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Factors that influence the entry–exit decision and intensity of participation of fishing fleet for the Galapagos lobster fishery

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ABSTRACT

The Galapagos Islands are a prime example of a place where fishery management policies have been established without first understanding the behavior of fishermen. Since the creation of the Galapagos Marine Reserve in 1998, there has not been a single study in the archipelago that investigates fishing behavior and the factors affecting this behavior. This paper addresses this gap in the literature by describing and analyzing the decisions of the fishing fleet for the red spiny lobster fishery. It focuses on factors that affect the short-term decisions regarding both participation and intensity of participation in the lobster fishery. This paper finds that the fishing fleet in the Galapagos Islands behaves as profit maximizing firms, because they consider all the benefits and costs that affect both their participation decision as well as their decision about how frequently to be active after they have decided to participate. The results also show that there is a large latent effort in the lobster fisheries that could threaten the sustainability of any initiatives aimed at increasing catchability, prices, or markets. It is expected that this analysis will be valuable to policy makers when designing or improving the management plans for Galapagos fisheries.

1. Introduction

In a paper published in 2007, Ray Hilborn [1] stated that "managing fisheries is managing people" and therefore effective management requires an "understanding of the motivation of fishermen and designing a management regime that aligns societal objectives with the incentives provided to fishermen". This assertion encapsulates a well-known idea expressed by fishery scientists over several decades [2–8]. But this idea despite its acceptance in the academic world is not yet the norm for fishery management in many parts of the planet [9–12]; and as Hilborn foreshadowed, ignoring the behavior of fishers when designing management policies has led to the fisheries that depend on such policies to be unsustainable [1].

The Galapagos Islands are an example of a place in which fishery management policies have been established without first understanding the behavior of fishermen [13]. Therefore, it can be argued that this lack of understanding of the fishers' behavior might be one of the reasons of why many of the policies applied in the Galapagos Marine Reserve (GMR) have been ineffective in achieving sustainable fisheries, as evidenced by the continued reduction in lobster and sea cucumber landings (Fig. 1).

There have been some attempts to account for behavior, preferences and/or needs of fishers when designing fisheries policies in the GMR. A major initiative for this purpose was the establishment of a co-management approach known as the Galapagos Participatory Management System (PMS) which has as one of its purposes to identify the needs of the fishers when establishing management policies. However, under the PMS, artisanal fishing is managed primarily by regulations enacted by the Galapagos National Park (GNP); those regulations are then adjusted seasonally (under some restrictions) by negotiation among the stakeholders [14,15]. In other words this is a special type of management system in which the authority (i.e. GNP) imposes the restrictions and the stakeholders determine the implementation of those restrictions. It is also a system where fishers are not the only stakeholders with a voice – naturalist guides, the tourism sector and the conservation sector also have a place in the decision-making system. In this system, regulators and stakeholders have conflicting interests: fishers want to catch as much as possible and the regulators want to restrict the extractive behavior, while non-fisher stakeholders may support or oppose the fishing sector as a strategy to achieve their independent goals. Therefore we would expect that fishers would not necessarily provide truthful information about their behavior

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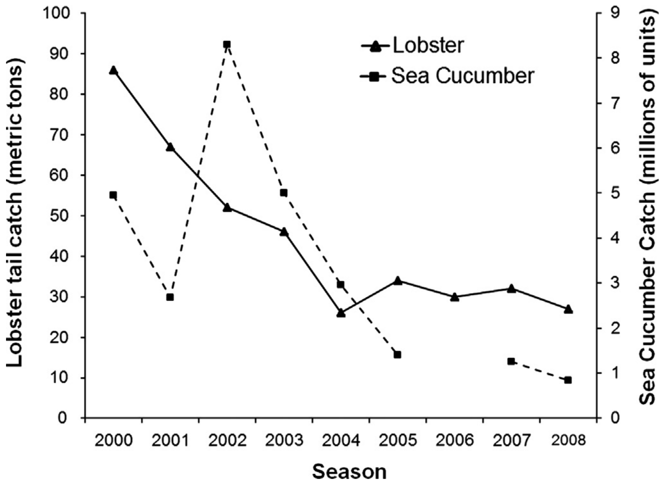

Fig. 1. Total catch (in metric tons of frozen tails) of spiny lobster in the GMR in fishing seasons 2000–2008; and total catch (in millions of individuals) of sea cucumbers in the same seasons. The source of this data is the Fisheries Database from the GNP and the CDF. No sea cucumber data were available for 2006.

and fishing needs, when this might run counter to their objective of maximizing both time and area for their fishing activity.

In the academic literature, from 1999 to 2012, there has been only one quantitative study published in peer-reviewed journals that analyzes any type of individual behavior of either fishers or the fishing fleet in the Galapagos Islands [16]. In this study its authors [16] analyzed exclusively the compliance behavior of artisanal fishermen in the GMR. Specifically, they were interested in determining the factors that influence boat-owners decisions to violate management regulations of the GMR. This study was important for designing monitoring and control policies, but it did not explain the individual fishing behavior and fishing decisions per se (i.e. what, when, where and/or how to fish) of fishers and the fishing fleet in the Galapagos Islands. Other studies have focused more on the heterogeneous nature of the fishing sector and on attempting to explain why the Participatory Management System largely failed to manage the fisheries sustainably over the first decade of its existence [15,17–20]. The advent of the sea cucumber fishery boom in particular, which began in the early 1990s, drove rapid growth of the sector, and an influx of part-time fishers who would take time off from their main jobs for the two-month annual fishing season, attracted by the prospect of large earnings [21]. The sea cucumber fishery, involving foreign Asian merchants working behind the scenes, and a series of local conflicts between fishers and other stakeholders, especially the GNP and the Charles Darwin Foundation (CDF), has been the subject of several studies over the last decade e.g. [15,17,18,22,23]. To a certain extent, this focus has distracted attention from research about fishing activities per se and from attempts to understand how individual fishers make decisions within this context.

