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Modeling the Fishing Behavior for the Galapagos Lobster Fishery

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1. INTRODUCTION

The overexploitation of the two more profitable marine species in the GMR (i.e. the red spiny lobster and the sea cucumber) confirms the prejudicial effects that command and control policies have had over the biological health of the marine resources in the Galapagos Islands during the last 14 years. In spite of that, the consensus of fisheries scientists that have worked in the Galapagos is that, it is not the quality of policies applied up today there, but the moral character and in some cases the cultural traits of the Galapagos fishermen the root of the fisheries problem in the GMR. In other words, they have concluded that the main cause of the fisheries problems in the Galapagos is the “bad behavior” of fishermen. Hence, there are those who have argued that fishermen suffer of shortsightedness which induces them to prefer short-term economic growth strategies that require the exhaustive exploitation of marine resources in the present (González et. al. 2008, Ospina 2006). There are others who asserted that the problem is the origin of fishermen. That is, that given that most of Galapagos fishermen migrated from mainland; they possess a “Frontier Mentality” and not an “Island Mentality” (Ospina 2006). In other words, it is asserted that Galapagos fishermen do not have a culture of ecological awareness about what implies living on the Islands, therefore they are unable to live sustainably there and they even have a depredatory view of the natural resources (Hearn 2008, Hardner 2004, Ospina 2006). And finally there are those who claim that greed is the root of the fisheries problem in the Galapagos Islands and therefore it doesn't have any solution (Sea Sheppard 2004, Toral 2008). Based on these arguments, fisheries scientists have arrived to a conclusion, that the only fisheries policies that make sense for the GMR are those that restrain the bad behavior of fishermen. In other words restrictive policies imposed by the authorities for the greater good of the society and the environment.

This has been the rationale in which the decision of imposing conventional regulatory policies is grounded; all of them command and control policies whose aim is to control fishing mortality through policing continuously the bad behavior of fishermen in Galapagos. According to those fishermen scientists this type of policies would assure the proper protection of the marine resources. But if the results are not like the expected ones (as actually has happened in the Galapagos Islands) the failure is attributed to a political process that does not listen to scientists (a claim that has also been frequently enunciated during these 14 years in the Galapagos).

However the rational process used by those fisheries scientists to propose their policy recommendations is flawed. This is because they have failed to characterize this “bad behavior” of fishermen first; and even worse they have not explained the reasons that motivate that behavior. As far as we know, there are not studies that try to describe and to explain the fishing behavior in the Galapagos Islands or that attempt to determine the factors that influence that behavior. Hence in this paper we expect to fill that gap in the literature through modeling and analyzing the fishing behavior of Galapagos fishing units of production (FUP) for the *Red Spiny Lobster Fishery*. We will determine what factors are determinant for the participation decision of FUPs for the lobster fishery as well as what factors are relevant for their frequency of participation after they have decided to participate.

Finally an important observation before starting is that the analyses for this paper will be based on the red spiny lobster fishery only. Then, when we refer to a fishing season in this paper, keep in mind that we are talking about the red spiny lobster season which lasts four months from September to December of any year.

2. CLASIFICACION OF FISHERMEN AND VESSELS IN THE GALAPAGOS FISHERIES.

The Galapagos National Park (GNP), the regulatory authority of the GMR, has classified fishermen into two categories: armadores and pescadores. *Armadores* are those fishermen who have at least one ship (i.e. panga, fibra or bote) and *Pescadores* are fishermen who do not possess any ship at all. According to the GNP's official record, 61.3% of the registered fishermen are classified as "pescadores", while the remaining 38.7% are classified as "armadores"¹. Thus vessels, which are considered as capital in this production system, are owned by a minority of fishermen.

There is another peculiarity in the relationship between armadores and vessels; this is that the ratio between registered vessels and registered armadores was equal to 0.83 in 2008. This indicates that some armadores owns more than one vessel. Even more, if we analyze a little more about this issue we find that during the period 2001-2008 the proportion of armadores who own more than one boat increased from a minimum of 9.72% in 2003 to a maximum of 13.98% in 2008 (Table 1). There was also an increment of more than 100% in the number of people who own more than two boats in 2008. This is an interesting trend, especially because happened in a moment in time when the health of the two most profitable fisheries is highly deteriorated. At the end this dynamic has produced that those boats that are owned by armadores who have multiple boats increase from 21.5% to 28.2% of the total number of registered vessels. This trend of accumulating boats in very few owners is a trend that hasn't stopped in the last years but it has accentuated. According to the 2011 Lobster Fishery Report (GNP 2011) approximately 18% of armadores owned more than one boat up today. Hence, as we previously said, this is an interesting trend because

¹ Pescadores are considered as labor for this production system.

occurs in a moment in which the profitability of the fishery activity has fallen, especially because of the collapse of the sea cucumber fishery and the contraction of the lobster fishery. Yet more, we observe that this trend started to accentuate after 2006, the year in which many considered that the sea cucumber fishery had collapsed.

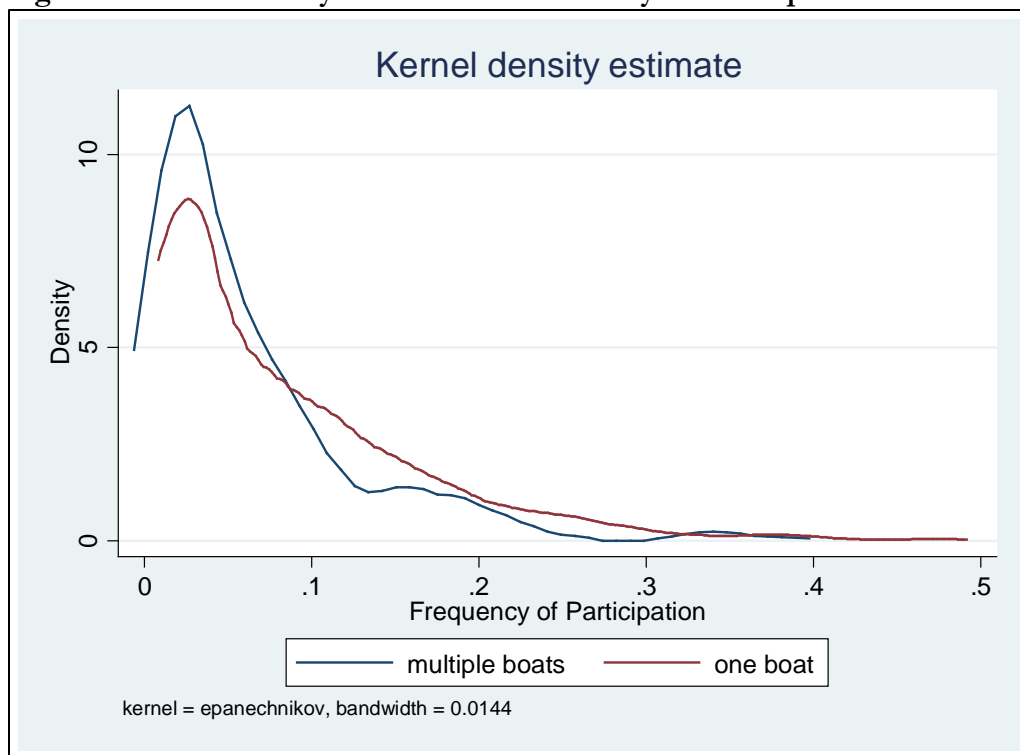
Table 1. Classification of armadores based on the number of vessels that they own

