalam, L., 2008. Behavioral economics for environmental policy. Ecological Economics 67 (4), 640-645.

Vollan, B., Prediger, S., Frolich, M., 2013. Co-managing common pool resources: Do formal rules have to be adapted to traditional ecological norms? Ecological Economics 95, 51-62

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314 (5800), 787-790.

Appendix A. Mexico

A.1. Individual Score Table

A.1.1. Baseline: Recovery Rate = 50% - Rounds 1-5

A.1.2.1. Marine Reserve: Recovery Rate = 40% - Rounds 6-10

A.1.2.2. Marine Reserve: Recovery Rate = 60% - Rounds 6-10

A.1.2.3. No Marine Reserve: Recovery Rate = 20% - Rounds 6-10

A.1.2.4. No Marine Reserve: Recovery Rate = 80% - Rounds 6-10

A.2. Individual Decision Sheet (Baseline and Treatments): Rounds 1-10

Appendix B. Colombia

B.1. Individual Score Table

B.2. Individual Decision Sheet - Baseline: Rounds 1-10

B.3. Individual Decision Sheet - Treatment: Rounds 11-20

B.3.1. Internal Regulation

B.3.2. Random Regulation

Table I

Table I. Summary of field experiments with fisheries in Latin America

Fishery	Region of study	Main results	Reference
Artisanal fisheries, Clam fisheries, and Trout fishery	Caribbean, south Pacific, and Andean region, all in Colombia	Cooperation under a low regulation penalty, and free-riding under a high regulation penalty; opposition to externally imposed regulations	(Cardenas 2005)
Artisanal fisheries (lobster, conch, snapper) and crab hunting	Providence Island, Colombia	Crab hunters were more willing to cooperate than fishers under tax and communication treatments.	(Castillo and Saysel 2005)
Artisanal fisheries	Baru Island, Colombia	High harvesting rate chosen with varying fish stock levels.	(Cardenas et al. 2008)
Artisanal fisheries	Caribbean coast, the Pacific coast and the Magdalena river (all in Colombia).	External regulation should complement existing informal regulations.	(Velez et al. 2008)
Fish or water extraction	Five villages in Colombia	Absence of enforcement conditioned the compliance of a regulation on the behavior of others.	(Rodriguez-Sickert et al. 2008)
Artisanal fisheries	Caribbean coast, Colombia.	Experiments under a co-management treatment showed more sustainable	(Moreno-Sanchez and Maldonado 2009)

Fishery	Region of study	Main results	Reference
		harvesting levels in a marine protected area.	
Artisanal fisheries	Caribbean coast, the Pacific coast and the Magdalena river (all in Colombia).	Altruism, conformity and reciprocity featured the harvesting decisions of fishers.	(Velez et al. 2009)

Table II

Table II. Scenarios shown to participants in the climatic change / marine reserves at Natividad Island, Baja, Mexico

Game stages	SCENARIOS			
First round (Baseline R:1-5)	Recovery rate (RR) = 50% (Nº = 37)			
Second round (Treatment) (R: 6-10)	Marine reserve implementation (Nº = 30)		No marine reserve implementation (Nº = 7)	
	Climatic variation	No climatic variation	Climatic variation	No climatic variation
	RR = 40%*	RR = 60%*	RR = 20%*	RR = 80%*

* The recovery rates were chosen according to the information of Guzmán del Proo et al. (2003) who found the changes in recruitment (presumably due to a higher level of hypoxia) for marine invertebrates before and after the 1997-1998 ENSO event at Bahia Tortugas, Baja peninsula, Mexico.