For this reason, the present paper tries to close this gap in the literature through analyzing the fishing behavior of the Galapagos fleet for the Red Spiny Lobster (*Panulirus penicillatus*) fishery. Specifically, it analyzes those factors that influence the entry–exit decision and intensity of participation for the Galapagos lobster fishery. The results of this paper show that the fishing fleet in the Galapagos Islands behaves as profit maximizing firms. Additionally, it found that there is a large latent effort in the Galapagos lobster fisheries that potentially could be a problem for the management policies of that fishery. Lastly, it is proposed that understanding the decision mechanism of the Galapagos fishing fleet may help to design sound fisheries management policies for the GMR.

2. Methods

2.1. Description of the fishery

Since late 1999, there have been approximately 1000 fishermen officially registered in the GMR. The GNP, the control authority of the GMR, classifies those fishermen into two categories: *Armadores* (~40% of all fishermen) and *Pescadores* (~60% of fishermen). Armadores own at least one boat and *Pescadores* do not own a single boat. Armadores do not always participate in fishing personally but their vessels are crewed by Pescadores. For these analyses, individual fishing vessels, not fishermen, were considered to be independent Fishing Units of Production (FUPs). A further assumption was that Armadores and the crew on each trip maximize a joint utility function that can be modeled as a unit as in the case of a firm.

The artisanal fishing fleet of Galapagos is divided into three types of vessels: *pangas* (small, slow, wooden boats), *fibras* (larger, faster fiberglass boats), and *botes* (large motherships that transport smaller vessels). The number of vessels increased from 254 to 446 between 1999 and 2002 and has been stable since then. It is important to highlight that the main reason for the rapid increase of the fleet size during the period 1999–2002 was the regulatory framework established by both the Galapagos Special Law (1998) and the Management Plan of the GMR (1999). These regulations imposed that the Galapagos fishery registry would be closed for new vessels after the process of refinement that the registry underwent during this period of three years (1999–2002). This generated an incentive to obtain new vessels and consequently to register them immediately in anticipation of financial returns. These returns included not only immediate benefits such as access to the highly profitable sea cucumber fishery but also future benefits such as the possibility of having access to a tourist permit, or license to transport tourists on fishing vessels. Therefore, the perceived political clout that the system created, along with the speculation that fishing permits might in the future be bought out or exchanged for tourism permits, generated a huge growth in the sector, and resulted in a highly heterogeneous group (see later in this paper, Section 3.1.) of non-fishermen, part-time fishermen and full time fishermen, focusing on a mixed bag of demersal fish, pelagic fish (hook and line fisheries), lobsters and sea cucumbers (dive fisheries) [14].

The analysis focused only on pangas and fibras, which represent 95% of the active fishing vessels. Botes were excluded because they are mostly used to transport pangas and fibras to distant fishing grounds (such as Darwin and Wolf islands). Only those FUPs that were active at least once (i.e., one day) during 2001–2008 were included in the analysis. The study period begins in 2001 because that was the earliest year in which annual price and ownership information was available. Data after 2008 was not used, due to suspected inaccuracies, especially for the landings data. As a consequence the sample size was constrained to 342 FUPs. In other words 49 FUPs that did not show any activity during the period of study were excluded. This provided 2736 observations which comprise the estimation sample.

2.2. Data sources

Lobster fishery landings were collected by both the CDF during the period 2001–2006 and the GNP during the period 2007–2008. Sea cucumber fishery data were obtained for the same period from the same sources.

The Galapagos Fishery Record (GFR), which is managed by the GNP, provided a list of the registered vessels for the study period. The year 2001 is the first in which data of that type were available since that year was used as baseline for the process of registration in the GFR, which was officially closed by 2002. Before that time, there was not any kind of official registration of vessels except for the membership records of the fishing cooperatives, which is confidential information.

The average annual price of lobster tails was obtained from records provided by the GNP whereas the diesel price was obtained from the official price table published by the public oil company in Ecuador (Petroecuador). Finally, the total number of tourists per year was obtained from GNP records.

2.3. Econometric modeling

This paper addresses the factors that affect not only the decision to participate but also the decision about how many days to be active, once the decision to participate has occurred (i.e. frequency of participation).

It is very likely that there is a self-selection process in the sample that affects the frequency of participation decision. This is because it is possible that the latter could be influenced by some unobservable characteristics of either Armadores or fishing crew that could affect simultaneously the frequency of participation and the choice of whether or not a FUP would participate in the fishing activity. In order to deal with this potential problem a Heckman's selection model was applied [24].

Let y_2^* denote the outcome of interest that in this specific case will be equal to the natural logarithm of the frequency of participation of a FUP measured as the proportion of days (with respect to the total number of days in a season) that a FUP is active when it decides to participate in the lobster fishery. This variable is observed if and only if a second (latent) variable y_1^* is greater than zero.