| Number of vessels | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|----------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 1 | 350 | 358 | 362 | 362 | 350 | 350 | 332 | 320 |
| 2 | 38 | 38 | 37 | 37 | 40 | 40 | 52 | 46 |
| 3 | 4 | 4 | 2 | 2 | 4 | 4 | 2 | 6 |
| 4 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 4 |
| Total Number of Armadores | 392 | 400 | 401 | 401 | 394 | 394 | 386 | 372 |

The dynamic of the ownership status of armadores of fishing vessels in the Galapagos Islands is very important, however we should determine if that dynamic has had an impact on the fishing behavior. For this purpose we will proceed to analyze if there is any difference in the participation and frequency of participation between those vessels that are owned by armadores who own only a boat (AWOOB) and those vessels that are owned by armadores who own multiple boats (AWOMB). For this purpose, we use a kernel estimation procedure to determine the density function of the level of participation (after they decide to participate) for those vessels that are owned by AWOOB, labeled in the graph as one boat, and those vessels that are owned by AWOMB, labeled in the graph as multiple boats. Thus we observe in Figure 1, that the curve labeled as *multiple boats* has more observations concentrated in the left side of the distribution (i.e. region of low participation) than the curve labeled as *one boat*. Even more when we conducted a Kolmogorov-Smirnov test to both distributions we found a $D=0.1281$ with a Corrected-P-value of 0.000 then we reject the null hypothesis of equality of distributions for both curve. On the other hand, if we apply

the same Kolmogorov-Smirnov test but using instead the variable that represents the decision of participation in a season for vessels owned by AWOMB or AWOOB, we found a $D=0.0442$ and a Corrected-P-Value equal to 0.292. Then we cannot reject the null hypothesis of equality of distributions for the decision of participations for these two groups. Therefore it can be concluded that even though the ownership status of the armador who owns an vessel apparently doesn't have a differential impact on the decision of participation, there is evidence that this ownership status it does have an impact on the intensity (or frequency) of participation; in a way that, those boats that are owned by AWOMB participate less frequently than those boats owned by AWOOB.

Figure 1. Kernel Density Estimation of Intensity of Participation of Vessels



This result is consistent with the observation that armadores not always participate in the fishing activity but they prefer to provide their ships to pescadores, so that they can use it to fish and after that to share their profits with those armadores (Castrejon 2009). Then the previous result

could be an indication that armadores would try to diversify the use of their boats as a way to reduce the risk of any catastrophe that could imply the total loss of them. Consequently, the frequency of use of boats owned by AWOOB will be lower than the intensity of use of vessels owned by AWOMB. This is because the latter in order to maximize profits would have to use his/her only boat as frequent as possible. Hence for any model that attempts to model the intensity of effort application it would be necessary to include as explanatory variable the ownership status of armadores.

The fishing vessels in the Galapagos Island are classified in three groups: botes, pangas and fibras (Castrejon 2009). However we can also classify vessels based on their fishing behavior during a season. Thus, during a season vessels can be classified as active and inactive vessels. Active vessels represent in average 48.05% of registered vessels per season during the period 2001-2008; while inactive vessels were the majority approximately 51.95%. In addition those vessels that were categorized as active during a season can be also classified into two categories: highly active (HA) and sporadically active (SA). If a vessel during a season is active at most three times per month we will categorize it as a SA vessel; however, if it is active more than three times per month this unit will be called as a HA vessel. We made this classification since we found important differences in the level of participation between these two groups of active vessels during the period 2001- 2008. Thus in average the participation rate per season of HA vessels was approximately 25.46% of the time, meanwhile the participation rate per season of SA vessels was in average 5.50%.

When we examined the composition of the total number of registered boats using this classification, we found that HA vessels represents in average 16.35% of the total number of registered ships per season during the period 2001-2008 while the remaining 31.70% could be

classified as SA vessels during the same period. That means that the frequency of participation of approximately 2/3 of the vessels that were active was low (i.e. in average less than 2 days per month). One of the possible explanations for this phenomenon is that the decision of participation and the decision of how many days a vessel would be active during a season after deciding to participate could be highly influenced by the cost of opportunity of alternative activities especially those related to the tourism sector. Then for modeling the participation decision specially, it is necessary to include a variable that represents the cost of opportunity derived from available labor alternatives in the archipelago, like the number of tourists that arrive to the islands per year or the annual growth rate of tourism.

Finally, it is important to note that there are three ports in the Galapagos Islands, they are: Puerto Baquerizo Moreno (located in San Cristobal Island), Puerto Villamil (located in Isabela Island) and Puerto Ayora (located in Santa Cruz Island). The socio-economic conditions in each of these three ports in the archipelago are completely different therefore the alternative job alternatives and their derived cost of opportunity for the fishery activity are expected to be different for each island. For instance Puerto Ayora (PA) is the most economically developed of the three ports and it is highly active in tourism activities. Puerto Baquerizo Moreno (PBM) has been growing rapidly in recent years as the tourism sector has been developing with a clear objective of being a direct competition to PA. Finally, Puerto Villamil (PV) is the less developed of the ports with a tourism sector very incipient. The perspectives of economic growth of PV are limited due to the reluctance of its population. Hence we considered important to consider the vessels' port of origin as a determinant factor on the observed fishing behavior of them. This is because we assumed that fishing behavior is influenced by the socio-economic environment and the economic prospects (i.e.

cost of opportunity) available to fishermen in their port of origin, since as we indicated, they are dissimilar in each port.