Table III

Table III. Variables introduced in the econometric model

Variable	Description	Expected sign
	Dependent	
CATCH	Harvesting level of participant i in round t+1	
	Independent	
CATCHI	Difference between social optimum harvest and the participant's i actual harvest in the previous round. It measures the willingness to cooperate of participant i.	(+,-)
CATCHJ	Difference between social optimum harvest and the participant's j actual harvest in the previous round. It measures the willingness to cooperate of the rest of participants.	(+,-)
POINTS	Difference in absolute value between the points of participant i and the rest of participants in the previous round. It measures the inequity aversion.	(+,-)
CLIMATE	Dichotomous variable for indicating whether (1) or not (0) a climatic event takes place in that round.	(-)
TREAT	Count variable for indicating the type of treatment: 1 for the baseline treatment, 2 for no marine reserve implemented, and 3 for marine reserve implemented.	(-)
GENDER	Dichotomous variable for indicating gender of participant: 1 for man and 0 for woman.	(+)
FISH	Dichotomous variable for indicating whether (1) or not (0) the participant is actually a fisher in real life.	(-)
RESERVE	Count variable for indicating the percent area that the participant would implement as marine reserve: 0-10%=1, 11-20%=2, 21-30%=3, 31-40%=4, 41-50%=5, 51-60%=6, 61-70%=7, 71-80%=8, 81-90%=9, 91-100%=10.	(-)

Table IV

Table IV. Econometric estimations for explaining the individual harvesting decisions (*CATCH*) of participants in the Natividad Island experiment

	Coefficient	Std. Err.	p > |Z|	
CATCHI	0.528	0.078	0.000	*
CATCHJ	0.481	0.259	0.064	*
POINTS	-0.001	0.001	0.377	
GENDER	0.701	2.03	0.043	*
TREAT	-0.223	0.314	0.077	*
CLIMATE	-0.241	0.446	0.091	*
RESERVE	-0.159	0.126	0.205	
FISH	-0.355	0.375	0.344	
CONSTANT	1.917	1.466	0.191	

* $p < 0.10$

R-squared = 0.458

Wald chi2(8) = 146.68
Prob > chi2 = 0.0000
N = 333

Table V

Table V. Variables introduced in the econometric model

Variable	Description	Expected sign
	Dependent	
CATCH	Harvesting level of participant i in round t+1	
	Independent	
EXPER	Continuous variable reflecting individual behavior based on years of fishing	(+)
CIVIL	Categorical variable indicating civil status of participant: 1 for free-union, 2 for married, 3 for single, 4 for divorced	(+,-)
INCOME	Monthly income from fishing activities	(+)
SCHOOL	Continuous variable indicating years of formal education	(-)
RELIGION	Categorical variable indicating religion: 1 for Catholic, 2 for Christian Evangelical or Pentecostal, 3 for agnostic	(+,-)
GENDER	Dichotomous variable for indicating gender of participant: 1 for man and 0 for woman.	(+)
CLIMATE	Dichotomous variable for indicating whether (1) or not (0) a climatic event takes place in that round	(-)

Table VI

Table VI. Econometric estimations for explaining the individual harvesting decisions (CATCH) of participants in the Tribugá Gulf experiment

	Coefficient	**Std. Err.**	**p > |Z|**	
EXPER	0.0041	0.00127	0.074	*
SCHOOL	-0.2382	0.01844	0.000	*
INCOME	0.0568	0.01589	0.000	*
AGE	0.0004	0.00131	0.720	
CIVIL	0.1206	0.02366	0.000	*
RELIGION	0.4195	0.0542	0.000	*
GENDER	0.4212	0.05390	0.000	*
CLIMATE	-0.07953	0.08907	0.000	*

* $p < 0.10$
R-squared = 0.445
Prob > chi2 = 0.000
N = 1500

Appendix A11

A.1.1. Baseline: Recovery Rate = 50% - Rounds 1-5

TABLE OF POINTS (PROFIT EXTRACTION + CONSERVATION)