In this case the latent variable y_1^* will be equal to the participation status of a FUP in the lobster fishery in any given season. This variable takes a value of one if the FUP participates at least one day in the lobster season and zero otherwise. In the end, the Heckman model will be composed of two equations; a *participation equation*, such as:

$$y_1 = \begin{cases} 1 & if \quad y_1^* > 0 \\ 0 & if \quad y_1^* \le 0 \end{cases} \tag{1}$$

and a resultant *outcome equation* such that

$$y_2 = \begin{cases} y_2^* & if \quad y_1^* > 0 \\ - & if \quad y_1^* \le 0 \end{cases} \tag{2}$$

As indicated previously this model specifies that y_2 is observed only when $y_1^* > 0$, whereas y_2 need not take on any meaningful value when $y_1^* \le 0$.

The standard model specifies a linear model with additive errors, so:

$$\begin{aligned} y_1^* &= X_1' \beta_1 + \varepsilon_1 \\ y_2^* &= X_2' \beta_2 + \varepsilon_2 \end{aligned} \tag{3}$$

where

$$corr(\varepsilon_1, \varepsilon_1) = \rho \tag{4}$$

It should be noted that an Ordinary Least Square (OLS) regression of y_2 on X_2 alone using just the observed positive values of y_2 leads to inconsistent estimation of β_2 unless $corr(\varepsilon_1,\varepsilon_2)=0$. If that is not the case the OLS model should be corrected for positive values of y_2 as follows:

$$y_2 = X_2' \beta_2 + \sigma_{12} \lambda(X_1' \hat{\beta}_1) + \nu \tag{5}$$

where σ_{12} is the covariance between ε_1 and ε_2, ν is an error term, $\hat{\beta}_1$ is a vector of estimator coefficients obtained by a Probit regression of y_1 on X_1 such as $Pr(y_1^* > 0) = \Phi(X_1' \hat{\beta}_1)$, and $\lambda(X_1' \hat{\beta}_1) = \phi(X_1' \hat{\beta}_1)/\Phi(X_1' \hat{\beta}_1)$ is the estimated Inverse Mills Ratio.

This model could be estimated through a Maximum Likelihood Estimation (MLE) procedure or a two-step OLS procedure. However, according to Nawata and Nagase [25] the Heckman's two-step estimators sometimes perform poorly and are not efficient. For this purpose a MLE procedure was used to estimate the Heckman model.

After estimating the model a test of whether or not $\rho=0$ is required in order to determine whether or not the errors are correlated and a sample selection correction is needed or in its defect if it is acceptable to analyze econometrically both equations (the outcome and participation one) separately.

For this purpose the X_2 array contained the following variables: natural logarithm of the average catch per trip (CPT) of the lobster fishery for each vessel during the previous season measured in Kg per trip plus one (CPT Lobster$_{t-1}$+1); natural logarithm of the average CPT of the sea cucumber fishery during the previous season measure in individuals per trip plus one (CPT Sea Cucumber$_{t-1}$+1); the average price of a Kg of lobster tails in the month previous to the opening date of the lobster season; the average price of diesel of the month previous to the start of the lobster season; a dummy variable for the port of origin of the FUP and another dummy variable to gather the effect of the ownership status of the Armador related to a FUP which takes a value of one if the owner of a FUP is an Armador who owns multiple boats and zero otherwise.

In the case of X_1 this array contains the same variables as X_2 array plus one more additional variable that will work as the exclusion restriction for the relationship between these two models. Specifically, there must be at least one variable which appears with a non-zero coefficient in the participation equation but does not appear in the outcome equation for identification and to generate credible estimates. If no such variable is available, it may be difficult to correct for sampling selectivity.

The exclusion restriction in the model is a variable that represents the total number of tourists that entered the Galapagos Islands in the 12 months previous to the opening of a lobster season. This information would work as a proxy variable for the growth of job opportunities that fishermen have available in the tourism sector, which is the most important economic sector in the archipelago. It was assumed that an increase in the number of tourists would increase the profitability of participating in this activity and would increase the opportunity cost of participating in the fishing activity. This consequently would affect the participation choice of FUP negatively, reducing the probability of a FUP to participate in that fishery. A further assumption was made that this variable would affect the choice about the frequency of participation only through its effect on the participation decision. This is reasonable, as the number of tourists was not expected to directly affect the frequency of participation except through its effect on the participation decision.

Table 1 provides a description of the variables in both arrays (X_1 and X_2) while Table 2 provides the ex ante expectations for the signs of the estimators of those variables in both the participation and frequency of participation equations.

3. Results

3.1. Fishery participation

During a season, vessels can be classified as active and inactive vessels. Thus on average 50% of registered vessels were inactive each year during the period 2001–2008. The frequency of participation of those active vessels in each season was on average 15

Table 1
Descriptive statistics for the variables used for the models of participation and frequency of participation.