2.2. CLASSIFICATION OF PANGAS AND FIBRAS BASED ON THEIR FREQUENCY OF PARTICIPATION

Before proceeding further it is important to highlight two important simplifications that we will apply along this paper. First, since armadores not always participate in the fishing activity but they borrow/lease their vessels so that others can use them; we will focus our analysis on each vessel treating them as an independent FUP; with that we assumed that the fishing crew would try to maximize the profit derived from each trip. Thus our modeling unit from now on will be individual vessels. And second, we would focus our analyses to the behavior of two types of vessels only; they are: pangas and fibras. We will make the latter simplification because botes are mostly used as a mean of transportation. Henceforth, when pescadores (and armadores) decide to take their fishing activities to farther locations (such as Darwin and Wolf islands) they hire a bote to transport fibras and pangas to that specific location. At the end, the catch that is registered is the individual catch for each fibra and panga that were transported in a bote. The owner of a bote is paid either with money or with product. Then to avoid problems of double counting we will focus in fibras and pangas only, which are the more numerous type of vessel in the archipelago anyway (i.e. 85% of the total number of registered vessels and 95% of the active vessels). Thus from now on when we refer in this paper to a FUP, we will be talking about pangas and fibras.

In this section we will analyze the composition of FUPs based on their level of participation (i.e. Inactive, Sporadically Active and Highly Active) as well as the average frequency of participation for each of these categories. For this purpose we conduct this analysis per island and during the

period 2001-2008. In Table 2 we can observe that the composition of FUPs given their level of activity differs for each port. Thus we observed that San Cristobal is the island with the highest proportion of inactive FUPs and is also the island with the lowest proportion of FUPs classified as HA in average per season. On the other hand Santa Cruz is the island with the highest proportion of FUPs considered HA and also it has the lowest proportion of inactive FUPs. On the other hand we found (Table 3) that there are small differences in the average level of participation per season for each type of active FUPs (i.e. highly active and sporadically active) in each island. However, these differences are similar with those found in the average composition of FUPs showed in Table 2. Hence, San Cristobal is the island that showed the lowest level of participation for both type of active FUPs and Santa Cruz is the island that showed the highest for both type too. This indicates the importance of including location regressors when modeling the choices for participation and intensity of participation in the Galapagos Island for FUPs.

Table 2. Percentage of FUPs classified based on their participation by island

| Classification | Isabela | San Cristobal | Santa Cruz |
|----------------------------|----------------|----------------------|-------------------|
| <i>Inactive</i> | 53.50% | 53.90% | 46.64% |
| <i>Sporadically Active</i> | 26.83% | 34.73% | 31.31% |
| <i>Highly Active</i> | 19.67% | 11.37% | 22.05% |

Table 3. Frequency of participation (days active divided by total number of days per season) of FUPs by island

| Type of Vessel | Isabela | | San Cristobal | | Santa Cruz | |
|----------------------------|----------------|------------------|----------------------|------------------|-------------------|------------------|
| | <i>Mean</i> | <i>Std. Dev.</i> | <i>Mean</i> | <i>Std. Dev.</i> | <i>Mean</i> | <i>Std. Dev.</i> |
| <i>Sporadically Active</i> | 6.09% | 4.15% | 5.01% | 3.83% | 6.11% | 4.28% |
| <i>Highly Active</i> | 24.98% | 17.80% | 23.35% | 7.52% | 26.86% | 10.54% |

Figure 2. Kernel Density Estimation for the Frequency of Participation of FUPs in San Cristobal

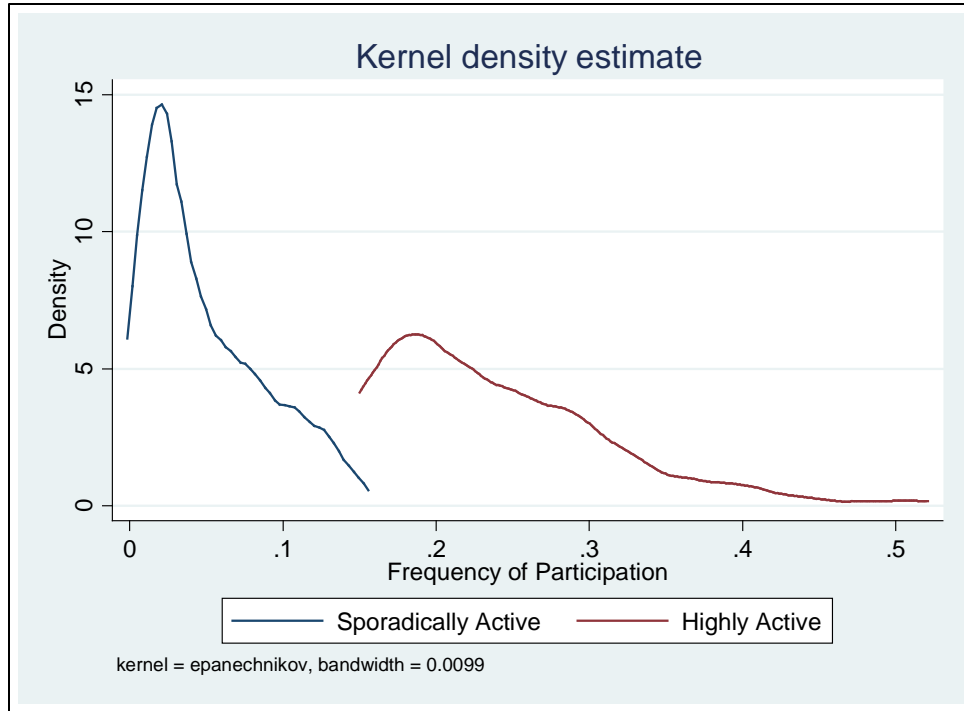


Figure 3. Kernel Density Estimation for the Frequency of Participation of FUPs in Santa Cruz