The level of extraction of them	My level of extraction: 1	2	3	4	5	6	7	8	9	10
0	1,593	1,685	1,778	1,870	1,963	2,055	2,148	2,240	2,333	2,425
1	1,585	1,678	1,770	1,863	1,955	2,048	2,140	2,233	2,325	2,418
2	1,578	1,670	1,763	1,855	1,948	2,040	2,133	2,225	2,318	2,410
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
50	1,218	1,310	1,403	1,495	1,588	1,680	1,773	1,865	1,958	2,050
51	1,210	1,303	1,395	1,488	1,580	1,673	1,765	1,858	1,950	2,043
52	1,203	1,295	1,388	1,480	1,573	1,665	1,758	1,850	1,943	2,035
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	843	935	1,028	1,120	1,213	1,305	1,398	1,490	1,583	1,675
101	835	928	1,020	1,113	1,205	1,298	1,390	1,483	1,575	1,668
102	828	920	1,013	1,105	1,198	1,290	1,383	1,475	1,568	1,660
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
189	175	268	360	453	545	638	730	823	915	1,008
190	168	260	353	445	538	630	723	815	908	1,000

A.1.2.1. Marine Reserve: Recovery Rate = 40% - Rounds 6-10

	TABLE OF POINTS (PROFIT EXTRACTION + CONSERVATION) My level of extraction									
The level of extraction of them	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	1,493	1,586	1,679	1,772	1,865	1,958	2,051	2,144	2,237	2,330
1	1,486	1,579	1,672	1,765	1,858	1,951	2,044	2,137	2,230	2,323
2	1,479	1,572	1,665	1,758	1,851	1,944	2,037	2,130	2,223	2,316
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
50	1,143	1,236	1,329	1,422	1,515	1,608	1,701	1,794	1,887	1,980
51	1,136	1,229	1,322	1,415	1,508	1,601	1,694	1,787	1,880	1,973
52	1,129	1,222	1,315	1,408	1,501	1,594	1,687	1,780	1,873	1,966
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	793	886	979	1,072	1,165	1,258	1,351	1,444	1,537	1,630
101	786	879	972	1,065	1,158	1,251	1,344	1,437	1,530	1,623
102	779	872	965	1,058	1,151	1,244	1,337	1,430	1,523	1,616
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
189	170	263	356	449	542	635	728	821	914	1,007
190	163	256	349	442	535	628	721	814	907	1,000

A.1.2.2. Marine Reserve: Recovery Rate = 60% - Rounds 6-10

	TABLE OF POINTS (PROFIT EXTRACTION + CONSERVATION) My level of extraction									
The level of extraction of them	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	1,692	1,784	1,876	1,968	2,060	2,152	2,244	2,336	2,428	2,520
1	1,684	1,776	1,868	1,960	2,052	2,144	2,236	2,328	2,420	2,512
2	1,676	1,768	1,860	1,952	2,044	2,136	2,228	2,320	2,412	2,504
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
50	1,292	1,384	1,476	1,568	1,660	1,752	1,844	1,936	2,028	2,120
51	1,284	1,376	1,468	1,560	1,652	1,744	1,836	1,928	2,020	2,112
52	1,276	1,368	1,460	1,552	1,644	1,736	1,828	1,920	2,012	2,104
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	892	984	1,076	1,168	1,260	1,352	1,444	1,536	1,628	1,720
101	884	976	1,068	1,160	1,252	1,344	1,436	1,528	1,620	1,712
102	876	968	1,060	1,152	1,244	1,336	1,428	1,520	1,612	1,704
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
189	180	272	364	456	548	640	732	824	916	1,008
190	172	264	356	448	540	632	724	816	908	1,000

A.1.2.3. No Marine Reserve: Recovery Rate = 20% - Rounds 6-10

TABLE OF POINTS (PROFIT EXTRACTION + CONSERVATION)

The level of extraction of them	My level of extraction: 1	2	3	4	5	6	7	8	9	10
0	1,294	1,388	1,482	1,576	1,670	1,764	1,858	1,952	2,046	2,140
1	1,288	1,382	1,476	1,570	1,664	1,758	1,852	1,946	2,040	2,134
2	1,282	1,376	1,470	1,564	1,658	1,752	1,846	1,940	2,034	2,128
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
50	994	1,088	1,182	1,276	1,370	1,464	1,558	1,652	1,746	1,840
51	988	1,082	1,176	1,270	1,364	1,458	1,552	1,646	1,740	1,834
52	982	1,076	1,170	1,264	1,358	1,452	1,546	1,640	1,734	1,828
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	694	788	882	976	1,070	1,164	1,258	1,352	1,446	1,540
101	688	782	876	970	1,064	1,158	1,252	1,346	1,440	1,534
102	682	776	870	964	1,058	1,152	1,246	1,340	1,434	1,528
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
189	160	254	348	442	536	630	724	818	912	1,006
190	154	248	342	436	530	624	718	812	906	1,000