Variable	Mean	Std. Dev.	Min.	Max.
Participation	0.500	0.503	0	1.0000
Days of participation *	15.381	16.494	1	117
Last year average catch per trip on the Lobster Fishery (Kg/trip)	7.301	15.057	0	87.72
Last year average catch per trip on the sea cucumber fishery (ind./trip)	278.256	694.293	0	5094
Isabela (location dummy)	0.306	0.460	0	1
San cristobal (location dummy)	0.439	0.496	0	1
Santa cruz (location dummy)	0.255	0.436	0	1
Price of lobster tail ($/Kg)	24.749	2.392	22.05	28.67
Price of diesel ($/gallon)	0.762	0.069	0.6	0.799
Proportion of vessel owned by an AWOMB	0.222	0.416	0	1
Number of tourist for the 12 months previous to a lobster season	107,197	31,386.36	68,856	161,859

* This specific statistic is based on the censored observations only; that is, those observations with a participation equal to one ($n=1361$).

Table 2
Ex-ante expectations for the sign of the coefficients of the explanatory variables of the outcome and participation equations in the Heckman model.

Variables	Outcome equation	Participation equation	Explanation
Last year average CPT on the lobster fishery (Kg/trip)	Positive	Positive	The more productive the FUP in the Lobster Fishery the more likely that it would participate in the Lobster Fishery and the higher the frequency of participation in that fishery.
Last year average CPT on the sea cucumber fishery (ind./trip)	Positive	Positive	The more productive the FUP in the Sea Cucumber Fishery the more likely that it would participate in the Lobster Fishery and the higher the frequency of participation in that fishery.
Proportion of vessel owned by an AWOMB	Negative	Negative	We expect that this variable would have a negative effect on both the participation and the frequency of participation choices.
Price of lobster tail ($/Kg)	Positive	Positive	We expect that the higher the price of lobster the higher the probability that any FUP will enter the fishing activity and the larger the number of days that this FUP will be active after deciding to participate.
Price of diesel ($/gallon)	Negative	Negative	We expect that the higher the price of diesel the less likely that any FUP will enter the fishing activity, and also the fewer the number of days that a FUP will be active after deciding to participate.
Number of tourists for the 12 months previous to a lobster season	N.A.	Negative	We assume a positive effect of the tourism on the opportunity cost of fisheries; therefore we expect that the sign of the variable tourism for the participation model will be negative and statistically significant.

days approximately; that is, 12.60% of the total days of a lobster fishing season.

The composition of FUPs given their level of activity differed for each port during the study period. San Cristobal had the highest proportion of inactive FUPs (56.57%) and the lowest frequency of participation (7.83%). In contrast, Isabela had the highest frequency of participation (19.48%; only 50.06% of FUPs were inactive) and Santa Cruz had the lowest proportion of inactive FUPs (38.45%; participation frequency was 12.57%). These differences indicate a differential impact of the opportunity cost derived from alternative activities in each of these three islands.

In addition those FUPs that were categorized as active in the lobster fishery can be also sub-classified into two further categories; namely, full-time and part-time participants. If a FUP is active at most once per week in average during the eight seasons that comprise our sample, it was categorized as a part-time participant; however, if a FUP is active more than once per week during the eight seasons it was categorized as a full-time participant. Based on this criterion 44 FUPs were full-time participants and 298 FUPs were part-time participants. From those 44 full-time participants FUP, 56.82% are from Isabela, 29.55% are from Santa Cruz and 13.64% are from San Cristobal. It is also important to note that the average participation rate of those FUPs classified as full-time participants was approximately 37.61% of the total days of a season (i.e. $n=122$ days), while the participation rate of part-time participants was on average 8.56%. Hence, the fact that during a season approximately 87% of the FUPs participate in average 10 days and only 13% of the FUPs participate in average 46 days, it provides a perspective of the high level of latent effort in the lobster fishery.

3.2. *Ownership of vessels*

The ratio between registered vessels and registered Armadores was equal to 0.83 in 2008 with an average of 0.88 during the period 2001–2008. This indicates that some Armadores own more than one vessel. Furthermore, during the period 2001–2008 the proportion of Armadores who owned more than one boat increased from a minimum of 9.72% of the total number of Armadores in 2003 to a maximum of 13.98% in 2008. The accumulation of vessels in the hands of very few owners is a trend that has not stopped in the last years but rather has intensified. According to the GNP Lobster Fishery Report from 2011 approximately 18% of Armadores owned more than one boat.

It is important to analyze the dynamics of the ownership status of Armadores in the Galapagos Islands, particularly if this ownership status has had an effect on fishing activity per se. For this purpose the ownership status of the Armador of a vessel was identified under two categories; that is, Armador who owns only one boat (AWOOB) or Armador who owns multiple boats (AWOMB). Then a kernel estimation procedure was used to determine the density function of the frequency of participation of boats from these two types of owners. Fig. 2 shows the curve labeled as AWOMB has more observations concentrated in the left side of the distribution than the other curve. In contrast, the curve labeled as AWOOB has a longer right tail. Both results indicate that boats owned by AWOOBs are more likely to show a high frequency of participation than those boats owned by AWOMBs. This is supported by a Kolmogorov–Smirnov (K–S) test of both distributions ($D=0.1325$, $P<0.0001$) through which the null hypothesis of equality of distributions for both curves was rejected. However,