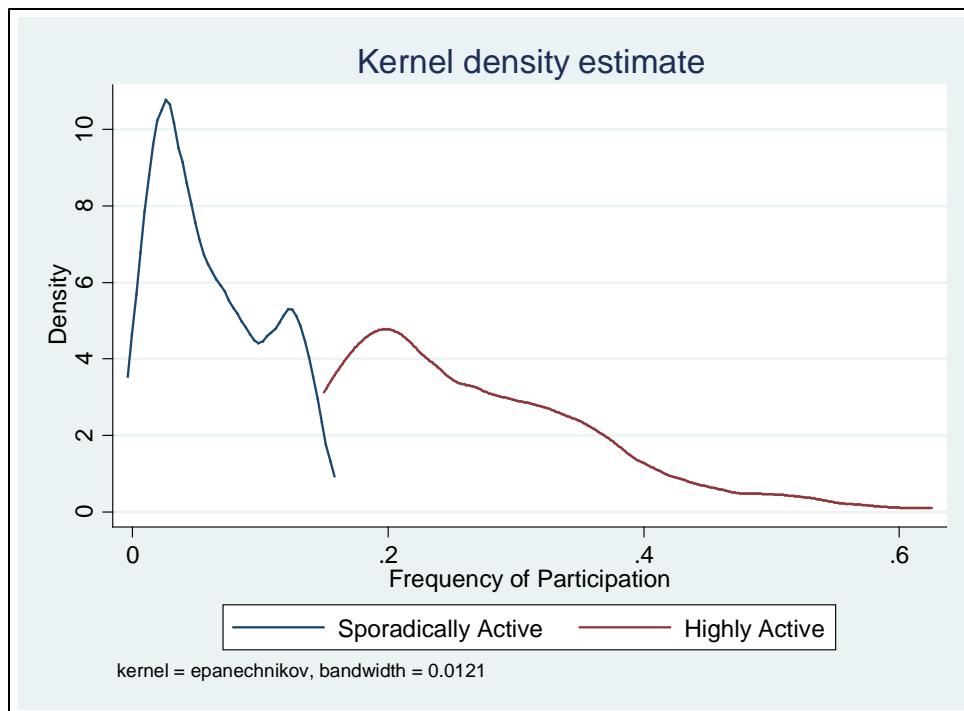
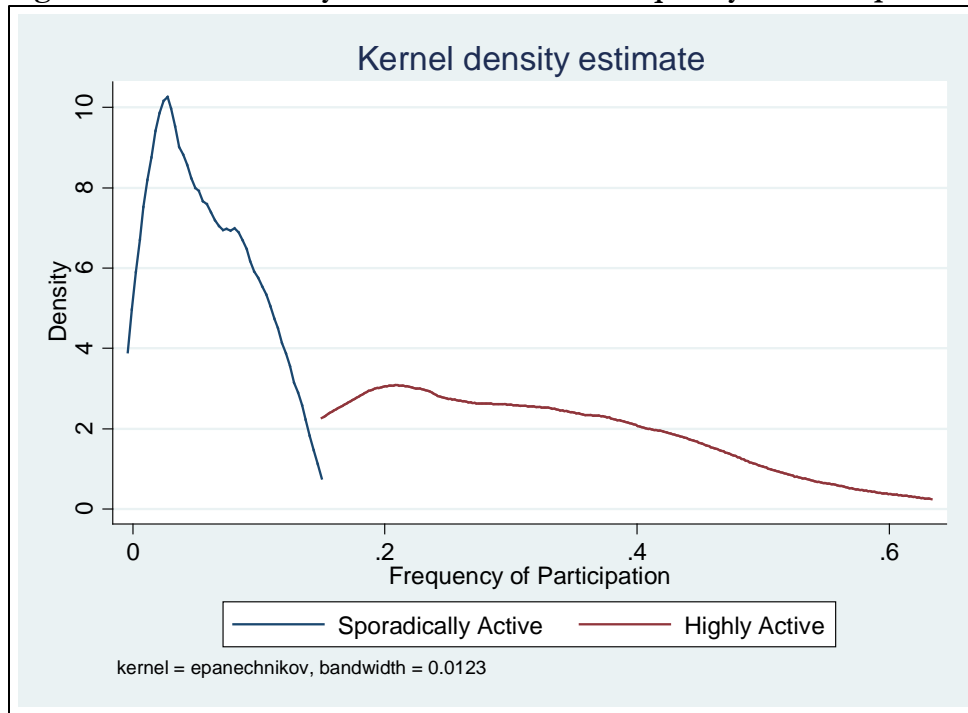


Figure 4. Kernel Density Estimation for the Frequency of Participation of FUPs in Isabela



Finally, when we analyze the frequency of participation between the two different classes of active FUPs (i.e. SA and HA) using a set of kernel densities (Figure 2 to 4) we found out a striking difference between the distribution functions of these two categories in each island, which confirms the rationale of making this classification among active FUPs.

3. ECONOMETRIC MODEL FOR PARTICIPATION AND INTENSITY OF PARTICIPATION FOR THE LOBSTER FISHERY

In the last section it was shown that there is a high level of non-participation in the lobster fishery but also that among those FUPs that participate there is a high percentage with a low frequency of participation. For this reason we considered that it is important to examine the factors that influence these fishing behaviors in the Galapagos lobster fishery.

Hence we are interested in estimating two models, the first one for the decision of participation in a fishing season (yes or no) and the second for the decision about frequency of participation after a FUP has decided to participate. Specifically the relationship that we will estimate to explain the frequency of participation is as follows:

$$\ln(f_{i,j,y} + 1) = \beta_1 \ln(1 + \text{CPUE}_{\text{Lobster},i,y-1}) + \beta_2 \ln(1 + \text{CPUE}_{\text{Sea Cucumber},i,y-1}) + \beta_3 d_{\text{Isabela}} + \beta_4 d_{\text{San Cristobal}} + \beta_5 d_{\text{AWOMB}} + \varepsilon_{i,j,y} \quad \text{iff } f_{i,j,y} > 0 \quad (1)$$

where f is the frequency of participation measured as the ratio between the number of days that a FUP was active and the total days of a season (i.e. 122 days); $\text{CPUE}_{\text{Lobster},y-1}$ is the average CPUE of a FUP on the lobster fishery during the previous season; and $\text{CPUE}_{\text{Sea Cucumber},y-1}$ is the average CPUE of a FUP on the sea cucumber fishery during the previous season. We also included two dummy variables for the port of origin of the FUP ($d_{\text{San Cristobal}}$ and d_{Isabela}) and an additional dummy to gather the effect of the ownership status of the armador related to a FUP (d_{AWOMB}). FUPs are denoted by the subscript i and armadores by j . Time is indexed by year and will be represented by the subscript y .

On the other hand the relationship that we will estimate to explain the decision of participation is the following:

$$p_{i,j,y} = \Theta[\alpha_1 \ln(1 + \text{CPUE}_{\text{Lobster},i,y-1}) + \alpha_2 \ln(1 + \text{CPUE}_{\text{Sea Cucumber},i,y-1}) + \alpha_3 d_{\text{Isabela}} + \alpha_4 d_{\text{San Cristobal}} + \alpha_5 d_{\text{AWOMB}} + \alpha_6 \text{Tourism}_{y-1}] + u_{i,j,y} \quad (2)$$

where p is 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 in the lobster season (regardless of the frequency) and zero otherwise. Most of the explanatory variables were explained for the previous model (equation 1) except for the variable $Tourism_{y-1}$ which represents the total number of tourist that entered to the Galapagos Islands in the 12 months previous to the opening of a lobster season.