Appendix A2

A.2. Individual Decision Sheet (Baseline and Treatments): Rounds 1-10

Rounds	My nevel the extraction	The level of extraction of them	Score
Practice 1			
Practice 2			
Practice 3			
1			
2			
3			
⋮			
10			
Total			

Appendix B1

B.1. Individual Score Table

	My own amount of yield							
Aggregated amount of other participants	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
4	758	790	818	840	858	870	878	880
5	738	770	798	820	838	850	858	860
6	718	750	778	800	818	830	838	840
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
10	638	670	698	720	738	750	758	760
11	618	650	678	700	718	730	738	740
12	598	630	658	680	698	710	718	720
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
20	438	470	498	520	538	550	558	560
21	418	450	478	500	518	530	538	540
22	398	430	458	480	498	510	518	520
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
30	238	270	298	320	338	350	358	360
31	218	250	278	300	318	330	338	340
32	198	230	258	280	298	310	318	320

Appendix B2

B.2. Individual Decision Sheet - Baseline: Rounds 1-10

Rounds	**A: Individual Amount of Yield**	**B: Aggregated Amount of Yield of Group**	**C (B-A): Aggregated Amount of Yield from other participants**	**D: Score**
Practice 1				
Practice 2				
Practice 3				
1				
2				
3				
⋮				
10				
Total				

Appendix B31

B.3.1. Internal Regulation

Rounds	Vote for regulation*		A: Individual Amount of Yield	B: Aggregated Amount of Yield of Group	C (B-A): Aggregated Amount of Yield from other participants	D: Score	E: Regulation Fine	F (D-E): Final Score	Fishing under unexpected conditions	
11	Y	N							Y	N
12	Y	N							Y	N
13	Y	N							Y	N
⋮										
20	Y	N							Y	N

*** The regulation applies only when the majority votes YES in the group; i.e. if there are at least 3 for YES votes, regulation is applied.**

Appendix B32

B.3.2. Random Regulation

Rounds	A: Individual Amount of Yield	B: Aggregated Amount of Yield of Group	C (B-A): Aggegated Amount of Yield from other participants	D: Score	E: Regulation Fine	F (D-E): Final Score	Fishing under unexpected conditions	
11							Y	N
12							Y	N
13							Y	N
⋮								
20							Y	N

A.1.2.4. No Marine Reserve: Recovery Rate = 80% - Rounds 6-10

		TABLE OF POINTS (PROFIT EXTRACTION + CONSERVATION) My level of extraction									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
The level of extraction of them	**0**	1,891	1,982	2,073	2,164	2,255	2,346	2,437	2,528	2,619	2,710
	1	1,882	1,973	2,064	2,155	2,246	2,337	2,428	2,519	2,610	2,701
	2	1,873	1,964	2,055	2,146	2,237	2,328	2,419	2,510	2,601	2,692
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	50	1,441	1,532	1,623	1,714	1,805	1,896	1,987	2,078	2,169	2,260
	51	1,432	1,523	1,614	1,705	1,796	1,887	1,978	2,069	2,160	2,251
	52	1,423	1,514	1,605	1,696	1,787	1,878	1,969	2,060	2,151	2,242
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	100	991	1,082	1,173	1,264	1,355	1,446	1,537	1,628	1,719	1,810
	101	982	1,073	1,164	1,255	1,346	1,437	1,528	1,619	1,710	1,801
	102	973	1,064	1,155	1,246	1,337	1,428	1,519	1,610	1,701	1,792
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	189	190	281	372	463	554	645	736	827	918	1,009
	190	181	272	363	454	545	636	727	818	909	1,000