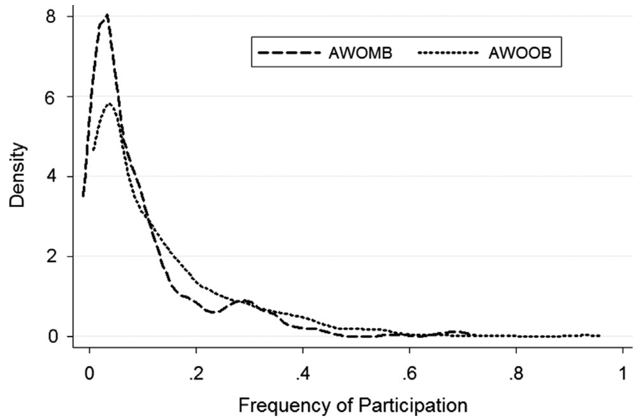

Fig. 2. Kernel density plot for the frequency of participation of FUPs (expressed as a percentage of the total number of days in a season). In this figure there are two curves; the first, labeled as AWOMB that represents FUPs that has as a proprietor an Armador who owns more than one boat; and the second, labeled as AWOOB which represents FUPs that has as a proprietor an Armador who owns only one boat. The kernel density plot is estimated using an Epanechnikov function and a bandwith of 0.0191.

Table 3
Estimated regressors for the Heckman model.

Variables	Outcome equation	Selection equation
Ln(1+CPT-lobster$_{t-1}$)	0.1044**	0.3478***
	(0.0473)	(0.0211)
Ln(1+CPT-sea cucumber$_{t-1}$)	0.0492**	0.1757***
	(0.0209)	(0.0098)
Isabela dummy	0.4300***	−0.4249***
	(0.0879)	(0.0735)
San cristobal dummy	−0.4676***	−0.3279***
	(0.0770)	(0.0671)
AWOMB	−0.2748***	−0.0423
	(0.0729)	(0.0649)
Tourism$_{t-1}$		−0.0055***
		(0.0016)
Diesel price	−2.4689***	−0.8029
	(0.4865)	(0.4888)
Lobster price	0.0844***	0.0343*
	(0.0157)	(0.0194)
Constant term	1.7567***	−0.2091
	(0.3723)	(0.4598)
Lambda (MLE Mill's ratio)	−0.0873	
	(0.2127)	
Rho	−0.0812	
	(0.1972)	
Number of observations	2736	
Censored observations	1361	
Uncensored observations	1375	

The dependent variable of the outcome equation is the natural log of the proportion of days of a season that a FUP is active when it decides to participate in the lobster fishery. For the participation equation the dependent variable is a binary variable that takes the value of one if a vessel participated in the lobster fishery in a season and 0 otherwise. Triple asterisk (***) indicates significance at the 1% level (**) at the 5% level and (*) at the 10% level. Standard errors in parentheses.

when comparing the proportion of boats that decide to participate per season for both types of proprietors, the null hypothesis that the difference of proportion is equal to zero at a 5% confidence level could not be rejected ($z=1.92$, $P=0.054$).

3.3. Econometric model estimation

3.3.1. Estimation of Heckman model

The MLE obtained in Table 3 were consistent with the ex-ante expectations. The past productivity of a FUP for either the lobster or the sea cucumber fisheries has a positive effect on both the decision to participate and the decision about frequency of participation of that FUP. Furthermore, the productivity of the lobster fishery has a larger impact on both decisions than the productivity of the sea cucumber fishery.

If a FUP is owned by an AWOMB both decisions are affected negatively. However this effect is only statistically significant for the participation decision. This suggests that those boats owned by AWOMB participate less frequently than those boats owned by AWOOB, although this ownership status does not have a statistically significant effect over the overall decision to participate.

The variable that represents the lobster price is positive and statistically significant for both equations; conversely the variable that represents the price of diesel is negative for both models but statistically significant only for the outcome equation. This implies that FUPs react to economic incentives that affect the costs and/or benefits related to the fishing activity through changing both their participation decision (affected by benefits only) as well as their frequency of participation (affected by benefits and costs).

The variable that represents the exclusion restriction (i.e. Tourism$_{t-1}$) is statistically significant and negative as expected. In other words, the growth of tourism affects negatively the decision of participation of a FUP in the lobster fishery implying a possible impact of the growth of this sector on the opportunity cost of fishing.

Finally, through the use of the Mill's Inverse Ratio for the MLE procedure; that is, the lambda estimator, the null hypothesis of the non-presence of selection bias from unobservable characteristics of either Armadores or the fishing crew that have decided to participate compared to those that have decided not to participate, could not be rejected. The estimator of the variable that represents the correlation between the errors of the outcome and the participation equation in the MLE procedure (i.e. ρ estimator) is not statistically significant, so that it can be concluded that the participation and the frequency of participation choices are independent. For this purpose a separate econometric analysis of both decisions was conducted. The results of this are summed up in the next sections.

3.3.2. Estimation of frequency of participation model—outcome equation

The decisions on frequency of participation and participation can be econometrically modeled on an individual basis. A series of models were estimated for the decision about how many days a FUP will be active (expressed as a relative proportion with respect to the total number of days in a lobster season) conditional on the fact that the FUP has decided to participate in the lobster fishery season (i.e. y_2).

The first specification that was used for this purpose was an OLS with robust standard errors clustered on the Armadores variable. It is very likely that there is correlation within Armadores but not across them; then with a clustered specification for the standard errors, the downward bias that arises from using regular or robust standard errors was corrected, and with that the inference obtained from those estimators was improved. The second specification that was used for this analysis was a Fixed Effect (FE) model[1] , which is equivalent to an OLS regression with a full set of Armador-specific fixed effects. This approach measured unobserved heterogeneity related to the owner characteristics that could be affecting the decision about frequency of participation.