It is important to specify that in equation 2 the cumulative distribution function $\Theta[\cdot]$ can be defined in two ways; that is, as a normal or as a logistic distribution. If we define $\Theta[\cdot]$ using a normal distribution we would obtain a linear probit model. On the other hand if we use the logistic distribution to define $\Theta[\cdot]$ we obtain the linear logistic regression. Along this paper we will use both distributions to estimate equation 2.

It is important to note that in both specifications (equations 1 and 2) we did not include a variable related to the type of FUP (i.e. panga or fibra). We decided to not include this variable because it is highly correlated with the location dummies. Thus when we conducted an analysis of statistical independence between location and type of FUP variables we determined a critical value of 253.0824 for the Pearson χ^2 and a critical value of 257.8795 for the LR χ^2 test; then we reject the null hypothesis of independence between these two variables. We even found a clear overrepresentation of Pangas in San Cristobal and Fibras in Isabela. Even more, we determined in some preliminary estimations that when we include a variable that define the type of vessel along with location dummies in a model specification, the former lost any statistical significance due to the effect of multicollinearity with the latter. Thus we decide to drop out the variables related to the type of FUP for the final specifications that we will use in this paper (equations 1 and 2).

In addition, for our estimation work we will use initially a Heckman Selection Model, since it is very likely that there could be a selection bias process that could be affecting the decision of frequency of participation. This bias could arise from a selection process that could appear during the decision of participation due to some unobservable characteristics of either armadores or the fishing crew. For this purpose we will proceed to estimate a Heckman model first and with that we verified whether the selection variable (either the mills ratio for the two step procedure or the rho for the MLE version) is statistically significant or not. If that variable is not significant then we would reject the hypothesis of the existence of selection bias by unobservable factors and consequently we would proceed to model both the participation decision and the level of intensity decision separately. The former, through the use of panel data models and the latter through the use of Logit and Probit models. Thus in this part we will show the results of those estimations but first we will provide a description of the data available for that purpose.

3.1. DESCRIPTION OF THE DATA

For the estimations of the models on this paper we will use landings data for the lobster fisheries collected during the period 2001-2008. This data was collected by the CDF and the GNP during two different periods. Hence, the subsample of observations corresponding to the period 1999-2006 was collected by the CDF; and the rest of the sample (i.e. 2007-2009) was collected by the GNP. We will also use the landings data of the sea cucumber fishery during the same period, 2001 – 2008.

Likewise we will utilize information about which boats and fishermen were legally able to participate in any fishery activity in the Galapagos Islands. We obtained that data from the Galapagos Fishery Record (GFR) which is managed by the GNP. The year 2001 is the first in which we have available data of that type 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 or fishermen, except for the membership records to the fishing cooperatives, which is confidential information. Thus we will use the information from the GFR along with the landings data to determine which vessels participated in a specific lobster fishing season and with that to identify their characteristics (especially to classify if the vessel was a panga or a fibra) as well as who the owners of any of those vessels were. Finally, we obtained data about the total number of tourist that has entered to the island per year as well as the rate of growth of tourism. This would work as a proxy variable for the job opportunities that fishermen have available during any given season.

Table 4 gives descriptive statistics for the 2,688 observations that comprise the estimation sample.

Table 4. Descriptive Statistics of Variables

| Variable | Mean | Std. Dev. | Min | Max |
|---|-------------|------------------|------------|------------|
| 1. Participation | 0.494 | 0.500 | 0 | 1.0000 |
| 2. Frequency of Participation | 0.066 | 0.112 | 0 | 0.6417 |
| 3. Last Year Average CPUE on the Lobster Fishery (Kg/day) | 6.570 | 10.391 | 0 | 76.884 |
| 4. Last Year Average CPUE on the Sea Cucumber Fishery (ind./day) | 247.369 | 577.461 | 0 | 4,949.667 |
| 5. Isabela (Location dummy) | 0.303 | 0.460 | 0 | 1 |
| 6. San Cristobal (Location dummy) | 0.440 | 0.450 | 0 | 1 |
| 7. Santa Cruz (Location dummy) | 0.257 | 0.437 | 0 | 1 |
| 8. AWOMB (dummy indicating the vessel is owned by an AWOMB) | 0.220 | 0.414 | 0 | 1 |
| 9. Number of tourist for the 12 months previous to a lobster season | 107,054 | 31,342 | 68,856 | 161,859 |

Note: Statistics are based on 2,688 observations.

3.2. ECONOMETRIC MODELS I: HECKMAN SELECTION MODELS

In section 2.2, we determined that there is a large level of non-participation in our sample and also that there is a high percentage of FUPs that after deciding to participate have a low frequency of participation. This could be an indication of the existence of a self-selection process in the sample, since it is very likely that the outcome of interest, in this case the level of effort applied to the system represented by the percentage of time that a boat decide to be active (i.e. intensity of participation), could be determined by some unobservable characteristics of either armadores or fishing crew that affect simultaneously the former decision and the individual choice of whether to participate or not in the fishing activity as well. In order to deal with this potential problem we will apply a Heckman's selection model.

The Heckman model is composed by two equations; a *selection equation*, that in our case will have the same structure as equation 2 and an *outcome equation* represented by the process shown in equation 1. We assume for this system of equations a bivariate normal distribution with zero means and correlation ρ . In other words we assume that:

$$u_{i,j,y} \sim N(0,1)$$

$$\varepsilon_{i,j,y} \sim N(0, \sigma^2)$$

$$\text{corr}(u_{i,j,y}, \varepsilon_{i,j,y}) = \rho$$

In addition the relationship of interest or outcome equation is a simple linear model of a dependent variable $f_{i,j,y}$ that is observed if and only if a second unobserved latent variable, in our case $p_{i,j,y}$, exceeds a particular threshold (in this case zero). In other words $Pr(p_{i,j,y} = 1) = \Phi(w_i'\gamma)$ which is similar to a Probit process like the one established for equation 2.