Figure 1

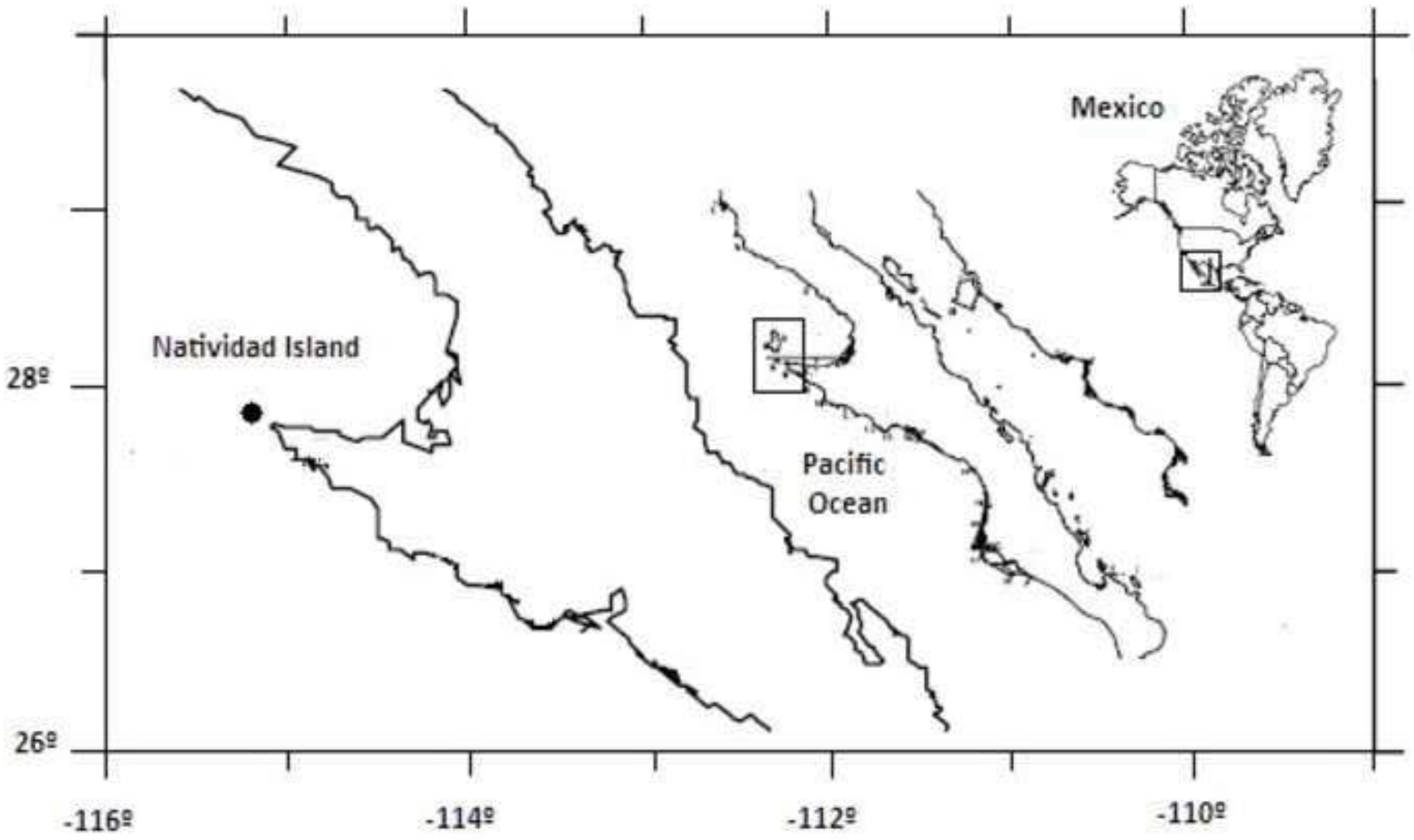
Mexico
Natividad Island
Pacific
Ocean
28º
26º
-116º
-114º
-112º
-110º