[1] We do not consider a Tobit because that specification makes a strong assumption; that is, that the same probability mechanism generates both the observations with zero (no participation) and the positives. We proved that this statement was false in the last section showing that the rho estimator was not different from zero; therefore we disregard the use of a Tobit.

While a FE estimator is consistent, it is not as efficient as a Random Effect (RE) estimator if the unobserved Armador-specific effect is uncorrelated with the observed regressors. The RE model treats the Armador-specific effect as random variables that are distributed independently of the regressors. This model is more efficient than FE when none of the regressors are correlated with the Armador-specific effects; however it is inconsistent when the opposite is true. Then this assumption of no correlation should be assessed always using a Hausman test [26,27] and with that to analyze if a RE approach is more appropriate than a FE one. As an anticipated result it is necessary to specify that in this specific case an RE model was omitted from the results since this specification was not appropriate based on the results obtained from a Hausman test ($\chi^2_7 = 40.07,\ P < 0.0001$).

It is important to remember that for these models only included data for which the participation was greater than zero ($y_1 > 0$). Therefore the sample size is reduced to 1361 observations, which is equal to the number of uncensored observations in the Heckman model.

For both specifications (i.e. OLS and FE) the sign of the estimators satisfies the ex-ante expectations (Table 4). Nonetheless, there are important differences in the statistical significance of the estimators for these two specifications. In particular, while all the regressors are statistically significant for the OLS specification, for the FE specification the only regressors that are statistically significant are: the past productivity of the FUP in the lobster fishery, the two price variables and the San Cristobal's dummy variable (which maintained its negative sign).

The full set of Armador-specific fixed effects are statistically significant according to a joint F-test for those variables, thereby this implies that OLS model alone could be mis-specified and inconsistent.

Finally, both specifications show an explanatory power with an R-squared that ranges between 0.1699 and 0.3448. Thus only a low level of explanation can be obtained when using models that try to explain the frequency of participation in the lobster fishery using explanatory variables that are related exclusively to previous season's activity as well as characteristics of the owner. This indicates that the decision about how frequent to participate in any given season could be influenced not by historical factors but mainly by the current (climatic, biological and economic) conditions observed during the same season. Further research using econometric structures that employ current variables are required in order to provide more explanation about the fishing behavior in the Galapagos Islands.

Table 4
Estimated regressors for the frequency of participation models (Eq. 1).

Variables	OLS	FE
Ln(1+CPT-lobster$_{t-1}$)	0.1210***	0.0441***
	(0.0254)	(0.0105)
Ln(1+CPT-sea cucumber$_{t-1}$)	0.0568***	0.0166
	(0.0111)	(0.0281)
Isabela dummy	0.4127***	0.1554
	(0.1110)	(0.2413)
San cristobal dummy	−0.4811***	−0.5059**
	(0.0930)	(0.2354)
AWOMB	−0.2780***	−0.0462
	(0.0816)	(0.1481)
Diesel price	−2.5159***	−2.7512***
	(0.4354)	(0.4906)
Lobster price	0.0833***	0.0587***
	(0.0153)	(0.0158)
Constant term	1.7217***	2.7466***
	(0.4106)	(0.4110)
Significance test for owner fixed effects [F(335,1018)]		2.10
R-squared	0.1699	0.3448
Number of observations	1361	
Number of clusters	336	

The dependent variable of the outcome equation is the natural log of the proportion of days of a season that a FUP is active when it decides to participate in the lobster fishery. Triple asterisk (***) indicates significance at the 1% level (**) at the 5% level and (*) at the 10% level. Standard errors in parentheses.

3.3.3. Estimation of participation model: participation equation

In the Heckman model, the participation equation is characterized by a Probit model through which probability that a FUP will participate in any given season is estimated. The results of estimating the same Probit model independently but using robust standard errors clustered on the Armador variable are reported in Table 5, along with the coefficients estimated for a second specification in which a Logit was used as cumulative distribution function. The results from estimating these models are consistent with the ex-ante expectations given in Table 2. In other words the participation behavior of Galapagos FUPs in the lobster fishery depend on the past performance of those FUPs in both the same lobster fishery and the sea cucumber fishery, as well as the potential benefits and costs of their participation in the fishery (including the opportunity cost derived from the tourism). In addition, both specifications show an acceptable level of explanatory power, with pseudo-R^2 values that range between 0.236 and 0.304. The model explains the participation behavior in the lobster fishery fairly well, and thus it is possible to use it for generating inferences about the marginal impact of each of the explanatory variables.

A set of marginal effects at the mean for each explanatory variable was calculated using the Logit specification. (Table 6). An increase of 1 Kg/day on the average CPT of lobster in the previous year increases the probability of participation in the lobster fishery by 10.20%. In the case of the sea cucumber an increment of the CPT on one individual per day increases the probability of participation in the lobster fishery by 5.17%. On the other hand if the owner of a FUP is an AWOMB the probability of participation falls approximately 1.57%, but this effect is not statistically significant. An increment of approximately 4000 tourists per year will reduce the

Table 5
Estimated regressors for the participation model (Eq. 2).