There are two ways to estimate this model:

a. HECKMAN'S TWO-STEP PROCEDURE

The assumptions of this estimation procedure are that both $u_{i,j,y}$ and $\varepsilon_{i,j,y}$ are independent of the explanatory variables and that $u_{i,j,y} \sim N(0,1)$ (Wooldridge 2002). The two-step procedure is the most common estimation method for the Heckman selection model and is implemented as follows:

- a) Estimate the selection equation (which is a Probit) by MLE to obtain estimates of γ .
- b) For each observation in the selected equation, compute: *i*) the inverse Mill's ratio which is equal to: $\hat{\lambda}_i = \frac{\phi(w_i \hat{\gamma})}{\Phi(w_i \hat{\gamma})}$ where ϕ denotes the standard normal density function and Φ is the standard cumulative distribution; and *ii*) $\hat{\delta}_i = \hat{\lambda}_i (\hat{\lambda}_i - w_i \hat{\gamma})$.
- c) Estimate β and $\beta_{\lambda} = \rho \sigma_{\varepsilon}$ by OLS of $f_{i,j,y}$ on the vector x and $\hat{\lambda}$.

The estimators from this two-step procedure are consistent and asymptotically normal. This procedure is often called a Heckit model. In this model the coefficient of the inverse Mill's ratio will indicate if there is selection bias. If the coefficient is statistically significant, then we know that there is selection bias, the opposite is also true assuming that the selection equation is specified correctly.

b. MLE ESTIMATION PROCEDURE

The Heckman model can also be estimated by MLE; however, this requires making a stronger assumption than those required for the two-step procedure. For MLE we need to assume that both $u_{i,j,y}$ and $\varepsilon_{i,j,y}$ are distributed bivariate normal with mean zero. It is also necessary that $u_{i,j,y} \sim N(0,1)$, $\varepsilon_{i,j,y} \sim N(0, \sigma^2)$ and $corr(u_{i,j,y}, \varepsilon_{i,j,y}) = \rho$. Thus the MLE estimation is not as general as the two-step procedure. In addition, the MLE procedure is less robust than the two-step procedure, and sometimes it is difficult to get it to converge (Wooldridge 2002). However the MLE estimation will be more efficient if $u_{i,j,y}$ and $\varepsilon_{i,j,y}$ are indeed jointly normally distributed.

It is important to emphasize also that for both estimation procedures an exclusion restriction is required so as to generate credible estimates. In other words there must be at least one variable which appears with a non-zero coefficient in the selection equation (equation 2) but does not appear in the equation of interest (equation 1). If no such variable is available, it may be difficult to correct for sampling selectivity. The exclusion restriction in this model will be represented by the inclusion of the variable $Tourism_{y-1}$ in the selection equation and not in the outcome equation. This variable gathered the effect of the growth of the tourism sector. We assume that this variable is related to the profitability of this sector and therefore it is assumed to be related with the cost of opportunity of the fishing activity. Then an increase in the number of tourist will increase the profitability of this activity and will increase the cost of opportunity of participating in the fishing activity as well. This consequently would affect the participation choice of FUP negatively. We assume that this variable will affect the choice about the intensity of participation only through its effect on the participation choice.

In addition we have established some ex-ante expectations about the sign of the regressors in both equations based on results showed previously and some ad hoc assumptions. These ex-ante expectations are shown in Table 5.

Table 5. Ex-ante Expectations for Sign of Regressors

| VARIABLES | EQUATION 1 | EQUATION 2 | EXPLANATION |
|--|------------|------------|---|
| Last Year Average CPUE on the Lobster Fishery (Kg/day) | Positive | Positive | The more productive the FUP the more likely that he would participate in the lobster fishery and the higher their intensity of participation |
| Last Year Average CPUE on the Sea Cucumber Fishery (ind/day) | Positive | Positive | |
| AWOMB | Negative | Negative | We expect that the ownership status of the armador of a vessel would have a negative effect on both the participation and the frequency of participation choices. However, from the results obtained in section 2.2 we expect that the variable AWOMB will be statistically significant for the frequency of participation equation only. The latter is congruent with the evidence that we found in section 2.2 which indicates that those boats who are owned by AWOMB participate less frequently than those boats owned by AWOOB. |
| TOURISM | N.A. | Negative | We assumed a positive effect of the tourism over the cost of opportunity of fisheries; therefore we expect that the sign of the variable tourism for the participation model will be negative and statistically significant. In addition it is important to emphasize here that the effect of this variable on the frequency of participation choice will be through its effect on the participation choice only (for that reason we will omit it from eq. 1). |

3.2.1. ESTIMATION OF HECKMAN MODELS

The estimators that we obtained by either the two-step or the MLE procedure, which are shown in Table 6, satisfied our ex-ante expectations. Thus we found that the past productivity of a FUP for either the lobster or the sea cucumber fisheries have a positive effect on both the decision of participation and the decision about frequency of participation. Even more, the productivity on the lobster fishery has a larger impact on both decisions than the productivity on the sea cucumber fishery.

We also observe that if a FUP is owned by an AWOMB both decisions will be affected negatively. However this effect will be only statistically significant for the participation decision, as we initially expected based on results shown in section 2.2. In addition the variable that represents the exclusion restriction (i.e. $Tourism_{y-1}$) is statistically significant and negative as we expected. In other words we found that the growth of tourism affects negatively the decision of participation of a FUP in the lobster fishery because of an increase in the cost of opportunity of fishing.

Finally when we analyzed the significance of the Mill's ratio, for the two-step estimation procedure, and the lambda estimator, for the MLE procedure, we found that we cannot reject the null hypothesis of the no presence of selection bias. Even more when we examined the value of rho (from the MLE column) we cannot reject the null hypothesis of independence of both equations either. This indicates that it is possible to analyze econometrically both equations (the outcome and selection one) separately. We will proceed to do that in the next sections of this paper.