Figure 2

Click here to download high resolution image

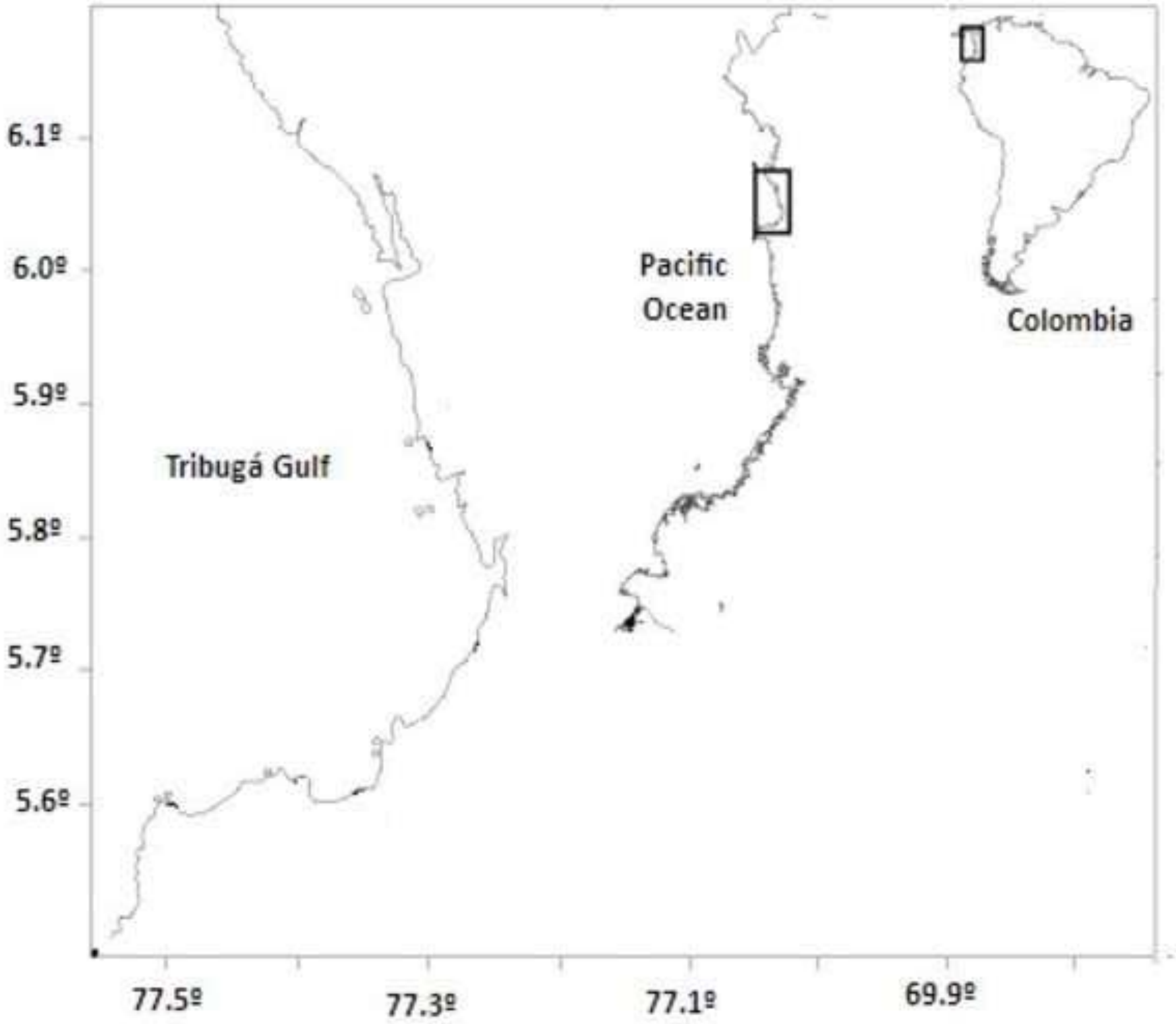

Figure 3