Variables	Probit	Logit
Ln(1+CPT-lobster$_{t-1}$)	0.3478***	0.5888***
	(0.0244)	(0.0422)
Ln(1+CPT-sea cucumber$_{t-1}$)	0.1756***	0.2982***
	(0.0110)	(0.0188)
Isabela dummy	−0.4249***	−0.7448***
	(0.0840)	(0.1417)
San cristobal dummy	−0.3280***	−0.5640***
	(0.0742)	(0.1244)
AWOMB	−0.0418	−0.0630
	(0.0663)	(0.1121)
Tourism$_{t-1}$	−0.0055***	−0.0099***
	(0.0015)	(0.0026)
Diesel price	−0.7957*	−1.3401*
	(0.4644)	(0.0190)
Lobster price	0.0345*	0.0662*
	(0.0186)	(0.032)
Constant term	−0.2162	−0.4703
	(0.4552)	(0.7708)
McFadden's R^2	0.236	0.238
McFadden's Adj R^2	0.232	0.233
Cragg and Uhler's R^2	0.279	0.281
Efron's R^2	0.303	0.304
Number of observations	2736	

The dependent variable is a binary variable that takes the value of one if a vessel participated in the lobster fishery in a season and 0 otherwise. Triple asterisk (***) indicates significance at the 1% level (**) at the 5% level and (*) at the 10% level. Standard errors in parentheses.

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Table 6
Marginal effects at the mean for changes in the explanatory variables of the Logit model for the participation equation (Eq. 2).

Variable	dy/dx	Std. Err.	z	P-value
Last year average catch per trip on the lobster fishery (Kg/day)	0.1020	0.0073	13.97	0.000
Last year average catch per trip on the sea cucumber fishery (ind/day)	0.0517	0.0033	15.87	0.000
Isabela dummy	−0.1834	0.0337	−5.44	0.000
San cristobal dummy	−0.1401	0.0305	−4.59	0.000
AWOMB	−0.0157	0.0280	−0.56	0.574
Number of tourists for the 12 months previous to a lobster season	−0.0025	0.0007	−3.84	0.000
Diesel price	−0.3350	0.1975	−1.70	0.090
Lobster price	0.0166	0.0079	2.09	0.037

participation in the lobster fishery by 1%. Thus, since on average the number of tourists has increased by 13,500 people per year, the annual reduction of participation in the lobster fishery because of tourism can be estimated as approximately 3.38% annually[2] . Finally, in the case of market variables the probability of participation of any FUP increases by 1.67% if there is an increment of $1 USD in the price of the Kg of lobster tail. On the other hand, in the case of the diesel price, an increment of $0.1 USD in the price of diesel reduces the participation rate by approximately 3.35%[3] .

4. Discussion

4.1. Latent effort

The main objective of this paper was to describe and explain the fishing behavior of the Galapagos fleet for the spiny lobster fishery, an analysis that is missing in the literature. A descriptive analysis found that FUPs from the three ports in the GMR showed a considerable level of inactivity in the lobster fishery, and that in addition, FUPs that were active during a season showed a low frequency of participation. This is an important result because it demonstrates a high level of latent effort for that fishery in both the extensive and the intensive margins. Such a high level of latent effort in the Galapagos lobster fishery may distort and counteract any management initiatives designed to improve the market conditions of the lobster either through increasing its value (i.e. price received by fishermen) or reducing its cost of capture. For example, recent initiatives included an unsuccessful experiment of changing from a dive fishery to a trap fishery [28], and a promotional marketing strategy aimed at selling live lobsters to local tourists [29], thus cutting out middlemen and increasing financial gains for the fishers. While well intentioned, these initiatives did not consider the effects that increased revenue might have on fishing effort for an already depleted resource, or the effects of switching to a trap fishery on dive fishers who are not boat owners, but who are the most economically vulnerable portion of the fishing sector.

Latent effort is a problem that is unequal in each port; for example, it is more serious in San Cristobal than it is in the other ports. This heterogeneity of participation behavior in each port suggests us that it is important to adjust fisheries policies in the Galapagos Islands according to the reality of each port rather than using the current approach of “one size fits all”.

The latent effort for the lobster fishery observed in this study is composed both of inactive vessels and of vessels which are not active to the full extent of their capability. Some of the latent effort in the former group may in actual fact be “ghost capacity”—vessels that are registered in the system with fishing permits but are not kept in working condition, rather are held with the expectation of using to transfer to a tourism permit [30]. Other vessels may be dedicated full time to other activities such as the open water hook and line fishery [31] or the incipient local based sports fishery [32]. This problem highlights the need to determine through a census mechanism what the real capacity of the lobster fishery is and to identify who the real users are. This would help to focus the benefits of the lobster fisheries policies exclusively to those whose income are intimately related to that activity and to improve the control and monitoring to reduce illegal fishing and tourism activities.

On the other hand the large number of part time vessels which only operate an average of 10 days throughout the 4-month season of the lobster fishery might be interpreted in several ways—it is possible that this level of participation is sufficient to cover the economic expectations of those FUPS, or rather, that these FUPS are engaged in other, primary activities during this period (which may include but not be limited to fishing), that are more attractive. Even for full time fishers, a significant amount of time will not be available for fishing within the season—the fishery is generally open from September through December, when sea conditions are generally rough at first, and this is often reflected by low initial catch per unit effort indices at the start of the season [33]. In addition, *P. penicillatus* inhabits shallow, exposed, rocky habitat, so access to these sites is often limited by wave action [34].