TABLE 6. Estimated regressors for Heckman Model

| VARIABLES | 2-step | MLE |
|--|------------------------|------------------------|
| <i>OUTCOME EQUATION</i> | | |
| Last Year Average CPUE on the Lobster Fishery (Kg/day) | 0.1799*** (0.0603) | 0.1549*** (0.0379) |
| Last Year Average CPUE on the Sea Cucumber Fishery (ind/day) | 0.0547*** (0.0265) | 0.0435*** (0.0162) |
| Isabela (Location dummy) | 0.3147**** (0.0968) | 0.3407*** (0.0834) |
| San Cristobal (Location dummy) | -0.4709*** (0.0806) | -0.4526*** (0.0728) |
| AWOMB | -0.2861*** (0.0746) | -0.2809*** (0.0737) |
| Constant term | 1.7658*** (0.3290) | 1.9116*** (0.1848) |
| <i>SELECTION EQUATION</i> | | |
| Last Year Average CPUE on the Lobster Fishery (Kg/day) | 0.3653*** (0.0216) | 0.3653*** (0.0216) |
| Last Year Average CPUE on the Sea Cucumber Fishery (ind/day) | 0.1695*** (0.0095) | 0.1695*** (0.0095) |
| Isabela (Location dummy) | -0.4371*** (0.0742) | -0.4370*** (0.0742) |
| San Cristobal (Location dummy) | -0.3160*** (0.0676) | -0.3160*** (0.0676) |
| AWOMB | -0.0376 (0.0657) | -0.0372 (0.0657) |
| Tourism | -0.0044*** (0.0009) | -0.0044*** (0.0009) |
| Constant Term | -0.0949 (0.1138) | -0.0936 (0.1139) |
| Mill's ratio | 0.1836 (0.2820) | |
| Lambda | | 0.0514 (0.1383) |
| Rho | | 0.0551 (0.1484) |
| Number of observations | 2,688 | 2,688 |
| Censored observations | 1,359 | 1,359 |
| Uncensored observations | 1,329 | 1,329 |

The dependent variable of the outcome equation is the log of the ratio of participation of a vessel and for the selection equation is a binary variable that takes the value of one if a vessel participated in a season and 0 otherwise. Triple asterisk (***) indicates significance at the 1% level (**) at the 5% level and (*) at the 10% level.

3.3. ECONOMETRIC MODELS II: FREQUENCY OF PARTICIPATION MODEL

After checking that both the Mill's ratio (two-step procedure) and the lambda (MLE procedure) for the estimated Heckman models from last section were not significant, we concluded that there was not selection bias on the decision for intensity of participation that came from unobservable characteristics of armadores or the fishing crew. In other words the variables that were used in the model were enough to characterize the effect of those unobservable characteristics. However we also found that the estimator of rho in the MLE procedure was not statistically significant, then the participation choice and the intensity of participation choice are independent. For this purpose we will proceed to conduct a separate econometric analysis of both decisions.

In this section we estimated a series of models for the decision about how many days a FUP will be active (compared to the total days of the season length) conditional on the fact that the FUP has decided to participate in the lobster fishery season. Our first specification models the data through an Ordinary Least Squared (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 we would correct the downward bias of using regular or robust standard errors.

Our second specification is a Fixed Effect (FE) model², which is equivalent to an OLS regression with a full set of armador-specific fixed effects. With this approach we would try to measure unobserved heterogeneity related to the owner characteristics that could be affecting the decision about frequency of participation. While the fixed effect estimator is consistent, it is not as

² We don't consider a Tobit specification because this model 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, and then we disregard the use of a Tobit.

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 effects as random variables that are distributed independently of the regressors. This model is more efficient than FE when none of the regressors is 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 and with that to analyze also if a RE is a more adequate approach than a FE.

It is necessary to specify that in this case our panel data is unbalanced because of the attrition of some owners and the appearance of new ones. This is not really a problem as long as the (strong) exogeneity condition is satisfied, which would assure the consistency of the estimates of either the FE model or RE model (the latter if and only if the Hausman test is satisfied too).

3.3.1. ESTIMATION RESULTS

In table 7, we report the results of estimating equation 1. It is important to remember that for this model we use only data for which the frequency of participation is greater than zero, therefore the number of observations is reduced to 1,329; that it is equal to the number of uncensored observations in the Heckman model.

In addition we would like to indicate that we conducted a Hausman test comparing FE and RE estimators, which indicated us that the FE model is appropriate ($\chi^2_5 = 24.7$). In other words we reject the assumption of no correlation between the regressors and the random effects. Hence, the RE effect is not consistent and it would be incorrect to use those estimators to make any inference and/or prediction. For that reason we decided to omit the results of that specification in table 7 and

show only the estimation results for the OLS and FE specification. Also we conduct a test through which it cannot be rejected the null hypothesis that the data satisfy the exogeneity condition ($F_{333,990} = 1.06$) then the results should be consistent, even though we use an unbalanced panel.

Table 7. Estimated regressors for frequency of participation model (Equation 1)

| VARIABLES | OLS | FE |
|--|----------------------|---------------------|
| Last Year Average CPUE on the Lobster Fishery (Kg/day) | 0.144*** (0.026) | 0.044*** (0.012) |
| Last Year Average CPUE on the Sea Cucumber Fishery (ind/day) | 0.039*** (0.010) | 0.004 (0.029) |
| Isabela (Location dummy) | 0.352*** (0.105) | 0.033 (0.245) |
| San Cristobal (Location dummy) | -0.445*** (0.091) | -0.277 (0.242) |
| AWOMB | -0.279*** (0.081) | 0.022 (0.161) |
| Constant term | 1.974*** (0.093) | 2.128*** (0.191) |
| Number of observations | 1,329 | 1,329 |
| Number of groups | 334 | 334 |
| Significance Test for owner fixed effects [F(333,990)] | | 1.857*** |
| R-squared | 0.1327 | 0.1814 |

The dependent variable is the log of the ratio of participation of a vessel. Triple asterisk (***) indicates significance at the 1% level (**) at the 5% level and (*) at the 10% level.

We can observe in table 7 that for both specifications the sign of the regressors satisfied our ex-ante expectations. Nonetheless, there are important differences in the significance of the estimators for these two specifications; then, we observe that all the regressors are statistically significant in the OLS specification; however for the FE specification the only regressor that is statistically significant is the one related to the past productivity of the FUP in the lobster fishery. Regarding to the appropriateness of these two specifications, we find that a joint F-test of the fixed effects is highly significant thereby open up the consistency of the OLS model to misspecification.

However it is important to emphasize that in both specifications the variable related to the past productivity on the lobster fishery is statistically significant, even though in the FE model the magnitude of the estimator is lower. Thus it can be concluded that the most important variable that predicts the level of effort intensity of a FUP in a lobster season is the level of productivity of that FUP in the previous season in that same fishery. This indicates that there is a persistence effect for the amount of effort applied to the lobster fishery for those who have been historically more productive. This is important because indicates that people are rational since they decide to put their effort based on their ability and past results.

Finally both specifications show a low degree of explanatory power with an R-squared that range between 0.1327 and 0.1814. Then, we conclude that we can only get a low level of explanation when we use models that try to explain the intensity of participation in the lobster fishery using exclusively explanatory variables that are related to previous season activity as well as characteristics of the boat and their owner. This could indicate that the decision of how much effort to apply in any given season could be influenced mainly by the actual conditions observed in the season like the abundance of the product, price of the product and climate factors and not by historical factors.