Click here to download high resolution image

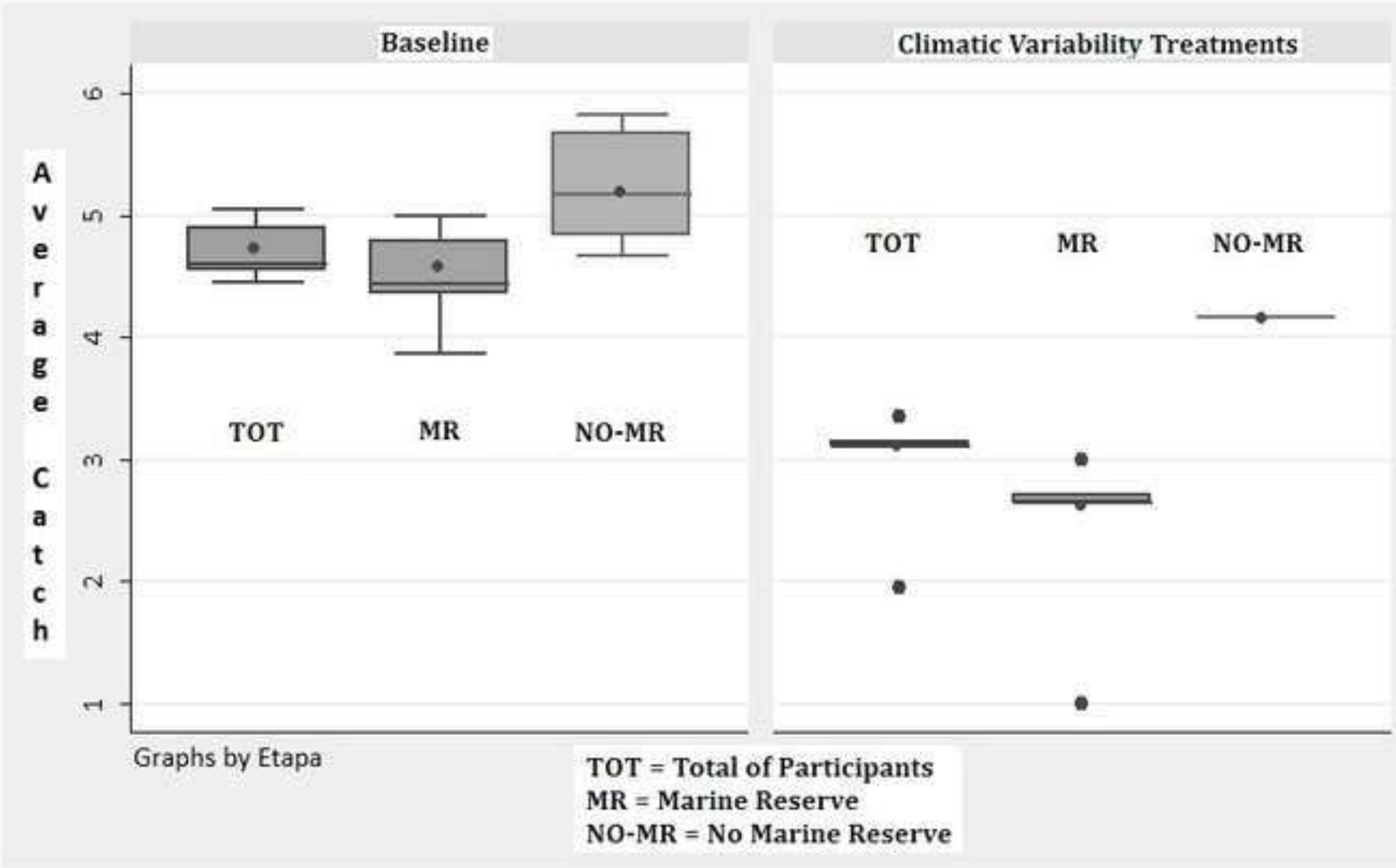

Figure 4

Click here to download high resolution image