4.2. Factors affecting FUP behavior

The decisions to participate and how frequently to participate in the lobster fishery are independent. Based on this result, a separate analysis of both decisions was conducted. For the decision to participate, there was a persistence effect for the amount of effort applied to the lobster fishery for those who had been historically more productive in either the lobster fishery or the sea cucumber fishery. Specifically, the FUP's past productivity in the lobster fishery was the main predictor for the decision to participate; such that FUPs that have been more productive year-upon-year are also more predisposed to participate.

For the frequency of participation in the lobster fishery, the decision was influenced by a process of cost-benefit analysis that fishermen undergo season by season based on the behavior of market variables (in this case, the price of lobster tails and the cost of diesel). This is important because it shows that FUPs understand the economic trade-off of their production decisions. Quantifying the effect of these economic variables could help to analyze the effect of some economic policies imposed on the fishing sector. For example, the diesel subsidy (which on average has equaled USD $0.11/gal) that the Ecuadorian government gave to the fishery sector has affected the fishing behavior in the GMR. Hence, based on these results, this subsidy has distorted the economic

[2] It is necessary to clarify that this section argues that an increase in the number of tourist would reduce the participation in the lobster fishery. This does not mean that there would be a reduction in the overall pressure on the marine ecosystems of the archipelago. The latter can only be determined with a general equilibrium analysis that is outside of the scope of this paper.

[3] The price of diesel in the islands is subsidized and has never surpassed a level of $0.80 per gallon. Then it is logical to suppose changes of prices less than a unit of US dollar.

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incentives of Galapagos FUPs, generating an artificial increase in participation in the lobster fishery by approximately 3.69% per year. This confirms previous results from the fisheries literature [35–37]; that is, that production subsidies (such as the diesel subsidy) distort the incentives and behavior of the fishing fleets and for that reason the diesel subsidy in the GMR should be reconsidered in the future.

It is also important to highlight that there was a significant effect of tourism on the decision to participate in the lobster fishery. This is evidence of the presence of an impact of the opportunity costs derived from alternative activities on the participation decision of FUP in Galapagos. However, based on the results obtained in the descriptive analysis, the opportunity cost effect is different for each island of origin. This reaffirms the importance of considering the heterogeneity among ports when designing fishery policies for the archipelago. San Cristobal is a case that should require further research; this is because FUPs from this island besides of showing a low participation in the lobster fishery, they also showed a lower frequency of participation than the other ports.

The ownership status of the Armador also had an impact on the FUP's frequency of participation in the lobster fishery; although the same ownership status did not have any differential impact on the decision to participate. This relationship could indicate that Armadores diversify the use of their boats as a way to reduce their risks, all else being equal.

Finally, in this paper it was only possible to generate models with a moderate level of explanation when explanatory variables that were related to the previous season's activity and the owner's characteristics were used. This could indicate that the decision regarding how much effort to apply in any given season could be influenced also by the season's present conditions (such as the abundance of the product in the fishing grounds, market conditions for the product, and climate factors). Therefore, future research on fishing behavior in the Galapagos Islands should focus on building models that use up-to-date variables (such as Discrete Choice Models) rather than models that use variables from a prior season.

5. Conclusions

This paper is one of the first attempts to quantitatively explain the behavior of Galapagos FUPs, which could help generate more sound marine policies in the archipelago. In this analysis it was shown that the fishing behavior of FUPs in the lobster fishery depends on the potential benefits and costs of their participation in that fishery as well as the particular economic conditions in the ports of origin of FUPs. The latter result suggests that given the heterogeneity of the economic and social conditions of the three ports of origin (i.e. San Cristobal, Santa Cruz and Isabela), “one size fits all” policies are likely to fail. Therefore, it is recommended that fisheries management policies are tailored to the specific socio-economic conditions of each of the three ports.

More importantly, it was found that the participation in the lobster fishery has been significantly below full capacity. This has produced an enormous latent effort in that fishery, which is a problem that has been neglected until now[4]. Given the size of the latent effort and the result that fishing behavior is influenced by costs and benefits derived from the activity, it is reasonable to assume that any improvements in either the state of the resource (i.e. lobster) or in its prices is likely to lead to an increase in effort, thus dissipating the potential for the resource to truly recover. Therefore, unless the issue of latent effort is first resolved, any initiative aimed at increasing catchability, prices or markets for the lobster fishery will likely have the opposite effect. This reaffirms the need to identify both non-fishers and bona-fide fishers (i.e. those whose income depends significantly from the lobster fishery in the Galapagos Islands). It is expected that by correctly identifying the members of the two groups, the fisheries management policies will enhance both their efficiency and distributional impacts. This identification task will not be difficult since, as was found in this analysis, most of the fishing effort in the lobster fishery is concentrated in a few FUPs and there is a high degree of persistence of the fishing effort between years. However, implementing policy related to this may not be an easy task, especially as it would essentially diffuse the political clout of the non-fisher components in leadership roles at the cooperatives.

Finally it is important to note that this is a short term analysis that uses explanatory variables that are related exclusively to both the characteristics of the FUPs and their expectations based on the experiences from previous season's activity. Further studies that analyze the long term behavior of FUPs through economic models that employ up-to-date variables interrelated with biological models of the lobster stock are necessary.

[4] The latent effort problem was only recently highlighted during a process of reforming the fisheries management framework for the Galapagos [15,28,38].

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