3.4. ECONOMETRIC MODELS II: INTENSITY OF PARTICIPATION MODEL

In the Heckman model the selection equation was characterized by a Probit through which we explain the probability that a FUP will participate in any given season. In table 8, we report the results of estimating the same Probit model but using robust standard errors clustered on the armador variable and also a second specification using a Logit as cumulative distribution function.

The results are consistent with our ex-ante expectations; that is, the estimated coefficients have the signs and the statistical significance that we expected initially given the results obtained for our descriptive analysis in section 2 and the Heckman model. In addition both specifications show a good level of explanatory power, with R^2 values that range between 0.235 and 0.306. The magnitude of this R^2 can be considered acceptable for this type of binary dependent variable models. Our conclusion is that this model explains fairly well the participation behavior in the lobster fishery, and then it is possible to use it for generating some inferences about the marginal impact of each of the explanatory variables.

Table 8. Estimated regressors for participation model (Equation 2)

| VARIABLES | Probit | Logit |
|--|------------------------|------------------------|
| Last Year Average CPUE on the Lobster Fishery (Kg/day) | 0.3653*** (0.0248) | 0.6182*** (0.0427) |
| Last Year Average CPUE on the Sea Cucumber Fishery (ind/day) | 0.1695*** (0.0097) | 0.28639*** (0.0166) |
| Isabela (Location dummy) | -0.4371*** (0.0848) | -0.7644*** (0.1443) |
| San Cristobal (Location dummy) | -0.3160*** (0.0728) | -0.5471*** (0.1227) |
| AWOMB | -0.0376 (0.0659) | -0.0554 (0.1122) |
| Tourism | -0.0044*** (0.0009) | -0.0075*** (0.0015) |
| Constant term | -0.0949 (0.1212) | -0.1165 (0.2043) |
| Number of observations | 2,688 | 2,688 |
| McFadden's R^2 | 0.239 | 0.241 |
| McFadden's Adj R^2 | 0.235 | 0.237 |
| Cragg & Uhler's R^2 | 0.282 | 0.284 |
| Efron's R^2 | 0.305 | 0.306 |

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

We calculate a set of marginal effects at the mean for each explanatory variable using as reference the Logit specification. (Table 9). Thus we observed that an increase of 1 Kg/day on the average CPUE of lobster in the previous year will increase in 10.71% the probability of participation in the lobster fishery. In the case of the sea cucumber an increment of the CPUE in one individual per day will increase the probability of participation in the lobster fishery in 4.96%. Likewise a FUP from Santa Cruz is 18.78% more likely to participate than a FUP from Isabela and 13.59% more likely to participate than any FUP from San Cristobal. On the other hand if the owner of a FUP is an AWOMB the probability of participation falls approximately 1.39% but this effect is not statistically significant. Finally an increment of approximately 5,263 tourists per year will contract the participation in the lobster fishery on 1%. Thus, since in average, the number of tourist has increased in 13,500 people per year, the annual contraction on participation on the lobster fishery because of the tourism can be estimated in approximately 2.6% annually.

Table 9. Marginal effects at the mean

| Variable | dy/dx | Std. Err. | z | P-value |
|--|--------------|------------------|----------|----------------|
| Last Year Average CPUE on the Lobster Fishery (Kg/day)) | 0.1071 | 0.0074 | 14.4900 | 0.0000 |
| Last Year Average CPUE on the Sea Cucumber Fishery (ind/day) | 0.0496 | 0.0029 | 17.3000 | 0.0000 |
| Isabela (Location dummy) | -0.1878 | 0.0341 | -5.5000 | 0.0000 |
| San Cristobal (Location dummy) | -0.1359 | 0.0301 | -4.5200 | 0.0000 |
| AWOMB | -0.0139 | 0.0280 | -0.4900 | 0.6210 |
| Tourism | -0.0019 | 0.0004 | -5.0700 | 0.0000 |

All these results indicates that the most important factor that affect the participation decision on the lobster fishery is the last year productivity of the FUP (in lobster and sea cucumber fisheries). Then a unit of increment in the CPUE of both fisheries (i.e. 1 KG/day for the lobster and 1 individual/day for the sea cucumber) will increase the probability of participation in approximately

15%. Therefore, we conclude (like in the case of equation 1) that there is a persistence of participation of those FUPs that are more productive year by year. Finally it is also important to highlight the effect of the tourism on the participation on the lobster fishery, as well as the difference on participation given the location of the FUP. Both variables indicate the presence of a strong effect of cost of opportunities from alternative activities on the fishing decisions of FUP in Galapagos.

4. SUMMARY

In this paper, we were able to determine some specific traits of the observed fishing behavior of vessels in the Galapagos Islands, as well as those factors that are considered as determinants for that behavior. Thus we found that during any given lobster fishery season vessels can be classified in three categories: inactive vessels who are the majority, approximately 52% of the total registered vessels, and active vessels that represent 48% of this group. However we also found important differences in the level of participation of active vessels, which allow us to divide this group into two sub-groups: highly active (HA) and sporadically active (SA). We found that 2/3 of active vessels in any given lobster fishery season can be classified as SA, which have a participation rate of 5.50%; while the remaining 1/3 of can be classified as HA with a participation rate of 25.46%.

Logit and Probit models revealed that the past productivity of a FUP (defined in this paper as pangas and fibras only) in the lobster and the sea cucumber fisheries is a good predictor for the participation choice of any FUP in the lobster fishery. On the other hand, when we analyze the decision about the intensity of participation we found that only the past productivity of the FUP in the same lobster fishery is a good predictor for that decision. We also determined that tourism will

affect negatively the decision of participation for FUP; this is because this variable represents an increase in the cost of opportunity of fishing.

The ownership status of the armador will also have an impact on the frequency of participation of a FUP but not in its decision of participation. In other words we found that if a FUP is owned by an AWOMB the intensity of participation will be lower than if the same FUP is owned by an AWOOB. This result is consistent with the observation that armadores not always participate in the fishing activity but they prefer to provide their vessel to other pescadores, so that they can use it to fish and after that to share the profits with them. Then it is likely that in order to reduce the risk of any catastrophe (that could imply the total loss of a vessel) armadores would diversify the use of their boats if they have more than one.

Finally we found that the goodness of fit of models that try to describe the intensity of participation using historical data is low. This clearly indicates that the decision about how frequent to participate in any given season could be influenced not by historical factors but mainly by the actual conditions observed during the same season. This justifies the use of other econometric structures that employ this type of current variables like GEV models for further works.

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